

## Introduction

This reference manual targets application developers. It provides complete information on how to use the STM32F05xxx/06xxx microcontroller memory and peripherals. It applies to the STM32F050x4/x6, STM32F051x4/x6/x8, STM32F060x4/x6 and STM32F061x4/x6/x8 devices.

For the purpose of this manual, STM32F05xxx/06xxx microcontrollers are referred to as "STM32F0xxxx".

The STM32F0xxxx is a family of microcontrollers with different memory sizes, packages and peripherals.

For ordering information, mechanical and electrical device characteristics, please refer to the corresponding datasheet.

For information on the ARM CORTEX™-M0 core, please refer to the *Cortex-M0 technical reference manual*.

## Related documents

- Cortex-M0 technical reference manual, available from:  
[http://infocenter.arm.com/help/topic/com.arm.doc.ddi0432c/DDI0432C\\_cortex\\_m0\\_r0p0\\_trm.pdf](http://infocenter.arm.com/help/topic/com.arm.doc.ddi0432c/DDI0432C_cortex_m0_r0p0_trm.pdf)
- STM32F0xxx Cortex-M0 programming manual (PM0215)
- STM32F0xxxx datasheets available from our website: <http://www.st.com>.

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# 1 Documentation conventions

## 1.1 List of abbreviations for registers

The following abbreviations are used in register descriptions:

read/write (rw)	Software can read and write to these bits.
read-only (r)	Software can only read these bits.
write-only (w)	Software can only write to this bit. Reading the bit returns the reset value.
always read at "0" (w_r0)	Writing '0' has no effect. Writing '1' starts an action (for example resets a flag...).
read/clear (rc_w1)	Software can read as well as clear this bit by writing 1. Writing '0' has no effect on the bit value.
read/clear (rc_w0)	Software can read as well as clear this bit by writing 0. Writing '1' has no effect on the bit value.
read/clear by read (rc_r)	Software can read this bit. Reading this bit automatically clears it to '0'. Writing '0' has no effect on the bit value.
read/set (rs)	Software can read as well as set this bit. Writing '0' has no effect on the bit value.
Reserved (Res.)	Reserved bit, must be kept at reset value.

## 1.2 Glossary

This section gives a brief definition of acronyms and abbreviations used in this document:

- **Low-density devices** are STM32F050xx and STM32F060xx microcontrollers where the Flash memory ranges between 16 and 32 Kbytes.
- **Medium-density devices** are STM32F051xx and STM32F061xx microcontrollers where the Flash memory ranges between 16 and 64 Kbytes.
- **Word**: data of 32-bit length.
- **Half-word**: data of 16-bit length.
- **Byte**: data of 8-bit length.
- **SWD-DP (SWD DEBUG PORT)**: SWD-DP provides a 2-pin (clock and data) interface based on the Serial Wire Debug (SWD) protocol. Please refer to the Cortex-M0 technical reference manual.
- **IAP (in-application programming)**: IAP is the ability to re-program the Flash memory of a microcontroller while the user program is running.
- **ICP (in-circuit programming)**: ICP is the ability to program the Flash memory of a microcontroller using the JTAG protocol, the SWD protocol or the bootloader while the device is mounted on the user application board.
- **Option bytes**: product configuration bits stored in the Flash memory.
- **OBL**: option byte loader.
- **AHB**: advanced high-performance bus.

### 1.3 Peripheral availability

For peripheral availability and number across all sales types, please refer to the datasheet.

## 2 System and memory overview

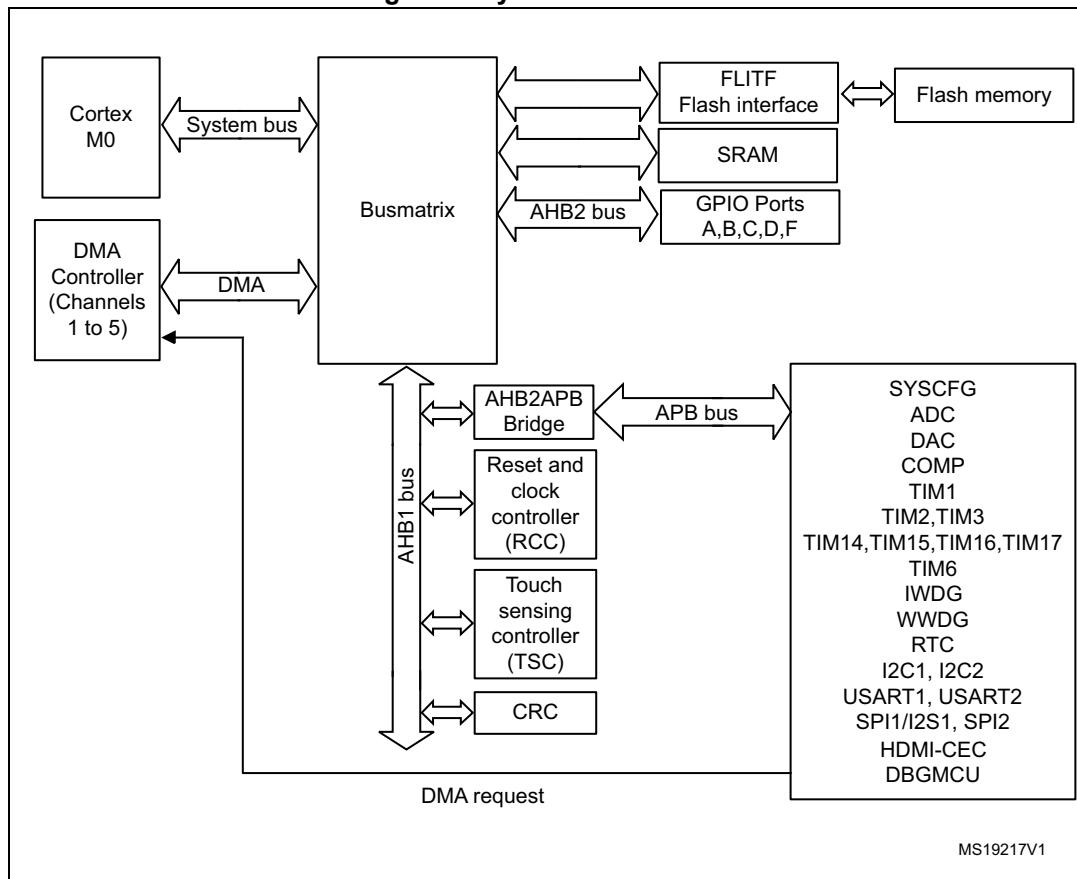
### 2.1 System architecture

The main system consists of:

- Two masters:
  - Cortex-M0 core AHB bus
  - GP-DMA (general-purpose DMA)
- Four slaves:
  - Internal SRAM
  - Internal Flash memory
  - AHB to APB, which connects all the APB peripherals
  - AHB dedicated to GPIO ports

These are interconnected using a multilayer AHB bus architecture as shown in [Figure 1](#):

**Figure 1. System architecture**



## System bus

This bus connects the system bus of the Cortex-M0 core (peripherals bus) to a BusMatrix which manages the arbitration between the core and the DMA.

## DMA bus

This bus connects the AHB master interface of the DMA to the BusMatrix which manages the access of CPU and DMA to SRAM, Flash memory and peripherals.

## BusMatrix

The BusMatrix manages the access arbitration between the core system bus and the DMA master bus. The arbitration uses a Round Robin algorithm. The BusMatrix is composed of two masters (DMA and System Bus) and four slaves (FLITF, SRAM, AHB2GPIO and AHB2APB bridges).

## AHB2APB bridge

The AHB2APB bridge provides a full synchronous connection between the AHB and the APB buses.

Refer to [Table 2.2.2 on page 38](#) for the address mapping of the peripherals connected to this bridge.

After each device reset, all peripheral clocks are disabled (except for the SRAM and FLITF). Before using a peripheral you have to enable its clock in the RCC\_AHBENR, RCC\_APB2ENR or RCC\_APB1ENR register.

*Note:* When a 16- or 8-bit access is performed on an APB register, the access is transformed into a 32-bit access: the bridge duplicates the 16- or 8-bit data to feed the 32-bit vector.

## 2.2 Memory organization

### 2.2.1 Introduction

Program memory, data memory, registers and I/O ports are organized within the same linear 4-Gbyte address space.

The bytes are coded in memory in Little Endian format. The lowest numbered byte in a word is considered the word's least significant byte and the highest numbered byte the most significant.

The addressable memory space is divided into 8 main blocks, each of 512 MB.

All the memory areas that are not allocated to on-chip memories and peripherals are considered "Reserved"). For the detailed mapping of available memory and register areas, please refer to the [Memory map and register boundary addresses](#) chapter and peripheral chapters.

## 2.2.2 Memory map and register boundary addresses

The following table gives the memory map and boundary addresses of the peripherals available in STM32F0xxxx devices.

**Table 1. STM32F05xxx memory map and peripheral register boundary addresses**

Bus	Boundary address	Size	Peripheral	Peripheral register map
	0xE000 0000 - 0xE00F FFFF	1MB	Cortex M0 internal peripherals	
	0x4800 1800 - 0x5FFF FFFF	~384 MB	Reserved	
AHB2	0x4800 1400 - 0x4800 17FF	1KB	GPIOF	<a href="#">Section 8.4.11 on page 138</a>
	0x4800 1000 - 0x4800 13FF	1KB	Reserved	
	0x4800 0C00 - 0x4800 0FFF	1KB	GPIOD	<a href="#">Section 8.4.11 on page 138</a>
	0x4800 0800 - 0x4800 0BFF	1KB	GPIOC	<a href="#">Section 8.4.11 on page 138</a>
	0x4800 0400 - 0x4800 07FF	1KB	GPIOB	<a href="#">Section 8.4.11 on page 138</a>
	0x4800 0000 - 0x4800 03FF	1KB	GPIOA	<a href="#">Section 8.4.11 on page 138</a>
	0x4002 4400 - 0x47FF FFFF	~128 MB	Reserved	
AHB1	0x4002 4000 - 0x4002 43FF	1 KB	TSC	<a href="#">Section 27.6.11 on page 710</a>
	0x4002 3400 - 0x4002 3FFF	3 KB	Reserved	
	0x4002 3000 - 0x4002 33FF	1 KB	CRC	<a href="#">Section 5.4.5 on page 70</a>
	0x4002 2400 - 0x4002 2FFF	3 KB	Reserved	
	0x4002 2000 - 0x4002 23FF	1 KB	FLASH interface	<a href="#">Section 3.6 on page 61</a>
	0x4002 1400 - 0x4002 1FFF	3 KB	Reserved	
	0x4002 1000 - 0x4002 13FF	1 KB	RCC	<a href="#">Section 7.4.15 on page 122</a>
	0x4002 0400 - 0x4002 0FFF	3 KB	Reserved	
	0x4002 0000 - 0x4002 03FF	1 KB	DMA	<a href="#">Section 10.4.7 on page 162</a>
	0x4001 8000 - 0x4001 FFFF	32 KB	Reserved	

**Table 1. STM32F05xxx memory map and peripheral register boundary addresses (continued)**

Bus	Boundary address	Size	Peripheral	Peripheral register map
APB	0x4001 5C00 - 0x4001 7FFF	9 KB	Reserved	
	0x4001 5800 - 0x4001 5BFF	1 KB	DBGMCU	
	0x4001 4C00 - 0x4001 57FF	3 KB	Reserved	
	0x4001 4800 - 0x4001 4BFF	1 KB	TIM17	<a href="#">Section 18.6.16 on page 448</a>
	0x4001 4400 - 0x4001 47FF	1 KB	TIM16	<a href="#">Section 18.6.16 on page 448</a>
	0x4001 4000 - 0x4001 43FF	1 KB	TIM15	<a href="#">Section 18.5.18 on page 429</a>
	0x4001 3C00 - 0x4001 3FFF	1 KB	Reserved	
	0x4001 3800 - 0x4001 3BFF	1 KB	USART1	<a href="#">Section 25.7.12 on page 637</a>
	0x4001 3400 - 0x4001 37FF	1 KB	Reserved	
	0x4001 3000 - 0x4001 33FF	1 KB	SPI1/I2S1	<a href="#">Section 26.7.10 on page 693</a>
	0x4001 2C00 - 0x4001 2FFF	1 KB	TIM1	<a href="#">Section 15.4.21 on page 298</a>
	0x4001 2800 - 0x4001 2BFF	1 KB	Reserved	
	0x4001 2400 - 0x4001 27FF	1 KB	ADC	<a href="#">Section 12.12.11 on page 211</a>
	0x4001 0800 - 0x4001 23FF	7 KB	Reserved	
	0x4001 0400 - 0x4001 07FF	1 KB	EXTI	<a href="#">Section 11.3.7 on page 174</a>
	0x4001 0000 - 0x4001 03FF	1 KB	SYSCFG COMP	<a href="#">Section 9.1.7 on page 147</a>
				<a href="#">Section 14.4.2 on page 230</a>
	0x4000 8000 - 0x4000 FFFF	32 KB	Reserved	

**Table 1. STM32F05xxx memory map and peripheral register boundary addresses (continued)**

Bus	Boundary address	Size	Peripheral	Peripheral register map
APB	0x4000 7C00 - 0x4000 7FFF	1 KB	Reserved	
	0x4000 7800 - 0x4000 7BFF	1 KB	CEC	<a href="#">Section 28.7.7 on page 731</a>
	0x4000 7400 - 0x4000 77FF	1 KB	DAC	<a href="#">Section 13.5.8 on page 222</a>
	0x4000 7000 - 0x4000 73FF	1 KB	PWR	<a href="#">Section 6.4.3 on page 84</a>
	0x4000 5C00 - 0x4000 6FFF	5 KB	Reserved	
	0x4000 5800 - 0x4000 5BFF	1 KB	I2C2	<a href="#">Section 24.7.12 on page 574</a>
	0x4000 5400 - 0x4000 57FF	1 KB	I2C1	<a href="#">Section 24.7.12 on page 574</a>
	0x4000 4800 - 0x4000 53FF	3 KB	Reserved	
	0x4000 4400 - 0x4000 47FF	1 KB	USART2	<a href="#">Section 25.7.12 on page 637</a>
	0x4000 3C00 - 0x4000 43FF	2 KB	Reserved	
	0x4000 3800 - 0x4000 3BFF	1 KB	SPI2	<a href="#">Section 26.7.10 on page 693</a>
	0x4000 3400 - 0x4000 37FF	1 KB	Reserved	
	0x4000 3000 - 0x4000 33FF	1 KB	IWDG	<a href="#">Section 21.4.6 on page 470</a>
	0x4000 2C00 - 0x4000 2FFF	1 KB	WWDG	<a href="#">Section 22.6.4 on page 476</a>
	0x4000 2800 - 0x4000 2BFF	1 KB	RTC	<a href="#">Section 23.6.17 on page 507</a>
	0x4000 2400 - 0x4000 27FF	1 KB	Reserved	
	0x4000 2000 - 0x4000 23FF	1 KB	TIM14	<a href="#">Section 17.4.12 on page 381</a>
	0x4000 1400 - 0x4000 1FFF	3 KB	Reserved	
	0x4000 1000 - 0x4000 13FF	1 KB	TIM6	<a href="#">Section 19.4.9 on page 461</a>
	0x4000 0800 - 0x4000 0FFF	2 KB	Reserved	
	0x4000 0400 - 0x4000 07FF	1 KB	TIM3	<a href="#">Section 16.4.19 on page 358</a>
	0x4000 0000 - 0x4000 03FF	1 KB	TIM2	<a href="#">Section 16.4.19 on page 358</a>
	0x2000 2000 - 0x3FFF FFFF	~512 MB	Reserved	
	0x2000 0000 - 0x2000 1FFF	8 KB	SRAM	<a href="#">Section 3 on page 44</a>
	0x1FFF FC00 - 0x1FFF FFFF	1 KB	Reserved	
	0x1FFF F800 - 0x1FFF FBFF	1 KB	Option bytes	<a href="#">Section 4 on page 62</a>
	0x1FFF EC00 - 0x1FFF F7FF	3 KB	System memory	
	0x0801 0000 - 0x1FFF EBFF	~384 MB	Reserved	
	0x0800 0000 - 0x0800 FFFF	64 KB	Main Flash memory	<a href="#">Section 3.6 on page 61</a>
	0x0001 0000 - 0x07FF FFFF	128 MB	Reserved	
	0x0000 0000 - 0x0000 FFFF	64 KB	Main Flash memory, system memory or SRAM depending on BOOT configuration	<a href="#">Section 2.5 on page 42</a>

## 2.3 Embedded SRAM

The STM32F0xxxx features up to 8 Kbytes of static SRAM. It can be accessed as bytes, half-words (16 bits) or full words (32 bits). This memory can be addressed at maximum system clock frequency without wait state and thus by both CPU and DMA.

### Parity check

The user can enable the parity check using the option bit RAM\_PARITY\_CHECK in the user option byte (refer to [Section 4: Option bytes](#)).

The data bus width is 36 bits because 4 bits are available for parity check (1 bit per byte) in order to increase memory robustness, as required for instance by Class B or SIL norms.

The parity bits are computed and stored when writing into the SRAM. Then, they are automatically checked when reading. If one bit fails, an NMI is generated. The same error can also be linked to the BRK\_IN Break input of TIMER15/TIM16/TIM7, with the SRAM\_PARITY\_LOCK control bit in the [SYSCFG configuration register 2 \(SYSCFG\\_CFGR2\)](#). The SRAM Parity Error flag (SRAM\_PEF) is available in the [SYSCFG configuration register 2 \(SYSCFG\\_CFGR2\)](#).

**Note:** *When enabling the RAM parity check, it is advised to initialize by software the whole RAM memory at the beginning of the code, to avoid getting parity errors when reading non-initialized locations.*

## 2.4 Flash memory overview

The Flash memory is composed of two distinct physical areas:

- The main Flash memory block. It contains the application program and user data if necessary.
- The information block. It is composed of two parts:
  - Option bytes for hardware and memory protection user configuration.
  - System memory which contains the proprietary boot loader code.Please, refer to [Section 3: Embedded Flash memory](#) for more details.

The Flash interface implements instruction access and data access based on the AHB protocol. It implements the prefetch buffer that speeds up CPU code execution. It also implements the logic necessary to carry out the Flash memory operations (Program/Erase) controlled through the Flash registers.

## 2.5 Boot configuration

In the STM32F0xxxx, three different boot modes can be selected through the BOOT0 pin and nBOOT1 bit in the User option byte, as shown in the following table.

**Table 2. Boot modes**

Boot mode selection		Boot mode	Aliasing
BOOT1 <sup>(1)</sup>	BOOT0		
x	0	Main Flash memory	Main Flash memory is selected as boot space
0	1	System memory	System memory is selected as boot space
1	1	Embedded SRAM	Embedded SRAM is selected as boot space

1. The BOOT1 value is the opposite of the nBOOT1 Option Bit.

The values on both BOOT0 pin and nBOOT1 bit are latched on the 4th rising edge of SYSCLK after a reset. It is up to the user to set nBOOT1 and BOOT0 to select the required boot mode.

The BOOT0 pin and nBOOT1 bit are also re-sampled when exiting from Standby mode. Consequently they must be kept in the required Boot mode configuration in Standby mode. After this startup delay has elapsed, the CPU fetches the top-of-stack value from address 0x0000 0000, then starts code execution from the boot memory at 0x0000 0004.

Depending on the selected boot mode, main Flash memory, system memory or SRAM is accessible as follows:

- Boot from main Flash memory: the main Flash memory is aliased in the boot memory space (0x0000 0000), but still accessible from its original memory space (0x0800 0000). In other words, the Flash memory contents can be accessed starting from address 0x0000 0000 or 0x0800 0000.
- Boot from system memory: the system memory is aliased in the boot memory space (0x0000 0000), but still accessible from its original memory space (0x1FFF EC00).
- Boot from the embedded SRAM: the SRAM is aliased in the boot memory space (0x0000 0000), but it is still accessible from its original memory space (0x2000 0000).

### Physical remap

Once the boot pins are selected, the application software can modify the memory accessible in the code area. This modification is performed by programming the MEM\_MODE bits in the [SYSCFG configuration register 1 \(SYSCFG\\_CFGR1\)](#). Unlike Cortex M3 and M4, the M0 CPU don't support the vector table relocation. For application code which is located in a different address than 0x0800 0000, some additional code must be added in order to be able to serve the application interrupts. A solution will be to relocate by software the vector table to the internal SRAM:

- Copy the vector table from the Flash (mapped at the base of the application load address) to the base address of the SRAM at 0x2000 0000.
- Remap SRAM at address 0x0000 0000, using SYSCFG configuration register 1.
- Then once an interrupt occurs, the CortexM0 processor will fetch the interrupt handler start address from the relocated vector table in SRAM, then it will jump to execute the interrupt handler located in the Flash.

This operation should be done at the initialization phase of the application. Please refer to AN4065 and attached IAP code from [www.st.com](http://www.st.com) for more details.

### **Embedded boot loader**

The embedded boot loader is located in the System memory, programmed by ST during production. It is used to reprogram the Flash memory using one of the following serial interfaces: USART1(PA9/PA10) or USART2(PA14/PA15).

For further details, please refer to AN2606.

## 3 Embedded Flash memory

### 3.1 Flash main features

- Up to 64 Kbytes of Flash memory
- Memory organization:
  - Main Flash memory block:  
16 Kwords ( $16\text{ K} \times 32\text{ bits}$ )
  - Information block:  
1 Kword ( $1\text{ K} \times 32\text{ bits}$ )

Flash memory interface features:

- Read interface with prefetch buffer ( $1 \times 32\text{-bit words}$ )
- Option byte Loader
- Flash Program / Erase operation
- Read / Write protection
- Low-power mode

### 3.2 Flash memory functional description

#### 3.2.1 Flash memory organization

The Flash memory is organized as 32-bit wide memory cells that can be used for storing both code and data constants.

The memory organization is based on a main Flash memory block containing 64 pages of 1 Kbyte or 16 sectors of 4 Kbytes (4 pages). The sector is the granularity of the write protection (see [Memory protection on page 52](#)).

**Table 3. Flash module organization**

Flash area	Flash memory addresses	Size (bytes)	Name	Description
Main Flash memory	0x0800 0000 - 0x0800 03FF	1 Kbyte	Page 0	Sector 0
	0x0800 0400 - 0x0800 07FF	1 Kbyte	Page 1	
	0x0800 0800 - 0x0800 0BFF	1 Kbyte	Page 2	
	0x0800 0C00 - 0x0800 0FFF	1 Kbyte	Page 3	
	:	:	:	
	0x0800 7000 - 0x0800 73FF	1 Kbyte	Page 60	
	0x0800 7400 - 0x0800 77FF	1 Kbyte	Page 61	
	0x0800 7800 - 0x0800 7BFF	1 Kbyte	Page 62	
	0x0800 7C00 - 0x0800 7FFF	1 Kbyte	Page 63	

**Table 3. Flash module organization (continued)**

<b>Flash area</b>	<b>Flash memory addresses</b>	<b>Size (bytes)</b>	<b>Name</b>	<b>Description</b>
Information block	0x1FFF EC00- 0x1FFF F7FF	3 Kbytes		System memory
	0x1FFF F800 - 0x1FFF F80B	6 x 2		Option bytes
Flash memory interface registers	0x4002 2000 - 0x4002 2003	4		FLASH_ACR
	0x4002 2004 - 0x4002 2007	4		FLASH_KEYR
	0x4002 2008 - 0x4002 200B	4		FLASH_OPTKEYR
	0x4002 200C - 0x4002 200F	4		FLASH_SR
	0x4002 2010 - 0x4002 2013	4		FLASH_CR
	0x4002 2014 - 0x4002 2017	4		FLASH_AR
	0x4002 2018 - 0x4002 201B	4		Reserved
	0x4002 201C - 0x4002 201F	4		FLASH_OBR
	0x4002 2020 - 0x4002 2023	4		FLASH_WRPR

The information block is divided into two parts:

1. System memory: used to boot the device in System memory boot mode. The area is reserved for use by STMicroelectronics and contains the boot loader which is used to reprogram the Flash memory through the USART1 or USART2 interface. It is programmed by ST when the device is manufactured, and protected against spurious write/erase operations. For further details, please refer to AN2606.
2. Option bytes

### 3.2.2 Read operations

The embedded Flash module can be addressed directly, as a common memory space. Any data read operation accesses the content of the Flash module through dedicated read senses and provides the requested data.

The instruction fetch and the data access are both done through the same AHB bus. Read accesses can be performed with the following options managed through the Flash access control register (FLASH\_ACR):

- Instruction fetch: Prefetch buffer enabled for a faster CPU execution.
- Latency: number of wait states for a correct read operation (from 0 to 1)

#### Instruction fetch

The Cortex-M0 fetches the instruction over the AHB bus. The prefetch block aims at increasing the efficiency of instruction fetching.

#### Prefetch buffer

The prefetch buffer is 3 blocks wide where each block consists of 4 bytes. The prefetch blocks are direct-mapped. A block can be completely replaced on a single read to the Flash memory as the size of the block matches the bandwidth of the Flash memory.

The implementation of this prefetch buffer makes a faster CPU execution possible as the CPU fetches one word at a time with the next word readily available in the prefetch buffer. This implies that the acceleration ratio will be of the order of 2 assuming that the code is aligned at a 64-bit boundary for the jumps.

However the prefetch buffer has an impact on the performance only when the wait state number is 1. In the other case (no wait state) the performance remains the same whatever the prefetch buffer status. There could be some impacts on the power consumption but this is strongly dependent from the actual application code.

### Prefetch controller

The prefetch controller decides to access the Flash memory depending on the available space in the prefetch buffer. The Controller initiates a read request when there is at least one block free in the prefetch buffer.

After reset, the state of the prefetch buffer is on.

The prefetch buffer is usually switched on/off during the initialization routine, while the microcontroller is running on the internal 8 MHz RC (HSI) oscillator.

### Access latency

In order to maintain the control signals to read the Flash memory, the ratio of the prefetch controller clock period to the access time of the Flash memory has to be programmed in the Flash access control register with the LATENCY[2:0] bits. This value gives the number of cycles needed to maintain the control signals of the Flash memory and correctly read the required data. After reset, the value is zero and only one cycle without additional wait states is required to access the Flash memory.

## 3.2.3 Flash program and erase operations

The STM32F0xxxx embedded Flash memory can be programmed using in-circuit programming or in-application programming.

The **in-circuit programming (ICP)** method is used to update the entire contents of the Flash memory, using the SWD protocol or the boot loader to load the user application into the microcontroller. ICP offers quick and efficient design iterations and eliminates unnecessary package handling or socketing of devices.

In contrast to the ICP method, **in-application programming (IAP)** can use any communication interface supported by the microcontroller (I/Os, USB, CAN, UART, I<sup>2</sup>C, SPI, etc.) to download programming data into memory. IAP allows the user to re-program the Flash memory while the application is running. Nevertheless, part of the application has to have been previously programmed in the Flash memory using ICP.

The program and erase operations can be performed over the whole product voltage range. They are managed through the following seven Flash registers:

- Key register (FLASH\_KEYR)
- Option byte key register (FLASH\_OPTKEYR)
- Flash control register (FLASH\_CR)
- Flash status register (FLASH\_SR)
- Flash address register (FLASH\_AR)
- Option byte register (FLASH\_OBR)
- Write protection register (FLASH\_WRPR)

An ongoing Flash memory operation will not block the CPU as long as the CPU does not access the Flash memory.

On the contrary, during a program/erase operation to the Flash memory, any attempt to read the Flash memory will stall the bus. The read operation will proceed correctly once the program/erase operation has completed. This means that code or data fetches cannot be made while a program/erase operation is ongoing.

For program and erase operations on the Flash memory (write/erase), the internal RC oscillator (HSI) must be ON.

### **Unlocking the Flash memory**

After reset, the Flash memory is protected against unwanted write or erase operations. The FLASH\_CR register is not accessible in write mode, except for the OBL\_LAUNCH bit, used to reload the option bits. An unlocking sequence should be written to the FLASH\_KEYR register to open the access to the FLASH\_CR register. This sequence consists of two write operations:

- Write KEY1 = 0x45670123
- Write KEY2 = 0xCDEF89AB

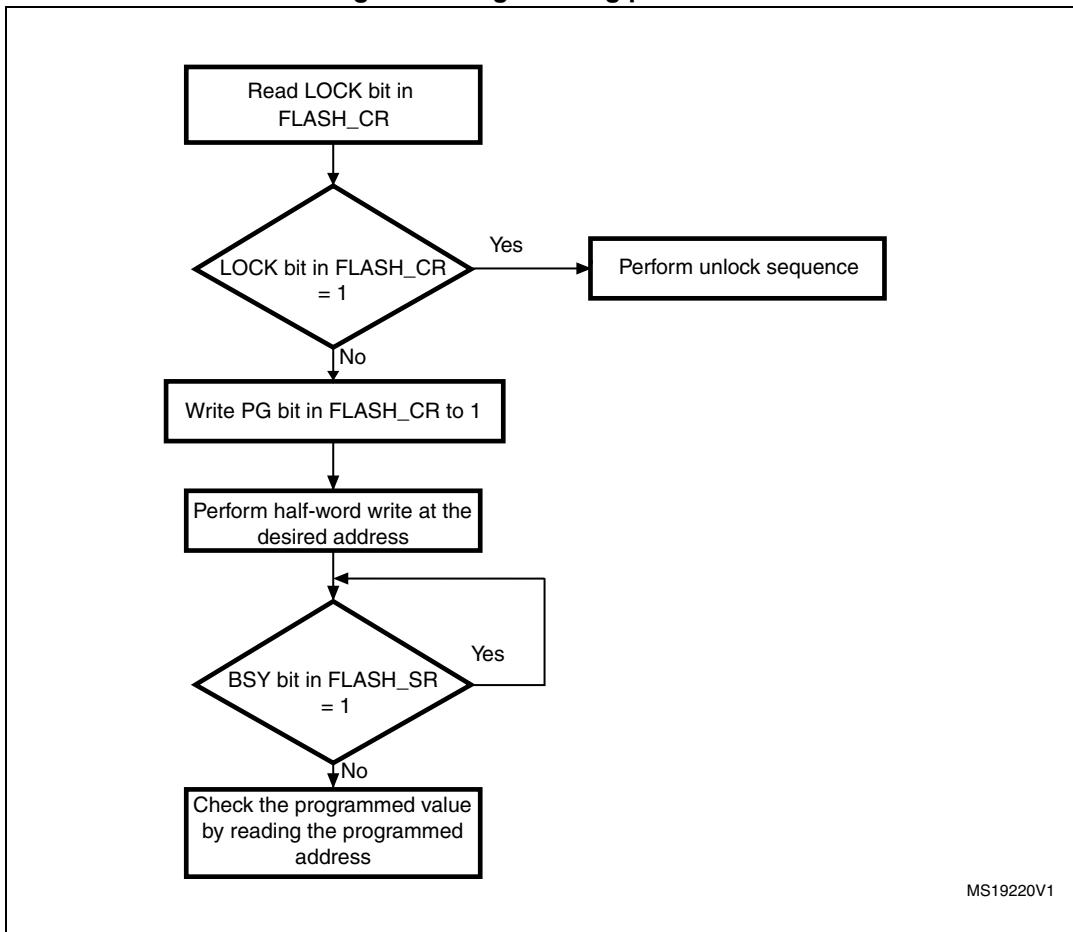
Any wrong sequence locks up the FLASH\_CR register until the next reset.

In the case of a wrong key sequence, a bus error is detected and a Hard Fault interrupt is generated. This is done after the first write cycle if KEY1 does not match, or during the second write cycle if KEY1 has been correctly written but KEY2 does not match.

The FLASH\_CR register can be locked again by user software by writing the LOCK bit in the FLASH\_CR register to 1.

### **Main Flash memory programming**

The main Flash memory can be programmed 16 bits at a time. The program operation is started when the CPU writes a half-word into a main Flash memory address with the PG bit of the FLASH\_CR register set. Any attempt to write data that are not half-word long will result in a bus error generating a Hard Fault interrupt.

**Figure 2. Programming procedure**

The Flash memory interface preliminarily reads the value at the addressed main Flash memory location and checks that it has been erased. If not, the program operation is skipped and a warning is issued by the PGERR bit in FLASH\_SR register. The only exception to this is when 0x0000 is programmed. In this case, the location is correctly programmed to 0x0000 and the PGERR bit is not set.

If the addressed main Flash memory location is write-protected by the FLASH\_WRPR register, the program operation is skipped and a warning is issued by the WRPRTERR bit in the FLASH\_SR register. The end of the program operation is indicated by the EOP bit in the FLASH\_SR register.

The main Flash memory programming sequence in standard mode is as follows:

1. Check that no main Flash memory operation is ongoing by checking the BSY bit in the FLASH\_SR register.
2. Set the PG bit in the FLASH\_CR register.
3. Perform the data write (half-word) at the desired address.
4. Wait until the BSY bit is reset in the FLASH\_SR register.
5. Check the EOP flag in the FLASH\_SR register (it is set when the programming operation has succeeded), and then clear it by software.

**Note:** *The registers are not accessible in write mode when the BSY bit of the FLASH\_SR register is set.*

## Flash memory erase

The Flash memory can be erased page by page or completely (Mass Erase).

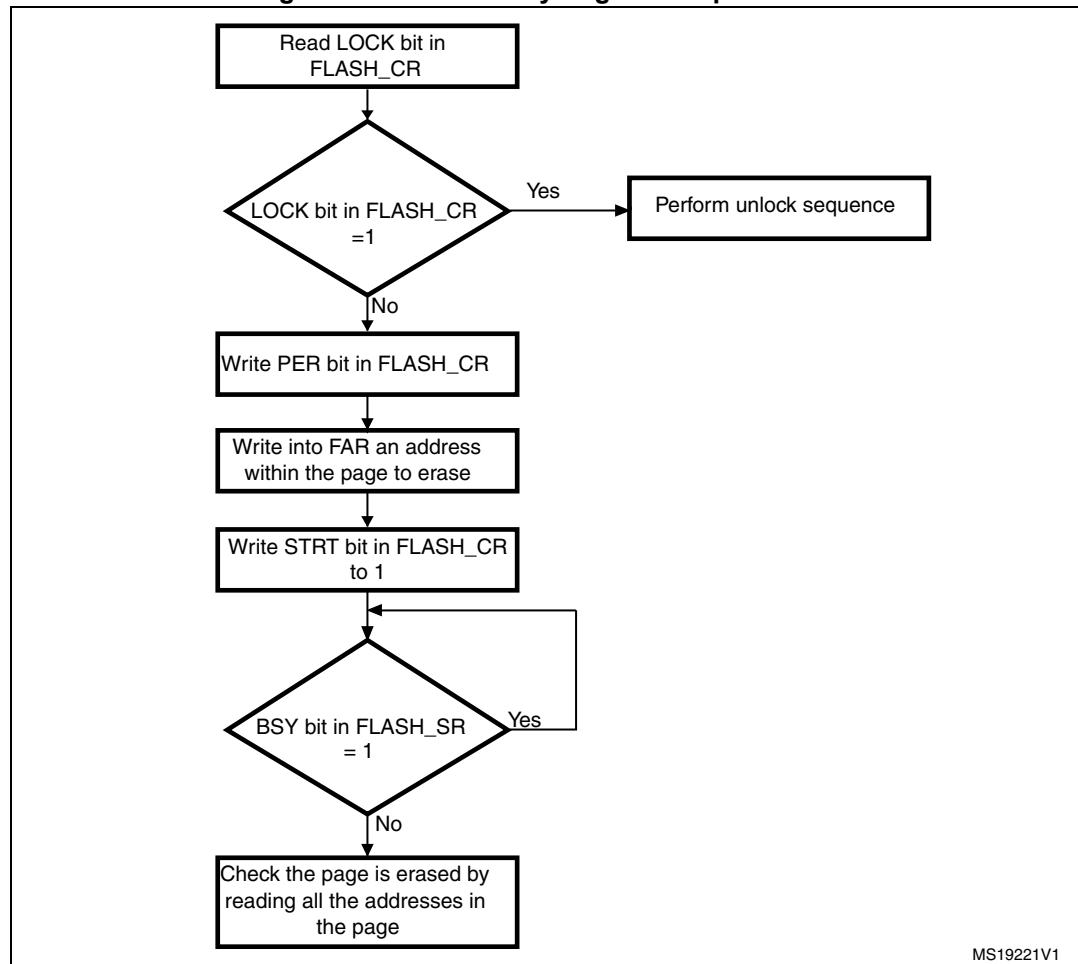
### Page Erase

To erase a page, the procedure below should be followed:

1. Check that no Flash memory operation is ongoing by checking the BSY bit in the FLASH\_CR register
2. Set the PER bit in the FLASH\_CR register.
3. Program the FLASH\_AR register to select a page to erase.
4. Set the STRT bit in the FLASH\_CR register (see note below).
5. Wait for the BSY bit to be reset.
6. Check the EOP flag in the FLASH\_SR register (it is set when the erase operation has succeeded), and then clear it by software.
7. Clear the EOP flag.

**Note:** *The software should start checking if the BSY bit equals “0” at least one CPU cycle after setting the STRT bit.*

**Figure 3. Flash memory Page Erase procedure**



MS19221V1

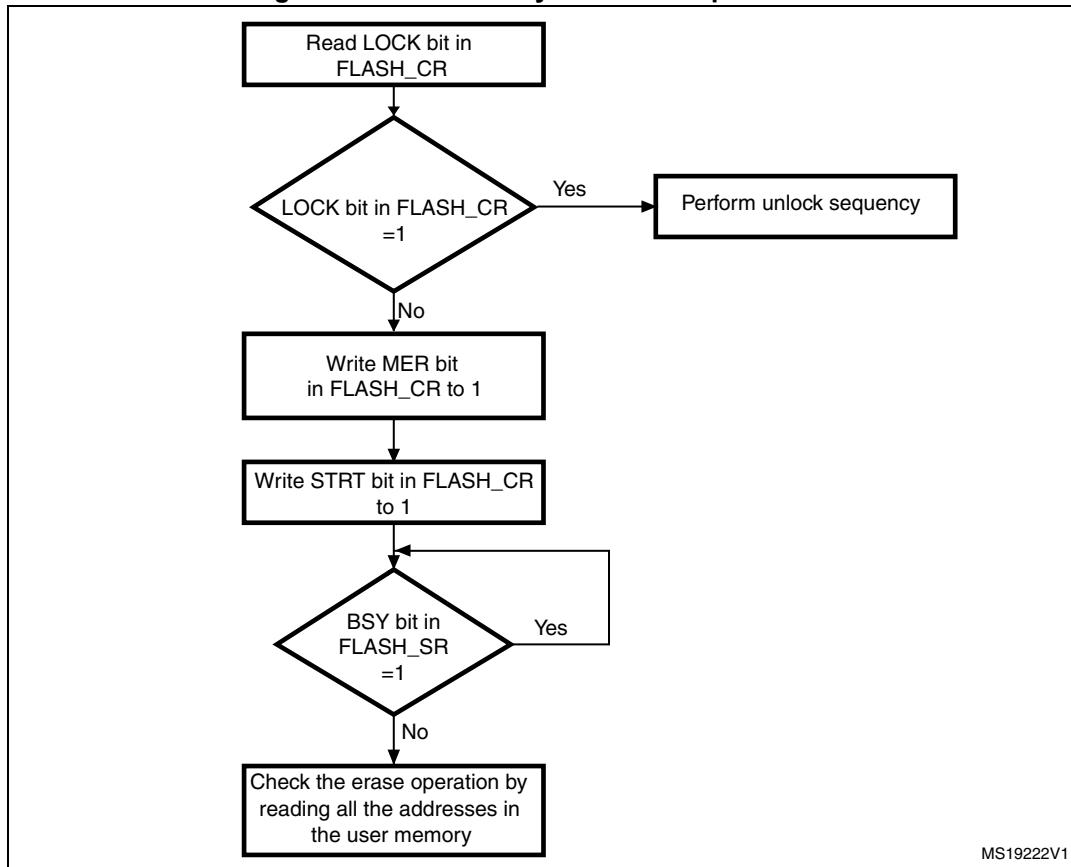
## Mass Erase

The Mass Erase command can be used to completely erase the user pages of the Flash memory. The information block is unaffected by this procedure. The following sequence is recommended:

1. Check that no Flash memory operation is ongoing by checking the BSY bit in the FLASH\_SR register.
2. Set the MER bit in the FLASH\_CR register.
3. Set the STRT bit in the FLASH\_CR register.
4. Wait until the BSY bit is reset in the FLASH\_SR register.
5. Check the EOP flag in the FLASH\_SR register (it is set when the programming operation has succeeded), and then clear it by software.
6. Clear the EOP flag.

*Note:* *The software should start checking if the BSY bit equals "0" at least one CPU cycle after setting the STRT bit.*

**Figure 4. Flash memory Mass Erase procedure**



## Option byte programming

The option bytes are programmed differently from normal user addresses. The number of option bytes is limited to 6 (2 for write protection, 1 for read protection, 1 for hardware configuration and 2 free bytes for user data). After unlocking the Flash access, the user has to authorize the programming of the option bytes by writing the same set of KEYS (KEY1 and KEY2) to the FLASH\_OPTKEYR register to set the OPTWRE bit in the FLASH\_CR register (refer to [Unlocking the Flash memory](#) for key values). Then the user has to set the OPTPG bit in the FLASH\_CR register and perform a half-word write operation at the desired Flash address.

The value of the addressed option byte is first read to check it is really erased. If not, the program operation is skipped and a warning is issued by the WRPRTERR bit in the FLASH\_SR register. The end of the program operation is indicated by the EOP bit in the FLASH\_SR register.

The option byte is automatically complemented into the next flash memory address before the programming operation starts. This guarantees that the option byte and its complement are always correct.

The sequence is as follows:

1. Check that no Flash memory operation is ongoing by checking the BSY bit in the FLASH\_SR register.
2. Unlock the OPTWRE bit in the FLASH\_CR register.
3. Set the OPTPG bit in the FLASH\_CR register
4. Write the data (half-word) to the desired address
5. Wait for the BSY bit to be reset.
6. Read the programmed value and verify.

When the Flash memory read protection option is changed from protected to unprotected, a Mass Erase of the main Flash memory is performed before reprogramming the read protection option. If the user wants to change an option other than the read protection option, then the mass erase is not performed. The erased state of the read protection option byte protects the Flash memory.

## Erase procedure

The option byte erase sequence is as follows:

1. Check that no Flash memory operation is ongoing by reading the BSY bit in the FLASH\_SR register
2. Unlock the OPTWRE bit in the FLASH\_CR register
3. Set the OPTER bit in the FLASH\_CR register
4. Set the STRT bit in the FLASH\_CR register
5. Wait for BSY to reset
6. Read the erased option bytes and verify

### 3.3 Memory protection

The user area of the Flash memory can be protected against read by untrusted code. The pages of the Flash memory can also be protected against unwanted write due to loss of program counter contexts. The write-protection granularity is one sector (four pages).

#### 3.3.1 Read protection

The read protection is activated by setting the RDP option byte and then, by applying a system reset to reload the new RDP option byte.

*Note:* If the read protection is set while the debugger is still connected through SWD, apply a POR (power-on reset) instead of a system reset.

There are three levels of read protection from no protection (level 0) to maximum protection or no debug (level 2). Refer to [Table 5: Access status versus protection level and execution modes](#).

The Flash memory is protected when the RDP option byte and its complement contain the pair of values shown in [Table 4](#).

**Table 4. Flash memory read protection status**

RDP byte value	RDP complement value	Read protection level
0xAA	0x55	Level 0 (ST production configuration)
Any value except 0xAA or 0xCC	Any value (not necessarily complementary) except 0x55 and 0x33	Level 1
0xCC	0x33	Level 2

The System memory area is read accessible whatever the protection level. It is never accessible for program/erase operation

#### Level 0: no protection

Read, program and erase operations into the main Flash memory area are possible.

The option bytes are as well accessible by all operations.

#### Level 1: read protection

This is the default protection level when RDP option byte is erased. It is defined as well when RDP value is at any value different from 0xAA and 0xCC, or even if the complement is not correct.

- **User mode:** Code executing in user mode can access main Flash memory and option bytes with all operations.
- **Debug, boot RAM and boot loader modes:** In debug mode (with SWD) or when code is running from boot RAM or boot loader, the main Flash memory and the backup registers (RTC\_BKPxR in the RTC) are totally inaccessible. In these modes, even a simple read access generates a bus error and a Hard Fault interrupt. The main Flash memory is program/erase protected to prevent malicious or unauthorized users from reprogramming any of the user code with a dump routine. Any

attempted program/erase operation sets the PGERR flag of Flash status register (FLASH\_SR).

When the RPD is reprogrammed to the value 0xAA to move back to Level 0, a mass erase of the main Flash memory is performed and the backup registers (RTC\_BKPxR in the RTC) are reset.

### Level 2: no debug

In this level, the protection level 1 is guaranteed. In addition, the CortexM0 debug capabilities are disabled. Consequently, the debug port (SWD), the boot from RAM (boot RAM mode) and the boot from System memory (boot loader mode) are no more available.

In user execution mode, all operations are allowed on the Main Flash memory. On the contrary, only read and program operations can be performed on the option bytes. Option bytes are not accessible for erase operations.

Moreover, the RDP bytes cannot be programmed. Thus, the level 2 cannot be removed at all: it is an irreversible operation. When attempting to program the RDP byte, the protection error flag WRPRTERR is set in the Flash\_SR register and an interrupt can be generated.

*Note:* The debug feature is also disabled under reset.

*STMicroelectronics is not able to perform analysis on defective parts on which the level 2 protection has been set.*

**Table 5. Access status versus protection level and execution modes**

Area	Protection level	User execution			Debug/ BootFromRam/ BootFromLoader		
		Read	Write	Erase	Read	Write	Erase
Main Flash memory	1	Yes	Yes	Yes	No	No	No <sup>(4)</sup>
	2	Yes	Yes	Yes	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>
System memory (2)	1	Yes	No	No	Yes	No	No
	2	Yes	No	No	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>
Option bytes (3)	1	Yes	Yes <sup>(4)</sup>	Yes	No	No	Yes
	2	Yes	Yes <sup>(5)</sup>	No	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>
Backup registers (6)	1	Yes	Yes	N/A	No	No	No
	2	Yes	Yes	N/A	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>	N/A <sup>(1)</sup>

1. When the protection level 2 is active, the Debug port, the boot from RAM and the boot from system memory are disabled.
2. The system memory is only read-accessible, whatever the protection level (0, 1 or 2) and execution mode.
3. When RDP level 1 is active, only the RDP bits are still available for read and write.
4. The main Flash memory is erased when the RDP option byte is changed from level 1 to level 0 (0xAA).
5. All option bytes can be programmed, except the RDP byte.
6. These registers are reset only when moving from RDP level 1 to level 0.

### Changing read protection level

It is easy to move from level 0 to level 1 by changing the value of the RDP byte to any value (except 0xCC).

By programming the 0xCC value in the RDP byte, it is possible to go to level 2 either directly from level 0 or from level 1.

On the contrary, the change to level 0 (no protection) is not possible without a main Flash memory Mass erase operation. This Mass erase is generated as soon as 0xAA is programmed in the RDP byte.

**Note:** When the Mass Erase command is used, the backup registers (RTC\_BKPxR in the RTC) are also reset.

To validate the protection level change, the option bytes must be reloaded through the "OBL\_LAUNCH" bit in Flash control register.

### 3.3.2 Write protection

The write protection is implemented with a granularity of one sector, i.e. four pages. It is activated by configuring the WRP[1:0] option bytes, and then by reloading them by setting the OBL\_LAUNCH bit in the FLASH\_CR register.

If a program or an erase operation is performed on a protected sector, the Flash memory returns a WRPRTERR protection error flag in the Flash memory Status Register (FLASH\_SR).

#### Write unprotection

To disable the write protection, two application cases are provided:

- Case 1: Read protection disabled after the write unprotection:
  - Erase the entire option byte area by using the OPTER bit in the Flash memory control register (FLASH\_CR)
  - Program the code 0xAA in the RDP byte to unprotect the memory. This operation forces a Mass Erase of the main Flash memory.
  - Set the OBL\_LAUNCH bit in the Flash control register (FLASH\_CR) to reload the option bytes (and the new WRP[1:0] bytes), and to disable the write protection
- Case 2: Read protection maintained active after the write unprotection, useful for in-application programming with a user boot loader:
  - Erase the entire option byte area by using the OPTER bit in the Flash memory control register (FLASH\_CR)
  - Set the OBL\_LAUNCH bit in the Flash control register (FLASH\_CR) to reload the option bytes (and the new WRP[1:0] bytes), and to disable the write protection.

### 3.3.3 Option byte write protection

The option bytes are always read-accessible and write-protected by default. To gain write access (Program/Erase) to the option bytes, a sequence of keys (same as for lock) has to be written into the OPTKEYR. A correct sequence of keys gives write access to the option bytes and this is indicated by OPTWRE in the FLASH\_CR register being set. Write access can be disabled by resetting the bit through software.

## 3.4 Flash interrupts

**Table 6. Flash interrupt request**

Interrupt event	Event flag	Enable control bit
End of operation	EOP	EOPIE
Write protection error	WRPRTERR	ERRIE
Programming error	PGERR	ERRIE

## 3.5 Flash register description

The Flash memory registers have to be accessed by 32-bit words (half-word and byte accesses are not allowed).

### 3.5.1 Flash access control register (FLASH\_ACR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.										
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	PRFT BS	PRFT BE	Res.	LATENCY[2:0]											
										r	rw		rw	rw	rw

Bits 31:6 Reserved, must be kept at reset value.

Bit 5 **PRFTBS**: Prefetch buffer status

This bit provides the status of the prefetch buffer.

0: Prefetch buffer is disabled

1: Prefetch buffer is enabled

*Note: The prefetch status is set to 1 as soon a first fetch request is done*

Bit 4 **PRFTBE**: Prefetch buffer enable

0: Prefetch is disabled

1: Prefetch is enabled

Bit 3 Reserved, must be kept at reset value.

Bits 2:0 **LATENCY[2:0]**: Latency

These bits represent the ratio of the SYSCLK (system clock) period to the Flash access time.

000: Zero wait state, if  $0 < \text{SYSCLK} \leq 24 \text{ MHz}$

001: One wait state, if  $24 \text{ MHz} < \text{SYSCLK} \leq 48 \text{ MHz}$

### 3.5.2 Flash key register (FLASH\_KEYR)

Address offset: 0x04

Reset value: 0XXXXX XXXX

All these register bits are write-only and will return a 0 when read.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FKEY[31:16]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FKEY[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:0 **FKEY**: Flash key

These bits represent the keys to unlock the Flash.

### 3.5.3 Flash option key register (FLASH\_OPTKEYR)

Address offset: 0x08

Reset value: 0XXXXX XXXX

All these register bits are write-only and will return a 0 when read.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OPTKEY[31:16]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OPTKEY[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:0 **OPTKEY**: Option byte key

These bits represent the keys to unlock the OPTWRE.

### 3.5.4 Flash status register (FLASH\_SR)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.											
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	EOP	WRPRT ERR	Res.	PG ERR	Res.	BSY									
										rw	rw		rw		r

Bits 31:6 Reserved, must be kept at reset value.

Bit 5 **EOP**: End of operation

Set by hardware when a Flash operation (programming / erase) is completed. Reset by writing a 1

*Note: EOP is asserted at the end of each successful program or erase operation*

Bit 4 **WRPRTERR**: Write protection error

Set by hardware when programming a write-protected address of the Flash memory.

Reset by writing 1.

Bit 3 Reserved, must be kept at reset value.

Bit 2 **PGERR**: Programming error

Set by hardware when an address to be programmed contains a value different from '0xFFFF' before programming.

Reset by writing 1.

*Note: The STRT bit in the FLASH\_CR register should be reset before starting a programming operation.*

Bit 1 Reserved, must be kept at reset value

Bit 0 **BSY**: Busy

This indicates that a Flash operation is in progress. This is set on the beginning of a Flash operation and reset when the operation finishes or when an error occurs.

### 3.5.5 Flash control register (FLASH\_CR)

Address offset: 0x10

Reset value: 0x0000 0080

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	OBL_LAUNCH	EOPIE	Res.	ERRIE	OPTWRE	Res.	LOCK	STRT	OPTER	OPTPG	Res.	MER	PER	PG
		rw	rw		rw	rw		rw	rw	rw	rw		rw	rw	rw

Bits 31:14 Reserved, must be kept at reset value.

Bit 13 **OBL\_LAUNCH**: Force option byte loading

When set to 1, this bit forces the option byte reloading. This operation generates a system reset.

0: Inactive

1: Active

Bit 12 **EOPIE**: End of operation interrupt enable

This bit enables the interrupt generation when the EOP bit in the FLASH\_SR register goes to 1.

0: Interrupt generation disabled

1: Interrupt generation enabled

Bit 11 Reserved, must be kept at reset value

Bit 10 **ERRIE**: Error interrupt enable

This bit enables the interrupt generation on an error when PGERR / WRPRTERR are set in the FLASH\_SR register.

0: Interrupt generation disabled

1: Interrupt generation enabled

Bit 9 **OPTWRE**: Option bytes write enable

When set, the option bytes can be programmed. This bit is set on writing the correct key sequence to the FLASH\_OPTKEYR register.

This bit can be reset by software

Bit 8 Reserved, must be kept at reset value.

Bit 7 **LOCK**: Lock

Write to 1 only. When it is set, it indicates that the Flash is locked. This bit is reset by hardware after detecting the unlock sequence.

In the event of unsuccessful unlock operation, this bit remains set until the next reset.

Bit 6 **STRT**: Start

This bit triggers an ERASE operation when set. This bit is set only by software and reset when the BSY bit is reset.

Bit 5 **OPTER**: Option byte erase

Option byte erase chosen.

Bit 4 **OPTPG**: Option byte programming

Option byte programming chosen.

Bit 3 Reserved, must be kept at reset value.

Bit 2 **MER**: Mass erase

Erase of all user pages chosen.

Bit 1 **PER**: Page erase

Page Erase chosen.

Bit 0 **PG**: Programming

Flash programming chosen.

### 3.5.6 Flash address register (FLASH\_AR)

Address offset: 0x14

Reset value: 0x0000 0000

This register is updated by hardware with the currently/last used address. For Page Erase operations, this should be updated by software to indicate the chosen page.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FAR[31:16]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FAR[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:0 **FAR**: Flash Address

Chooses the address to program when programming is selected, or a page to erase when Page Erase is selected.

*Note:* Write access to this register is blocked when the BSY bit in the FLASH\_SR register is set.

### 3.5.7 Flash Option byte register (FLASH\_OBR)

Address offset 0x1C

Reset value: 0xXXXX XX0X

The reset value of this register depends on the value programmed in the option bytes.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Data1								Data0							
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	RAM_PARITY_CHECK	VDDA_MONITOR	nBOOT1	Res.	nRST_STDBY	nRST_STOP	WDG_SW	Res.	Res.	Res.	Res.	Res.	RDPRT[1:0]	OPTERR	
	r	r	r		r	r	r						r	r	r

Bits 31:24 Data1

Bits 23:16 Data0

Bits 15:8 User option bytes:

Bit 15: reserved

Bit 14: RAM\_PARITY\_CHECK

Bit 13: VDDA\_MONITOR

Bit 12: nBOOT1

Bit 11: reserved

Bit 10: nRST\_STDBY

Bit 9: nRST\_STOP

Bit 8: WDG\_SW

Bits 7:3 Reserved, must be kept at reset value.

Bits 2:1 **RDPRT[1:0]**: Read protection level status

00: Read protection level 0 is enabled (ST production configuration)

01: Read protection level 1 is enabled

11: Read protection level 2 is enabled.

Bit 0 **OPTERR: Option byte error**

When set, this indicates that the loaded option byte and its complement do not match. The corresponding byte and its complement are read as 0xFF in the FLASH\_OBR or FLASH\_WRPR register.

### 3.5.8 Write protection register (FLASH\_WRPR)

Address offset: 0x20

Reset value: 0xFFFFFFFF

The reset value of this register depends on the value programmed in the option bytes.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WRP[15:0]															

Bits 31:0 **WRP**: Write protect

This register contains the write-protection option bytes loaded by the OBL.

### 3.6 Flash register map

Table 7. Flash interface - register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0			
0x000	<b>FLASH_ACR</b>	Res.																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
0x004	<b>FLASH_KEYR</b>	FKEY[31:0]																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
0x008	<b>FLASH_OPTKEYR</b>	OPTKEY[31:0]																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
0x00C	<b>FLASH_SR</b>	Res.																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
0x010	<b>FLASH_CR</b>	Res.																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
0x014	<b>FLASH_AR</b>	FAR[31:0]																																		
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
0x01C	<b>FLASH_OBR</b>	Data1																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
0x020	<b>FLASH_WRPTR</b>	Data0																																		
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
WRP[15:0]																																				

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 4 Option bytes

There are six option bytes. They are configured by the end user depending on the application requirements. As a configuration example, the watchdog may be selected in hardware or software mode.

A 32-bit word is split up as follows in the option bytes.

**Table 8. Option byte format**

31-24	23-16	15 -8	7-0
Complemented option byte 1	Option byte 1	Complemented option byte 0	Option byte 0

The organization of these bytes inside the information block is as shown in [Table 9](#).

The option bytes can be read from the memory locations listed in [Table 9](#) or from the Option byte register (FLASH\_OBR).

*Note:* *The new programmed option bytes (user, read/write protection) are loaded after a system reset.*

**Table 9. Option byte organization**

Address	[31:24]	[23:16]	[15:8]	[7:0]
0xFFFF F800	nUSER	USER	nRDP	RDP
0xFFFF F804	nData1	Data1	nData0	Data0
0xFFFF F808	nWRP1	WRP1	nWRP0	WRP0

On every system reset, the option byte loader (OBL) reads the information block and stores the data into the Option byte register (FLASH\_OBR) and the Write protection register (FLASH\_WRP). Each option byte also has its complement in the information block. During option loading, by verifying the option bit and its complement, it is possible to check that the loading has correctly taken place. If this is not the case, an option byte error (OPTERR) is generated. When a comparison error occurs, the corresponding option byte is forced to 0xFF. The comparator is disabled when the option byte and its complement are both equal to 0xFF (Electrical Erase state).

## 4.1 Option byte description

### 4.1.1 User and read protection option bytes

Flash memory address: 0x1FFF F800

ST production value: 0x00FF 55AA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
nUSER										USER					
<small>rw</small>															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nRDP										RDP					
<small>rw</small>															

Bits 31:24 **nUSER**: User option byte complement

Bits 23:16 **USER**: User option byte (stored in FLASH\_OBR[15:8])

Bit 23: Reserved

Bit 22: **RAM\_PARITY\_CHECK**

0: RAM parity check enabled

1: RAM parity check disabled

Bit 21: **VDDA\_MONITOR**

0: V<sub>DDA</sub> power supply supervisor disabled

1: V<sub>DDA</sub> power supply supervisor enabled

Bit 20: **nBOOT1**

Together with the BOOT0 pin, it selects the boot mode to the main Flash memory SRAM or to the System memory.

Refer to [Section 2.5: Boot configuration](#) for more details.

Bit 19: Reserved

Bit 18: **nRST\_STDBY**

0: Reset generated when entering Standby mode.

1: No reset generated.

Bit 17: **nRST\_STOP**

0: Reset generated when entering Stop mode

1: No reset generated

Bit 16: **WDG\_SW**

0: Hardware watchdog

1: Software watchdog

Bits 15:8 **nRDP**: Read protection option byte complement

Bits 7:0 **RDP**: Read protection option byte

The value of this byte defines the Flash memory protection level

0xAA: level 0 (ST production configuration)

0XX (except 0xAA & 0xCC): Level 1

0xCC: Level 2

*Note: Read protection level status is stored in bits RDPRT[1:0] of the [Flash Option byte register \(FLASH\\_OBR\)](#). For more details about read protection, refer to [Section 3.3.1: Read protection](#).*

#### 4.1.2 User data option bytes

Flash memory address: 0x1FFF F804

ST production value: 0x00FF 00FF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
nData1								Data1							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nData0								Data0							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 **nData1**: User data byte 1 complement

Bits 23:16 **Data1**: User data byte 1 value (stored in FLASH\_OBR[31:24])

Bits 15:8 **nData0**: User data byte 0 complement

Bits 7:0 **Data0**: User data byte 0 value (stored in FLASH\_OBR[23:16])

#### 4.1.3 Write protection option bytes 1

Flash memory address: 0x1FFF F808

ST production value: 0x00FF 00FF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
nWRP1								WRP1							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nWRP0								WRP0							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 **nWRP1**: Flash memory write protection option byte 1 complement

Bits 23:16 **WRP1**: Flash memory write protection option byte 1 value (stored in FLASH\_WRPR[15:8])

Bits 15:8 **nWRP0**: Flash memory write protection option byte 0 complement

Bits 7:0 **WRP0**: Flash memory write protection option byte 0 value (stored in FLASH\_WRPR[7:0])

Refer to [Section 3.3.2: Write protection](#) for more details.

#### 4.1.4 Option byte map

The following table summarizes the option bytes.

**Table 10. Option byte map and ST production values**

Offset	Option bytes	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	User and read protection	nUSER								USER		nRDP		RDP																			
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	1	0	1	0	1	0	1	0
0x04	User data	nData1								Data1		nData0		Data0																			
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0x08	Write protection 1	nWRP1								WRP1		nWRP0		WRP0																			
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

## 5 Cyclic redundancy check calculation unit (CRC)

### 5.1 Introduction

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code from a 32-bit data word and a generator polynomial.

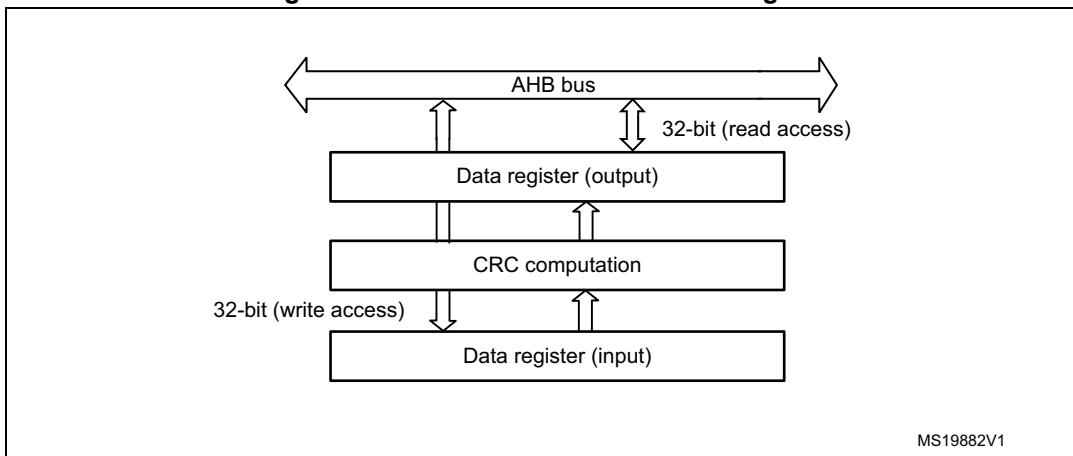
Among other applications, CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the functional safety standards, they offer a means of verifying the Flash memory integrity. The CRC calculation unit helps compute a signature of the software during runtime, to be compared with a reference signature generated at link time and stored at a given memory location.

### 5.2 CRC main features

- Uses CRC-32 (Ethernet) polynomial: 0x4C11DB7  
$$X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$$
- Handles 8,16, 32 bit data size
- Programmable CRC initial value
- Single input/output 32-bit data register
- Input buffer to avoid bus stall during calculation
- CRC computation done in 4 AHB clock cycles (HCLK) for 32-bit data
- General-purpose 8-bit register (can be used for temporary storage)
- Reversibility option on I/O data

## 5.3 CRC functional description

Figure 5. CRC calculation unit block diagram



The CRC calculation unit has a single 32-bit read/write data register (CRC\_DR). It is used to input new data (write access), and holds the result of the previous CRC calculation (read access).

Each write operation to the data register creates a combination of the previous CRC value (stored in CRC\_DR) and the new one. CRC computation is done on the whole 32-bit data word or byte by byte depending on the format of the data being written.

The CRC\_DR register can be accessed by word, right-aligned half-word and right-aligned byte. For the other registers only 32-bit access is allowed.

The duration of the computation depends on data width:

- 4 AHB clock cycles for 32-bit
- 2 AHB clock cycles for 16-bit
- 1 AHB clock cycles for 8-bit

An input buffer allows to immediately write a second data without waiting for any wait states due to the previous CRC calculation.

The data size can be dynamically adjusted to minimize the number of write accesses for a given number of bytes. For instance, a CRC for 5 bytes can be computed with a word write followed by a byte write.

The input data can be reversed, to manage the various endianness schemes. The reversing operation can be performed on 8 bits, 16 bits and 32 bits depending on the REV\_IN[1:0] bits in the CRC\_CR register.

For example: input data 0x1A2B3C4D is used for CRC calculation as:

- 0x58D43CB2 with bit-reversal done by byte
- 0xD458B23C with bit-reversal done by half-word
- 0xB23CD458 with bit-reversal done on the full word

The output data can also be reversed by setting the REV\_OUT bit in the CRC\_CR register.

The operation is done at bit level: for example, output data 0x11223344 is converted into 0x22CC4488.

The CRC calculator can be initialized to a programmable value using the RESET control bit in the CRC\_CR register (the default value is 0xFFFFFFFF).

The initial CRC value can be programmed with the CRC\_INIT register. The CRC\_DR register is automatically initialized upon CRC\_INIT register write access.

The CRC\_IDR register can be used to hold a temporary value related to CRC calculation. It is not affected by the RESET bit in the CRC\_CR register.

## 5.4 CRC registers

### 5.4.1 Data register (CRC\_DR)

Address offset: 0x00

Reset value: 0xFFFF FFFF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DR[31:16]															
rw															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DR[15:0]															
rw															

Bits 31:0 **DR[31:0]: Data register bits**

This register is used to write new data to the CRC calculator.

It holds the previous CRC calculation result when it is read.

If the data size is less than 32 bits, the least significant bits are used to write/read the correct value.

### 5.4.2 Independent data register (CRC\_IDR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.								IDR[7:0]							
															rw

Bits 31:8 Reserved, must be kept cleared.

Bits 7:0 **IDR[7:0]**: General-purpose 8-bit data register bits

These bits can be used as a temporary storage location for one byte.

This register is not affected by CRC resets generated by the RESET bit in the CRC\_CR register

### 5.4.3 Control register (CRC\_CR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	REV_OUT	REV_IN[1:0]	Res.	Res.	Res.	Res.	Res.	RESET							
								rw	rw	rw					rs

Bits 31:8 Reserved, must be kept cleared.

Bit 7 **REV\_OUT**: Reverse output data

This bit controls the reversal of the bit order of the output data.

0: Bit order not affected

1: Bit-reversed output format

Bits 6:5 **REV\_IN[1:0]**: Reverse input data

These bits control the reversal of the bit order of the input data

00: Bit order not affected

01: Bit reversal done by byte

10: Bit reversal done by half-word

11: Bit reversal done by word

Bits 4:1 Reserved, must be kept cleared.

Bit 0 **RESET**: RESET bit

This bit is set by software to reset the CRC calculation unit and set the data register to the value stored in the CRC\_INIT register. This bit can only be set, it is automatically cleared by hardware

#### 5.4.4 Initial CRC value (CRC\_INIT)

Address offset: 0x10

Reset value: 0xFFFF FFFF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CRC_INIT[31:16]															
rw															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRC_INI[15:0]															
rw															

Bits 31:0 **CRC\_INIT**: Programmable initial CRC value

This register is used to write the CRC initial value.

#### 5.4.5 CRC register map

Table 11. CRC register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	<b>CRC_DR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DR[31:0]																	
		1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
0x04	<b>CRC_IDR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IDR[7:0]																	
		1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
0x08	<b>CRC_CR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.																		
		1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
0x10	<b>CRC_INIT</b>	CRC_INIT[31:0]															REV_OUT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	1	1	1	1	1	1	1	1	1	1	1	1		RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.	RES.

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 6 Power control (PWR)

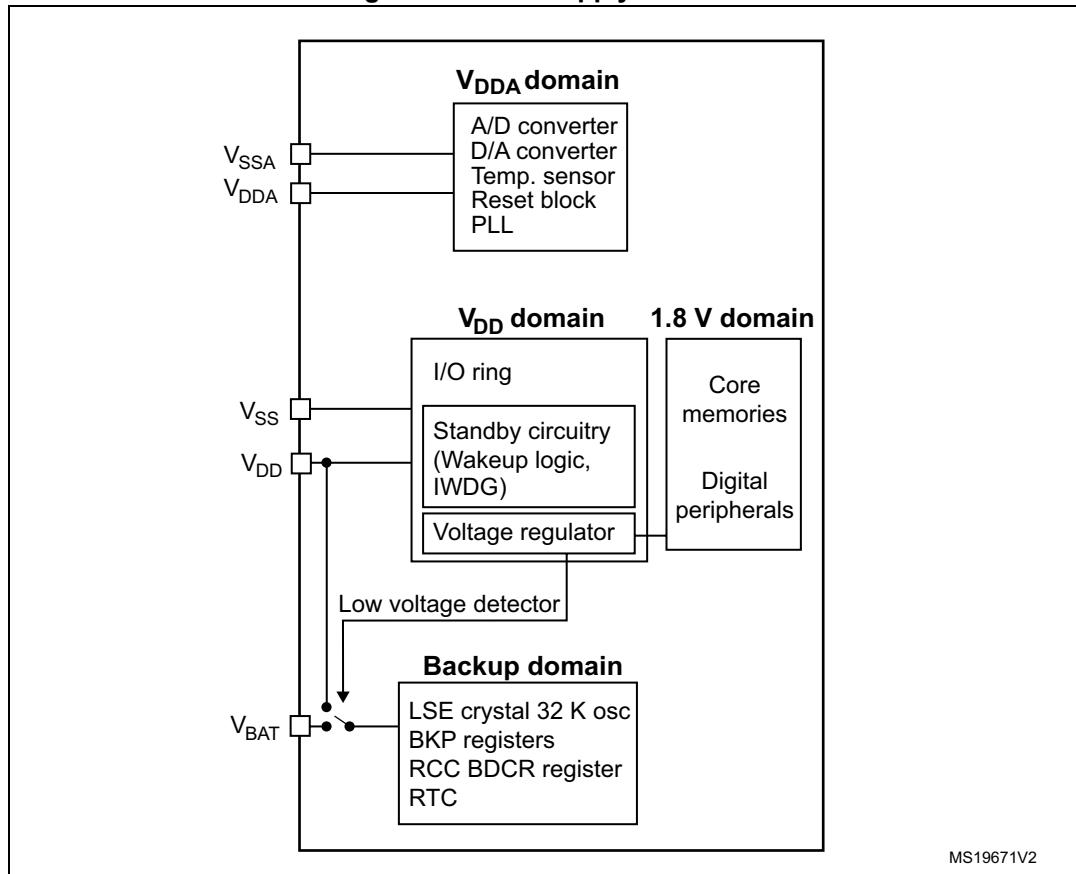
### 6.1 Power supplies

The STM32F05xxx subfamily embeds a voltage regulator in order to supply the internal 1.8 V digital power domain, unlike the STM32F06xxx subfamily where the stable 1.8 V must be delivered by the application.

- The STM32F05x devices require a 2.0 V - 3.6 V operating supply voltage ( $V_{DD}$ ) and a 2.0 V - 3.6 V analog supply voltage ( $V_{DDA}$ ).
- The STM32F06x devices require a 1.8 V  $\pm 8\%$  operating supply voltage ( $V_{DD}$ ) and a 1.65 V - 3.6 V analog supply voltage ( $V_{DDA}$ ).

The real-time clock (RTC) and backup registers can be powered from the  $V_{BAT}$  voltage when the main  $V_{DD}$  supply is powered off.

**Figure 6. Power supply overview**



MS19671V2

### 6.1.1 Independent A/D and D/A converter supply and reference voltage

To improve conversion accuracy and to extend the supply flexibility, the ADC and the DAC have an independent power supply which can be separately filtered and shielded from noise on the PCB.

- The ADC and DAC voltage supply input is available on a separate  $V_{DDA}$  pin.
- An isolated supply ground connection is provided on pin  $V_{SSA}$ .

The  $V_{DDA}$  supply/reference voltage can be equal or higher than  $V_{DD}$ .

When a single supply is used,  $V_{DDA}$  can be externally connected to  $V_{DD}$ , through the external filtering circuit in order to ensure a noise free  $V_{DDA}$ /reference voltage.

When  $V_{DDA}$  is different from  $V_{DD}$ ,  $V_{DDA}$  must always be higher or equal to  $V_{DD}$ . To keep safe potential difference in between  $V_{DDA}$  and  $V_{DD}$  during power-up/power-down, an external Shottky diode may be used between  $V_{DD}$  and  $V_{DDA}$ . Refer to the datasheet for the maximum allowed difference.

### 6.1.2 Battery backup domain

To retain the content of the Backup registers and supply the RTC function when  $V_{DD}$  is turned off,  $V_{BAT}$  pin can be connected to an optional standby voltage supplied by a battery or by another source.

The  $V_{BAT}$  pin powers the RTC unit, the LSE oscillator and the PC13 to PC15 IOs, allowing the RTC to operate even when the main power supply is turned off. The switch to the  $V_{BAT}$  supply is controlled by the Power Down Reset embedded in the Reset block.

---

**Warning:** During  $t_{RSTTEMPO}$  (temporization at  $V_{DD}$  startup) or after a PDR is detected, the power switch between  $V_{BAT}$  and  $V_{DD}$  remains connected to  $V_{BAT}$ .

During the startup phase, if  $V_{DD}$  is established in less than  $t_{RSTTEMPO}$  (Refer to the datasheet for the value of  $t_{RSTTEMPO}$ ) and  $V_{DD} > V_{BAT} + 0.6$  V, a current may be injected into  $V_{BAT}$  through an internal diode connected between  $V_{DD}$  and the power switch ( $V_{BAT}$ ).

If the power supply/battery connected to the  $V_{BAT}$  pin cannot support this current injection, it is strongly recommended to connect an external low-drop diode between this power supply and the  $V_{BAT}$  pin.

---

If no external battery is used in the application, it is recommended to connect  $V_{BAT}$  externally to  $V_{DD}$  with a 100 nF external ceramic decoupling capacitor (for more details refer to AN4080).

When the backup domain is supplied by  $V_{DD}$  (analog switch connected to  $V_{DD}$ ), the following functions are available:

- PC13, PC14 and PC15 can be used as GPIO pins
- PC13, PC14 and PC15 can be configured by RTC or LSE (refer to [Section 23.3: RTC functional description on page 478](#))

**Note:** Due to the fact that the analog switch can transfer only a limited amount of current (3 mA), the use of GPIOs PC13 to PC15 in output mode is restricted: the speed has to be limited to 2 MHz with a maximum load of 30 pF and these IOs must not be used as a current source (e.g. to drive an LED).

When the backup domain is supplied by  $V_{BAT}$  (analog switch connected to  $V_{BAT}$  because  $V_{DD}$  is not present), the following functions are available:

- PC13, PC14 and PC15 can be controlled only by RTC or LSE (refer to [Section 23.3: RTC functional description on page 478](#))

### 6.1.3 Voltage regulator

The voltage regulator is always enabled after Reset. It works in three different modes depending on the application modes.

- In Run mode, the regulator supplies full power to the 1.8 V domain (core, memories and digital peripherals).
- In Stop mode the regulator supplies low-power to the 1.8 V domain, preserving contents of registers and SRAM
- In Standby Mode, the regulator is powered off. The contents of the registers and SRAM are lost except for the Standby circuitry and the Backup Domain.

**Note:** In STM32F06x devices, the voltage regulator is bypassed and the microcontroller must be powered from a nominal  $V_{DD} = 1.8 \text{ V} \pm 8\%$  supply.

## 6.2 Power supply supervisor

### 6.2.1 Power on reset (POR) / power down reset (PDR)

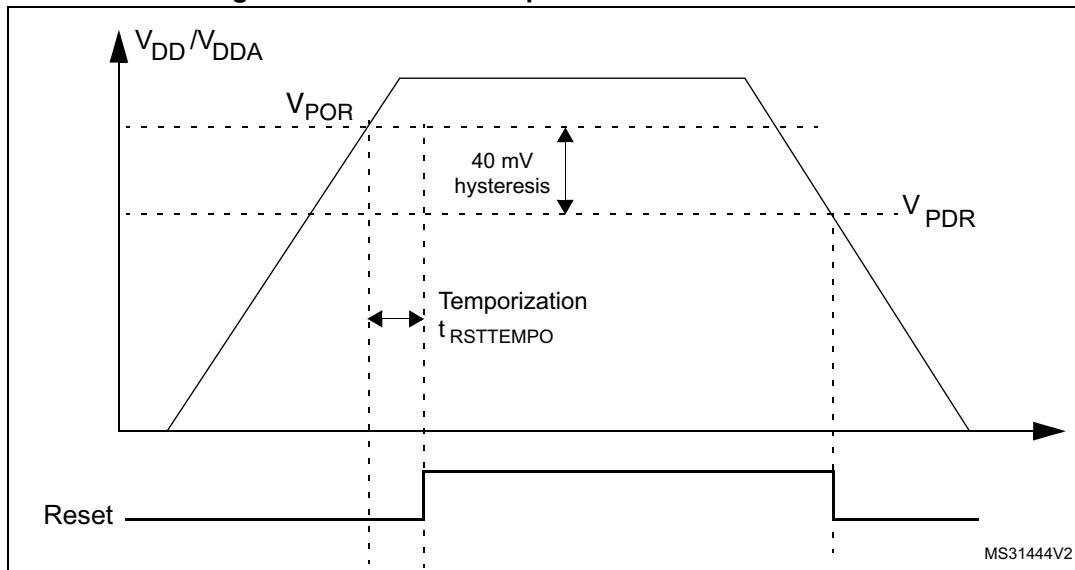
The device has an integrated power-on reset (POR) and power-down reset (PDR) circuits which are always active and ensure proper operation above a threshold of 2 V.

The device remains in Reset mode when the monitored supply voltage is below a specified threshold,  $V_{POR/PDR}$ , without the need for an external reset circuit.

- The POR monitors only the  $V_{DD}$  supply voltage. During the startup phase  $V_{DDA}$  must arrive first and be greater than or equal to  $V_{DD}$ .
- The PDR monitors both the  $V_{DD}$  and  $V_{DDA}$  supply voltages. However, the  $V_{DDA}$  power supply supervisor can be disabled (by programming a dedicated option bit  $V_{DDA\_MONITOR}$ ) to reduce the power consumption if the application is designed to make sure that  $V_{DDA}$  is higher than or equal to  $V_{DD}$ .

For more details on the power on / power down reset threshold, refer to the electrical characteristics section in the datasheet.

Figure 7. Power on reset/power down reset waveform



### External NPOR signal

In STM32F06x devices, the PB2 I/O is not available and is replaced by the NPOR functionality used for power on reset.

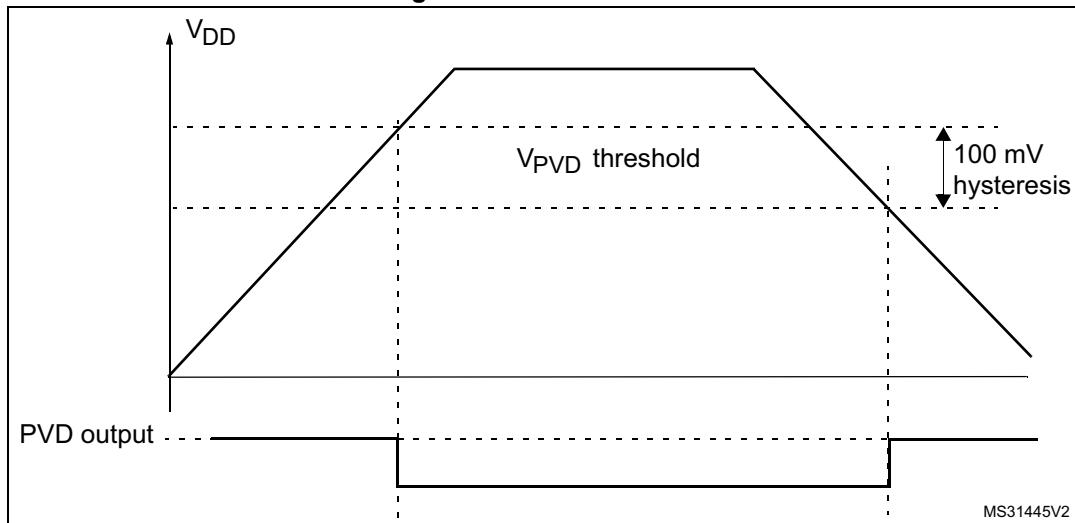
To guarantee a proper power on and power down reset to the device, the NPOR pin must be held low until  $V_{DD}$  is stable or before turning off the supply. When  $V_{DD}$  is stable, the reset state can be exited by putting the NPOR pin in high impedance. The NPOR pin has an internal pull-up connected to  $V_{DDA}$ .

### 6.2.2 Programmable voltage detector (PVD)

You can use the PVD to monitor the  $V_{DD}$  power supply by comparing it to a threshold selected by the PLS[2:0] bits in the [Power control register \(PWR\\_CR\)](#).

The PVD is enabled by setting the PVDE bit.

A PVDO flag is available, in the [Power control/status register \(PWR\\_CSR\)](#), to indicate if  $V_{DD}$  is higher or lower than the PVD threshold. This event is internally connected to the EXTI line16 and can generate an interrupt if enabled through the EXTI registers. The PVD output interrupt can be generated when  $V_{DD}$  drops below the PVD threshold and/or when  $V_{DD}$  rises above the PVD threshold depending on EXTI line16 rising/falling edge configuration. As an example the service routine could perform emergency shutdown tasks.

**Figure 8. PVD thresholds**

### 6.3 Low-power modes

By default, the microcontroller is in Run mode after a system or a power Reset. Several low-power modes are available to save power when the CPU does not need to be kept running, for example when waiting for an external event. It is up to the user to select the mode that gives the best compromise between low-power consumption, short startup time and available wakeup sources.

The device features three low-power modes:

- Sleep mode (CPU clock off, all peripherals including Cortex-M0 core peripherals like NVIC, SysTick, etc. are kept running)
- Stop mode (all clocks are stopped)
- Standby mode (1.8V domain powered-off)

In addition, the power consumption in Run mode can be reduced by one of the following means:

- Slowing down the system clocks
- Gating the clocks to the APB and AHB peripherals when they are unused.

**Table 12. Low-power mode summary**

Mode name	Entry	wakeup	Effect on 1.8V domain clocks	Effect on V <sub>DD</sub> domain clocks	Voltage regulator
Sleep (Sleep now or Sleep-on - exit)	WFI	Any interrupt	CPU clock OFF no effect on other clocks or analog clock sources	None	ON
	WFE	Wakeup event			
Stop	PDDS and LPDS bits + SLEEPDEEP bit + WFI or WFE	Any EXTI line (configured in the EXTI registers) Specific communication peripherals on reception events (CEC, USART, I2C)	All 1.8V domain clocks OFF	HSI and HSE oscillators OFF	ON or in low-power mode (depends on <i>Power control register (PWR_CR)</i> )
					OFF
Standby	PDDS bit + SLEEPDEEP bit + WFI or WFE	WKUP pin rising edge, RTC alarm, external reset in NRST pin, IWDG reset			

**Caution:** On STM32F06x devices, the Stop mode is available, but it is meaningless to distinguish between voltage regulator in Low power mode and voltage regulator in Run mode because the regulator is not used and the core is supplied directly from an external source. Consequently, the Standby mode is not available on those devices.

### 6.3.1 Slowing down system clocks

In Run mode the speed of the system clocks (SYSCLK, HCLK, PCLK) can be reduced by programming the prescaler registers. These prescalers can also be used to slow down peripherals before entering Sleep mode.

For more details refer to [Section 7.4.2: Clock configuration register \(RCC\\_CFGR\)](#).

### 6.3.2 Peripheral clock gating

In Run mode, the HCLK and PCLK for individual peripherals and memories can be stopped at any time to reduce power consumption.

To further reduce power consumption in Sleep mode the peripheral clocks can be disabled prior to executing the WFI or WFE instructions.

Peripheral clock gating is controlled by the *AHB peripheral clock enable register (RCC\_AHBENR)*, the *APB peripheral clock enable register 2 (RCC\_APB2ENR)* and the *APB peripheral clock enable register 1 (RCC\_APB1ENR)*.

### 6.3.3 Sleep mode

#### Entering Sleep mode

The Sleep mode is entered by executing the WFI (Wait For Interrupt) or WFE (Wait for Event) instructions. Two options are available to select the Sleep mode entry mechanism, depending on the SLEEPONEXIT bit in the Cortex-M0 System Control register:

- Sleep-now: if the SLEEPONEXIT bit is cleared, the MCU enters Sleep mode as soon as WFI or WFE instruction is executed.
- Sleep-on-exit: if the SLEEPONEXIT bit is set, the MCU enters Sleep mode as soon as it exits the lowest priority ISR.

In the Sleep mode, all I/O pins keep the same state as in the Run mode.

Refer to [Table 13](#) and [Table 14](#) for details on how to enter Sleep mode.

#### Exiting Sleep mode

If the WFI instruction is used to enter Sleep mode, any peripheral interrupt acknowledged by the nested vectored interrupt controller (NVIC) can wake up the device from Sleep mode.

If the WFE instruction is used to enter Sleep mode, the MCU exits Sleep mode as soon as an event occurs. The wakeup event can be generated either by:

- enabling an interrupt in the peripheral control register but not in the NVIC, and enabling the SEVONPEND bit in the Cortex-M0 System Control register. When the MCU resumes from WFE, the peripheral interrupt pending bit and the peripheral NVIC IRQ channel pending bit (in the NVIC interrupt clear pending register) have to be cleared.
- or configuring an external or internal EXTI line in event mode. When the CPU resumes from WFE, it is not necessary to clear the peripheral interrupt pending bit or the NVIC IRQ channel pending bit as the pending bit corresponding to the event line is not set.

This mode offers the lowest wakeup time as no time is wasted in interrupt entry/exit.

Refer to [Table 13](#) and [Table 14](#) for more details on how to exit Sleep mode.

**Table 13. Sleep-now**

Sleep-now mode	Description
<b>Mode entry</b>	WFI (Wait for Interrupt) or WFE (Wait for Event) while: – SLEEPDEEP = 0 and – SLEEPONEXIT = 0 Refer to the Cortex-M0 System Control register.
<b>Mode exit</b>	If WFI was used for entry: Interrupt: Refer to <a href="#">Table 26: Vector table</a> If WFE was used for entry Wakeup event: Refer to <a href="#">Section 11.2.3: Wakeup event management</a>
<b>Wakeup latency</b>	None

**Table 14. Sleep-on-exit**

Sleep-on-exit	Description
<b>Mode entry</b>	WFI (wait for interrupt) while: – SLEEPDEEP = 0 and – SLEEPONEXIT = 1 Refer to the Cortex-M0 System Control register.
<b>Mode exit</b>	Interrupt: Refer to <a href="#">Table 26: Vector table</a> .
<b>Wakeup latency</b>	None

### 6.3.4 Stop mode

The Stop mode is based on the Cortex-M0 deepsleep mode combined with peripheral clock gating. The voltage regulator can be configured either in normal or low-power mode. In Stop mode, all clocks in the 1.8 V domain are stopped, the PLL, the HSI and the HSE oscillators are disabled. SRAM and register contents are preserved.

In the Stop mode, all I/O pins keep the same state as in the Run mode.

#### Entering Stop mode

Refer to [Table 15](#) for details on how to enter the Stop mode.

To further reduce power consumption in Stop mode, the internal voltage regulator can be put in low-power mode. This is configured by the LPDS bit of the [Power control register \(PWR\\_CR\)](#).

If Flash memory programming is ongoing, the Stop mode entry is delayed until the memory access is finished.

If an access to the APB domain is ongoing, The Stop mode entry is delayed until the APB access is finished.

In Stop mode, the following features can be selected by programming individual control bits:

- Independent watchdog (IWDG): the IWDG is started by writing to its Key register or by hardware option. Once started it cannot be stopped except by a Reset. See [Section 21.3: IWDG functional description](#) in [Section 21: Independent watchdog \(IWDG\)](#).

- real-time clock (RTC): this is configured by the RTCEN bit in the [Backup domain control register \(RCC\\_BDCR\)](#)
- Internal RC oscillator (LSI): this is configured by the LSION bit in the [Control/status register \(RCC\\_CSR\)](#).
- External 32.768 kHz oscillator (LSE): this is configured by the LSEON bit in the [Backup domain control register \(RCC\\_BDCR\)](#).

The ADC or DAC can also consume power during Stop mode, unless they are disabled before entering this mode. Refer to [ADC control register \(ADC\\_CR\)](#) and [DAC control register \(DAC\\_CR\)](#) for details on how to disable them.

### Exiting Stop mode

Refer to [Table 15](#) for more details on how to exit Stop mode.

When exiting Stop mode by issuing an interrupt or a wakeup event, the HSI oscillator is selected as system clock.

When the voltage regulator operates in low-power mode, an additional startup delay is incurred when waking up from Stop mode. By keeping the internal regulator ON during Stop mode, the consumption is higher although the startup time is reduced.

**Table 15. Stop mode**

Stop mode	Description
<b>Mode entry</b>	<p>WFI (Wait for Interrupt) or WFE (Wait for Event) while:</p> <ul style="list-style-type: none"> <li>Set SLEEPDEEP bit in Cortex-M0 System Control register</li> <li>Clear PDDE bit in Power Control register (PWR_CR)</li> <li>Select the voltage regulator mode by configuring LPDS bit in PWR_CR</li> </ul> <p><b>Note:</b> To enter Stop mode, all EXTI Line pending bits (in <a href="#">Pending register (EXTI_PR)</a>) and RTC Alarm flag must be reset. Otherwise, the Stop mode entry procedure is ignored and program execution continues.</p>
<b>Mode exit</b>	<p>If WFI was used for entry:</p> <ul style="list-style-type: none"> <li>Any EXTI Line configured in Interrupt mode (the corresponding EXTI Interrupt vector must be enabled in the NVIC).</li> <li>Some specific communication peripherals (CEC, USART, I2C) interrupts, when programmed in wakeup mode (the peripheral must be programmed in wakeup mode and the corresponding interrupt vector must be enabled in the NVIC).</li> </ul> <p>Refer to <a href="#">Table 26: Vector table</a>.</p> <p>If WFE was used for entry:</p> <ul style="list-style-type: none"> <li>Any EXTI Line configured in event mode. Refer to <a href="#">Section 11.2.3: Wakeup event management on page 167</a></li> </ul>
<b>Wakeup latency</b>	HSI wakeup time + regulator wakeup time from Low-power mode

### 6.3.5 Standby mode

The Standby mode allows to achieve the lowest power consumption. It is based on the Cortex-M0 deepsleep mode, with the voltage regulator disabled. The 1.8 V domain is consequently powered off. The PLL, the HSI oscillator and the HSE oscillator are also switched off. SRAM and register contents are lost except for registers in the Backup domain and Standby circuitry (see [Figure 6](#)).

**Caution:** The Standby mode is not available on STM32F06x devices.

#### Entering Standby mode

Refer to [Table 16](#) for more details on how to enter Standby mode.

In Standby mode, the following features can be selected by programming individual control bits:

- Independent watchdog (IWDG): the IWDG is started by writing to its Key register or by hardware option. Once started it cannot be stopped except by a reset. See [Section 21.3: IWDG functional description](#) in [Section 21: Independent watchdog \(IWDG\)](#).
- real-time clock (RTC): this is configured by the RTCEN bit in the Backup domain control register (RCC\_BDCR)
- Internal RC oscillator (LSI): this is configured by the LSION bit in the Control/status register (RCC\_CSR).
- External 32.768 kHz oscillator (LSE): this is configured by the LSEON bit in the Backup domain control register (RCC\_BDCR)

#### Exiting Standby mode

The microcontroller exits the Standby mode when an external reset (NRST pin), an IWDG reset, a rising edge on one of the enabled WKUPx pins or the rising edge of an RTC alarm occurs (see [Figure 197: RTC block diagram](#)). All registers are reset after wakeup from Standby except for [Power control/status register \(PWR\\_CSR\)](#).

After waking up from Standby mode, program execution restarts in the same way as after a Reset (boot pin sampling, option bytes loading, reset vector is fetched, etc.). The SBF status flag in the [Power control/status register \(PWR\\_CSR\)](#) indicates that the MCU was in Standby mode.

Refer to [Table 16](#) for more details on how to exit Standby mode.

**Table 16. Standby mode**

Standby mode	Description
<b>Mode entry</b>	WFI (Wait for Interrupt) or WFE (Wait for Event) while: – Set SLEEPDEEP in Cortex-M0 System Control register – Set PDDS bit in Power Control register (PWR_CR) – Clear WUF bit in Power Control/Status register (PWR_CSR)
<b>Mode exit</b>	WKUP pin rising edge, RTC alarm event's rising edge, external Reset in NRST pin, IWDG Reset.
<b>Wakeup latency</b>	Reset phase

### I/O states in Standby mode

In Standby mode, all I/O pins are high impedance except:

- Reset pad (still available)
- PC13, PC14 and PC15 if configured by RTC or LSE
- WKUPx pins

### Debug mode

By default, the debug connection is lost if the application puts the MCU in Stop or Standby mode while the debug features are used. This is due to the fact that the Cortex-M0 core is no longer clocked.

However, by setting some configuration bits in the DBGMCU\_CR register, the software can be debugged even when using the low-power modes extensively.

### 6.3.6 Auto-wakeup from low-power mode

The RTC can be used to wakeup the MCU from low-power mode without depending on an external interrupt (Auto-wakeup mode). The RTC provides a programmable time base for waking up from Stop or Standby mode at regular intervals. For this purpose, two of the three alternative RTC clock sources can be selected by programming the RTCSEL[1:0] bits in the *Backup domain control register (RCC\_BDCR)*:

- Low-power 32.768 kHz external crystal oscillator (LSE OSC)  
This clock source provides a precise time base with very low-power consumption (less than 1 $\mu$ A added consumption in typical conditions)
- Low-power internal RC Oscillator (LSI)  
This clock source has the advantage of saving the cost of the 32.768 kHz crystal. This internal RC Oscillator is designed to add minimum power consumption.

To wakeup from Stop mode with an RTC alarm event, it is necessary to:

- Configure the EXTI Line 17 to be sensitive to rising edge
- Configure the RTC to generate the RTC alarm

To wakeup from Standby mode, there is no need to configure the EXTI Line 17.

## 6.4 Power control registers

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

### 6.4.1 Power control register (PWR\_CR)

Address offset: 0x00

Reset value: 0x0000 0000 (reset by wakeup from Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res	Res	Res	Res	Res	Res	Res	Res								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res	DBP	PLS[2:0]			PVDE	CSBF	CWUF	PDDS	LPDS						
							rw	rw	rw	rw	rw	rc_w1	rc_w1	rw	rw

Bits 31:9 Reserved, must be kept at reset value.

Bit 8 **DBP**: Disable backup domain write protection.

In reset state, the RTC and backup registers are protected against parasitic write access. This bit must be set to enable write access to these registers.

- 0: Access to RTC and Backup registers disabled
- 1: Access to RTC and Backup registers enabled

Bits 7:5 **PLS[2:0]**: PVD level selection.

These bits are written by software to select the voltage threshold detected by the Power Voltage Detector.

Once the PVD\_LOCK is enabled in the [SYSCFG configuration register 2 \(SYSCFG\\_CFGR2\)](#), the PLS[2:0] bits cannot be programmed anymore.

- 000: PVD threshold 0
- 001: PVD threshold 1
- 010: PVD threshold 2
- 011: PVD threshold 3
- 100: PVD threshold 4
- 101: PVD threshold 5
- 110: PVD threshold 6
- 111: PVD threshold 7

Refer to the electrical characteristics of the datasheet for more details.

Bit 4 **PVDE**: Power voltage detector enable.

This bit is set and cleared by software. Once the PVD\_LOCK is enabled in the [SYSCFG configuration register 2 \(SYSCFG\\_CFGR2\)](#) register, the PVDE bit cannot be programmed anymore.

- 0: PVD disabled
- 1: PVD enabled

Bit 3 **CSBF**: Clear standby flag.

This bit is always read as 0.

- 0: No effect
- 1: Clear the SBF Standby Flag (write).

Bit 2 **CWUF**: Clear wakeup flag.

This bit is always read as 0.

0: No effect

1: Clear the WUF Wakeup Flag **after 2 System clock cycles**. (write)

Bit 1 **PDDS**: Power down deepsleep.

This bit is set and cleared by software. It works together with the LPDS bit.

0: Enter Stop mode when the CPU enters Deepsleep. The regulator status depends on the LPDS bit.

1: Enter Standby mode when the CPU enters Deepsleep.

Bit 0 **LPDS**: Low-power deepsleep.

This bit is set and cleared by software. It works together with the PDDS bit.

0: Voltage regulator on during Stop mode

1: Voltage regulator in low-power mode during Stop mode

*Note: When a peripheral that can work in STOP mode requires a clock, the Power controller automatically switch the voltage regulator from Low-power mode to Normal mode and remains in this mode until the request disappears.*

## 6.4.2 Power control/status register (PWR\_CSR)

Address offset: 0x04

Reset value: 0x0000 0000 (not reset by wakeup from Standby mode)

Additional APB cycles are needed to read this register versus a standard APB read.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res	Res	Res	Res	Res	Res	Res	Res	Res	Res						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res	Res	Res	Res	Res	Res	EWUP2	EWUP1	Res	Res	Res	Res	Res	PVDO	SBF	WUF
						rw	rw						r	r	r

Bits 31:10 Reserved, must be kept at reset value.

Bit 9 **EWUP2**: Enable WKUP2 pin

This bit is set and cleared by software.

0: WKUP2 pin is used for general purpose I/O. An event on the WKUP2 pin does not wakeup the device from Standby mode.

1: WKUP2 pin is used for wakeup from Standby mode and forced in input pull down configuration (rising edge on WKUP2 pin wakes-up the system from Standby mode).

*Note: This bit is reset by a system Reset.*

Bit 8 **EWUP1**: Enable WKUP1 pin

This bit is set and cleared by software.

0: WKUP1 pin is used for general purpose I/O. An event on the WKUP1 pin does not wakeup the device from Standby mode.

1: WKUP1 pin is used for wakeup from Standby mode and forced in input pull down configuration (rising edge on WKUP1 pin wakes-up the system from Standby mode).

*Note: This bit is reset by a system Reset.*

Bits 7:3 Reserved, must be kept at reset value.

**Bit 2 PVDO:** PVD output

This bit is set and cleared by hardware. It is valid only if PVD is enabled by the PVDE bit.

0:  $V_{DD}$  is lower than the PVD threshold selected with the PLS[2:0] bits.

1:  $V_{DD}$  is higher than the PVD threshold selected with the PLS[2:0] bits.

Notes:

1. The PVD is stopped by Standby mode. For this reason, this bit is equal to 0 after Standby or reset until the PVDE bit is set.
2. Once the PVD is enabled and configured in the PWR\_CR register, PVDO can be used to generate an interrupt through the External Interrupt controller.

**Bit 1 SBF:** Standby flag

This bit is set by hardware when the device enters Standby mode and it is cleared only by a POR/PDR (power on reset/power down reset) or by setting the CSBF bit in the [Power control register \(PWR\\_CR\)](#)

0: Device has not been in Standby mode

1: Device has been in Standby mode

**Bit 0 WUF:** Wakeup flag

This bit is set by hardware to indicate that the device received a wakeup event. It is cleared only by a POR/PDR (power on reset/power down reset) or by setting the CWUF bit in the [Power control register \(PWR\\_CR\)](#)

0: No wakeup event occurred

1: A wakeup event was received from one of the enabled WKUPx pins or from the RTC alarm.

*Note: An additional wakeup event is detected if one WKUPx pin is enabled (by setting the EWUP bit) when its pin level is already high.*

### 6.4.3 PWR register map

The following table summarizes the PWR registers.

**Table 17. PWR register map and reset values**

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x000	PWR_CR	Res.																															
	Reset value																																
0x004	PWR_CSR	Res.																															
	Reset value																																

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 7 Reset and clock control (RCC)

### 7.1 Reset

There are three types of reset, defined as system reset, power reset and backup domain reset.

#### 7.1.1 Power reset

A power reset is generated when one of the following events occurs:

1. Power-on/power-down reset (POR/PDR reset)
2. When exiting Standby mode

A power reset sets all registers to their reset values except the Backup domain ([Figure 6 on page 73](#)).

In STM32F06x devices, the POR/PDR reset is not functional and the Standby mode is not available. Power reset must be provided from an external NPOR pin (active low and released by the application when all supply voltages are stabilized).

#### 7.1.2 System reset

A system reset sets all registers to their reset values except the reset flags in the clock controller CSR register and the registers in the Backup domain (see [Figure 6 on page 73](#)).

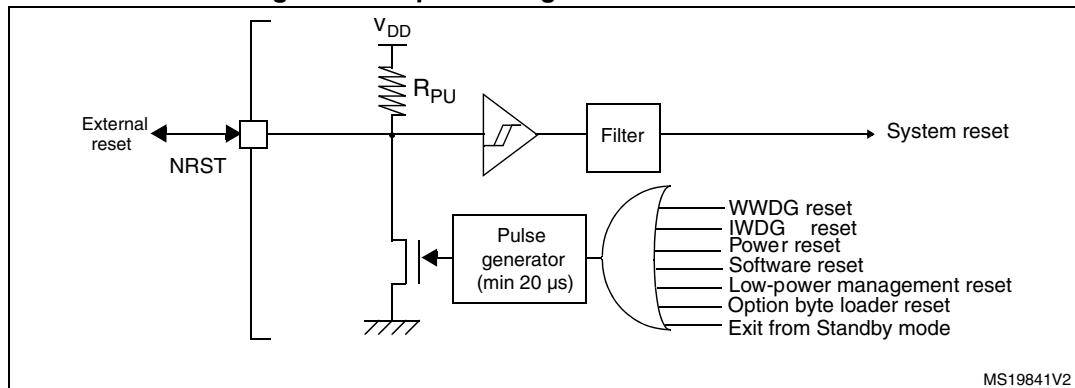
A system reset is generated when one of the following events occurs:

1. A low level on the NRST pin (external reset)
2. Window watchdog event (WWDG reset)
3. Independent watchdog event (IWDG reset)
4. A software reset (SW reset) (see [Software reset](#))
5. Low-power management reset (see [Low-power management reset](#))
6. Option byte loader reset (see [Option byte loader reset](#))
7. A power reset

The reset source can be identified by checking the reset flags in the Control/Status register, RCC\_CSR (see [Section 7.4.10: Control/status register \(RCC\\_CSR\)](#)).

These sources act on the NRST pin and it is always kept low during the delay phase. The RESET service routine vector is fixed at address 0x0000\_0004 in the memory map.

The system reset signal provided to the device is output on the NRST pin. The pulse generator guarantees a minimum reset pulse duration of 20 µs for each internal reset source. In case of an external reset, the reset pulse is generated while the NRST pin is asserted low.

**Figure 9. Simplified diagram of the reset circuit**

### Software reset

The SYSRESETREQ bit in Cortex-M0 Application Interrupt and Reset Control Register must be set to force a software reset on the device. Refer to the *Cortex™-M0 technical reference manual* for more details.

### Low-power management reset

There are two ways to generate a low-power management reset:

1. Reset generated when entering Standby mode:

This type of reset is enabled by resetting nRST\_STDBY bit in User Option Bytes. In this case, whenever a Standby mode entry sequence is successfully executed, the device is reset instead of entering Standby mode.

2. Reset when entering Stop mode:

This type of reset is enabled by resetting nRST\_STOP bit in User Option Bytes. In this case, whenever a Stop mode entry sequence is successfully executed, the device is reset instead of entering Stop mode.

For further information on the User Option Bytes, refer to [Section 4: Option bytes](#).

### Option byte loader reset

The option byte loader reset is generated when the OBL\_LAUNCH bit (bit 13) is set in the FLASH\_CR register. This bit is used to launch the option byte loading by software.

## 7.1.3 Backup domain reset

The backup domain has two specific resets that affect only the backup domain ([Figure 6 on page 73](#)).

A backup domain reset only affects the LSE oscillator, the RTC, the Backup register and the RCC Backup Domain Control Register. It is generated when one of the following events occurs.

1. Software reset, triggered by setting the BDRST bit in the [Backup domain control register \(RCC\\_BDCR\)](#).
2. V<sub>DD</sub> power-up if V<sub>BAT</sub> has been disconnected when it was low.

The Backup registers are also reset when one of the following events occurs:

1. RTC tamper detection event.
2. Change of the read out protection from level 1 to level 0.

## 7.2 Clocks

Three different clock sources can be used to drive the system clock (SYSCLK):

- HSI 8 MHz RC oscillator clock
- HSE oscillator clock
- PLL clock

The devices have the following additional clock sources:

- 40 kHz low speed internal RC (LSI RC) which drives the independent watchdog and optionally the RTC used for Auto-wakeup from Stop/Standy mode.
- 32.768 kHz low speed external crystal (LSE crystal) which optionally drives the real-time clock (RTCCLK)
- 14 MHz high speed internal RC (HSI14) dedicated for ADC.

Each clock source can be switched on or off independently when it is not used, to optimize power consumption.

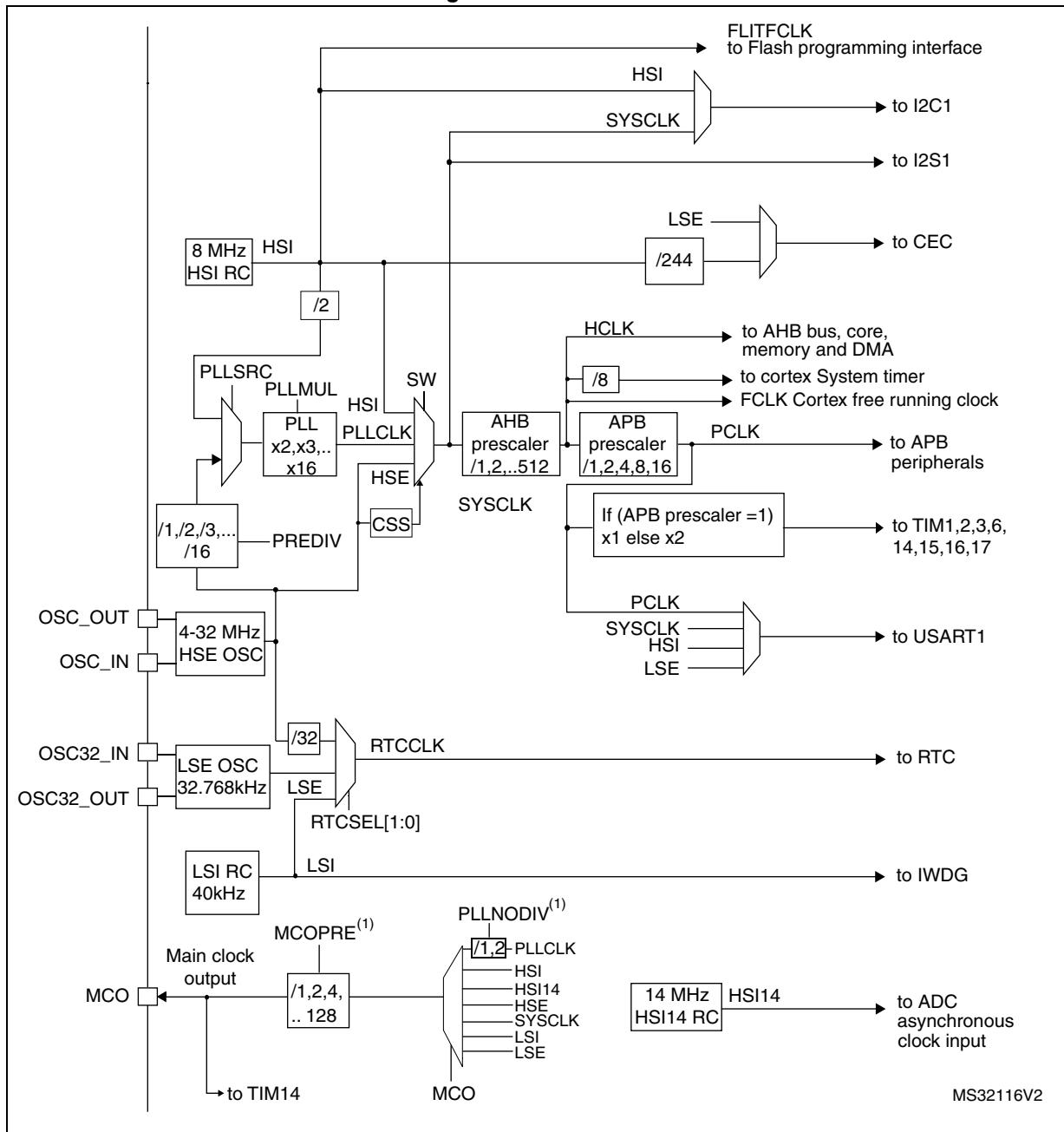
Several prescalers can be used to configure the frequency of the AHB and the APB domains. The AHB and the APB domains maximum frequency is 48 MHz.

All the peripheral clocks are derived from their bus clock (HCLK or PCLK) except:

- The Flash memory programming interface clock (FLITFCLK) which is always the HSI clock.
- The option byte loader clock which is always the HSI clock
- The ADC clock which is derived (selected by software) from one of the two following sources:
  - dedicated HSI14 clock, to run always at the maximum sampling rate
  - APB clock (PCLK) divided by 2 or 4
- The USART1 clock which is derived (selected by software) from one of the four following sources:
  - system clock
  - HSI clock
  - LSE clock
  - APB clock (PCLK)
- The I2C1 clock which is derived (selected by software) from one of the two following sources:
  - system clock
  - HSI clock
- The CEC clock which is derived from the HSI clock divided by 244 or from the LSE clock.
- The I2S1 clock which is always the system clock.
- The RTC clock which is derived from the LSE, LSI or from the HSE clock divided by 32.
- The timer clock frequencies are automatically fixed by hardware. There are two cases:
  - if the APB prescaler is 1, the timer clock frequencies are set to the same frequency as that of the APB domain;
  - otherwise, they are set to twice (x2) the frequency of the APB domain.
- The IWDG clock which is always the LSI clock.

The RCC feeds the Cortex System Timer (SysTick) external clock with the AHB clock (HCLK) divided by 8. The SysTick can work either with this clock or directly with the Cortex clock (HCLK), configurable in the SysTick Control and Status Register.

Figure 10. Clock tree



1. Not available on medium-density devices.

FCLK acts as Cortex-M0's free-running clock. For more details refer to the *ARM Cortex™-M0 r0p0 technical reference manual (TRM)*.

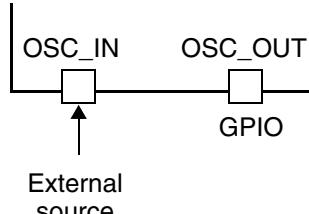
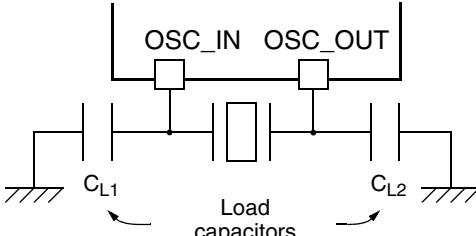
### 7.2.1 HSE clock

The high speed external clock signal (HSE) can be generated from two possible clock sources:

- HSE external crystal/ceramic resonator
- HSE user external clock

The resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. The loading capacitance values must be adjusted according to the selected oscillator.

**Figure 11. HSE/ LSE clock sources**

Clock source	Hardware configuration
External clock	
Crystal/Ceramic resonators	

### External crystal/ceramic resonator (HSE crystal)

The 4 to 32 MHz external oscillator has the advantage of producing a very accurate rate on the main clock.

The associated hardware configuration is shown in [Figure 11](#). Refer to the electrical characteristics section of the *datasheet* for more details.

The HSERDY flag in the [Clock control register \(RCC\\_CR\)](#) indicates if the HSE oscillator is stable or not. At startup, the clock is not released until this bit is set by hardware. An interrupt can be generated if enabled in the [Clock interrupt register \(RCC\\_CIR\)](#).

The HSE Crystal can be switched on and off using the HSEON bit in the [Clock control register \(RCC\\_CR\)](#).

**Caution:** To switch ON the HSE oscillator, 512 HSE clock pulses need to be seen by an internal stabilization counter after the HSEON bit is set. Even in the case that no crystal or resonator is connected to the device, excessive external noise on the OSC\_IN pin may still lead the oscillator to start. Once the oscillator is started, it needs another 6 HSE clock pulses to complete a switching OFF sequence. If for any reason the oscillations are no more present on the OSC\_IN pin, the oscillator cannot be switched OFF, locking the OSC pins from any other use and introducing unwanted power consumption. To avoid such situation, it is strongly recommended to always enable the Clock Security System (CSS) which is able to switch OFF the oscillator even in this case.

### External source (HSE bypass)

In this mode, an external clock source must be provided. It can have a frequency of up to 32 MHz. You select this mode by setting the HSEBYP and HSEON bits in the [Clock control register \(RCC\\_CR\)](#). The external clock signal (square, sinus or triangle) with ~40-60% duty cycle depending on the frequency (refer to the *datasheet*) has to drive the OSC\_IN pin while the OSC\_OUT pin can be used a GPIO. See [Figure 11](#).

## 7.2.2 HSI clock

The HSI clock signal is generated from an internal 8 MHz RC oscillator and can be used directly as a system clock or divided by 2 to be used as PLL input.

The HSI RC oscillator has the advantage of providing a clock source at low cost (no external components). It also has a faster startup time than the HSE crystal oscillator however, even with calibration the frequency is less accurate than an external crystal oscillator or ceramic resonator.

### Calibration

RC oscillator frequencies can vary from one chip to another due to manufacturing process variations, this is why each device is factory calibrated by ST for 1% accuracy at  $T_A=25^\circ\text{C}$ .

After reset, the factory calibration value is loaded in the HSICAL[7:0] bits in the [Clock control register \(RCC\\_CR\)](#).

If the application is subject to voltage or temperature variations this may affect the RC oscillator speed. You can trim the HSI frequency in the application using the HSITRIM[4:0] bits in the [Clock control register \(RCC\\_CR\)](#).

For more details on how to measure the HSI frequency variation please refer to [Section 7.2.12: Internal/external clock measurement with TIM14 on page 95](#)

The HSIRDY flag in the [Clock control register \(RCC\\_CR\)](#) indicates if the HSI RC is stable or not. At startup, the HSI RC output clock is not released until this bit is set by hardware.

The HSI RC can be switched on and off using the HSION bit in the [Clock control register \(RCC\\_CR\)](#).

The HSI signal can also be used as a backup source (Auxiliary clock) if the HSE crystal oscillator fails. Refer to [Section 7.2.7: Clock security system \(CSS\) on page 93](#).

Furthermore it is possible to drive the HSI clock to the MCO multiplexer. Then the clock could be driven to the Timer 14 giving the ability to the user to calibrate the oscillator.

### 7.2.3 PLL

The internal PLL can be used to multiply the HSI or HSE output clock frequency. Refer to [Figure 10](#) and [Clock control register \(RCC\\_CR\)](#).

The PLL configuration (selection of the input clock, predivider and multiplication factor) must be done before enabling the PLL. Once the PLL is enabled, these parameters cannot be changed.

To modify the PLL configuration, proceed as follows:

1. Disable the PLL by setting PLLON to 0.
2. Wait until PLLRDY is cleared. The PLL is now fully stopped.
3. Change the desired parameter.
4. Enable the PLL again by setting PLLON to 1.

An interrupt can be generated when the PLL is ready, if enabled in the [Clock interrupt register \(RCC\\_CIR\)](#).

The PLL output frequency must be set in the range 16–48 MHz.

### 7.2.4 LSE clock

The LSE crystal is a 32.768 kHz Low Speed External crystal or ceramic resonator. It has the advantage of providing a low-power but highly accurate clock source to the real-time clock peripheral (RTC) for clock/calendar or other timing functions.

The LSE crystal is switched on and off using the LSEON bit in [Backup domain control register \(RCC\\_BDCR\)](#). The crystal oscillator driving strength can be changed at runtime using the LSEDRV[1:0] bits in the [Backup domain control register \(RCC\\_BDCR\)](#) to obtain the best compromise between robustness and short start-up time on one side and low power-consumption on the other.

The LSERDY flag in the [Backup domain control register \(RCC\\_BDCR\)](#) indicates whether the LSE crystal is stable or not. At startup, the LSE crystal output clock signal is not released until this bit is set by hardware. An interrupt can be generated if enabled in the [Clock interrupt register \(RCC\\_CIR\)](#).

**Caution:** To switch ON the LSE oscillator, 4096 LSE clock pulses need to be seen by an internal stabilization counter after the LSEON bit is set. Even in the case that no crystal or resonator is connected to the device, excessive external noise on the OSC32\_IN pin may still lead the oscillator to start. Once the oscillator is started, it needs another 6 LSE clock pulses to complete a switching OFF sequence. If for any reason the oscillations are no more present on the OSC\_IN pin, the oscillator cannot be switched OFF, locking the OSC32 pins from any

other use and introducing unwanted power consumption. The only way to recover such situation is to perform the Backup domain reset by software.

#### External source (LSE bypass)

In this mode, an external clock source must be provided. It can have a frequency of up to 1 MHz. You select this mode by setting the LSEBYP and LSEON bits in the [Backup domain control register \(RCC\\_BDCR\)](#). The external clock signal (square, sinus or triangle) with ~50% duty cycle has to drive the OSC32\_IN pin while the OSC32\_OUT pin can be used as GPIO. See [Figure 11](#).

### 7.2.5 LSI clock

The LSI RC acts as an low-power clock source that can be kept running in Stop and Standby mode for the independent watchdog (IWDG) and RTC. The clock frequency is around 40 kHz (between 30 kHz and 60 kHz). For more details, refer to the electrical characteristics section of the datasheets.

The LSI RC can be switched on and off using the LSION bit in the [Control/status register \(RCC\\_CSR\)](#).

The LSIRDY flag in the [Control/status register \(RCC\\_CSR\)](#) indicates if the LSI oscillator is stable or not. At startup, the clock is not released until this bit is set by hardware. An interrupt can be generated if enabled in the [Clock interrupt register \(RCC\\_CIR\)](#).

### 7.2.6 System clock (SYSCLK) selection

Three different clock sources can be used to drive the system clock (SYSCLK):

- HSI oscillator
- HSE oscillator
- PLL

After a system reset, the HSI oscillator is selected as system clock. When a clock source is used directly or through the PLL as a system clock, it is not possible to stop it.

A switch from one clock source to another occurs only if the target clock source is ready (clock stable after startup delay or PLL locked). If a clock source which is not yet ready is selected, the switch will occur when the clock source becomes ready. Status bits in the [Clock control register \(RCC\\_CR\)](#) indicate which clock(s) is (are) ready and which clock is currently used as a system clock.

### 7.2.7 Clock security system (CSS)

Clock Security System can be activated by software. In this case, the clock detector is enabled after the HSE oscillator startup delay, and disabled when this oscillator is stopped.

If a failure is detected on the HSE clock, the HSE oscillator is automatically disabled, a clock failure event is sent to the break input of the advanced-control timers (TIM1) and general-purpose timers (TIM15, TIM16 and TIM17) and an interrupt is generated to inform the software about the failure (Clock Security System Interrupt CSSI), allowing the MCU to perform rescue operations. The CSSI is linked to the Cortex-M0 NMI (Non-Maskable Interrupt) exception vector.

**Note:** Once the CSS is enabled and if the HSE clock fails, the CSS interrupt occurs and an NMI is automatically generated. The NMI will be executed indefinitely unless the CSS interrupt

*pending bit is cleared. As a consequence, in the NMI ISR user must clear the CSS interrupt by setting the CSSC bit in the [Clock interrupt register \(RCC\\_CIR\)](#).*

If the HSE oscillator is used directly or indirectly as the system clock (indirectly means: it is used as PLL input clock, and the PLL clock is used as system clock), a detected failure causes a switch of the system clock to the HSI oscillator and the disabling of the HSE oscillator. If the HSE clock (divided or not) is the clock entry of the PLL used as system clock when the failure occurs, the PLL is disabled too.

### 7.2.8 ADC clock

The ADC clock selection is done inside the ADC\_CFGR2 (refer to [Section 12.12.5: ADC configuration register 2 \(ADC\\_CFGR2\) on page 207](#)). It can be either the dedicated 14 MHz RC oscillator (HSI14) or PCLK divided by 2 or 4. The 14 MHz RC oscillator can be configured by software either to be turned on/off (“auto-off mode”) by the ADC interface or to be always enabled. The HSI 14 MHz RC oscillator cannot be turned on by ADC interface when the APB clock is selected as an ADC kernel clock.

### 7.2.9 RTC clock

The RTCCLK clock source can be either the HSE/32, LSE or LSI clocks. This is selected by programming the RTCSEL[1:0] bits in the [Backup domain control register \(RCC\\_BDCR\)](#). This selection cannot be modified without resetting the Backup domain. The system must be always configured in a way that the PCLK frequency is greater than or equal to the RTCCLK frequency for proper operation of the RTC.

The LSE clock is in the Backup domain, whereas the HSE and LSI clocks are not. Consequently:

- If LSE is selected as RTC clock:
  - The RTC continues to work even if the  $V_{DD}$  supply is switched off, provided the  $V_{BAT}$  supply is maintained.
- If LSI is selected as the RTC clock:
  - The RTC state is not guaranteed if the  $V_{DD}$  supply is powered off.
- If the HSE clock divided by 32 is used as the RTC clock:
  - The RTC state is not guaranteed if the  $V_{DD}$  supply is powered off or if the internal voltage regulator is powered off (removing power from the 1.8 V domain).

### 7.2.10 Independent watchdog clock

If the Independent watchdog (IWDG) is started by either hardware option or software access, the LSI oscillator is forced ON and cannot be disabled. After the LSI oscillator temporization, the clock is provided to the IWDG.

### 7.2.11 Clock-out capability

The microcontroller clock output (MCO) capability allows the clock to be output onto the external MCO pin. The configuration registers of the corresponding GPIO port must be programmed in alternate function mode. One of the following clock signals can be selected as the MCO clock:

- HSI14
- SYSCLK
- HSI
- HSE
- PLL clock divided by 2 or direct (on low-density devices only)
- LSE
- LSI

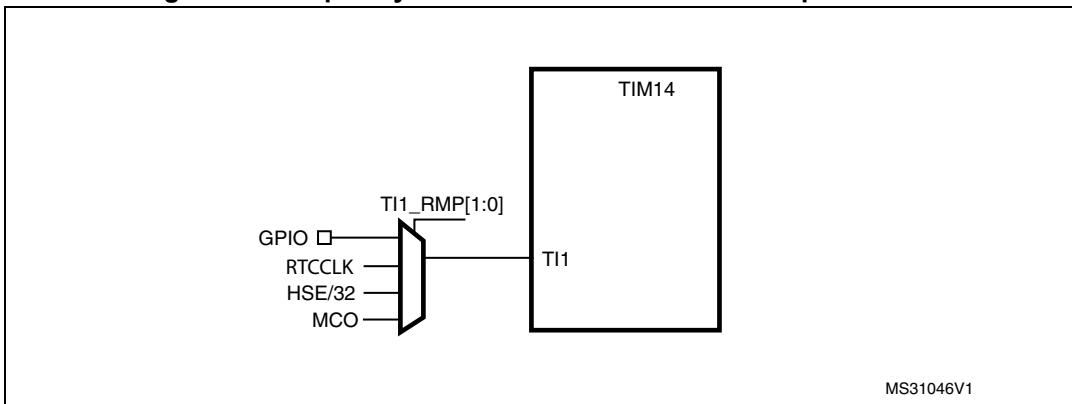
The selection is controlled by the MCO[2:0] bits of the *Clock configuration register (RCC\_CFGR)*.

On low-density devices, the additional bit PLLNODIV of this register controls the divider bypass for a PLL clock input to MCO. The MCO frequency can be reduced by a configurable binary divider, controlled by the MCOPRE[2..0] bits of the *Clock configuration register (RCC\_CFGR)*.

### 7.2.12 Internal/external clock measurement with TIM14

It is possible to indirectly measure the frequency of all on-board clock sources by mean of the TIM14 channel 1 input capture. As represented on *Figure 12*.

**Figure 12. Frequency measurement with TIM14 in capture mode**



The input capture channel of the Timer 14 can be a GPIO line or an internal clock of the MCU. This selection is performed through the TI1\_RMP [1:0] bits in the TIM14\_OR register. The possibilities available are the following ones.

- TIM14 Channel1 is connected to the GPIO. Refer to the alternate function mapping in the device datasheets.
- TIM14 Channel1 is connected to the RTCCLK.
- TIM14 Channel1 is connected to the HSE/32 Clock.
- TIM14 Channel1 is connected to the microcontroller clock output (MCO). Refer to section [Section 7.2.11: Clock-out capability](#) for MCO clock configuration.

### Calibration of the HSI

The primary purpose of connecting the LSE, through the MCO multiplexer, to the channel 1 input capture is to be able to precisely measure the HSI system clocks (for this, the HSI should be used as the system clock source). The number of HSI clock counts between consecutive edges of the LSE signal provides a measure of the internal clock period. Taking advantage of the high precision of LSE crystals (typically a few tens of ppm's), it is possible to determine the internal clock frequency with the same resolution, and trim the source to compensate for manufacturing-process- and/or temperature- and voltage-related frequency deviations.

The HSI oscillator has dedicated user-accessible calibration bits for this purpose.

The basic concept consists in providing a relative measurement (e.g. the HSI/LSE ratio): the precision is therefore closely related to the ratio between the two clock sources. The higher the ratio is, the better the measurement will be.

If LSE is not available, HSE/32 will be the better option in order to reach the most precise calibration possible.

### Calibration of the LSI

The calibration of the LSI will follow the same pattern that for the HSI, but changing the reference clock. It will be necessary to connect LSI clock to the channel 1 input capture of the TIM14. Then define the HSE as system clock source, the number of its clock counts between consecutive edges of the LSI signal provides a measure of the internal low speed clock period.

The basic concept consists in providing a relative measurement (e.g. the HSE/LSI ratio): the precision is therefore closely related to the ratio between the two clock sources. The higher the ratio is, the better the measurement will be.

### Calibration of the HSI14

For the HSI14, because of its high frequency, it is not possible to have a precise resolution. However a solution could be to clock Timer 14 with HSE through PLL to reach 48 MHz, and to use the input capture line with the HSI14 and the capture prescaler defined to the higher value. In that configuration, we got a ratio of 27 events. It is still a bit low to have an accurate calibration. In order to increase the measure accuracy, it is advised to count the HSI periods after multiple cycles of Timer 14. Using polling to treat the capture event will be necessary in this case.

## 7.3 Low power modes

APB peripheral clocks and DMA clock can be disabled by software.

Sleep mode stops the CPU clock. The memory interface clocks (Flash and RAM interfaces) can be stopped by software during sleep mode. The AHB to APB bridge clocks are disabled by hardware during Sleep mode when all the clocks of the peripherals connected to them are disabled.

Stop mode stops all the clocks in the core supply domain and disables the PLL and the HSI, HSI14 and HSE oscillators.

HDMI CEC, USART1 and I2C1 have the capability to enable the HSI oscillator even when the MCU is in Stop mode (if HSI is selected as the clock source for that peripheral). When

the system is in Stop mode, with the regulator in LP mode, the clock request coming from any of those three peripherals moves the regulator to MR mode in order to have the proper current drive capability for the core logic. The regulator moves back to LP mode once this request is removed without waking up the MCU.

HDMI CEC and USART1 can also be driven by the LSE oscillator when the system is in Stop mode (if LSE is selected as clock source for that peripheral) and the LSE oscillator is enabled (LSEON) but they do not have the capability to turn on the LSE oscillator.

Standby mode stops all the clocks in the core supply domain and disables the PLL and the HSI, HSI14 and HSE oscillators.

The CPU's deepsleep mode can be overridden for debugging by setting the DBG\_STOP or DBG\_STANDBY bits in the DBGMCU\_CR register.

When waking up from deepsleep after an interrupt (Stop mode) or reset (Standby mode), the HSI oscillator is selected as system clock.

If a Flash programming operation is on going, deepsleep mode entry is delayed until the Flash interface access is finished. If an access to the APB domain is ongoing, deepsleep mode entry is delayed until the APB access is finished.

## 7.4 RCC registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 7.4.1 Clock control register (RCC\_CR)

Address offset: 0x00

Reset value: 0x0000 XX83 where X is undefined.

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	PLL RDY	POLLON	Res.	Res.	Res.	Res.	CSS ON	HSE BYP	HSE RDY	HSE ON
						r	rw					rw	rw	r	rw
HSICAL[7:0]								HSITRIM[4:0]							
r	r	r	r	r	r	r	r	rw	rw	rw	rw	rw		r	rw

Bits 31:26 Reserved, must be kept at reset value.

Bit 25 **PLLRDY**: PLL clock ready flag

Set by hardware to indicate that the PLL is locked.

- 0: PLL unlocked
- 1: PLL locked

Bit 24 **POLLON**: PLL enable

Set and cleared by software to enable PLL.

Cleared by hardware when entering Stop or Standby mode. This bit can not be reset if the PLL clock is used as system clock or is selected to become the system clock.

- 0: PLL OFF
- 1: PLL ON

Bits 23:20 Reserved, must be kept at reset value.

Bit 19 **CSSON**: Clock security system enable

Set and cleared by software to enable the clock security system. When CSSON is set, the clock detector is enabled by hardware when the HSE oscillator is ready, and disabled by hardware if a HSE clock failure is detected.

- 0: Clock security system disabled (clock detector OFF).
- 1: Clock security system enabled (clock detector ON if the HSE is ready, OFF if not).

Bit 18 **HSEBYP**: HSE crystal oscillator bypass

Set and cleared by software to bypass the oscillator with an external clock. The external clock must be enabled with the HSEON bit set, to be used by the device. The HSEBYP bit can be written only if the HSE oscillator is disabled.

- 0: HSE crystal oscillator not bypassed
- 1: HSE crystal oscillator bypassed with external clock

**Bit 17 HSERDY:** HSE clock ready flag

Set by hardware to indicate that the HSE oscillator is stable. This bit needs 6 cycles of the HSE oscillator clock to fall down after HSEON reset.

- 0: HSE oscillator not ready
- 1: HSE oscillator ready

**Bit 16 HSEON:** HSE clock enable

Set and cleared by software.

Cleared by hardware to stop the HSE oscillator when entering Stop or Standby mode. This bit cannot be reset if the HSE oscillator is used directly or indirectly as the system clock.

- 0: HSE oscillator OFF
- 1: HSE oscillator ON

**Bits 15:8 HSICAL[7:0]:** HSI clock calibration

These bits are initialized automatically at startup. They are adjusted by SW through the HSITRIM setting.

**Bits 7:3 HSITRIM[4:0]:** HSI clock trimming

These bits provide an additional user-programmable trimming value that is added to the HSICAL[7:0] bits. It can be programmed to adjust to variations in voltage and temperature that influence the frequency of the HSI.

The default value is 16, which, when added to the HSICAL value, should trim the HSI to 8 MHz  $\pm 1\%$ . The trimming step ( $F_{hsitrim}$ ) is around 40 kHz between two consecutive HSICAL steps.

Bit 2 Reserved, must be kept at reset value.

**Bit 1 HSIRDY:** HSI clock ready flag

Set by hardware to indicate that HSI oscillator is stable. After the HSION bit is cleared, HSIRDY goes low after 6 HSI oscillator clock cycles.

- 0: HSI oscillator not ready
- 1: HSI oscillator ready

**Bit 0 HSION:** HSI clock enable

Set and cleared by software.

Set by hardware to force the HSI oscillator ON when leaving Stop or Standby mode or in case of failure of the HSE crystal oscillator used directly or indirectly as system clock. This bit cannot be reset if the HSI is used directly or indirectly as system clock or is selected to become the system clock.

- 0: HSI oscillator OFF
- 1: HSI oscillator ON

### 7.4.2 Clock configuration register (RCC\_CFGR)

Address offset: 0x04

Reset value: 0x0000 0000

Access: 0 ≤ wait state ≤ 2, word, half-word and byte access

1 or 2 wait states inserted only if the access occurs during clock source switch.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
PLL NODIV	MCOPRE[2:0]				MCO[2:0]			Res.	Res.	Res.	PLLMUL[3:0]				PLL XTPRE	PLL SRC
rw	rw	rw	rw		rw	rw	rw			rw	rw	rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Res.	ADCP RE	Res.	Res.	Res.	PPRE[2:0]			HPRE[3:0]				SWS[1:0]		SW[1:0]		
	rw				rw	rw	rw	rw	rw	rw	rw	r	r	rw	rw	

Bit 31 **PLLNODIV**: PLL clock not divided for MCO (not available on medium-density devices)

This bit is set and cleared by software. It switches off divider by 2 for PLL connection to MCO.

0: PLL is divided by 2 for MCO

1: PLL is not divided for MCO

Bits 30:28 **MCOPRE**: Microcontroller Clock Output Prescaler (not available on medium-density devices)

These bits are set and cleared by software to select the MCO prescaler division factor. It is highly recommended to change this prescaler before the MCO output is enabled.

000: MCO is divided by 1

001: MCO is divided by 2

010: MCO is divided by 4

.....

111: MCO is divided by 128

Bit 27 Reserved, must be kept at reset value.

Bits 26:24 **MCO**: Microcontroller clock output

Set and cleared by software.

000: MCO output disabled, no clock on MCO

001: Internal RC 14 MHz (HSI14) oscillator clock selected

010: Internal low speed (LSI) oscillator clock selected

011: External low speed (LSE) oscillator clock selected

100: System clock selected

101: Internal RC 8 MHz (HSI) oscillator clock selected

110: External 4-32 MHz (HSE) oscillator clock selected

111: PLL clock selected (divided by 1 or 2, depending on PLLNODIV)

*Note: This clock output may have some truncated cycles at startup or during MCO clock source switching.*

Bits 23:22 Reserved, must be kept at reset value.

Bits 21:18 **PLLMUL:** PLL multiplication factor

These bits are written by software to define the PLL multiplication factor. These bits can be written only when PLL is disabled.

Caution: The PLL output frequency must not exceed 48 MHz.

- 0000: PLL input clock x 2
- 0001: PLL input clock x 3
- 0010: PLL input clock x 4
- 0011: PLL input clock x 5
- 0100: PLL input clock x 6
- 0101: PLL input clock x 7
- 0110: PLL input clock x 8
- 0111: PLL input clock x 9
- 1000: PLL input clock x 10
- 1001: PLL input clock x 11
- 1010: PLL input clock x 12
- 1011: PLL input clock x 13
- 1100: PLL input clock x 14
- 1101: PLL input clock x 15
- 1110: PLL input clock x 16
- 1111: PLL input clock x 16

Bit 17 **PLLXTPRE:** HSE divider for PLL input clock

This bit is the same bit as bit PREDIV[0] from RCC\_CFGR2. Refer to RCC\_CFGR2 PREDIV bits description for its meaning.

Bit 16 **PLLSRC:** PLL input clock source

Set and cleared by software to select PLL clock source. This bit can be written only when PLL is disabled.

- 0: HSI/2 selected as PLL input clock
- 1: HSE/PREDIV selected as PLL input clock (refer to [Section 7.4.12: Clock configuration register 2 \(RCC\\_CFGR2\) on page 119](#))

Bit 15 Reserved, must be kept at reset value.

Bit 14 **ADCPRE:** ADC prescaler

Obsolete setting. Proper ADC clock selection is done inside the ADC\_CFGR2 (refer to [Section 12.12.5: ADC configuration register 2 \(ADC\\_CFGR2\) on page 207](#)).

Bits 13:11 Reserved, must be kept at reset value.

Bits 10:8 **PPRE:** PCLK prescaler

Set and cleared by software to control the division factor of the APB clock (PCLK).

- 0xx: HCLK not divided
- 100: HCLK divided by 2
- 101: HCLK divided by 4
- 110: HCLK divided by 8
- 111: HCLK divided by 16

**Bits 7:4 HPRE:** HLCK prescaler

Set and cleared by software to control the division factor of the AHB clock.

- 0xxx: SYSCLK not divided
- 1000: SYSCLK divided by 2
- 1001: SYSCLK divided by 4
- 1010: SYSCLK divided by 8
- 1011: SYSCLK divided by 16
- 1100: SYSCLK divided by 64
- 1101: SYSCLK divided by 128
- 1110: SYSCLK divided by 256
- 1111: SYSCLK divided by 512

**Bits 3:2 SWS:** System clock switch status

Set and cleared by hardware to indicate which clock source is used as system clock.

- 00: HSI oscillator used as system clock
- 01: HSE oscillator used as system clock
- 10: PLL used as system clock
- 11: not applicable

**Bits 1:0 SW:** System clock switch

Set and cleared by software to select SYSCLK source.

Cleared by hardware to force HSI selection when leaving Stop and Standby mode or in case of failure of the HSE oscillator used directly or indirectly as system clock (if the Clock Security System is enabled).

- 00: HSI selected as system clock
- 01: HSE selected as system clock
- 10: PLL selected as system clock
- 11: not allowed

### 7.4.3 Clock interrupt register (RCC\_CIR)

Address offset: 0x08

Reset value: 0x0000 0000

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CSSC	Res.	HSI14 RDYC	PLL RDYC	HSE RDYC	HSI RDYC	LSE RDYC	LSI RDYC
								w		w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	HSI14 RDYIE	PLL RDYIE	HSE RDYIE	HSI RDYIE	LSE RDYIE	LSI RDYIE	CSSF	Res.	HSI14 RDYF	PLL RDYF	HSE RDYF	HSI RDYF	LSE RDYF	LSI RDYF
		rw	rw	rw	rw	rw	rw	r		r	r	r	r	r	r

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **CSSC:** Clock security system interrupt clear

This bit is set by software to clear the CSSF flag.

0: No effect

1: Clear CSSF flag

Bit 22 Reserved, must be kept at reset value.

Bit 21 **HSI14RDYC:** HSI14 Ready Interrupt Clear

This bit is set by software to clear the HSI14RDYF flag.

0: No effect

1: Clear HSI14RDYF flag

Bit 20 **PLLRDYC:** PLL ready interrupt clear

This bit is set by software to clear the PLLRDYF flag.

0: No effect

1: Clear PLLRDYF flag

Bit 19 **HSERDYC:** HSE ready interrupt clear

This bit is set by software to clear the HSERDYF flag.

0: No effect

1: Clear HSERDYF flag

Bit 18 **HSIRDYC:** HSI ready interrupt clear

This bit is set software to clear the HSIRDYF flag.

0: No effect

1: Clear HSIRDYF flag

Bit 17 **LSERDYC:** LSE ready interrupt clear

This bit is set by software to clear the LSERDYF flag.

0: No effect

1: LSERDYF cleared

Bit 16 **LSIRDYC:** LSI ready interrupt clear

This bit is set by software to clear the LSIRDYF flag.

0: No effect

1: LSIRDYF cleared

Bits 15:14 Reserved, must be kept at reset value.

Bit 13 **HSI14RDYIE:** HSI14 ready interrupt enable

Set and cleared by software to enable/disable interrupt caused by the HSI14 oscillator stabilization.

0: HSI14 ready interrupt disabled

1: HSI14 ready interrupt enabled

Bit 12 **PLL RDYIE:** PLL ready interrupt enable

Set and cleared by software to enable/disable interrupt caused by PLL lock.

0: PLL lock interrupt disabled

1: PLL lock interrupt enabled

Bit 11 **HSE RDYIE:** HSE ready interrupt enable

Set and cleared by software to enable/disable interrupt caused by the HSE oscillator stabilization.

0: HSE ready interrupt disabled

1: HSE ready interrupt enabled

Bit 10 **HSI RDYIE:** HSI ready interrupt enable

Set and cleared by software to enable/disable interrupt caused by the HSI oscillator stabilization.

0: HSI ready interrupt disabled

1: HSI ready interrupt enabled

Bit 9 **LSE RDYIE:** LSE ready interrupt enable

Set and cleared by software to enable/disable interrupt caused by the LSE oscillator stabilization.

0: LSE ready interrupt disabled

1: LSE ready interrupt enabled

Bit 8 **LSI RDYIE:** LSI ready interrupt enable

Set and cleared by software to enable/disable interrupt caused by the LSI oscillator stabilization.

0: LSI ready interrupt disabled

1: LSI ready interrupt enabled

Bit 7 **CSSF:** Clock security system interrupt flag

Set by hardware when a failure is detected in the HSE oscillator.

Cleared by software setting the CSSC bit.

0: No clock security interrupt caused by HSE clock failure

1: Clock security interrupt caused by HSE clock failure

Bit 6 Reserved, must be kept at reset value.

Bit 5 **HSI14RDYF:** HSI14 ready interrupt flag

Set by hardware when the HSI14 becomes stable and HSI14RDYIE is set in a response to setting the HSI14ON bit in [Clock control register 2 \(RCC\\_CR2\)](#). When HSI14ON is not set but the HSI14 oscillator is enabled by the peripheral through a clock request, this bit is not set and no interrupt is generated.

Cleared by software setting the HSI14RDYC bit.

0: No clock ready interrupt caused by the HSI14 oscillator

1: Clock ready interrupt caused by the HSI14 oscillator

**Bit 4 PLLRDYF:** PLL ready interrupt flag

Set by hardware when the PLL locks and PLLRDYDIE is set.

Cleared by software setting the PLLRDYC bit.

0: No clock ready interrupt caused by PLL lock

1: Clock ready interrupt caused by PLL lock

**Bit 3 HSERDYF:** HSE ready interrupt flag

Set by hardware when the HSE clock becomes stable and HSERDYDIE is set.

Cleared by software setting the HSERDYC bit.

0: No clock ready interrupt caused by the HSE oscillator

1: Clock ready interrupt caused by the HSE oscillator

**Bit 2 HSIRDYF:** HSI ready interrupt flag

Set by hardware when the HSI clock becomes stable and HSIRDYDIE is set in a response to setting the HSION (refer to [Clock control register \(RCC\\_CR\)](#)). When HSION is not set but the HSI oscillator is enabled by the peripheral through a clock request, this bit is not set and no interrupt is generated.

Cleared by software setting the HSIRDYC bit.

0: No clock ready interrupt caused by the HSI oscillator

1: Clock ready interrupt caused by the HSI oscillator

**Bit 1 LSERDYF:** LSE ready interrupt flag

Set by hardware when the LSE clock becomes stable and LSERDYDIE is set.

Cleared by software setting the LSERDYC bit.

0: No clock ready interrupt caused by the LSE oscillator

1: Clock ready interrupt caused by the LSE oscillator

**Bit 0 LSIRDYF:** LSI ready interrupt flag

Set by hardware when the LSI clock becomes stable and LSIRDYDIE is set.

Cleared by software setting the LSIRDYC bit.

0: No clock ready interrupt caused by the LSI oscillator

1: Clock ready interrupt caused by the LSI oscillator

**7.4.4 APB peripheral reset register 2 (RCC\_APB2RSTR)**

Address offset: 0x0C

Reset value: 0x00000000

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG MCU RST	Res.	Res.	Res.	TIM17 RST	TIM16 RST	TIM15 RST
									rw				rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	USART1 RST	Res.	SPI1 RST	TIM1 RST	Res.	ADC RST	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SYS CFG RST
	rw		rw	rw		rw									rw

Bits 31:23 Reserved, must be kept at reset value.

Bits 22 **DBGMCURST:** Debug MCU reset

Set and cleared by software.

0: No effect

1: Resets Debug MCU

Bits 21:19 Reserved, must be kept at reset value.

Bit 18 **TIM17RST:** TIM17 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM17 timer

Bit 17 **TIM16RST:** TIM16 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM16 timer

Bit 16 **TIM15RST:** TIM15 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM15 timer

Bit 15 Reserved, must be kept at reset value.

Bit 14 **USART1RST:** USART1 reset

Set and cleared by software.

0: No effect

1: Reset USART1

Bit 13 Reserved, must be kept at reset value.

Bit 12 **SPI1RST:** SPI1 reset

Set and cleared by software.

0: No effect

1: Reset SPI1

Bit 11 **TIM1RST:** TIM1 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM1 timer

Bit 10 Reserved, must be kept at reset value.

Bit 9 **ADCRST:** ADC interface reset

Set and cleared by software.

0: No effect

1: Reset ADC interface

Bits 8:1 Reserved, must be kept at reset value.

Bit 0 **SYSCFGRST:** SYSCFG reset

Set and cleared by software.

0: No effect

1: Reset SYSCFG

### 7.4.5 APB peripheral reset register 1 (RCC\_APB1RSTR)

Address offset: 0x10

Reset value: 0x0000 0000

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	CEC RST	DAC RST	PWR RST	Res.	Res.	Res.	Res.	Res.	I2C2 RST	I2C1 RST	Res.	Res.	Res.	USART2 RST	Res.
	rw	rw	rw						rw	rw				rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SPI2 RST	Res.	Res.	WWDG RST	Res.	Res.	TIM14 RST	Res.	Res.	Res.	TIM6 RST	Res.	Res.	TIM3 RST	TIM2 RST
	rw			rw			rw				rw			rw	rw

Bit 31 Reserved, must be kept at reset value.

Bit 30 **CECRST**: HDMI CEC reset

Set and cleared by software.

0: No effect

1: Reset HDMI CEC

Bit 29 **DACRST**: DAC interface reset

Set and cleared by software.

0: No effect

1: Reset DAC interface

Bit 28 **PWRRST**: Power interface reset

Set and cleared by software.

0: No effect

1: Reset power interface

Bits 27:23 Reserved, must be kept at reset value.

Bit 22 **I2C2RST**: I2C2 reset

Set and cleared by software.

0: No effect

1: Reset I2C2

Bit 21 **I2C1RST**: I2C1 reset

Set and cleared by software.

0: No effect

1: Reset I2C1

Bits 20:18 Reserved.

Bit 17 **USART2RST**: USART2 reset

Set and cleared by software.

0: No effect

1: Reset USART2

Bits 16:15 Reserved, must be kept at reset value.

Bit 14 **SPI2RST:** SPI2 reset

Set and cleared by software.

0: No effect

1: Reset SPI2

Bits 13:12 Reserved, must be kept at reset value.

Bit 11 **WWDGRST:** Window watchdog reset

Set and cleared by software.

0: No effect

1: Reset window watchdog

Bits 10:9 Reserved, must be kept at reset value.

Bit 8 **TIM14RST:** TIM14 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM14

Bits 7:5 Reserved, must be kept at reset value.

Bit 4 **TIM6RST:** TIM6 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM6

Bit 3:2 Reserved, must be kept at reset value.

Bit 1 **TIM3RST:** TIM3 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM3

Bit 0 **TIM2RST:** TIM2 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM2

### 7.4.6 AHB peripheral clock enable register (RCC\_AHBENR)

Address offset: 0x14

Reset value: 0x0000 0014

Access: no wait state, word, half-word and byte access

**Note:** When the peripheral clock is not active, the peripheral register values may not be readable by software and the returned value is always 0x0.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	TSCEN	Res.	IOPF EN	Res.	IOPD EN	IOPC EN	IOPB EN	IOPA EN	Res.						
							rw		rw		rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	CRC EN	Res.	FLITF EN	Res.	SRAM EN	Res.	DMA EN							
									rw		rw		rw		rw

Bits 31:25 Reserved, must be kept at reset value.

Bit 24 **TSCEN:** Touch sensing controller clock enable

Set and cleared by software.

- 0: TSC clock disabled
- 1: TSC clock enabled

Bit 23 Reserved, must be kept at reset value.

Bit 22 **IOPFEN:** I/O port F clock enable

Set and cleared by software.

- 0: I/O port F clock disabled
- 1: I/O port F clock enabled

Bit 21 Reserved, must be kept at reset value.

Bit 20 **IOPDEN:** I/O port D clock enable

Set and cleared by software.

- 0: I/O port D clock disabled
- 1: I/O port D clock enabled

Bit 19 **IOPCEN:** I/O port C clock enable

Set and cleared by software.

- 0: I/O port C clock disabled
- 1: I/O port C clock enabled

Bit 18 **IOPBEN:** I/O port B clock enable

Set and cleared by software.

- 0: I/O port B clock disabled
- 1: I/O port B clock enabled

Bit 17 **IOPAEN:** I/O port A clock enable

Set and cleared by software.

- 0: I/O port A clock disabled
- 1: I/O port A clock enabled

Bits 16:7 Reserved, must be kept at reset value.

Bit 6 **CRCEN**: CRC clock enable

Set and cleared by software.

0: CRC clock disabled

1: CRC clock enabled

Bit 5 Reserved, must be kept at reset value.

Bit 4 **FLITFEN**: FLITF clock enable

Set and cleared by software to disable/enable FLITF clock during Sleep mode.

0: FLITF clock disabled during Sleep mode

1: FLITF clock enabled during Sleep mode

Bit 3 Reserved, must be kept at reset value.

Bit 2 **SRAMEN**: SRAM interface clock enable

Set and cleared by software to disable/enable SRAM interface clock during Sleep mode.

0: SRAM interface clock disabled during Sleep mode.

1: SRAM interface clock enabled during Sleep mode

Bit 1 Reserved, must be kept at reset value.

Bit 0 **DMAEN**: DMA clock enable

Set and cleared by software.

0: DMA clock disabled

1: DMA clock enabled

#### 7.4.7 APB peripheral clock enable register 2 (RCC\_APB2ENR)

Address: 0x18

Reset value: 0x0000 0000

Access: word, half-word and byte access

No wait states, except if the access occurs while an access to a peripheral in the APB domain is on going. In this case, wait states are inserted until the access to APB peripheral is finished.

**Note:** When the peripheral clock is not active, the peripheral register values may not be readable by software and the returned value is always 0x0.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBGMCUEN	Res.	Res.	Res.	TIM17EN	TIM16EN	TIM15EN
									rw				rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	USART1EN	Res.	SPI1EN	TIM1EN	Res.	ADCEN	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SYSRCCOMPEN
	rw		rw	rw		rw									rw

Bits 31:23 Reserved, must be kept at reset value.

Bit 22 **DBGMCUEN** MCU debug module clock enable

Set and reset by software.

0: MCU debug module clock disabled

1: MCU debug module enabled

Bits 21:19 Reserved, must be kept at reset value.

Bit 18 **TIM17EN**: TIM17 timer clock enable

Set and cleared by software.

0: TIM17 timer clock disabled

1: TIM17 timer clock enabled

Bit 17 **TIM16EN**: TIM16 timer clock enable

Set and cleared by software.

0: TIM16 timer clock disabled

1: TIM16 timer clock enabled

Bit 16 **TIM15EN**: TIM15 timer clock enable

Set and cleared by software.

0: TIM15 timer clock disabled

1: TIM15 timer clock enabled

Bit 15 Reserved, must be kept at reset value.

Bit 14 **USART1EN**: USART1clock enable

Set and cleared by software.

0: USART1clock disabled

1: USART1clock enabled

Bit 13 Reserved, must be kept at reset value.

Bit 12 **SPI1EN**: SPI1 clock enable

Set and cleared by software.

0: SPI1 clock disabled

1: SPI1 clock enabled

Bit 11 **TIM1EN**: TIM1 timer clock enable

Set and cleared by software.

0: TIM1 timer clock disabled

1: TIM1P timer clock enabled

Bit 10 Reserved, must be kept at reset value.

Bit 9 **ADCEN**: ADC interface clock enable

Set and cleared by software.

0: ADC interface disabled

1: ADC interface clock enabled

Bits 8:1 Reserved, must be kept at reset value.

Bit 0 **SYSCFGCOMPEN**: SYSCFG & COMP clock enable

Set and cleared by software.

0: SYSCFG & COMP clock disabled

1: SYSCFG & COMP clock enabled

### 7.4.8 APB peripheral clock enable register 1 (RCC\_APB1ENR)

Address: 0x1C

Reset value: 0x0000 0000

Access: word, half-word and byte access

No wait state, except if the access occurs while an access to a peripheral on APB domain is on going. In this case, wait states are inserted until this access to APB peripheral is finished.

**Note:** *When the peripheral clock is not active, the peripheral register values may not be readable by software and the returned value is always 0x0.*

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	CEC EN	DAC EN	PWR EN	Res.	Res.	Res.	Res.	I2C2 EN	I2C1 EN	Res.	Res.	Res.	USART 2EN	Res.	Res.
	rw	rw	rw					rw	rw				rw		rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SPI2 EN	Res.	Res.	WWD GEN	Res.	Res.	TIM14 EN	Res.	Res.	Res.	TIM6 EN	Res.	Res.	TIM3 EN	TIM2 EN
	rw			rw			rw				rw			rw	rw

Bit 31 Reserved, must be kept at reset value.

Bit 30 **CECEN:** HDMI CEC clock enable

Set and cleared by software.

0: HDMI CEC clock disabled

1: HDMI CEC clock enabled

Bit 29 **DACEN:** DAC interface clock enable

Set and cleared by software.

0: DAC interface clock disabled

1: DAC interface clock enabled

Bit 28 **PWREN:** Power interface clock enable

Set and cleared by software.

0: Power interface clock disabled

1: Power interface clock enabled

Bit 27:24 Reserved, must be kept at reset value.

Bit 22 **I2C2EN:** I2C2 clock enable

Set and cleared by software.

0: I2C2 clock disabled

1: I2C2 clock enabled

Bit 21 **I2C1EN:** I2C1 clock enable

Set and cleared by software.

0: I2C1 clock disabled

1: I2C1 clock enabled

Bits 20:18 Reserved, must be kept at reset value.

Bit 17 **USART2EN:** USART2 clock enable

Set and cleared by software.

0: USART2 clock disabled

1: USART2 clock enabled

Bits 16:15 Reserved, must be kept at reset value.

Bit 14 **SPI2EN:** SPI2 clock enable

Set and cleared by software.

0: SPI2 clock disabled

1: SPI2 clock enabled

Bits 13:12 Reserved, must be kept at reset value.

Bit 11 **WWDGEN:** Window watchdog clock enable

Set and cleared by software.

0: Window watchdog clock disabled

1: Window watchdog clock enabled

Bits 10:9 Reserved, must be kept at reset value.

Bit 8 **TIM14EN:** TIM14 timer clock enable

Set and cleared by software.

0: TIM14 clock disabled

1: TIM14 clock enabled

Bits 7:5 Reserved, must be kept at reset value.

Bit 4 **TIM6EN:** TIM6 timer clock enable

Set and cleared by software.

0: TIM6 clock disabled

1: TIM6 clock enabled

Bits 3:2 Reserved, must be kept at reset value.

Bit 1 **TIM3EN:** TIM3 timer clock enable

Set and cleared by software.

0: TIM3 clock disabled

1: TIM3 clock enabled

Bit 0 **TIM2EN:** TIM2 timer clock enable

Set and cleared by software.

0: TIM2 clock disabled

1: TIM2 clock enabled

### 7.4.9 Backup domain control register (RCC\_BDCR)

Address offset: 0x20

Reset value: 0x0000 0018, reset by Backup domain Reset.

Access: 0 ≤ wait state ≤ 3, word, half-word and byte access

Wait states are inserted in case of successive accesses to this register.

**Note:** The LSEON, LSEBYP, RTCSEL and RTCEN bits of the [Backup domain control register \(RCC\\_BDCR\)](#) are in the Backup domain. As a result, after Reset, these bits are write-protected and the DBP bit in the [Power control register \(PWR\\_CR\)](#) has to be set before these can be modified. Refer to [Section 6.1.2 on page 76](#) for further information. These bits are only reset after a Backup domain Reset (see [Section 7.1.3: Backup domain reset](#)). Any internal or external Reset will not have any effect on these bits.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BDRST
															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RTC EN	Res.	Res.	Res.	Res.	Res.	RTCSEL[1:0]		Res.	Res.	Res.	LSEDRV[1:0]	LSE BYP	LSE RDY	LSEON	
rw						rw	rw				rw	rw	rw	r	rw

Bits 31:17 Reserved, must be kept at reset value.

Bit 16 **BDRST:** Backup domain software reset

Set and cleared by software.

0: Reset not activated

1: Resets the entire Backup domain

Bit 15 **RTCEN:** RTC clock enable

Set and cleared by software.

0: RTC clock disabled

1: RTC clock enabled

Bits 14:10 Reserved, must be kept at reset value.

Bits 9:8 **RTCSEL[1:0]:** RTC clock source selection

Set by software to select the clock source for the RTC. Once the RTC clock source has been selected, it cannot be changed anymore unless the Backup domain is reset. The BDRST bit can be used to reset them.

00: No clock

01: LSE oscillator clock used as RTC clock

10: LSI oscillator clock used as RTC clock

11: HSE oscillator clock divided by 32 used as RTC clock

Bits 7:5 Reserved, must be kept at reset value.

**Bits 4:3 LSEDRV** LSE oscillator drive capability

Set and reset by software to modulate the LSE oscillator's drive capability. A reset of the backup domain restores the default value.

- 00: 'Xtal mode' lower driving capability
- 01: 'Xtal mode' medium low driving capability
- 10: 'Xtal mode' medium high driving capability
- 11: 'Xtal mode' higher driving capability (reset value)

*Note: The oscillator is in Xtal mode when it is not in bypass mode.*

**Bit 2 LSEBYP:** LSE oscillator bypass

Set and cleared by software to bypass oscillator in debug mode. This bit can be written only when the external 32 kHz oscillator is disabled.

- 0: LSE oscillator not bypassed
- 1: LSE oscillator bypassed

**Bit 1 LSERDY:** LSE oscillator ready

Set and cleared by hardware to indicate when the external 32 kHz oscillator is stable. After the LSEON bit is cleared, LSERDY goes low after 6 external low-speed oscillator clock cycles.

- 0: LSE oscillator not ready
- 1: LSE oscillator ready

**Bit 0 LSEON:** LSE oscillator enable

Set and cleared by software.

- 0: LSE oscillator OFF
- 1: LSE oscillator ON

### 7.4.10 Control/status register (RCC\_CSR)

Address: 0x24

Reset value: 0xFFFF 0000, reset by system Reset, except reset flags by power Reset only.

Access: 0 ≤ wait state ≤ 3, word, half-word and byte access

Wait states are inserted in case of successive accesses to this register.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LPWR RSTF	WWWDG RSTF	IWDG RSTF	SFT RSTF	POR RSTF	PIN RSTF	OB LRSTF	RMVF	V18PW RRSTF	Res.	Res.	Res.	Res.	Res.	Res.	Res.
rw	rw	rw	rw	rw	rw	rw	rw	rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	LSI RDY	LSION
														r	rw

#### Bit 31 LPWRRSTF: Low-power reset flag

Set by hardware when a Low-power management reset occurs.

Cleared by writing to the RMVF bit.

- 0: No Low-power management reset occurred
- 1: Low-power management reset occurred

For further information on Low-power management reset, refer to [Low-power management reset](#).

#### Bit 30 WWDRSTF: Window watchdog reset flag

Set by hardware when a window watchdog reset occurs.

Cleared by writing to the RMVF bit.

- 0: No window watchdog reset occurred
- 1: Window watchdog reset occurred

#### Bit 29 IWDGRSTF: Independent watchdog reset flag

Set by hardware when an independent watchdog reset from V<sub>DD</sub> domain occurs.

Cleared by writing to the RMVF bit.

- 0: No watchdog reset occurred
- 1: Watchdog reset occurred

#### Bit 28 SFTRSTF: Software reset flag

Set by hardware when a software reset occurs.

Cleared by writing to the RMVF bit.

- 0: No software reset occurred
- 1: Software reset occurred

#### Bit 27 PORRSTF: POR/PDR reset flag

Set by hardware when a POR/PDR reset occurs.

Cleared by writing to the RMVF bit.

- 0: No POR/PDR reset occurred
- 1: POR/PDR reset occurred

**Bit 26 PINRSTF:** PIN reset flag

Set by hardware when a reset from the NRST pin occurs.

Cleared by writing to the RMVF bit.

0: No reset from NRST pin occurred

1: Reset from NRST pin occurred

**Bit 25 OBLRSTF:** Option byte loader reset flag

Set by hardware when a reset from the OBL occurs.

Cleared by writing to the RMVF bit.

0: No reset from OBL occurred

1: Reset from OBL occurred

**Bit 24 RMVF:** Remove reset flag

Set by software to clear the reset flags.

0: No effect

1: Clear the reset flags

**Bit 23 V18PWRRSTF:** Reset flag of the 1.8 V domain, reset by software by writing the RMVF bit.

Set by hardware when a POR/PDR of the 1.8 V domain occurred.

0: No POR/PDR reset of the 1.8 V domain occurred

1: POR/PDR reset of the 1.8 V domain occurred

**Caution:** On the STM32F06xx family, this flag must be read as reserved.

Bits 22:2 Reserved, must be kept at reset value.

**Bit 1 LSIRDY:** LSI oscillator ready

Set and cleared by hardware to indicate when the LSI oscillator is stable. After the LSION bit is cleared, LSIRDY goes low after 3 LSI oscillator clock cycles.

0: LSI oscillator not ready

1: LSI oscillator ready

**Bit 0 LSION:** LSI oscillator enable

Set and cleared by software.

0: LSI oscillator OFF

1: LSI oscillator ON

### 7.4.11 AHB peripheral reset register (RCC\_AHBRSTR)

Address: 0x28

Reset value: 0x0000 0000

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	TSC RST	Res.	IOPF RST	Res.	IOPD RST	IOPC RST	IOPB RST	IOPA RST	Res.						
							rw		rw		rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.							

Bits 31:25 Reserved, must be kept at reset value.

Bit 24 **TSCRST:** Touch sensing controller reset

Set and cleared by software.

0: No effect

1: Reset TSC

Bit 23 Reserved, must be kept at reset value.

Bit 22 **IOPFRST:** I/O port F reset

Set and cleared by software.

0: No effect

1: Reset I/O port F

Bit 21 Reserved, must be kept at reset value.

Bit 20 **IOPDRST:** I/O port D reset

Set and cleared by software.

0: No effect

1: Reset I/O port D

Bit 19 **IOPCRST:** I/O port C reset

Set and cleared by software.

0: No effect

1: Reset I/O port C

Bit 18 **IOPBRST:** I/O port B reset

Set and cleared by software.

0: No effect

1: Reset I/O port B

Bit 17 **IOPARST:** I/O port A reset

Set and cleared by software.

0: No effect

1: Reset I/O port A

Bits 16:0 Reserved, must be kept at reset value.

### 7.4.12 Clock configuration register 2 (RCC\_CFGR2)

Address: 0x2C

Reset value: 0x0000 0000

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	PREDIV[3:0]														
												rw	rw	rw	rw

Bits 31:4 Reserved, must be kept at reset value.

Bits 3:0 **PREDIV[3:0]** PREDIV division factor

These bits are set and cleared by software to select PREDIV division factor. They can be written only when the PLL is disabled.

Note: Bit 0 is the same bit as bit 17 in *Clock configuration register (RCC\_CFGR)*, so modifying bit 17 *Clock configuration register (RCC\_CFGR)* also modifies bit 0 in *Clock configuration register 2 (RCC\_CFGR2)* (for compatibility with other STM32 products)

- 0000: PREDIV input clock not divided
- 0001: PREDIV input clock divided by 2
- 0010: PREDIV input clock divided by 3
- 0011: PREDIV input clock divided by 4
- 0100: PREDIV input clock divided by 5
- 0101: PREDIV input clock divided by 6
- 0110: PREDIV input clock divided by 7
- 0111: PREDIV input clock divided by 8
- 1000: PREDIV input clock divided by 9
- 1001: PREDIV input clock divided by 10
- 1010: PREDIV input clock divided by 11
- 1011: PREDIV input clock divided by 12
- 1100: PREDIV input clock divided by 13
- 1101: PREDIV input clock divided by 14
- 1110: PREDIV input clock divided by 15
- 1111: PREDIV input clock divided by 16

### 7.4.13 Clock configuration register 3 (RCC\_CFGR3)

Address: 0x30

Reset value: 0x0000 0000

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	ADC SW	Res.	CEC SW	Res.	I2C1 SW	Res.	Res.	USART1SW[1:0]							
							rw		rw		rw			rw	rw

Bits 31:9 Reserved, must be kept at reset value.

Bit 8 **ADCSW**: ADC clock source selection

Obsolete setting. To be kept at reset value, connecting the HSI14 clock to the ADC asynchronous clock input. Proper ADC clock selection is done inside the ADC\_CFGR2 (refer to [Section 12.12.5: ADC configuration register 2 \(ADC\\_CFGR2\) on page 207](#)).

Bit 7 Reserved, must be kept at reset value.

Bit 6 **CECSW**: HDMI CEC clock source selection

This bit is set and cleared by software to select the CEC clock source.

- 0: HSI clock, divided by 244, selected as CEC clock (default)
- 1: LSE clock selected as CEC clock

Bit 5 Reserved, must be kept at reset value.

Bit 4 **I2C1SW**: I2C1 clock source selection

This bit is set and cleared by software to select the I2C1 clock source.

- 0: HSI clock selected as I2C1 clock source (default)
- 1: System clock (SYSCLK) selected as I2C1 clock

Bits 3:2 Reserved, must be kept at reset value.

Bits 1:0 **USART1SW[1:0]**: USART1 clock source selection

This bit is set and cleared by software to select the USART1 clock source.

- 00: PCLK selected as USART1 clock source (default)
- 01: System clock (SYSCLK) selected as USART1 clock
- 10: LSE clock selected as USART1 clock
- 11: HSI clock selected as USART1 clock

### 7.4.14 Clock control register 2 (RCC\_CR2)

Address: 0x34

Reset value: 0x0000 XX80, where X is undefined.

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
HSI14CAL[7:0]								HSI14TRIM[4:0]						HSI14 DIS	HSI14 RDY	HSI14 ON
r	r	r	r	r	r	r	r	rw	rw	rw	rw	rw	rw	r	rw	

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:8 **HSI14CAL[7:0]**: HSI14 clock calibration

These bits are initialized automatically at startup.

Bits 7:3 **HSI14TRIM[4:0]**: HSI14 clock trimming

These bits provide an additional user-programmable trimming value that is added to the HSI14CAL[7:0] bits. It can be programmed to adjust to variations in voltage and temperature that influence the frequency of the HSI14.

The default value is 16, which, when added to the HSI14CAL value, should trim the HSI to 8 MHz  $\pm$  1%. The trimming step ( $F_{hsitrim}$ ) is around 50 kHz between two consecutive HSICAL steps.

Bit 2 **HSI14DIS** HSI14 clock request from ADC disable

Set and cleared by software.

When set this bit prevents the ADC interface from enabling the HSI14 oscillator.

0: ADC interface can turn on the HSI14 oscillator

1: ADC interface can not turn on the HSI14 oscillator

Bit 1 **HSI14RDY**: HSI14 clock ready flag

Set by hardware to indicate that HSI14 oscillator is stable. After the HSI14ON bit is cleared, HSI14RDY goes low after 6 HSI14 oscillator clock cycles.

0: HSI14 oscillator not ready

1: HSI14 oscillator ready

Bit 0 **HSI14ON**: HSI14 clock enable

Set and cleared by software.

0: HSI14 oscillator OFF

1: HSI14 oscillator ON

### 7.4.15 RCC register map

The following table gives the RCC register map and the reset values.

**Table 18. RCC register map and reset values**

**Table 18. RCC register map and reset values (continued)**

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 8 General-purpose I/Os (GPIO)

### 8.1 GPIO introduction

Each general-purpose I/O port has four 32-bit configuration registers (GPIOx\_MODER, GPIOx\_OTYPER, GPIOx\_OSPEEDR and GPIOx\_PUPDR), two 32-bit data registers (GPIOx\_IDR and GPIOx\_ODR) and a 32-bit set/reset register (GPIOx\_BSRR). Ports A and B also have a 32-bit locking register (GPIOx\_LCKR) and two 32-bit alternate function selection registers (GPIOx\_AFRH and GPIOx\_AFRL).

### 8.2 GPIO main features

- Output states: push-pull or open drain + pull-up/down
- Output data from output data register (GPIOx\_ODR) or peripheral (alternate function output)
- Speed selection for each I/O
- Input states: floating, pull-up/down, analog
- Input data to input data register (GPIOx\_IDR) or peripheral (alternate function input)
- Bit set and reset register (GPIOx\_BSRR) for bitwise write access to GPIOx\_ODR
- Locking mechanism (GPIOx\_LCKR) provided to freeze the port A or B I/O port configuration
- Analog function
- Alternate function selection registers for ports A and B (at most 16 AFs possible per I/O)
- Fast toggle capable of changing every two clock cycles
- Highly flexible pin multiplexing allows the use of I/O pins as GPIOs or as one of several peripheral functions

### 8.3 GPIO functional description

Subject to the specific hardware characteristics of each I/O port listed in the datasheet, each port bit of the general-purpose I/O (GPIO) ports can be individually configured by software in several modes:

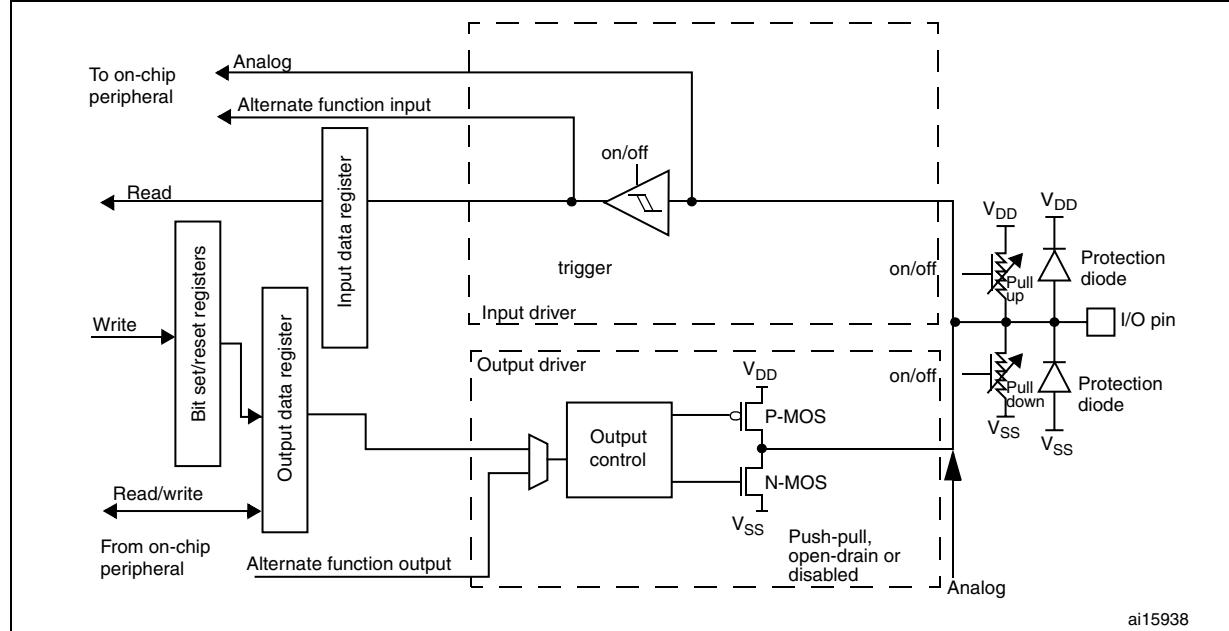
- Input floating
- Input pull-up
- Input-pull-down
- Analog
- Output open-drain with pull-up or pull-down capability
- Output push-pull with pull-up or pull-down capability
- Alternate function push-pull with pull-up or pull-down capability
- Alternate function open-drain with pull-up or pull-down capability

Each I/O port bit is freely programmable, however the I/O port registers have to be accessed as 32-bit words, half-words or bytes. The purpose of the GPIOx\_BSRR and GPIOx\_BRR registers is to allow atomic read/modify accesses to any of the GPIOx\_ODR

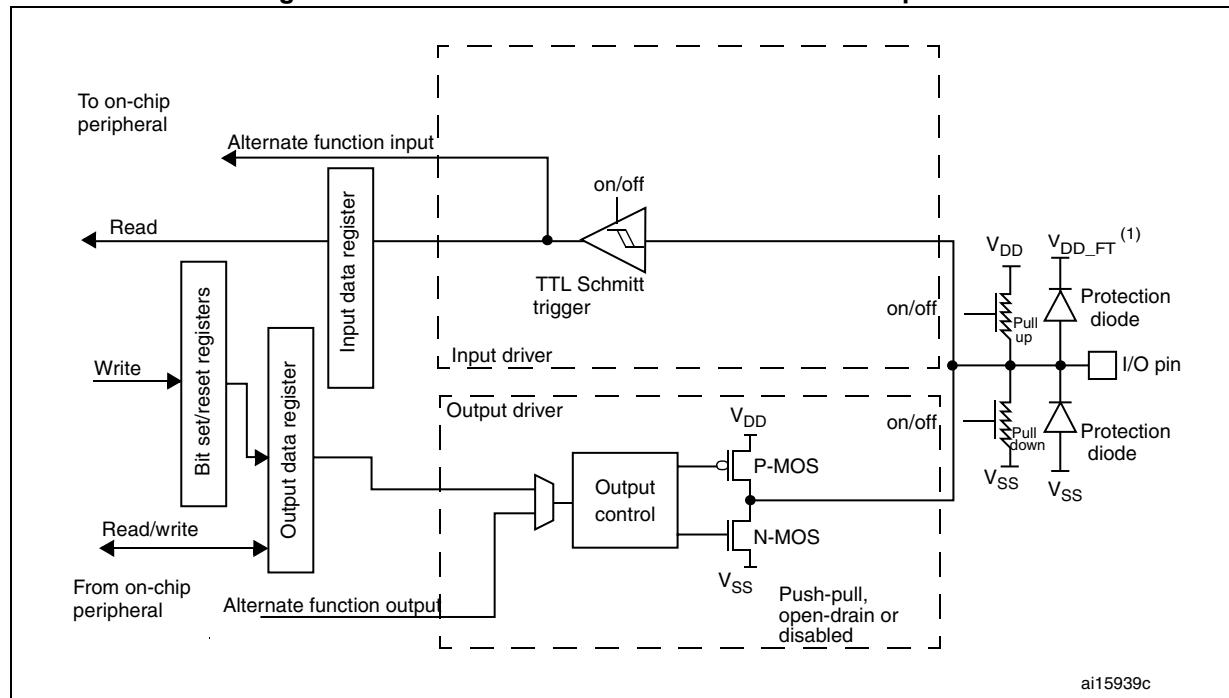
registers. In this way, there is no risk of an IRQ occurring between the read and the modify access.

*Figure 13* and *Figure 14* show the basic structures of a standard and a 5 V tolerant I/O port bit, respectively. *Table 20* gives the possible port bit configurations.

**Figure 13. Basic structure of a standard I/O port bit**



**Figure 14. Basic structure of a five-volt tolerant I/O port bit**



1.  $V_{DD\_FT}$  is a potential specific to five-volt tolerant I/Os and different from  $V_{DD}$ .

Table 19. Port bit configuration table<sup>(1)</sup>

MODER(i) [1:0]	OTYPER(i)	OSPEEDR(i) [B:A]	PUPDR(i) [1:0]		I/O configuration	
01	0	SPEED [B:A]	0	0	GP output	PP
	0		0	1	GP output	PP + PU
	0		1	0	GP output	PP + PD
	0		1	1	Reserved	
	1		0	0	GP output	OD
	1		0	1	GP output	OD + PU
	1		1	0	GP output	OD + PD
	1		1	1	Reserved (GP output OD)	
10	0	SPEED [B:A]	0	0	AF	PP
	0		0	1	AF	PP + PU
	0		1	0	AF	PP + PD
	0		1	1	Reserved	
	1		0	0	AF	OD
	1		0	1	AF	OD + PU
	1		1	0	AF	OD + PD
	1		1	1	Reserved	
00	x	x	x	0	0	Input
	x	x	x	0	1	Input
	x	x	x	1	0	Input
	x	x	x	1	1	Reserved (input floating)
11	x	x	x	0	0	Input/output
	x	x	x	0	1	Reserved
	x	x	x	1	0	
	x	x	x	1	1	

1. GP = general-purpose, PP = push-pull, PU = pull-up, PD = pull-down, OD = open-drain, AF = alternate function.

### 8.3.1 General-purpose I/O (GPIO)

During and just after reset, the alternate functions are not active and the I/O ports are configured in input floating mode.

The debug pins are in AF pull-up/pull-down after reset:

- PA14: SWCLK in pull-down
- PA13: SWDIO in pull-up

When the pin is configured as output, the value written to the output data register (GPIOx\_ODR) is output on the I/O pin. It is possible to use the output driver in push-pull mode or open-drain mode (only the low level is driven, high level is HI-Z).

The input data register (GPIO<sub>x</sub>\_IDR) captures the data present on the I/O pin at every AHB clock cycle.

All GPIO pins have weak internal pull-up and pull-down resistors, which can be activated or not depending on the value in the GPIO<sub>x</sub>\_PUPDR register.

### 8.3.2 I/O pin alternate function multiplexer and mapping

The device I/O pins are connected to onboard peripherals/modules through a multiplexer that allows only one peripheral's alternate function (AF) connected to an I/O pin at a time. In this way, there can be no conflict between peripherals available on the same I/O pin.

Each I/O pin has a multiplexer with up to sixteen alternate function inputs (AF0 to AF15) that can be configured through the GPIO<sub>x</sub>\_AFRL (for pin 0 to 7) and GPIO<sub>x</sub>\_AFRH (for pin 8 to 15) registers:

- After reset all I/Os are connected to alternate function 0 (AF0)
- The specific alternate function assignments for each pin are detailed in the device datasheet.

In addition to this flexible I/O multiplexing architecture, each peripheral has alternate functions mapped onto different I/O pins to optimize the number of peripherals available in smaller packages.

To use an I/O in a given configuration, you have to proceed as follows:

- **Debug function:** after each device reset these pins are assigned as alternate function pins immediately usable by the debugger host
- **GPIO:** configure the desired I/O as output, input or analog in the GPIO<sub>x</sub>\_MODER register.
- **Peripheral alternate function:**
  - Connect the I/O to the desired AFx in the GPIO<sub>x</sub>\_AFRL or GPIO<sub>x</sub>\_AFRH register
  - Select the type, pull-up/pull-down and output speed via the GPIO<sub>x</sub>\_OTYPER, GPIO<sub>x</sub>\_PUPDR and GPIO<sub>x</sub>\_OSPEEDER registers, respectively
  - Configure the desired I/O as an alternate function in the GPIO<sub>x</sub>\_MODER register
- **Additional functions:**
  - For the ADC and DAC, configure the desired I/O in analog mode in the GPIO<sub>x</sub>\_MODER register and configure the required function in the ADC or DAC registers.
  - For the additional functions like RTC, WKUPx and oscillators, configure the required function in the related RTC, PWR and RCC registers. These functions have priority over the configuration in the standard GPIO registers.

Please refer to the “Alternate function mapping” table in the device datasheet for the detailed mapping of the alternate function I/O pins.

### 8.3.3 I/O port control registers

Each of the GPIO ports has four 32-bit memory-mapped control registers (GPIO<sub>x</sub>\_MODER, GPIO<sub>x</sub>\_OTYPER, GPIO<sub>x</sub>\_OSPEEDER, GPIO<sub>x</sub>\_PUPDR) to configure up to 16 I/Os. The GPIO<sub>x</sub>\_MODER register is used to select the I/O mode (input, output, AF, analog). The GPIO<sub>x</sub>\_OTYPER and GPIO<sub>x</sub>\_OSPEEDER registers are used to select the output type (push-pull or open-drain) and speed. The GPIO<sub>x</sub>\_PUPDR register is used to select the pull-up/pull-down whatever the I/O direction.

### 8.3.4 I/O port data registers

Each GPIO has two 16-bit memory-mapped data registers: input and output data registers (GPIO<sub>x</sub>\_IDR and GPIO<sub>x</sub>\_ODR). GPIO<sub>x</sub>\_ODR stores the data to be output, it is read/write accessible. The data input through the I/O are stored into the input data register (GPIO<sub>x</sub>\_IDR), a read-only register.

See [Section 8.4.5: GPIO port input data register \(GPIO<sub>x</sub>\\_IDR\) \(x = A..D, F\)](#) and [Section 8.4.6: GPIO port output data register \(GPIO<sub>x</sub>\\_ODR\) \(x = A..D, F\)](#) for the register descriptions.

### 8.3.5 I/O data bitwise handling

The bit set reset register (GPIO<sub>x</sub>\_BSRR) is a 32-bit register which allows the application to set and reset each individual bit in the output data register (GPIO<sub>x</sub>\_ODR). The bit set reset register has twice the size of GPIO<sub>x</sub>\_ODR.

To each bit in GPIO<sub>x</sub>\_ODR, correspond two control bits in GPIO<sub>x</sub>\_BSRR: BS(i) and BR(i). When written to 1, bit BS(i) **sets** the corresponding ODR(i) bit. When written to 1, bit BR(i) **resets** the ODR(i) corresponding bit.

Writing any bit to 0 in GPIO<sub>x</sub>\_BSRR does not have any effect on the corresponding bit in GPIO<sub>x</sub>\_ODR. If there is an attempt to both set and reset a bit in GPIO<sub>x</sub>\_BSRR, the set action takes priority.

Using the GPIO<sub>x</sub>\_BSRR register to change the values of individual bits in GPIO<sub>x</sub>\_ODR is a “one-shot” effect that does not lock the GPIO<sub>x</sub>\_ODR bits. The GPIO<sub>x</sub>\_ODR bits can always be accessed directly. The GPIO<sub>x</sub>\_BSRR register provides a way of performing atomic bitwise handling.

There is no need for the software to disable interrupts when programming the GPIO<sub>x</sub>\_ODR at bit level: it is possible to modify one or more bits in a single atomic AHB write access.

### 8.3.6 GPIO locking mechanism

It is possible to freeze the port A and B GPIO control registers by applying a specific write sequence to the GPIO<sub>x</sub>\_LCKR register. The frozen registers are GPIO<sub>x</sub>\_MODER, GPIO<sub>x</sub>\_OTYPER, GPIO<sub>x</sub>\_OSPEEDR, GPIO<sub>x</sub>\_PUPDR, GPIO<sub>x</sub>\_AFRL and GPIO<sub>x</sub>\_AFRH.

To write the GPIO<sub>x</sub>\_LCKR register, a specific write / read sequence has to be applied. When the right LOCK sequence is applied to bit 16 in this register, the value of LCKR[15:0] is used to lock the configuration of the I/Os (during the write sequence the LCKR[15:0] value must be the same). When the LOCK sequence has been applied to a port bit, the value of the port bit can no longer be modified until the next reset. Each GPIO<sub>x</sub>\_LCKR bit freezes the corresponding bit in the control registers (GPIO<sub>x</sub>\_MODER, GPIO<sub>x</sub>\_OTYPER, GPIO<sub>x</sub>\_OSPEEDR, GPIO<sub>x</sub>\_PUPDR, GPIO<sub>x</sub>\_AFRL and GPIO<sub>x</sub>\_AFRH).

The LOCK sequence (refer to [Section 8.4.8: GPIO port configuration lock register \(GPIO<sub>x</sub>\\_LCKR\) \(x = A..B\)](#)) can only be performed using a word (32-bit long) access to the GPIO<sub>x</sub>\_LCKR register due to the fact that GPIO<sub>x</sub>\_LCKR bit 16 has to be set at the same time as the [15:0] bits.

For more details please refer to LCKR register description in [Section 8.4.8: GPIO port configuration lock register \(GPIO<sub>x</sub>\\_LCKR\) \(x = A..B\)](#).

### 8.3.7 I/O alternate function input/output

Two registers are provided to select one of the alternate function inputs/outputs available for each I/O. With these registers, you can connect an alternate function to some other pin as required by your application.

This means that a number of possible peripheral functions are multiplexed on each GPIO using the GPIOx\_AFRL and GPIOx\_AFRH alternate function registers. The application can thus select any one of the possible functions for each I/O. The AF selection signal being common to the alternate function input and alternate function output, a single channel is selected for the alternate function input/output of one I/O.

To know which functions are multiplexed on each GPIO pin, refer to the device datasheet.

### 8.3.8 External interrupt/wakeup lines

All ports have external interrupt capability. To use external interrupt lines, the port must be configured in input mode, refer to [the Extended interrupts and events controller \(EXTI\)](#) and to the [Wakeup event management](#) section.

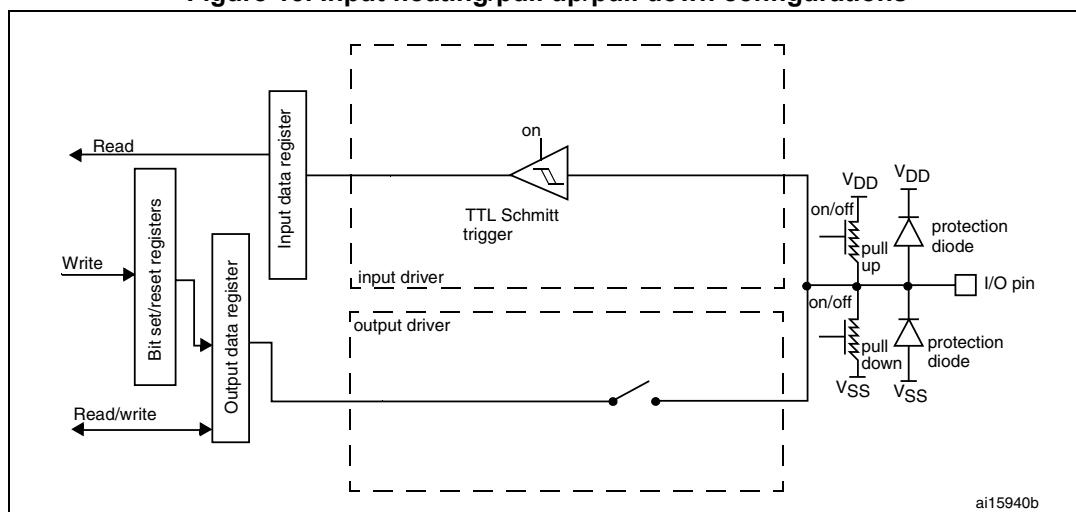
### 8.3.9 Input configuration

When the I/O port is programmed as input:

- The output buffer is disabled
- The Schmitt trigger input is activated
- The pull-up and pull-down resistors are activated depending on the value in the GPIOx\_PUPDR register
- The data present on the I/O pin are sampled into the input data register every AHB clock cycle
- A read access to the input data register provides the I/O state

[Figure 15](#) shows the input configuration of the I/O port bit.

**Figure 15. Input floating/pull up/pull down configurations**



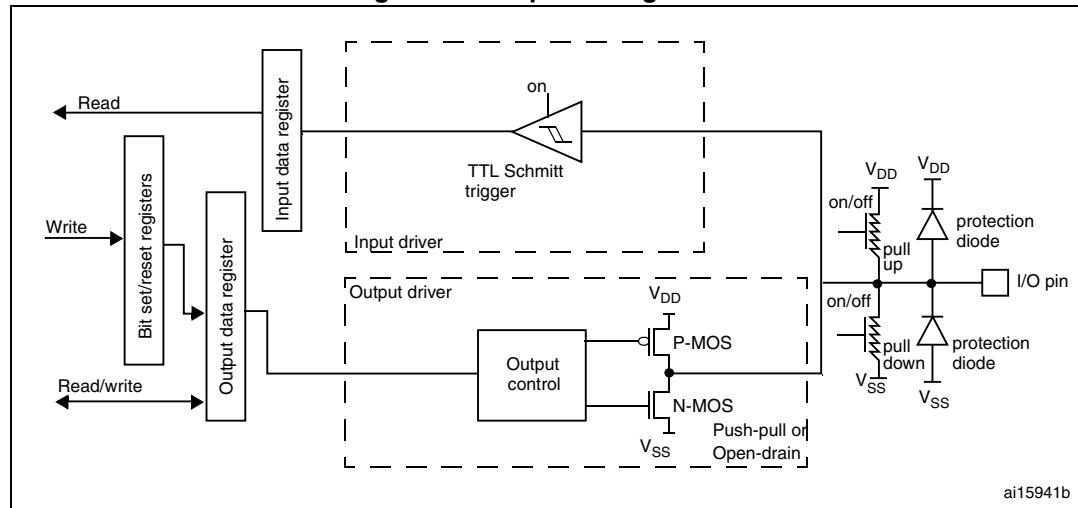
### 8.3.10 Output configuration

When the I/O port is programmed as output:

- The output buffer is enabled:
  - Open drain mode: A “0” in the Output register activates the N-MOS whereas a “1” in the Output register leaves the port in Hi-Z (the P-MOS is never activated)
  - Push-pull mode: A “0” in the Output register activates the N-MOS whereas a “1” in the Output register activates the P-MOS
- The Schmitt trigger input is activated
- The weak pull-up and pull-down resistors are activated or not depending on the value in the GPIOx\_PUPDR register
- The data present on the I/O pin are sampled into the input data register every AHB clock cycle
- A read access to the input data register gets the I/O state
- A read access to the output data register gets the last written value

*Figure 16* shows the output configuration of the I/O port bit.

**Figure 16. Output configuration**

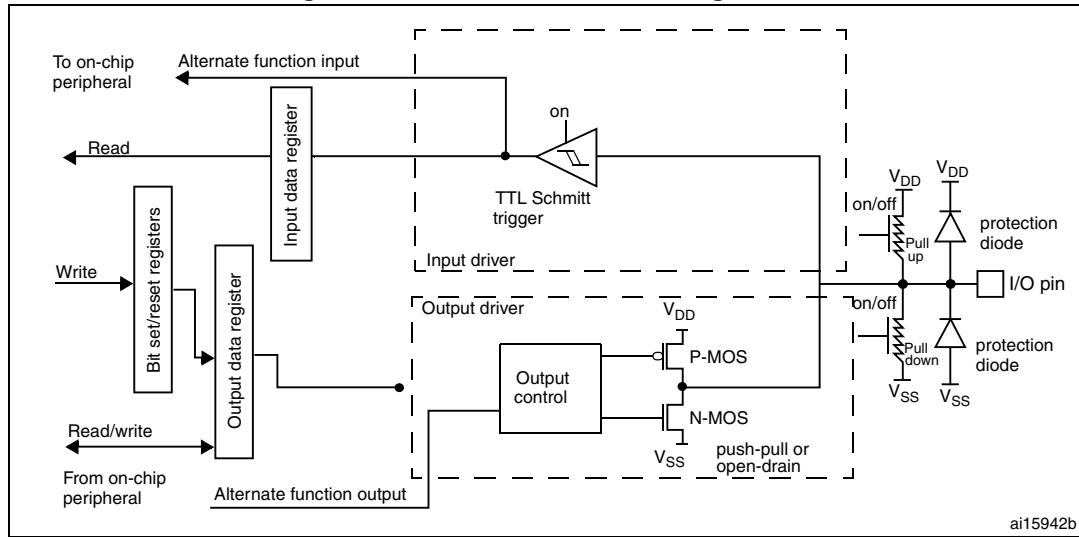


### 8.3.11 Alternate function configuration

When the I/O port is programmed as alternate function:

- The output buffer can be configured in open-drain or push-pull mode
- The output buffer is driven by the signals coming from the peripheral (transmitter enable and data)
- The Schmitt trigger input is activated
- The weak pull-up and pull-down resistors are activated or not depending on the value in the GPIOx\_PUPDR register
- The data present on the I/O pin are sampled into the input data register every AHB clock cycle
- A read access to the input data register gets the I/O state

*Figure 17* shows the Alternate function configuration of the I/O port bit.

**Figure 17. Alternate function configuration**

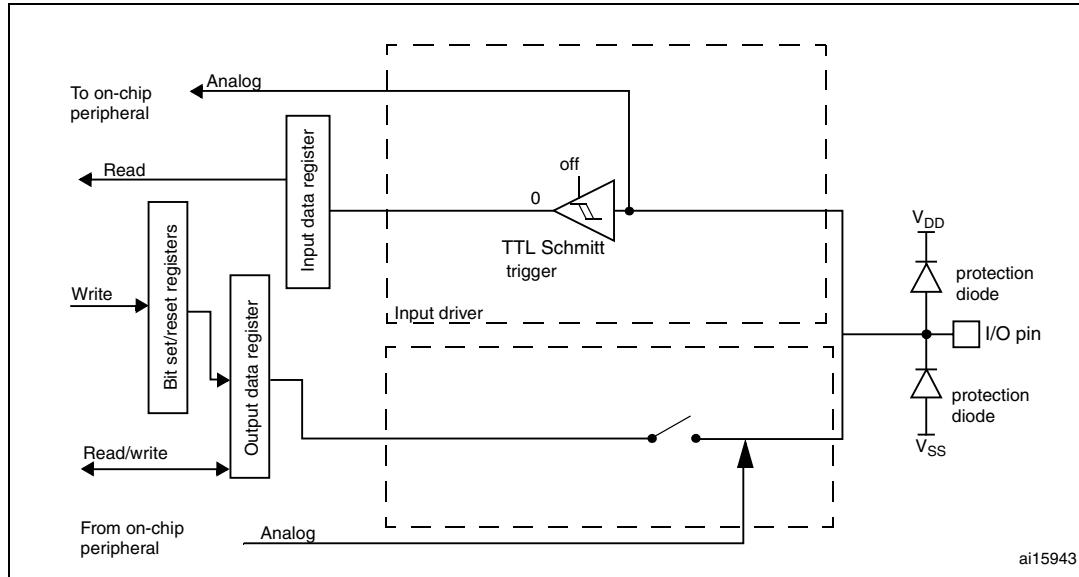
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### 8.3.12 Analog configuration

When the I/O port is programmed as analog configuration:

- The output buffer is disabled
- The Schmitt trigger input is deactivated, providing zero consumption for every analog value of the I/O pin. The output of the Schmitt trigger is forced to a constant value (0).
- The weak pull-up and pull-down resistors are disabled
- Read access to the input data register gets the value “0”

*Figure 18* shows the high-impedance, analog-input configuration of the I/O port bit.

**Figure 18. High impedance-analog configuration**

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### 8.3.13 Using the HSE or LSE oscillator pins as GPIOs

When the HSE or LSE oscillator is switched OFF (default state after reset), the related oscillator pins can be used as normal GPIOs.

When the HSE or LSE oscillator is switched ON (by setting the HSEON or LSEON bit in the RCC\_CSR register) the oscillator takes control of its associated pins and the GPIO configuration of these pins has no effect.

When the oscillator is configured in a user external clock mode, only the OSC\_IN or OSC32\_IN pin is reserved for clock input and the OSC\_OUT or OSC32\_OUT pin can still be used as normal GPIO.

### 8.3.14 Using the GPIO pins in the backup supply domain

The PC13/PC14/PC15 GPIO functionality is lost when the core supply domain is powered off (when the device enters Standby mode). In this case, if their GPIO configuration is not bypassed by the RTC configuration, these pins are set in an analog input mode.

For details about I/O control by the RTC, refer to [Section 23.3: RTC functional description on page 478](#).

## 8.4 GPIO registers

This section gives a detailed description of the GPIO registers.

For a summary of register bits, register address offsets and reset values, refer to [Table 20](#).

The peripheral registers can be written in word, half word or byte mode.

### 8.4.1 GPIO port mode register (GPIOx\_MODER) (x = A..D, F)

Address offset: 0x00

Reset values:

- 0x2800 0000 for port A
- 0x0000 0000 for other ports

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MODER15[1:0]	MODER14[1:0]	MODER13[1:0]	MODER12[1:0]	MODER11[1:0]	MODER10[1:0]	MODER9[1:0]	MODER8[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MODER7[1:0]	MODER6[1:0]	MODER5[1:0]	MODER4[1:0]	MODER3[1:0]	MODER2[1:0]	MODER1[1:0]	MODERO[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 2y+1:2y **MODERy[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O mode.

00: Input mode (reset state)

01: General purpose output mode

10: Alternate function mode

11: Analog mode

### 8.4.2 GPIO port output type register (GPIOx\_OTYPER) (x = A..D, F)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OT15	OT14	OT13	OT12	OT11	OT10	OT9	OT8	OT7	OT6	OT5	OT4	OT3	OT2	OT1	OT0
rw															

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **OTy[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O output type.

- 0: Output push-pull (reset state)
- 1: Output open-drain

### 8.4.3 GPIO port output speed register (GPIOx\_OSPEEDR) (x = A..D, F)

Address offset: 0x08

Reset value:

- 0x0C00 0000 for port A
- 0x0000 0000 for other ports

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OSPEEDR15[1:0]	OSPEEDR14[1:0]	OSPEEDR13[1:0]	OSPEEDR12[1:0]	OSPEEDR11[1:0]	OSPEEDR10[1:0]	OSPEEDR9[1:0]	OSPEEDR8[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OSPEEDR7[1:0]	OSPEEDR6[1:0]	OSPEEDR5[1:0]	OSPEEDR4[1:0]	OSPEEDR3[1:0]	OSPEEDR2[1:0]	OSPEEDR1[1:0]	OSPEEDR0[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 2y+1:2y **OSPEEDRy[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O output speed.

- x0: Low speed
- 01: Medium speed
- 11: High speed

Note: Refer to the device datasheet for the frequency specifications and the power supply and load conditions for each speed.

#### 8.4.4 GPIO port pull-up/pull-down register (GPIOx\_PUPDR) (x = A..D, F)

Address offset: 0x0C

Reset values:

- 0x2400 0000 for port A
- 0x0000 0000 for other ports

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PUPDR15[1:0]	PUPDR14[1:0]	PUPDR13[1:0]	PUPDR12[1:0]	PUPDR11[1:0]	PUPDR10[1:0]	PUPDR9[1:0]	PUPDR8[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PUPDR7[1:0]	PUPDR6[1:0]	PUPDR5[1:0]	PUPDR4[1:0]	PUPDR3[1:0]	PUPDR2[1:0]	PUPDR1[1:0]	PUPDR0[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 2y+1:2y **PUPDR<sub>y</sub>[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O pull-up or pull-down

- 00: No pull-up, pull-down
- 01: Pull-up
- 10: Pull-down
- 11: Reserved

#### 8.4.5 GPIO port input data register (GPIOx\_IDR) (x = A..D, F)

Address offset: 0x10

Reset value: 0x0000 XXXX (where X means undefined)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IDR15	IDR14	IDR13	IDR12	IDR11	IDR10	IDR9	IDR8	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **IDR[15:0]**: Port input data

These bits are read-only. They contain the input value of the corresponding I/O port.

### 8.4.6 GPIO port output data register (GPIOx\_ODR) (x = A..D, F)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ODR15	ODR14	ODR13	ODR12	ODR11	ODR10	ODR9	ODR8	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **ODR[15:0]**: Port output data

These bits can be read and written by software.

*Note:* For atomic bit set/reset, the ODR bits can be individually set and reset by writing to the GPIOx\_BSRR register (x = A..D, F).

### 8.4.7 GPIO port bit set/reset register (GPIOx\_BSRR) (x = A..D, F)

Address offset: 0x18

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
BR15	BR14	BR13	BR12	BR11	BR10	BR9	BR8	BR7	BR6	BR5	BR4	BR3	BR2	BR1	BR0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BS15	BS14	BS13	BS12	BS11	BS10	BS9	BS8	BS7	BS6	BS5	BS4	BS3	BS2	BS1	BS0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:16 **BRy**: Port x reset bit y (y = 0..15)

These bits are write-only. A read to these bits returns the value 0x0000.

0: No action on the corresponding ODRx bit

1: Resets the corresponding ODRx bit

*Note:* If both BSx and BRx are set, BSx has priority.

Bits 15:0 **BSy**: Port x set bit y (y= 0..15)

These bits are write-only. A read to these bits returns the value 0x0000.

0: No action on the corresponding ODRx bit

1: Sets the corresponding ODRx bit

### 8.4.8 GPIO port configuration lock register (GPIOx\_LCKR) (x = A..B)

This register is used to lock the configuration of the port bits when a correct write sequence is applied to bit 16 (LCKK). The value of bits [15:0] is used to lock the configuration of the GPIO. During the write sequence, the value of LCKR[15:0] must not change. When the LOCK sequence has been applied on a port bit, the value of this port bit can no longer be modified until the next reset.

**Note:** *A specific write sequence is used to write to the GPIOx\_LCKR register. Only word access (32-bit long) is allowed during this locking sequence.*

Each lock bit freezes a specific configuration register (control and alternate function registers).

Address offset: 0x1C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	LCKK
															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LCK15	LCK14	LCK13	LCK12	LCK11	LCK10	LCK9	LCK8	LCK7	LCK6	LCK5	LCK4	LCK3	LCK2	LCK1	LCK0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:17 Reserved, must be kept at reset value.

**Bit 16 LCKK:** Lock key

This bit can be read any time. It can only be modified using the lock key write sequence.

0: Port configuration lock key not active

1: Port configuration lock key active. The GPIOx\_LCKR register is locked until an MCU reset occurs.

LOCK key write sequence:

WR LCKR[16] = '1' + LCKR[15:0]

WR LCKR[16] = '0' + LCKR[15:0]

WR LCKR[16] = '1' + LCKR[15:0]

RD LCKR

RD LCKR[16] = '1' (this read operation is optional but it confirms that the lock is active)

**Note:** *During the LOCK key write sequence, the value of LCK[15:0] must not change.*

*Any error in the lock sequence aborts the lock.*

*After the first lock sequence on any bit of the port, any read access on the LCKK bit will return '1' until the next CPU reset.*

**Bits 15:0 LCKy:** Port x lock bit y (y= 0..15)

These bits are read/write but can only be written when the LCKK bit is '0'.

0: Port configuration not locked

1: Port configuration locked

### 8.4.9 GPIO alternate function low register (GPIOx\_AFRL) (x = A..B)

Address offset: 0x20

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AFRL7[3:0]				AFRL6[3:0]				AFRL5[3:0]				AFRL4[3:0]			
rw	rw	rw	rw												
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AFRL3[3:0]				AFRL2[3:0]				AFRL1[3:0]				AFRL0[3:0]			
rw	rw	rw	rw												

Bits 31:0 **AFRLy**: Alternate function selection for port x pin y (y = 0..7)

These bits are written by software to configure alternate function I/Os

AFRLy selection:

0000: AF0	1000: Reserved
0001: AF1	1001: Reserved
0010: AF2	1010: Reserved
0011: AF3	1011: Reserved
0100: AF4 (Port A only)	1100: Reserved
0101: AF5 (Port A only)	1101: Reserved
0110: AF6 (Port A only)	1110: Reserved
0111: AF7 (Port A only)	1111: Reserved

### 8.4.10 GPIO alternate function high register (GPIOx\_AFRH) (x = A..B)

Address offset: 0x24

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AFRH15[3:0]				AFRH14[3:0]				AFRH13[3:0]				AFRH12[3:0]			
rw	rw	rw	rw												
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AFRH11[3:0]				AFRH10[3:0]				AFRH9[3:0]				AFRH8[3:0]			
rw	rw	rw	rw												

Bits 31:0 **AFRHy**: Alternate function selection for port x pin y (y = 8..15)

These bits are written by software to configure alternate function I/Os

AFRHy selection:

0000: AF0	1000: Reserved
0001: AF1	1001: Reserved
0010: AF2	1010: Reserved
0011: AF3	1011: Reserved
0100: AF4 (Port A only)	1100: Reserved
0101: AF5 (Port A only)	1101: Reserved
0110: AF6 (Port A only)	1110: Reserved
0111: AF7 (Port A only)	1111: Reserved

### 8.4.11 GPIO port bit reset register (GPIOx\_BRR) (x=A..D, F)

Address offset: 0x28

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BR15	BR14	BR13	BR12	BR11	BR10	BR9	BR8	BR7	BR6	BR5	BR4	BR3	BR2	BR1	BR0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:16 Reserved

Bits 15:0 **BRy**: Port x Reset bit y (y= 0 .. 15)

These bits are write-only. A read to these bits returns the value 0x0000

0: No action on the corresponding ODRx bit

1: Reset the corresponding ODRx bit

## 8.4.12 GPIO register map

The following table gives the GPIO register map and reset values.

**Table 20. GPIO register map and reset values**

Offset	Register
0x00	GPIOA_MODER
0x00	GPIOx_MODER (where x = B..D, F)
0x04	GPIOx_OTYPER (where x = A..D, F)
0x08	GPIOA_OSPEEDR
0x08	GPIOx_OSPEEDR (where x = B..D, F)
0x0C	GPIOA_PUPDR
0x0C	GPIOx_PUPDR (where x = B..D, F)
0x10	GPIOx_IDR (where x = A..D, F)
0x14	GPIOx_ODR (where x = A..D, F)
0x18	GPIOx_BSRR (where x = A..D, F)
	Reset value
0 BR15	Res. 0 PUPDR15[1:0] 0 PUPDR15[1:0]
0 BR14	Res. 0 PUPDR14[1:0] 0 PUPDR14[1:0]
0 BR13	Res. 0 PUPDR13[1:0] 0 PUPDR13[1:0]
0 BR12	Res. 0 PUPDR12[1:0] 0 PUPDR12[1:0]
0 BR11	Res. 0 PUPDR11[1:0] 0 PUPDR11[1:0]
0 BR10	Res. 0 PUPDR10[1:0] 0 PUPDR10[1:0]
0 BR9	Res. 0 PUPDR9[1:0] 0 PUPDR9[1:0]
0 BR8	Res. 0 PUPDR8[1:0] 0 PUPDR8[1:0]
0 BR7	Res. 0 PUPDR7[1:0] 0 PUPDR7[1:0]
0 BR6	Res. 0 PUPDR6[1:0] 0 PUPDR6[1:0]
0 BR5	Res. 0 PUPDR5[1:0] 0 PUPDR5[1:0]
0 BR4	Res. 0 PUPDR4[1:0] 0 PUPDR4[1:0]
0 BR3	Res. 0 PUPDR3[1:0] 0 PUPDR3[1:0]
0 BR2	Res. 0 PUPDR2[1:0] 0 PUPDR2[1:0]
0 BR1	Res. 0 PUPDR1[1:0] 0 PUPDR1[1:0]
0 BR0	Res. 0 PUPDR0[1:0] 0 PUPDR0[1:0]
0 BS15	0 IDR15 0 PUPDR15[1:0] 0 PUPDR15[1:0]
0 BS14	0 IDR14 0 PUPDR14[1:0] 0 PUPDR14[1:0]
0 BS13	0 IDR13 0 PUPDR13[1:0] 0 PUPDR13[1:0]
0 BS12	0 IDR12 0 PUPDR12[1:0] 0 PUPDR12[1:0]
0 BS11	0 IDR11 0 PUPDR11[1:0] 0 PUPDR11[1:0]
0 BS10	0 IDR10 0 PUPDR10[1:0] 0 PUPDR10[1:0]
0 BS9	0 IDR9 0 PUPDR9[1:0] 0 PUPDR9[1:0]
0 BS8	0 IDR8 0 PUPDR8[1:0] 0 PUPDR8[1:0]
0 BS7	0 IDR7 0 PUPDR7[1:0] 0 PUPDR7[1:0]
0 BS6	0 IDR6 0 PUPDR6[1:0] 0 PUPDR6[1:0]
0 BS5	0 IDR5 0 PUPDR5[1:0] 0 PUPDR5[1:0]
0 BS4	0 IDR4 0 PUPDR4[1:0] 0 PUPDR4[1:0]
0 BS3	0 IDR3 0 PUPDR3[1:0] 0 PUPDR3[1:0]
0 BS2	0 IDR2 0 PUPDR2[1:0] 0 PUPDR2[1:0]
0 BS1	0 IDR1 0 PUPDR1[1:0] 0 PUPDR1[1:0]
0 BS0	0 IDR0 0 PUPDR0[1:0] 0 PUPDR0[1:0]
	Reset value
0 OSPEEDR15[1:0]	0 OSPEEDR15[1:0]
0 OSPEEDR14[1:0]	0 OSPEEDR14[1:0]
0 OSPEEDR13[1:0]	0 OSPEEDR13[1:0]
0 OSPEEDR12[1:0]	0 OSPEEDR12[1:0]
0 OSPEEDR11[1:0]	0 OSPEEDR11[1:0]
0 OSPEEDR10[1:0]	0 OSPEEDR10[1:0]
0 OSPEEDR9[1:0]	0 OSPEEDR9[1:0]
0 OSPEEDR8[1:0]	0 OSPEEDR8[1:0]
0 OSPEEDR7[1:0]	0 OSPEEDR7[1:0]
0 OSPEEDR6[1:0]	0 OSPEEDR6[1:0]
0 OSPEEDR5[1:0]	0 OSPEEDR5[1:0]
0 OSPEEDR4[1:0]	0 OSPEEDR4[1:0]
0 OSPEEDR3[1:0]	0 OSPEEDR3[1:0]
0 OSPEEDR2[1:0]	0 OSPEEDR2[1:0]
0 OSPEEDR1[1:0]	0 OSPEEDR1[1:0]
0 OSPEEDR0[1:0]	0 OSPEEDR0[1:0]
0 MDER15[1:0]	0 MDER15[1:0]
0 MDER14[1:0]	1 MDER14[1:0]
0 MDER13[1:0]	1 MDER13[1:0]
0 MDER12[1:0]	0 MDER12[1:0]
0 MDER11[1:0]	0 MDER11[1:0]
0 MDER10[1:0]	0 MDER10[1:0]
0 MDER9[1:0]	0 MDER9[1:0]
0 MDER8[1:0]	0 MDER8[1:0]
0 MDER7[1:0]	0 MDER7[1:0]
0 MDER6[1:0]	0 MDER6[1:0]
0 MDER5[1:0]	0 MDER5[1:0]
0 MDER4[1:0]	0 MDER4[1:0]
0 MDER3[1:0]	0 MDER3[1:0]
0 MDER2[1:0]	0 MDER2[1:0]
0 MDER1[1:0]	0 MDER1[1:0]
0 MDER0[1:0]	0 MDER0[1:0]
31	30
29	28
27	26
25	24
23	22
19	18
17	16
15	14
13	12
9	8
5	4
3	2
1	0
0	0

Table 20. GPIO register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x1C	<b>GPIOx_LCKR</b> (where x = A..B)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x20	<b>GPIOx_AFRL</b> (where x = A..B)	AFRL7[3:0]	AFRL6[3:0]	AFRL5[3:0]	AFRL4[3:0]	AFRL3[3:0]	AFRL2[3:0]	AFRL1[3:0]	AFRL0[3:0]																								
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x24	<b>GPIOx_AFRH</b> (where x = A..B)	AFRH15[3:0]	AFRH14[3:0]	AFRH13[3:0]	AFRH12[3:0]	AFRH11[3:0]	AFRH10[3:0]	AFRH9[3:0]	AFRH8[3:0]																								
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x28	<b>GPIOx_BRR</b> (where x = A..D,F)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 9 System configuration controller (SYSCFG)

The devices feature a set of configuration registers. The main purposes of the system configuration controller are the following:

- Enabling/disabling I<sup>2</sup>C Fast Mode Plus on some IO ports
- Remapping some DMA trigger sources from TIM16 and TIM17, USART1, and ADC to different DMA channels
- Remapping the memory located at the beginning of the code area
- Managing the external interrupt line connection to the GPIOs
- Managing robustness feature

### 9.1 SYSCFG registers

#### 9.1.1 SYSCFG configuration register 1 (SYSCFG\_CFGR1)

This register is used for specific configurations on memory remap.

Two bits are used to configure the type of memory accessible at address 0x0000 0000. These bits are used to select the physical remap by software and so, bypass the hardware BOOT selection.

After reset these bits take the value selected by the BOOT pin (BOOT0) and by the option bit (nBOOT1).

Address offset: 0x00

Reset value: 0x0000 000X (X is the memory mode selected by the BOOT0 pin and nBOOT1 option bit)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	I2C_PA10_FM+	I2C_PA9_FM+	Res.	I2C1_FM+	I2C_PB9_FM+	I2C_PB8_FM+	I2C_PB7_FM+	I2C_PB6_FM+
								rw	rw		rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	TIM17_DMA_RMP	TIM16_DMA_RMP	USART1_RX_DMA_RMP	USART1_TX_DMA_RMP	ADC_DMA_RMP	Res.	Res.	Res.	Res.	Res.	Res.	MEM_MODE [1:0]	
			rw	rw	rw	rw	rw							rw	rw

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:22 **I2C\_PAx\_FM+:** Fast Mode Plus (FM+) driving capability activation bits. Available on low-density devices only.

These bits are set and cleared by software. Each bit enables I<sup>2</sup>C FM+ mode for PA10, and PA9 I/Os.

0: PAx pin operates in standard mode.

1: I<sup>2</sup>C FM+ mode enabled on PAx pin, and the Speed control is bypassed.

Bit 21 Reserved.

Bit 20 **I2C1\_FM+**: FM+ driving capability activation for I2C1. Not available on medium-density devices.

This bit is set and cleared by software. This bit is OR-ed with I2C\_Pxx\_FM+ bits.

0: FM+ mode is controlled by I2C\_Pxx\_FM+ bits only.

1: FM+ mode is enabled on all I2C1 pins selected through selection bits in GPIOx\_AFR registers. This is the only way to enable the FM+ mode for pads without a dedicated I2C\_Pxx\_FM+ control bit.

Bits 19:16 **I2C\_PBx\_FM+**: Fast Mode Plus (FM) driving capability activation bits.

These bits are set and cleared by software. Each bit enables I<sup>2</sup>C FM+ mode for PB6, PB7, PB8, and PB9 I/Os.

0: PBx pin operates in standard mode.

1: I<sup>2</sup>C FM+ mode enabled on PBx pin, and the Speed control is bypassed.

Bits 15:13 Reserved, must be kept at reset value.

Bit 12 **TIM17\_DMA\_RMP**: TIM17 DMA request remapping bit

This bit is set and cleared by software. It controls the remapping of TIM17 DMA request.

0: No remap (TIM17\_CH1 and TIM17\_UP DMA requests mapped on DMA channel 1)

1: Remap (TIM17\_CH1 and TIM17\_UP DMA requests mapped on DMA channel 2)

Bit 11 **TIM16\_DMA\_RMP**: TIM16 DMA request remapping bit

This bit is set and cleared by software. It controls the remapping of TIM16 DMA request.

0: No remap (TIM16\_CH1 and TIM16\_UP DMA requests mapped on DMA channel 3)

1: Remap (TIM16\_CH1 and TIM16\_UP DMA requests mapped on DMA channel 4)

Bit 10 **USART1\_RX\_DMA\_RMP**: USART1\_RX DMA request remapping bit

This bit is set and cleared by software. It controls the remapping of USART1\_RX DMA request.

0: No remap (USART1\_RX DMA request mapped on DMA channel 3)

1: Remap (USART1\_RX DMA request mapped on DMA channel 5)

Bit 9 **USART1\_TX\_DMA\_RMP**: USART1\_TX DMA remapping bit

This bit is set and cleared by software. It bit controls the remapping of USART1\_TX DMA request.

0: No remap (USART1\_TX DMA request mapped on DMA channel 2)

1: Remap (USART1\_TX DMA request mapped on DMA channel 4)

Bit 8 **ADC\_DMA\_RMP**: ADC DMA remapping bit

This bit is set and cleared by software. It controls the remapping of ADC DMA request.

0: No remap (ADC DMA request mapped on DMA channel 1)

1: Remap (ADC DMA request mapped on DMA channel 2)

Bits 7:2 Reserved, must be kept at reset value.

Bits 1:0 **MEM\_MODE[1:0]**: Memory mapping selection bits

These bits are set and cleared by software. They control the memory internal mapping at address 0x0000 0000. After reset these bits take on the memory mapping selected by BOOT0 pin and nBOOT1 option bit.

x0: Main Flash memory mapped at 0x0000 0000

01: System Flash memory mapped at 0x0000 0000

11: Embedded SRAM mapped at 0x0000 0000

### 9.1.2 SYSCFG external interrupt configuration register 1 (SYSCFG\_EXTICR1)

Address offset: 0x08

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.												
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI3[3:0]				EXTI2[3:0]				EXTI1[3:0]				EXTI0[3:0]			
rw	rw	rw	rw												

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 0 to 3)

These bits are written by software to select the source input for the EXTIx external interrupt.

- x000: PA[x] pin
- x001: PB[x] pin
- x010: PC[x] pin
- x011: PD[x] pin
- x100: reserved
- x101: PF[x] pin
- other configurations: reserved

**Note:** Some of the I/O pins mentioned in the above register may not be available on small packages.

### 9.1.3 SYSCFG external interrupt configuration register 2 (SYSCFG\_EXTICR2)

Address offset: 0x0C

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.												
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI7[3:0]				EXTI6[3:0]				EXTI5[3:0]				EXTI4[3:0]			
rw	rw	rw	rw												

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 4 to 7)

These bits are written by software to select the source input for the EXTIx external interrupt.

- x000: PA[x] pin
- x001: PB[x] pin
- x010: PC[x] pin
- x011: reserved
- x100: reserved
- x101: PF[x] pin
- other configurations: reserved

**Note:** Some of the I/O pins mentioned in the above register may not be available on small packages.

#### 9.1.4 SYSCFG external interrupt configuration register 3 (SYSCFG\_EXTICR3)

Address offset: 0x10

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI11[3:0]				EXTI10[3:0]				EXTI9[3:0]				EXTI8[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 8 to 11)

These bits are written by software to select the source input for the EXTIx external interrupt.

- x000: PA[x] pin
- x001: PB[x] pin
- x010: PC[x] pin
- other configurations: reserved

**Note:** Some of the I/O pins mentioned in the above register may not be available on small packages.

### 9.1.5 SYSCFG external interrupt configuration register 4 (SYSCFG\_EXTICR4)

Address offset: 0x14

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.												
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI15[3:0]				EXTI14[3:0]				EXTI13[3:0]				EXTI12[3:0]			
rw	rw	rw	rw												

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 12 to 15)

These bits are written by software to select the source input for the EXTIx external interrupt.

x000: PA[x] pin

x001: PB[x] pin

x010: PC[x] pin

other configurations: reserved

**Note:** Some of the I/O pins mentioned in the above register may not be available on small packages.

### 9.1.6 SYSCFG configuration register 2 (SYSCFG\_CFGR2)

Address offset: 0x18

System reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SRAM_PEF	Res.	Res.	Res.	Res.	Res.	PVD_LOCK	SRAM_PARITY_LOCK	LOCKUP_LOCK						
							rc_w1						rw	rw	rw

Bits 31:9 Reserved, must be kept at reset value

#### Bit 8 **SRAM\_PEF**: SRAM parity flag

This bit is set by hardware when an SRAM parity error is detected. It is cleared by software by writing '1'.

0: No SRAM parity error detected

1: SRAM parity error detected

Bits 7:3 Reserved, must be kept at reset value

#### Bit 2 **PVD\_LOCK**: PVD lock enable bit

This bit is set by software and cleared by a system reset. It can be used to enable and lock the PVD connection to TIM1/15/16/17 Break input, as well as the PVDE and PLS[2:0] in the PWR\_CR register.

0: PVD interrupt disconnected from TIM1/15/16/17 Break input. PVDE and PLS[2:0] bits can be programmed by the application.

1: PVD interrupt connected to TIM1/15/16/17 Break input, PVDE and PLS[2:0] bits are read only.

#### Bit 1 **SRAM\_PARITY\_LOCK**: SRAM parity lock bit

This bit is set by software and cleared by a system reset. It can be used to enable and lock the SRAM parity error signal connection to TIM1/15/16/17 Break input.

0: SRAM parity error disconnected from TIM1/15/16/17 Break input

1: SRAM parity error connected to TIM1/15/16/17 Break input

#### Bit 0 **LOCKUP\_LOCK**: Cortex-M0 LOCKUP bit enable bit

This bit is set by software and cleared by a system reset. It can be used to enable and lock the connection of Cortex-M0 LOCKUP (Hardfault) output to TIM1/15/16/17 Break input.

0: Cortex-M0 LOCKUP output disconnected from TIM1/15/16/17 Break input

1: Cortex-M0 LOCKUP output connected to TIM1/15/16/17 Break input

### 9.1.7 SYSCFG register maps

The following table gives the SYSCFG register map and the reset values.

**Table 21. SYSCFG register map and reset values**

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	<b>SYSCFG_CFGR1</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	I2C_PA10_FM+	I2C_PA9_FM+	Res.	I2C1_FM+	I2C_PB9_FM+	I2C_PB8_FM+	I2C_PB7_FM+	I2C_PB6_FM+	Res.	Res.	Res.	EXTI3[3:0]	EXTI2[3:0]	EXTI1[3:0]	EXTI0[3:0]	X	X	X	X	X				
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0										
0x08	<b>SYSCFG_EXTICR1</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI7[3:0]	EXTI6[3:0]	EXTI5[3:0]	EXTI4[3:0]									
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0										
0x0C	<b>SYSCFG_EXTICR2</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI11[3:0]	EXTI10[3:0]	EXTI9[3:0]	EXTI8[3:0]									
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0										
0x10	<b>SYSCFG_EXTICR3</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI15[3:0]	EXTI14[3:0]	EXTI13[3:0]	EXTI12[3:0]									
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0										
0x14	<b>SYSCFG_EXTICR4</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI17[3:0]	EXTI16[3:0]	EXTI15[3:0]	EXTI14[3:0]									
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0										
0x18	<b>SYSCFG_CFGR2</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI1[3:0]	EXTI0[3:0]	EXTI19[3:0]	EXTI18[3:0]									
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0										

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 10 Direct memory access controller (DMA)

### 10.1 DMA introduction

Direct memory access (DMA) is used in order to provide high-speed data transfer between peripherals and memory as well as memory to memory. Data can be quickly moved by DMA without any CPU actions. This keeps CPU resources free for other operations.

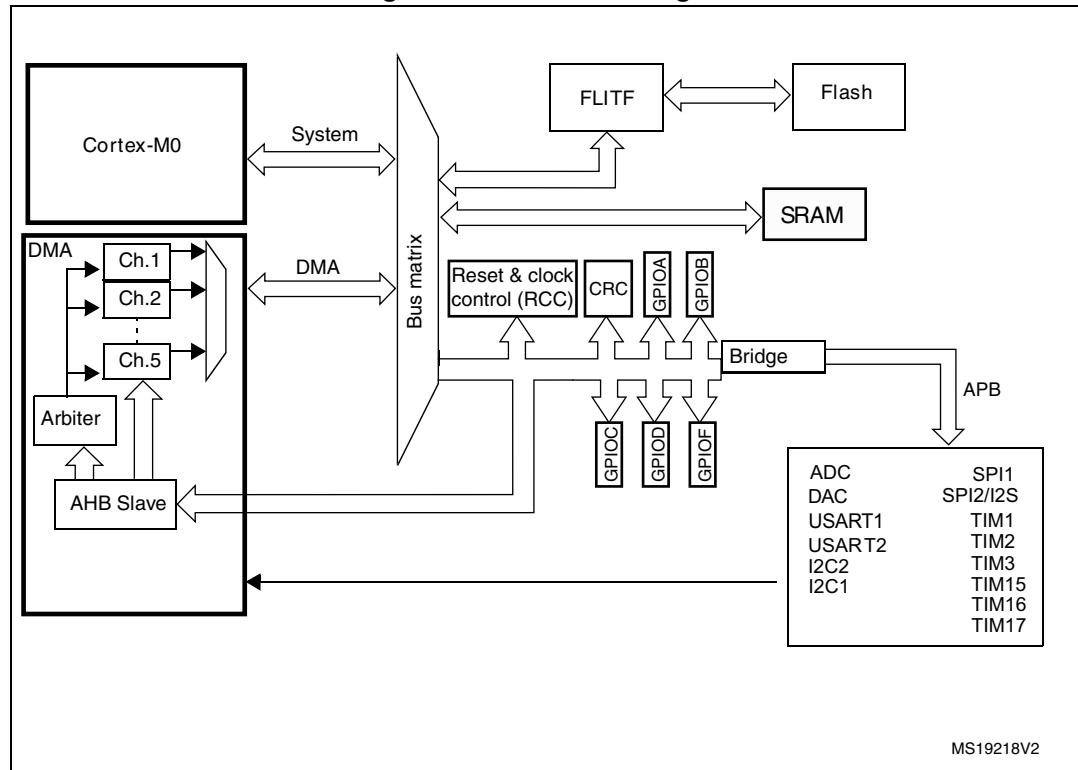
The DMA controller has 5 channels in total, each dedicated to managing memory access requests from one or more peripherals. It has an arbiter for handling the priority between DMA requests.

### 10.2 DMA main features

- 5 independently configurable channels (requests)
- Each channel is connected to dedicated hardware DMA requests, software trigger is also supported on each channel. This configuration is done by software.
- Priorities between requests from channels of one DMA are software programmable (4 levels consisting of *very high, high, medium, low*) or hardware in case of equality (request 1 has priority over request 2, etc.)
- Independent source and destination transfer size (byte, half word, word), emulating packing and unpacking. Source/destination addresses must be aligned on the data size.
- Support for circular buffer management
- 3 event flags (DMA Half Transfer, DMA Transfer complete and DMA Transfer Error) logically ORed together in a single interrupt request for each channel
- Memory-to-memory transfer
- Peripheral-to-memory and memory-to-peripheral, and peripheral-to-peripheral transfers
- Access to Flash, SRAM, APB and AHB peripherals as source and destination
- Programmable number of data to be transferred: up to 65536

The block diagram is shown in the following figure.

**Figure 19. DMA block diagram**



MS19218V2

## 10.3 DMA functional description

The DMA controller performs direct memory transfer by sharing the system bus with the Cortex-M0 core. The DMA request may stop the CPU access to the system bus for some bus cycles, when the CPU and DMA are targeting the same destination (memory or peripheral). The bus matrix implements round-robin scheduling, thus ensuring at least half of the system bus bandwidth (both to memory and peripheral) for the CPU.

### 10.3.1 DMA transactions

After an event, the peripheral sends a request signal to the DMA Controller. The DMA controller serves the request depending on the channel priorities. As soon as the DMA Controller accesses the peripheral, an Acknowledge is sent to the peripheral by the DMA Controller. The peripheral releases its request as soon as it gets the Acknowledge from the DMA Controller. Once the request is deasserted by the peripheral, the DMA Controller releases the Acknowledge. If there are more requests, the peripheral can initiate the next transaction.

In summary, each DMA transfer consists of three operations:

- The loading of data from the peripheral data register or a location in memory addressed through an internal current peripheral/memory address register. The start address used

- for the first transfer is the base peripheral/memory address programmed in the DMA\_CPARx or DMA\_CMARx register
- The storage of the data loaded to the peripheral data register or a location in memory addressed through an internal current peripheral/memory address register. The start address used for the first transfer is the base peripheral/memory address programmed in the DMA\_CPARx or DMA\_CMARx register
- The post-decrementing of the DMA\_CNDTRx register, which contains the number of transactions that have still to be performed.

### 10.3.2 Arbiter

The arbiter manages the channel requests based on their priority and launches the peripheral/memory access sequences.

The priorities are managed in two stages:

- Software: each channel priority can be configured in the DMA\_CCRx register. There are four levels:
  - Very high priority
  - High priority
  - Medium priority
  - Low priority
- Hardware: if 2 requests have the same software priority level, the channel with the lowest number will get priority versus the channel with the highest number. For example, channel 2 gets priority over channel 4.

### 10.3.3 DMA channels

Each channel can handle DMA transfer between a peripheral register located at a fixed address and a memory address. The amount of data to be transferred (up to 65535) is programmable. The register which contains the amount of data items to be transferred is decremented after each transaction.

#### Programmable data sizes

Transfer data sizes of the peripheral and memory are fully programmable through the PSIZE and MSIZE bits in the DMA\_CCRx register.

#### Pointer incrementation

Peripheral and memory pointers can optionally be automatically post-incremented after each transaction depending on the PINC and MINC bits in the DMA\_CCRx register. If incremented mode is enabled, the address of the next transfer will be the address of the previous one incremented by 1, 2 or 4 depending on the chosen data size. The first transfer address is the one programmed in the DMA\_CPARx/DMA\_CMARx registers. During transfer operations, these registers keep the initially programmed value. The current transfer addresses (in the current internal peripheral/memory address register) are not accessible by software.

If the channel is configured in noncircular mode, no DMA request is served after the last transfer (that is once the number of data items to be transferred has reached zero). In order to reload a new number of data items to be transferred into the DMA\_CNDTRx register, the DMA channel must be disabled.

**Note:** If a DMA channel is disabled, the DMA registers are not reset. The DMA channel registers (DMA\_CCRx, DMA\_CPARx and DMA\_CMARx) retain the initial values programmed during the channel configuration phase.

In circular mode, after the last transfer, the DMA\_CNDTRx register is automatically reloaded with the initially programmed value. The current internal address registers are reloaded with the base address values from the DMA\_CPARx/DMA\_CMARx registers.

### Channel configuration procedure

The following sequence should be followed to configure a DMA channelx (where x is the channel number).

1. Set the peripheral register address in the DMA\_CPARx register. The data will be moved from/ to this address to/ from the memory after the peripheral event.
2. Set the memory address in the DMA\_CMARx register. The data will be written to or read from this memory after the peripheral event.
3. Configure the total number of data to be transferred in the DMA\_CNDTRx register. After each peripheral event, this value will be decremented.
4. Configure the channel priority using the PL[1:0] bits in the DMA\_CCRx register
5. Configure data transfer direction, circular mode, peripheral & memory incremented mode, peripheral & memory data size, and interrupt after half and/or full transfer in the DMA\_CCRx register
6. Activate the channel by setting the ENABLE bit in the DMA\_CCRx register.

As soon as the channel is enabled, it can serve any DMA request from the peripheral connected on the channel.

Once half of the bytes are transferred, the half-transfer flag (HTIF) is set and an interrupt is generated if the Half-Transfer Interrupt Enable bit (HTIE) is set. At the end of the transfer, the Transfer Complete Flag (TCIF) is set and an interrupt is generated if the Transfer Complete Interrupt Enable bit (TCIE) is set.

### Circular mode

Circular mode is available to handle circular buffers and continuous data flows (e.g. ADC scan mode). This feature can be enabled using the CIRC bit in the DMA\_CCRx register. When circular mode is activated, the number of data to be transferred is automatically reloaded with the initial value programmed during the channel configuration phase, and the DMA requests continue to be served.

### Memory-to-memory mode

The DMA channels can also work without being triggered by a request from a peripheral. This mode is called Memory to Memory mode.

If the MEM2MEM bit in the DMA\_CCRx register is set, then the channel initiates transfers as soon as it is enabled by software by setting the Enable bit (EN) in the DMA\_CCRx register. The transfer stops once the DMA\_CNDTRx register reaches zero. Memory to Memory mode may not be used at the same time as Circular mode.

### 10.3.4 Programmable data width, data alignment and endians

When PSIZE and MSIZE are not equal, the DMA performs some data alignments as described in [Table 22: Programmable data width & endian behavior \(when bits PINC = MINC = 1\)](#).

**Table 22. Programmable data width & endian behavior (when bits PINC = MINC = 1)**

Source port width	Destination port width	Number of data items to transfer (NDT)	Source content: address / data	Transfer operations	Destination content: address / data
8	8	4	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3	1: READ B0[7:0] @0x0 then WRITE B0[7:0] @0x0 2: READ B1[7:0] @0x1 then WRITE B1[7:0] @0x1 3: READ B2[7:0] @0x2 then WRITE B2[7:0] @0x2 4: READ B3[7:0] @0x3 then WRITE B3[7:0] @0x3	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3
8	16	4	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3	1: READ B0[7:0] @0x0 then WRITE 00B0[15:0] @0x0 2: READ B1[7:0] @0x1 then WRITE 00B1[15:0] @0x2 3: READ B3[7:0] @0x2 then WRITE 00B2[15:0] @0x4 4: READ B4[7:0] @0x3 then WRITE 00B3[15:0] @0x6	@0x0 / 00B0 @0x2 / 00B1 @0x4 / 00B2 @0x6 / 00B3
8	32	4	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3	1: READ B0[7:0] @0x0 then WRITE 000000B0[31:0] @0x0 2: READ B1[7:0] @0x1 then WRITE 000000B1[31:0] @0x4 3: READ B3[7:0] @0x2 then WRITE 000000B2[31:0] @0x8 4: READ B4[7:0] @0x3 then WRITE 000000B3[31:0] @0xC	@0x0 / 000000B0 @0x4 / 000000B1 @0x8 / 000000B2 @0xC / 000000B3
16	8	4	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6	1: READ B1B0[15:0] @0x0 then WRITE B0[7:0] @0x0 2: READ B3B2[15:0] @0x2 then WRITE B2[7:0] @0x1 3: READ B5B4[15:0] @0x4 then WRITE B4[7:0] @0x2 4: READ B7B6[15:0] @0x6 then WRITE B6[7:0] @0x3	@0x0 / B0 @0x1 / B2 @0x2 / B4 @0x3 / B6
16	16	4	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6	1: READ B1B0[15:0] @0x0 then WRITE B1B0[15:0] @0x0 2: READ B3B2[15:0] @0x2 then WRITE B3B2[15:0] @0x2 3: READ B5B4[15:0] @0x4 then WRITE B5B4[15:0] @0x4 4: READ B7B6[15:0] @0x6 then WRITE B7B6[15:0] @0x6	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6
16	32	4	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6	1: READ B1B0[15:0] @0x0 then WRITE 0000B1B0[31:0] @0x0 2: READ B3B2[15:0] @0x2 then WRITE 0000B3B2[31:0] @0x4 3: READ B5B4[15:0] @0x4 then WRITE 0000B5B4[31:0] @0x8 4: READ B7B6[15:0] @0x6 then WRITE 0000B7B6[31:0] @0xC	@0x0 / 0000B1B0 @0x4 / 0000B3B2 @0x8 / 0000B5B4 @0xC / 0000B7B6
32	8	4	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC	1: READ B3B2B1B0[31:0] @0x0 then WRITE B0[7:0] @0x0 2: READ B7B6B5B4[31:0] @0x4 then WRITE B4[7:0] @0x1 3: READ BBBAB9B8[31:0] @0x8 then WRITE B8[7:0] @0x2 4: READ BFBEBDBC[31:0] @0xC then WRITE BC[7:0] @0x3	@0x0 / B0 @0x1 / B4 @0x2 / B8 @0x3 / BC
32	16	4	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC	1: READ B3B2B1B0[31:0] @0x0 then WRITE B1B0[7:0] @0x0 2: READ B7B6B5B4[31:0] @0x4 then WRITE B5B4[7:0] @0x1 3: READ BBBAB9B8[31:0] @0x8 then WRITE B9B8[7:0] @0x2 4: READ BFBEBDBC[31:0] @0xC then WRITE BDBC[7:0] @0x3	@0x0 / B1B0 @0x2 / B5B4 @0x4 / B9B8 @0x6 / BDBC
32	32	4	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC	1: READ B3B2B1B0[31:0] @0x0 then WRITE B3B2B1B0[31:0] @0x0 2: READ B7B6B5B4[31:0] @0x4 then WRITE B7B6B5B4[31:0] @0x4 3: READ BBBAB9B8[31:0] @0x8 then WRITE BBBAB9B8[31:0] @0x8 4: READ BFBEBDBC[31:0] @0xC then WRITE BFBEBDBC[31:0] @0xC	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC

#### Addressing an AHB peripheral that does not support byte or halfword write operations

When the DMA initiates an AHB byte or halfword write operation, the data are duplicated on the unused lanes of the HWDATA[31:0] bus. So when the used AHB slave peripheral does not support byte or halfword write operations (when HSIZE is not used by the peripheral)

and does not generate any error, the DMA writes the 32 HWDATA bits as shown in the two examples below:

- To write the halfword “0xABCD”, the DMA sets the HWDATA bus to “0xABCDABCD” with HSIZE = HalfWord
- To write the byte “0xAB”, the DMA sets the HWDATA bus to “0xABABABAB” with HSIZE = Byte

Assuming that the AHB/APB bridge is an AHB 32-bit slave peripheral that does not take the HSIZE data into account, it will transform any AHB byte or halfword operation into a 32-bit APB operation in the following manner:

- an AHB byte write operation of the data “0xB0” to 0x0 (or to 0x1, 0x2 or 0x3) will be converted to an APB word write operation of the data “0xB0B0B0B0” to 0x0
- an AHB halfword write operation of the data “0xB1B0” to 0x0 (or to 0x2) will be converted to an APB word write operation of the data “0xB1B0B1B0” to 0x0

For instance, if you want to write the APB backup registers (16-bit registers aligned to a 32-bit address boundary), you must configure the memory source size (MSIZE) to “16-bit” and the peripheral destination size (PSIZE) to “32-bit”.

### 10.3.5 Error management

A DMA transfer error can be generated by reading from or writing to a reserved address space. When a DMA transfer error occurs during a DMA read or a write access, the faulty channel is automatically disabled through a hardware clear of its EN bit in the corresponding Channel configuration register (DMA\_CCRx). The channel's transfer error interrupt flag (TEIF) in the DMA\_IFR register is set and an interrupt is generated if the transfer error interrupt enable bit (TEIE) in the DMA\_CCRx register is set.

### 10.3.6 Interrupts

An interrupt can be produced on a Half-transfer, Transfer complete or Transfer error for each DMA channel. Separate interrupt enable bits are available for flexibility.

**Table 23. DMA interrupt requests**

Interrupt event	Event flag	Enable control bit
Half-transfer	HTIF	HTIE
Transfer complete	TCIF	TCIE
Transfer error	TEIF	TEIE

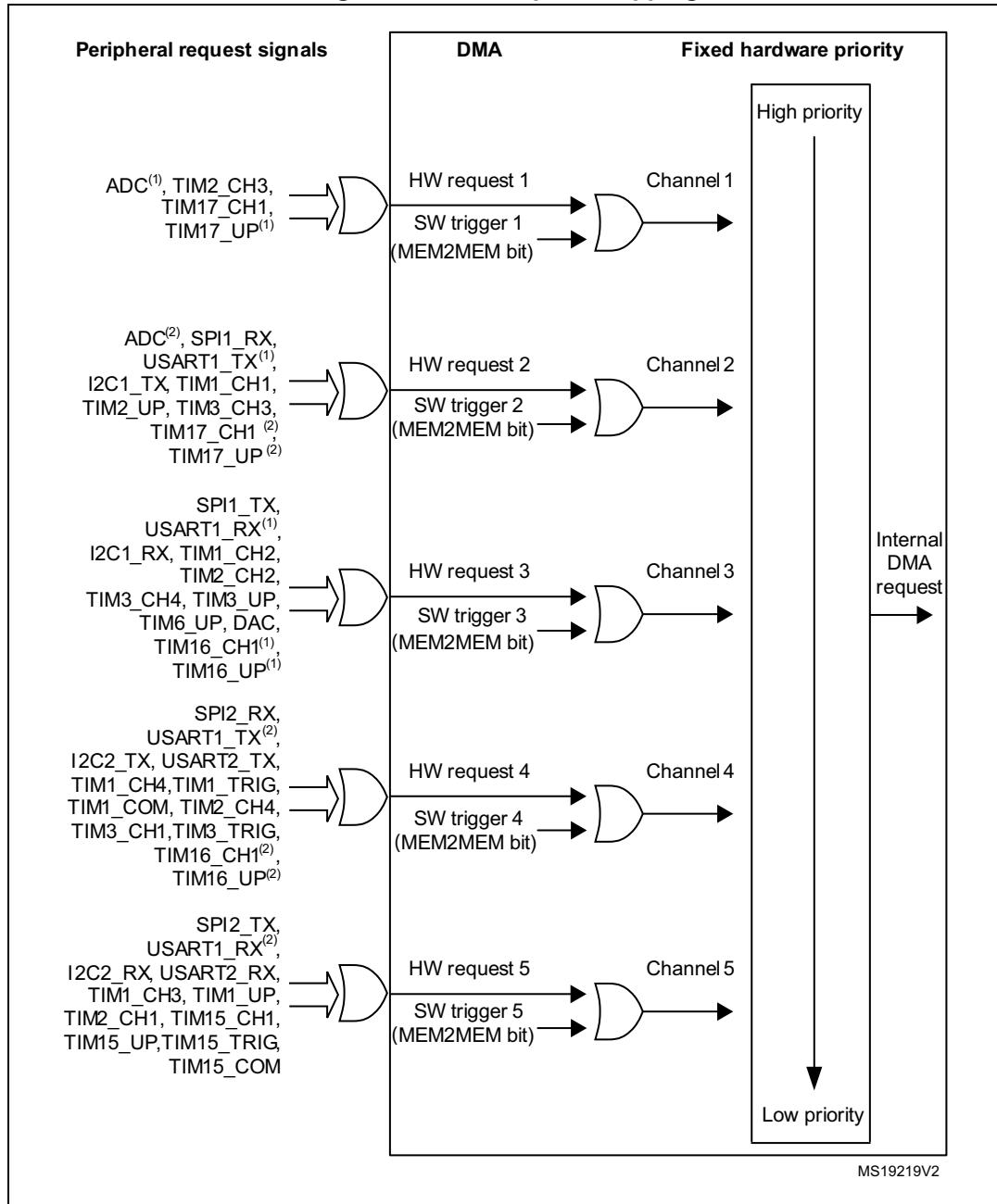
### 10.3.7 DMA request mapping

#### DMA controller

The hardware requests from the peripherals (TIMx, ADC, DAC, SPI, I2C, and USARTx) are simply logically ORed before entering the DMA. This means that on one channel, only one request must be enabled at a time. Refer to [Figure 20: DMA request mapping](#).

The peripheral DMA requests can be independently activated/de-activated by programming the DMA control bit in the registers of the corresponding peripheral.

Figure 20. DMA request mapping



1. DMA request mapped on this DMA channel only if the corresponding remapping bit is cleared in the SYSCFG\_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG\\_CFGR1\) on page 141](#).
2. DMA request mapped on this DMA channel only if the corresponding remapping bit is set in the SYSCFG\_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG\\_CFGR1\) on page 141](#).

*Table 24* lists the DMA requests for each channel.

**Table 24. Summary of DMA requests for each channel**

Peripherals	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
<b>ADC</b>	ADC <sup>(1)</sup>	ADC <sup>(2)</sup>			
<b>SPI</b>		SPI1_RX	SPI1_TX	SPI2_RX	SPI2_TX
<b>USART</b>		USART1_TX <sup>(1)</sup>	USART1_RX <sup>(1)</sup>	USART1_TX <sup>(2)</sup> USART2_TX	USART1_RX <sup>(2)</sup> USART2_RX
<b>I2C</b>		I2C1_TX	I2C1_RX	I2C2_TX	I2C2_RX
<b>TIM1</b>		TIM1_CH1	TIM1_CH2	TIM1_CH4 TIM1_TRIG TIM1_COM	TIM1_CH3 TIM1_UP
<b>TIM2</b>	TIM2_CH3	TIM2_UP	TIM2_CH2	TIM2_CH4	TIM2_CH1
<b>TIM3</b>		TIM3_CH3	TIM3_CH4 TIM3_UP	TIM3_CH1 TIM3_TRIG	
<b>TIM6 / DAC</b>			TIM6_UP DAC		
<b>TIM15</b>					TIM15_CH1 TIM15_UP TIM15_TRIG TIM15_COM
<b>TIM16</b>			TIM16_CH1 <sup>(1)</sup> TIM16_UP <sup>(1)</sup>	TIM16_CH1 <sup>(2)</sup> TIM16_UP <sup>(2)</sup>	
<b>TIM17</b>	TIM17_CH1 <sup>(1)</sup> TIM17_UP <sup>(1)</sup>	TIM17_CH1 <sup>(2)</sup> TIM17_UP <sup>(2)</sup>			

1. DMA request mapped on this DMA channel only if the corresponding remapping bit is cleared in the SYSCFG\_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG\\_CFGR1\) on page 141](#).
2. DMA request mapped on this DMA channel only if the corresponding remapping bit is set in the SYSCFG\_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG\\_CFGR1\) on page 141](#).

## 10.4 DMA registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by bytes (8-bit), half-words (16-bit) or words (32-bit).

### 10.4.1 DMA interrupt status register (DMA\_ISR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TEIF5	HTIF5	TCIF5	GIF5
												r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TEIF4	HTIF4	TCIF4	GIF4	TEIF3	HTIF3	TCIF3	GIF3	TEIF2	HTIF2	TCIF2	GIF2	TEIF1	HTIF1	TCIF1	GIF1
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:28 Reserved, must be kept at reset value.

Bits 19, 15, 11, 7, 3 **TEIF<sub>x</sub>**: Channel x transfer error flag ( $x = 1 \dots 5$ )

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA\_IFCR register.

0: No transfer error (TE) on channel x

1: A transfer error (TE) occurred on channel x

Bits 18, 14, 10, 6, 2 **HTIF<sub>x</sub>**: Channel x half transfer flag ( $x = 1 \dots 5$ )

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA\_IFCR register.

0: No half transfer (HT) event on channel x

1: A half transfer (HT) event occurred on channel x

Bits 17, 13, 9, 5, 1 **TCIF<sub>x</sub>**: Channel x transfer complete flag ( $x = 1 \dots 5$ )

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA\_IFCR register.

0: No transfer complete (TC) event on channel x

1: A transfer complete (TC) event occurred on channel x

Bits 16, 12, 8, 4, 0 **GIF<sub>x</sub>**: Channel x global interrupt flag ( $x = 1 \dots 5$ )

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA\_IFCR register.

0: No TE, HT or TC event on channel x

1: A TE, HT or TC event occurred on channel x

### 10.4.2 DMA interrupt flag clear register (DMA\_IFCR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTEIF5	CHTIF5	CTCIF5	CGIF5
												w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CTEIF4	CHTIF4	CTCIF4	CGIF4	CTEIF3	CHTIF3	CTCIF3	CGIF3	CTEIF2	CHTIF2	CTCIF2	CGIF2	CTEIF1	CHTIF1	CTCIF1	CGIF1
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:28 Reserved, must be kept at reset value.

Bits 19, 15, 11, 7, 3 **CTEIFx**: Channel x transfer error clear (x = 1 ..5)

This bit is set and cleared by software.

0: No effect

1: Clears the corresponding TEIF flag in the DMA\_ISR register

Bits 18, 14, 10, 6, 2 **CHTIFx**: Channel x half transfer clear (x = 1 ..5)

This bit is set and cleared by software.

0: No effect

1: Clears the corresponding HTIF flag in the DMA\_ISR register

Bits 17, 13, 9, 5, 1 **CTCIFx**: Channel x transfer complete clear (x = 1 ..5)

This bit is set and cleared by software.

0: No effect

1: Clears the corresponding TCIF flag in the DMA\_ISR register

Bits 16, 12, 8, 4, 0 **CGIFx**: Channel x global interrupt clear (x = 1 ..5)

This bit is set and cleared by software.

0: No effect

1: Clears the GIF, TEIF, HTIF and TCIF flags in the DMA\_ISR register

### 10.4.3 DMA channel x configuration register (DMA\_CCRx) (x = 1..5, where x = channel number)

Address offset: 0x08 + 0d20 × (channel number – 1)

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MEM2 MEM	PL[1:0]		MSIZE[1:0]		PSIZE[1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:15 Reserved, must be kept at reset value.

Bit 14 **MEM2MEM:** Memory to memory mode

This bit is set and cleared by software.

0: Memory to memory mode disabled

1: Memory to memory mode enabled

Bits 13:12 **PL[1:0]:** Channel priority level

These bits are set and cleared by software.

00: Low

01: Medium

10: High

11: Very high

Bits 11:10 **MSIZE[1:0]:** Memory size

These bits are set and cleared by software.

00: 8-bits

01: 16-bits

10: 32-bits

11: Reserved

Bits 9:8 **PSIZE[1:0]:** Peripheral size

These bits are set and cleared by software.

00: 8-bits

01: 16-bits

10: 32-bits

11: Reserved

Bit 7 **MINC:** Memory increment mode

This bit is set and cleared by software.

0: Memory increment mode disabled

1: Memory increment mode enabled

Bit 6 **PINC:** Peripheral increment mode

This bit is set and cleared by software.

0: Peripheral increment mode disabled

1: Peripheral increment mode enabled

**Bit 5 CIRC:** Circular mode

This bit is set and cleared by software.

0: Circular mode disabled

1: Circular mode enabled

**Bit 4 DIR:** Data transfer direction

This bit is set and cleared by software.

0: Read from peripheral

1: Read from memory

**Bit 3 TEIE:** Transfer error interrupt enable

This bit is set and cleared by software.

0: TE interrupt disabled

1: TE interrupt enabled

**Bit 2 HTIE:** Half transfer interrupt enable

This bit is set and cleared by software.

0: HT interrupt disabled

1: HT interrupt enabled

**Bit 1 TCIE:** Transfer complete interrupt enable

This bit is set and cleared by software.

0: TC interrupt disabled

1: TC interrupt enabled

**Bit 0 EN:** Channel enable

This bit is set and cleared by software.

0: Channel disabled

1: Channel enabled

#### 10.4.4 DMA channel x number of data register (DMA\_CNDTRx) (x = 1..5, where x = channel number)

Address offset: 0x0C + 0d20 × (channel number – 1)

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **NDT[15:0]**: Number of data to transfer

Number of data to be transferred (0 up to 65535). This register can only be written when the channel is disabled. Once the channel is enabled, this register is read-only, indicating the remaining bytes to be transmitted. This register decrements after each DMA transfer.

Once the transfer is completed, this register can either stay at zero or be reloaded automatically by the value previously programmed if the channel is configured in auto-reload mode.

If this register is zero, no transaction can be served whether the channel is enabled or not.

#### 10.4.5 DMA channel x peripheral address register (DMA\_CPARx) (x = 1..5, where x = channel number)

Address offset: 0x10 + 0d20 × (channel number – 1)

Reset value: 0x0000 0000

This register must *not* be written when the channel is enabled.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PA [31:16]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PA [15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **PA[31:0]**: Peripheral address

Base address of the peripheral data register from/to which the data will be read/written.

When PSIZE is 01 (16-bit), the PA[0] bit is ignored. Access is automatically aligned to a half-word address.

When PSIZE is 10 (32-bit), PA[1:0] are ignored. Access is automatically aligned to a word address.

### 10.4.6 DMA channel x memory address register (DMA\_CMARx) (x = 1..5, where x = channel number)

Address offset: 0x14 + 0d20 × (channel number – 1)

Reset value: 0x0000 0000

This register must *not* be written when the channel is enabled.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MA [31:16]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MA [15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

#### Bits 31:0 **MA[31:0]: Memory address**

Base address of the memory area from/to which the data will be read/written.

When MSIZE is 01 (16-bit), the MA[0] bit is ignored. Access is automatically aligned to a half-word address.

When MSIZE is 10 (32-bit), MA[1:0] are ignored. Access is automatically aligned to a word address.

#### **10.4.7 DMA register map**

The following table gives the DMA register map and the reset values.

**Table 25. DMA register map and reset values**

Table 25. DMA register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x048	DMA_CNDTR4	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0														
	Reset value																																	
0x04C	DMA_CPAR4																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x050	DMA_CMAR4																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x054																																		
0x058	DMA_CCR5	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															
	Reset value																																	
0x05C	DMA_CNDTR5	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															
	Reset value																																	
0x060	DMA_CPAR5																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x064	DMA_CMAR5																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 11 Interrupts and events

### 11.1 Nested vectored interrupt controller (NVIC)

#### 11.1.1 NVIC main features

- 32 maskable interrupt channels (not including the sixteen Cortex-M0 interrupt lines)
- 4 programmable priority levels (2 bits of interrupt priority are used)
- Low-latency exception and interrupt handling
- Power management control
- Implementation of System Control Registers

The NVIC and the processor core interface are closely coupled, which enables low latency interrupt processing and efficient processing of late arriving interrupts.

All interrupts including the core exceptions are managed by the NVIC. For more information on exceptions and NVIC programming, refer to the PM0215 programming manual.

#### 11.1.2 SysTick calibration value register

The SysTick calibration value is set to 6000, which gives a reference time base of 1 ms with the SysTick clock set to 6 MHz (max f<sub>HCLK</sub>/8).

#### 11.1.3 Interrupt and exception vectors

*Table 26* is the vector table for STM32F0xxxx devices. Please consider peripheral availability on given device.

**Table 26. Vector table**

Position	Priority	Type of priority	Acronym	Description	Address
-	-	-	Reserved		0x0000 0000
-3	fixed	Reset	Reset		0x0000 0004
-2	fixed	NMI	NMI	Non maskable interrupt. The RCC Clock Security System (CSS) is linked to the NMI vector.	0x0000 0008
-1	fixed	HardFault	HardFault	All class of fault	0x0000 000C
3	settable	SVCall	SVCall	System service call via SWI instruction	0x0000 002C
5	settable	PendSV	PendSV	Pendable request for system service	0x0000 0038
6	settable	SysTick	SysTick	System tick timer	0x0000 003C

**Table 26. Vector table (continued)**

<b>Position</b>	<b>Priority</b>	<b>Type of priority</b>	<b>Acronym</b>	<b>Description</b>	<b>Address</b>
0	7	settable	WWDG	Window Watchdog interrupt	0x0000 0040
1	8	settable	PVD	PVD through EXTI line detection interrupt	0x0000 0044
2	9	settable	RTC	RTC global interrupt	0x0000 0048
3	10	settable	FLASH	Flash global interrupt	0x0000 004C
4	11	settable	RCC	RCC global interrupt	0x0000 0050
5	12	settable	EXTI0_1	EXTI Line[1:0] interrupts	0x0000 0054
6	13	settable	EXTI2_3	EXTI Line[3:2] interrupts	0x0000 0058
7	14	settable	EXTI4_15	EXTI Line[15:4] interrupts	0x0000 005C
8	15	settable	TSC	Touch sensing interrupt	0x0000 0060
9	16	settable	DMA_CH1	DMA channel 1 interrupt	0x0000 0064
10	17	settable	DMA_CH2_3	DMA channel 2 and 3 interrupts	0x0000 0068
11	18	settable	DMA_CH4_5	DMA channel 4 and 5 interrupts	0x0000 006C
12	19	settable	ADC_COMP	ADC and comparator 1 and 2 interrupts	0x0000 0070
13	20	settable	TIM1_BRK_UP_TRG_COM	TIM1 Break, update, trigger and commutation interrupt	0x0000 0074
14	21	settable	TIM1_CC	TIM1 Capture Compare interrupt	0x0000 0078
15	22	settable	TIM2	TIM2 global interrupt	0x0000 007C
16	23	settable	TIM3	TIM3 global interrupt	0x0000 0080
17	24	settable	TIM6_DAC	TIM6 global interrupt and DAC underrun interrupt	0x0000 0084
18	25	settable	reserved		0x0000 0088
19	26	settable	TIM14	TIM14 global interrupt	0x0000 008C
20	27	settable	TIM15	TIM15 global interrupt	0x0000 0090
21	28	settable	TIM16	TIM16 global interrupt	0x0000 0094
22	29	settable	TIM17	TIM17 global interrupt	0x0000 0098
23	30	settable	I2C1	I <sup>2</sup> C1 global interrupt	0x0000 009C
24	31	settable	I2C2	I <sup>2</sup> C2 global interrupt	0x0000 00A0
25	32	settable	SPI1	SPI1 global interrupt	0x0000 00A4
26	33	settable	SPI2	SPI2 global interrupt	0x0000 00A8
27	34	settable	USART1	USART1 global interrupt	0x0000 00AC

**Table 26. Vector table (continued)**

<b>Position</b>	<b>Priority</b>	<b>Type of priority</b>	<b>Acronym</b>	<b>Description</b>	<b>Address</b>
28	35	settable	USART2	USART2 global interrupt	0x0000 00B0
29	36	settable	reserved		0x0000 00B4
30	37		CEC	CEC global interrupt	0x0000 00B8
31	38	settable	reserved		0x0000 00BC

## 11.2 Extended interrupts and events controller (EXTI)

The extended interrupts and events controller (EXTI) manages the external and internal asynchronous events/interrupts and generates the event request to the CPU/Interrupt Controller and a wake-up request to the Power Manager.

The EXTI allows the management of up to 28 external/internal event line (21 external event lines and 7 internal event lines).

The active edge of each external interrupt line can be chosen independently, whilst for internal interrupt the active edge is always the rising one. An interrupt could be left pending: in case of an external one, a status register is instantiated and indicates the source of the interrupt; an event is always a simple pulse and it's used for triggering the core Wake-up (e.g. Cortex-M0 RXEV pin). For internal interrupts, the pending status is assured by the generating IP, so no need for a specific flag. Each input line can be masked independently for interrupt or event generation, in addition the internal lines are sampled only in STOP mode. This controller allows also to emulate the (only) external events by software, multiplexed with the corresponding hardware event line, by writing to a dedicated register.

### 11.2.1 Main features

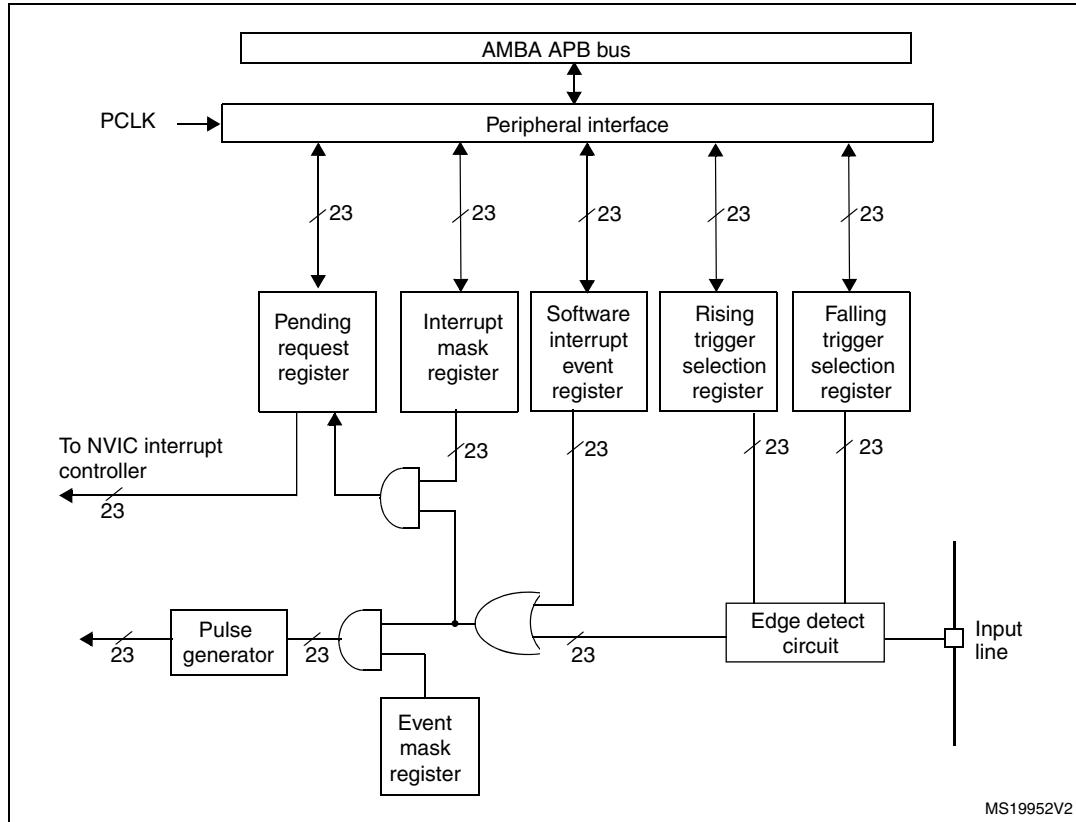
The EXTI main features are the following:

- support generation of up to 28 event/interrupt requests;
- Independent configuration of each line as an external or an internal event requests;
- Independent mask on each event/interrupt line
- Automatic disable of internal lines when system is not in STOP mode
- Independent trigger for external event/interrupt line
- Dedicated status bit for external interrupt line;
- Emulation for all the external event requests.

### 11.2.2 Block diagram

The extended interrupt/event block diagram is shown in [Figure 21](#).

**Figure 21. EXTI external interrupt/event block diagram**



### 11.2.3 Wakeup event management

The STM32F0xxxx is able to handle external or internal events in order to wake up the core (WFE). The wakeup event can be generated either by:

- enabling an interrupt in the peripheral control register but not in the NVIC, and enabling the SEVONPEND bit in the Cortex-M0 System Control register. When the MCU resumes from WFE, the EXTI peripheral interrupt pending bit and the peripheral NVIC IRQ channel pending bit (in the NVIC interrupt clear pending register) have to be cleared.
- or by configuring an external or internal EXTI line in event mode. When the CPU resumes from WFE, it is not necessary to clear the peripheral interrupt pending bit or the NVIC IRQ channel pending bit as the pending bit corresponding to the event line is not set.

### 11.2.4 Asynchronous Internal Interrupts

Some communication peripherals (UART, I2C, CEC) are able to generate events when the system is in run mode and also when the system is in stop mode allowing to wake up the system from stop mode.

To accomplish this, the peripheral is asked to generate both a synchronized (to the system clock, e.g. APB clock) and an asynchronous version of the event.

### 11.2.5 Functional description

For the external interrupt lines, to generate the interrupt, the interrupt line should be configured and enabled. This is done by programming the two trigger registers with the desired edge detection and by enabling the interrupt request by writing a '1' to the corresponding bit in the interrupt mask register. When the selected edge occurs on the external interrupt line, an interrupt request is generated. The pending bit corresponding to the interrupt line is also set. This request is reset by writing a '1' in the pending register.

For the internal interrupt lines, the active edge is always the rising edge, the interrupt is enabled by default in the interrupt mask register and there is no corresponding pending bit in the pending register.

To generate the event, the event line should be configured and enabled. This is done by programming the two trigger registers with the desired edge detection and by enabling the event request by writing a '1' to the corresponding bit in the event mask register. When the selected edge occurs on the event line, an event pulse is generated. The pending bit corresponding to the event line is not set.

For the external lines, an interrupt/event request can also be generated by software by writing a '1' in the software interrupt/event register.

**Note:** *The interrupts or events associated to the internal lines can be triggered only when the system is in STOP mode. If the system is still running, no interrupt/event is generated.*

#### Hardware interrupt selection

To configure a line as interrupt source, use the following procedure:

- Configure the corresponding mask bit in the EXTI\_IMR register.
- Configure the Trigger Selection bits of the Interrupt line (EXTI\_RTSR and EXTI\_FTSR)
- Configure the enable and mask bits that control the NVIC IRQ channel mapped to the EXTI so that an interrupt coming from one of the EXTI line can be correctly acknowledged.

#### Hardware event selection

To configure a line as event source, use the following procedure:

- Configure the corresponding mask bit in the EXTI\_EMR register.
- Configure the Trigger Selection bits of the Event line (EXTI\_RTSR and EXTI\_FTSR)

#### Software interrupt/event selection

Any of the external lines can be configured as software interrupt/event lines. The following is the procedure to generate a software interrupt.

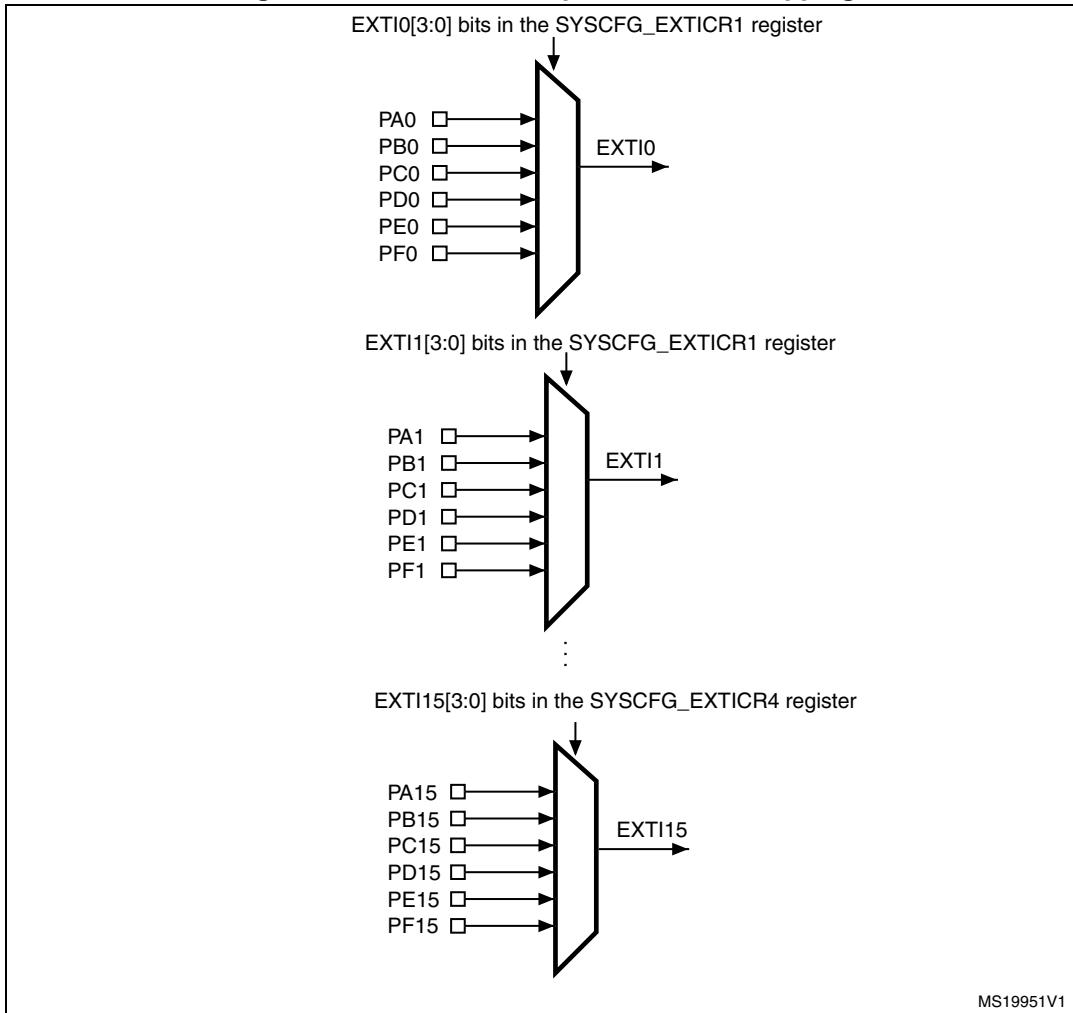
- Configure the corresponding mask bit (EXTI\_IMR, EXTI\_EMR)
- Set the required bit of the software interrupt register (EXTI\_SWIER)

### 11.2.6 External and internal interrupt/event line mapping

In the STM32F0xxxx, 28 interrupt/event lines are available: 7 lines are internal (including the reserved ones) and the remaining 21 lines are external.

The GPIOs are connected to the 16 external interrupt/event lines in the following manner:

**Figure 22. External interrupt/event GPIO mapping**



The remaining lines are connected as follow:

- EXTI line 16 is connected to the PVD output
- EXTI line 17 is connected to the RTC Alarm event
- EXTI line 18 is reserved (internally held low)
- EXTI line 19 is connected to RTC tamper and Timestamps
- EXTI line 20 is reserved (internally held low)
- EXTI line 21 is connected to Comparator 1 output
- EXTI line 22 is connected to Comparator 2 output
- EXTI line 23 is connected to I2C1 wakeup
- EXTI line 24 is reserved (internally held low)
- EXTI line 25 is connected to USART1 wakeup
- EXTI line 26 is reserved (internally held low)
- EXTI line 27 is connected to CEC wakeup.

*Note:* *EXTI lines 18, 20, 23, 24, 25, 26 and 27 are internal.*

## 11.3 EXTI registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers have to be accessed by words (32-bit).

### 11.3.1 Interrupt mask register (EXTI\_IMR)

Address offset: 0x00

Reset value: 0x0F94 0000 (See note below)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	MR27	MR26	MR25	MR24	MR23	MR22	MR21	MR20	MR19	MR18	MR17	MR16
				rw											
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MR15	MR14	MR13	MR12	MR11	MR10	MR9	MR8	MR7	MR6	MR5	MR4	MR3	MR2	MR1	MR0
rw															

Bits 31:28 Reserved, must be kept at reset value (0).

Bits 27:0 **MRx**: Interrupt Mask on external/internal line x

0: Interrupt request from Line x is masked

1: Interrupt request from Line x is not masked

*Note:* *The reset value for the internal lines (18, 20, 23, 24, 25, 26 and 27) is set to '1' in order to enable the interrupt by default.*

### 11.3.2 Event mask register (EXTI\_EMR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	MR27	MR26	MR25	MR24	MR23	MR22	MR21	MR20	MR19	MR18	MR17	MR16
				rw											
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MR15	MR14	MR13	MR12	MR11	MR10	MR9	MR8	MR7	MR6	MR5	MR4	MR3	MR2	MR1	MR0
rw															

Bits 31:28 Reserved, must be kept at reset value (0).

Bits 27:0 **MR<sub>x</sub>**: Event mask on external/internal line x

0: Event request from Line x is masked

1: Event request from Line x is not masked

### 11.3.3 Rising trigger selection register (EXTI\_RTSR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
Res.	TR19	Res.	TR17	TR16												
													rw		rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
TR15	TR14	TR13	TR12	TR11	TR10	TR9	TR8	TR7	TR6	TR5	TR4	TR3	TR2	TR1	TR0	
rw																

Bits 31:20 Reserved, must be kept at reset value.

Bit 19 **TR19**: Rising trigger event configuration bit of line 19

0: Rising trigger disabled (for Event and Interrupt) for input line

1: Rising trigger enabled (for Event and Interrupt) for input line.

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **TR<sub>x</sub>**: Rising trigger event configuration bit of line x (x = 17 to 0)

0: Rising trigger disabled (for Event and Interrupt) for input line

1: Rising trigger enabled (for Event and Interrupt) for input line.

**Note:** The external wakeup lines are edge triggered. No glitches must be generated on these lines. If a rising edge on an external interrupt line occurs during a write operation to the EXTI\_RTSR register, the pending bit is not set.

Rising and falling edge triggers can be set for the same interrupt line. In this case, both generate a trigger condition.

### 11.3.4 Falling trigger selection register (EXTI\_FTSR)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	TR19	Res.	TR17	TR16											
												rw		rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TR15	TR14	TR13	TR12	TR11	TR10	TR9	TR8	TR7	TR6	TR5	TR4	TR3	TR2	TR1	TR1
rw															

Bits 31:20 Reserved, must be kept at reset value.

Bit 19 **TR19**: Falling trigger event configuration bit of line 19

- 0: Rising trigger disabled (for Event and Interrupt) for input line
- 1: Rising trigger enabled (for Event and Interrupt) for input line.

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **TRx**: Falling trigger event configuration bit of line x (x = 17 to 0)

- 0: Rising trigger disabled (for Event and Interrupt) for input line
- 1: Rising trigger enabled (for Event and Interrupt) for input line.

**Note:** *The external wakeup lines are edge triggered. No glitches must be generated on these lines. If a rising edge on an external interrupt line occurs during a write operation to the EXTI\_FTSR register, the pending bit is not set.*

*Rising and falling edge triggers can be set for the same interrupt line. In this case, both generate a trigger condition.*

### 11.3.5 Software interrupt event register (EXTI\_SWIER)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SWIER 19	Res.	SWIER 17	SWIER 16
												rw		rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SWIER 15	SWIER 14	SWIER 13	SWIER 12	SWIER 11	SWIER 10	SWIER 9	SWIER 8	SWIER 7	SWIER 6	SWIER 5	SWIER 4	SWIER 3	SWIER 2	SWIER 1	SWIER 0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:20 Reserved, must be kept at reset value.

Bits 19 **SWIER19**: Software interrupt on line 19

Writing a 1 to this bit when it is at 0 sets PR19 pending bit in EXTI\_PR. If the interrupt is enabled on this line on the EXTI\_IMR and EXTI\_EMR, an interrupt request is generated.

This bit is cleared by clearing the corresponding bit of EXTI\_PR (by writing a 1 into the bit).

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **SWIERx**: Software interrupt on line x (x = 17 to 0)

Writing a 1 to this bit when it is at 0 sets the corresponding pending bit in EXTI\_PR. If the interrupt is enabled on this line on the EXTI\_IMR and EXTI\_EMR, an interrupt request is generated.

This bit is cleared by clearing the corresponding bit of EXTI\_PR (by writing a 1 into the bit).

### 11.3.6 Pending register (EXTI\_PR)

Address offset: 0x14

Reset value: undefined

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	PR19	Res.	PR17	PR16											
												rc_w1		rc_w1	rc_w1
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PR15	PR14	PR13	PR12	PR11	PR10	PR9	PR8	PR7	PR6	PR5	PR4	PR3	PR2	PR1	PR0
rc_w1															

Bits 31:20 Reserved, must be kept at reset value.

Bits 19 **PR19**: Pending bit on line 19

0: No trigger request occurred

1: selected trigger request occurred

This bit is set when the selected edge event arrives on the external interrupt line.

This bit is cleared by writing a 1 into the bit or by changing the sensitivity of the edge detector.

Bits 18 Reserved, must be kept at reset value.

Bits 19:0 **PRx**: Pending bit on line x (x = 17 to 0)

0: No trigger request occurred

1: selected trigger request occurred

This bit is set when the selected edge event arrives on the external interrupt line.

This bit is cleared by writing a 1 into the bit or by changing the sensitivity of the edge detector.

### 11.3.7 EXTI register map

The following table gives the EXTI register map and the reset values.

**Table 27. External interrupt/event controller register map and reset values**

Offset	Register	Reset value	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0								
0x00	<b>EXTI_IMR</b>	Res.																																								
	Reset value																																									
0x04	<b>EXTI_EMR</b>	Res.																																								
	Reset value																																									
0x08	<b>EXTI_RTSR</b>	Res.																																								
	Reset value																																									
0x0C	<b>EXTI_FTSR</b>	Res.																																								
	Reset value																																									
0x10	<b>EXTI_SWIER</b>	Res.																																								
	Reset value																																									
0x14	<b>EXTI_PR</b>	Res.																																								
	Reset value																																									

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 12 Analog-to-digital converter (ADC)

### 12.1 Introduction

The 12-bit ADC is a successive approximation analog-to-digital converter. It has up to 19 multiplexed channels allowing it to measure signals from 16 external and 3 internal sources. A/D conversion of the various channels can be performed in single, continuous, scan or discontinuous mode. The result of the ADC is stored in a left-aligned or right-aligned 16-bit data register.

The analog watchdog feature allows the application to detect if the input voltage goes outside the user-defined higher or lower thresholds.

An efficient low power mode is implemented to allow very low consumption at low frequency.

## 12.2 ADC main features

- High performance
  - 12-bit, 10-bit, 8-bit or 6-bit configurable resolution
  - ADC conversion time: 1.0  $\mu$ s for 12-bit resolution (1 MHz), 0.93  $\mu$ s conversion time for 10 bit resolution, faster conversion times can be obtained by lowering resolution.
  - Self-calibration
  - Programmable sampling time
  - Data alignment with built-in data coherency
  - DMA support
- Low power
  - Application can reduce PCLK frequency for low power operation while still keeping optimum ADC performance. For example, 1.0  $\mu$ s conversion time is kept, whatever the frequency of PCLK)
  - Wait mode: prevents ADC overrun in applications with low frequency PCLK
  - Auto off mode: ADC is automatically powered off except during the active conversion phase. This dramatically reduces the power consumption of the ADC.
- Analog input channels
  - 16 external analog inputs
  - 1 channel for internal temperature sensor ( $V_{SENSE}$ )
  - 1 channel for internal reference voltage ( $V_{REFINT}$ )
  - 1 channel for monitoring external  $V_{BAT}$  power supply pin.
- Start-of-conversion can be initiated:
  - By software
  - By hardware triggers with configurable polarity (internal timer events from TIM1, TIM2, TIM3 and TIM15)
- Conversion modes
  - Can convert a single channel or can scan a sequence of channels.
  - Single mode converts selected inputs once per trigger
  - Continuous mode converts selected inputs continuously
  - Discontinuous mode
- Interrupt generation at the end of sampling, end of conversion, end of sequence conversion, and in case of analog watchdog or overrun events
- Analog watchdog
- ADC supply requirements: 2.4 V to 3.6 V
- ADC input range:  $V_{SSA} \leq V_{IN} \leq V_{DDA}$

*Figure 23* shows the block diagram of the ADC.

## 12.3 ADC pins and internal signals

**Table 28. ADC internal signals**

Internal signal name	Signal type	Description
TRGx	Input	ADC conversion triggers
V <sub>SENSE</sub>	Input	Internal temperature sensor output voltage
V <sub>REFINT</sub>	Input	Internal voltage reference output voltage
V <sub>BAT/2</sub>	Input	V <sub>BAT</sub> pin input voltage divided by 2

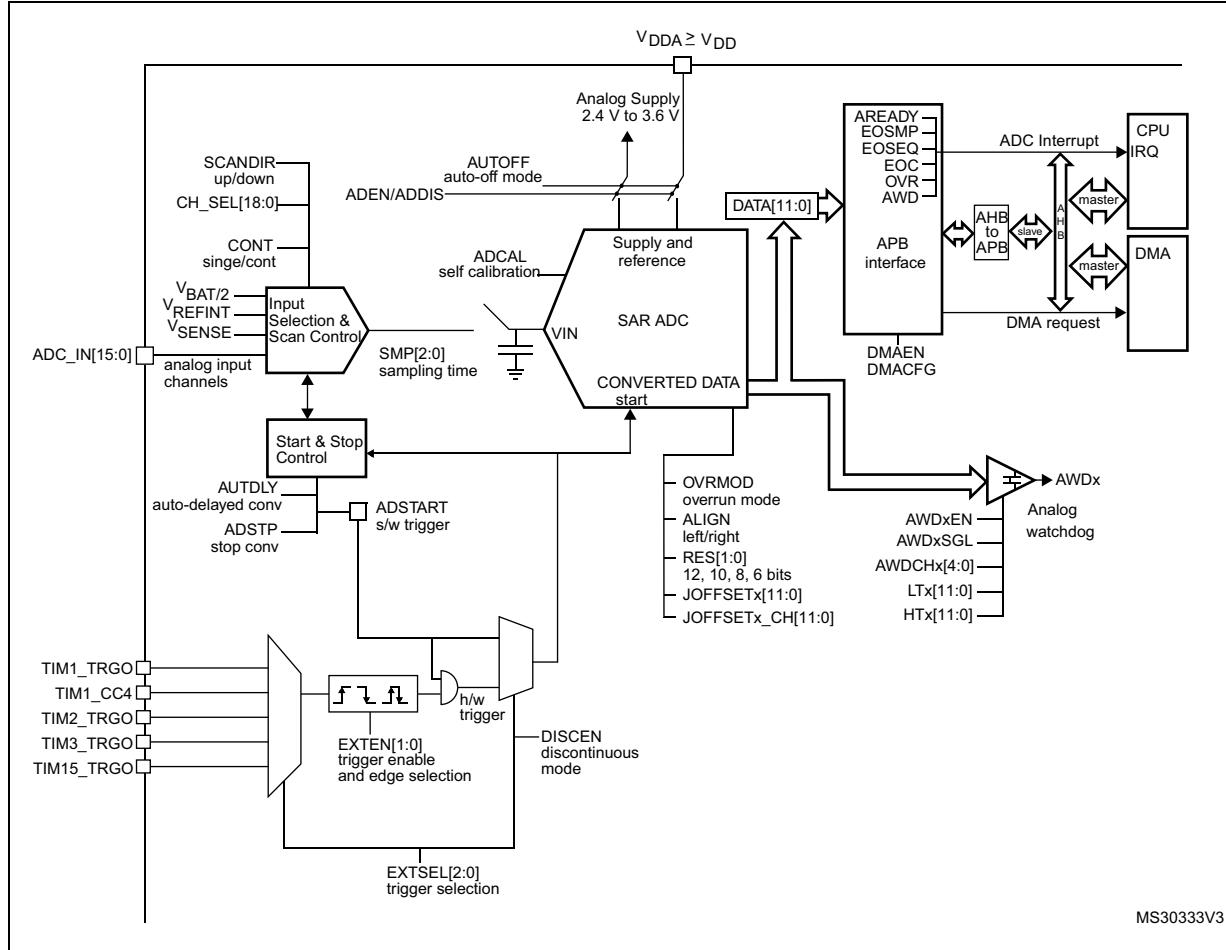
**Table 29. ADC pins**

Name	Signal type	Remarks
V <sub>DDA</sub>	Input, analog power supply	Analog power supply and positive reference voltage for the ADC, V <sub>DDA</sub> ≥ V <sub>DD</sub>
V <sub>SSA</sub>	Input, analog supply ground	Ground for analog power supply. Must be at V <sub>SS</sub> potential
ADC_IN[15:0]	Analog input signals	16 analog input channels

## 12.4 ADC functional description

Figure 23 shows the ADC block diagram and Table 29 gives the ADC pin description.

Figure 23. ADC block diagram



### 12.4.1 Calibration (ADCAL)

The ADC has a calibration feature. During the procedure, the ADC calculates a calibration factor which is internally applied to the ADC until the next ADC power-off. The application must not use the ADC during calibration and must wait until it is complete.

Calibration should be performed before starting A/D conversion. It removes the offset error which may vary from chip to chip due to process variation.

The calibration is initiated by software by setting bit ADCAL=1. Calibration can only be initiated when the ADC is disabled (when ADEN=0). ADCAL bit stays at 1 during all the calibration sequence. It is then cleared by hardware as soon the calibration completes. After this, the calibration factor can be read from the ADC\_DR register (from bits 6 to 0).

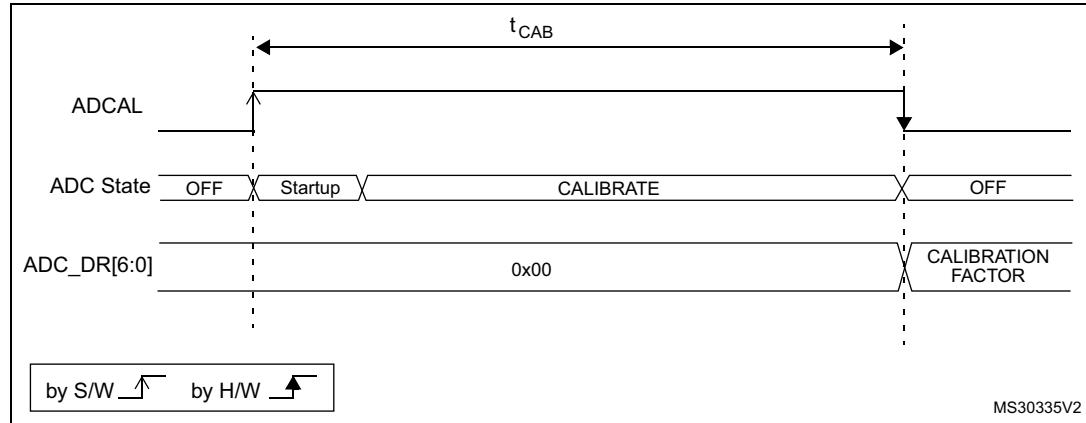
The internal analog calibration is kept if the ADC is disabled (ADEN=0). When the ADC operating conditions change (V<sub>DDA</sub> changes are the main contributor to ADC offset variations and temperature change to a lesser extend), it is recommended to re-run a calibration cycle.

The calibration factor is lost each time power is removed from the ADC (for example when the product enters STANDBY or VBAT mode).

#### Calibration software procedure:

1. Ensure that ADEN=0
2. Set ADCAL=1
3. Wait until ADCAL=0
4. The calibration factor can be read from bits 6:0 of ADC\_DR.

**Figure 24. ADC calibration**



#### 12.4.2 ADC on-off control (ADEN, ADDIS, ADRDY)

At MCU power-up, the ADC is disabled and put in power-down mode (ADEN=0).

As shown in [Figure 25](#), the ADC needs a stabilization time of  $t_{STAB}$  before it starts converting accurately.

Two control bits are used to enable or disable the ADC:

- Set ADEN=1 to enable the ADC. The ADRDY flag is set as soon as the ADC is ready for operation.
- Set ADDIS=1 to disable the ADC and put the ADC in power down mode. The ADEN and ADDIS bits are then automatically cleared by hardware as soon as the ADC is fully disabled.

Conversion can then start either by setting SWSTART=1 (refer to [Section 12.5: Conversion on external trigger and trigger polarity \(EXTSEL, EXTEN\) on page 186](#)) or when an external trigger event occurs if triggers are enabled.

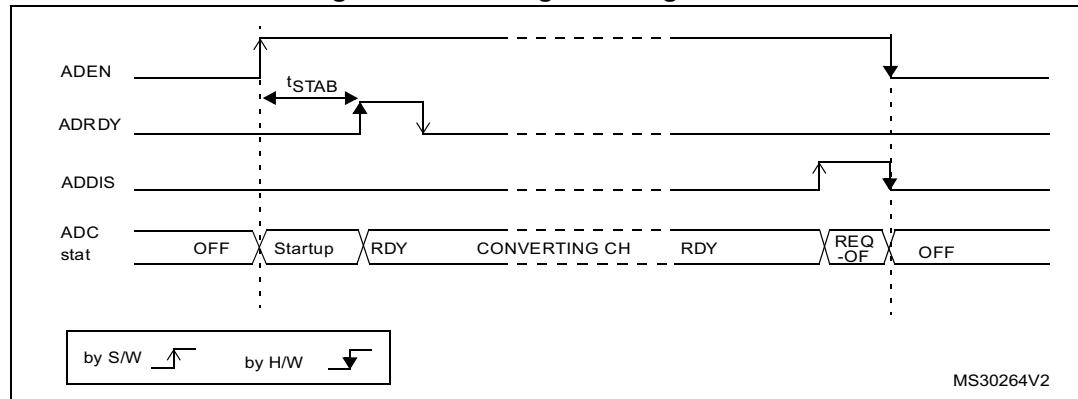
Follow this procedure to enable the ADC:

- Set ADEN=1 in the ADC\_CR register.
- Wait until ADRDY=1 in the ADC\_ISR register (ADRDY is set after the ADC startup time). This can be handled by interrupt if the interrupt is enabled by setting the ADRDYIE bit in the ADC\_IER register.

Follow this procedure to disable the ADC:

- Check that ADSTART=0 in the ADC\_CR register to ensure that no conversion is ongoing. If required, stop any ongoing conversion by writing 1 to the ADSTP bit in the ADC\_CR register and waiting until this bit is read at 0.
- Set ADDIS=1 in the ADC\_CR register.
- If required by the application, wait until ADEN=0 in the ADC\_CR register, indicating that the ADC is fully disabled (ADDIS is automatically reset once ADEN=0).

**Figure 25. Enabling/disabling the ADC**

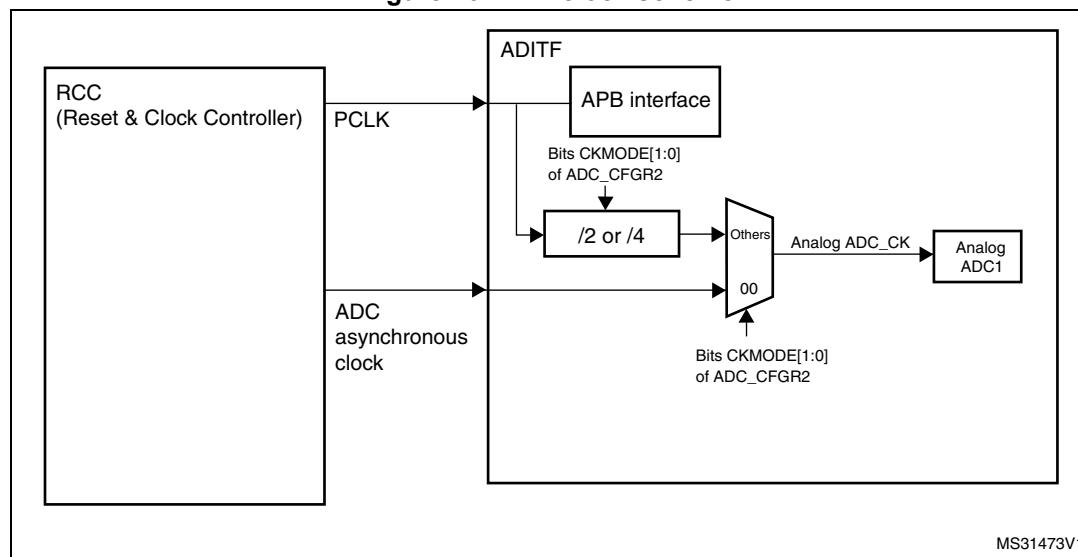


**Note:** In auto-off mode (AUTOFF=1) the power-on/off phases are performed automatically, by hardware and the ADRDY flag is not set.

#### 12.4.3 ADC clock (CKMODE)

The ADC has a dual clock-domain architecture, so that the ADC can be feeded with a clock (ADC asynchronous clock) independent from the APB clock (PCLK).

**Figure 26. ADC clock scheme**



1. Refer to [Section 7: Reset and clock control \(RCC\) on page 85](#) to see how PCLK and ADC asynchronous clock are enabled.

The input clock of the analog ADC can be selected between two different clock sources (see [Figure 26: ADC clock scheme on page 180](#)):

- a) The ADC clock can be a specific clock source, named “ADC asynchronous clock” which is independent and asynchronous with the APB clock.  
Refer to RCC Section for more information on generating this clock source.  
To select this scheme, bits CKMODE[1:0] of the ADC\_CFGR2 register must be reset.
- b) The ADC clock can be derived from the APB clock of the ADC bus interface, divided by a programmable factor (2 or 4) according to bits CKMODE[1:0].  
To select this scheme, bits CKMODE[1:0] of the ADC\_CFGR2 register must be different from “00”.

Option a) has the advantage of reaching the maximum ADC clock frequency whatever the APB clock scheme selected.

Option b) has the advantage of bypassing the clock domain resynchronizations. This can be useful when the ADC is triggered by a timer and if the application requires that the ADC is precisely triggered without any uncertainty (otherwise, an uncertainty of the trigger instant is added by the resynchronizations between the two clock domains).

**Table 30. Latency between trigger and start of conversion**

ADC clock source	CKMODE[1:0]	Latency between the trigger event and the start of conversion
Dedicated 14MHz clock	00	Latency is not deterministic (jitter)
PCLK divided by 2	01	Latency is deterministic (no jitter) and equal to 2.75 ADC clock cycles
PCLK divided by 4	10	Latency is deterministic (no jitter) and equal to 2.625 ADC clock cycles

#### 12.4.4 Configuring the ADC

Software must write to the ADCAL and ADEN bits in the ADC\_CR register if the ADC is disabled (ADEN must be 0).

Software must only write to the ADSTART and ADDIS bits in the ADC\_CR register only if the ADC is enabled and there is no pending request to disable the ADC (ADEN = 1 and ADDIS = 0).

For all the other control bits in the ADC\_IER, ADC\_CFGRi, ADC\_SMPR, ADC\_TR, ADC\_CHSELR and ADC\_CCR registers, software must only write to the configuration control bits if the ADC is enabled (ADEN = 1) and if there is no conversion ongoing (ADSTART = 0).

Software must only write to the ADSTP bit in the ADC\_CR register if the ADC is enabled (and possibly converting) and there is no pending request to disable the ADC (ADSTART = 1 and ADDIS = 0)

**Note:** *There is no hardware protection preventing software from making write operations forbidden by the above rules. If such a forbidden write access occurs, the ADC may enter an undefined state. To recover correct operation in this case, the ADC must be disabled (clear ADEN=0 and all the bits in the ADC\_CR register).*

### 12.4.5 Channel selection (CHSEL, SCANDIR)

There are up to 19 multiplexed channels:

- 16 analog inputs from GPIO pins (ADC\_IN0...ADC\_IN15)
- 3 internal analog inputs (Temperature Sensor, Internal Reference Voltage, VBAT channel)

It is possible to convert a single channel or to automatically scan a sequence of channels.

The sequence of the channels to be converted must be programmed in the ADC\_CHSEL register: each analog input channel has a dedicated selection bit (CHSEL0...CHSEL18).

The order in which the channels will be scanned can be configured by programming the bit SCANDIR bit in the ADC\_CFGR1 register:

- SCANDIR=0: forward scan Channel 0 to Channel 18
- SCANDIR=1: backward scan Channel 18 to Channel 0

#### Temperature sensor, $V_{REFINT}$ and $V_{BAT}$ internal channels

The temperature sensor is connected to channel ADC\_IN16. The internal voltage reference  $V_{REFINT}$  is connected to channel ADC1\_IN17. The  $V_{BAT}$  channel is connected to channel ADC1\_IN18.

### 12.4.6 Programmable sampling time (SMP)

Before starting a conversion, the ADC needs to establish a direct connection between the voltage source to be measured and the embedded sampling capacitor of the ADC. This sampling time must be enough for the input voltage source to charge the sample and hold capacitor to the input voltage level.

Having a programmable sampling time allows to trim the conversion speed according to the input resistance of the input voltage source.

The ADC samples the input voltage for a number of ADC clock cycles that can be modified using the SMP[2:0] bits in the ADC\_SMPR register.

This programmable sampling time is common to all channels. If required by the application, the software can change and adapt this sampling time between each conversions.

The total conversion time is calculated as follows:

$$t_{CONV} = \text{Sampling time} + 12.5 \times \text{ADC clock cycles}$$

Example:

With ADC\_CLK = 14 MHz and a sampling time of 1.5 ADC clock cycles:

$$t_{CONV} = 1.5 + 12.5 = 14 \text{ ADC clock cycles} = 1 \mu\text{s}$$

The ADC indicates the end of the sampling phase by setting the EOSMP flag.

### 12.4.7 Single conversion mode (CONT=0)

In Single conversion mode, the ADC performs a single sequence of conversions, converting all the channels once. This mode is selected when CONT=0 in the ADC\_CFGR1 register. Conversion is started by either:

- Setting the ADSTART bit in the ADC\_CR register
- Hardware trigger event

Inside the sequence, after each conversion is complete:

- The converted data are stored in the 16-bit ADC\_DR register
- The EOC (end of conversion) flag is set
- An interrupt is generated if the EOCIE bit is set

After the sequence of conversions is complete:

- The EOSEQ (end of sequence) flag is set
- An interrupt is generated if the EOSEQIE bit is set

Then the ADC stops until a new external trigger event occurs or the ADSTART bit is set again.

*Note:* To convert a single channel, program a sequence with a length of 1.

### 12.4.8 Continuous conversion mode (CONT=1)

In continuous conversion mode, when a software or hardware trigger event occurs, the ADC performs a sequence of conversions, converting all the channels once and then automatically re-starts and continuously performs the same sequence of conversions. This mode is selected when CONT=1 in the ADC\_CFGR1 register. Conversion is started by either:

- Setting the ADSTART bit in the ADC\_CR register
- Hardware trigger event

Inside the sequence, after each conversion is complete:

- The converted data are stored in the 16-bit ADC\_DR register
- The EOC (end of conversion) flag is set
- An interrupt is generated if the EOCIE bit is set

After the sequence of conversions is complete:

- The EOSEQ (end of sequence) flag is set
- An interrupt is generated if the EOSEQIE bit is set

Then, a new sequence restarts immediately and the ADC continuously repeats the conversion sequence.

*Note:*

- 1 To convert a single channel, program a sequence with a length of 1.
- 2 It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.

### 12.4.9 Starting conversions (ADSTART)

Software starts ADC conversions by setting ADSTART=1.

When ADSTART is set, the conversion:

- Starts immediately if EXTN = 0x0 (software trigger)
- At the next active edge of the selected hardware trigger if EXTN ≠ 0x0

The ADSTART bit is also used to indicate whether an ADC operation is currently ongoing. It is possible to re-configure the ADC while ADSTART=0, indicating that the ADC is idle.

The ADSTART bit is cleared by hardware:

- In single mode with software trigger (CONT=0, EXTSEL=0x0)
  - At any end of conversion sequence (EOSEQ=1)
- In all cases (CONT=x, EXTSEL=x)
  - After execution of the ADSTP procedure invoked by software (see [Section 12.4.11: Stopping an ongoing conversion \(ADSTP\) on page 185](#))

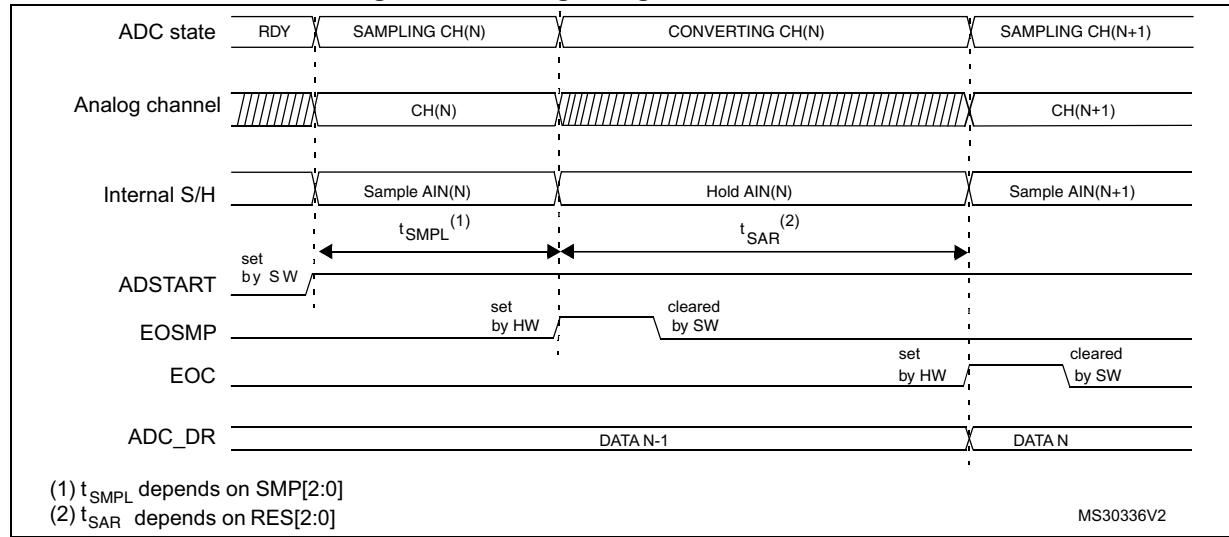
- Note:**
- 1 *In continuous mode (CONT=1), the ADSTART bit is not cleared by hardware when the EOSEQ flag is set because the sequence is automatically relaunched.*
  - 2 *When hardware trigger is selected in single mode (CONT=0 and EXTSEL ≠ 0x00), ADSTART is not cleared by hardware when the EOSEQ flag is set. This avoids the need for software having to set the ADSTART bit again and ensures the next trigger event is not missed.*

### 12.4.10 Timings

The elapsed time between the start of a conversion and the end of conversion is the sum of the configured sampling time plus the successive approximation time depending on data resolution:

$$t_{ADC} = t_{SMPL} + t_{SAR} = [ 1.5 \text{ } l_{min} + 12.5 \text{ } l_{12bit} ] \times t_{ADC\_CLK}$$

$$t_{ADC} = t_{SMPL} + t_{SAR} = 107.1 \text{ ns } l_{min} + 892.8 \text{ ns } l_{12bit} = 1 \mu\text{s } l_{min} \text{ (for } f_{ADC\_CLK} = 14 \text{ MHz)}$$

**Figure 27. Analog to digital conversion time**

### 12.4.11 Stopping an ongoing conversion (ADSTP)

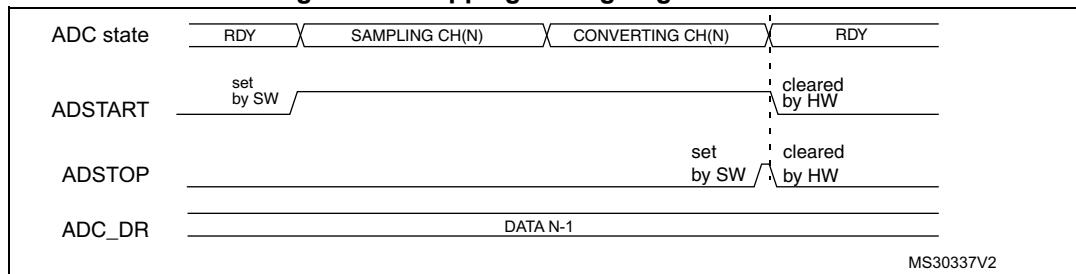
The software can decide to stop any ongoing conversions by setting ADSTP=1 in the ADC\_CR register.

This will reset the ADC operation and the ADC will be idle, ready for a new operation.

When the ADSTP bit is set by software, any ongoing conversion is aborted and the result is discarded (ADC\_DR register is not updated with the current conversion).

The scan sequence is also aborted and reset (meaning that restarting the ADC would restart a new sequence)

Once this procedure is complete, the ADSTP and ADSTART bits are both cleared by hardware and the software must wait until ADSTART=0 before starting new conversions.

**Figure 28. Stopping an ongoing conversion**

## 12.5 Conversion on external trigger and trigger polarity (EXTSEL, EXTEN)

A conversion or a sequence of conversion can be triggered either by software or by an external event (for example timer capture). If the EXTEN[1:0] control bits are not equal to “0b00”, then external events are able to trigger a conversion with the selected polarity. The trigger selection is effective once software has set bit ADSTART=1.

Any hardware triggers which occur while a conversion is ongoing are ignored.

If bit ADSTART=0, any hardware triggers which occur are ignored.

[Table 31](#) provides the correspondence between the EXTEN[1:0] values and the trigger polarity.

**Table 31. Configuring the trigger polarity**

Source	EXTEN[1:0]
Trigger detection disabled	00
Detection on rising edge	01
Detection on falling edge	10
Detection on both rising and falling edges	11

**Note:** *The polarity of the external trigger can be changed only when the ADC is not converting (ADSTART= 0).*

The EXTSEL[2:0] control bits are used to select which of 8 possible events can trigger conversions.

[Table 32](#) gives the possible external trigger for regular conversion.

Software source trigger events can be generated by setting the ADSTART bit in the ADC\_CR register.

**Table 32. External triggers**

Name	Source	EXTSEL[2:0]
TRG0	TIM1_TRGO	000
TRG1	TIM1_CC4	001
TRG2	TIM2_TRGO	010
TRG3	TIM3_TRGO	011
TRG4	TIM15_TRGO	100
TRG5	Reserved	101
TRG6	Reserved	110
TRG7	Reserved	111

**Note:** *The trigger selection can be changed only when the ADC is not converting (ADSTART= 0).*

### 12.5.1 Discontinuous mode (DISCEN)

This mode is enabled by setting the DISCEN bit in the ADC\_CFGR1 register.

In this mode (DISCEN=1), a hardware or software trigger event is required to start each conversion defined in the sequence. On the contrary, if DISCEN=0, a single hardware or software trigger event successively starts all the conversions defined in the sequence.

Example:

- DISCEN=1, channels to be converted = 0, 3, 7, 10
  - 1st trigger: channel 0 is converted and an EOC event is generated
  - 2nd trigger: channel 3 is converted and an EOC event is generated
  - 3rd trigger: channel 7 is converted and an EOC event is generated
  - 4th trigger: channel 10 is converted and both EOC and EOSEQ events are generated.
  - 5th trigger: channel 0 is converted and an EOC event is generated
  - 6th trigger: channel 3 is converted and an EOC event is generated
  - ...
- DISCEN=0, channels to be converted = 0, 3, 7, 10
  - 1st trigger: the complete sequence is converted: channel 0, then 3, 7 and 10. Each conversion generates an EOC event and the last one also generates an EOSEQ event.
  - Any subsequent trigger events will restart the complete sequence.

**Note:** *It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.*

### 12.5.2 Programmable resolution (RES) - fast conversion mode

It is possible to obtain faster conversion times ( $t_{SAR}$ ) by reducing the ADC resolution.

The resolution can be configured to be either 12, 10, 8, or 6 bits by programming the RES[1:0] bits in the ADC\_CFGR1 register. Lower resolution allows faster conversion times for applications where high data precision is not required.

**Note:** *The RES[1:0] bit must only be changed when the ADEN bit is reset.*

The result of the conversion is always 12 bits wide and any unused LSB bits are read as zeroes.

Lower resolution reduces the conversion time needed for the successive approximation steps as shown in [Table 33](#).

**Table 33.  $t_{SAR}$  timings depending on resolution**

<b>RES[1:0] bits</b>	<b><math>t_{SAR}</math> (ADC clock cycles)</b>	<b><math>t_{SAR}</math> (ns) at <math>f_{ADC} = 14</math> MHz</b>	<b><math>t_{SMPL}</math> (min) (ADC clock cycles)</b>	<b><math>t_{ADC}</math> (ADC clock cycles) (with min. <math>t_{SMPL}</math>)</b>	<b><math>t_{ADC}</math> (<math>\mu</math>s) at <math>f_{ADC} = 14</math> MHz</b>
12	12.5	893 ns	1.5	14	1000 ns
10	11.5	821 ns	1.5	13	928 ns
8	9.5	678 ns	1.5	11	785 ns
6	7.5	535 ns	1.5	9	643 ns

### 12.5.3 End of conversion, end of sampling phase (EOC, EOSMP flags)

The ADC indicates each end of conversion (EOC) event.

The ADC sets the EOC flag in the ADC\_ISR register as soon as a new conversion data result is available in the ADC\_DR register. An interrupt can be generated if the EOCIE bit is set in the ADC\_IER register. The EOC flag is cleared by software either by writing 1 to it, or by reading the ADC\_DR register.

The ADC also indicates the end of sampling phase by setting the EOSMP flag in the ADC\_ISR register. The EOSMP flag is cleared by software by writing 1 to it. An interrupt can be generated if the EOSMPIE bit is set in the ADC\_IER register.

The aim of this interrupt is to allow the processing to be synchronized with the conversions. Typically, an analog multiplexer can be accessed in hidden time during the conversion phase, so that the multiplexer is positioned when the next sampling starts.

**Note:** *As there is only a very short time left between the end of the sampling and the end of the conversion, it is recommended to use polling or a WFE instruction rather than an interrupt and a WFI instruction.*

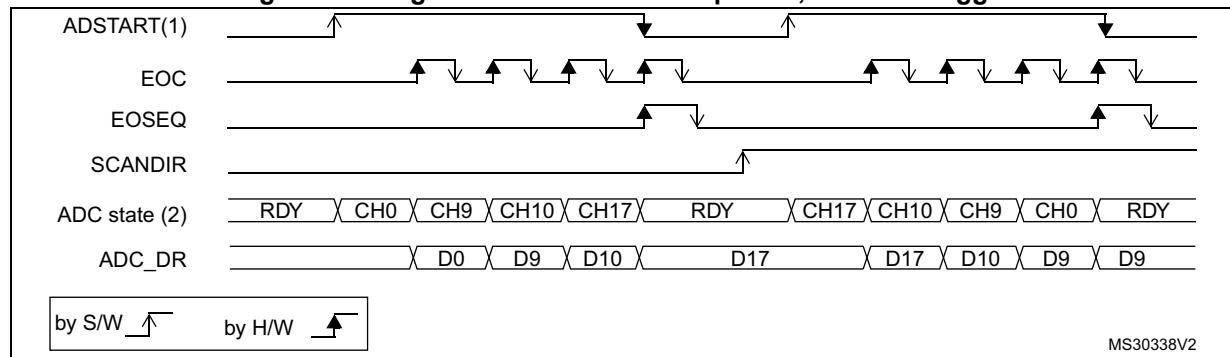
### 12.5.4 End of conversion sequence (EOSEQ flag)

The ADC notifies the application of each end of sequence (EOSEQ) event.

The ADC sets the EOSEQ flag in the ADC\_ISR register as soon as the last data result of a conversion sequence is available in the ADC\_DR register. An interrupt can be generated if the EOSEQIE bit is set in the ADC\_IER register. The EOSEQ flag is cleared by software by writing 1 to it.

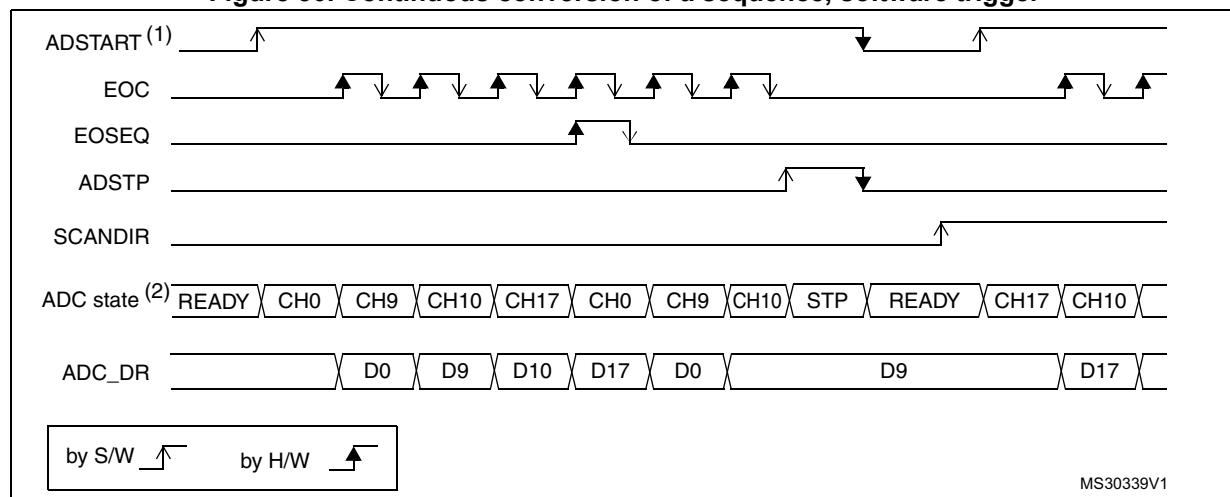
### 12.5.5 Example timing diagrams (single/continuous modes hardware/software triggers)

**Figure 29. Single conversions of a sequence, software trigger**

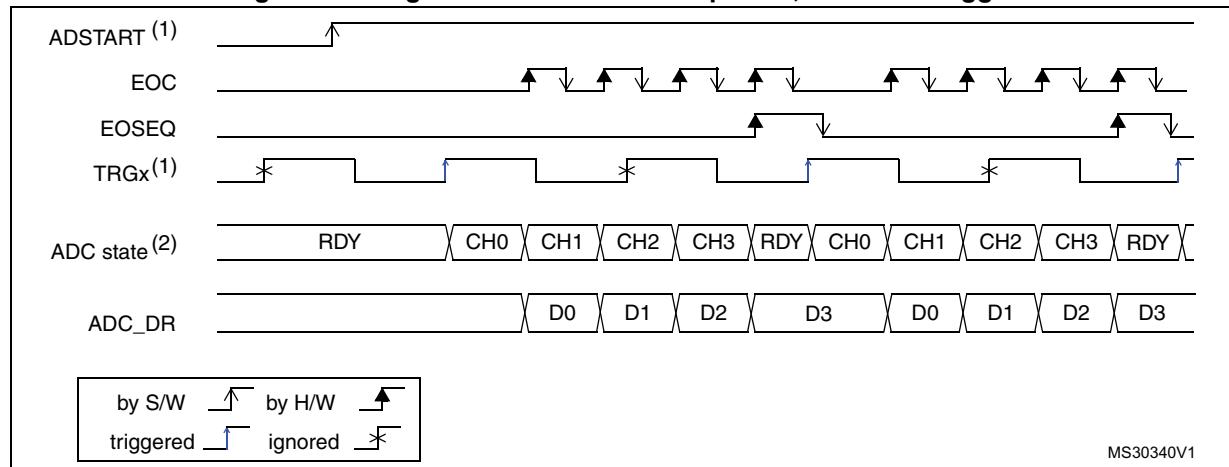


1. EXTEN=0x0, CONT=0
2. CHSEL=0x20601, WAIT=0, AUTOFF=0

**Figure 30. Continuous conversion of a sequence, software trigger**

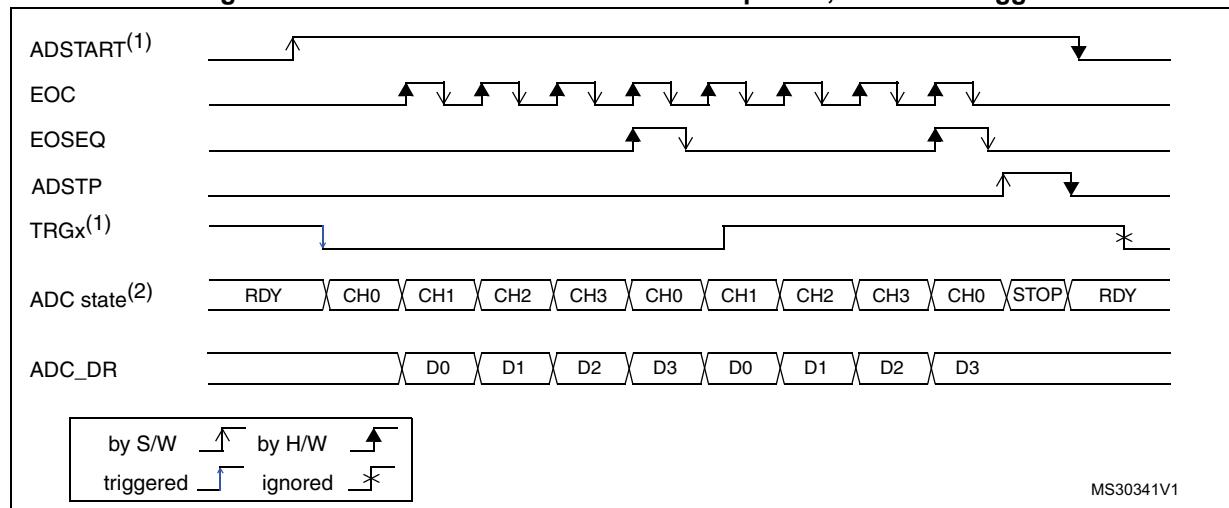


1. EXTEN=0x0, CONT=1,
2. CHSEL=0x20601, WAIT=0, AUTOFF=0

**Figure 31. Single conversions of a sequence, hardware trigger**

1. EXTSEL=TRGx (over-frequencied), EXTEN=0x1 (rising edge), CONT=0

2. CHSEL=0xF, SCANDIR=0, WAIT=0, AUTOFF=0

**Figure 32. Continuous conversions of a sequence, hardware trigger**

1. EXTSEL=TRGx, EXTEN=0x2 (falling edge), CONT=1

2. CHSEL=0xF, SCANDIR=0, WAIT=0, AUTOFF=0

## 12.6 Data management

### 12.6.1 Data register & data alignment (ADC\_DR, ALIGN)

At the end of each conversion (when an EOC event occurs), the result of the converted data is stored in the ADC\_DR data register which is 16-bit wide.

The format of the ADC\_DR depends on the configured data alignment and resolution.

The ALIGN bit in the ADC\_CFGR1 register selects the alignment of the data stored after conversion. Data can be right-aligned (ALIGN=0) or left-aligned (ALIGN=1) as shown in [Figure 33](#).

**Figure 33. Data alignment and resolution**

ALIGN	RES	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0x0	0x0															DR[11:0]
	0x1		0x00														DR[9:0]
	0x2			0x00													DR[7:0]
	0x3				0x00												DR[5:0]
1	0x0					DR[11:0]											0x0
	0x1					DR[9:0]											0x00
	0x2					DR[7:0]											0x00
	0x3					0x00						DR[5:0]					0x0

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### 12.6.2 ADC overrun (OVR, OVRMOD)

The overrun flag (OVR) indicates a data overrun event, when the converted data was not read in time by the CPU or the DMA, before the data from a new conversion is available.

The OVR flag is set in the ADC\_ISR register if the EOC flag is still at '1' at the time when a new conversion completes. An interrupt can be generated if the OVRIE bit is set in the ADC\_IER register.

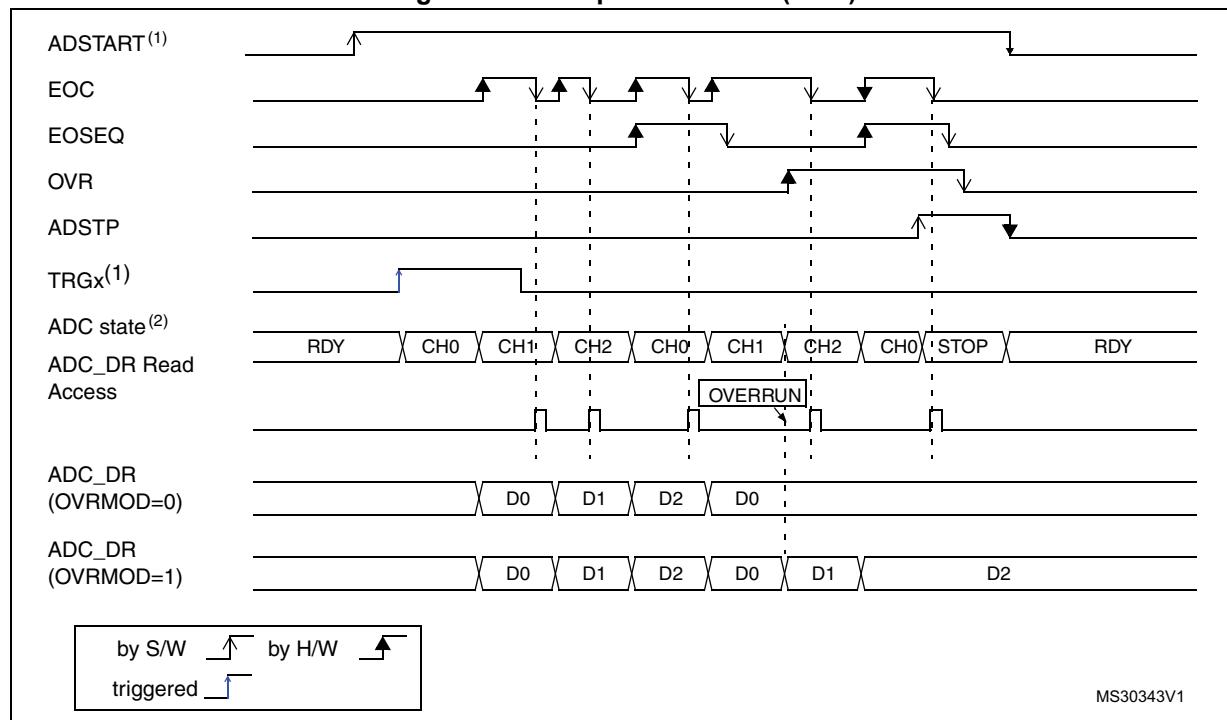
When an overrun condition occurs, the ADC keeps operating and can continue to convert unless the software decides to stop and reset the sequence by setting the ADSTP bit in the ADC\_CR register.

The OVR flag is cleared by software by writing 1 to it.

It is possible to configure if the data is preserved or overwritten when an overrun event occurs by programming the OVRMOD bit in the ADC\_CFGR1 register:

- OVRMOD=0
  - An overrun event preserves the data register from being overwritten: the old data is maintained and the new conversion is discarded. If OVR remains at 1, further conversions can be performed but the resulting data is discarded.
- OVRMOD=1
  - The data register is overwritten with the last conversion result and the previous unread data is lost. If OVR remains at 1, further conversions can be performed and the ADC\_DR register always contains the data from the latest conversion.

Figure 34. Example of overrun (OVR)



### 12.6.3 Managing a sequence of data converted without using the DMA

If the conversions are slow enough, the conversion sequence can be handled by software. In this case the software must use the EOC flag and its associated interrupt to handle each data result. Each time a conversion is complete, the EOC bit is set in the ADC\_ISR register and the ADC\_DR register can be read. The OVRMOD bit in the ADC\_CFGR1 register should be configured to 0 to manage overrun events as an error.

### 12.6.4 Managing converted data without using the DMA without overrun

It may be useful to let the ADC convert one or more channels without reading the data after each conversion. In this case, the OVRMOD bit must be configured at 1 and the OVR flag should be ignored by the software. When OVRMOD=1, an overrun event does not prevent the ADC from continuing to convert and the ADC\_DR register always contains the latest conversion data.

### 12.6.5 Managing converted data using the DMA

Since all converted channel values are stored in a single data register, it is efficient to use DMA when converting more than one channel. This avoids losing the conversion data results stored in the ADC\_DR register.

When DMA mode is enabled (DMAEN bit set to 1 in the ADC\_CFGR1 register), a DMA request is generated after the conversion of each channel. This allows the transfer of the converted data from the ADC\_DR register to the destination location selected by the software.

Despite this, if an overrun occurs (OVR=1) because the DMA could not serve the DMA transfer request in time, the ADC stops generating DMA requests and the data

corresponding to the new conversion is not transferred by the DMA. Which means that all the data transferred to the RAM can be considered as valid.

Depending on the configuration of OVRMOD bit, the data is either preserved or overwritten (refer to [Section 12.6.2: ADC overrun \(OVR, OVRMOD\) on page 191](#)).

The DMA transfer requests are blocked until the software clears the OVR bit.

Two different DMA modes are proposed depending on the application use and are configured with bit DMACFG in the ADC\_CFGR1 register:

- DMA one shot mode (DMACFG=0).  
This mode should be selected when the DMA is programmed to transfer a fixed number of data words.
- DMA circular mode (DMACFG=1)  
This mode should be selected when programming the DMA in circular mode or double buffer mode.

### DMA one shot mode (DMACFG=0)

In this mode, the ADC generates a DMA transfer request each time a new conversion data word is available and stops generating DMA requests once the DMA has reached the last DMA transfer (when a DMA\_EOT interrupt occurs, see [Section 10: Direct memory access controller \(DMA\) on page 148](#)) even if a conversion has been started again.

When the DMA transfer is complete (all the transfers configured in the DMA controller have been done):

- The content of the ADC data register is frozen.
- Any ongoing conversion is aborted and its partial result discarded
- No new DMA request is issued to the DMA controller. This avoids generating an overrun error if there are still conversions which are started.
- The scan sequence is stopped and reset
- The DMA is stopped

### DMA circular mode (DMACFG=1)

In this mode, the ADC generates a DMA transfer request each time a new conversion data word is available in the data register, even if the DMA has reached the last DMA transfer. This allows the DMA to be configured in circular mode to handle a continuous analog input data stream.

## 12.7 Low power features

### 12.7.1 Wait mode conversion

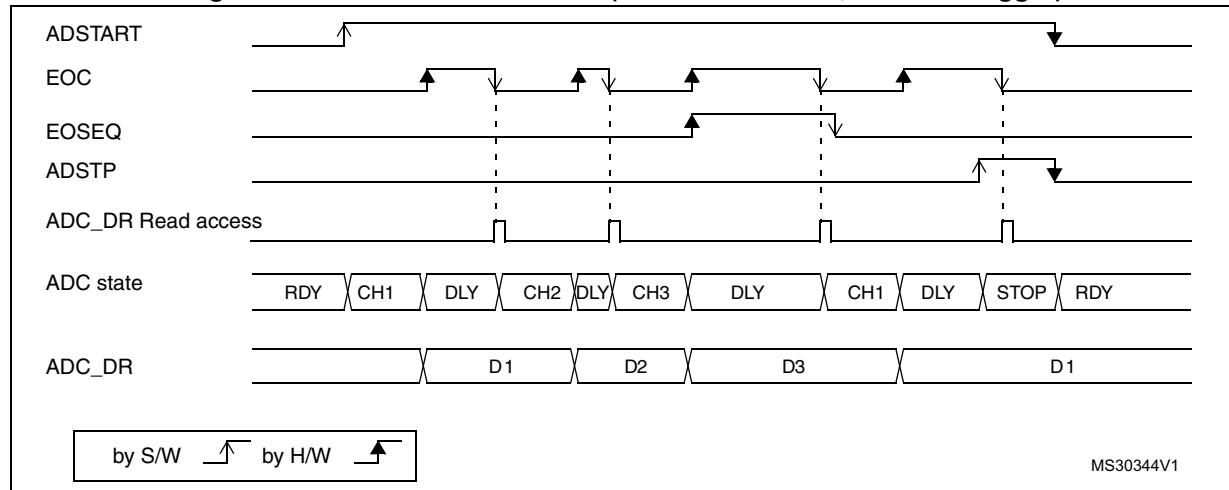
Wait mode conversion can be used to simplify the software as well as optimizing the performance of applications clocked at low frequency where there might be a risk of ADC overrun occurring.

When the WAIT bit is set to 1 in the ADC\_CFGR1 register, a new conversion can start only if the previous data has been treated, once the ADC\_DR register has been read or if the EOC bit has been cleared.

This is a way to automatically adapt the speed of the ADC to the speed of the system that reads the data.

**Note:** Any hardware triggers which occur while a conversion is ongoing or during the wait time preceding the read access are ignored.

**Figure 35. Wait mode conversion (continuous mode, software trigger)**



1. EXTEN=0x0, CONT=1
2. CHSEL=0x3, SCANDIR=0, WAIT=1, AUTOFF=0

### 12.7.2 Auto-off mode (AUTOFF)

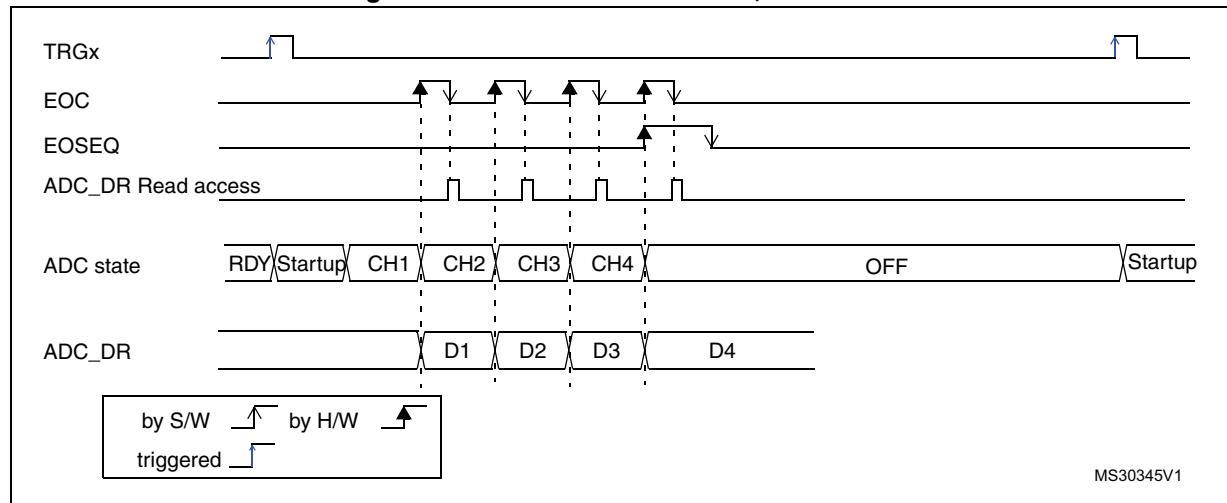
The ADC has an automatic power management feature which is called auto-off mode, and is enabled by setting AUTOFF=1 in the ADC\_CFGR1 register.

When AUTOFF=1, the ADC is always powered off when not converting and automatically wakes-up when a conversion is started (by software or hardware trigger). A startup-time is automatically inserted between the trigger event which starts the conversion and the sampling time of the ADC. The ADC is then automatically disabled once the sequence of conversions is complete.

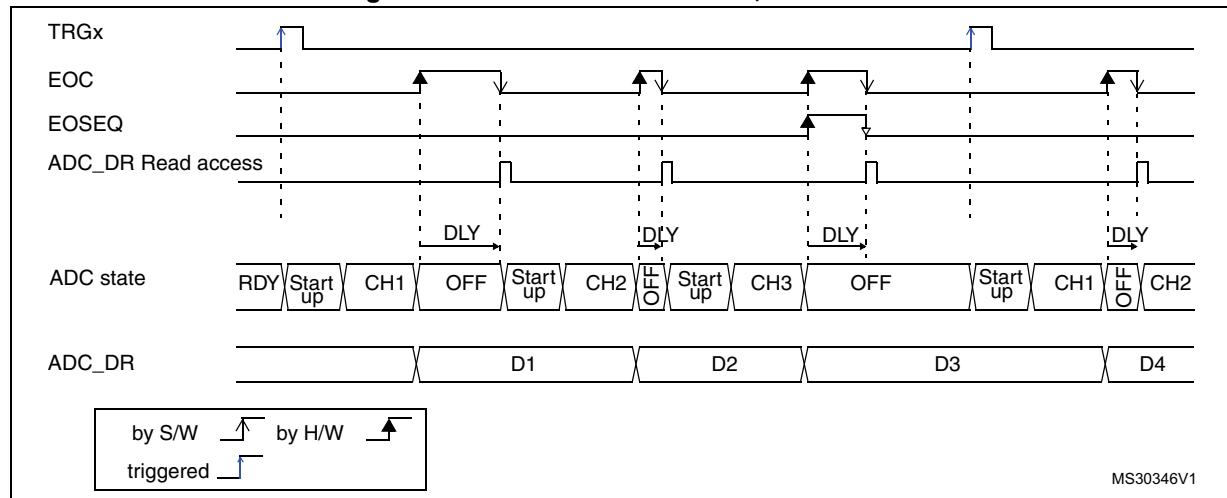
Auto-off mode can cause a dramatic reduction in the power consumption of applications which need relatively few conversions or when conversion requests are timed far enough apart (for example with a low frequency hardware trigger) to justify the extra power and extra time used for switching the ADC on and off.

Auto-off mode can be combined with the wait mode conversion (WAIT=1) for applications clocked at low frequency. This combination can provide significant power savings if the ADC is automatically powered-off during the wait phase and restarted as soon as the ADC\_DR register is read by the application (see [Figure 37: Behavior with WAIT=1, AUTOFF=1](#)).

**Note:** Please refer to the [Section 7: Reset and clock control \(RCC\) on page 85](#) for the description of how to manage the dedicated 14 MHz internal oscillator. The ADC interface can automatically switch ON/OFF the 14 MHz internal oscillator to save power.

**Figure 36. Behavior with WAIT=0, AUTOFF=1**

- EXTSEL=TRGx, EXTEN=0x1 (rising edge), CONT=x, ADSTART=1, CHSEL=0xF, SCANDIR=0, WAIT=1, AUTOFF=1

**Figure 37. Behavior with WAIT=1, AUTOFF=1**

- EXTSEL=TRGx, EXTEN=0x1 (rising edge), CONT=x, ADSTART=1, CHSEL=0xF, SCANDIR=0, WAIT=1, AUTOFF=1

## 12.8 Analog window watchdog (AWDEN, AWDSGL, AWDCH, AWD\_HTR/LTR, AWD)

The AWD analog watchdog feature is enabled by setting the AWDEN bit in the ADC\_CFGR1 register. It is used to monitor that either one selected channel or all enabled channels (see [Table 35: Analog watchdog channel selection](#)) remain within a configured voltage range (window) as shown in [Figure 38](#).

The AWD analog watchdog status bit is set if the analog voltage converted by the ADC is below a lower threshold or above a higher threshold. These thresholds are programmed in the 12 least significant bits of the ADC\_HTR and ADC\_LTR 16-bit registers. An interrupt can be enabled by setting the AWDIE bit in the ADC\_IER register.

The AWD flag is cleared by software by writing 1 to it.

When converting a data with a resolution of less than 12-bit (according to bits DRES[1:0]), the LSB of the programmed thresholds must be kept cleared because the internal comparison is always performed on the full 12-bit raw converted data (left aligned).

*Table 34* describes how the comparison is performed for all the possible resolutions.

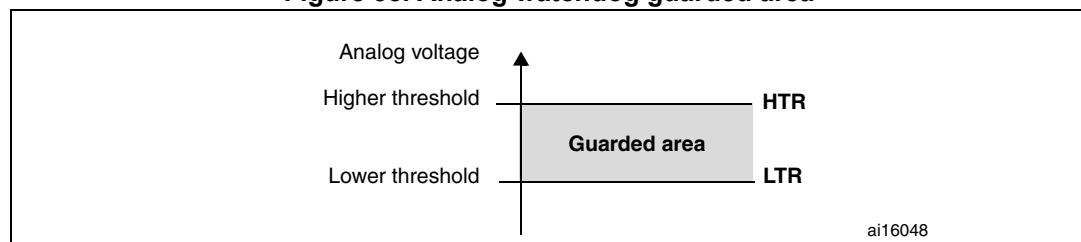
**Table 34. Analog watchdog comparison**

Resolution bits RES[1:0]	Analog Watchdog comparison between:		Comments
	Raw converted data, left aligned <sup>(1)</sup>	Thresholds	
00: 12-bit	DATA[11:0]	LT[11:0] and HT[11:0]	-
01: 10-bit	DATA[11:2],00	LT[11:0] and HT[11:0]	The user must configure LT1[1:0] and HT1[1:0] to "00"
10: 8-bit	DATA[11:4],0000	LT[11:0] and HT[11:0]	The user must configure LT1[3:0] and HT1[3:0] to "0000"
11: 6-bit	DATA[11:6],000000	LT[11:0] and HT[11:0]	The user must configure LT1[5:0] and HT1[5:0] to "000000"

1. The watchdog comparison is performed on the raw converted data before any alignment calculation.

*Table 35* shows how to configure the AWDSGL and AWDEN bits in the ADC\_CFGR1 register to enable the analog watchdog on one or more channels.

**Figure 38. Analog watchdog guarded area**



**Table 35. Analog watchdog channel selection**

Channels guarded by the analog watchdog	AWDSGL bit	AWDEN bit
None	x	0
All channels	0	1
Single <sup>(1)</sup> channel	1	1

1. Selected by the AWDCH[4:0] bits

## 12.9 Temperature sensor and internal reference voltage

The temperature sensor can be used to measure the junction temperature ( $T_J$ ) of the device. The temperature sensor is internally connected to the ADC1\_IN16 input channel which is used to convert the sensor's output voltage to a digital value. The sampling time for the temperature sensor's analog pin must be greater than 2.2  $\mu$ s. When not in use, the sensor can be put in power down mode.

The internal voltage reference (VREFINT) provides a stable (bandgap) voltage output for the ADC and Comparators. VREFINT is internally connected to the ADC\_IN17 input channel. The precise voltage of VREFINT is individually measured for each part by ST during production test and stored in the system memory area. It is accessible in read-only mode.

*Figure 39* shows the block diagram of connections between the temperature sensor, the internal voltage reference and the ADC.

The TSEN bit must be set to enable the conversion of ADC1\_IN16 (temperature sensor) and the VREFEN bit must be set to enable the conversion of ADC1\_IN17 (VREFINT).

The temperature sensor output voltage changes linearly with temperature. The offset of this line varies from chip to chip due to process variation (up to 45 °C from one chip to another).

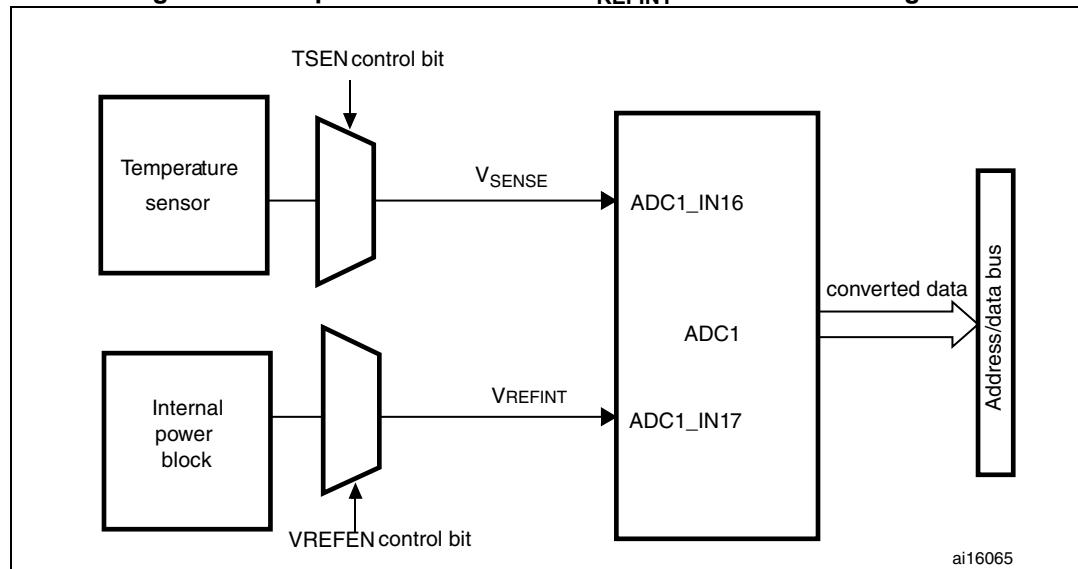
The internal temperature sensor is more suited for applications that detect temperature variations instead of absolute temperatures. If accurate temperature readings are needed, an external temperature sensor part should be used.

During the manufacturing process, the calibration data of the temperature sensor and the internal voltage reference are stored in the system memory area. The user application can then read them and use them to improve the accuracy of the temperature sensor or the internal reference. Refer to the datasheet for additional information.

## Main features

- Supported temperature range: –40 to 125 °C
- Linearity: ±2 °C max., precision depending on calibration

**Figure 39. Temperature sensor and V<sub>REFINT</sub> channel block diagram**



### Reading the temperature

To use the sensor:

1. Select the ADC1\_IN16 input channel
2. Select a sampling time of 17.1  $\mu$ s
3. Set the TSEN bit in the ADC\_CCR register to wake up the temperature sensor from power down mode
4. Start the ADC conversion by setting the ADSTART bit in the ADC\_CR register (or by external trigger)
5. Read the resulting  $V_{SENSE}$  data in the ADC\_DR register
6. Calculate the temperature using the following formula:

$$\text{Temperature (in } ^\circ\text{C)} = \{(V_{25} - V_{SENSE}) / \text{Avg\_Slope}\} + 25$$

Where:

- $V_{25}$  =  $V_{SENSE}$  value for 25° C
- Avg\_Slope = average slope of the temperature vs.  $V_{SENSE}$  curve (given in mV/°C or  $\mu$ V/°C)

Refer to the datasheet's electrical characteristics section for the actual values of  $V_{25}$  and Avg\_Slope.

**Note:** *The sensor has a startup time after waking from power down mode before it can output  $V_{SENSE}$  at the correct level. The ADC also has a startup time after power-on, so to minimize the delay, the ADEN and TSEN bits should be set at the same time.*

## 12.10 Battery voltage monitoring

The VBATEN bit in the ADC\_CCR register allows the application to measure the backup battery voltage on the  $V_{BAT}$  pin. As the  $V_{BAT}$  voltage could be higher than  $V_{DDA}$ , to ensure the correct operation of the ADC, the  $V_{BAT}$  pin is internally connected to a bridge divider by 2. This bridge is automatically enabled when VBATEN is set, to connect  $V_{BAT}/2$  to the ADC1\_IN18 input channel. As a consequence, the converted digital value is half the  $V_{BAT}$  voltage. To prevent any unwanted consumption on the battery, it is recommended to enable the bridge divider only when needed, for ADC conversion.

## 12.11 ADC interrupts

An interrupt can be generated by any of the following events:

- ADC power-up, when the ADC is ready (ADRDY flag)
- End of any conversion (EOC flag)
- End of a sequence of conversions (EOSEQ flag)
- When an analog watchdog detection occurs (AWD flag)
- When the end of sampling phase occurs (EOSMP flag)
- when a data overrun occurs (OVR flag)

Separate interrupt enable bits are available for flexibility.

**Table 36. ADC interrupts**

Interrupt event	Event flag	Enable control bit
ADC ready	ADRDY	ADRDYIE
End of conversion	EOC	EOCIE
End of sequence of conversions	EOSEQ	EOSEQIE
Analog watchdog status bit is set	AWD	AWDIE
End of sampling phase	EOSMP	EOSMPIE
Overrun	OVR	OVRIE

## 12.12 ADC registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 12.12.1 ADC interrupt and status register (ADC\_ISR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.												
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	AWD	Res.	Res.	OVR	EOSEQ	EOC	EOSMP	ADRDY							
								r_w1			r_w1	r_w1	rc_w1	r_w1	r_w1

Bits 31:8 Reserved, must be kept at reset value.

#### Bit 7 AWD: Analog watchdog flag

This bit is set by hardware when the converted voltage crosses the values programmed in the ADC\_LTR and ADC\_HTR registers. It is cleared by software writing 1 to it.

0: No analog watchdog event occurred (or the flag event was already acknowledged and cleared by software)

1: Analog watchdog event occurred

Bit 6:5 Reserved, must be kept at reset value.

#### Bit 4 OVR: ADC overrun

This bit is set by hardware when an overrun occurs, meaning that a new conversion has complete while the EOC flag was already set. It is cleared by software writing 1 to it.

0: No overrun occurred (or the flag event was already acknowledged and cleared by software)

1: Overrun has occurred

#### Bit 3 EOSEQ: End of sequence flag

This bit is set by hardware at the end of the conversion of a sequence of channels selected by the CHSEL bits. It is cleared by software writing 1 to it.

0: Conversion sequence not complete (or the flag event was already acknowledged and cleared by software)

1: Conversion sequence complete

#### Bit 2 EOC: End of conversion flag

This bit is set by hardware at the end of each conversion of a channel when a new data result is available in the ADC\_DR register. It is cleared by software writing 1 to it or by reading the ADC\_DR register.

0: Channel conversion not complete (or the flag event was already acknowledged and cleared by software)

1: Channel conversion complete

#### Bit 1 EOSMP: End of sampling flag

This bit is set by hardware during the conversion, at the end of the sampling phase.

0: Not at the end of the sampling phase (or the flag event was already acknowledged and cleared by software)

1: End of sampling phase reached

**Bit 0 ADRDY:** ADC ready

This bit is set by hardware after the ADC has been enabled (bit ADEN=1) and when the ADC reaches a state where it is ready to accept conversion requests.

It is cleared by software writing 1 to it.

0: ADC not yet ready to start conversion (or the flag event was already acknowledged and cleared by software)

1: ADC is ready to start conversion

### 12.12.2 ADC interrupt enable register (ADC\_IER)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	AWD IE	Res.	Res.	OVRIE	EOSEQ IE	EOCIE	EOSMP IE	ADRDY IE							
								rw			rw	rw	rw	rw	rw

Bits 31:8 Reserved, must be kept at reset value.

**Bit 7 AWDIE:** Analog watchdog interrupt enable

This bit is set and cleared by software to enable/disable the analog watchdog interrupt.

0: Analog watchdog interrupt disabled

1: Analog watchdog interrupt enabled

*Note:* Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 6:5 Reserved, must be kept at reset value.

**Bit 4 OVRIE:** Overrun interrupt enable

This bit is set and cleared by software to enable/disable the overrun interrupt.

0: Overrun interrupt disabled

1: Overrun interrupt enabled. An interrupt is generated when the OVR bit is set.

*Note:* Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

**Bit 3 EOSEQIE:** End of conversion sequence interrupt enable

This bit is set and cleared by software to enable/disable the end of sequence of conversions interrupt.

0: EOSEQ interrupt disabled

1: EOSEQ interrupt enabled. An interrupt is generated when the EOSEQ bit is set.

*Note:* Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

**Bit 2 EOCIE:** End of conversion interrupt enable

This bit is set and cleared by software to enable/disable the end of conversion interrupt.

0: EOC interrupt disabled

1: EOC interrupt enabled. An interrupt is generated when the EOC bit is set.

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bit 1 EOSMPIE:** End of sampling flag interrupt enable

This bit is set and cleared by software to enable/disable the end of the sampling phase interrupt.

0: EOSMP interrupt disabled.

1: EOSMP interrupt enabled. An interrupt is generated when the EOSMP bit is set.

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bits 0 ADRDYIE:** ADC ready interrupt enable

This bit is set and cleared by software to enable/disable the ADC Ready interrupt.

0: ADRDY interrupt disabled.

1: ADRDY interrupt enabled. An interrupt is generated when the ADRDY bit is set.

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

### 12.12.3 ADC control register (ADC\_CR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AD CAL	Res.	Res.	Res.	Res.	Res.										
rs															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	AD STP	Res.	AD START	AD DIS	AD EN
											rs		rs	rs	rs

**Bit 31 ADCAL:** ADC calibration

This bit is set by software to start the calibration of the ADC.

It is cleared by hardware after calibration is complete.

0: Calibration complete

1: Write 1 to calibrate the ADC. Read at 1 means that a calibration is in progress.

*Note: Software is allowed to set ADCAL only when the ADC is disabled (ADCAL=0, ADSTART=0, ADSTP=0, ADDIS=0 and ADEN=0).*

Bits 30:5 Reserved, must be kept at reset value.

**Bit 4 ADSTP:** ADC stop conversion command

This bit is set by software to stop and discard an ongoing conversion (ADSTP Command).

It is cleared by hardware when the conversion is effectively discarded and the ADC is ready to accept a new start conversion command.

0: No ADC stop conversion command ongoing

1: Write 1 to stop the ADC. Read 1 means that an ADSTP command is in progress.

*Note: Software is allowed to set ADSTP only when ADSTART=1 and ADDIS=0 (ADC is enabled and may be converting and there is no pending request to disable the ADC)*

**Bit 3 Reserved,** must be kept at reset value.**Bit 2 ADSTART:** ADC start conversion command

This bit is set by software to start ADC conversion. Depending on the EXTEN [1:0] configuration bits, a conversion either starts immediately (software trigger configuration) or once a hardware trigger event occurs (hardware trigger configuration).

It is cleared by hardware:

- In single conversion mode when software trigger is selected (EXTSEL=0x0): at the assertion of the End of Conversion Sequence (EOSEQ) flag.
- In all cases: after the execution of the ADSTP command, at the same time as the ADSTP bit is cleared by hardware.

0: No ADC conversion is ongoing.

1: Write 1 to start the ADC. Read 1 means that the ADC is operating and may be converting.

*Note: Software is allowed to set ADSTART only when ADEN=1 and ADDIS=0 (ADC is enabled and there is no pending request to disable the ADC)*

**Bit 1 ADDIS:** ADC disable command

This bit is set by software to disable the ADC (ADDIS command) and put it into power-down state (OFF state).

It is cleared by hardware once the ADC is effectively disabled (ADEN is also cleared by hardware at this time).

0: No ADDIS command ongoing

1: Write 1 to disable the ADC. Read 1 means that an ADDIS command is in progress.

*Note: Software is allowed to set ADDIS only when ADEN=1 and ADSTART=0 (which ensures that no conversion is ongoing)*

**Bit 0 ADEN:** ADC enable command

This bit is set by software to enable the ADC. The ADC will be effectively ready to operate once the ADRDY flag has been set.

It is cleared by hardware when the ADC is disabled, after the execution of the ADDIS command.

0: ADC is disabled (OFF state)

1: Write 1 to enable the ADC.

*Note: Software is allowed to set ADEN only when all bits of ADC\_CR registers are 0 (ADCAL=0, ADSTP=0, ADSTART=0, ADDIS=0 and ADEN=0)*

### 12.12.4 ADC configuration register 1 (ADC\_CFGR1)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	AWDCH[4:0]					Res.	Res.	AWD EN	AWD SGL	Res.	Res.	Res.	Res.	Res.	DISC EN
	rw	rw	rw	rw	rw			rw	rw						rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AUT OFF	WAIT	CONT	OVR MOD	EXTEN[1:0]	Res.	EXTSEL[2:0]			ALIGN	RES[1:0]		SCAN DIR	DMA CFG	DMA EN	
rw	rw	rw	rw	rw		rw			rw	rw	rw	rw	rw	rw	rw

Bit 31 Reserved, must be kept at reset value.

Bits 30:26 **AWDCH[4:0]**: Analog watchdog channel selection

These bits are set and cleared by software. They select the input channel to be guarded by the analog watchdog.

00000: ADC analog input Channel 0 monitored by AWD

00001: ADC analog input Channel 1 monitored by AWD

.....

10011: ADC analog input Channel 18 monitored by AWD

other values: Reserved, must not be used

*Note: The channel selected by the AWDCH[4:0] bits must be also set into the CHSEL register*

*Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bits 25:24 Reserved, must be kept at reset value.

Bit 23 **AWDEN**: Analog watchdog enable

This bit is set and cleared by software.

0: Analog watchdog disabled

1: Analog watchdog enabled

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bit 22 **AWDSGL**: Enable the watchdog on a single channel or on all channels

This bit is set and cleared by software to enable the analog watchdog on the channel identified by the AWDCH[4:0] bits or on all the channels

0: Analog watchdog enabled on all channels

1: Analog watchdog enabled on a single channel

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bits 21:17 Reserved, must be kept at reset value.

**Bit 16 DISCEN:** Discontinuous mode

This bit is set and cleared by software to enable/disable discontinuous mode.

- 0: Discontinuous mode disabled
- 1: Discontinuous mode enabled

*Note: It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.*

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bit 15 AUTOFF:** Auto-off mode

This bit is set and cleared by software to enable/disable auto-off mode.

- 0: Auto-off mode disabled
- 1: Auto-off mode enabled

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bit 14 WAIT:** Wait conversion mode

This bit is set and cleared by software to enable/disable wait conversion mode.

- 0: Wait conversion mode off
- 1: Wait conversion mode on

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bit 13 CONT:** Single / continuous conversion mode

This bit is set and cleared by software. If it is set, conversion takes place continuously until it is cleared.

- 0: Single conversion mode
- 1: Continuous conversion mode

*Note: It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.*

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bit 12 OVRMOD:** Overrun management mode

This bit is set and cleared by software and configure the way data overruns are managed.

- 0: ADC\_DR register is preserved with the old data when an overrun is detected.
- 1: ADC\_DR register is overwritten with the last conversion result when an overrun is detected.

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

**Bits 11:10 EXTN[1:0]:** External trigger enable and polarity selection

These bits are set and cleared by software to select the external trigger polarity and enable the trigger.

- 00: Hardware trigger detection disabled (conversions can be started by software)
- 01: Hardware trigger detection on the rising edge
- 10: Hardware trigger detection on the falling edge
- 11: Hardware trigger detection on both the rising and falling edges

*Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bit 9 Reserved, must be kept at reset value.

Bits 8:6 **EXTSEL[2:0]**: External trigger selection

These bits select the external event used to trigger the start of conversion:

- 000: TRG0
- 001: TRG1
- 010: TRG2
- 011: TRG3
- 100: TRG4
- 101: TRG5
- 110: TRG6
- 111: TRG7

*Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bit 5 **ALIGN**: Data alignment

This bit is set and cleared by software to select right or left alignment. Refer to [Figure 33: Data alignment and resolution on page 191](#)

- 0: Right alignment
- 1: Left alignment

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bit 4:3 **RES[1:0]**: Data resolution

These bits are written by software to select the resolution of the conversion.

- 00: 12 bits
- 01: 10 bits
- 10: 8 bits
- 11: 6 bits

*Note: Software is allowed to write these bits only when ADEN=0 .*

Bit 2 **SCANDIR**: Scan sequence direction

This bit is set and cleared by software to select the direction in which the channels will be scanned in the sequence.

- 0: Upward scan (from CHSEL0 to CHSEL16)
- 1: Backward scan (from CHSEL16 to CHSEL0)

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bit 1 **DMACFG**: Direct memory access configuration

This bit is set and cleared by software to select between two DMA modes of operation and is effective only when DMAEN=1.

- 0: DMA one shot mode selected
- 1: DMA circular mode selected

For more details, refer to [Section 12.6.5: Managing converted data using the DMA on page 192](#)

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bit 0 **DMAEN**: Direct memory access enable

This bit is set and cleared by software to enable the generation of DMA requests. This allows to use the DMA controller to manage automatically the converted data. For more details, refer to [Section 12.6.5: Managing converted data using the DMA on page 192](#).

- 0: DMA disabled
- 1: DMA enabled

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

### 12.12.5 ADC configuration register 2 (ADC\_CFGR2)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CKMODE[1:0]		Res.													
rw	rw														
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.

Bits 31:30 CKMODE[1:0]: ADC clock mode

These bits are set and cleared by software to define how the analog ADC is clocked :

00: CK\_ADC (Asynchronous clock mode), generated at product level (refer to RCC section)

01: PCLK/2 (Synchronous clock mode)

10: PCLK/4 (Synchronous clock mode)

11: Reserved

In all synchronous clock modes, there is no jitter in the delay from a timer trigger to the start of a conversion.

*Note: Software is allowed to write these bits only when the ADC is disabled (ADCAL=0, ADSTART=0, ADSTP=0, ADDIS=0 and ADEN=0).*

Bits 29:0 Reserved, must be kept at reset value.

### 12.12.6 ADC sampling time register (ADC\_SMPR)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.														
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SMP[2:0]														
															rw

Bits 31:3 Reserved, must be kept at reset value.

Bits 2:0 **SMP[2:0]: Sampling time selection**

These bits are written by software to select the sampling time that applies to all channels.

- 000: 1.5 ADC clock cycles
- 001: 7.5 ADC clock cycles
- 010: 13.5 ADC clock cycles
- 011: 28.5 ADC clock cycles
- 100: 41.5 ADC clock cycles
- 101: 55.5 ADC clock cycles
- 110: 71.5 ADC clock cycles
- 111: 239.5 ADC clock cycles

*Note:* Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

**12.12.7 ADC watchdog threshold register (ADC\_TR)**

Address offset: 0x20

Reset value: 0xFFFF 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16		
Res.	Res.	Res.	Res.	HT[11:0]													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
Res.	Res.	Res.	Res.	LT[11:0]													
				rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	

Bits 31:28 Reserved, must be kept at reset value.

Bit 27:16 **HT[11:0]: Analog watchdog higher threshold**

These bits are written by software to define the higher threshold for the analog watchdog.

Refer to [Section 12.8: Analog window watchdog \(AWDEN, AWDSGL, AWDCH, AWD\\_HTR/LTR, AWD\) on page 195](#)

*Note:* Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 15:12 Reserved, must be kept at reset value.

Bit 11:0 **LT[11:0]: Analog watchdog lower threshold**

These bits are written by software to define the lower threshold for the analog watchdog.

Refer to [Section 12.8: Analog window watchdog \(AWDEN, AWDSGL, AWDCH, AWD\\_HTR/LTR, AWD\) on page 195](#)

*Note:* Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

### 12.12.8 ADC channel selection register (ADC\_CHSELR)

Address offset: 0x28

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CHSEL 18	CHSEL 17	CHSEL 16
													rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CHSEL 15	CHSEL 14	CHSEL 13	CHSEL 12	CHSEL 11	CHSEL 10	CHSEL 9	CHSEL 8	CHSEL 7	CHSEL 6	CHSEL 5	CHSEL 4	CHSEL 3	CHSEL 2	CHSEL 1	CHSEL 0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:19 Reserved, must be kept at reset value.

Bits 18:0 **CHSELx**: Channel-x selection

These bits are written by software and define which channels are part of the sequence of channels to be converted.

0: Input Channel-x is not selected for conversion

1: Input Channel-x is selected for conversion

*Note:* Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

### 12.12.9 ADC data register (ADC\_DR)

Address offset: 0x40

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DATA[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **DATA[15:0]**: Converted data

These bits are read-only. They contain the conversion result from the last converted channel. The data are left- or right-aligned as shown in [Figure 33: Data alignment and resolution on page 191](#).

Just after a calibration is complete, DATA[6:0] contains the calibration factor.

### 12.12.10 ADC common configuration register (ADC\_CCR)

Address offset: 0x308

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	VBAT EN	TS EN	VREF EN	Res.	Res.	Res.	Res.	Res.	Res.						
							rw	rw	rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.							

Bits 31:25 Reserved, must be kept at reset value.

Bit 24 **VBATEN**: V<sub>BAT</sub> enable

This bit is set and cleared by software to enable/disable the V<sub>BAT</sub> channel.

- 0: V<sub>BAT</sub> channel disabled
- 1: V<sub>BAT</sub> channel enabled

*Note:* Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 23 **TSEN**: Temperature sensor enable

This bit is set and cleared by software to enable/disable the temperature sensor.

- 0: Temperature sensor disabled
- 1: Temperature sensor enabled

*Note:* Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 22 **VREFEN**: V<sub>REFINT</sub> enable

This bit is set and cleared by software to enable/disable the V<sub>REFINT</sub>.

- 0: V<sub>REFINT</sub> disabled
- 1: V<sub>REFINT</sub> enabled

*Note:* Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 21:0 Reserved, must be kept at reset value.

### 12.12.11 ADC register map

The following table summarizes the ADC registers.

**Table 37. ADC register map and reset values**

Offset	Register	Reset value	31
0x00	ADC_ISR	Res.	Res.
	Reset value	0	30
0x04	ADC_IER	Res.	Res.
	Reset value	0	29
0x08	ADC_CR	Res.	Res.
	Reset value	0	28
0x0C	ADC_CFGR1	Res.	Res.
	Reset value	0	27
0x10	ADC_CFGR2	Res.	Res.
	Reset value	0	26
0x14	ADC_SMPR	Res.	Res.
	Reset value	0	25
0x18	Reserved	Res.	Res.
0x1C	Reserved	Res.	Res.
0x20	ADC_TR	HT[11:0]	Res.
	Reset value	1 1 1 1 1 1 1 1 1 1 1 1	19
0x24	Reserved	Res.	Res.
0x28	ADC_CHSELR	Res.	Res.
	Reset value	0 0 CHSEL18 CHSEL17 CHSEL16 CHSEL15 CHSEL14 CHSEL13 CHSEL12 CHSEL11 CHSEL10 CHSEL9 CHSEL8 CHSEL7 CHSEL6 CHSEL5 CHSEL4 CHSEL3 CHSEL2 CHSEL1 CHSEL0	18
0x30	Reserved	Res.	Res.
	Res.	Res.	Res.
0x34	ADC_DR	Res.	Res.
	Reset value	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	10
0x38	Res.	Res.	Res.
	Res.	Res.	Res.
0x3C	Res.	Res.	Res.
	Res.	Res.	Res.
0x40	ADC_DR	DATA[15:0]	Res.
	Reset value	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	9
0x44	Res.	Res.	Res.
	Res.	Res.	Res.
0x304	Res.	Res.	Res.
	Res.	Res.	Res.

**Table 37. ADC register map and reset values (continued)**

<b>Offset</b>	<b>Register</b>	<b>31</b>	<b>30</b>	<b>29</b>	<b>28</b>	<b>27</b>	<b>26</b>	<b>25</b>	<b>24</b>	<b>23</b>	<b>22</b>	<b>21</b>	<b>20</b>	<b>19</b>	<b>18</b>	<b>17</b>	<b>16</b>	<b>15</b>	<b>14</b>	<b>13</b>	<b>12</b>	<b>11</b>	<b>10</b>	<b>9</b>	<b>8</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>0</b>
0x308	ADC_CCR	Res.	VBATEN	0	TSEN	0	VREFEN	0	Res.	0	Res.	0	Res.	0	Res.	0	Res.	0															
	Reset value																																

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 13 Digital-to-analog converter (DAC)

This section applies to medium-density devices only.

### 13.1 DAC introduction

The DAC module is a 12-bit, voltage output digital-to-analog converter. The DAC can be configured in 8- or 12-bit mode and may be used in conjunction with the DMA controller. In 12-bit mode, the data could be left- or right-aligned. An input reference voltage,  $V_{DDA}$  (shared with ADC) is available. The output can optionally be buffered for higher current drive.

### 13.2 DAC main features

The devices integrate one 12-bit DAC channel, DAC1, which output is DAC\_OUT.

DAC main features are the following:

- Left or right data alignment in 12-bit mode
- Synchronized update capability
- DMA capability
- DMA underrun error detection
- External triggers for conversion
- Programmable internal buffer
- Input voltage reference,  $V_{DDA}$

*Figure 40* shows the block diagram of a DAC channel and *Table 38* gives the pin description.

Figure 40. DAC block diagram

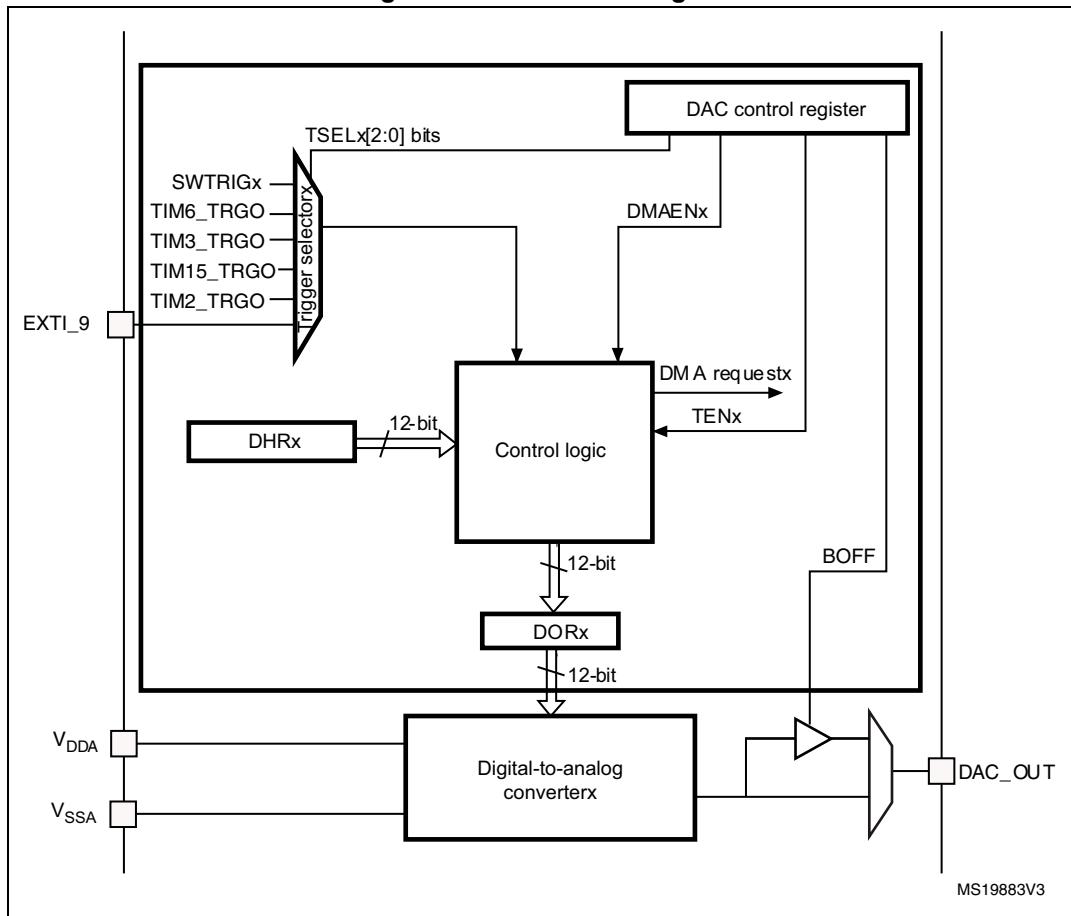


Table 38. DAC pins

Name	Signal type	Remarks
V <sub>DDA</sub>	Input, analog supply	Analog power supply
V <sub>SSA</sub>	Input, analog supply ground	Ground for analog power supply
DAC_OUT	Analog output signal	DAC channelx analog output

**Note:** Once the DAC channel1 is enabled, the corresponding GPIO pin (PA4) is automatically connected to the analog converter output (DAC\_OUT). In order to avoid parasitic consumption, the PA4 pin should first be configured to analog (AIN).

### 13.3 Single mode functional description

#### 13.3.1 DAC channel enable

The DAC channel can be powered on by setting the EN1 bit in the DAC\_CR register. The DAC channel is then enabled after a startup time  $t_{WAKEUP}$ .

**Note:** The ENx bit enables the analog DAC Channelx macrocell only. The DAC Channelx digital interface is enabled even if the ENx bit is reset.

### 13.3.2 DAC output buffer enable

The DAC integrates an output buffer that can be used to reduce the output impedance, and to drive external loads directly without having to add an external operational amplifier. The DAC channel output buffer can be enabled and disabled using the BOFF1 bit in the DAC\_CR register.

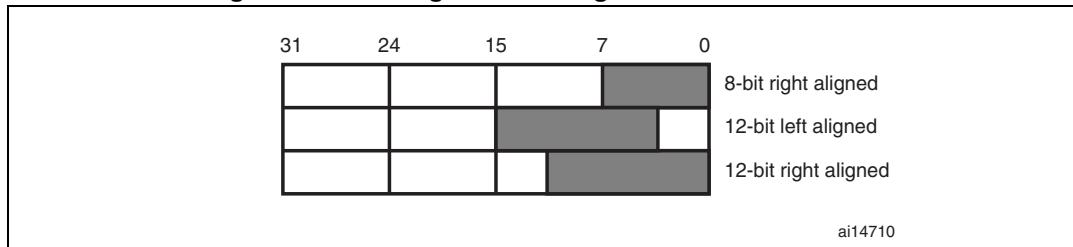
### 13.3.3 DAC data format

Depending on the selected configuration mode, the data have to be written into the specified register as described below:

- There are three possibilities:
  - 8-bit right alignment: the software has to load data into the DAC\_DHR8Rx [7:0] bits (stored into the DHRx[11:4] bits)
  - 12-bit left aligned: the software has to load data into the DAC\_DHR12Lx [15:4] bits (stored into the DHRx[11:0] bits)
  - 12-bit right alignment: the software has to load data into the DAC\_DHR12Rx [11:0] bits (stored into the DHRx[11:0] bits)

Depending on the loaded DAC\_DHRyyxx register, the data written by the user is shifted and stored into the corresponding DHRx (data holding registerx, which are internal non-memory-mapped registers). The DHRx register is then loaded into the DORx register either automatically, by software trigger or by an external event trigger.

**Figure 41. Data registers in single DAC channel mode**

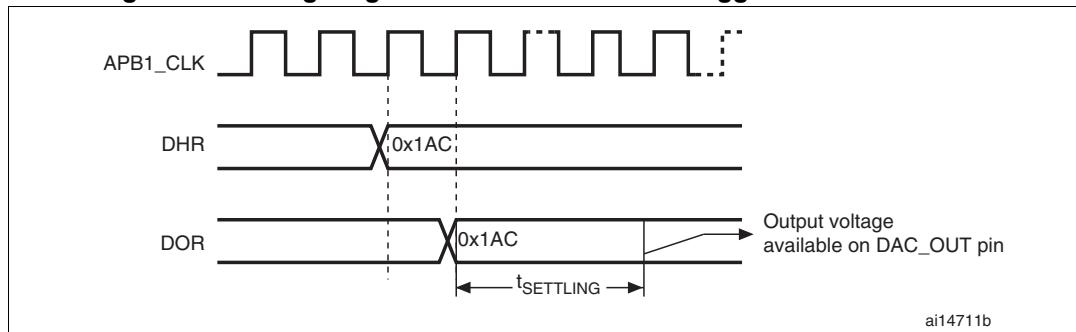


### 13.3.4 DAC conversion

The DAC\_DORx cannot be written directly and any data transfer to the DAC channelx must be performed by loading the DAC\_DHRx register (write to DAC\_DHR8Rx, DAC\_DHR12Lx, DAC\_DHR12Rx).

Data stored in the DAC\_DHRx register are automatically transferred to the DAC\_DORx register after one APB1 clock cycle, if no hardware trigger is selected (TENx bit in DAC\_CR register is reset). However, when a hardware trigger is selected (TENx bit in DAC\_CR register is set) and a trigger occurs, the transfer is performed three PCLK1 clock cycles later.

When DAC\_DORx is loaded with the DAC\_DHRx contents, the analog output voltage becomes available after a time  $t_{SETTLING}$  that depends on the power supply voltage and the analog output load.

**Figure 42. Timing diagram for conversion with trigger disabled TEN = 0**

### 13.3.5 DAC output voltage

Digital inputs are converted to output voltages on a linear conversion between 0 and VDDA.

The analog output voltages on each DAC channel pin are determined by the following equation:

$$\text{DACOutput} = V_{\text{DDA}} \times \frac{\text{DOR}}{4095}$$

### 13.3.6 DAC trigger selection

If the TENx control bit is set, conversion can then be triggered by an external event (timer counter, external interrupt line). The TSELx[2:0] control bits determine which out of 8 possible events will trigger conversion as shown in [Table 39](#).

**Table 39. External triggers**

Source	Type	TSEL[2:0]
Timer 6 TRGO event	Internal signal from on-chip timers	000
Timer 3TRGO event		001
Reserved		010
Timer 15 TRGO event		011
Timer 2 TRGO event		100
Reserved		101
EXTI line9	External pin	110
SWTRIG	Software control bit	111

Each time a DAC interface detects a rising edge on the selected timer TRGO output, or on the selected external interrupt line 9, the last data stored into the DAC\_DHRx register are transferred into the DAC\_DORx register. The DAC\_DORx register is updated three APB1 cycles after the trigger occurs.

If the software trigger is selected, the conversion starts once the SWTRIG bit is set. SWTRIG is reset by hardware once the DAC\_DORx register has been loaded with the DAC\_DHRx register contents.

**Note:** *TSELx[2:0] bit cannot be changed when the ENx bit is set.*

*When software trigger is selected, the transfer from the DAC\_DHRx register to the DAC\_DORx register takes only one APB1 clock cycle.*

## 13.4 DMA request

Each DAC channel has a DMA capability. Two DMA channels are used to service DAC channel DMA requests.

A DAC DMA request is generated when an external trigger (but not a software trigger) occurs while the DMAENx bit is set. The value of the DAC\_DHRx register is then transferred to the DAC\_DORx register.

### DMA underrun

The DAC DMA request is not queued so that if a second external trigger arrives before the acknowledgement for the first external trigger is received (first request), then no new request is issued and the DMA channelx underrun flag DMAUDRx in the DAC\_SR register is set, reporting the error condition. DMA data transfers are then disabled and no further DMA request is treated. The DAC channelx continues to convert old data.

The software should clear the DMAUDRx flag by writing “1”, clear the DMAEN bit of the used DMA stream and re-initialize both DMA and DAC channelx to restart the transfer correctly. The software should modify the DAC trigger conversion frequency or lighten the DMA workload to avoid a new DMA. Finally, the DAC conversion can be resumed by enabling both DMA data transfer and conversion trigger.

For each DAC channel, an interrupt is also generated if the corresponding DMAUDRIEx bit in the DAC\_CR register is enabled.

## 13.5 DAC registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers have to be accessed by words (32-bit).

### 13.5.1 DAC control register (DAC\_CR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
Res.	Res.	Res.	Res.	Res.				Res.		Res.				Res.	Res.	
15		13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Res.	Res.	DMAUDRIE1	DMAEN1	Res.				Res.		TSEL1[2:0]				TEN1	BOFF1	EN1
		rw	rw							rw	rw	rw	rw	rw	rw	rw

Bits 31:14 Reserved, must be kept at reset value.

Bit 13 **DMAUDRIE1**: DAC channel1 DMA Underrun Interrupt enable

This bit is set and cleared by software.

0: DAC channel1 DMA Underrun Interrupt disabled

1: DAC channel1 DMA Underrun Interrupt enabled

Bit 12 **DMAEN1**: DAC channel1 DMA enable

This bit is set and cleared by software.

0: DAC channel1 DMA mode disabled

1: DAC channel1 DMA mode enabled

Bits 11:8 Reserved, must be kept at reset value.

Bits 7:6 Reserved, must be kept at reset value.

Bits 5:3 **TSEL1[2:0]**: DAC channel1 trigger selection

These bits select the external event used to trigger DAC channel1.

000: Timer 6 TRGO event

001: Timer 8 TRGO event

010: Timer 7 TRGO event

011: Timer 5 TRGO event

100: Timer 2 TRGO event

101: Timer 4 TRGO event

110: External line9

111: Software trigger

*Note: Only used if bit TEN1 = 1 (DAC channel1 trigger enabled).*

Bit 2 **TEN1**: DAC channel1 trigger enable

This bit is set and cleared by software to enable/disable DAC channel1 trigger.

0: DAC channel1 trigger disabled and data written into the DAC\_DHRx register are transferred one APB1 clock cycle later to the DAC\_DOR1 register

1: DAC channel1 trigger enabled and data from the DAC\_DHRx register are transferred three APB1 clock cycles later to the DAC\_DOR1 register

*Note: When software trigger is selected, the transfer from the DAC\_DHRx register to the DAC\_DOR1 register takes only one APB1 clock cycle.*

Bit 1 **BOFF1**: DAC channel1 output buffer disable

This bit is set and cleared by software to enable/disable DAC channel1 output buffer.

0: DAC channel1 output buffer enabled

1: DAC channel1 output buffer disabled

Bit 0 **EN1**: DAC channel1 enable

This bit is set and cleared by software to enable/disable DAC channel1.

0: DAC channel1 disabled

1: DAC channel1 enabled

### 13.5.2 DAC software trigger register (DAC\_SWTRIGR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SWTRIG1														
															w

Bits 31:1 Reserved, must be kept at reset value.

Bit 0 **SWTRIG1**: DAC channel1 software trigger

This bit is set and cleared by software to enable/disable the software trigger.

- 0: Software trigger disabled
- 1: Software trigger enabled

*Note: This bit is cleared by hardware (one APB1 clock cycle later) once the DAC\_DHR1 register value has been loaded into the DAC\_DOR1 register.*

### 13.5.3 DAC channel1 12-bit right-aligned data holding register (DAC\_DHR12R1)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.												
				rw											
DACC1DHR[11:0]															

Bits 31:12 Reserved, must be kept at reset value.

Bits 11:0 **DACC1DHR[11:0]**: DAC channel1 12-bit right-aligned data

These bits are written by software which specifies 12-bit data for DAC channel1.

### 13.5.4 DAC channel1 12-bit left aligned data holding register (DAC\_DHR12L1)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DACC1DHR[11:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:4 **DACC1DHR[11:0]**: DAC channel1 12-bit left-aligned data

These bits are written by software which specifies 12-bit data for DAC channel1.

Bits 3:0 Reserved, must be kept at reset value.

### 13.5.5 DAC channel1 8-bit right aligned data holding register (DAC\_DHR8R1)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	rw														

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **DACC1DHR[7:0]**: DAC channel1 8-bit right-aligned data

These bits are written by software which specifies 8-bit data for DAC channel1.

### 13.5.6 DAC channel1 data output register (DAC\_DOR1)

Address offset: 0x2C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.												

Bits 31:12 Reserved, must be kept at reset value.

Bit 11:0 **DACC1DOR[11:0]**: DAC channel1 data output

These bits are read-only, they contain data output for DAC channel1.

### 13.5.7 DAC status register (DAC\_SR)

Address offset: 0x34

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	DMAUDR1	Res.												
		rc_w1													

Bits 31:14 Reserved, must be kept at reset value.

Bit 13 **DMAUDR1**: DAC channel1 DMA underrun flag

This bit is set by hardware and cleared by software (by writing it to 1).

0: No DMA underrun error condition occurred for DAC channel1

1: DMA underrun error condition occurred for DAC channel1 (the currently selected trigger is driving DAC channel1 conversion at a frequency higher than the DMA service capability rate)

Bits 12:0 Reserved, must be kept at reset value.

### 13.5.8 DAC register map

*Table 40* summarizes the DAC registers.

**Table 40. DAC register map and reset values**

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 14 Comparator (COMP)

This section applies to medium-density devices only.

### 14.1 COMP introduction

The STM32F0x1xx embeds two general purpose comparators COMP1 and COMP2 that can be used either as standalone devices (all terminal are available on I/Os) or combined with the timers. They can be used for a variety of functions including:

- Wake-up from low-power mode triggered by an analog signal,
- Analog signal conditioning,
- Cycle-by-cycle current control loop when combined with the DAC and a PWM output from a timer.

### 14.2 COMP main features

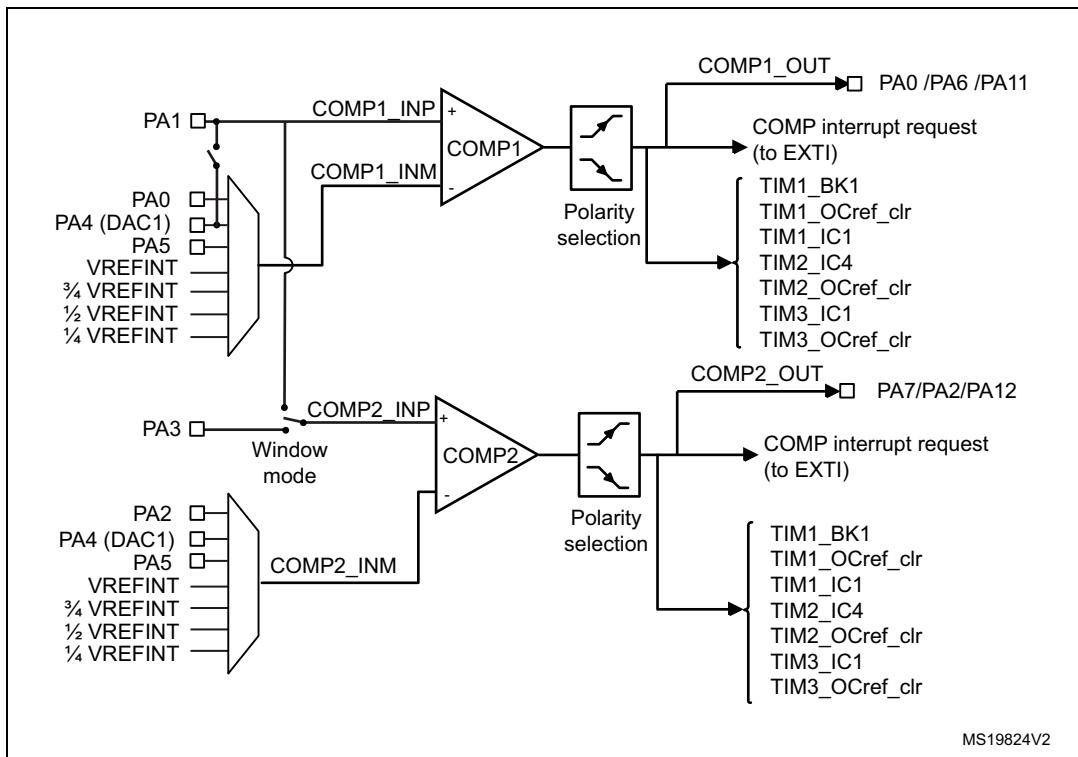
- Rail-to-rail comparators
- Each comparator has configurable positive and negative inputs used for flexible voltage selection:
  - 3 I/O pins
  - DAC1
  - Internal reference voltage and three submultiple values (1/4, 1/2, 3/4) provided by scaler (buffered voltage divider).
- Programmable hysteresis
- Programmable speed and consumption
- The outputs can be redirected to an I/O or to multiple timer inputs for triggering:
  - Capture events
  - OCref\_clr events (for cycle-by-cycle current control)
  - Break events for fast PWM shutdowns
- COMP1 and COMP2 comparators can be combined in a window comparator.
- The two comparators can be combined in a window comparator
- Each comparator has interrupt generation capability with wake-up from Sleep and Stop modes (through the EXTI controller)

## 14.3 COMP functional description

### 14.3.1 General description

The block diagram of the comparators is shown in [Figure 43: Comparators block diagram](#).

**Figure 43. Comparators block diagram**



### 14.3.2 Clock

The COMP clock provided by the clock controller is synchronous with the PCLK (APB clock).

There is no clock enable control bit provided in the RCC controller. Reset and clock enable bits are common for COMP and SYSCFG.

**Note:** *Important: The polarity selection logic and the output redirection to the port works independently from the PCLK clock. This allows the comparator to work even in Stop mode.*

### 14.3.3 Comparator inputs and outputs

The I/Os used as comparators inputs must be configured in analog mode in the GPIOs registers.

The comparator output can be connected to the I/Os using the alternate function channel given in “Alternate function mapping” table in the datasheet.

The output can also be internally redirected to a variety of timer input for the following purposes:

- Emergency shut-down of PWM signals, using BKIN
- Cycle-by-cycle current control, using OCref\_clr inputs
- Input capture for timing measures

It is possible to have the comparator output simultaneously redirected internally and externally.

#### 14.3.4 Interrupt and wakeup

The comparator outputs are internally connected to the Extended interrupts and events controller. Each comparator has its own EXTI line and can generate either interrupts or events. The same mechanism is used to exit from low power modes.

Refer to Interrupt and events section for more details.

#### 14.3.5 Power mode

The comparator power consumption versus propagation delay can be adjusted to have the optimum trade-off for a given application.

The bits COMPxMODE[1:0] in COMP\_CSR register can be programmed as follows:

- 00: High speed / full power
- 01: Medium speed / medium power
- 10: Low speed / low power
- 11: Very-low speed / ultra-low power

#### 14.3.6 Comparator LOCK mechanism

The comparators can be used for safety purposes, such as over-current or thermal protection. For applications having specific functional safety requirements, it is necessary to insure that the comparator programming cannot be altered in case of spurious register access or program counter corruption.

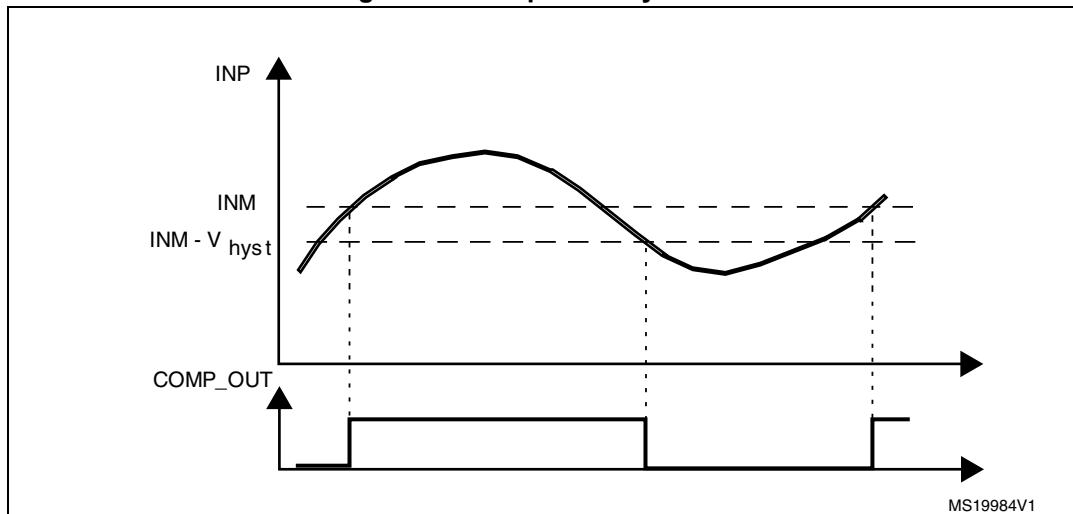
For this purpose, the comparator control and status registers can be write-protected (read-only).

Once the programming is completed, using bits 30:16 and 15:0 of COMP\_CSR, the COMPxLOCK bit must be set to 1. This causes the whole COMP\_CSR register to become read-only, including the COMPxLOCK bit.

The write protection can only be reset by a MCU reset.

#### 14.3.7 Hysteresis

The comparator includes a programmable hysteresis to avoid spurious output transitions in case of noisy signals. The hysteresis can be disabled if it is not needed (for instance when exiting from low power mode) to be able to force the hysteresis value using external components.

**Figure 44. Comparator hysteresis**

## 14.4 COMP registers

### 14.4.1 COMP control and status register (COMP\_CSR)

Address offset: 0x1C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
COMP 2LOCK	COMP 2OUT	COMP2HYST [1:0]	COMP 2POL	COMP2OUTSEL[2:0]			WNDW EN	COMP2INSEL[2:0]			COMP2MODE [1:0]	Res.	COMP2 EN		
rwo	r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r		rw/r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
COMP 1LOCK	COMP 1OUT	COMP1HYST [1:0]	COMP 1POL	COMP1OUTSEL[2:0]			Res.	COMP1INSEL[2:0]			COMP1MODE [1:0]	COMP1 SW1	COMP1 EN		
rwo	r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r		rw/r	rw/r	rw/r	rw/r	rw/r	rw/r	rw/r

#### Bit 31 COMP2LOCK: Comparator 2 lock

This bit is write-once. It is set by software. It can only be cleared by a system reset.

It allows to have all control bits of comparator 2 as read-only.

0: COMP\_CSR[31:16] bits are read-write.

1: COMP\_CSR[31:16] bits are read-only.

#### Bit 30 COMP2OUT: Comparator 2 output

This read-only bit is a copy of comparator 2 output state.

0: Output is low (non-inverting input below inverting input).

1: Output is high (non-inverting input above inverting input).

#### Bits 29:28 COMP2HYST[1:0] Comparator 2 hysteresis

These bits control the hysteresis level.

00: No hysteresis

01: Low hysteresis

10: Medium hysteresis

11: High hysteresis

Please refer to the electrical characteristics for the hysteresis values.

#### Bit 27 COMP2POL: Comparator 2 output polarity

This bit is used to invert the comparator 2 output.

0: Output is not inverted

1: Output is inverted

#### Bits 26:24 COMP2OUTSEL[2:0]: Comparator 2 output selection

These bits select the destination of the comparator output.

000: No selection

001: Timer 1 break input

010: Timer 1 Input capture 1

011: Timer 1 OCrefclear input

100: Timer 2 input capture 4

101: Timer 2 OCrefclear input

110: Timer 3 input capture 1

111: Timer 3 OCrefclear input

Bit 23 **WNDWEN**: Window mode enable

This bit connects the non-inverting input of COMP2 to COMP1's non-inverting input, which is simultaneously disconnected from PA3.

- 0: Window mode disabled
- 1: Window mode enabled

Bits 22:20 **COMP2INSEL[2:0]**: Comparator 2 inverting input selection

These bits allows to select the source connected to the inverting input of the comparator 2.

- 000: 1/4 of Vrefint
- 001: 1/2 of Vrefint
- 010: 3/4 of Vrefint
- 011: Vrefint
- 100: COMP2\_INM4 (PA4 or DAC if enabled)
- 101: COMP2\_INM5 (PA5)
- 110: COMP2\_INM6 (PA2)
- 111: Reserved

Bits 19:18 **COMP2MODE[1:0]**: Comparator 2 mode

These bits control the operating mode of the comparator 2 and allows to adjust the speed/consumption.

- 00: High speed / full power
- 01: Medium speed / medium power
- 10: Low speed / low power
- 11: Very-low speed / ultra-low power

Bit 17 Reserved, must be kept at reset value.

Bit 16 **COMP2EN**: Comparator 2 enable

This bit switches ON/OFF the comparator2.

- 0: Comparator 2 disabled
- 1: Comparator 2 enabled

Bit 15 **COMP1LOCK**: Comparator 1 lock

This bit is write-once. It is set by software. It can only be cleared by a system reset.

It allows to have all control bits of comparator 1 as read-only.

- 0: COMP\_CSR[15:0] bits are read-write.
- 1: COMP\_CSR[15:0] bits are read-only.

Bit 14 **COMP1OUT**: Comparator 1 output

This read-only bit is a copy of comparator 1 output state.

- 0: Output is low (non-inverting input below inverting input).
- 1: Output is high (non-inverting input above inverting input).

Bits 13:12 **COMP1HYST[1:0]** Comparator 1 hysteresis

These bits are controlling the hysteresis level.

- 00: No hysteresis
- 01: Low hysteresis
- 10: Medium hysteresis
- 11: High hysteresis

Please refer to the electrical characteristics for the hysteresis values.

Bit 11 **COMP1POL**: Comparator 1 output polarity

This bit is used to invert the comparator 1 output.

- 0: output is not inverted
- 1: output is inverted

Bits 10:8 **COMP1OUTSEL[2:0]**: Comparator 1 output selection

These bits selects the destination of the comparator 1 output.

- 000: no selection
- 001: Timer 1 break input
- 010: Timer 1 Input capture 1
- 011: Timer 1 OCrefclear input
- 100: Timer 2 input capture 4
- 101: Timer 2 OCrefclear input
- 110: Timer 3 input capture 1
- 111: Timer 3 OCrefclear input

Bit 7 Reserved, must be kept at reset value.

Bits 6:4 **COMP1INSEL[2:0]**: Comparator 1 inverting input selection

These bits select the source connected to the inverting input of the comparator 1.

- 000: 1/4 of Vrefint
- 001: 1/2 of Vrefint
- 010: 3/4 of Vrefint
- 011: Vrefint
- 100: COMP1\_INM4 (PA4 or DAC if enabled)
- 101: COMP1\_INM5 (PA5)
- 110: COMP1\_INM6 (PA0)
- 111: Reserved

Bits 3:2 **COMP1MODE[1:0]**: Comparator 1 mode

These bits control the operating mode of the comparator 1 and allows to adjust the speed/consumption.

- 00: High speed / full power
- 01: Medium speed / medium power
- 10: Low speed / low power
- 11: Very-low speed / ultra-low power

Bit 1 **COMP1SW1**: Comparator 1 non inverting input DAC switch

This bit closes a switch between comparator 1 non-inverting input on PA0 and PA4 (DAC) I/O.

- 0: Switch open
- 1: Switch closed

*Note: This switch is solely intended to redirect signals onto high impedance input, such as COMP1 non-inverting input (highly resistive switch).*

Bit 0 **COMP1EN**: Comparator 1 enable

This bit switches COMP1 ON/OFF.

- 0: Comparator 1 disabled
- 1: Comparator 1 enabled

### 14.4.2 COMP register map

The following table summarizes the comparator registers.

**Table 41. COMP register map and reset values**

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
0x1C	<b>COMP_CSR</b>	COMP2LOCK	COMP2OUT	COMP2HYST[1:0]	COMP2POL	COMP2OUTSEL[2:0]	COMP2INSEL[2:0]	COMP2MODE[1:0]	Res.	COMP2EN	COMP1LOCK	COMP1OUT	COMP1HYST[1:0]	COMP1POL	COMP1OUTSEL[2:0]	Res.	COMP1INSEL[2:0]	COMP1MODE[1:0]	COMP1SW1	COMP1EN																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 15 Advanced-control timers (TIM1)

### 15.1 TIM1 introduction

The advanced-control timers (TIM1) consist of a 16-bit auto-reload counter driven by a programmable prescaler.

It may be used for a variety of purposes, including measuring the pulse lengths of input signals (input capture) or generating output waveforms (output compare, PWM, complementary PWM with dead-time insertion).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

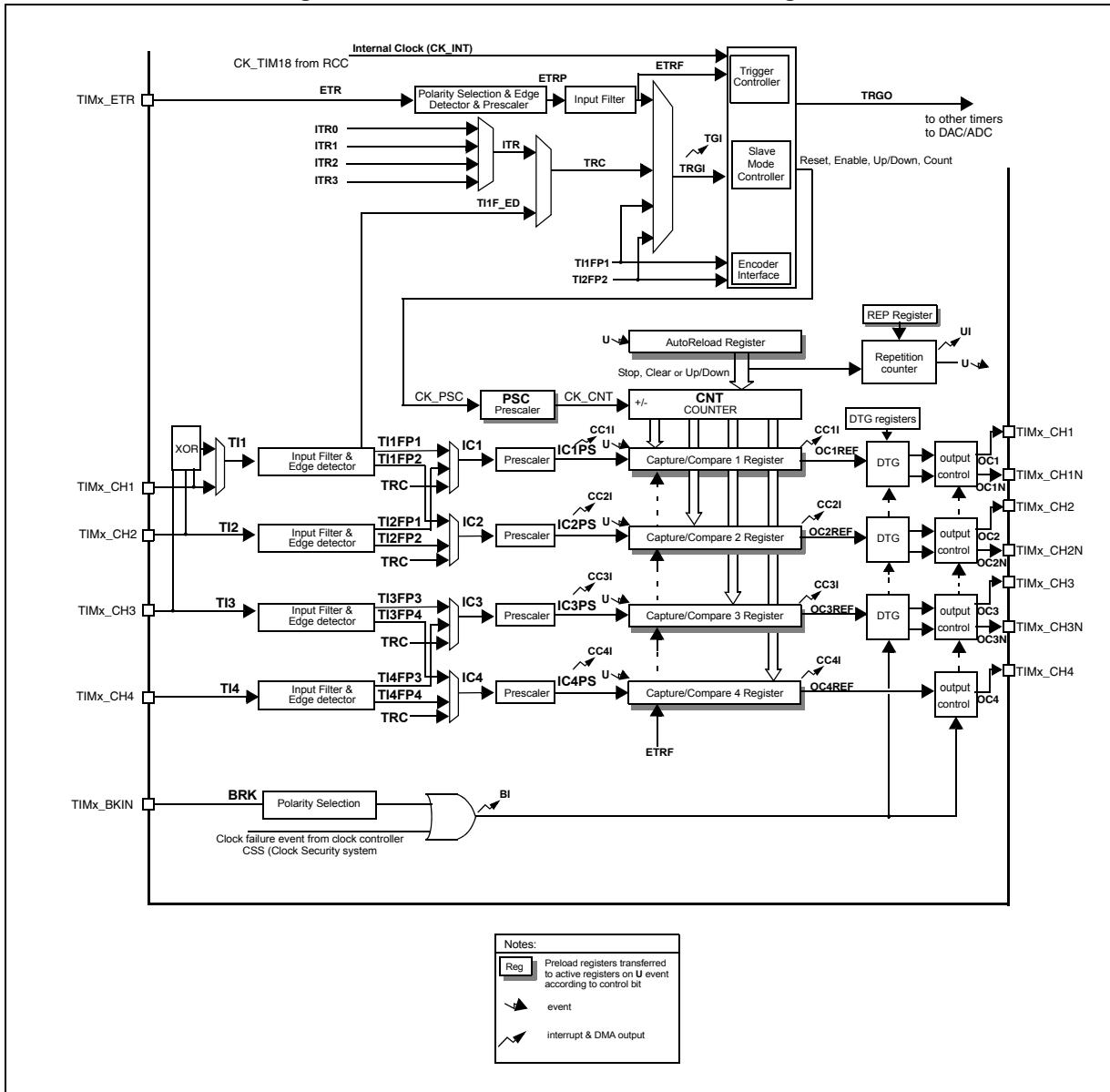
The advanced-control (TIM1) and general-purpose (TIMx) timers are completely independent, and do not share any resources. They can be synchronized together as described in [Section 15.3.20](#).

### 15.2 TIM1 main features

TIM1 timer features include:

- 16-bit up, down, up/down auto-reload counter.
- 16-bit programmable prescaler allowing dividing (also “on the fly”) the counter clock frequency either by any factor between 1 and 65535.
- Up to 4 independent channels for:
  - Input Capture
  - Output Compare
  - PWM generation (Edge- and Center-aligned modes)
  - One-pulse mode output
- Complementary outputs with programmable dead-time
- Synchronization circuit to control the timer with external signals and to interconnect several timers together.
- Repetition counter to update the timer registers only after a given number of cycles of the counter.
- Break input to put the timer’s output signals in reset state or in a known state.
- Interrupt/DMA generation on the following events:
  - Update: counter overflow/underflow, counter initialization (by software or internal/external trigger)
  - Trigger event (counter start, stop, initialization or count by internal/external trigger)
  - Input capture
  - Output compare
  - Break input
- Supports incremental (quadrature) encoder and hall-sensor circuitry for positioning purposes
- Trigger input for external clock or cycle-by-cycle current management

Figure 45. Advanced-control timer block diagram



## 15.3 TIM1 functional description

### 15.3.1 Time-base unit

The main block of the programmable advanced-control timer is a 16-bit counter with its related auto-reload register. The counter can count up, down or both up and down. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter register (TIMx\_CNT)
- Prescaler register (TIMx\_PSC)
- Auto-reload register (TIMx\_ARR)
- Repetition counter register (TIMx\_RCR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx\_CR1 register. The update event is sent when the counter reaches the overflow (or underflow when downcounting) and if the UDIS bit equals 0 in the TIMx\_CR1 register. It can also be generated by software. The generation of the update event is described in detailed for each configuration.

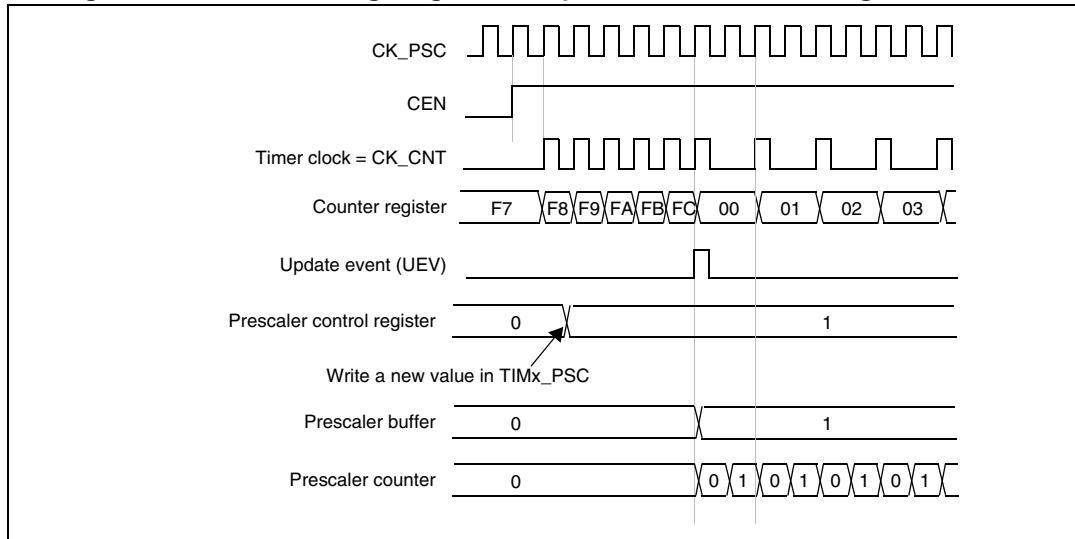
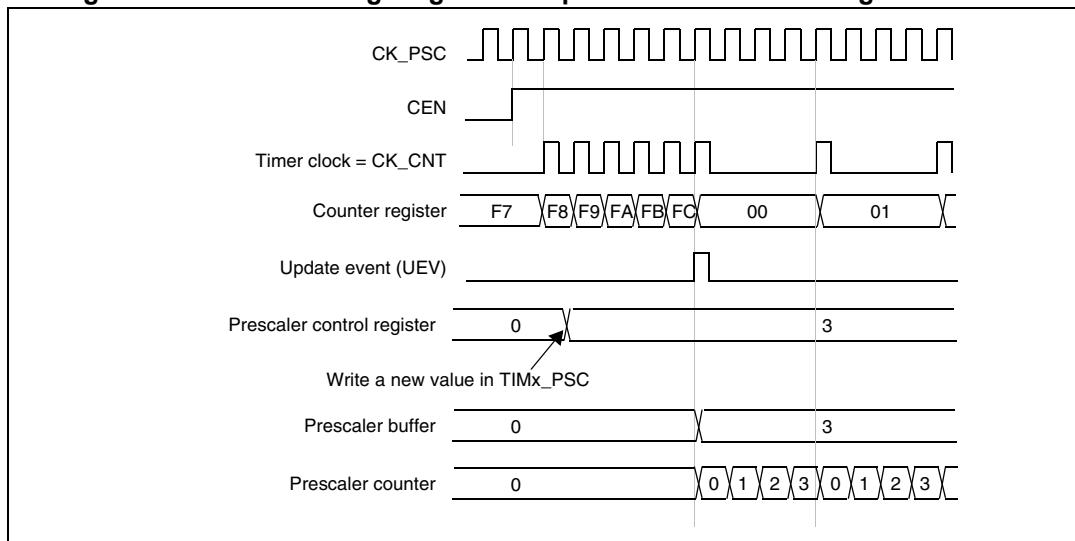
The counter is clocked by the prescaler output CK\_CNT, which is enabled only when the counter enable bit (CEN) in TIMx\_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

Note that the counter starts counting 1 clock cycle after setting the CEN bit in the TIMx\_CR1 register.

#### Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx\_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

*Figure 47* and *Figure 48* give some examples of the counter behavior when the prescaler ratio is changed on the fly:

**Figure 46. Counter timing diagram with prescaler division change from 1 to 2****Figure 47. Counter timing diagram with prescaler division change from 1 to 4**

### 15.3.2 Counter modes

#### Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx\_ARR register), then restarts from 0 and generates a counter overflow event.

If the repetition counter is used, the update event (UEV) is generated after upcounting is repeated for the number of times programmed in the repetition counter register (TIMx\_RCR). Else the update event is generated at each counter overflow.

Setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller) also generates an update event.

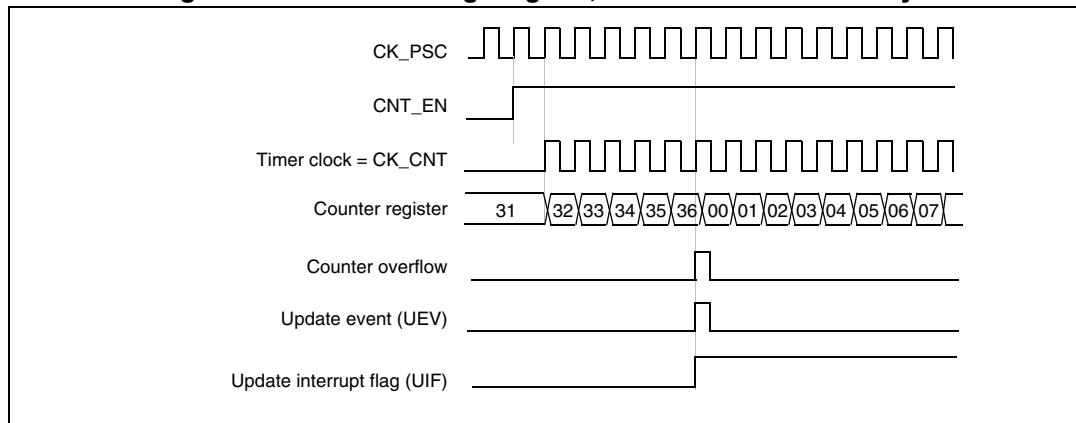
The UEV event can be disabled by software by setting the UDIS bit in the TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

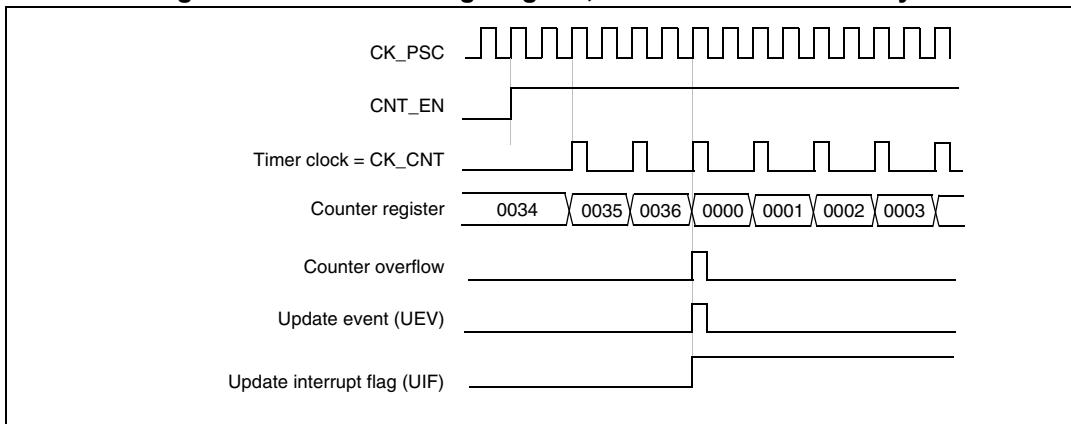
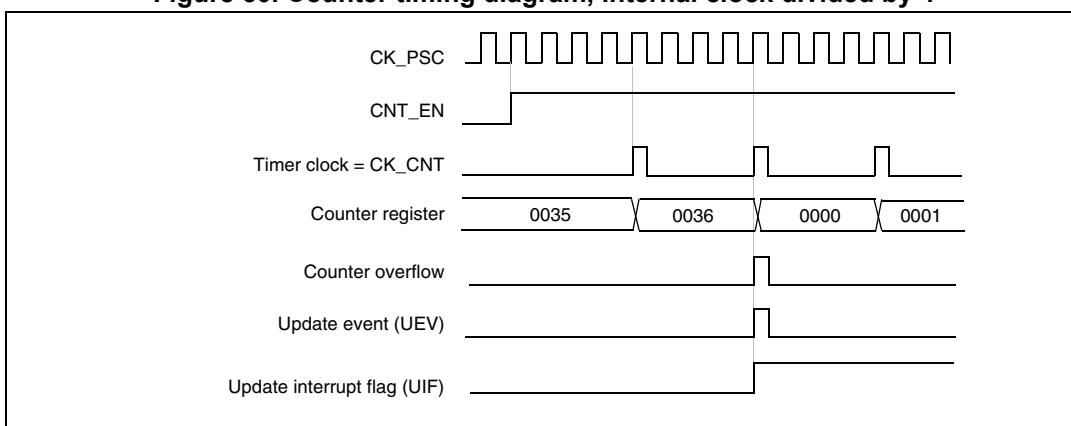
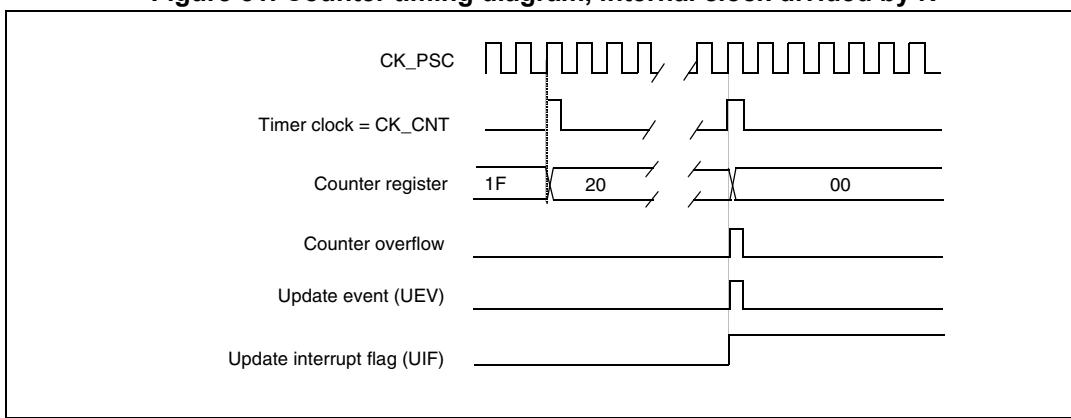
When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

- The repetition counter is reloaded with the content of TIMx\_RCR register,
- The auto-reload shadow register is updated with the preload value (TIMx\_ARR),
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register).

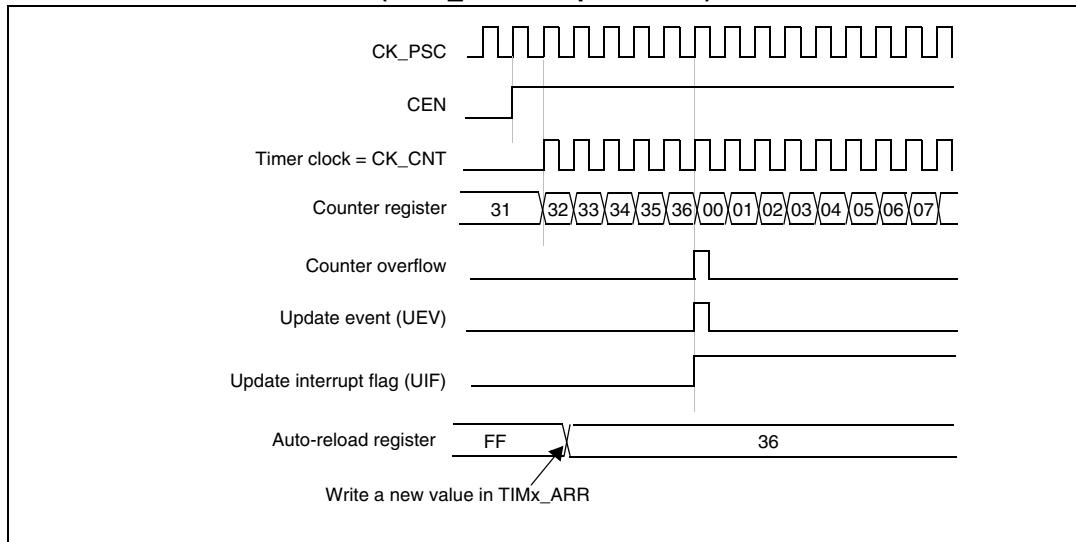
The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR=0x36.

**Figure 48. Counter timing diagram, internal clock divided by 1**

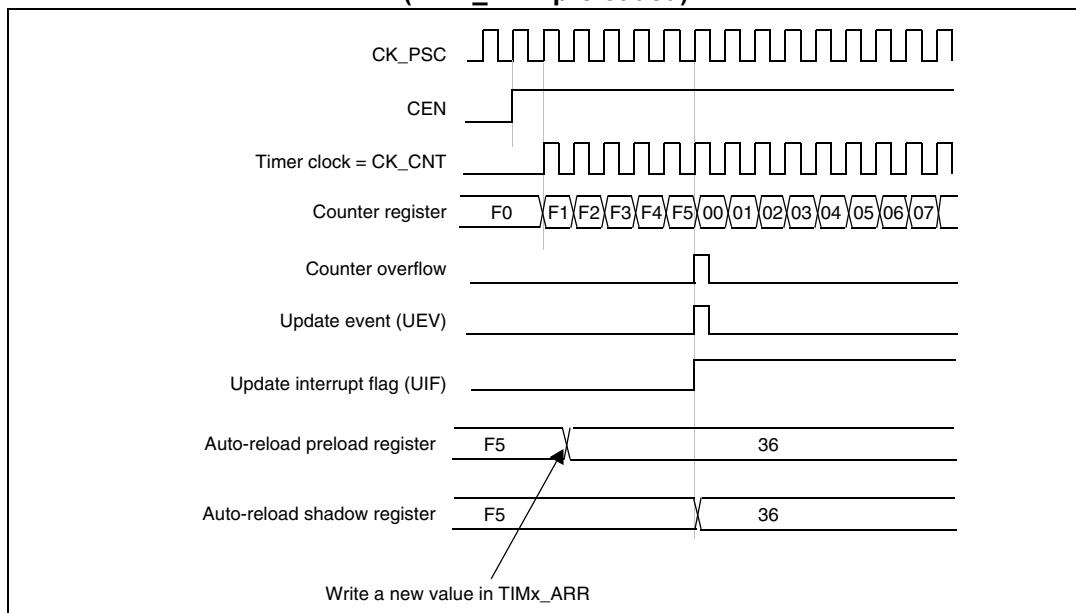


**Figure 49. Counter timing diagram, internal clock divided by 2****Figure 50. Counter timing diagram, internal clock divided by 4****Figure 51. Counter timing diagram, internal clock divided by N**

**Figure 52. Counter timing diagram, update event when ARPE=0  
(TIMx\_ARR not preloaded)**



**Figure 53. Counter timing diagram, update event when ARPE=1  
(TIMx\_ARR preloaded)**



### Downcounting mode

In downcounting mode, the counter counts from the auto-reload value (content of the TIMx\_ARR register) down to 0, then restarts from the auto-reload value and generates a counter underflow event.

If the repetition counter is used, the update event (UEV) is generated after downcounting is repeated for the number of times programmed in the repetition counter register (TIMx\_RCR). Else the update event is generated at each counter underflow.

Setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller) also generates an update event.

The UEV update event can be disabled by software by setting the UDIS bit in TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until UDIS bit has been written to 0. However, the counter restarts from the current auto-reload value, whereas the counter of the prescaler restarts from 0 (but the prescale rate doesn't change).

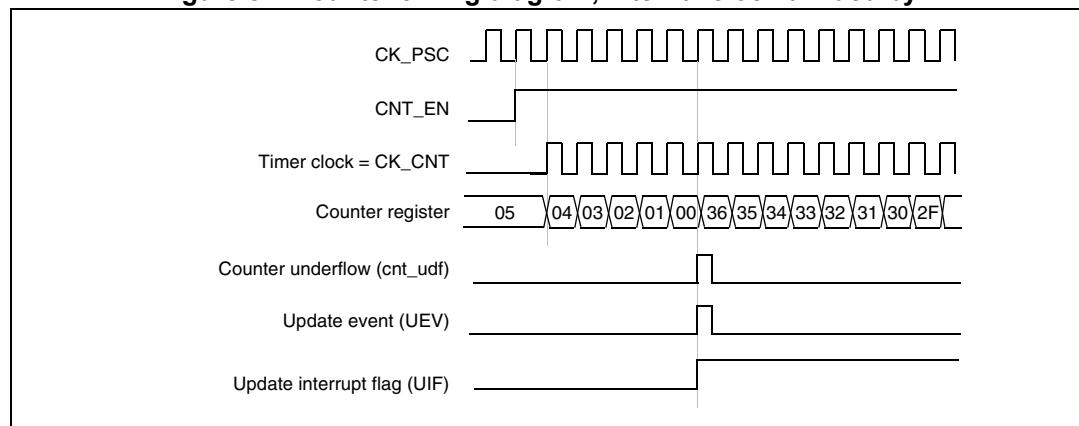
In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

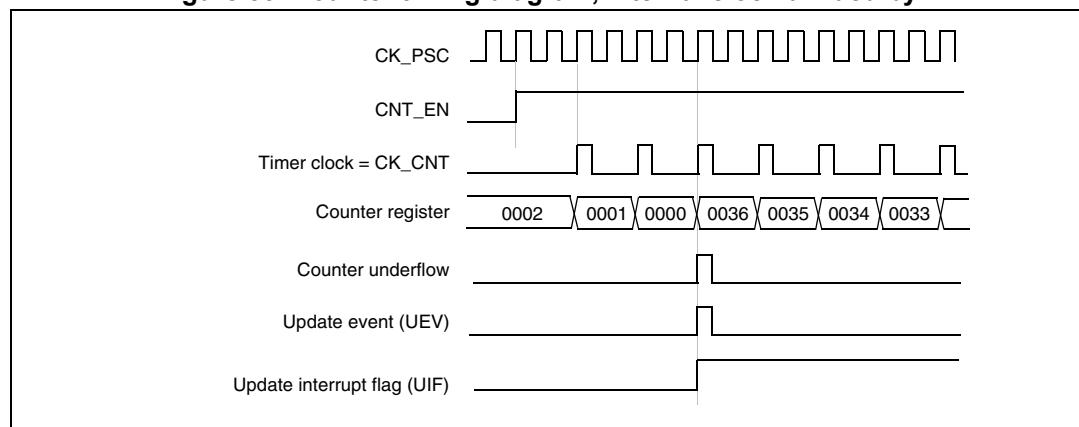
- The repetition counter is reloaded with the content of TIMx\_RCR register
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register)
- The auto-reload active register is updated with the preload value (content of the TIMx\_ARR register). Note that the auto-reload is updated before the counter is reloaded, so that the next period is the expected one

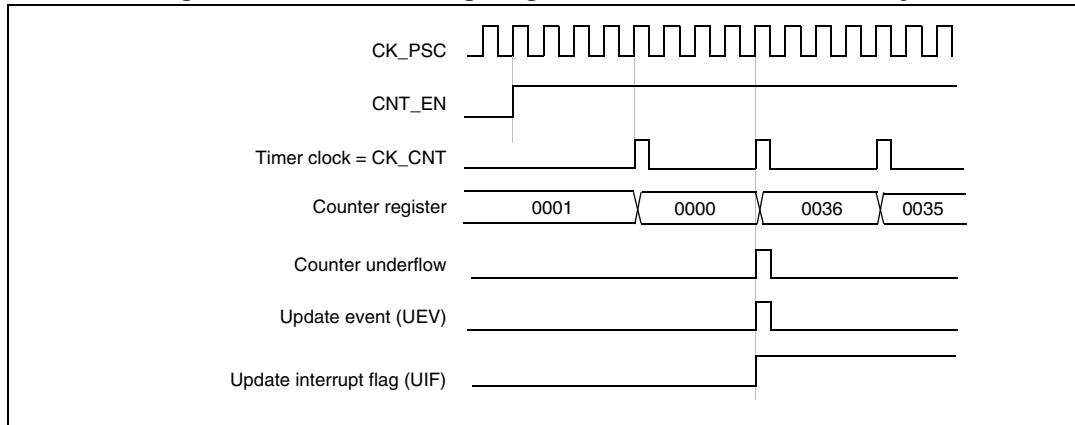
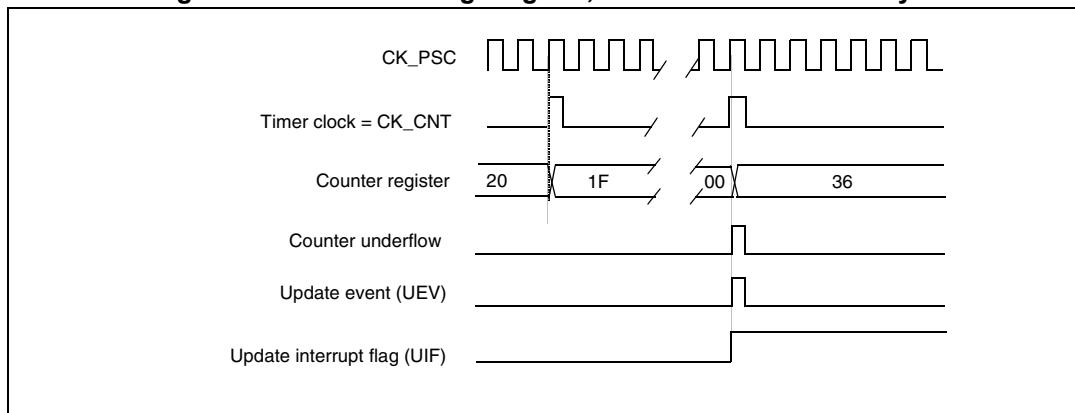
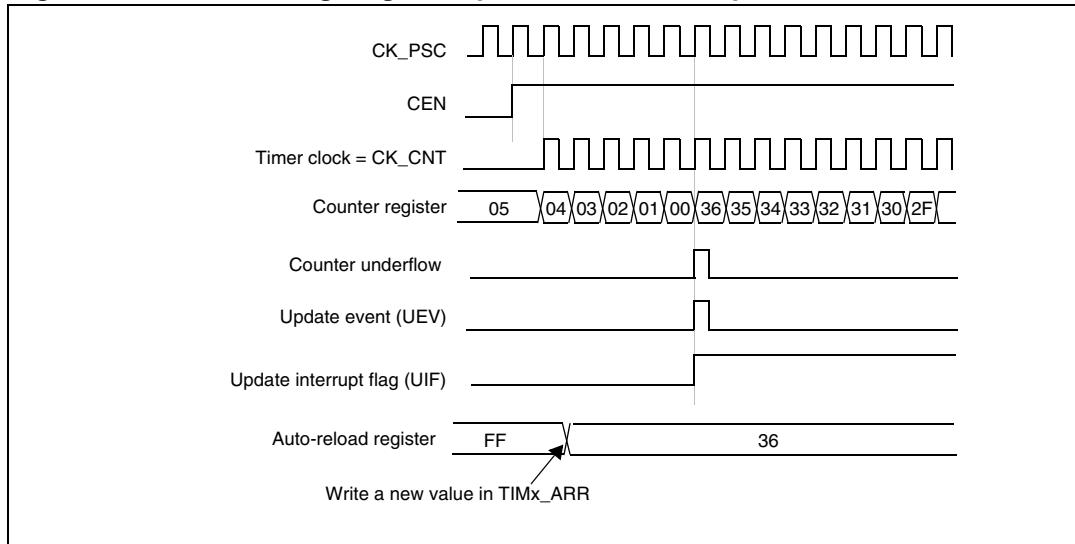
The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR=0x36.

**Figure 54. Counter timing diagram, internal clock divided by 1**



**Figure 55. Counter timing diagram, internal clock divided by 2**



**Figure 56. Counter timing diagram, internal clock divided by 4****Figure 57. Counter timing diagram, internal clock divided by N****Figure 58. Counter timing diagram, update event when repetition counter is not used**

### Center-aligned mode (up/down counting)

In center-aligned mode, the counter counts from 0 to the auto-reload value (content of the TIMx\_ARR register) – 1, generates a counter overflow event, then counts from the auto-reload value down to 1 and generates a counter underflow event. Then it restarts counting from 0.

Center-aligned mode is active when the CMS bits in TIMx\_CR1 register are not equal to '00'. The Output compare interrupt flag of channels configured in output is set when: the counter counts down (Center aligned mode 1, CMS = "01"), the counter counts up (Center aligned mode 2, CMS = "10") the counter counts up and down (Center aligned mode 3, CMS = "11").

In this mode, the DIR direction bit in the TIMx\_CR1 register cannot be written. It is updated by hardware and gives the current direction of the counter.

The update event can be generated at each counter overflow and at each counter underflow or by setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller) also generates an update event. In this case, the counter restarts counting from 0, as well as the counter of the prescaler.

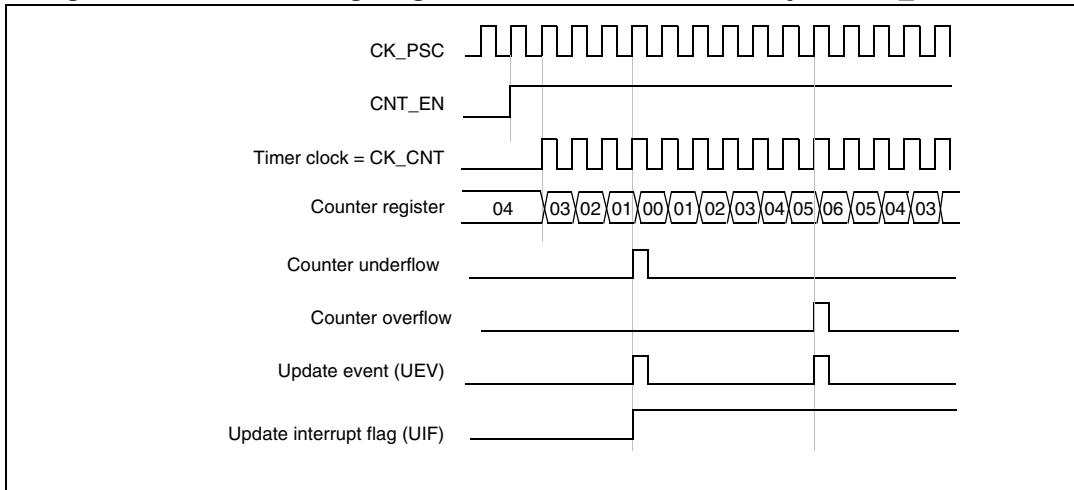
The UEV update event can be disabled by software by setting the UDIS bit in the TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until UDIS bit has been written to 0. However, the counter continues counting up and down, based on the current auto-reload value.

In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an UEV update event but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

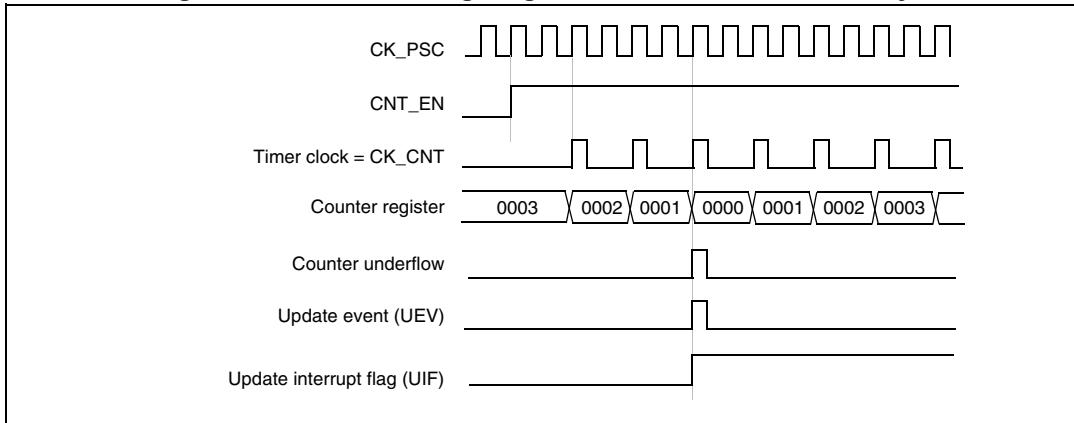
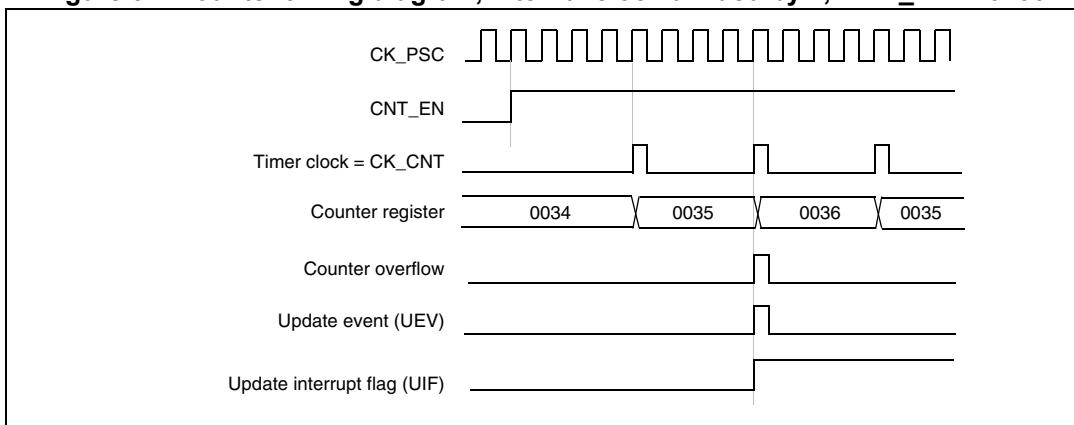
When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

- The repetition counter is reloaded with the content of TIMx\_RCR register
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register)
- The auto-reload active register is updated with the preload value (content of the TIMx\_ARR register). Note that if the update source is a counter overflow, the auto-reload is updated before the counter is reloaded, so that the next period is the expected one (the counter is loaded with the new value).

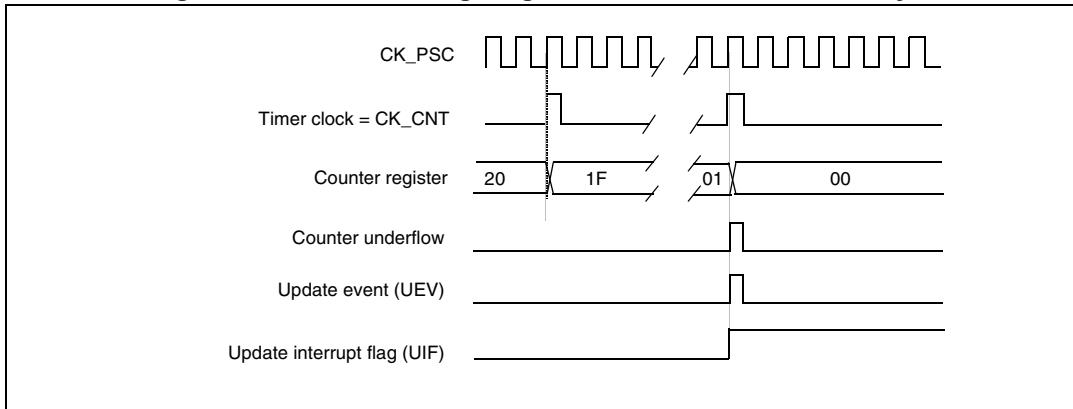
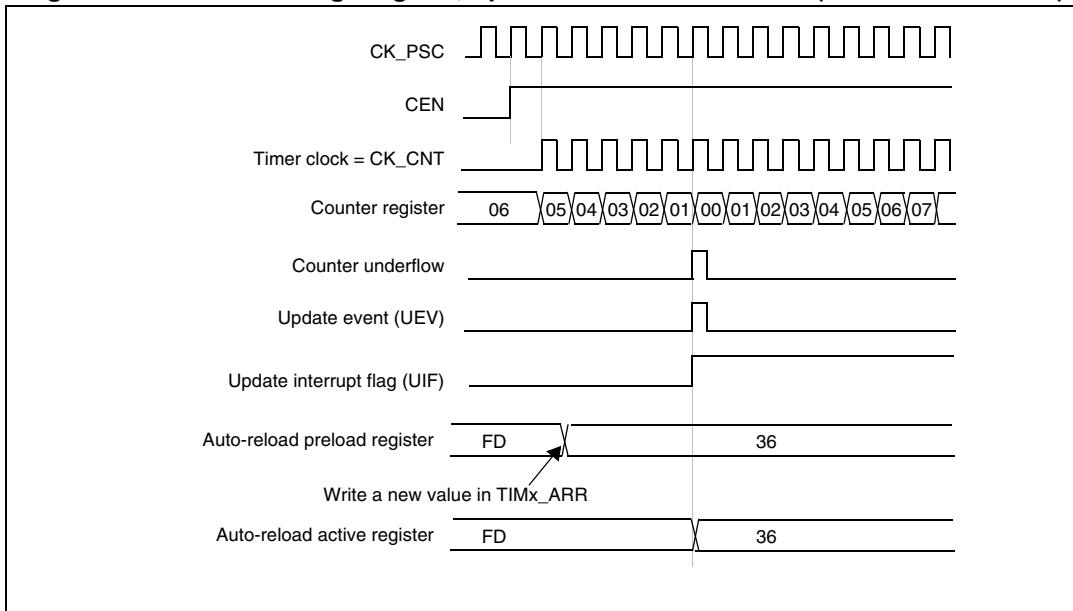
The following figures show some examples of the counter behavior for different clock frequencies.

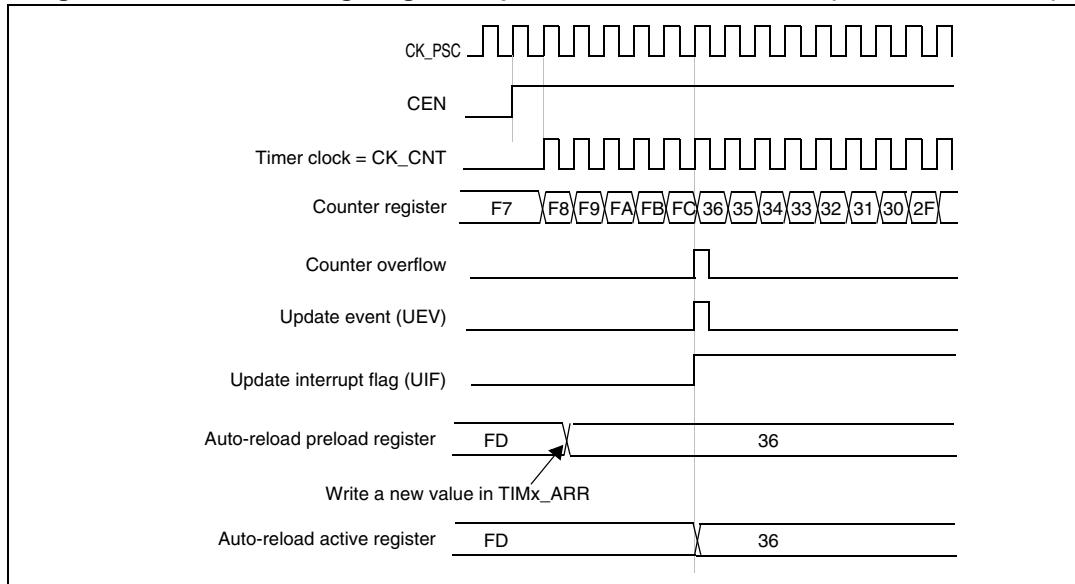
**Figure 59. Counter timing diagram, internal clock divided by 1, TIMx\_ARR = 0x6**

1. Here, center-aligned mode 1 is used (for more details refer to [Section 15.4: TIM1 registers on page 273](#)).

**Figure 60. Counter timing diagram, internal clock divided by 2****Figure 61. Counter timing diagram, internal clock divided by 4, TIMx\_ARR=0x36**

1. Center-aligned mode 2 or 3 is used with an UIF on overflow.

**Figure 62. Counter timing diagram, internal clock divided by N****Figure 63. Counter timing diagram, update event with ARPE=1 (counter underflow)**

**Figure 64. Counter timing diagram, Update event with ARPE=1 (counter overflow)**

### 15.3.3 Repetition counter

[Section 15.3.1: Time-base unit](#) describes how the update event (UEV) is generated with respect to the counter overflows/underflows. It is actually generated only when the repetition counter has reached zero. This can be useful when generating PWM signals.

This means that data are transferred from the preload registers to the shadow registers (TIMx\_ARR auto-reload register, TIMx\_PSC prescaler register, but also TIMx\_CCRx capture/compare registers in compare mode) every N counter overflows or underflows, where N is the value in the TIMx\_RCR repetition counter register.

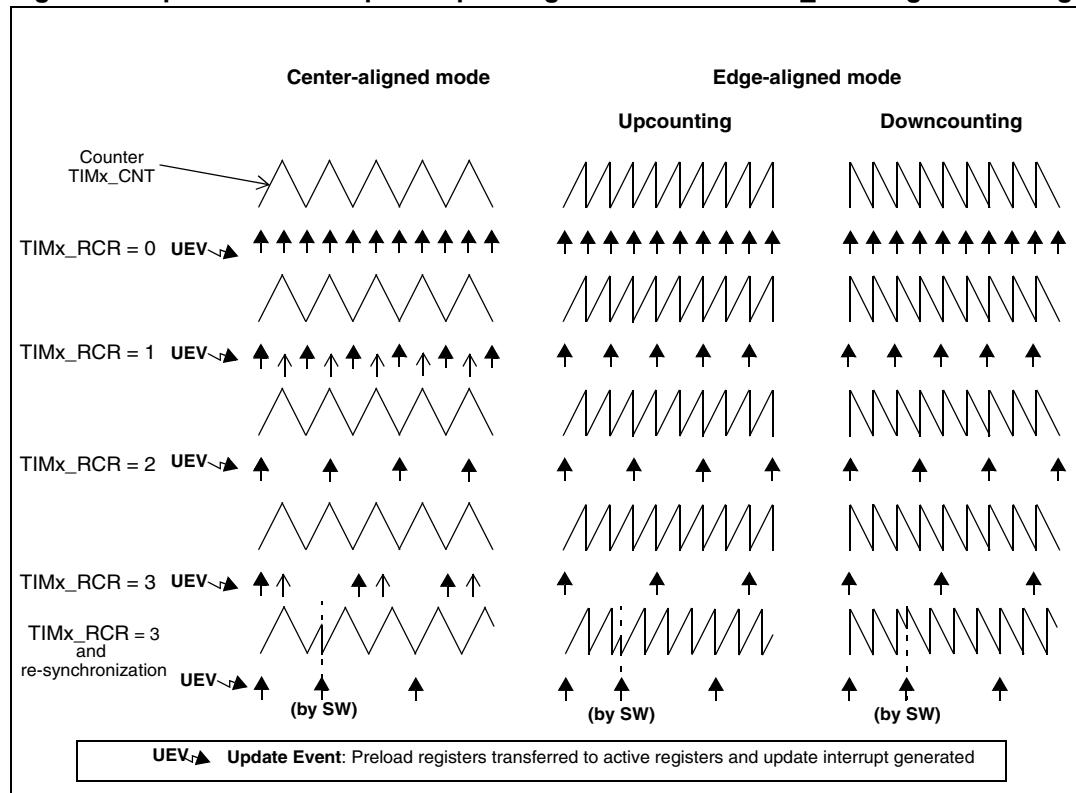
The repetition counter is decremented:

- At each counter overflow in upcounting mode,
  - At each counter underflow in downcounting mode,
  - At each counter overflow and at each counter underflow in center-aligned mode.
- Although this limits the maximum number of repetition to 128 PWM cycles, it makes it possible to update the duty cycle twice per PWM period. When refreshing compare registers only once per PWM period in center-aligned mode, maximum resolution is  $2 \times T_{ck}$ , due to the symmetry of the pattern.

The repetition counter is an auto-reload type; the repetition rate is maintained as defined by the TIMx\_RCR register value (refer to [Figure 65](#)). When the update event is generated by software (by setting the UG bit in TIMx\_EGR register) or by hardware through the slave mode controller, it occurs immediately whatever the value of the repetition counter is and the repetition counter is reloaded with the content of the TIMx\_RCR register.

In center-aligned mode, for odd values of RCR, the update event occurs either on the overflow or on the underflow depending on when the RCR register was written and when the counter was started. If the RCR was written before starting the counter, the UEV occurs on the overflow. If the RCR was written after starting the counter, the UEV occurs on the underflow. For example for RCR = 3, the UEV is generated on each 4th overflow or underflow event depending on when RCR was written.

Figure 65. Update rate examples depending on mode and TIMx\_RCR register settings



### 15.3.4 Clock sources

The counter clock can be provided by the following clock sources:

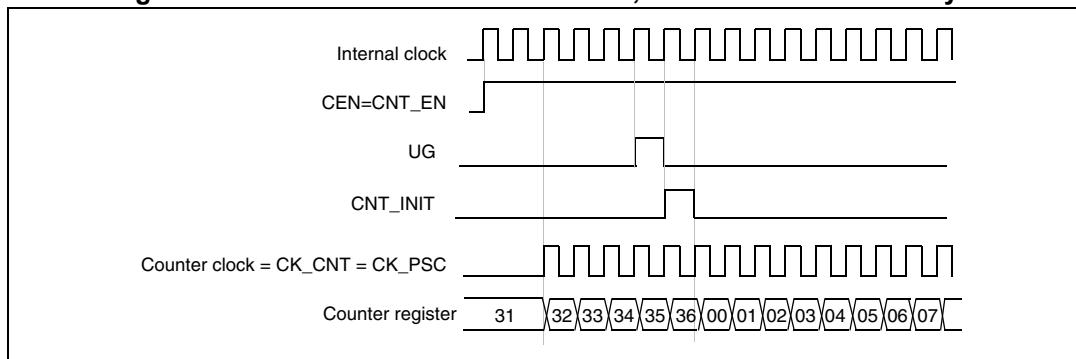
- Internal clock (CK\_INT)
- External clock mode1: external input pin
- External clock mode2: external trigger input ETR
- Internal trigger inputs (ITRx): using one timer as prescaler for another timer, for example, you can configure Timer 1 to act as a prescaler for Timer 2. Refer to [Using one timer as prescaler for another timer](#) for more details.

#### Internal clock source (CK\_INT)

If the slave mode controller is disabled (SMS=000), then the CEN, DIR (in the TIMx\_CR1 register) and UG bits (in the TIMx\_EGR register) are actual control bits and can be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK\_INT.

[Figure 66](#) shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

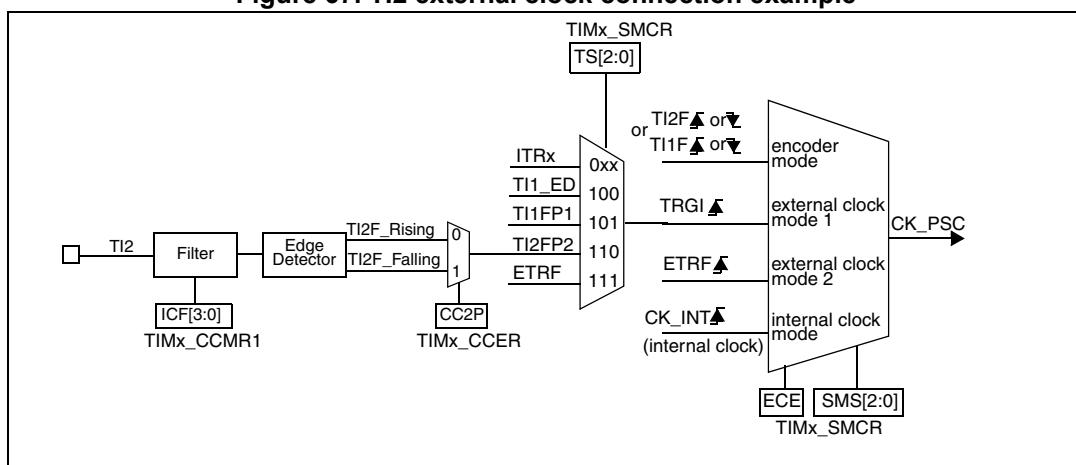
**Figure 66. Control circuit in normal mode, internal clock divided by 1**



#### External clock source mode 1

This mode is selected when SMS=111 in the TIMx\_SMCR register. The counter can count at each rising or falling edge on a selected input.

**Figure 67. TI2 external clock connection example**



For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

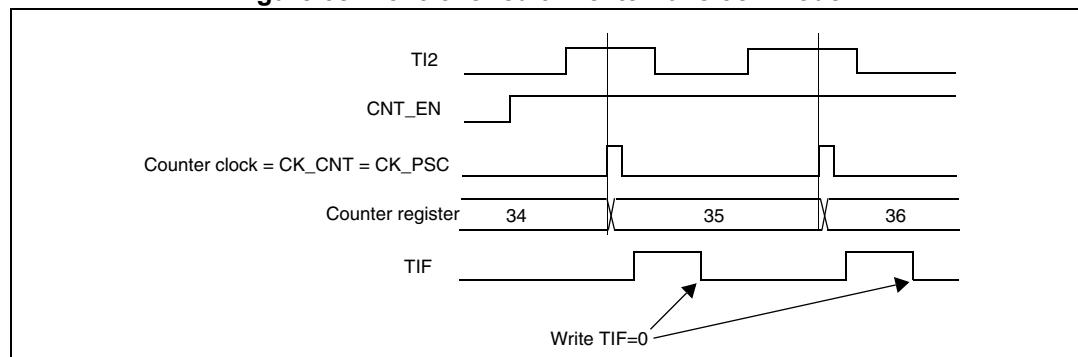
1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S = '01' in the TIMx\_CCMR1 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIMx\_CCMR1 register (if no filter is needed, keep IC2F=0000).
3. Select rising edge polarity by writing CC2P=0 in the TIMx\_CCER register.
4. Configure the timer in external clock mode 1 by writing SMS=111 in the TIMx\_SMCR register.
5. Select TI2 as the trigger input source by writing TS=110 in the TIMx\_SMCR register.
6. Enable the counter by writing CEN=1 in the TIMx\_CR1 register.

*Note:* The capture prescaler is not used for triggering, so you don't need to configure it.

When a rising edge occurs on TI2, the counter counts once and the TIF flag is set.

The delay between the rising edge on TI2 and the actual clock of the counter is due to the resynchronization circuit on TI2 input.

**Figure 68. Control circuit in external clock mode 1**



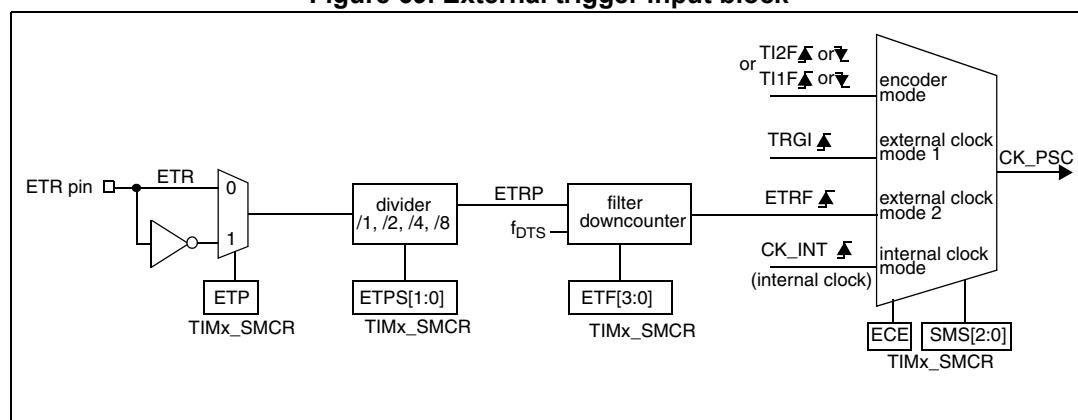
## External clock source mode 2

This mode is selected by writing ECE=1 in the TIMx\_SMCR register.

The counter can count at each rising or falling edge on the external trigger input ETR.

The [Figure 69](#) gives an overview of the external trigger input block.

**Figure 69. External trigger input block**



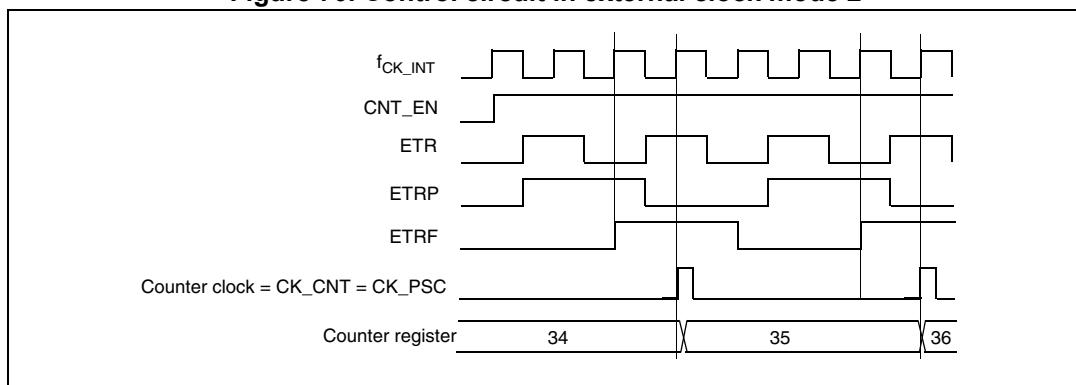
For example, to configure the upcounter to count each 2 rising edges on ETR, use the following procedure:

1. As no filter is needed in this example, write ETF[3:0]=0000 in the TIMx\_SMCR register.
2. Set the prescaler by writing ETPS[1:0]=01 in the TIMx\_SMCR register
3. Select rising edge detection on the ETR pin by writing ETP=0 in the TIMx\_SMCR register
4. Enable external clock mode 2 by writing ECE=1 in the TIMx\_SMCR register.
5. Enable the counter by writing CEN=1 in the TIMx\_CR1 register.

The counter counts once each 2 ETR rising edges.

The delay between the rising edge on ETR and the actual clock of the counter is due to the resynchronization circuit on the ETRP signal.

**Figure 70. Control circuit in external clock mode 2**



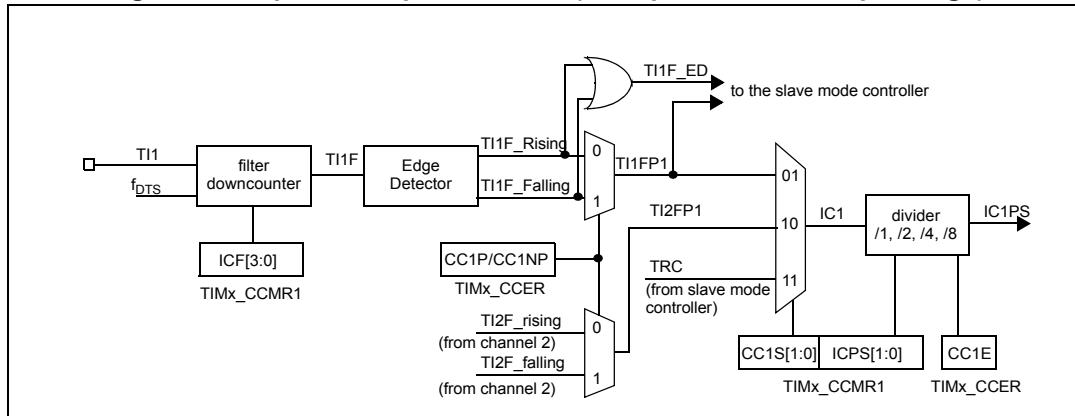
### 15.3.5 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

*Figure 71 to Figure 74* give an overview of one Capture/Compare channel.

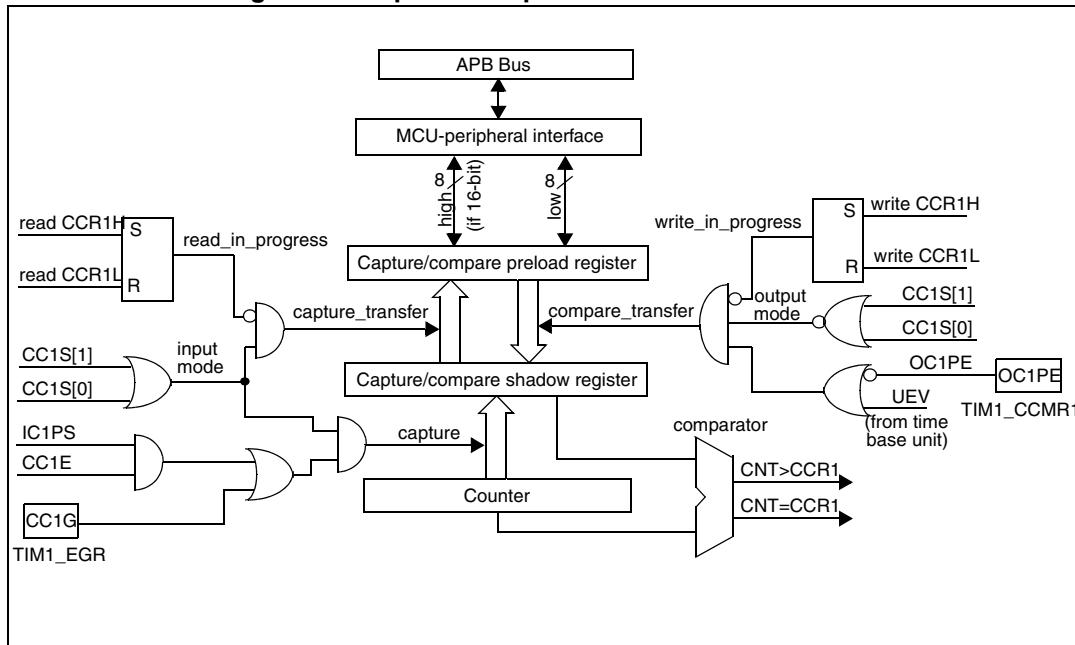
The input stage samples the corresponding TIx input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

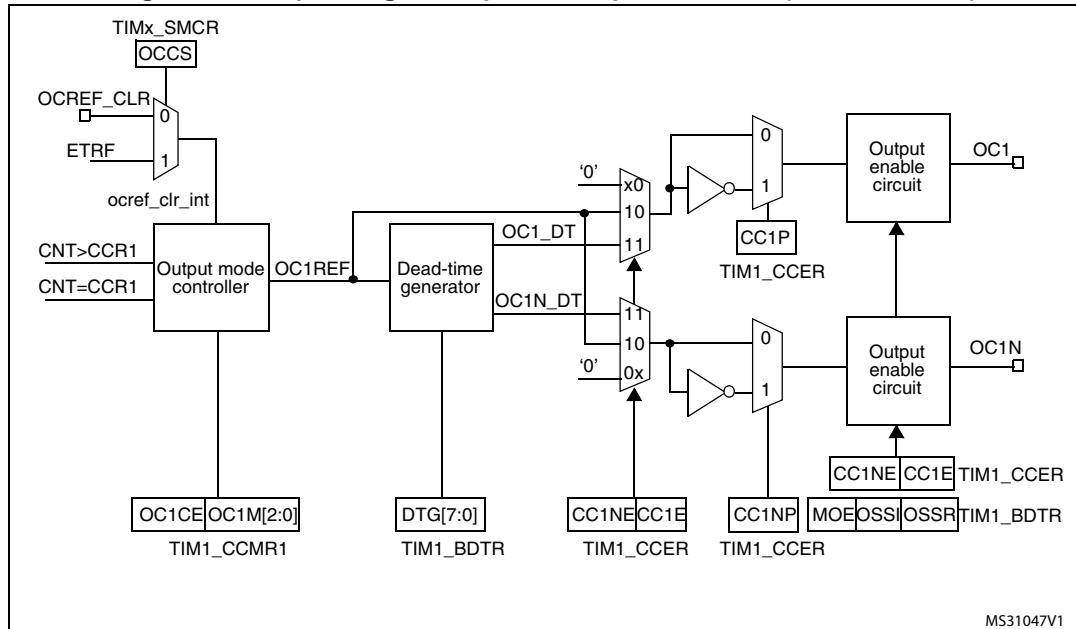
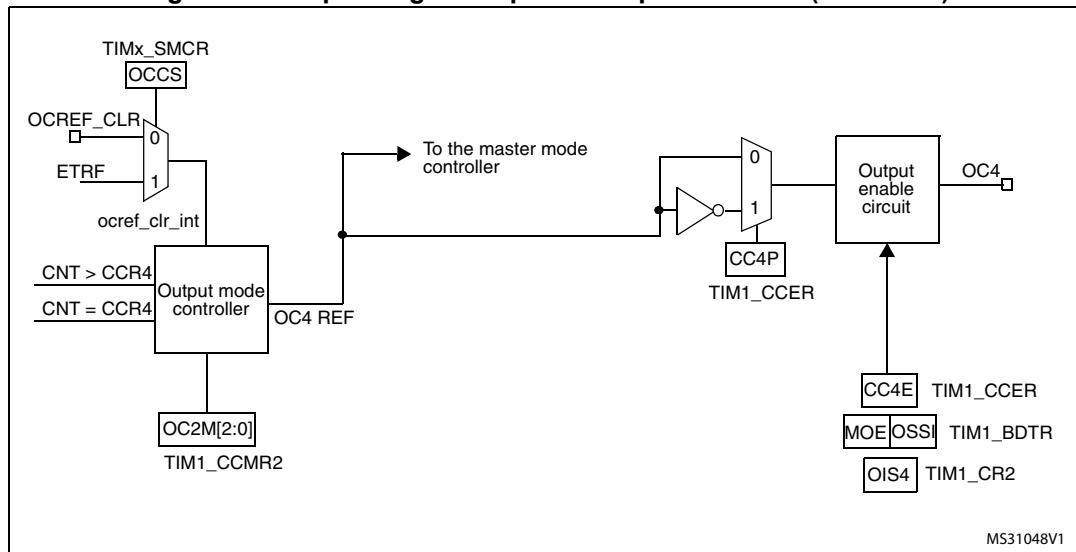
Figure 71. Capture/compare channel (example: channel 1 input stage)



The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

Figure 72. Capture/compare channel 1 main circuit



**Figure 73. Output stage of capture/compare channel (channel 1 to 3)****Figure 74. Output stage of capture/compare channel (channel 4)**

The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

### 15.3.6 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx\_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCxIF flag (TIMx\_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx\_SR register) is set. CCxIF can be cleared by software by writing it to '0' or by reading the captured data stored in the TIMx\_CCRx register. CCxOF is cleared when you write it to '0'.

The following example shows how to capture the counter value in TIMx\_CCR1 when TI1 input rises. To do this, use the following procedure:

- Select the active input: TIMx\_CCR1 must be linked to the TI1 input, so write the CC1S bits to 01 in the TIMx\_CCMR1 register. As soon as CC1S becomes different from 00, the channel is configured in input and the TIMx\_CCR1 register becomes read-only.
- Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx\_CCMRx register). Let's imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been detected (sampled at  $f_{DTS}$  frequency). Then write IC1F bits to 0011 in the TIMx\_CCMR1 register.
- Select the edge of the active transition on the TI1 channel by writing CC1P and CC1NP bits to 0 in the TIMx\_CCER register (rising edge in this case).
- Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to '00' in the TIMx\_CCMR1 register).
- Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx\_CCER register.
- If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx\_DIER register, and/or the DMA request by setting the CC1DE bit in the TIMx\_DIER register.

When an input capture occurs:

- The TIMx\_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.
- A DMA request is generated depending on the CC1DE bit.

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

*Note:*

*IC interrupt and/or DMA requests can be generated by software by setting the corresponding CCxG bit in the TIMx\_EGR register.*

### 15.3.7 PWM input mode

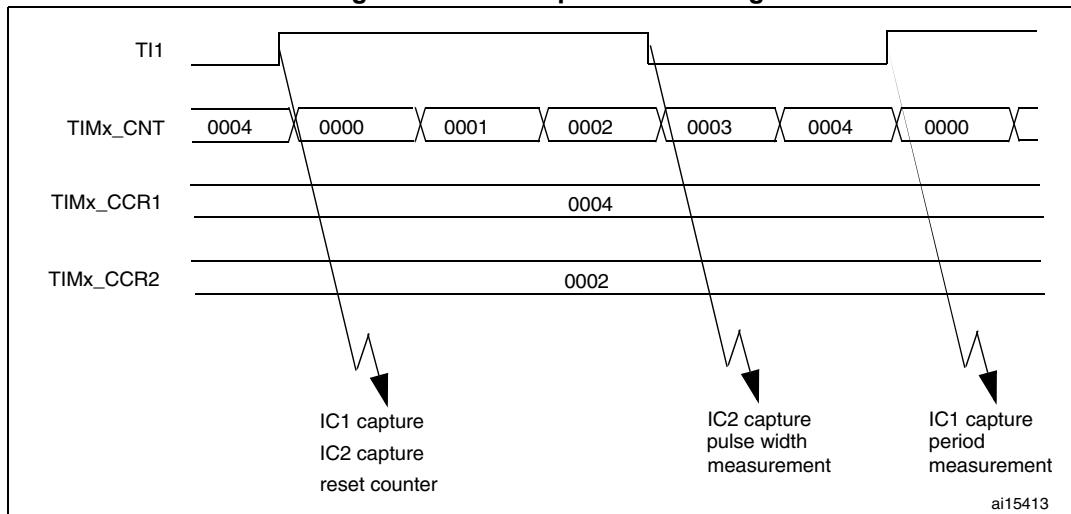
This mode is a particular case of input capture mode. The procedure is the same except:

- Two ICx signals are mapped on the same TIx input.
- These 2 ICx signals are active on edges with opposite polarity.
- One of the two TIxFP signals is selected as trigger input and the slave mode controller is configured in reset mode.

For example, you can measure the period (in TIMx\_CCR1 register) and the duty cycle (in TIMx\_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on CK\_INT frequency and prescaler value):

- Select the active input for TIMx\_CCR1: write the CC1S bits to 01 in the TIMx\_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP1 (used both for capture in TIMx\_CCR1 and counter clear): write the CC1P and CC1NP bits to '0' (active on rising edge).
- Select the active input for TIMx\_CCR2: write the CC2S bits to 10 in the TIMx\_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP2 (used for capture in TIMx\_CCR2): write the CC2P bit to '1' (active on falling edge).
- Select the valid trigger input: write the TS bits to 101 in the TIMx\_SMCR register (TI1FP1 selected).
- Configure the slave mode controller in reset mode: write the SMS bits to 100 in the TIMx\_SMCR register.
- Enable the captures: write the CC1E and CC2E bits to '1' in the TIMx\_CCER register.

**Figure 75. PWM input mode timing**



### 15.3.8 Forced output mode

In output mode (CCxS bits = 00 in the TIMx\_CCMRx register), each output compare signal (OCxREF and then OCx/OCxN) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (OCXREF/OCx) to its active level, you just need to write 101 in the OCxM bits in the corresponding TIMx\_CCMRx register. Thus OCXREF is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

For example: CCxP=0 (OCx active high) => OCx is forced to high level.

The OCxREF signal can be forced low by writing the OCxM bits to 100 in the TIMx\_CCMRx register.

Anyway, the comparison between the TIMx\_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt and DMA requests can be sent accordingly. This is described in the output compare mode section below.

### 15.3.9 Output compare mode

This function is used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

- Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx\_CCMRx register) and the output polarity (CCxP bit in the TIMx\_CCER register). The output pin can keep its level (OCXM=000), be set active (OCXM=001), be set inactive (OCXM=010) or can toggle (OCXM=011) on match.
- Sets a flag in the interrupt status register (CCxIF bit in the TIMx\_SR register).
- Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx\_DIER register).
- Sends a DMA request if the corresponding enable bit is set (CCxDE bit in the TIMx\_DIER register, CCDS bit in the TIMx\_CR2 register for the DMA request selection).

The TIMx\_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx\_CCMRx register.

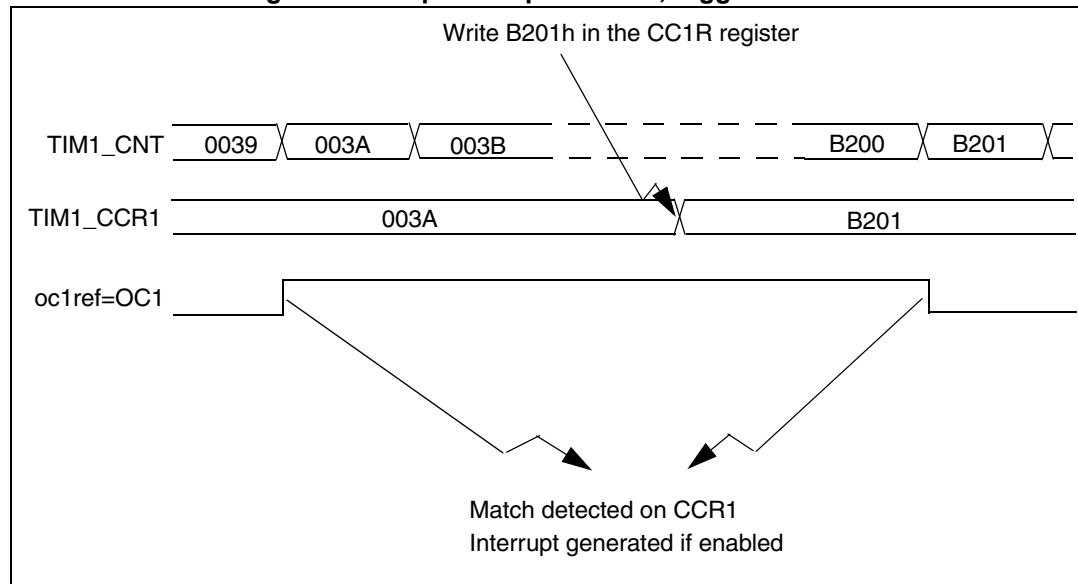
In output compare mode, the update event UEV has no effect on OCxREF and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One Pulse mode).

Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx\_ARR and TIMx\_CCRx registers.
3. Set the CCxIE bit if an interrupt request is to be generated.
4. Select the output mode. For example:
  - Write OCxM = 011 to toggle OCx output pin when CNT matches CCRx
  - Write OCxPE = 0 to disable preload register
  - Write CCxP = 0 to select active high polarity
  - Write CCxE = 1 to enable the output
5. Enable the counter by setting the CEN bit in the TIMx\_CR1 register.

The TIMx\_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE='0', else TIMx\_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 76](#).

**Figure 76. Output compare mode, toggle on OC1**



### 15.3.10 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx\_ARR register and a duty cycle determined by the value of the TIMx\_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing '110' (PWM mode 1) or '111' (PWM mode 2) in the OCxM bits in the TIMx\_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx\_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx\_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx\_EGR register.

OCx polarity is software programmable using the CCxP bit in the TIMx\_CCER register. It can be programmed as active high or active low. OCx output is enabled by a combination of the CCxE, CCxNE, MOE, OSS1 and OSSR bits (TIMx\_CCER and TIMx\_BDTR registers). Refer to the TIMx\_CCER register description for more details.

In PWM mode (1 or 2), TIMx\_CNT and TIMx\_CCRx are always compared to determine whether  $\text{TIMx\_CCR}_x \leq \text{TIMx\_CNT}$  or  $\text{TIMx\_CNT} \leq \text{TIMx\_CCR}_x$  (depending on the direction of the counter).

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIMx\_CR1 register.

### PWM edge-aligned mode

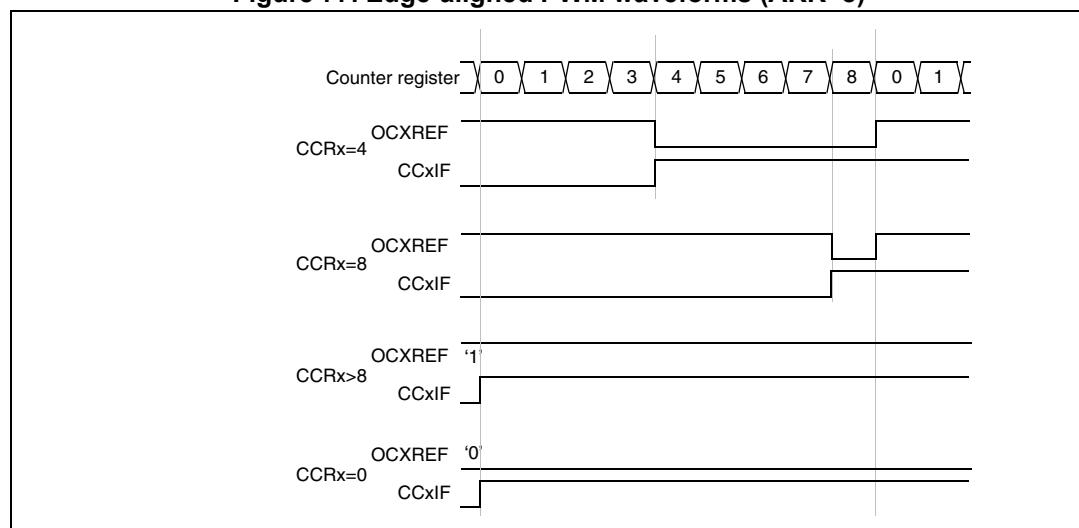
- Upcounting configuration

Upcounting is active when the DIR bit in the TIMx\_CR1 register is low. Refer to the [Upcounting mode on page 235](#).

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as  $\text{TIMx\_CNT} < \text{TIMx\_CCR}_x$  else it becomes low. If the compare value in TIMx\_CCRx is greater than the auto-reload value (in TIMx\_ARR) then OCxREF is held at '1'. If the compare value is 0 then OCxRef is held at '0'.

[Figure 77](#) shows some edge-aligned PWM waveforms in an example where TIMx\_ARR=8.

**Figure 77. Edge-aligned PWM waveforms (ARR=8)**



- Downcounting configuration

Downcounting is active when DIR bit in TIMx\_CR1 register is high. Refer to the [Downcounting mode on page 237](#)

In PWM mode 1, the reference signal OCxRef is low as long as  $\text{TIMx\_CNT} > \text{TIMx\_CCR}_x$  else it becomes high. If the compare value in TIMx\_CCRx is greater than the auto-reload value in TIMx\_ARR, then OCxREF is held at '1'. 0% PWM is not possible in this mode.

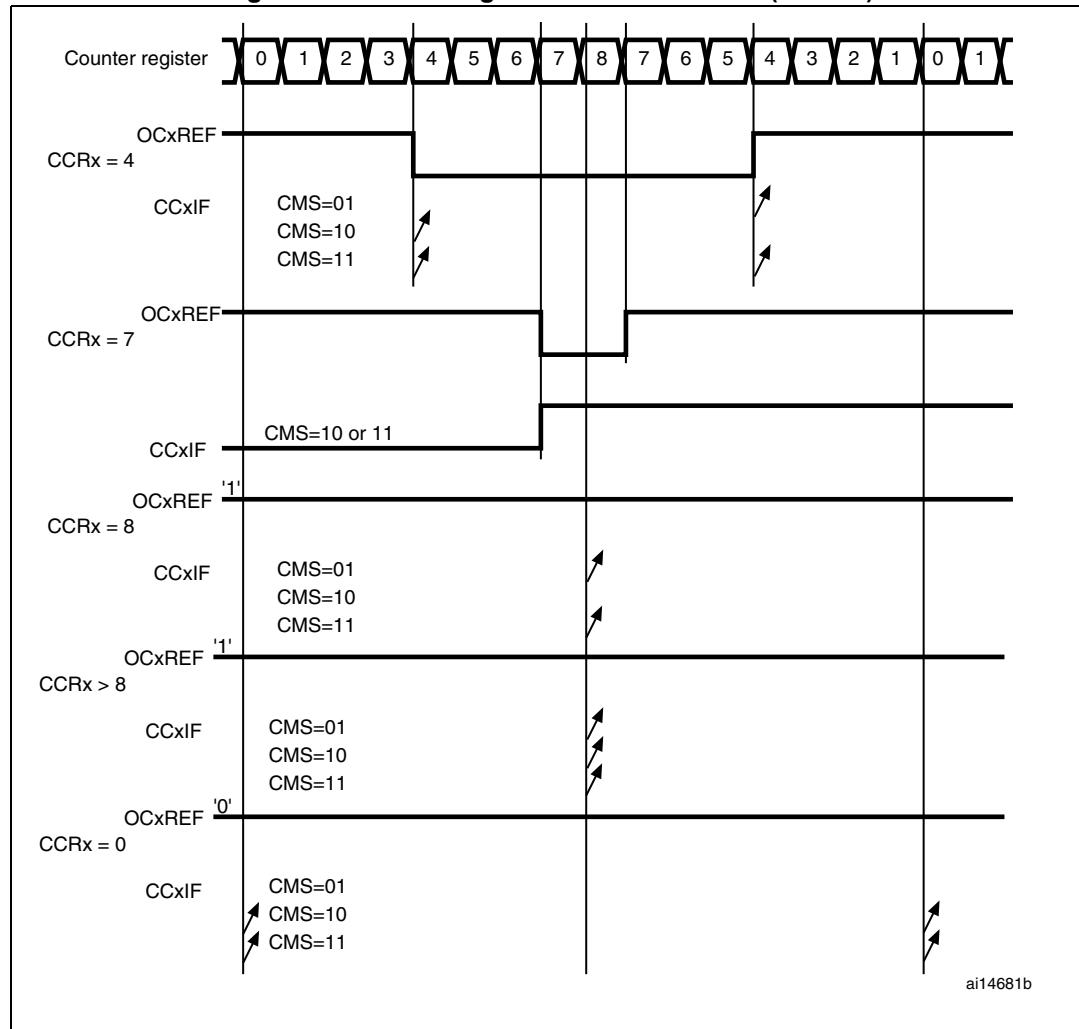
## PWM center-aligned mode

Center-aligned mode is active when the CMS bits in TIMx\_CR1 register are different from '00' (all the remaining configurations having the same effect on the OCxRef/OCx signals). The compare flag is set when the counter counts up, when it counts down or both when it counts up and down depending on the CMS bits configuration. The direction bit (DIR) in the TIMx\_CR1 register is updated by hardware and must not be changed by software. Refer to the [Center-aligned mode \(up/down counting\) on page 240](#).

*Figure 78* shows some center-aligned PWM waveforms in an example where:

- TIMx\_ARR=8,
  - PWM mode is the PWM mode 1,
  - The flag is set when the counter counts down corresponding to the center-aligned mode 1 selected for CMS=01 in TIMx\_CR1 register.

**Figure 78. Center-aligned PWM waveforms (ARR=8)**



Hints on using center-aligned mode:

- When starting in center-aligned mode, the current up-down configuration is used. It means that the counter counts up or down depending on the value written in the DIR bit in the TIMx\_CR1 register. Moreover, the DIR and CMS bits must not be changed at the same time by the software.
- Writing to the counter while running in center-aligned mode is not recommended as it can lead to unexpected results. In particular:
  - The direction is not updated if you write a value in the counter that is greater than the auto-reload value (TIMx\_CNT>TIMx\_ARR). For example, if the counter was counting up, it continues to count up.
  - The direction is updated if you write 0 or write the TIMx\_ARR value in the counter but no Update Event UEV is generated.
- The safest way to use center-aligned mode is to generate an update by software (setting the UG bit in the TIMx\_EGR register) just before starting the counter and not to write the counter while it is running.

### 15.3.11 Complementary outputs and dead-time insertion

The advanced-control timers (TIM1) can output two complementary signals and manage the switching-off and the switching-on instants of the outputs.

This time is generally known as dead-time and you have to adjust it depending on the devices you have connected to the outputs and their characteristics (intrinsic delays of level-shifters, delays due to power switches...)

You can select the polarity of the outputs (main output OC<sub>x</sub> or complementary OC<sub>xN</sub>) independently for each output. This is done by writing to the CC<sub>xP</sub> and CC<sub>xNP</sub> bits in the TIMx\_CCER register.

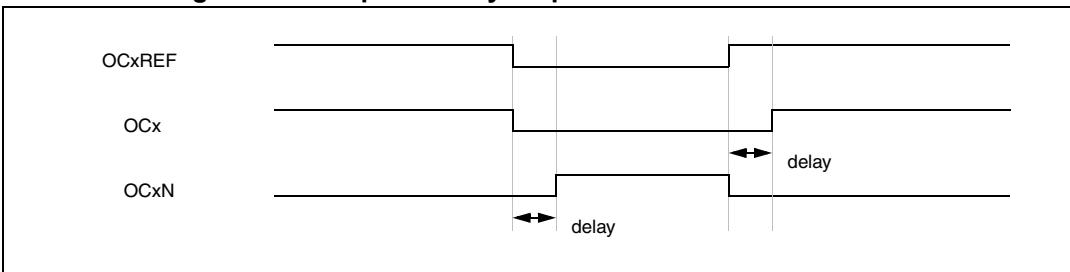
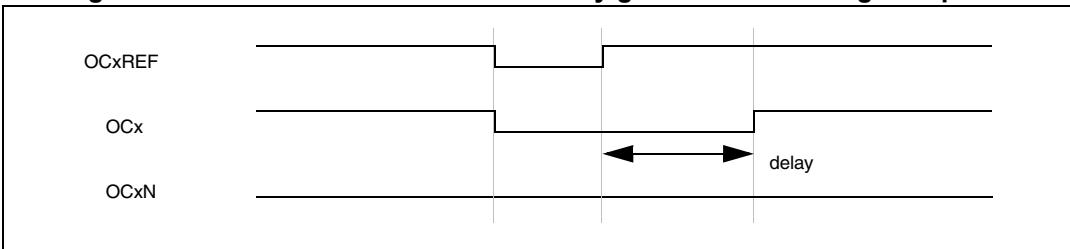
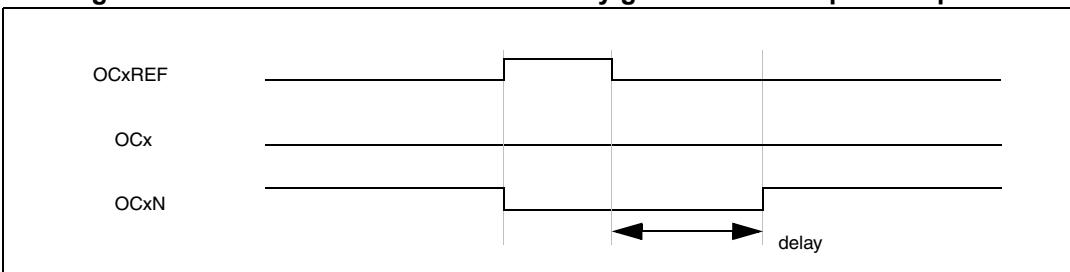
The complementary signals OC<sub>x</sub> and OC<sub>xN</sub> are activated by a combination of several control bits: the CC<sub>xE</sub> and CC<sub>xNE</sub> bits in the TIMx\_CCER register and the MOE, OIS<sub>x</sub>, OIS<sub>xN</sub>, OSS<sub>I</sub> and OSS<sub>R</sub> bits in the TIMx\_BDTR and TIMx\_CR2 registers. Refer to [Table 44: Output control bits for complementary OC<sub>x</sub> and OC<sub>xN</sub> channels with break feature on page 290](#) for more details. In particular, the dead-time is activated when switching to the IDLE state (MOE falling down to 0).

Dead-time insertion is enabled by setting both CC<sub>xE</sub> and CC<sub>xNE</sub> bits, and the MOE bit if the break circuit is present. There is one 10-bit dead-time generator for each channel. From a reference waveform OC<sub>xREF</sub>, it generates 2 outputs OC<sub>x</sub> and OC<sub>xN</sub>. If OC<sub>x</sub> and OC<sub>xN</sub> are active high:

- The OC<sub>x</sub> output signal is the same as the reference signal except for the rising edge, which is delayed relative to the reference rising edge.
- The OC<sub>xN</sub> output signal is the opposite of the reference signal except for the rising edge, which is delayed relative to the reference falling edge.

If the delay is greater than the width of the active output (OC<sub>x</sub> or OC<sub>xN</sub>) then the corresponding pulse is not generated.

The following figures show the relationships between the output signals of the dead-time generator and the reference signal OC<sub>xREF</sub>. (we suppose CC<sub>xP</sub>=0, CC<sub>xNP</sub>=0, MOE=1, CC<sub>xE</sub>=1 and CC<sub>xNE</sub>=1 in these examples)

**Figure 79. Complementary output with dead-time insertion.****Figure 80. Dead-time waveforms with delay greater than the positive pulse.****Figure 81. Dead-time waveforms with delay greater than the negative pulse.**

The dead-time delay is the same for each of the channels and is programmable with the DTG bits in the TIMx\_BDTR register. Refer to [Section 15.4.18: TIM1 break and dead-time register \(TIM1\\_BDTR\) on page 294](#) for delay calculation.

#### Re-directing OCxREF to OCx or OCxN

In output mode (forced, output compare or PWM), OCxREF can be re-directed to the OCx output or to OCxN output by configuring the CCxE and CCxNE bits in the TIMx\_CCER register.

This allows you to send a specific waveform (such as PWM or static active level) on one output while the complementary remains at its inactive level. Other alternative possibilities are to have both outputs at inactive level or both outputs active and complementary with dead-time.

**Note:** When only OCxN is enabled (CCxE=0, CCxNE=1), it is not complemented and becomes active as soon as OCxREF is high. For example, if CCxNP=0 then OCxN=OCxRef. On the other hand, when both OCx and OCxN are enabled (CCxE=CCxNE=1) OCx becomes active when OCxREF is high whereas OCxN is complemented and becomes active when OCxREF is low.

### 15.3.12 Using the break function

When using the break function, the output enable signals and inactive levels are modified according to additional control bits (MOE, OSS1 and OSSR bits in the TIMx\_BDTR register, OISx and OISxN bits in the TIMx\_CR2 register). In any case, the OCx and OCxN outputs cannot be set both to active level at a given time. Refer to [Table 44: Output control bits for complementary OCx and OCxN channels with break feature on page 290](#) for more details.

The break source can be either the break input pin or a clock failure event, generated by the Clock Security System (CSS), from the Reset Clock Controller. For further information on the Clock Security System, refer to [Section 7.2.7: Clock security system \(CSS\)](#).

When exiting from reset, the break circuit is disabled and the MOE bit is low. You can enable the break function by setting the BKE bit in the TIMx\_BDTR register. The break input polarity can be selected by configuring the BKP bit in the same register. BKE and BKP can be modified at the same time. When the BKE and BKP bits are written, a delay of 1 APB clock cycle is applied before the writing is effective. Consequently, it is necessary to wait 1 APB clock period to correctly read back the bit after the write operation.

Because MOE falling edge can be asynchronous, a resynchronization circuit has been inserted between the actual signal (acting on the outputs) and the synchronous control bit (accessed in the TIMx\_BDTR register). It results in some delays between the asynchronous and the synchronous signals. In particular, if you write MOE to 1 whereas it was low, you must insert a delay (dummy instruction) before reading it correctly. This is because you write the asynchronous signal and read the synchronous signal.

When a break occurs (selected level on the break input):

- The MOE bit is cleared asynchronously, putting the outputs in inactive state, idle state or in reset state (selected by the OSS1 bit). This feature functions even if the MCU oscillator is off.
- Each output channel is driven with the level programmed in the OISx bit in the TIMx\_CR2 register as soon as MOE=0. If OSS1=0 then the timer releases the enable output else the enable output remains high.
- When complementary outputs are used:
  - The outputs are first put in reset state inactive state (depending on the polarity). This is done asynchronously so that it works even if no clock is provided to the timer.
  - If the timer clock is still present, then the dead-time generator is reactivated in order to drive the outputs with the level programmed in the OISx and OISxN bits after a dead-time. Even in this case, OCx and OCxN cannot be driven to their active level together. Note that because of the resynchronization on MOE, the dead-time duration is a bit longer than usual (around 2 ck\_tim clock cycles).
  - If OSS1=0 then the timer releases the enable outputs else the enable outputs remain or become high as soon as one of the CCxE or CCxNE bits is high.
- The break status flag (BIF bit in the TIMx\_SR register) is set. An interrupt can be generated if the BIE bit in the TIMx\_DIER register is set. A DMA request can be sent if the BDE bit in the TIMx\_DIER register is set.
- If the AOE bit in the TIMx\_BDTR register is set, the MOE bit is automatically set again at the next update event UEV. This can be used to perform a regulation, for instance. Else, MOE remains low until you write it to '1' again. In this case, it can be used for security and you can connect the break input to an alarm from power drivers, thermal sensors or any security components.

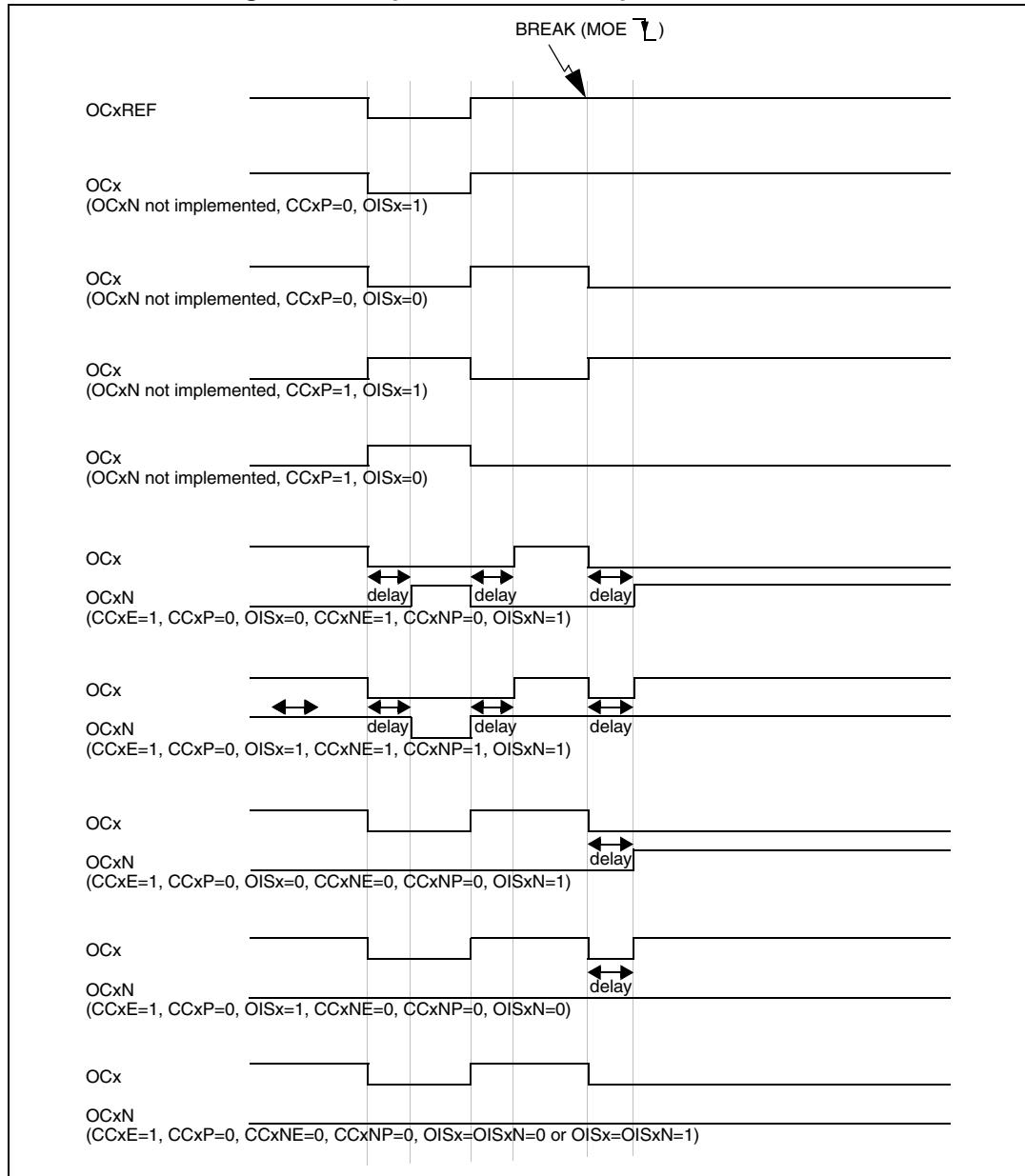
**Note:** *The break inputs is acting on level. Thus, the MOE cannot be set while the break input is active (neither automatically nor by software). In the meantime, the status flag BIF cannot be cleared.*

The break can be generated by the BRK input which has a programmable polarity and an enable bit BKE in the TIMx\_BDTR Register.

In addition to the break input and the output management, a write protection has been implemented inside the break circuit to safeguard the application. It allows you to freeze the configuration of several parameters (dead-time duration, OCx/OCxN polarities and state when disabled, OCxM configurations, break enable and polarity). You can choose from 3 levels of protection selected by the LOCK bits in the TIMx\_BDTR register. Refer to [Section 15.4.18: TIM1 break and dead-time register \(TIM1\\_BDTR\) on page 294](#). The LOCK bits can be written only once after an MCU reset.

The [Figure 82](#) shows an example of behavior of the outputs in response to a break.

Figure 82. Output behavior in response to a break



### 15.3.13 Clearing the OCxREF signal on an external event

The OCxREF signal of a given channel can be cleared when a high level is applied on the OCREF\_CLR\_INPUT (OCxCE enable bit in the corresponding TIMx\_CCMRx register set to '1'). OCxREF remains low until the next update event (UEV) occurs. This function can only be used in Output compare and PWM modes. It does not work in Forced mode.

OCREF\_CLR\_INPUT can be selected between the OCREF\_CLR input and ETRF (ETR after the filter) by configuring the OCCS bit in the TIMx\_SMCR register.

When ETRF is chosen, ETR must be configured as follows:

The OCxREF signal for a given channel can be driven Low by applying a High level to the ETRF input (OCxCE enable bit of the corresponding TIMx\_CCMRx register set to '1'). The OCxREF signal remains Low until the next update event, UEV, occurs.

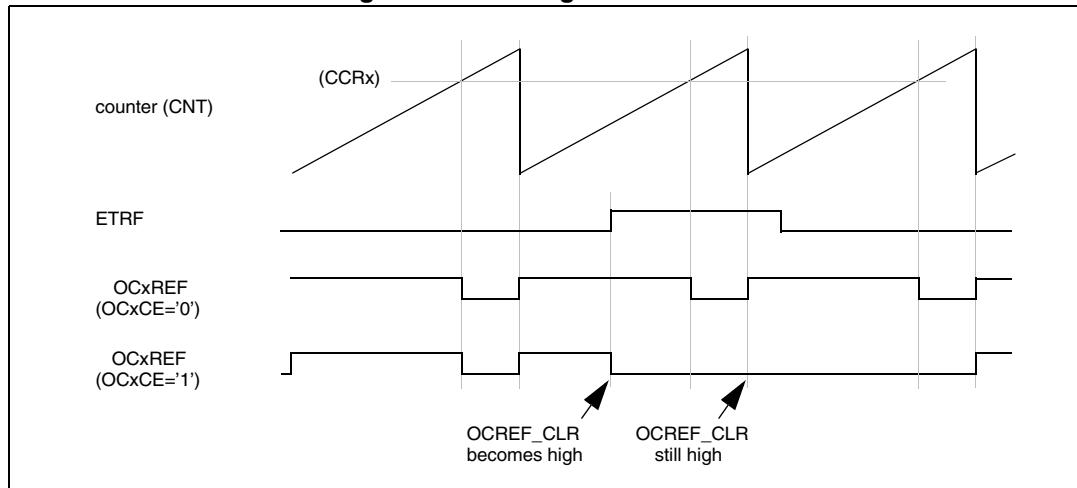
This function can only be used in output compare and PWM modes, and does not work in forced mode.

For example, the OCxREF signal can be connected to the output of a comparator to be used for current handling. In this case, the ETR must be configured as follow:

1. The External Trigger Prescaler should be kept off: bits ETPS[1:0] of the TIMx\_SMCR register set to '00'.
2. The external clock mode 2 must be disabled: bit ECE of the TIMx\_SMCR register set to '0'.
3. The External Trigger Polarity (ETP) and the External Trigger Filter (ETF) can be configured according to the user needs.

*Figure 83* shows the behavior of the OCxREF signal when the ETRF Input becomes High, for both values of the enable bit OCxCE. In this example, the timer TIMx is programmed in PWM mode.

**Figure 83. Clearing TIMx OCxREF**



Note:

*In case of a PWM with a 100 % duty cycle (if CCRx>ARR), then OCxREF is enabled again at the next counter overflow.*

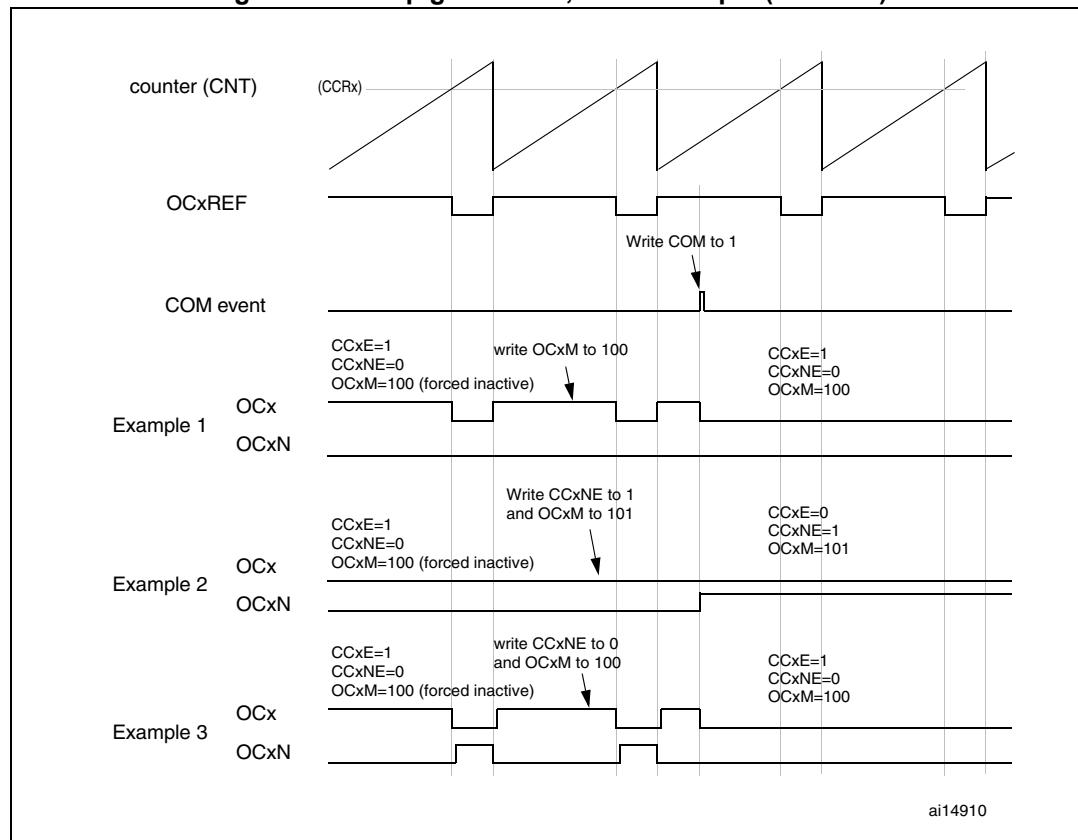
### 15.3.14 6-step PWM generation

When complementary outputs are used on a channel, preload bits are available on the OCxM, CCxE and CCxNE bits. The preload bits are transferred to the shadow bits at the COM commutation event. Thus you can program in advance the configuration for the next step and change the configuration of all the channels at the same time. COM can be generated by software by setting the COM bit in the TIMx\_EGR register or by hardware (on TRGI rising edge).

A flag is set when the COM event occurs (COMIF bit in the TIMx\_SR register), which can generate an interrupt (if the COMIE bit is set in the TIMx\_DIER register) or a DMA request (if the COMDE bit is set in the TIMx\_DIER register).

The [Figure 84](#) describes the behavior of the OCx and OCxN outputs when a COM event occurs, in 3 different examples of programmed configurations.

**Figure 84. 6-step generation, COM example (OSSR=1)**



### 15.3.15 One-pulse mode

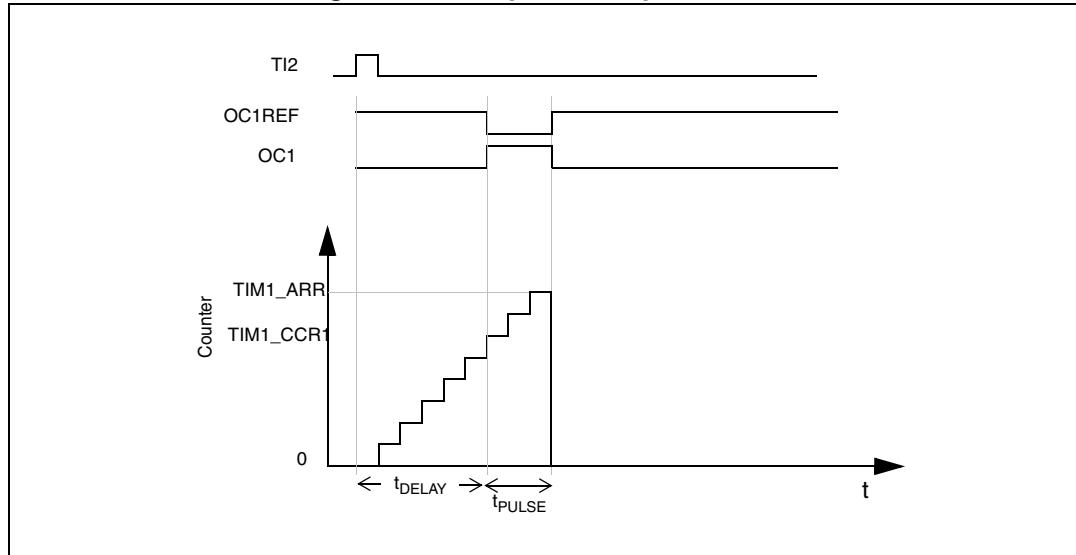
One-pulse mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

Starting the counter can be controlled through the slave mode controller. Generating the waveform can be done in output compare mode or PWM mode. You select One-pulse mode by setting the OPM bit in the TIMx\_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

- In upcounting: CNT < CCRx  $\leq$  ARR (in particular, 0 < CCRx)
- In downcounting: CNT > CCRx

**Figure 85. Example of one pulse mode**



For example you may want to generate a positive pulse on OC1 with a length of  $t_{PULSE}$  and after a delay of  $t_{DELAY}$  as soon as a positive edge is detected on the TI2 input pin.

Let's use TI2FP2 as trigger 1:

- Map TI2FP2 to TI2 by writing CC2S='01' in the TIMx\_CCMR1 register.
- TI2FP2 must detect a rising edge, write CC2P='0' and CC2NP='0' in the TIMx\_CCER register.
- Configure TI2FP2 as trigger for the slave mode controller (TRGI) by writing TS='110' in the TIMx\_SMCR register.
- TI2FP2 is used to start the counter by writing SMS to '110' in the TIMx\_SMCR register (trigger mode).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The  $t_{DELAY}$  is defined by the value written in the TIMx\_CCR1 register.
- The  $t_{PULSE}$  is defined by the difference between the auto-reload value and the compare value (TIMx\_ARR - TIMx\_CCR1).
- Let's say you want to build a waveform with a transition from '0' to '1' when a compare match occurs and a transition from '1' to '0' when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC1M=111 in the TIMx\_CCMR1 register. You can optionally enable the preload registers by writing OC1PE='1' in the TIMx\_CCMR1 register and ARPE in the TIMx\_CR1 register. In this case you have to write the compare value in the TIMx\_CCR1 register, the auto-reload value in the TIMx\_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0' in this example.

In our example, the DIR and CMS bits in the TIMx\_CR1 register should be low.

You only want 1 pulse (Single mode), so you write '1' in the OPM bit in the TIMx\_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0). When OPM bit in the TIMx\_CR1 register is set to '0', so the Repetitive Mode is selected.

#### **Particular case: OCx fast enable:**

In One-pulse mode, the edge detection on TIx input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay  $t_{DELAY}$  min we can get.

If you want to output a waveform with the minimum delay, you can set the OCxFE bit in the TIMx\_CCMRx register. Then OCxRef (and OCx) are forced in response to the stimulus, without taking in account the comparison. Its new level is the same as if a compare match had occurred. OCxFE acts only if the channel is configured in PWM1 or PWM2 mode.

### **15.3.16 Encoder interface mode**

To select Encoder Interface mode write SMS='001' in the TIMx\_SMCR register if the counter is counting on TI2 edges only, SMS='010' if it is counting on TI1 edges only and SMS='011' if it is counting on both TI1 and TI2 edges.

Select the TI1 and TI2 polarity by programming the CC1P and CC2P bits in the TIMx\_CCER register. When needed, you can program the input filter as well. CC1NP and CC2NP must be kept low.

The two inputs TI1 and TI2 are used to interface to an incremental encoder. Refer to [Table 42](#). The counter is clocked by each valid transition on TI1FP1 or TI2FP2 (TI1 and TI2 after input filter and polarity selection, TI1FP1=TI1 if not filtered and not inverted, TI2FP2=TI2 if not filtered and not inverted) assuming that it is enabled (CEN bit in TIMx\_CR1 register written to '1'). The sequence of transitions of the two inputs is evaluated and generates count pulses as well as the direction signal. Depending on the sequence the counter counts up or down, the DIR bit in the TIMx\_CR1 register is modified by hardware accordingly. The DIR bit is calculated at each transition on any input (TI1 or TI2), whatever the counter is counting on TI1 only, TI2 only or both TI1 and TI2.

Encoder interface mode acts simply as an external clock with direction selection. This means that the counter just counts continuously between 0 and the auto-reload value in the TIMx\_ARR register (0 to ARR or ARR down to 0 depending on the direction). So you must configure TIMx\_ARR before starting. in the same way, the capture, compare, prescaler, repetition counter, trigger output features continue to work as normal. Encoder mode and External clock mode 2 are not compatible and must not be selected together.

In this mode, the counter is modified automatically following the speed and the direction of the incremental encoder and its content, therefore, always represents the encoder's position. The count direction correspond to the rotation direction of the connected sensor. The table summarizes the possible combinations, assuming TI1 and TI2 don't switch at the same time.

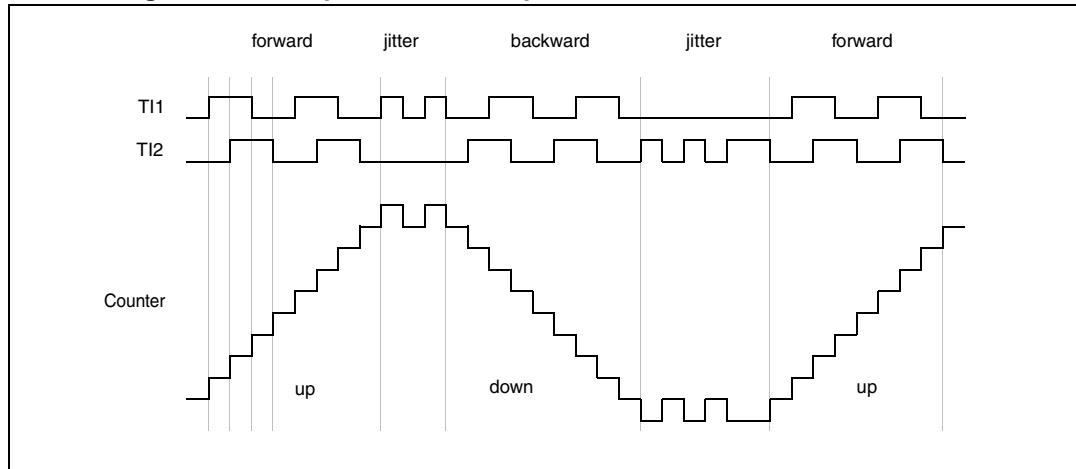
**Table 42. Counting direction versus encoder signals**

Active edge	Level on opposite signal (TI1FP1 for TI2, TI2FP2 for TI1)	TI1FP1 signal		TI2FP2 signal	
		Rising	Falling	Rising	Falling
Counting on TI1 only	High	Down	Up	No Count	No Count
	Low	Up	Down	No Count	No Count
Counting on TI2 only	High	No Count	No Count	Up	Down
	Low	No Count	No Count	Down	Up
Counting on TI1 and TI2	High	Down	Up	Up	Down
	Low	Up	Down	Down	Up

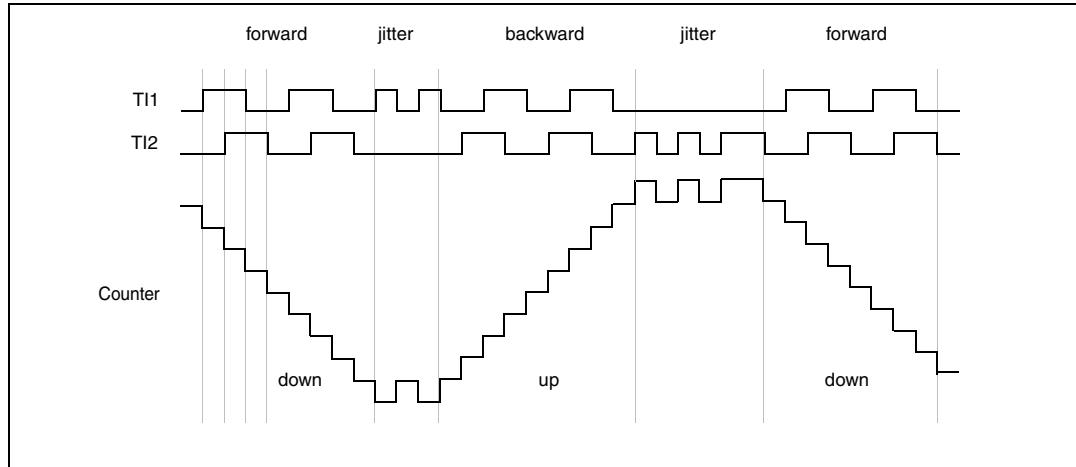
An external incremental encoder can be connected directly to the MCU without external interface logic. However, comparators are normally be used to convert the encoder's differential outputs to digital signals. This greatly increases noise immunity. The third encoder output which indicate the mechanical zero position, may be connected to an external interrupt input and trigger a counter reset.

*Figure 86* gives an example of counter operation, showing count signal generation and direction control. It also shows how input jitter is compensated where both edges are selected. This might occur if the sensor is positioned near to one of the switching points. For this example we assume that the configuration is the following:

- CC1S='01' (TIMx\_CCMR1 register, TI1FP1 mapped on TI1).
- CC2S='01' (TIMx\_CCMR2 register, TI1FP2 mapped on TI2).
- CC1P='0' (TIMx\_CCER register, TI1FP1 non-inverted, TI1FP1=TI1).
- CC2P='0' (TIMx\_CCER register, TI1FP2 non-inverted, TI1FP2= TI2).
- SMS='011' (TIMx\_SMCR register, both inputs are active on both rising and falling edges).
- CEN='1' (TIMx\_CR1 register, Counter enabled).

**Figure 86. Example of counter operation in encoder interface mode.**

*Figure 87* gives an example of counter behavior when TI1FP1 polarity is inverted (same configuration as above except CC1P='1').

**Figure 87. Example of encoder interface mode with TI1FP1 polarity inverted.**

The timer, when configured in Encoder Interface mode provides information on the sensor's current position. You can obtain dynamic information (speed, acceleration, deceleration) by measuring the period between two encoder events using a second timer configured in capture mode. The output of the encoder which indicates the mechanical zero can be used for this purpose. Depending on the time between two events, the counter can also be read at regular times. You can do this by latching the counter value into a third input capture register if available (then the capture signal must be periodic and can be generated by another timer). When available, it is also possible to read its value through a DMA request generated by a real-time clock.

### 15.3.17 Timer input XOR function

The TI1S bit in the TIMx\_CR2 register, allows the input filter of channel 1 to be connected to the output of a XOR gate, combining the three input pins TIMx\_CH1, TIMx\_CH2 and TIMx\_CH3.

The XOR output can be used with all the timer input functions such as trigger or input capture. An example of this feature used to interface Hall sensors is given in [Section 15.3.18](#) below.

### 15.3.18 Interfacing with Hall sensors

This is done using the advanced-control timers (TIM1) to generate PWM signals to drive the motor and another timer TIMx (TIM2 or TIM3) referred to as “interfacing timer” in [Figure 88](#). The “interfacing timer” captures the 3 timer input pins (CC1, CC2, CC3) connected through a XOR to the TI1 input channel (selected by setting the TI1S bit in the TIMx\_CR2 register).

The slave mode controller is configured in reset mode; the slave input is TI1F\_ED. Thus, each time one of the 3 inputs toggles, the counter restarts counting from 0. This creates a time base triggered by any change on the Hall inputs.

On the “interfacing timer”, capture/compare channel 1 is configured in capture mode, capture signal is TRC (See [Figure 71: Capture/compare channel \(example: channel 1 input stage\) on page 248](#)). The captured value, which corresponds to the time elapsed between 2 changes on the inputs, gives information about motor speed.

The “interfacing timer” can be used in output mode to generate a pulse which changes the configuration of the channels of the advanced-control timer (TIM1) (by triggering a COM event). The TIM1 timer is used to generate PWM signals to drive the motor. To do this, the interfacing timer channel must be programmed so that a positive pulse is generated after a programmed delay (in output compare or PWM mode). This pulse is sent to the advanced-control timer (TIM1) through the TRGO output.

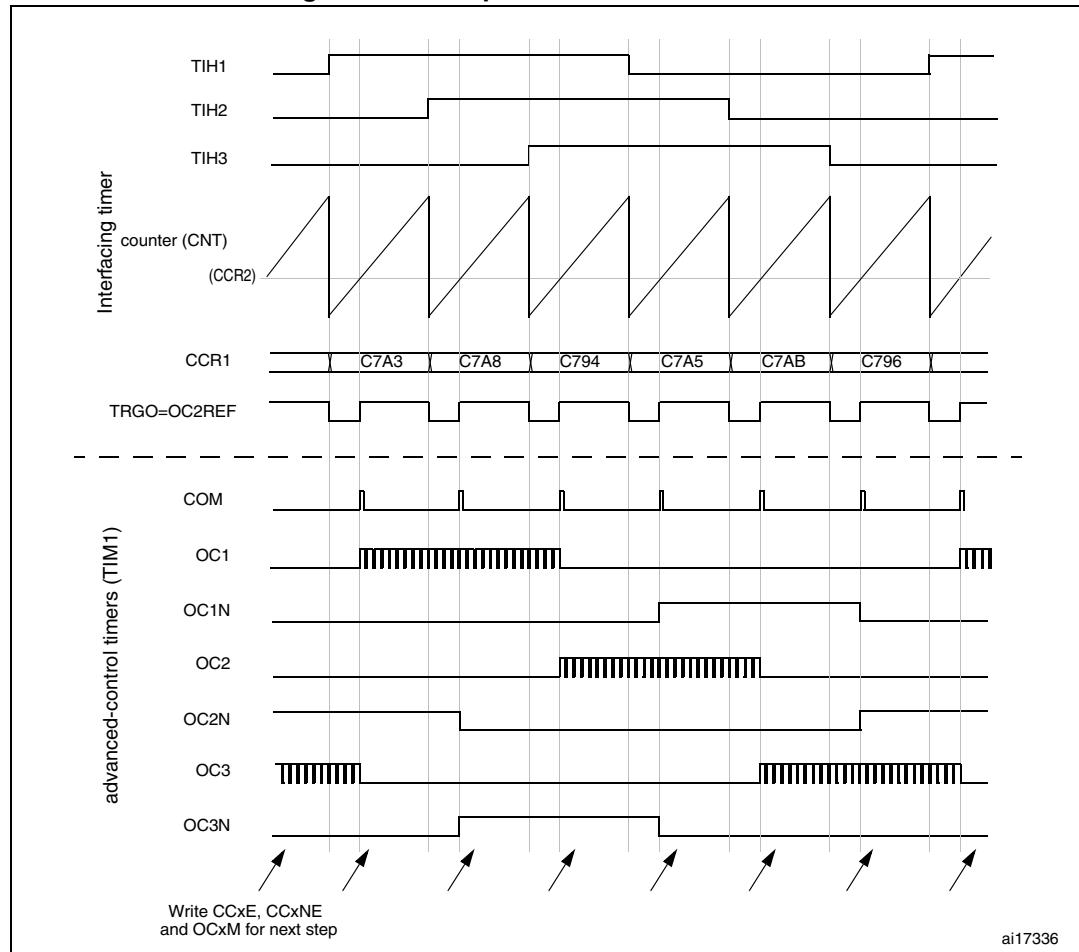
Example: you want to change the PWM configuration of your advanced-control timer TIM1 after a programmed delay each time a change occurs on the Hall inputs connected to one of the TIMx timers.

- Configure 3 timer inputs XORed to the TI1 input channel by writing the TI1S bit in the TIMx\_CR2 register to ‘1’,
- Program the time base: write the TIMx\_ARR to the max value (the counter must be cleared by the TI1 change. Set the prescaler to get a maximum counter period longer than the time between 2 changes on the sensors,
- Program channel 1 in capture mode (TRC selected): write the CC1S bits in the TIMx\_CCMR1 register to ‘01’. You can also program the digital filter if needed,
- Program channel 2 in PWM 2 mode with the desired delay: write the OC2M bits to ‘111’ and the CC2S bits to ‘00’ in the TIMx\_CCMR1 register,
- Select OC2REF as trigger output on TRGO: write the MMS bits in the TIMx\_CR2 register to ‘101’,

In the advanced-control timer TIM1, the right ITR input must be selected as trigger input, the timer is programmed to generate PWM signals, the capture/compare control signals are preloaded (CCPC=1 in the TIMx\_CR2 register) and the COM event is controlled by the trigger input (CCUS=1 in the TIMx\_CR2 register). The PWM control bits (CCxE, OCxM) are written after a COM event for the next step (this can be done in an interrupt subroutine generated by the rising edge of OC2REF).

*Figure 88 describes this example.*

**Figure 88. Example of hall sensor interface**



### 15.3.19 TIMx and external trigger synchronization

The TIMx timer can be synchronized with an external trigger in several modes: Reset mode, Gated mode and Trigger mode.

#### Slave mode: Reset mode

The counter and its prescaler can be reinitialized in response to an event on a trigger input. Moreover, if the URS bit from the TIMx\_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIMx\_ARR, TIMx\_CCRx) are updated.

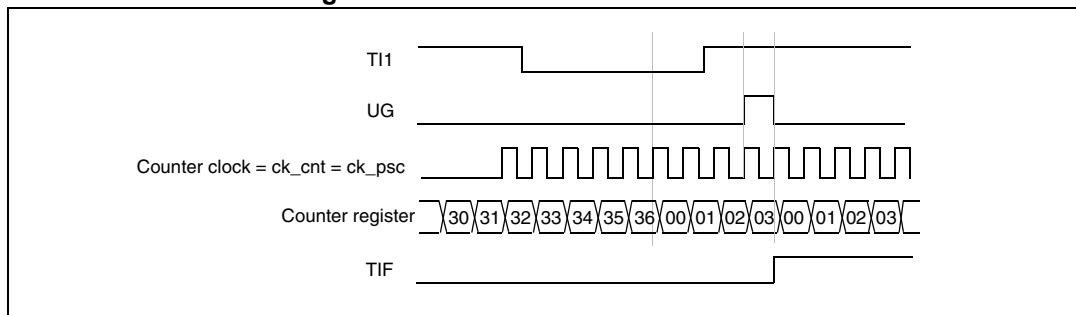
In the following example, the upcounter is cleared in response to a rising edge on TI1 input:

- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S = 01 in the TIMx\_CCMR1 register. Write CC1P=0 and CC1NP='0' in TIMx\_CCER register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.
- Start the counter by writing CEN=1 in the TIMx\_CR1 register.

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIMx\_SR register) and an interrupt request, or a DMA request can be sent if enabled (depending on the TIE and TDE bits in TIMx\_DIER register).

The following figure shows this behavior when the auto-reload register TIMx\_ARR=0x36. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

**Figure 89. Control circuit in reset mode**



### Slave mode: Gated mode

The counter can be enabled depending on the level of a selected input.

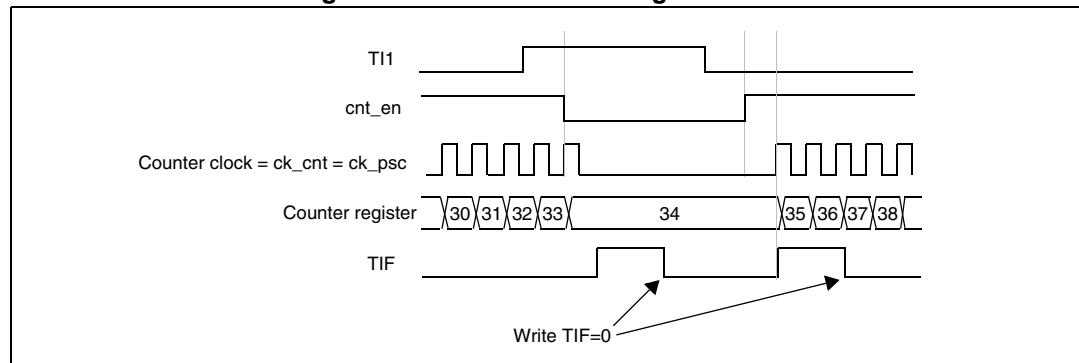
In the following example, the upcounter counts only when TI1 input is low:

- Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S=01 in TIMx\_CCER register. Write CC1P=1 and CC1NP='0' in TIMx\_CCER register to validate the polarity (and detect low level only).
- Configure the timer in gated mode by writing SMS=101 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.
- Enable the counter by writing CEN=1 in the TIMx\_CR1 register (in gated mode, the counter doesn't start if CEN=0, whatever is the trigger input level).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag in the TIMx\_SR register is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual stop of the counter is due to the resynchronization circuit on TI1 input.

**Figure 90. Control circuit in gated mode**



### Slave mode: Trigger mode

The counter can start in response to an event on a selected input.

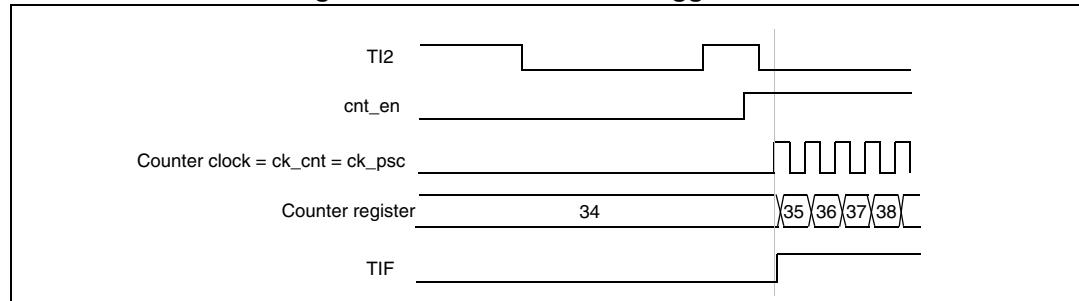
In the following example, the upcounter starts in response to a rising edge on TI2 input:

- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep IC2F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC2S bits are configured to select the input capture source only, CC2S=01 in TIMx\_CCMR1 register. Write CC2P=1 and CC2NP=0 in TIMx\_CCER register to validate the polarity (and detect low level only).
- Configure the timer in trigger mode by writing SMS=110 in TIMx\_SMCR register. Select TI2 as the input source by writing TS=110 in TIMx\_SMCR register.

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual start of the counter is due to the resynchronization circuit on TI2 input.

**Figure 91. Control circuit in trigger mode**



### Slave mode: external clock mode 2 + trigger mode

The external clock mode 2 can be used in addition to another slave mode (except external clock mode 1 and encoder mode). In this case, the ETR signal is used as external clock input, and another input can be selected as trigger input (in reset mode, gated mode or trigger mode). It is recommended not to select ETR as TRGI through the TS bits of TIMx\_SMCR register.

In the following example, the upcounter is incremented at each rising edge of the ETR signal as soon as a rising edge of TI1 occurs:

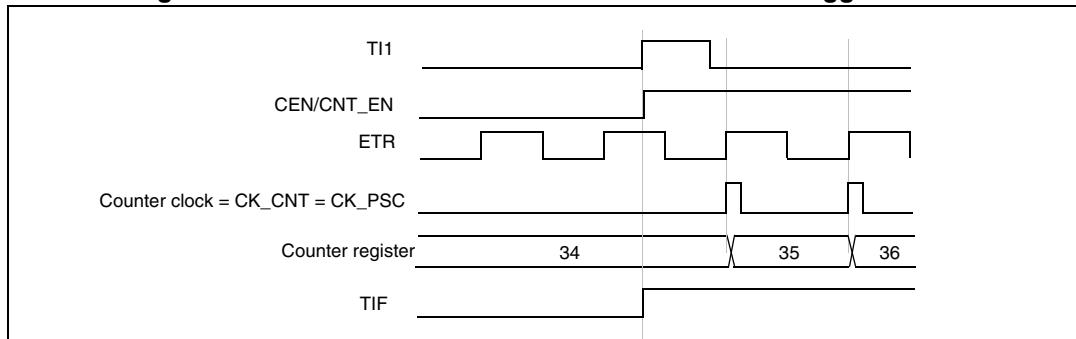
- Configure the external trigger input circuit by programming the TIMx\_SMCR register as follows:
  - ETF = 0000: no filter
  - ETPS=00: prescaler disabled
  - ETP=0: detection of rising edges on ETR and ECE=1 to enable the external clock mode 2.

2. Configure the channel 1 as follows, to detect rising edges on TI:
  - IC1F=0000: no filter.
  - The capture prescaler is not used for triggering and does not need to be configured.
  - CC1S=01in TIMx\_CCMR1 register to select only the input capture source
  - CC1P=0 and CC1NP='0' in TIMx\_CCER register to validate the polarity (and detect rising edge only).
3. Configure the timer in trigger mode by writing SMS=110 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.

A rising edge on TI1 enables the counter and sets the TIF flag. The counter then counts on ETR rising edges.

The delay between the rising edge of the ETR signal and the actual reset of the counter is due to the resynchronization circuit on ETRP input.

**Figure 92. Control circuit in external clock mode 2 + trigger mode**



### 15.3.20 Timer synchronization

The TIM timers are linked together internally for timer synchronization or chaining. Refer to [Section 16.3.15: Timer synchronization on page 331](#) for details.

### 15.3.21 Debug mode

When the microcontroller enters debug mode (Cortex™-M0 core halted), the TIMx counter either continues to work normally or stops, depending on DBG\_TIMx\_STOP configuration bit in DBG module.

## 15.4 TIM1 registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 15.4.1 TIM1 control register 1 (TIM1\_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	CMS[1:0]		DIR	OPM	URS	UDIS	CEN

Bits 15:10 Reserved, must be kept at reset value.

Bits 9:8 **CKD[1:0]**: Clock division

This bit-field indicates the division ratio between the timer clock (CK\_INT) frequency and the dead-time and sampling clock ( $t_{DTS}$ ) used by the dead-time generators and the digital filters (ETR, TIx),

- 00:  $t_{DTS}=t_{CK\_INT}$
- 01:  $t_{DTS}=2*t_{CK\_INT}$
- 10:  $t_{DTS}=4*t_{CK\_INT}$
- 11: Reserved, do not program this value

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIMx\_ARR register is not buffered
- 1: TIMx\_ARR register is buffered

Bits 6:5 **CMS[1:0]**: Center-aligned mode selection

00: Edge-aligned mode. The counter counts up or down depending on the direction bit (DIR).

01: Center-aligned mode 1. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx\_CCMRx register) are set only when the counter is counting down.

10: Center-aligned mode 2. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx\_CCMRx register) are set only when the counter is counting up.

11: Center-aligned mode 3. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx\_CCMRx register) are set both when the counter is counting up or down.

*Note:* It is not allowed to switch from edge-aligned mode to center-aligned mode as long as the counter is enabled (CEN=1).

Bit 4 **DIR**: Direction

- 0: Counter used as upcounter
- 1: Counter used as downcounter

*Note:* This bit is read only when the timer is configured in Center-aligned mode or Encoder mode.

Bit 3 **OPM**: One pulse mode

- 0: Counter is not stopped at update event
- 1: Counter stops counting at the next update event (clearing the bit CEN)

**Bit 2 URS:** Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt or DMA request if enabled.

These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

**Bit 1 UDIS:** Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

**Bit 0 CEN:** Counter enable

0: Counter disabled

1: Counter enabled

*Note: External clock, gated mode and encoder mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.*

### 15.4.2 TIM1 control register 2 (TIM1\_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	OIS4	OIS3N	OIS3	OIS2N	OIS2	OIS1N	OIS1	TI1S	MMS[2:0]	CCDS	CCUS	Res.	CCPC		

Bit 15 Reserved, must be kept at reset value.

Bit 14 **OIS4:** Output Idle state 4 (OC4 output)

refer to OIS1 bit

Bit 13 **OIS3N:** Output Idle state 3 (OC3N output)

refer to OIS1N bit

Bit 12 **OIS3:** Output Idle state 3 (OC3 output)

refer to OIS1 bit

Bit 11 **OIS2N:** Output Idle state 2 (OC2N output)

refer to OIS1N bit

Bit 10 **OIS2**: Output Idle state 2 (OC2 output)

refer to OIS1 bit

Bit 9 **OIS1N**: Output Idle state 1 (OC1N output)

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

*Note: This bit cannot be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bit 8 **OIS1**: Output Idle state 1 (OC1 output)

0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0

1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

*Note: This bit cannot be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bit 7 **TI1S**: TI1 selection

0: The TIMx\_CH1 pin is connected to TI1 input

1: The TIMx\_CH1, CH2 and CH3 pins are connected to the TI1 input (XOR combination)

Bits 6:4 **MMS[1:0]**: Master mode selection

These bits allow to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx\_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter Enable signal CNT\_EN is used as trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enable. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIMx\_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

011: **Compare Pulse** - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred (TRGO).

100: **Compare** - OC1REF signal is used as trigger output (TRGO)

101: **Compare** - OC2REF signal is used as trigger output (TRGO)

110: **Compare** - OC3REF signal is used as trigger output (TRGO)

111: **Compare** - OC4REF signal is used as trigger output (TRGO)

Bit 3 **CCDS**: Capture/compare DMA selection

0: CCx DMA request sent when CCx event occurs

1: CCx DMA requests sent when update event occurs

Bit 2 **CCUS**: Capture/compare control update selection

0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit only

1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI

*Note: This bit acts only on channels that have a complementary output.*

Bit 1 Reserved, must be kept at reset value.

Bit 0 **CCPC**: Capture/compare preloaded control

0: CCxE, CCxNE and OCxM bits are not preloaded

1: CCxE, CCxNE and OCxM bits are preloaded, after having been written, they are updated only when a communication event (COM) occurs (COMG bit set or rising edge detected on TRGI, depending on the CCUS bit).

*Note: This bit acts only on channels that have a complementary output.*

### 15.4.3 TIM1 slave mode control register (TIM1\_SMCR)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ETP	ECE	ETPS[1:0]		ETF[3:0]			MSM	TS[2:0]			OCCS	SMS[2:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 **ETP**: External trigger polarity

This bit selects whether ETR or ETR is used for trigger operations

0: ETR is non-inverted, active at high level or rising edge.

1: ETR is inverted, active at low level or falling edge.

Bit 14 **ECE**: External clock enable

This bit enables External clock mode 2.

0: External clock mode 2 disabled

1: External clock mode 2 enabled. The counter is clocked by any active edge on the ETRF signal.

*Note: 1: Setting the ECE bit has the same effect as selecting external clock mode 1 with TRGI connected to ETRF (SMS=111 and TS=111).*

*2: It is possible to simultaneously use external clock mode 2 with the following slave modes: reset mode, gated mode and trigger mode. Nevertheless, TRGI must not be connected to ETRF in this case (TS bits must not be 111).*

*3: If external clock mode 1 and external clock mode 2 are enabled at the same time, the external clock input is ETRF.*

Bits 13:12 **ETPS[1:0]**: External trigger prescaler

External trigger signal ETRP frequency must be at most 1/4 of TIMxCLK frequency. A prescaler can be enabled to reduce ETRP frequency. It is useful when inputting fast external clocks.

00: Prescaler OFF

01: ETRP frequency divided by 2

10: ETRP frequency divided by 4

11: ETRP frequency divided by 8

Bits 11:8 **ETF[3:0]**: External trigger filter

This bit-field then defines the frequency used to sample ETRP signal and the length of the digital filter applied to ETRP. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, sampling is done at  $f_{DTS}$
- 0001:  $f_{SAMPLING} = f_{CK\_INT}$ , N=2
- 0010:  $f_{SAMPLING} = f_{CK\_INT}$ , N=4
- 0011:  $f_{SAMPLING} = f_{CK\_INT}$ , N=8
- 0100:  $f_{SAMPLING} = f_{DTS}/2$ , N=6
- 0101:  $f_{SAMPLING} = f_{DTS}/2$ , N=8
- 0110:  $f_{SAMPLING} = f_{DTS}/4$ , N=6
- 0111:  $f_{SAMPLING} = f_{DTS}/4$ , N=8
- 1000:  $f_{SAMPLING} = f_{DTS}/8$ , N=6
- 1001:  $f_{SAMPLING} = f_{DTS}/8$ , N=8
- 1010:  $f_{SAMPLING} = f_{DTS}/16$ , N=5
- 1011:  $f_{SAMPLING} = f_{DTS}/16$ , N=6
- 1100:  $f_{SAMPLING} = f_{DTS}/16$ , N=8
- 1101:  $f_{SAMPLING} = f_{DTS}/32$ , N=5
- 1110:  $f_{SAMPLING} = f_{DTS}/32$ , N=6
- 1111:  $f_{SAMPLING} = f_{DTS}/32$ , N=8

Bit 7 **MSM**: Master/slave mode

- 0: No action
- 1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between the current timer and its slaves (through TRGO). It is useful if we want to synchronize several timers on a single external event.

Bits 6:4 **TS[2:0]**: Trigger selection

This bit-field selects the trigger input to be used to synchronize the counter.

- 000: Internal Trigger 0 (ITR0)
- 001: Internal Trigger 1 (ITR1)
- 010: Internal Trigger 2 (ITR2)
- 011: Internal Trigger 3 (ITR3)
- 100: TI1 Edge Detector (TI1F\_ED)
- 101: Filtered Timer Input 1 (TI1FP1)
- 110: Filtered Timer Input 2 (TI2FP2)
- 111: External Trigger input (ETRF)

See [Table 43: TIMx Internal trigger connection on page 278](#) for more details on ITRx meaning for each Timer.

*Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.*

Bit 3 **OCCS**: OCREF clear selection.

This bit is used to select the OCREF clear source.

- 0:OCREF\_CLR\_INT is connected to the OCREF\_CLR input
- 1: OCREF\_CLR\_INT is connected to ETRF

Bits 2:0 **SMS:** Slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Slave mode disabled - if CEN = '1' then the prescaler is clocked directly by the internal clock.

001: Encoder mode 1 - Counter counts up/down on TI2FP2 edge depending on TI1FP1 level.

010: Encoder mode 2 - Counter counts up/down on TI1FP1 edge depending on TI2FP2 level.

011: Encoder mode 3 - Counter counts up/down on both TI1FP1 and TI2FP2 edges depending on the level of the other input.

100: Reset Mode - Rising edge of the selected trigger input (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger input (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

*Note: The gated mode must not be used if TI1F\_ED is selected as the trigger input (TS='100'). Indeed, TI1F\_ED outputs 1 pulse for each transition on TI1F, whereas the gated mode checks the level of the trigger signal.*

**Table 43. TIMx Internal trigger connection**

Slave TIM	ITR0 (TS = 000)	ITR1 (TS = 001)	ITR2 (TS = 010)	ITR3 (TS = 011)
TIM1	TIM15	TIM2	TIM3	TIM17

#### 15.4.4 TIM1 DMA/interrupt enable register (TIM1\_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TDE	COMDE	CC4DE	CC3DE	CC2DE	CC1DE	UDE	BIE	TIE	COMIE	CC4IE	CC3IE	CC2IE	CC1IE	UIE

Bit 15 Reserved, must be kept at reset value.

Bit 14 **TDE:** Trigger DMA request enable

- 0: Trigger DMA request disabled
- 1: Trigger DMA request enabled

Bit 13 **COMDE:** COM DMA request enable

- 0: COM DMA request disabled
- 1: COM DMA request enabled

Bit 12 **CC4DE:** Capture/Compare 4 DMA request enable

- 0: CC4 DMA request disabled
- 1: CC4 DMA request enabled

- Bit 11 **CC3DE**: Capture/Compare 3 DMA request enable  
0: CC3 DMA request disabled  
1: CC3 DMA request enabled
- Bit 10 **CC2DE**: Capture/Compare 2 DMA request enable  
0: CC2 DMA request disabled  
1: CC2 DMA request enabled
- Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable  
0: CC1 DMA request disabled  
1: CC1 DMA request enabled
- Bit 8 **UDE**: Update DMA request enable  
0: Update DMA request disabled  
1: Update DMA request enabled
- Bit 7 **BIE**: Break interrupt enable  
0: Break interrupt disabled  
1: Break interrupt enabled
- Bit 6 **TIE**: Trigger interrupt enable  
0: Trigger interrupt disabled  
1: Trigger interrupt enabled
- Bit 5 **COMIE**: COM interrupt enable  
0: COM interrupt disabled  
1: COM interrupt enabled
- Bit 4 **CC4IE**: Capture/Compare 4 interrupt enable  
0: CC4 interrupt disabled  
1: CC4 interrupt enabled
- Bit 3 **CC3IE**: Capture/Compare 3 interrupt enable  
0: CC3 interrupt disabled  
1: CC3 interrupt enabled
- Bit 2 **CC2IE**: Capture/Compare 2 interrupt enable  
0: CC2 interrupt disabled  
1: CC2 interrupt enabled
- Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable  
0: CC1 interrupt disabled  
1: CC1 interrupt enabled
- Bit 0 **UIE**: Update interrupt enable  
0: Update interrupt disabled  
1: Update interrupt enabled

### 15.4.5 TIM1 status register (TIM1\_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	CC4OF	CC3OF	CC2OF	CC1OF	Res.	BIF	TIF	COMIF	CC4IF	CC3IF	CC2IF	CC1IF	UIF

Bits 15:13 Reserved, must be kept at reset value.

Bit 12 **CC4OF**: Capture/Compare 4 overcapture flag  
refer to CC1OF description

Bit 11 **CC3OF**: Capture/Compare 3 overcapture flag  
refer to CC1OF description

Bit 10 **CC2OF**: Capture/Compare 2 overcapture flag  
refer to CC1OF description

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected.

1: The counter value has been captured in TIMx\_CCR1 register while CC1IF flag was already set

Bit 8 Reserved, must be kept at reset value.

Bit 7 **BIF**: Break interrupt flag

This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.

0: No break event occurred.

1: An active level has been detected on the break input.

Bit 6 **TIF**: Trigger interrupt flag

This flag is set by hardware on trigger event (active edge detected on TRGI input when the slave mode controller is enabled in all modes but gated mode). It is cleared by software.

0: No trigger event occurred.

1: Trigger interrupt pending.

Bit 5 **COMIF**: COM interrupt flag

This flag is set by hardware on COM event (when Capture/compare Control bits - CCxE, CCxNE, OCxM - have been updated). It is cleared by software.

0: No COM event occurred.

1: COM interrupt pending.

Bit 4 **CC4IF**: Capture/Compare 4 interrupt flag

refer to CC1IF description

Bit 3 **CC3IF**: Capture/Compare 3 interrupt flag

refer to CC1IF description

Bit 2 **CC2IF**: Capture/Compare 2 interrupt flag  
refer to CC1IF description

Bit 1 **CC1IF**: Capture/Compare 1 interrupt flag

**If channel CC1 is configured as output:**

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx\_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIMx\_CNT matches the content of the TIMx\_CCR1 register. When the contents of TIMx\_CCR1 are greater than the contents of TIMx\_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

**If channel CC1 is configured as input:**

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx\_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx\_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow or underflow regarding the repetition counter value (update if repetition counter = 0) and if the UDIS=0 in the TIMx\_CR1 register.

- When CNT is reinitialized by software using the UG bit in TIMx\_EGR register, if URS=0 and UDIS=0 in the TIMx\_CR1 register.

- When CNT is reinitialized by a trigger event (refer to [Section 15.4.3: TIM1 slave mode control register \(TIM1\\_SMCR\)](#)), if URS=0 and UDIS=0 in the TIMx\_CR1 register.

## 15.4.6 TIM1 event generation register (TIM1\_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	BG	TG	COMG	CC4G	CC3G	CC2G	CC1G	UG							

Bits 15:8 Reserved, must be kept at reset value.

Bit 7 **BG**: Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A break event is generated. MOE bit is cleared and BIF flag is set. Related interrupt or DMA transfer can occur if enabled.

**Bit 6 **TG**: Trigger generation**

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: The TIF flag is set in TIMx\_SR register. Related interrupt or DMA transfer can occur if enabled.

**Bit 5 **COMG**: Capture/Compare control update generation**

This bit can be set by software, it is automatically cleared by hardware

0: No action

1: When CCPC bit is set, it allows to update CCxE, CCxNE and OCxM bits

*Note: This bit acts only on channels having a complementary output.*

**Bit 4 **CC4G**: Capture/Compare 4 generation**

Refer to CC1G description

**Bit 3 **CC3G**: Capture/Compare 3 generation**

Refer to CC1G description

**Bit 2 **CC2G**: Capture/Compare 2 generation**

Refer to CC1G description

**Bit 1 **CC1G**: Capture/Compare 1 generation**

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

**If channel CC1 is configured as output:**

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

**If channel CC1 is configured as input:**

The current value of the counter is captured in TIMx\_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

**Bit 0 **UG**: Update generation**

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Reinitialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx\_ARR) if DIR=1 (downcounting).

### 15.4.7 TIM1 capture/compare mode register 1 (TIM1\_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CC<sub>x</sub>S bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OC<sub>xx</sub> describes its function when the channel is configured in output, IC<sub>xx</sub> describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
OC2 CE	OC2M[2:0]			OC2 PE	OC2 FE	CC2S[1:0]	OC1 CE	OC1M[2:0]			OC1 PE	OC1 FE	CC1S[1:0]			
IC2F[3:0]			IC2PSC[1:0]				IC1F[3:0]			IC1PSC[1:0]						
RW	RW	RW	RW	RW	RW		RW	RW	RW	RW	RW	RW	RW	RW	RW	

#### Output compare mode

Bit 15 **OC2CE**: Output Compare 2 clear enable

Bits 14:12 **OC2M[2:0]**: Output Compare 2 mode

Bit 11 **OC2PE**: Output Compare 2 preload enable

Bit 10 **OC2FE**: Output Compare 2 fast enable

Bits 9:8 **CC2S[1:0]**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output

01: CC2 channel is configured as input, IC2 is mapped on TI2

10: CC2 channel is configured as input, IC2 is mapped on TI1

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through the TS bit (TIMx\_SMCR register)

*Note:* CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx\_CCER).

Bit 7 **OC1CE**: Output Compare 1 clear enable

OC1CE: Output Compare 1 Clear Enable

0: OC1Ref is not affected by the ETRF Input

1: OC1Ref is cleared as soon as a High level is detected on ETRF input

**Bits 6:4 OC1M:** Output Compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

- 000: Frozen - The comparison between the output compare register TIMx\_CCR1 and the counter TIMx\_CNT has no effect on the outputs (this mode is used to generate a timing base).
- 001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).
- 010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).
- 011: Toggle - OC1REF toggles when TIMx\_CNT=TIMx\_CCR1.
- 100: Force inactive level - OC1REF is forced low.
- 101: Force active level - OC1REF is forced high.
- 110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx\_CNT<TIMx\_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx\_CNT>TIMx\_CCR1 else active (OC1REF='1').
- 111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx\_CNT<TIMx\_CCR1 else active. In downcounting, channel 1 is active as long as TIMx\_CNT>TIMx\_CCR1 else inactive.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S='00' (the channel is configured in output).*

*2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode.*

*3: On channels having a complementary output, this bit field is preloaded. If the CCPC bit is set in the TIMx\_CR2 register then the OC1M active bits take the new value from the preloaded bits only when a COM event is generated.*

**Bit 3 OC1PE:** Output Compare 1 preload enable

0: Preload register on TIMx\_CCR1 disabled. TIMx\_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx\_CCR1 enabled. Read/Write operations access the preload register. TIMx\_CCR1 preload value is loaded in the active register at each update event.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S='00' (the channel is configured in output).*

*2: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx\_CR1 register). Else the behavior is not guaranteed.*

**Bit 2 OC1FE:** Output Compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently from the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OCFE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC1 channel is configured as output
- 01: CC1 channel is configured as input, IC1 is mapped on TI1
- 10: CC1 channel is configured as input, IC1 is mapped on TI2
- 11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx\_CCER).*

### Input capture mode

Bits 15:12 **IC2F**: Input capture 2 filter

Bits 11:10 **IC2PSC[1:0]**: Input capture 2 prescaler

Bits 9:8 **CC2S**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC2 channel is configured as output
- 01: CC2 channel is configured as input, IC2 is mapped on TI2
- 10: CC2 channel is configured as input, IC2 is mapped on TI1
- 11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx\_CCER).*

Bits 7:4 **IC1F[3:0]**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, sampling is done at  $f_{DTS}$
- 0001:  $f_{SAMPLING} = f_{CK\_INT}$ , N=2
- 0010:  $f_{SAMPLING} = f_{CK\_INT}$ , N=4
- 0011:  $f_{SAMPLING} = f_{CK\_INT}$ , N=8
- 0100:  $f_{SAMPLING} = f_{DTS}/2$ , N=6
- 0101:  $f_{SAMPLING} = f_{DTS}/2$ , N=8
- 0110:  $f_{SAMPLING} = f_{DTS}/4$ , N=6
- 0111:  $f_{SAMPLING} = f_{DTS}/4$ , N=8
- 1000:  $f_{SAMPLING} = f_{DTS}/8$ , N=6
- 1001:  $f_{SAMPLING} = f_{DTS}/8$ , N=8
- 1010:  $f_{SAMPLING} = f_{DTS}/16$ , N=5
- 1011:  $f_{SAMPLING} = f_{DTS}/16$ , N=6
- 1100:  $f_{SAMPLING} = f_{DTS}/16$ , N=8
- 1101:  $f_{SAMPLING} = f_{DTS}/32$ , N=5
- 1110:  $f_{SAMPLING} = f_{DTS}/32$ , N=6
- 1111:  $f_{SAMPLING} = f_{DTS}/32$ , N=8

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as CC1E='0' (TIMx\_CCER register).

- 00: no prescaler, capture is done each time an edge is detected on the capture input
- 01: capture is done once every 2 events
- 10: capture is done once every 4 events
- 11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note:* CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx\_CCER).

### 15.4.8 TIM1 capture/compare mode register 2 (TIM1\_CCMR2)

Address offset: 0x1C

Reset value: 0x0000

Refer to the above CCMR1 register description.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OC4 CE	OC4M[2:0]			OC4 PE	OC4 FE	CC4S[1:0]	OC3 CE.	OC3M[2:0]			OC3 PE	OC3 FE	CC3S[1:0]		
IC4F[3:0]			IC4PSC[1:0]		IC3F[3:0]			IC3PSC[1:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

#### Output compare mode

Bit 15 **OC4CE**: Output compare 4 clear enable

Bits 14:12 **OC4M**: Output compare 4 mode

Bit 11 **OC4PE**: Output compare 4 preload enable

Bit 10 **OC4FE**: Output compare 4 fast enable

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note:* CC4S bits are writable only when the channel is OFF (CC4E = '0' in TIMx\_CCER).

Bit 7 **OC3CE**: Output compare 3 clear enable

Bits 6:4 **OC3M**: Output compare 3 mode

Bit 3 **OC3PE**: Output compare 3 preload enable

Bit 2 **OC3FE**: Output compare 3 fast enable

Bits 1:0 **CC3S**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note:* CC3S bits are writable only when the channel is OFF (CC3E = '0' in TIMx\_CCER).

## Input capture mode

Bits 15:12 **IC4F**: Input capture 4 filter

Bits 11:10 **IC4PSC**: Input capture 4 prescaler

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC4S bits are writable only when the channel is OFF (CC4E = '0' in TIMx\_CCER).*

Bits 7:4 **IC3F**: Input capture 3 filter

Bits 3:2 **IC3PSC**: Input capture 3 prescaler

Bits 1:0 **CC3S**: Capture/compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC3S bits are writable only when the channel is OFF (CC3E = '0' in TIMx\_CCER).*

## 15.4.9 TIM1 capture/compare enable register (TIM1\_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	CC4P	CC4E	CC3NP	CC3NE	CC3P	CC3E	CC2NP	CC2NE	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E

Bits 15:14 Reserved, must be kept at reset value.

Bit 13 **CC4P**: Capture/Compare 4 output polarity

refer to CC1P description

Bit 12 **CC4E**: Capture/Compare 4 output enable

refer to CC1E description

Bit 11 **CC3NP**: Capture/Compare 3 complementary output polarity

refer to CC1NP description

Bit 10 **CC3NE**: Capture/Compare 3 complementary output enable

refer to CC1NE description

Bit 9 **CC3P**: Capture/Compare 3 output polarity

refer to CC1P description

Bit 8 **CC3E**: Capture/Compare 3 output enable

refer to CC1E description

Bit 7 **CC2NP**: Capture/Compare 2 complementary output polarity  
refer to CC1NP description

Bit 6 **CC2NE**: Capture/Compare 2 complementary output enable  
refer to CC1NE description

Bit 5 **CC2P**: Capture/Compare 2 output polarity  
refer to CC1P description

Bit 4 **CC2E**: Capture/Compare 2 output enable  
refer to CC1E description

Bit 3 **CC1NP**: Capture/Compare 1 complementary output polarity  
**CC1 channel configuration as output:**

- 0: OC1N active high.
- 1: OC1N active low.

**CC1 channel configuration as input:**

This bit is used in conjunction with CC1P to define the polarity of TI1FP1 and TI2FP1. Refer to CC1P description.

*Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx\_CR2 register then the CC1NP active bit takes the new value from the preloaded bits only when a Commutation event is generated.*

*Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S="00" (the channel is configured in output).*

Bit 2 **CC1NE**: Capture/Compare 1 complementary output enable

- 0: Off - OC1N is not active. OC1N level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

- 1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

*Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx\_CR2 register then the CC1NE active bit takes the new value from the preloaded bits only when a Commutation event is generated.*

Bit 1 **CC1P**: Capture/Compare 1 output polarity

**CC1 channel configured as output:**

- 0: OC1 active high
- 1: OC1 active low

**CC1 channel configured as input:**

CC1NP/CC1P bits select the active polarity of TI1FP1 and TI2FP1 for trigger or capture operations.

- 00: non-inverted/rising edge

The circuit is sensitive to TIxFP1 rising edge (capture or trigger operations in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger operation in gated mode or encoder mode).

- 01: inverted/falling edge

The circuit is sensitive to TIxFP1 falling edge (capture or trigger operations in reset, external clock or trigger mode), TIxFP1 is inverted (trigger operation in gated mode or encoder mode).

- 10: reserved, do not use this configuration.

- 11: non-inverted/both edges

The circuit is sensitive to both TIxFP1 rising and falling edges (capture or trigger operations in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger operation in gated mode). This configuration must not be used in encoder mode.

*Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx\_CR2 register then the CC1P active bit takes the new value from the preloaded bits only when a Commutation event is generated.*

*Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bit 0 **CC1E**: Capture/Compare 1 output enable

**CC1 channel configured as output:**

- 0: Off - OC1 is not active. OC1 level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

- 1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

**CC1 channel configured as input:**

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx\_CCR1) or not.

- 0: Capture disabled.

- 1: Capture enabled.

*Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx\_CR2 register then the CC1E active bit takes the new value from the preloaded bits only when a Commutation event is generated.*

**Table 44. Output control bits for complementary OCx and OCxN channels with break feature**

Control bits					Output states <sup>(1)</sup>	
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state
1	X	0	0	0	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	0	1	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		0	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		1	0	1	Off-State (output enabled with inactive state) OCx=CCxP, OCx_EN=1	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		1	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Off-State (output enabled with inactive state) OCxN=CCxNP, OCxN_EN=1
		1	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
0	X	0	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		0	0	1	Output Disabled (not driven by the timer)	
		0	1	0	Asynchronously: OCx=CCxP, OCx_EN=0, OCxN=CCxNP, OCxN_EN=0	
		0	1	1	Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state.	
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		1	0	1	Off-State (output enabled with inactive state)	
		1	1	0	Asynchronously: OCx=CCxP, OCx_EN=1, OCxN=CCxNP, OCxN_EN=1	
		1	1	1	Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state.	

- When both outputs of a channel are not used ( $CCxE = CCxNE = 0$ ), the OISx, OISxN, CCxP and CCxNP bits must be kept cleared.

**Note:** *The state of the external I/O pins connected to the complementary OCx and OCxN channels depends on the OCx and OCxN channel state and the GPIO registers.*

#### 15.4.10 TIM1 counter (TIM1\_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Counter value

#### 15.4.11 TIM1 prescaler (TIM1\_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency ( $CK_{CNT}$ ) is equal to  $f_{CK\_PSC} / (PSC[15:0] + 1)$ .

PSC contains the value to be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx\_EGR register or through trigger controller when configured in “reset mode”).

#### 15.4.12 TIM1 auto-reload register (TIM1\_ARR)

Address offset: 0x2C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 15.3.1: Time-base unit on page 233](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

### 15.4.13 TIM1 repetition counter register (TIM1\_RCR)

Address offset: 0x30

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	REP[7:0]														
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved, must be kept at reset value.

Bits 7:0 **REP[7:0]**: Repetition counter value

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to active registers) when preload registers are enable, as well as the update interrupt generation rate, if this interrupt is enable.

Each time the REP\_CNT related downcounter reaches zero, an update event is generated and it restarts counting from REP value. As REP\_CNT is reloaded with REP value only at the repetition update event U\_RC, any write to the TIMx\_RCR register is not taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to:

- the number of PWM periods in edge-aligned mode
- the number of half PWM period in center-aligned mode.

### 15.4.14 TIM1 capture/compare register 1 (TIM1\_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

**If channel CC1 is configured as output:**

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signaled on OC1 output.

**If channel CC1 is configured as input:**

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

### 15.4.15 TIM1 capture/compare register 2 (TIM1\_CCR2)

Address offset: 0x38

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR2[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR2[15:0]**: Capture/Compare 2 value

**If channel CC2 is configured as output:**

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC2 output.

**If channel CC2 is configured as input:**

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

### 15.4.16 TIM1 capture/compare register 3 (TIM1\_CCR3)

Address offset: 0x3C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR3[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR3[15:0]**: Capture/Compare value

**If channel CC3 is configured as output:**

CCR3 is the value to be loaded in the actual capture/compare 3 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR3 register (bit OC3PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC3 output.

**If channel CC3 is configured as input:**

CCR3 is the counter value transferred by the last input capture 3 event (IC3).

### 15.4.17 TIM1 capture/compare register 4 (TIM1\_CCR4)

Address offset: 0x40

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR4[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR4[15:0]**: Capture/Compare value

**If channel CC4 is configured as output:**

CCR4 is the value to be loaded in the actual capture/compare 4 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR4 register (bit OC4PE). Else the preload value is copied in the active capture/compare 4 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC4 output.

**If channel CC4 is configured as input:**

CCR4 is the counter value transferred by the last input capture 4 event (IC4).

### 15.4.18 TIM1 break and dead-time register (TIM1\_BDTR)

Address offset: 0x44

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DTG[7:0]															
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK[1:0]		DTG[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

**Note:** As the bits AOE, BKP, BKE, OSSR and DTG[7:0] can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIMx\_BDTR register.

**Bit 15 MOE: Main output enable**

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state.

1: OC and OCN outputs are enabled if their respective enable bits are set (CCxE, CCxNE in TIMx\_CCER register).

See OC/OCN enable description for more details ([Section 15.4.9: TIM1 capture/compare enable register \(TIM1\\_CCER\) on page 287](#)).

**Bit 14 AOE: Automatic output enable**

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not active)

**Note:** This bit cannot be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).

Bit 13 **BKP**: Break polarity

- 0: Break input BRK is active low
- 1: Break input BRK is active high

*Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).*

*Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.*

Bit 12 **BKE**: Break enable

- 0: Break inputs (BRK and CCS clock failure event) disabled
- 1: Break inputs (BRK and CCS clock failure event) enabled

*Note: This bit cannot be modified when LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).*

*Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.*

Bit 11 **OSSR**: Off-state selection for Run mode

This bit is used when MOE=1 on channels having a complementary output which are configured as outputs. OSSR is not implemented if no complementary output is implemented in the timer.

See OC/OCN enable description for more details ([Section 15.4.9: TIM1 capture/compare enable register \(TIM1\\_CCER\) on page 287](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0).
- 1: When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCxE=1 or CCxNE=1. Then, OC/OCN enable output signal=1

*Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bit 10 **OSSI**: Off-state selection for Idle mode

This bit is used when MOE=0 on channels configured as outputs.

See OC/OCN enable description for more details ([Section 15.4.9: TIM1 capture/compare enable register \(TIM1\\_CCER\) on page 287](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0).
- 1: When inactive, OC/OCN outputs are forced first with their idle level as soon as CCxE=1 or CCxNE=1. OC/OCN enable output signal=1

*Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bits 9:8 **LOCK[1:0]**: Lock configuration

These bits offer a write protection against software errors.

- 00: LOCK OFF - No bit is write protected.
- 01: LOCK Level 1 = DTG bits in TIMx\_BDTR register, OISx and OISxN bits in TIMx\_CR2 register and BKE/BKP/AOE bits in TIMx\_BDTR register can no longer be written.
- 10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CCxP/CCxNP bits in TIMx\_CCER register, as long as the related channel is configured in output through the CCxS bits) as well as OSSR and OSSI bits can no longer be written.
- 11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OCxM and OCxPE bits in TIMx\_CCMRx registers, as long as the related channel is configured in output through the CCxS bits) can no longer be written.

*Note: The LOCK bits can be written only once after the reset. Once the TIMx\_BDTR register has been written, their content is frozen until the next reset.*

**Bits 7:0 DTG[7:0]: Dead-time generator setup**

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT correspond to this duration.

$DTG[7:5]=0xx \Rightarrow DT=DTG[7:0] \times t_{dtg}$  with  $t_{dtg}=t_{DTS}$ .

$DTG[7:5]=10x \Rightarrow DT=(64+DTG[5:0]) \times t_{dtg}$  with  $T_{dtg}=2 \times t_{DTS}$ .

$DTG[7:5]=110 \Rightarrow DT=(32+DTG[4:0]) \times t_{dtg}$  with  $T_{dtg}=8 \times t_{DTS}$ .

$DTG[7:5]=111 \Rightarrow DT=(32+DTG[4:0]) \times t_{dtg}$  with  $T_{dtg}=16 \times t_{DTS}$ .

Example if  $T_{DTS}=125$  ns (8 MHz), dead-time possible values are:

0 to 15875 ns by 125 ns steps,

16 us to 31750 ns by 250 ns steps,

32 us to 63 us by 1 us steps,

64 us to 126 us by 2 us steps

*Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register).*

### 15.4.19 TIM1 DMA control register (TIM1\_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	Res.	DBA[4:0]				

Bits 15:13 Reserved, must be kept at reset value.

**Bits 12:8 DBL[4:0]: DMA burst length**

This 5-bit vector defines the number of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx\_DMAR address)

00000: 1 transfer

00001: 2 transfers

00010: 3 transfers

...

10001: 18 transfers

Bits 7:5 Reserved, must be kept at reset value.

**Bits 4:0 DBA[4:0]: DMA base address**

This 5-bit vector defines the base-address for DMA transfers (when read/write access are done through the TIMx\_DMAR address). DBA is defined as an offset starting from the address of the TIMx\_CR1 register.

Example:

00000: TIMx\_CR1,

00001: TIMx\_CR2,

00010: TIMx\_SMCR,

...

**Example:** Let us consider the following transfer: DBL = 7 transfers and DBA = TIMx\_CR1. In this case the transfer is done to/from 7 registers starting from the TIMx\_CR1 address.

### 15.4.20 TIM1 DMA address for full transfer (TIM1\_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write operation to the DMAR register accesses the register located at the address (TIMx\_CR1 address) + (DBA + DMA index) × 4

where TIMx\_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx\_DCR register, DMA index is automatically controlled by the DMA transfer, and ranges from 0 to DBL (DBL configured in TIMx\_DCR).

#### Example of how to use the DMA burst feature

In this example the timer DMA burst feature is used to update the contents of the CCRx registers ( $x = 2, 3, 4$ ) with the DMA transferring half words into the CCRx registers.

This is done in the following steps:

1. Configure the corresponding DMA channel as follows:
  - DMA channel peripheral address is the DMAR register address
  - DMA channel memory address is the address of the buffer in the RAM containing the data to be transferred by DMA into CCRx registers.
  - Number of data to transfer = 3 (See note below).
  - Circular mode disabled.
2. Configure the DCR register by configuring the DBA and DBL bit fields as follows:  
DBL = 3 transfers, DBA = 0xE.
3. Enable the TIMx update DMA request (set the UDE bit in the DIER register).
4. Enable TIMx
5. Enable the DMA channel

**Note:** This example is for the case where every CCRx register to be updated once. If every CCRx register is to be updated twice for example, the number of data to transfer should be 6. Let's take the example of a buffer in the RAM containing data1, data2, data3, data4, data5 and data6. The data is transferred to the CCRx registers as follows: on the first update DMA request, data1 is transferred to CCR2, data2 is transferred to CCR3, data3 is transferred to CCR4 and on the second update DMA request, data4 is transferred to CCR2, data5 is transferred to CCR3 and data6 is transferred to CCR4.

#### 15.4.21 TIM1 register map

TIM1 registers are mapped as 16-bit addressable registers as described in the table below:

**Table 45. TIM1 register map and reset values**

Offset	Register	Reset value
0x00	TIM1_CR1	31
	Reset value	Res.
0x04	TIM1_CR2	30
	Reset value	Res.
0x08	TIM1_SMCR	29
	Reset value	Res.
0x0C	TIM1_DIER	28
	Reset value	Res.
0x10	TIM1_SR	27
	Reset value	Res.
0x14	TIM1_EGR	26
	Reset value	Res.
0x18	TIM1_CCMR1 Output compare mode	25
	Reset value	Res.
	TIM1_CCMR1 Input capture mode	24
	Reset value	Res.
0x1C	TIM1_CCMR2 Output compare mode	23
	Reset value	Res.
	TIM1_CCMR2 Input capture mode	22
0x20	TIM1_CCER	21
	Reset value	Res.
0x24	TIM1_CNT	20
	Reset value	Res.
0x28	TIM1_PSC	19
	Reset value	Res.
0x2C	TIM1_ARR	18
	Reset value	Res.
0x30	TIM1_RCR	17
	Reset value	Res.
CNT[15:0]		
PSC[15:0]		
ARR[15:0]		
REP[7:0]		

**Table 45. TIM1 register map and reset values (continued)**

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 16 General-purpose timers (TIM2 and TIM3)

### 16.1 TIM2 and TIM3 introduction

The general-purpose timers consist of a 16-bit or 32-bit auto-reload counter driven by a programmable prescaler.

They may be used for a variety of purposes, including measuring the pulse lengths of input signals (*input capture*) or generating output waveforms (*output compare and PWM*).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

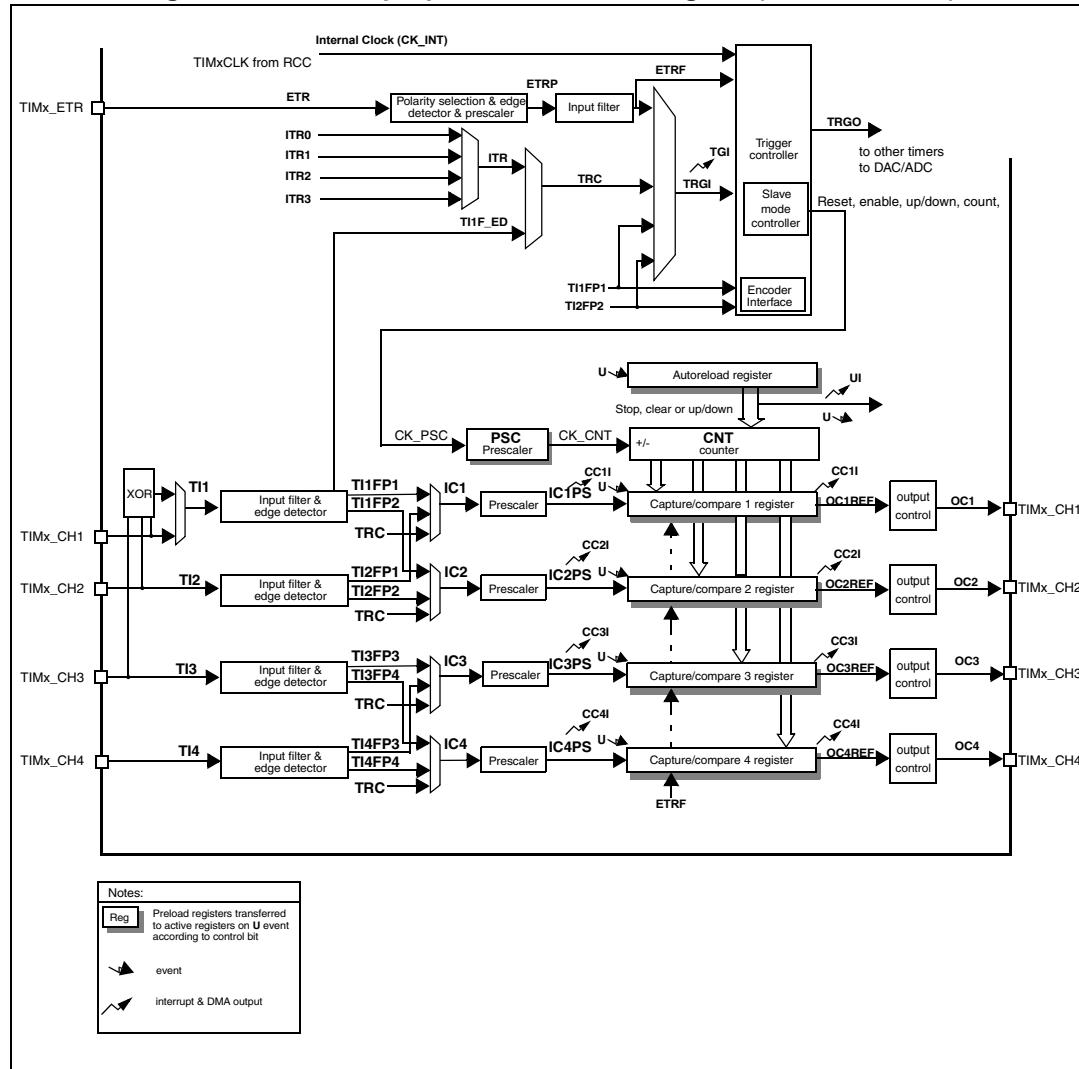
The timers are completely independent, and do not share any resources. They can be synchronized together as described in [Section 16.3.15](#).

### 16.2 TIM2 and TIM3 main features

General-purpose TIMx timer features include:

- 16-bit (TIM3) or 32-bit (TIM2) up, down, up/down auto-reload counter.
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535.
- Up to 4 independent channels for:
  - Input capture
  - Output compare
  - PWM generation (Edge- and Center-aligned modes)
  - One-pulse mode output
- Synchronization circuit to control the timer with external signals and to interconnect several timers.
- Interrupt/DMA generation on the following events:
  - Update: counter overflow/underflow, counter initialization (by software or internal/external trigger)
  - Trigger event (counter start, stop, initialization or count by internal/external trigger)
  - Input capture
  - Output compare
- Supports incremental (quadrature) encoder and hall-sensor circuitry for positioning purposes
- Trigger input for external clock or cycle-by-cycle current management

Figure 93. General-purpose timer block diagram (TIM2 and TIM3)



## 16.3 TIM2 and TIM3 functional description

### 16.3.1 Time-base unit

The main block of the programmable timer is a 16-bit/32-bit counter with its related auto-reload register. The counter can count up but also down or both up and down. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter Register (TIMx\_CNT)
- Prescaler Register (TIMx\_PSC)
- Auto-Reload Register (TIMx\_ARR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx\_CR1 register. The update event is sent when the counter reaches the overflow (or underflow when downcounting) and if the UDIS bit equals 0 in the TIMx\_CR1 register. It can also be generated by software. The generation of the update event is described in detail for each configuration.

The counter is clocked by the prescaler output CK\_CNT, which is enabled only when the counter enable bit (CEN) in TIMx\_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

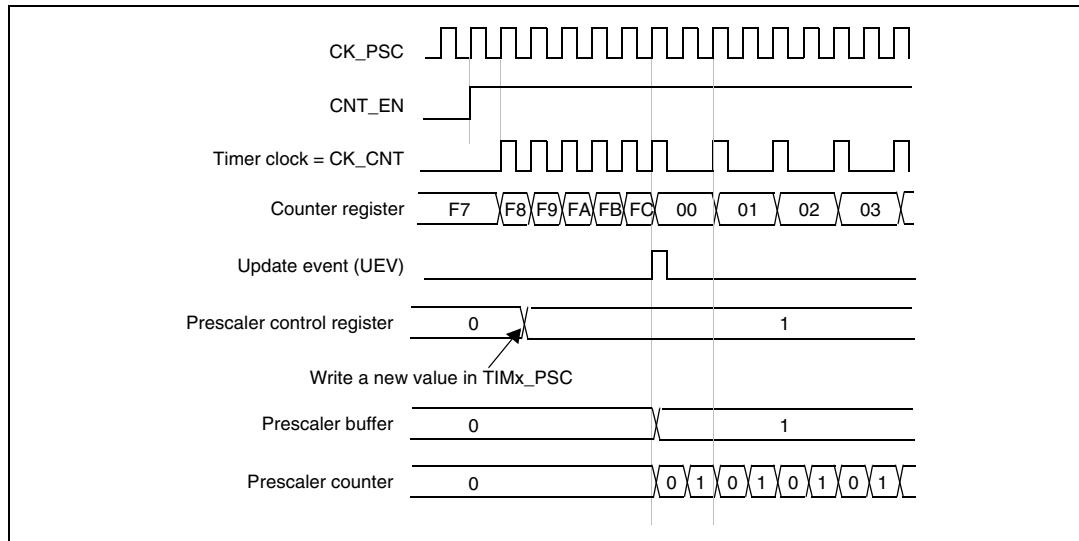
Note that the actual counter enable signal CNT\_EN is set 1 clock cycle after CEN.

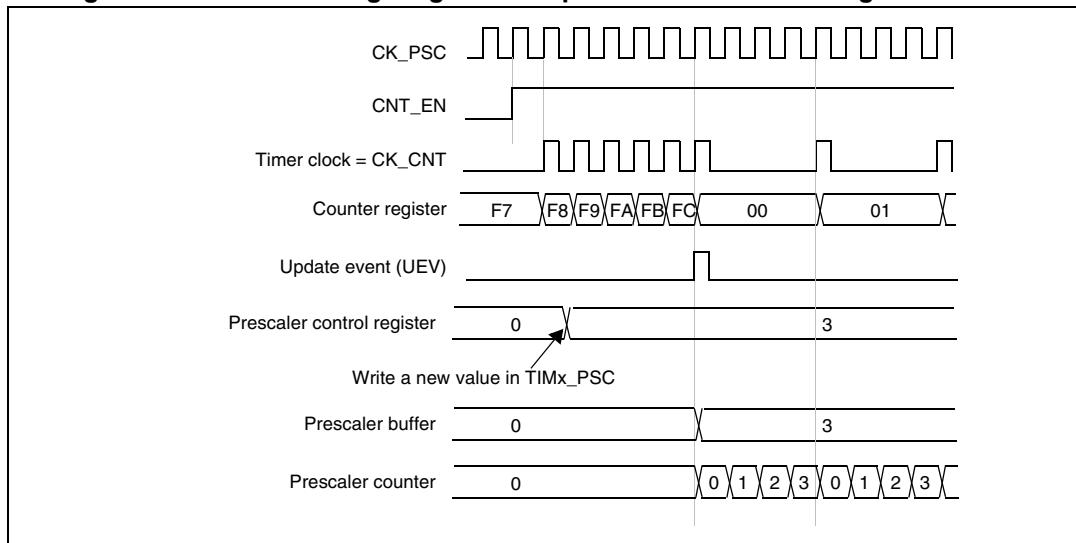
### Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit/32-bit register (in the TIMx\_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

*Figure 94* and *Figure 95* give some examples of the counter behavior when the prescaler ratio is changed on the fly:

**Figure 94. Counter timing diagram with prescaler division change from 1 to 2**



**Figure 95. Counter timing diagram with prescaler division change from 1 to 3**

### 16.3.2 Counter modes

#### Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx\_ARR register), then restarts from 0 and generates a counter overflow event.

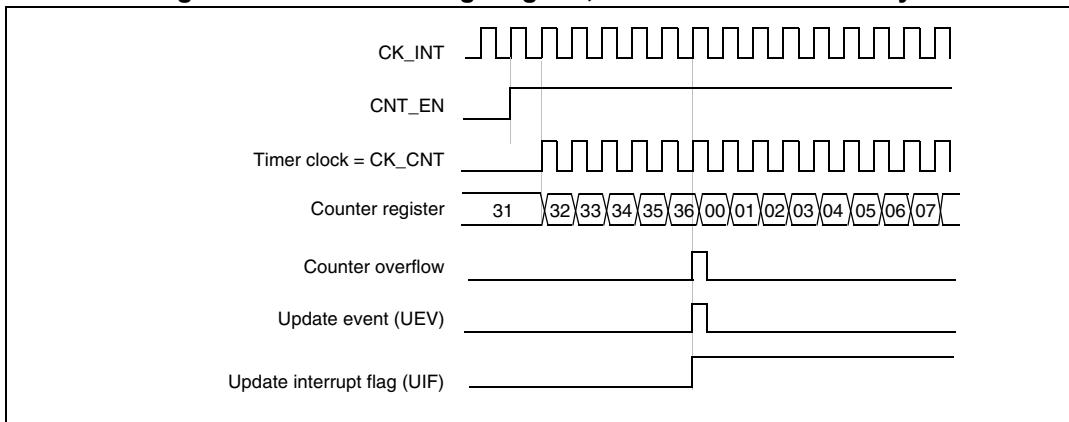
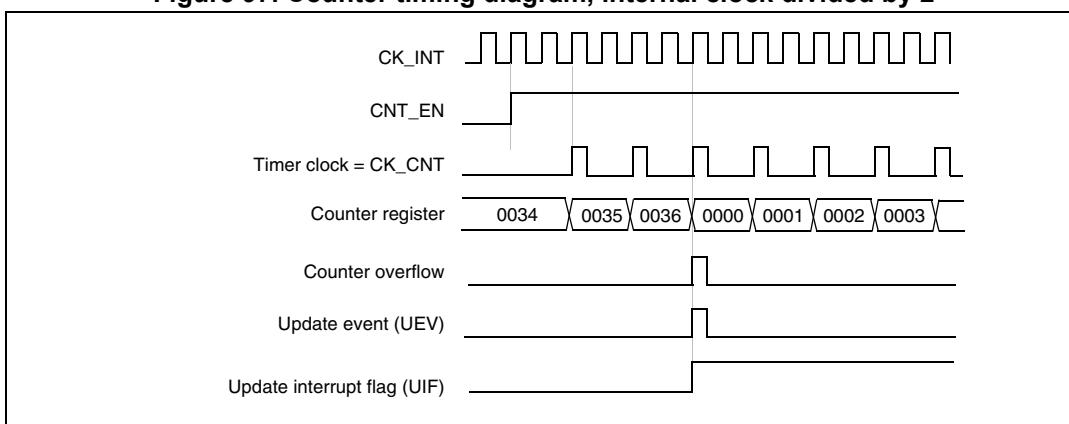
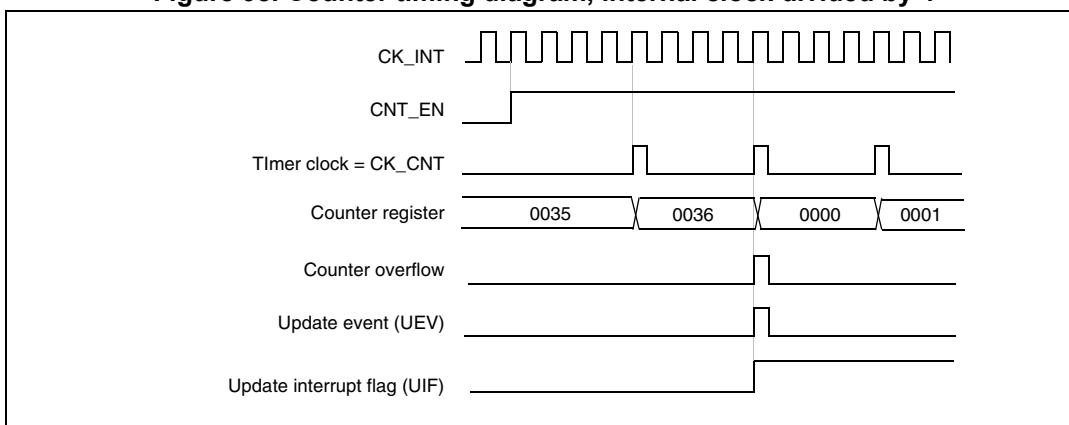
An Update event can be generated at each counter overflow or by setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller).

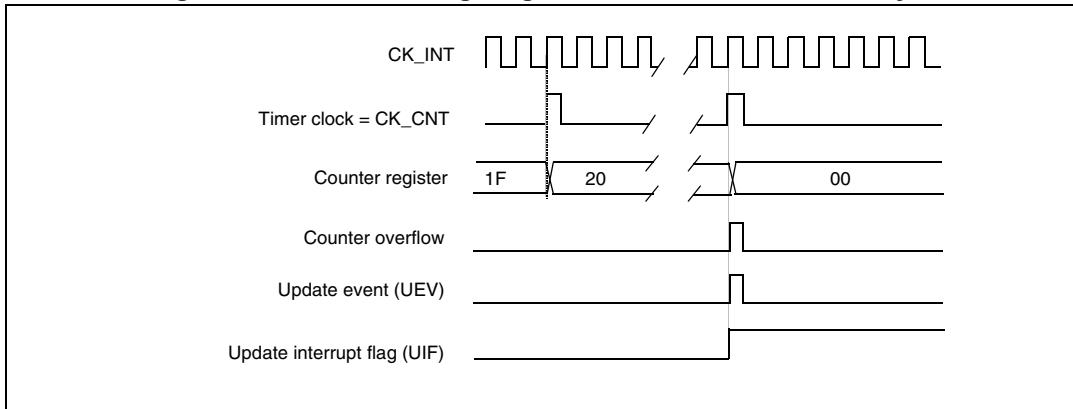
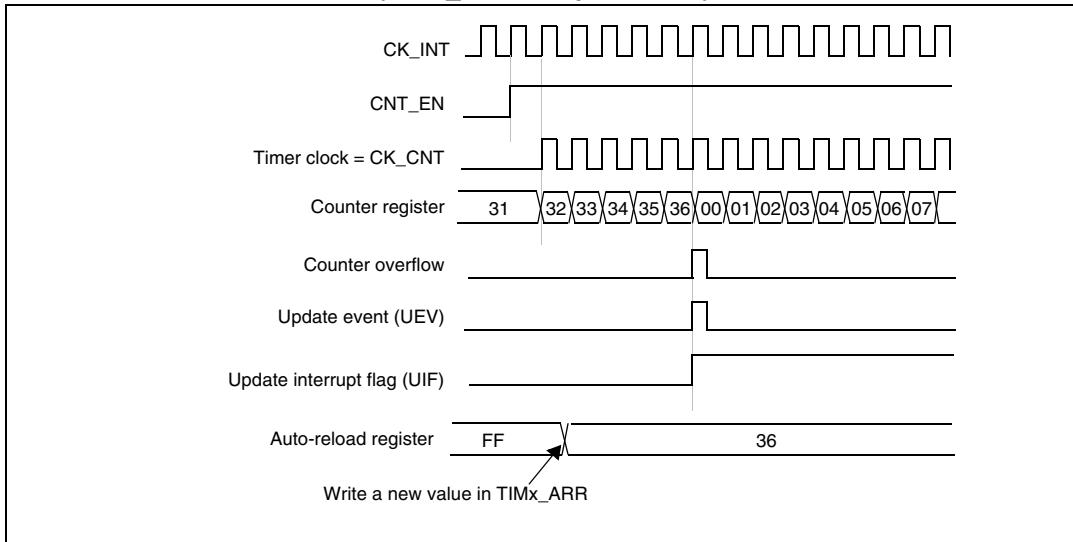
The UEV event can be disabled by software by setting the UDIS bit in TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

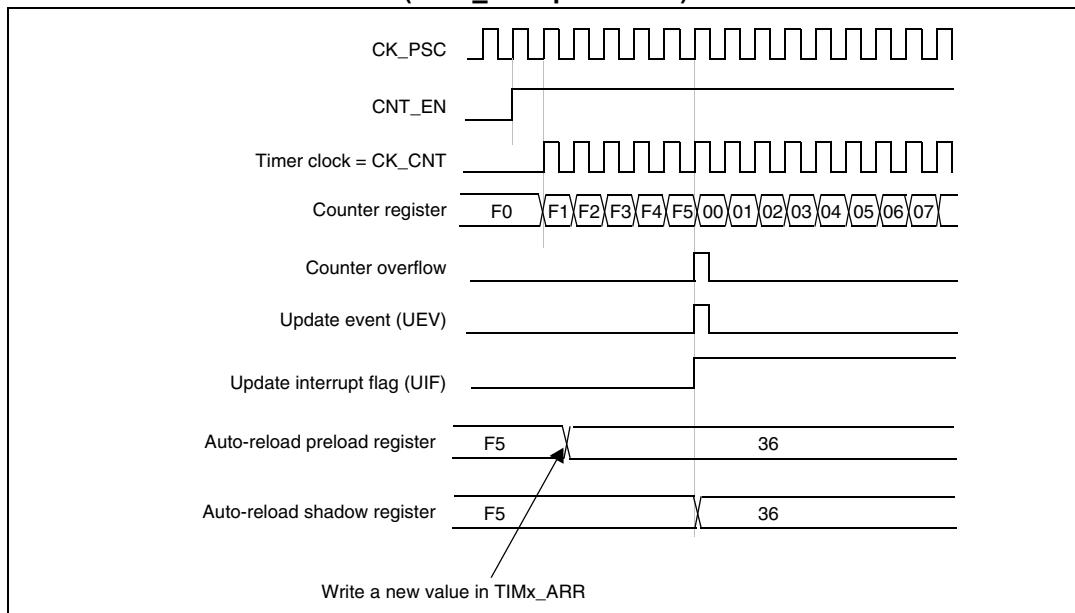
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register)
- The auto-reload shadow register is updated with the preload value (TIMx\_ARR)

The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR=0x36.

**Figure 96. Counter timing diagram, internal clock divided by 1****Figure 97. Counter timing diagram, internal clock divided by 2****Figure 98. Counter timing diagram, internal clock divided by 4**

**Figure 99. Counter timing diagram, internal clock divided by N****Figure 100. Counter timing diagram, Update event when ARPE=0  
(TIMx\_ARR not preloaded)**

**Figure 101. Counter timing diagram, Update event when ARPE=1  
(TIMx\_ARR preloaded)**



### Downcounting mode

In downcounting mode, the counter counts from the auto-reload value (content of the TIMx\_ARR register) down to 0, then restarts from the auto-reload value and generates a counter underflow event.

An Update event can be generated at each counter underflow or by setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller).

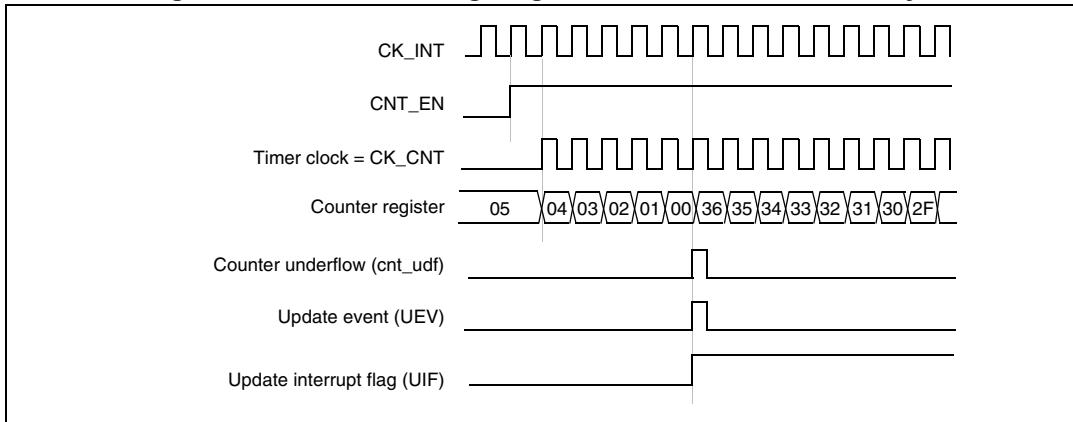
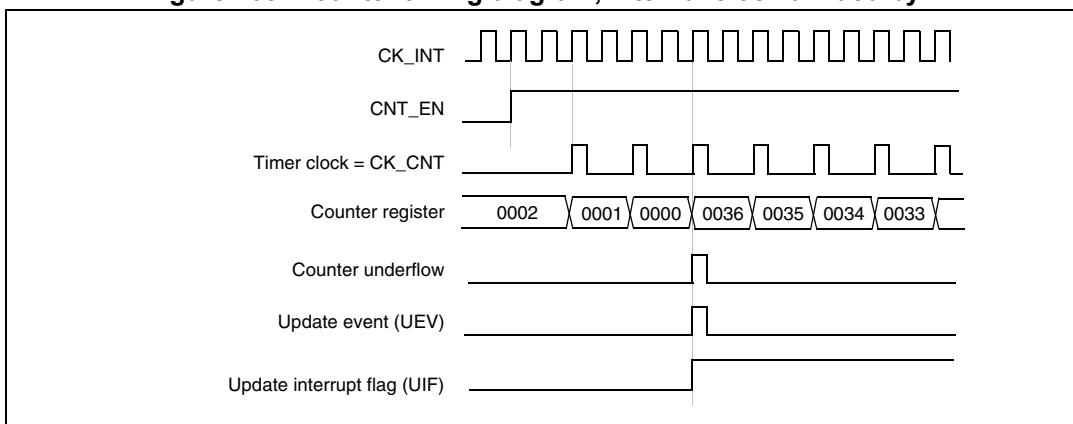
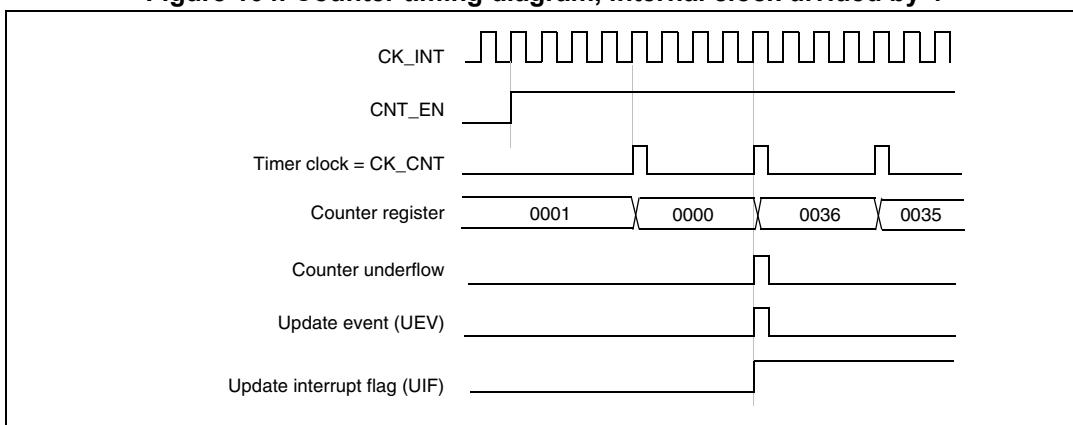
The UEV update event can be disabled by software by setting the UDIS bit in TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until UDIS bit has been written to 0. However, the counter restarts from the current auto-reload value, whereas the counter of the prescaler restarts from 0 (but the prescale rate doesn't change).

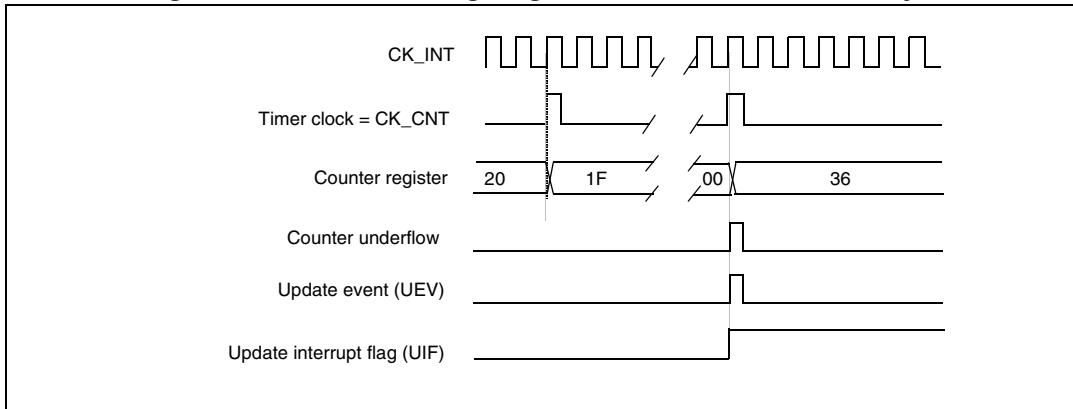
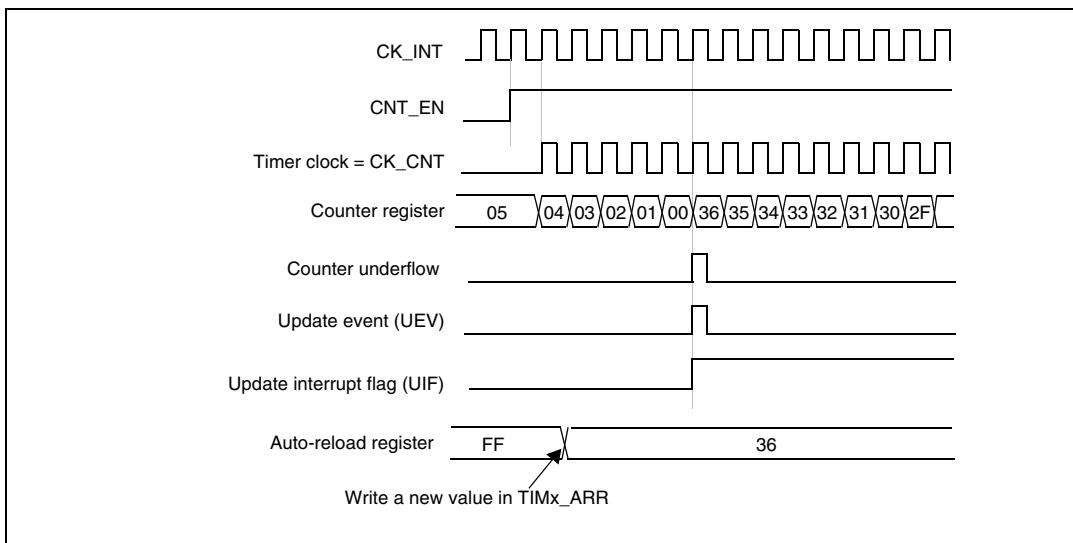
In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register).
- The auto-reload active register is updated with the preload value (content of the TIMx\_ARR register). Note that the auto-reload is updated before the counter is reloaded, so that the next period is the expected one.

The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR=0x36.

**Figure 102. Counter timing diagram, internal clock divided by 1****Figure 103. Counter timing diagram, internal clock divided by 2****Figure 104. Counter timing diagram, internal clock divided by 4**

**Figure 105. Counter timing diagram, internal clock divided by N****Figure 106. Counter timing diagram, Update event when repetition counter is not used**

### Center-aligned mode (up/down counting)

In center-aligned mode, the counter counts from 0 to the auto-reload value (content of the TIMx\_ARR register) – 1, generates a counter overflow event, then counts from the auto-reload value down to 1 and generates a counter underflow event. Then it restarts counting from 0.

Center-aligned mode is active when the CMS bits in TIMx\_CR1 register are not equal to '00'. The Output compare interrupt flag of channels configured in output is set when: the counter counts down (Center aligned mode 1, CMS = "01"), the counter counts up (Center aligned mode 2, CMS = "10") or the counter counts up and down (Center aligned mode 3, CMS = "11").

In this mode, the direction bit (DIR from TIMx\_CR1 register) cannot be written. It is updated by hardware and gives the current direction of the counter.

The update event can be generated at each counter overflow and at each counter underflow or by setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller) also generates an update event. In this case, the counter restarts counting from 0, as well as the counter of the prescaler.

The UEV update event can be disabled by software by setting the UDIS bit in TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter continues counting up and down, based on the current auto-reload value.

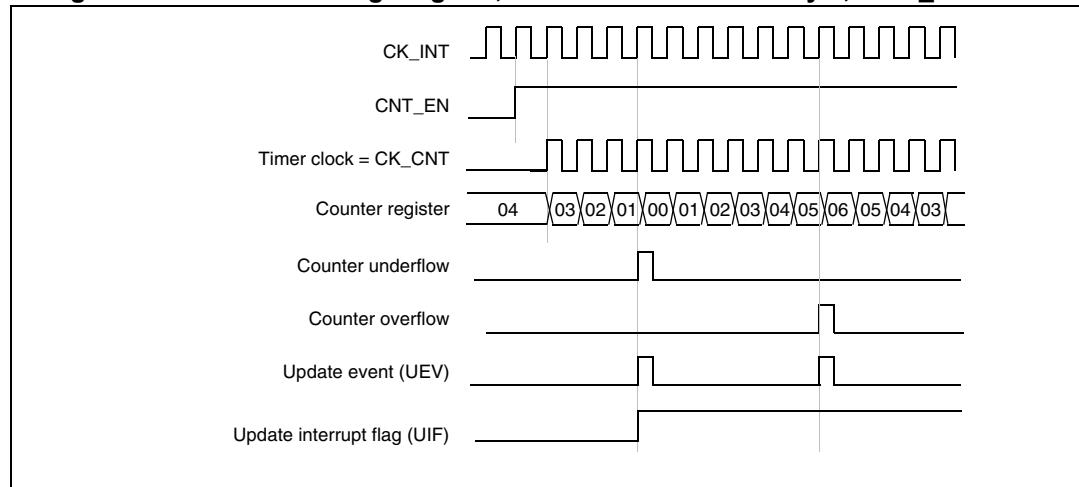
In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupt when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

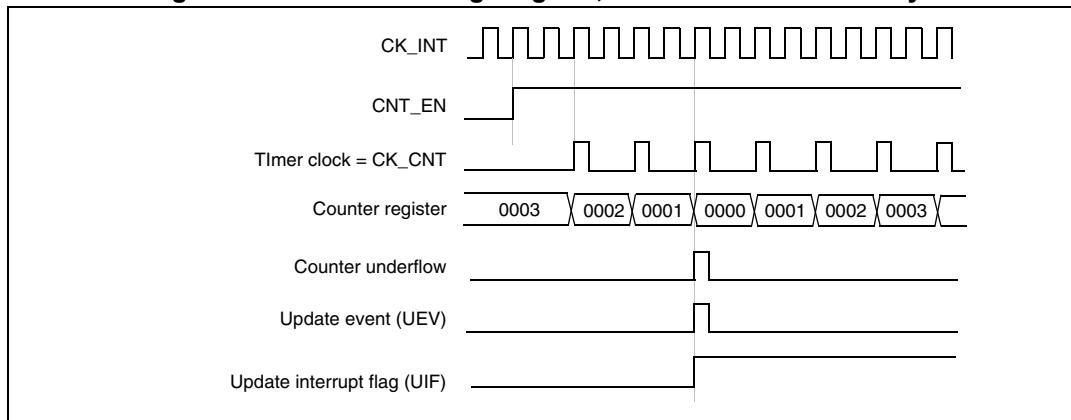
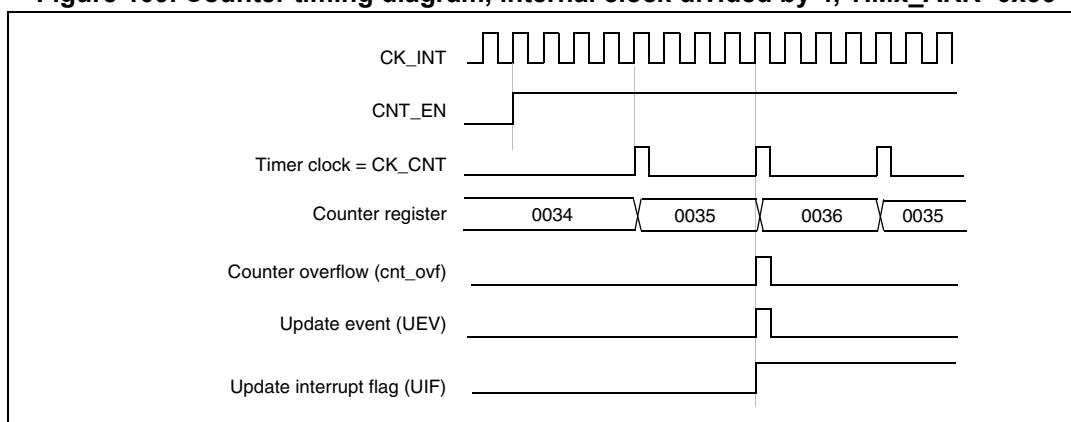
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register).
- The auto-reload active register is updated with the preload value (content of the TIMx\_ARR register). Note that if the update source is a counter overflow, the auto-reload is updated before the counter is reloaded, so that the next period is the expected one (the counter is loaded with the new value).

The following figures show some examples of the counter behavior for different clock frequencies.

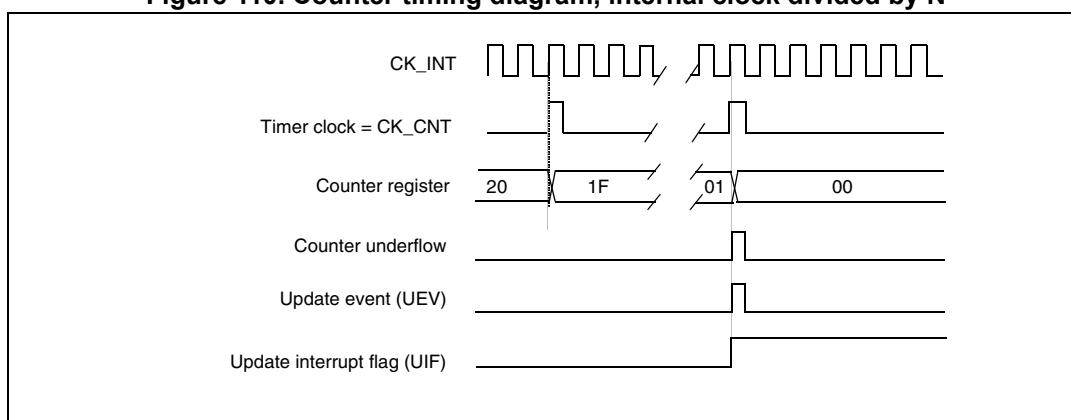
**Figure 107. Counter timing diagram, internal clock divided by 1, TIMx\_ARR=0x6**

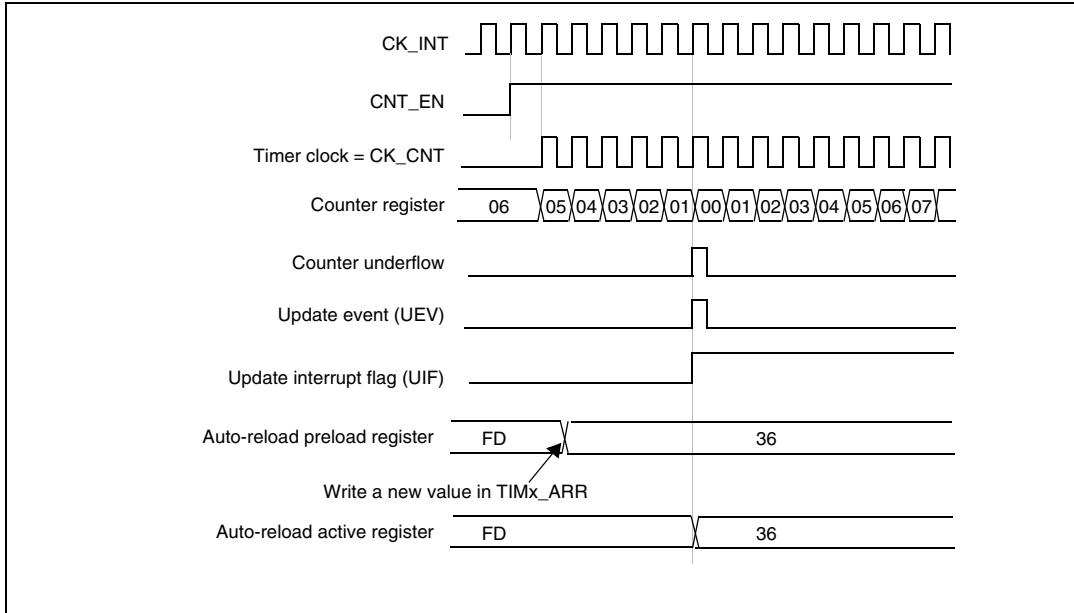
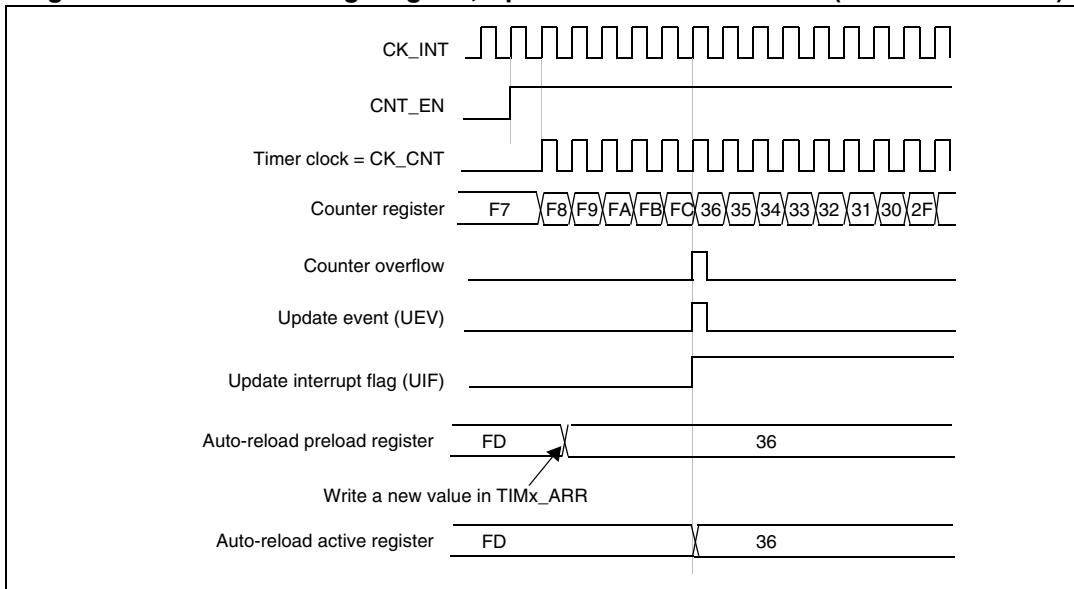


1. Here, center-aligned mode 1 is used (for more details refer to [Section 16.4.1: TIM2 and TIM3 control register 1 \(TIM2\\_CR1 and TIM3\\_CR1\) on page 337](#)).

**Figure 108. Counter timing diagram, internal clock divided by 2****Figure 109. Counter timing diagram, internal clock divided by 4, TIMx\_ARR=0x36**

1. Center-aligned mode 2 or 3 is used with an UIF on overflow.

**Figure 110. Counter timing diagram, internal clock divided by N**

**Figure 111. Counter timing diagram, Update event with ARPE=1 (counter underflow)****Figure 112. Counter timing diagram, Update event with ARPE=1 (counter overflow)**

### 16.3.3 Clock sources

The counter clock can be provided by the following clock sources:

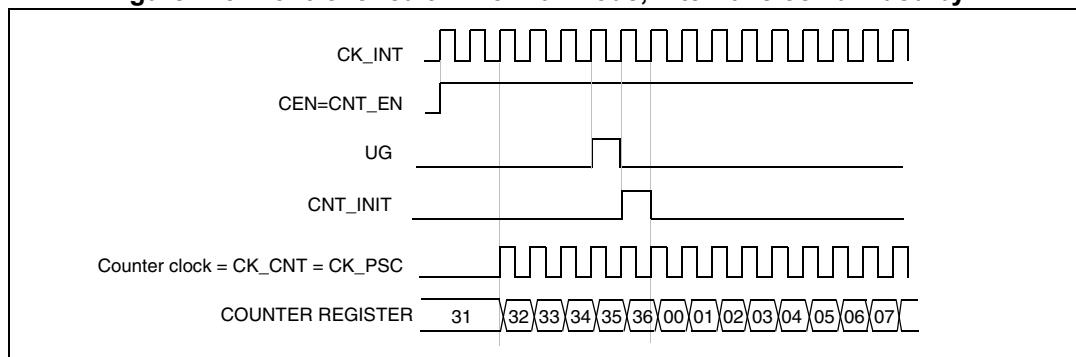
- Internal clock (CK\_INT)
- External clock mode1: external input pin (TIx)
- External clock mode2: external trigger input (ETR)
- Internal trigger inputs (ITRx): using one timer as prescaler for another timer, for example, you can configure Timer 1 to act as a prescaler for Timer 2. Refer to : [Using one timer as prescaler for another on page 331](#) for more details.

#### Internal clock source (CK\_INT)

If the slave mode controller is disabled (SMS=000 in the TIMx\_SMCR register), then the CEN, DIR (in the TIMx\_CR1 register) and UG bits (in the TIMx\_EGR register) are actual control bits and can be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK\_INT.

*Figure 113* shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

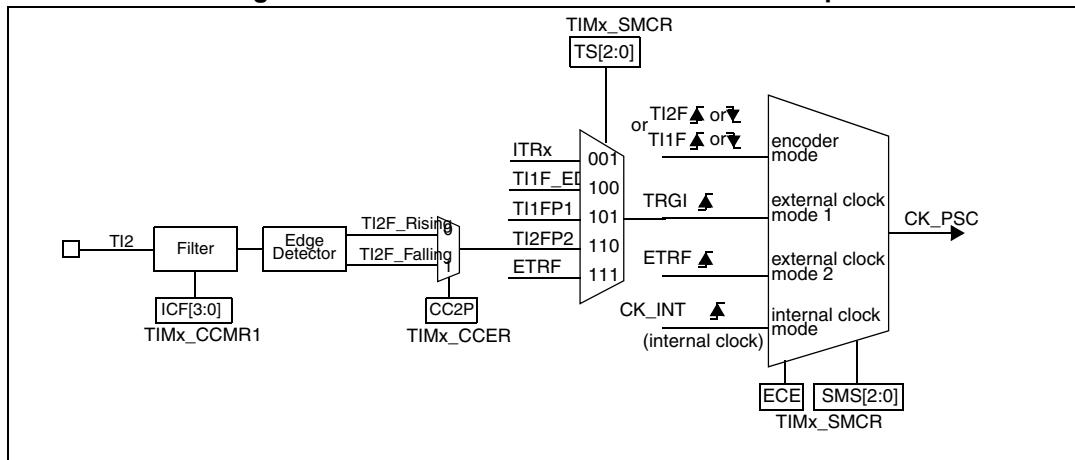
**Figure 113. Control circuit in normal mode, internal clock divided by 1**



#### External clock source mode 1

This mode is selected when SMS=111 in the TIMx\_SMCR register. The counter can count at each rising or falling edge on a selected input.

Figure 114. TI2 external clock connection example



For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S= '01 in the TIMx\_CCMR1 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIMx\_CCMR1 register (if no filter is needed, keep IC2F=0000).

*Note:*

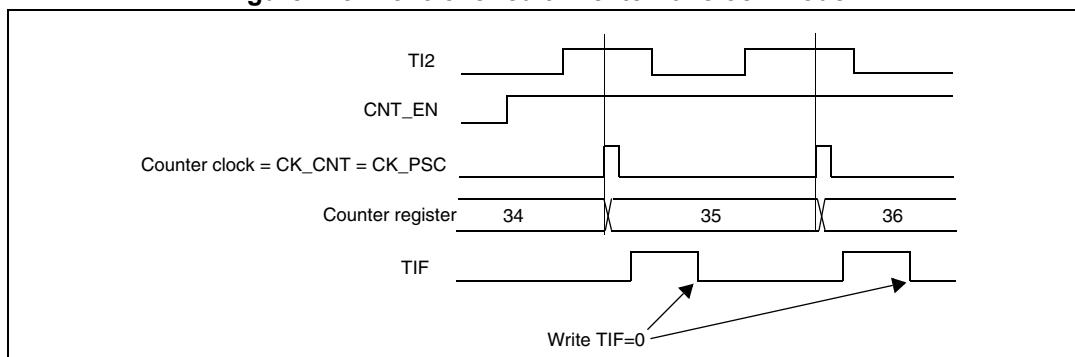
*The capture prescaler is not used for triggering, so you don't need to configure it.*

3. Select rising edge polarity by writing CC2P=0 and CC2NP=0 in the TIMx\_CCER register.
4. Configure the timer in external clock mode 1 by writing SMS=111 in the TIMx\_SMCR register.
5. Select TI2 as the input source by writing TS=110 in the TIMx\_SMCR register.
6. Enable the counter by writing CEN=1 in the TIMx\_CR1 register.

When a rising edge occurs on TI2, the counter counts once and the TIF flag is set.

The delay between the rising edge on TI2 and the actual clock of the counter is due to the resynchronization circuit on TI2 input.

Figure 115. Control circuit in external clock mode 1



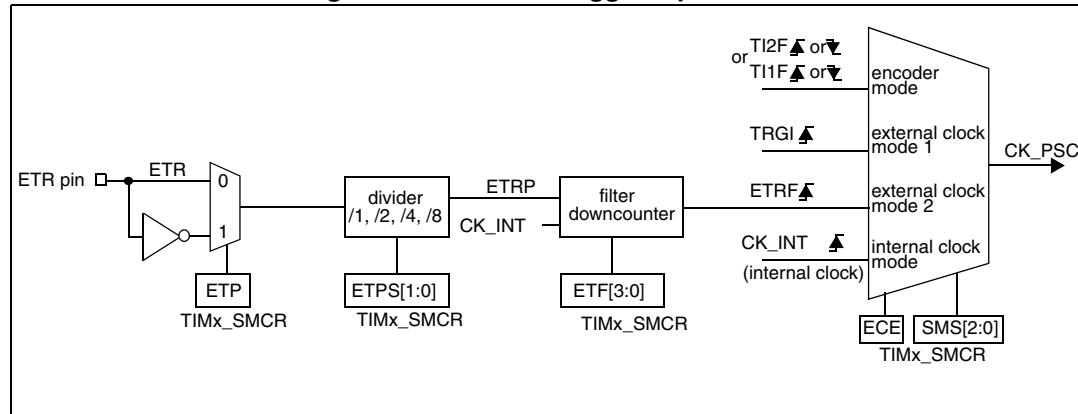
### External clock source mode 2

This mode is selected by writing ECE=1 in the TIMx\_SMCR register.

The counter can count at each rising or falling edge on the external trigger input ETR.

The [Figure 116](#) gives an overview of the external trigger input block.

**Figure 116. External trigger input block**



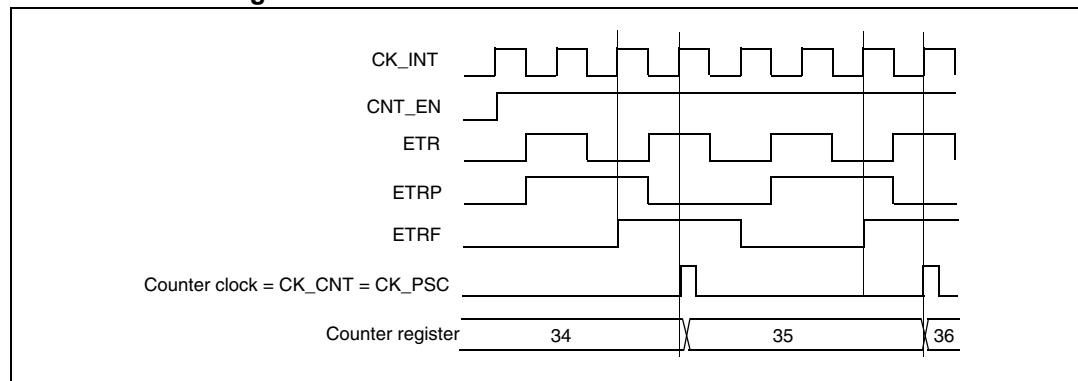
For example, to configure the upcounter to count each 2 rising edges on ETR, use the following procedure:

1. As no filter is needed in this example, write ETF[3:0]=0000 in the TIMx\_SMCR register.
2. Set the prescaler by writing ETPS[1:0]=01 in the TIMx\_SMCR register
3. Select rising edge detection on the ETR pin by writing ETP=0 in the TIMx\_SMCR register
4. Enable external clock mode 2 by writing ECE=1 in the TIMx\_SMCR register.
5. Enable the counter by writing CEN=1 in the TIMx\_CR1 register.

The counter counts once each 2 ETR rising edges.

The delay between the rising edge on ETR and the actual clock of the counter is due to the resynchronization circuit on the ETRP signal.

**Figure 117. Control circuit in external clock mode 2**



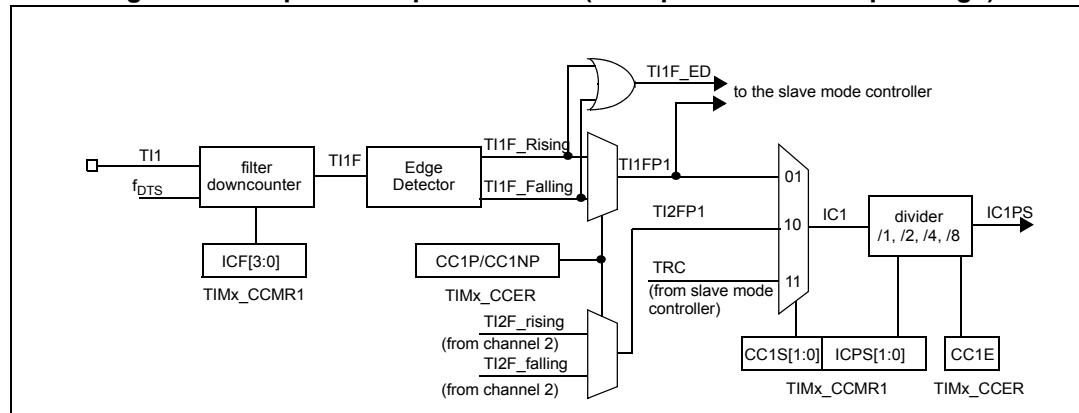
### 16.3.4 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

The following figure gives an overview of one Capture/Compare channel.

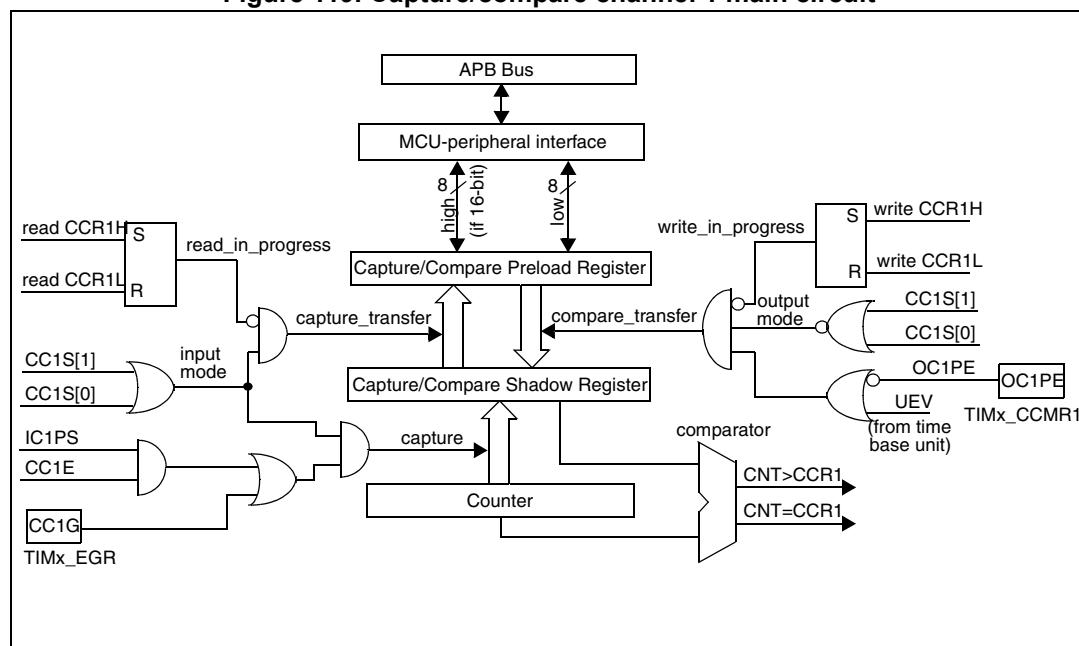
The input stage samples the corresponding TIx input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

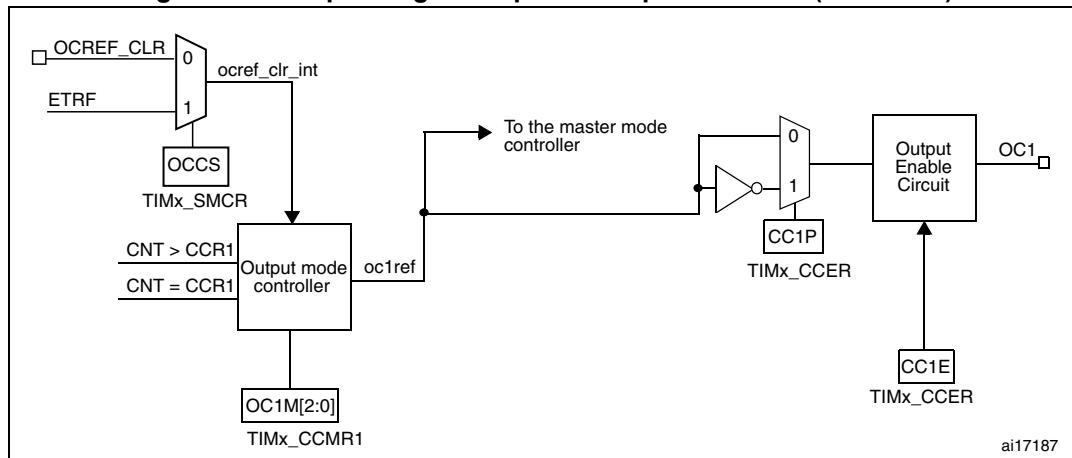
**Figure 118. Capture/compare channel (example: channel 1 input stage)**



The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

**Figure 119. Capture/compare channel 1 main circuit**



**Figure 120. Output stage of capture/compare channel (channel 1)**

The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

### 16.3.5 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx\_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCxIF flag (TIMx\_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx\_SR register) is set. CCxIF can be cleared by software by writing it to 0 or by reading the captured data stored in the TIMx\_CCRx register. CCxOF is cleared when you write it to 0.

The following example shows how to capture the counter value in TIMx\_CCR1 when TI1 input rises. To do this, use the following procedure:

- Select the active input: TIMx\_CCR1 must be linked to the TI1 input, so write the CC1S bits to 01 in the TIMx\_CCMR1 register. As soon as CC1S becomes different from 00, the channel is configured in input and the TIMx\_CCR1 register becomes read-only.
- Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx\_CCMRx register). Let's imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been

detected (sampled at  $f_{DTS}$  frequency). Then write IC1F bits to 0011 in the TIMx\_CCMR1 register.

- Select the edge of the active transition on the TI1 channel by writing the CC1P and CC1NP bits to 0 in the TIMx\_CCER register (rising edge in this case).
- Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to 00 in the TIMx\_CCMR1 register).
- Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx\_CCER register.
- If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx\_DIER register, and/or the DMA request by setting the CC1DE bit in the TIMx\_DIER register.

When an input capture occurs:

- The TIMx\_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.
- A DMA request is generated depending on the CC1DE bit.

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

*Note: IC interrupt and/or DMA requests can be generated by software by setting the corresponding CCxG bit in the TIMx\_EGR register.*

### 16.3.6 PWM input mode

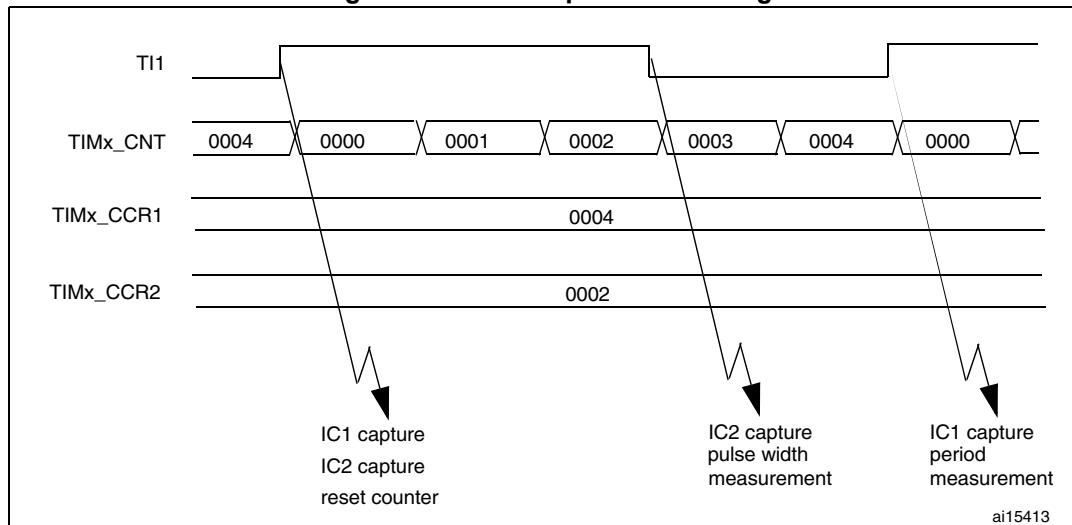
This mode is a particular case of input capture mode. The procedure is the same except:

- Two ICx signals are mapped on the same TIx input.
- These 2 ICx signals are active on edges with opposite polarity.
- One of the two TIxFP signals is selected as trigger input and the slave mode controller is configured in reset mode.

For example, you can measure the period (in TIMx\_CCR1 register) and the duty cycle (in TIMx\_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on CK\_INT frequency and prescaler value):

- Select the active input for TIMx\_CCR1: write the CC1S bits to 01 in the TIMx\_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP1 (used both for capture in TIMx\_CCR1 and counter clear): write the CC1P to '0' and the CC1NP bit to '0' (active on rising edge).
- Select the active input for TIMx\_CCR2: write the CC2S bits to 10 in the TIMx\_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP2 (used for capture in TIMx\_CCR2): write the CC2P bit to '1' and the CC2NP bit to '0' (active on falling edge).
- Select the valid trigger input: write the TS bits to 101 in the TIMx\_SMCR register (TI1FP1 selected).
- Configure the slave mode controller in reset mode: write the SMS bits to 100 in the TIMx\_SMCR register.
- Enable the captures: write the CC1E and CC2E bits to '1' in the TIMx\_CCER register.

**Figure 121. PWM input mode timing**



### 16.3.7 Forced output mode

In output mode (CCxS bits = 00 in the TIMx\_CCMRx register), each output compare signal (OCxREF and then OCx) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (ocxref/OCx) to its active level, you just need to write 101 in the OCxM bits in the corresponding TIMx\_CCMRx register. Thus ocxref is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

e.g.: CCxP=0 (OCx active high) => OCx is forced to high level.

ocxref signal can be forced low by writing the OCxM bits to 100 in the TIMx\_CCMRx register.

Anyway, the comparison between the TIMx\_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt and DMA requests can be sent accordingly. This is described in the Output Compare Mode section.

### 16.3.8 Output compare mode

This function is used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

- Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx\_CCMRx register) and the output polarity (CCxP bit in the TIMx\_CCER register). The output pin can keep its level (OCXM=000), be set active (OCXM=001), be set inactive (OCXM=010) or can toggle (OCXM=011) on match.
- Sets a flag in the interrupt status register (CCxIF bit in the TIMx\_SR register).
- Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx\_DIER register).
- Sends a DMA request if the corresponding enable bit is set (CCxDE bit in the TIMx\_DIER register, CCDS bit in the TIMx\_CR2 register for the DMA request selection).

The TIMx\_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx\_CCMRx register.

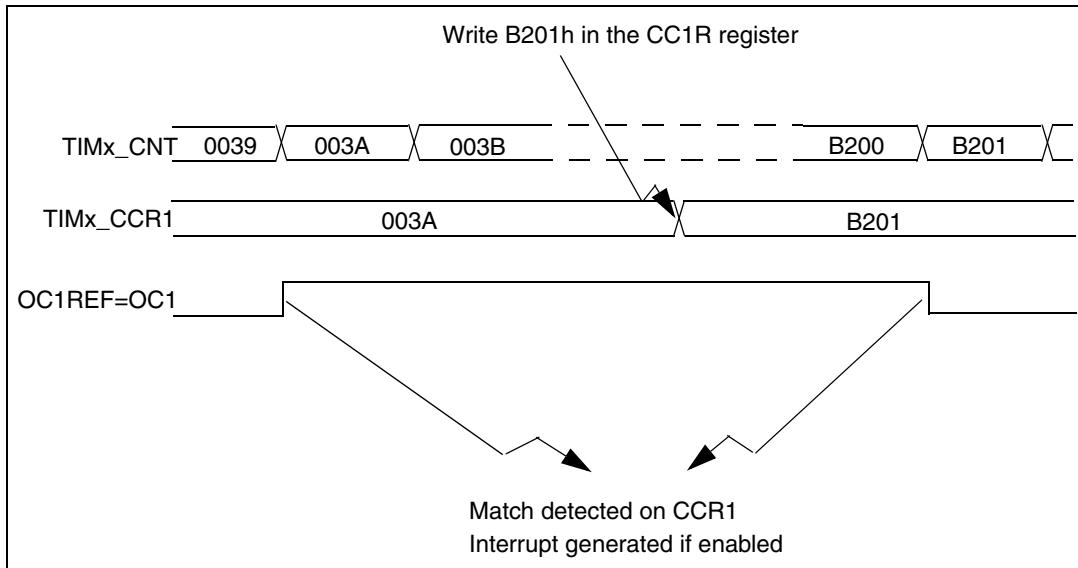
In output compare mode, the update event UEV has no effect on ocxref and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One-pulse mode).

Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx\_ARR and TIMx\_CCRx registers.
3. Set the CCxIE and/or CCxDE bits if an interrupt and/or a DMA request is to be generated.
4. Select the output mode. For example, you must write OCxM=011, OCxPE=0, CCxP=0 and CCxE=1 to toggle OCx output pin when CNT matches CCRx, CCRx preload is not used, OCx is enabled and active high.
5. Enable the counter by setting the CEN bit in the TIMx\_CR1 register.

The TIMx\_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE=0, else TIMx\_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 122](#).

**Figure 122. Output compare mode, toggle on OC1.**



### 16.3.9 PWM mode

Pulse width modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx\_ARR register and a duty cycle determined by the value of the TIMx\_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing 110 (PWM mode 1) or '111 (PWM mode 2) in the OCxM bits in the TIMx\_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx\_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx\_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx\_EGR register.

OCx polarity is software programmable using the CCxP bit in the TIMx\_CCER register. It can be programmed as active high or active low. OCx output is enabled by the CCxE bit in the TIMx\_CCER register. Refer to the TIMx\_CCERx register description for more details.

In PWM mode (1 or 2), TIMx\_CNT and TIMx\_CCRx are always compared to determine whether TIMx\_CCRx≤TIMx\_CNT or TIMx\_CNT≤TIMx\_CCRx (depending on the direction of the counter). However, to comply with the OCREF\_CLR functionality (OCREF can be cleared by an external event through the ETR signal until the next PWM period), the OCREF signal is asserted only:

- When the result of the comparison changes, or
- When the output compare mode (OCxM bits in TIMx\_CCMRx register) switches from the “frozen” configuration (no comparison, OCxM='000) to one of the PWM modes (OCxM='110 or '111).

This forces the PWM by software while the timer is running.

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIMx\_CR1 register.

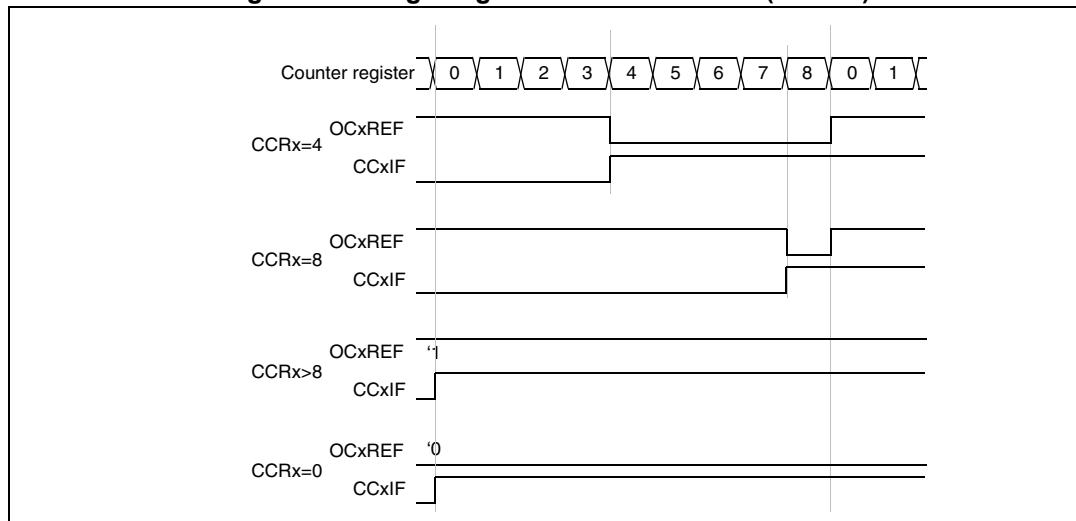
### PWM edge-aligned mode

Upcounting configuration

Upcounting is active when the DIR bit in the TIMx\_CR1 register is low. Refer to the [Section : Upcounting mode on page 303](#).

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as  $\text{TIMx\_CNT} < \text{TIMx\_CCR}_x$  else it becomes low. If the compare value in  $\text{TIMx\_CCR}_x$  is greater than the auto-reload value (in TIMx\_ARR) then OCxREF is held at '1. If the compare value is 0 then OCxREF is held at '0'. [Figure 123](#) shows some edge-aligned PWM waveforms in an example where TIMx\_ARR=8.

**Figure 123. Edge-aligned PWM waveforms (ARR=8)**



### Downcounting configuration

Downcounting is active when DIR bit in TIMx\_CR1 register is high. Refer to [Downcounting mode on page 306](#)

In PWM mode 1, the reference signal ocxref is low as long as  $\text{TIMx\_CNT} > \text{TIMx\_CCR}_x$  else it becomes high. If the compare value in  $\text{TIMx\_CCR}_x$  is greater than the auto-reload value in TIMx\_ARR, then ocxref is held at '1. 0% PWM is not possible in this mode.

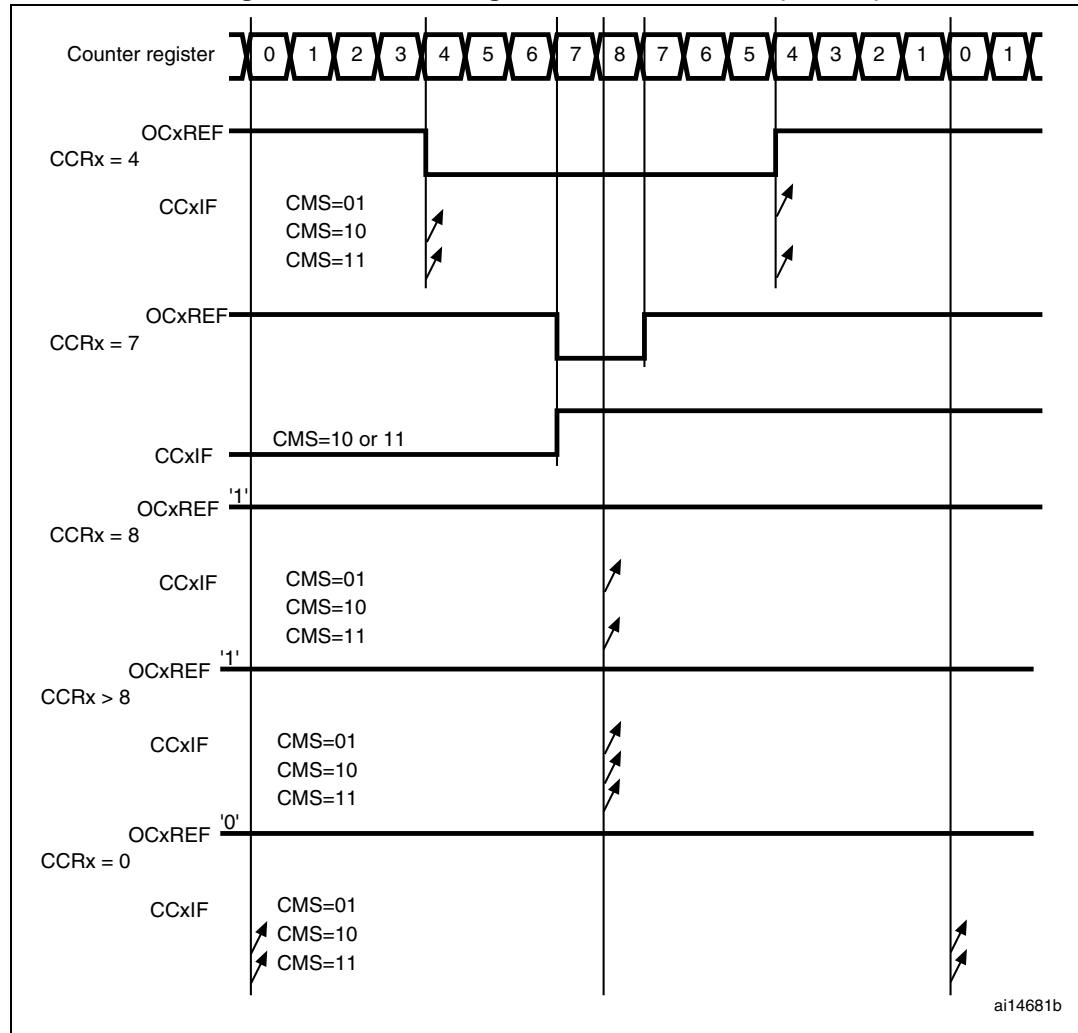
### PWM center-aligned mode

Center-aligned mode is active when the CMS bits in TIMx\_CR1 register are different from '00 (all the remaining configurations having the same effect on the ocxref/OCx signals). The compare flag is set when the counter counts up, when it counts down or both when it counts up and down depending on the CMS bits configuration. The direction bit (DIR) in the TIMx\_CR1 register is updated by hardware and must not be changed by software. Refer to the [Center-aligned mode \(up/down counting\) on page 308](#).

[Figure 124](#) shows some center-aligned PWM waveforms in an example where:

- TIMx\_ARR=8,
  - PWM mode is the PWM mode 1,
  - The flag is set when the counter counts down corresponding to the center-aligned mode 1 selected for CMS=01 in TIMx\_CR1 register.

**Figure 124. Center-aligned PWM waveforms (ARR=8)**



Hints on using center-aligned mode:

- When starting in center-aligned mode, the current up-down configuration is used. It means that the counter counts up or down depending on the value written in the DIR bit in the TIMx\_CR1 register. Moreover, the DIR and CMS bits must not be changed at the same time by the software.
- Writing to the counter while running in center-aligned mode is not recommended as it can lead to unexpected results. In particular:
  - The direction is not updated if you write a value in the counter that is greater than the auto-reload value ( $\text{TIMx_CNT} > \text{TIMx_ARR}$ ). For example, if the counter was counting up, it continues to count up.
  - The direction is updated if you write 0 or write the  $\text{TIMx_ARR}$  value in the counter but no Update Event UEV is generated.
- The safest way to use center-aligned mode is to generate an update by software (setting the UG bit in the TIMx\_EGR register) just before starting the counter and not to write the counter while it is running.

### 16.3.10 One-pulse mode

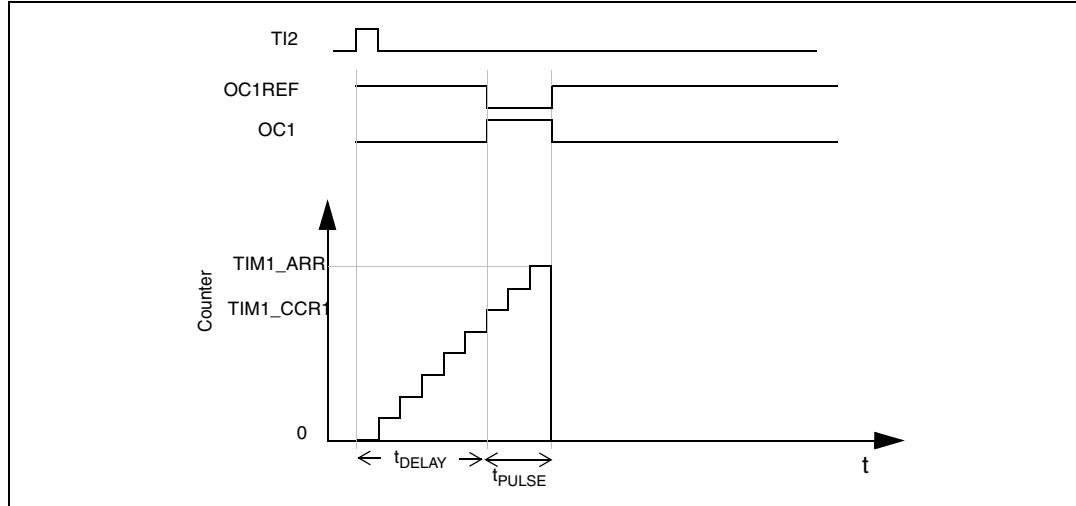
One-pulse mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

Starting the counter can be controlled through the slave mode controller. Generating the waveform can be done in output compare mode or PWM mode. You select One-pulse mode by setting the OPM bit in the TIMx\_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

- In upcounting:  $\text{CNT} < \text{CCR}_x \leq \text{ARR}$  (in particular,  $0 < \text{CCR}_x$ ),
- In downcounting:  $\text{CNT} > \text{CCR}_x$ .

**Figure 125. Example of one-pulse mode.**



For example you may want to generate a positive pulse on OC1 with a length of  $t_{PULSE}$  and after a delay of  $t_{DELAY}$  as soon as a positive edge is detected on the TI2 input pin.

Use TI2FP2 as trigger 1:

- Map TI2FP2 on TI2 by writing IC2S=01 in the TIMx\_CCMR1 register.
- TI2FP2 must detect a rising edge, write CC2P=0 and CC2NP='0' in the TIMx\_CCER register.
- Configure TI2FP2 as trigger for the slave mode controller (TRGI) by writing TS=110 in the TIMx\_SMCR register.
- TI2FP2 is used to start the counter by writing SMS to '110 in the TIMx\_SMCR register (trigger mode).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The  $t_{DELAY}$  is defined by the value written in the TIMx\_CCR1 register.
- The  $t_{PULSE}$  is defined by the difference between the auto-reload value and the compare value (TIMx\_ARR - TIMx\_CCR1).
- Let's say you want to build a waveform with a transition from '0 to '1 when a compare match occurs and a transition from '1 to '0 when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC1M=111 in the TIMx\_CCMR1 register. You can optionally enable the preload registers by writing OC1PE=1 in the TIMx\_CCMR1 register and ARPE in the TIMx\_CR1 register. In this case you have to write the compare value in the TIMx\_CCR1 register, the auto-reload value in the TIMx\_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0 in this example.

In our example, the DIR and CMS bits in the TIMx\_CR1 register should be low.

You only want 1 pulse (Single mode), so you write '1 in the OPM bit in the TIMx\_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0). When OPM bit in the TIMx\_CR1 register is set to '0', so the Repetitive Mode is selected.

#### **Particular case: OCx fast enable:**

In One-pulse mode, the edge detection on TIx input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay  $t_{DELAY}$  min we can get.

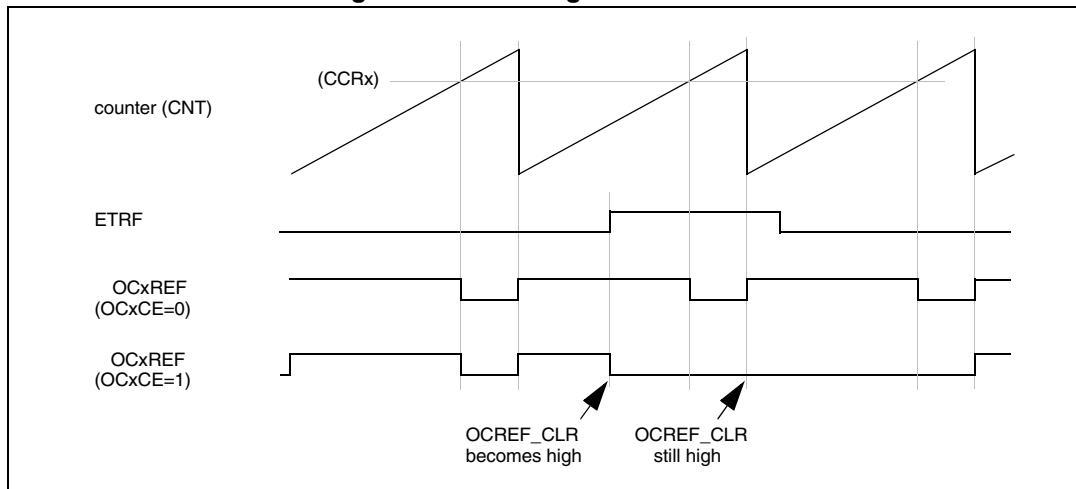
If you want to output a waveform with the minimum delay, you can set the OCxFE bit in the TIMx\_CCMRx register. Then OCxRef (and OCx) is forced in response to the stimulus, without taking in account the comparison. Its new level is the same as if a compare match had occurred. OCxFE acts only if the channel is configured in PWM1 or PWM2 mode.

#### **16.3.11 Clearing the OCxREF signal on an external event**

1. The external trigger prescaler should be kept off: bits ETPS[1:0] in the TIMx\_SMCR register are cleared to 00.
2. The external clock mode 2 must be disabled: bit ECE in the TIM1\_SMCR register is cleared to 0.
3. The external trigger polarity (ETP) and the external trigger filter (ETF) can be configured according to the application's needs.

[Figure 126](#) shows the behavior of the OC<sub>x</sub>REF signal when the ETRF input becomes high, for both values of the OC<sub>x</sub>CE enable bit. In this example, the timer TIMx is programmed in PWM mode.

**Figure 126. Clearing TIMx OC<sub>x</sub>REF**



1. In case of a PWM with a 100% duty cycle (if CCRx>ARR), OC<sub>x</sub>REF is enabled again at the next counter overflow.

### 16.3.12 Encoder interface mode

To select Encoder Interface mode write SMS='001 in the TIMx\_SMCR register if the counter is counting on TI2 edges only, SMS=010 if it is counting on TI1 edges only and SMS=011 if it is counting on both TI1 and TI2 edges.

Select the TI1 and TI2 polarity by programming the CC1P and CC2P bits in the TIMx\_CCER register. CC1NP and CC2NP must be kept cleared. When needed, you can program the input filter as well.

The two inputs TI1 and TI2 are used to interface to an incremental encoder. Refer to [Table 46](#). The counter is clocked by each valid transition on TI1FP1 or TI2FP2 (TI1 and TI2 after input filter and polarity selection, TI1FP1=TI1 if not filtered and not inverted, TI2FP2=TI2 if not filtered and not inverted) assuming that it is enabled (CEN bit in TIMx\_CR1 register written to '1'). The sequence of transitions of the two inputs is evaluated and generates count pulses as well as the direction signal. Depending on the sequence the counter counts up or down, the DIR bit in the TIMx\_CR1 register is modified by hardware accordingly. The DIR bit is calculated at each transition on any input (TI1 or TI2), whatever the counter is counting on TI1 only, TI2 only or both TI1 and TI2.

Encoder interface mode acts simply as an external clock with direction selection. This means that the counter just counts continuously between 0 and the auto-reload value in the TIMx\_ARR register (0 to ARR or ARR down to 0 depending on the direction). So you must configure TIMx\_ARR before starting. In the same way, the capture, compare, prescaler, trigger output features continue to work as normal.

In this mode, the counter is modified automatically following the speed and the direction of the incremental encoder and its content, therefore, always represents the encoder's position. The count direction correspond to the rotation direction of the connected sensor. The table summarizes the possible combinations, assuming TI1 and TI2 don't switch at the same time.

Table 46. Counting direction versus encoder signals

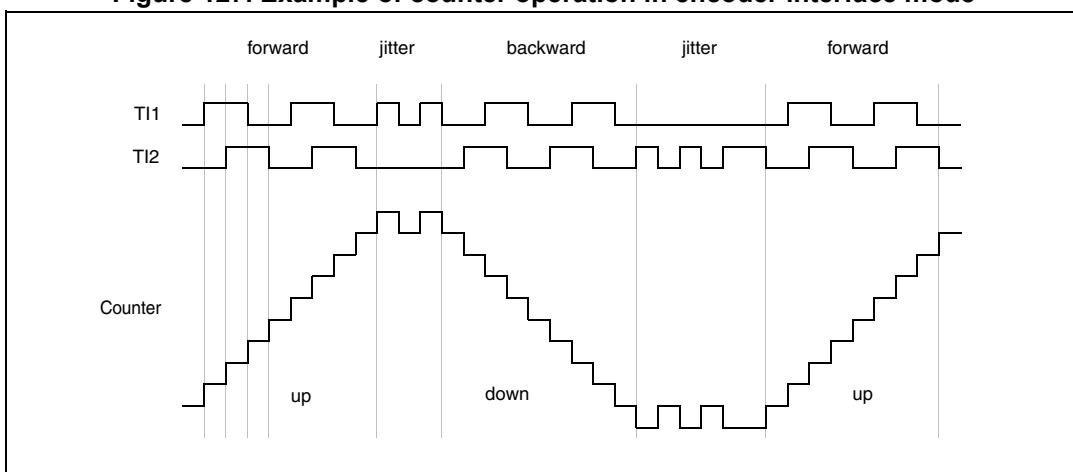
Active edge	Level on opposite signal (TI1FP1 for TI2, TI2FP2 for TI1)	TI1FP1 signal		TI2FP2 signal	
		Rising	Falling	Rising	Falling
Counting on TI1 only	High	Down	Up	No Count	No Count
	Low	Up	Down	No Count	No Count
Counting on TI2 only	High	No Count	No Count	Up	Down
	Low	No Count	No Count	Down	Up
Counting on TI1 and TI2	High	Down	Up	Up	Down
	Low	Up	Down	Down	Up

An external incremental encoder can be connected directly to the MCU without external interface logic. However, comparators are normally be used to convert the encoder's differential outputs to digital signals. This greatly increases noise immunity. The third encoder output which indicate the mechanical zero position, may be connected to an external interrupt input and trigger a counter reset.

*Figure 127* gives an example of counter operation, showing count signal generation and direction control. It also shows how input jitter is compensated where both edges are selected. This might occur if the sensor is positioned near to one of the switching points. For this example we assume that the configuration is the following:

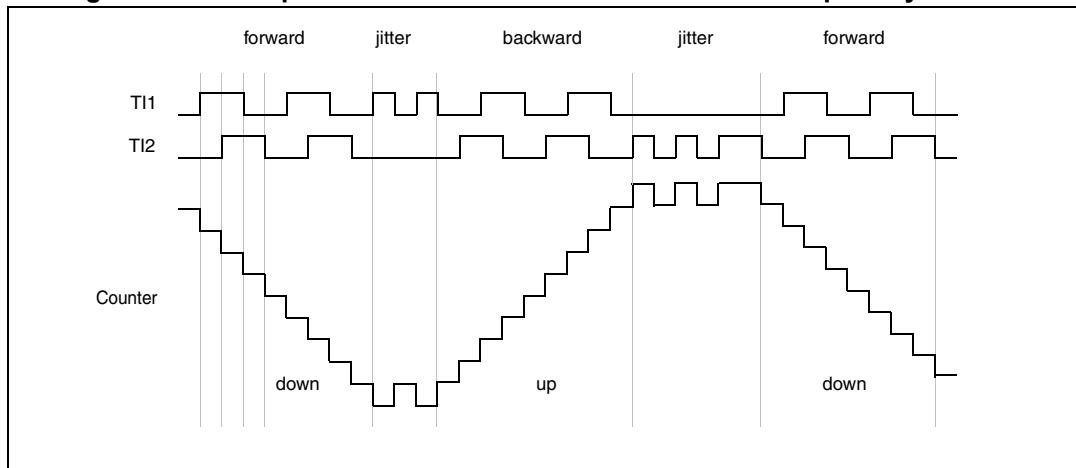
- CC1S= 01 (TIMx\_CCMR1 register, TI1FP1 mapped on TI1)
- CC2S= 01 (TIMx\_CCMR2 register, TI2FP2 mapped on TI2)
- CC1P=0, CC1NP = '0' (TIMx\_CCER register, TI1FP1 noninverted, TI1FP1=TI1)
- CC2P=0, CC2NP = '0' (TIMx\_CCER register, TI2FP2 noninverted, TI2FP2=TI2)
- SMS= 011 (TIMx\_SMCR register, both inputs are active on both rising and falling edges)
- CEN= 1 (TIMx\_CR1 register, Counter is enabled)

Figure 127. Example of counter operation in encoder interface mode



*Figure 128* gives an example of counter behavior when TI1FP1 polarity is inverted (same configuration as above except CC1P=1).

**Figure 128. Example of encoder interface mode with TI1FP1 polarity inverted**



The timer, when configured in Encoder Interface mode provides information on the sensor's current position. You can obtain dynamic information (speed, acceleration, deceleration) by measuring the period between two encoder events using a second timer configured in capture mode. The output of the encoder which indicates the mechanical zero can be used for this purpose. Depending on the time between two events, the counter can also be read at regular times. You can do this by latching the counter value into a third input capture register if available (then the capture signal must be periodic and can be generated by another timer). when available, it is also possible to read its value through a DMA request generated by a Real-Time clock.

### 16.3.13 Timer input XOR function

The TI1S bit in the TIM1\_CR2 register, allows the input filter of channel 1 to be connected to the output of a XOR gate, combining the three input pins TIMx\_CH1 to TIMx\_CH3.

The XOR output can be used with all the timer input functions such as trigger or input capture.

An example of this feature used to interface Hall sensors is given in [Section 15.3.18 on page 267](#).

### 16.3.14 Timers and external trigger synchronization

The TIMx Timers can be synchronized with an external trigger in several modes: Reset mode, Gated mode and Trigger mode.

#### Slave mode: Reset mode

The counter and its prescaler can be reinitialized in response to an event on a trigger input. Moreover, if the URS bit from the TIMx\_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIMx\_ARR, TIMx\_CCRx) are updated.

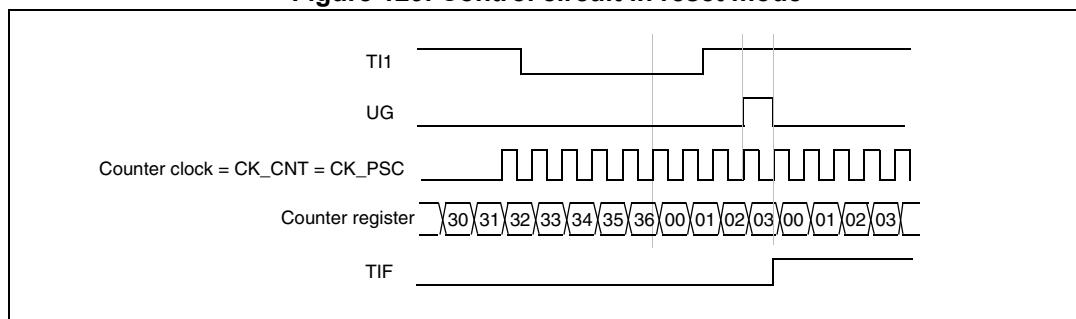
In the following example, the upcounter is cleared in response to a rising edge on TI1 input:

- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S = 01 in the TIMx\_CCMR1 register. Write CC1P=0 and CC1NP=0 in TIMx\_CCER register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.
- Start the counter by writing CEN=1 in the TIMx\_CR1 register.

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIMx\_SR register) and an interrupt request, or a DMA request can be sent if enabled (depending on the TIE and TDE bits in TIMx\_DIER register).

The following figure shows this behavior when the auto-reload register TIMx\_ARR=0x36. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

**Figure 129. Control circuit in reset mode**



### Slave mode: Gated mode

The counter can be enabled depending on the level of a selected input.

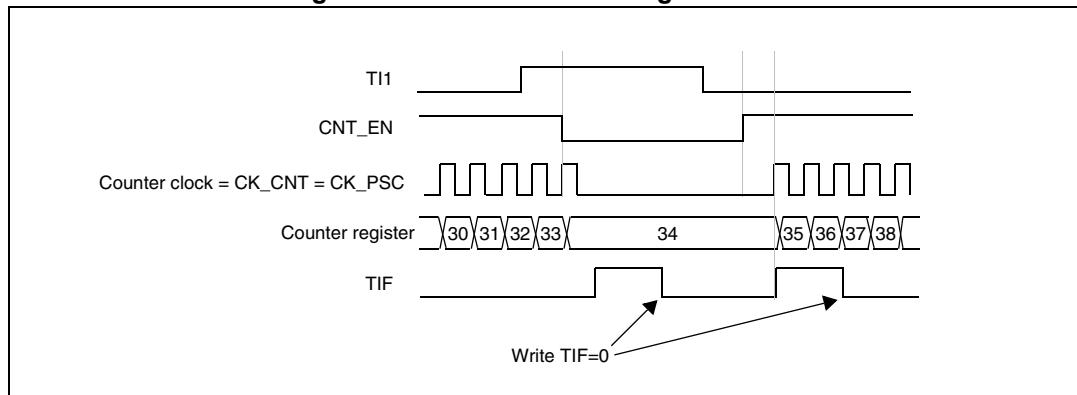
In the following example, the upcounter counts only when TI1 input is low:

- Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S=01 in TIMx\_CCMR1 register. Write CC1P=1 and CC1NP=0 in TIMx\_CCER register to validate the polarity (and detect low level only).
- Configure the timer in gated mode by writing SMS=101 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.
- Enable the counter by writing CEN=1 in the TIMx\_CR1 register (in gated mode, the counter doesn't start if CEN=0, whatever is the trigger input level).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag in the TIMx\_SR register is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual stop of the counter is due to the resynchronization circuit on TI1 input.

**Figure 130. Control circuit in gated mode**



- The configuration "CCxP=CCxNP=1" (detection of both rising and falling edges) does not have any effect in gated mode because gated mode acts on a level and not on an edge.

### Slave mode: Trigger mode

The counter can start in response to an event on a selected input.

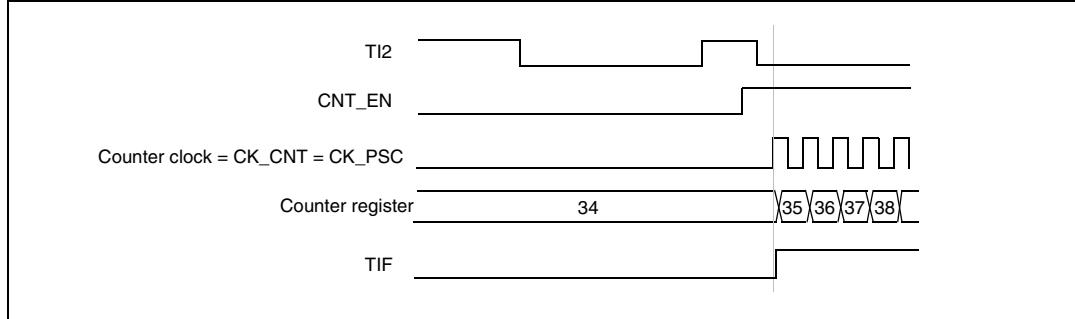
In the following example, the upcounter starts in response to a rising edge on TI2 input:

- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep IC2F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. CC2S bits are selecting the input capture source only, CC2S=01 in TIMx\_CCMR1 register. Write CC2P=1 and CC2NP=0 in TIMx\_CCER register to validate the polarity (and detect low level only).
- Configure the timer in trigger mode by writing SMS=110 in TIMx\_SMCR register. Select TI2 as the input source by writing TS=110 in TIMx\_SMCR register.

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual start of the counter is due to the resynchronization circuit on TI2 input.

**Figure 131. Control circuit in trigger mode**



### Slave mode: External Clock mode 2 + trigger mode

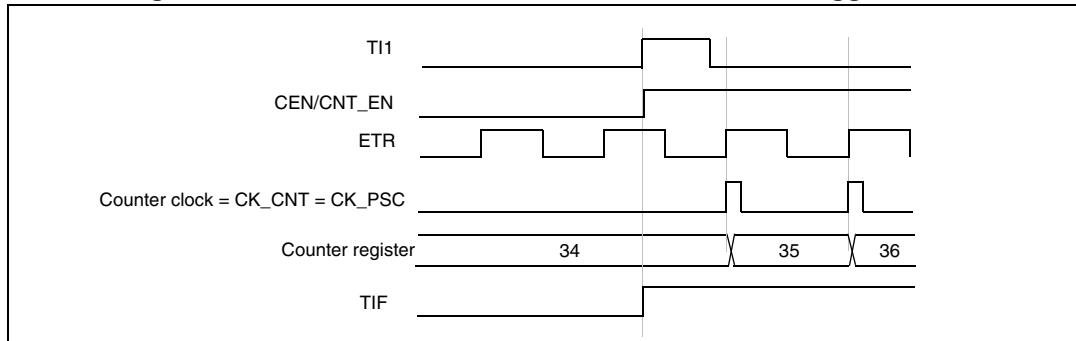
The external clock mode 2 can be used in addition to another slave mode (except external clock mode 1 and encoder mode). In this case, the ETR signal is used as external clock input, and another input can be selected as trigger input when operating in reset mode, gated mode or trigger mode. It is recommended not to select ETR as TRGI through the TS bits of TIMx\_SMCR register.

In the following example, the upcounter is incremented at each rising edge of the ETR signal as soon as a rising edge of TI1 occurs:

1. Configure the external trigger input circuit by programming the TIMx\_SMCR register as follows:
  - ETF = 0000: no filter
  - ETPS=00: prescaler disabled
  - ETP=0: detection of rising edges on ETR and ECE=1 to enable the external clock mode 2.
2. Configure the channel 1 as follows, to detect rising edges on TI:
  - IC1F=0000: no filter.
  - The capture prescaler is not used for triggering and does not need to be configured.
  - CC1S=01 in TIMx\_CCMR1 register to select only the input capture source
  - CC1P=0 and CC1NP=0 in TIMx\_CCER register to validate the polarity (and detect rising edge only).
3. Configure the timer in trigger mode by writing SMS=110 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.

A rising edge on TI1 enables the counter and sets the TIF flag. The counter then counts on ETR rising edges.

The delay between the rising edge of the ETR signal and the actual reset of the counter is due to the resynchronization circuit on ETRP input.

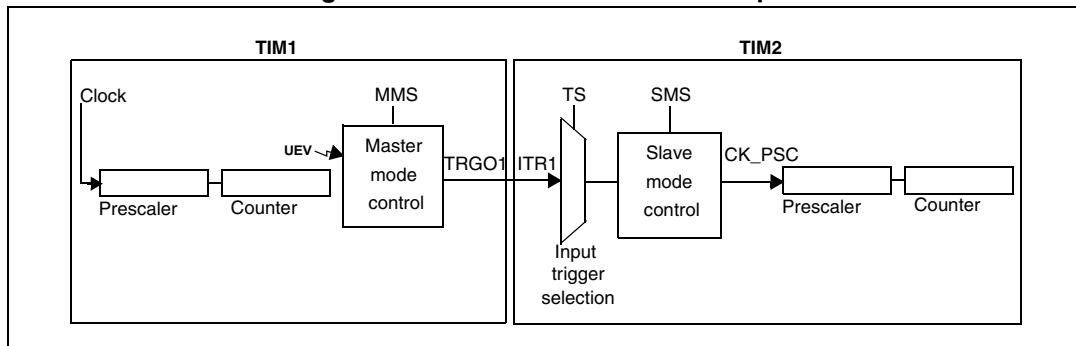
**Figure 132. Control circuit in external clock mode 2 + trigger mode**

### 16.3.15 Timer synchronization

The TIMx timers are linked together internally for timer synchronization or chaining. When one Timer is configured in Master Mode, it can reset, start, stop or clock the counter of another Timer configured in Slave Mode.

[Figure 133: Master/Slave timer example](#) presents an overview of the trigger selection and the master mode selection blocks.

#### Using one timer as prescaler for another

**Figure 133. Master/Slave timer example**

For example, you can configure Timer 1 to act as a prescaler for Timer 2. Refer to [Figure 133](#). To do this:

- Configure Timer 1 in master mode so that it outputs a periodic trigger signal on each update event UEV. If you write MMS=010 in the TIM1\_CR2 register, a rising edge is output on TRGO1 each time an update event is generated.
- To connect the TRGO1 output of Timer 1 to Timer 2, Timer 2 must be configured in slave mode using ITR1 as internal trigger. You select this through the TS bits in the TIM2\_SMCR register (writing TS=000).
- Then you put the slave mode controller in external clock mode 1 (write SMS=111 in the TIM2\_SMCR register). This causes Timer 2 to be clocked by the rising edge of the periodic Timer 1 trigger signal (which correspond to the timer 1 counter overflow).
- Finally both timers must be enabled by setting their respective CEN bits (TIMx\_CR1 register).

**Note:** If OCx is selected on Timer 1 as trigger output (MMS=1xx), its rising edge is used to clock the counter of timer 2.

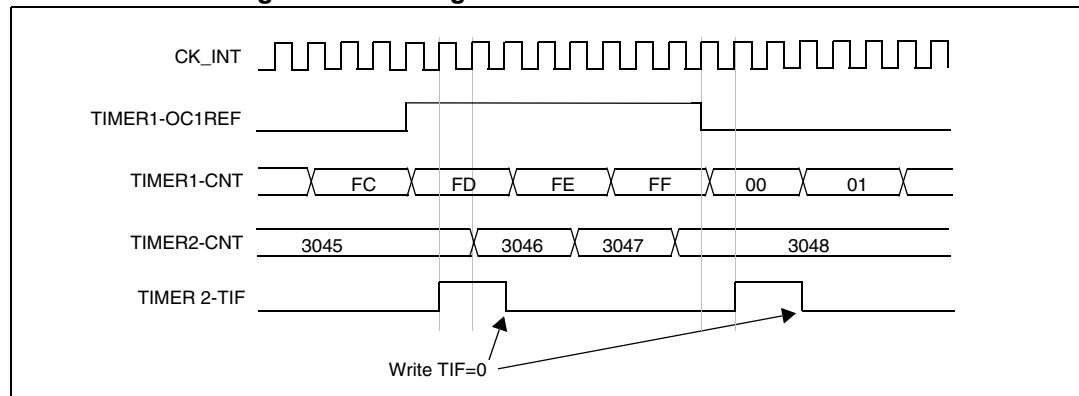
### Using one timer to enable another timer

In this example, we control the enable of Timer 2 with the output compare 1 of Timer 1. Refer to [Figure 133](#) for connections. Timer 2 counts on the divided internal clock only when OC1REF of Timer 1 is high. Both counter clock frequencies are divided by 3 by the prescaler compared to CK\_INT ( $f_{CK\_CNT} = f_{CK\_INT}/3$ ).

- Configure Timer 1 master mode to send its Output Compare 1 Reference (OC1REF) signal as trigger output (MMS=100 in the TIM1\_CR2 register).
- Configure the Timer 1 OC1REF waveform (TIM1\_CCMR1 register).
- Configure Timer 2 to get the input trigger from Timer 1 (TS=000 in the TIM2\_SMCR register).
- Configure Timer 2 in gated mode (SMS=101 in TIM2\_SMCR register).
- Enable Timer 2 by writing '1 in the CEN bit (TIM2\_CR1 register).
- Start Timer 1 by writing '1 in the CEN bit (TIM1\_CR1 register).

**Note:** *The counter 2 clock is not synchronized with counter 1, this mode only affects the Timer 2 counter enable signal.*

**Figure 134. Gating timer 2 with OC1REF of timer 1**

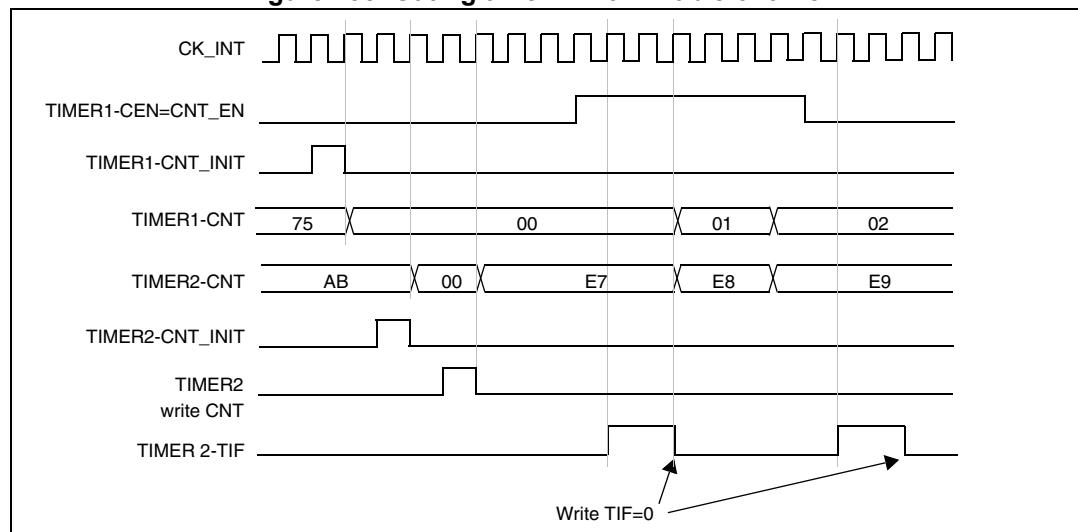


In the example in [Figure 134](#), the Timer 2 counter and prescaler are not initialized before being started. So they start counting from their current value. It is possible to start from a given value by resetting both timers before starting Timer 1. You can then write any value you want in the timer counters. The timers can easily be reset by software using the UG bit in the TIMx\_EGR registers.

In the next example, we synchronize Timer 1 and Timer 2. Timer 1 is the master and starts from 0. Timer 2 is the slave and starts from 0xE7. The prescaler ratio is the same for both timers. Timer 2 stops when Timer 1 is disabled by writing '0' to the CEN bit in the TIM1\_CR1 register:

- Configure Timer 1 master mode to send its Output Compare 1 Reference (OC1REF) signal as trigger output (MMS=100 in the TIM1\_CR2 register).
- Configure the Timer 1 OC1REF waveform (TIM1\_CCMR1 register).
- Configure Timer 2 to get the input trigger from Timer 1 (TS=000 in the TIM2\_SMCR register).
- Configure Timer 2 in gated mode (SMS=101 in TIM2\_SMCR register).
- Reset Timer 1 by writing '1' in UG bit (TIM1\_EGR register).
- Reset Timer 2 by writing '1' in UG bit (TIM2\_EGR register).
- Initialize Timer 2 to 0xE7 by writing '0xE7' in the timer 2 counter (TIM2\_CNTL).
- Enable Timer 2 by writing '1' in the CEN bit (TIM2\_CR1 register).
- Start Timer 1 by writing '1' in the CEN bit (TIM1\_CR1 register).
- Stop Timer 1 by writing '0' in the CEN bit (TIM1\_CR1 register).

**Figure 135. Gating timer 2 with Enable of timer 1**

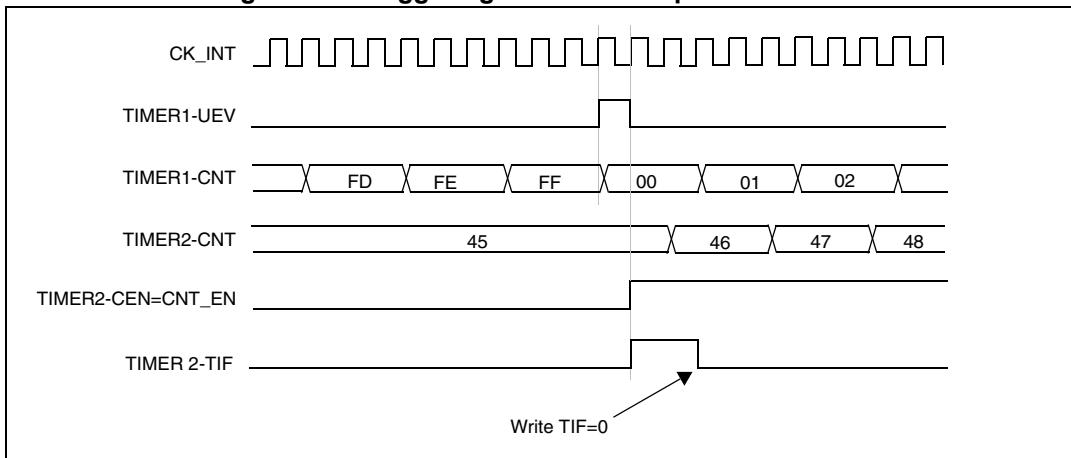


### Using one timer to start another timer

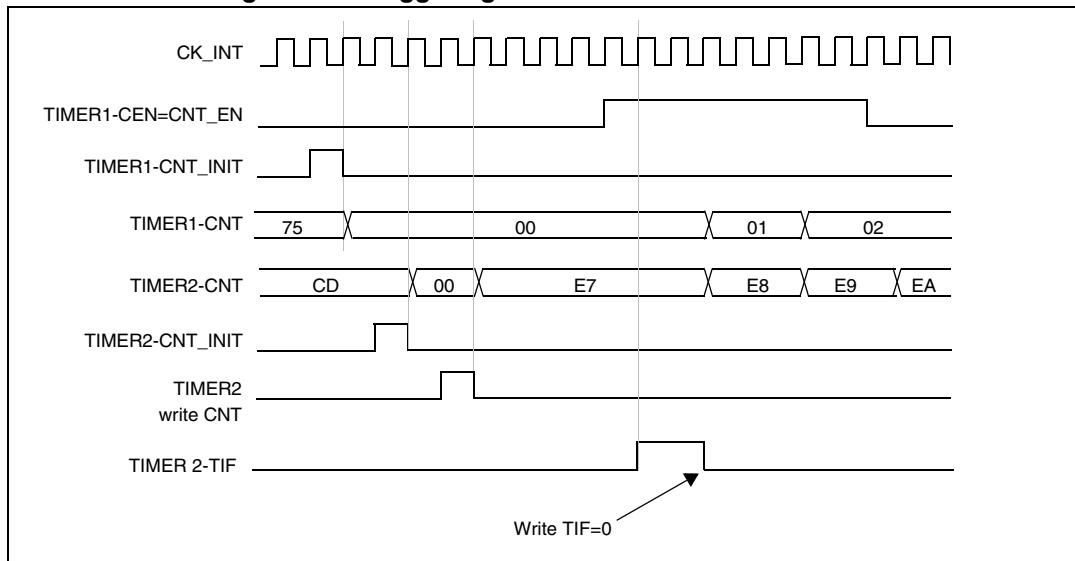
In this example, we set the enable of Timer 2 with the update event of Timer 1. Refer to [Figure 133](#) for connections. Timer 2 starts counting from its current value (which can be nonzero) on the divided internal clock as soon as the update event is generated by Timer 1. When Timer 2 receives the trigger signal its CEN bit is automatically set and the counter counts until we write '0 to the CEN bit in the TIM2\_CR1 register. Both counter clock frequencies are divided by 3 by the prescaler compared to CK\_INT ( $f_{CK\_CNT} = f_{CK\_INT}/3$ ).

- Configure Timer 1 master mode to send its Update Event (UEV) as trigger output (MMS=010 in the TIM1\_CR2 register).
- Configure the Timer 1 period (TIM1\_ARR registers).
- Configure Timer 2 to get the input trigger from Timer 1 (TS=000 in the TIM2\_SMCR register).
- Configure Timer 2 in trigger mode (SMS=110 in TIM2\_SMCR register).
- Start Timer 1 by writing '1 in the CEN bit (TIM1\_CR1 register).

**Figure 136. Triggering timer 2 with update of timer 1**



As in the previous example, you can initialize both counters before starting counting. [Figure 137](#) shows the behavior with the same configuration as in [Figure 136](#) but in trigger mode instead of gated mode (SMS=110 in the TIM2\_SMCR register).

**Figure 137. Triggering timer 2 with Enable of timer 1**

### Using one timer as prescaler for another timer

For example, you can configure Timer 1 to act as a prescaler for Timer 2. Refer to [Figure 133](#) for connections. To do this:

- Configure Timer 1 master mode to send its Update Event (UEV) as trigger output (MMS=010 in the TIM1\_CR2 register). then it outputs a periodic signal on each counter overflow.
- Configure the Timer 1 period (TIM1\_ARR registers).
- Configure Timer 2 to get the input trigger from Timer 1 (TS=000 in the TIM2\_SMCR register).
- Configure Timer 2 in external clock mode 1 (SMS=111 in TIM2\_SMCR register).
- Start Timer 2 by writing '1 in the CEN bit (TIM2\_CR1 register).
- Start Timer 1 by writing '1 in the CEN bit (TIM1\_CR1 register).

### Starting 2 timers synchronously in response to an external trigger

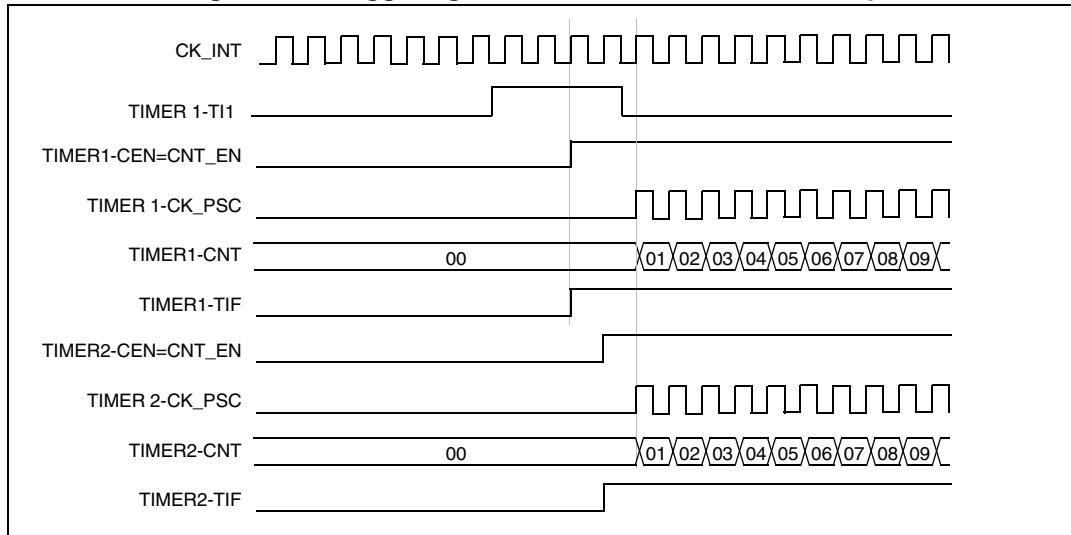
In this example, we set the enable of timer 1 when its TI1 input rises, and the enable of Timer 2 with the enable of Timer 1. Refer to [Figure 133](#) for connections. To ensure the counters are aligned, Timer 1 must be configured in Master/Slave mode (slave with respect to TI1, master with respect to Timer 2):

- Configure Timer 1 master mode to send its Enable as trigger output (MMS=001 in the TIM1\_CR2 register).
- Configure Timer 1 slave mode to get the input trigger from TI1 (TS=100 in the TIM1\_SMCR register).
- Configure Timer 1 in trigger mode (SMS=110 in the TIM1\_SMCR register).
- Configure the Timer 1 in Master/Slave mode by writing MSM=1 (TIM1\_SMCR register).
- Configure Timer 2 to get the input trigger from Timer 1 (TS=000 in the TIM2\_SMCR register).
- Configure Timer 2 in trigger mode (SMS=110 in the TIM2\_SMCR register).

When a rising edge occurs on TI1 (Timer 1), both counters starts counting synchronously on the internal clock and both TIF flags are set.

**Note:** *In this example both timers are initialized before starting (by setting their respective UG bits). Both counters starts from 0, but you can easily insert an offset between them by writing any of the counter registers (TIMx\_CNT). You can see that the master/slave mode insert a delay between CNT\_EN and CK\_PSC on timer 1.*

**Figure 138. Triggering timer 1 and 2 with timer 1 TI1 input**



### 16.3.16 Debug mode

When the microcontroller enters debug mode (Cortex™-M0 core - halted), the TIMx counter either continues to work normally or stops, depending on DBG\_TIMx\_STOP configuration bit in DBGMCU module.

## 16.4 TIM2 and TIM3 registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

### 16.4.1 TIM2 and TIM3 control register 1 (TIM2\_CR1 and TIM3\_CR1)

Address offset: 0x000

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	CMS		DIR	OPM	URS	UDIS	CEN

Bits 15:10 Reserved, always read as 0.

Bits 9:8 **CKD**: Clock division

This bit-field indicates the division ratio between the timer clock (CK\_INT) frequency and sampling clock used by the digital filters (ETR, TIx),

- 00:  $t_{DTS} = t_{CK\_INT}$
- 01:  $t_{DTS} = 2 \times t_{CK\_INT}$
- 10:  $t_{DTS} = 4 \times t_{CK\_INT}$
- 11: Reserved

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIMx\_ARR register is not buffered
- 1: TIMx\_ARR register is buffered

Bits 6:5 **CMS**: Center-aligned mode selection

00: Edge-aligned mode. The counter counts up or down depending on the direction bit (DIR).

01: Center-aligned mode 1. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx\_CCMRx register) are set only when the counter is counting down.

10: Center-aligned mode 2. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx\_CCMRx register) are set only when the counter is counting up.

11: Center-aligned mode 3. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx\_CCMRx register) are set both when the counter is counting up or down.

*Note:* It is not allowed to switch from edge-aligned mode to center-aligned mode as long as the counter is enabled (CEN=1)

Bit 4 **DIR**: Direction

- 0: Counter used as upcounter
- 1: Counter used as downcounter

*Note:* This bit is read only when the timer is configured in Center-aligned mode or Encoder mode.

Bit 3 **OPM**: One-pulse mode

- 0: Counter is not stopped at update event
- 1: Counter stops counting at the next update event (clearing the bit CEN)

**Bit 2 URS:** Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt or DMA request if enabled.

These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

**Bit 1 UDIS:** Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

**Bit 0 CEN:** Counter enable

0: Counter disabled

1: Counter enabled

*Note: External clock, gated mode and encoder mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.*

CEN is cleared automatically in one-pulse mode, when an update event occurs.

### 16.4.2 TIM2 and TIM3 control register 2 (TIM2\_CR2 and TIM3\_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TI1S	MMS[2:0]	CCDS	Res.	Res.	Res.	Res.	Res.							

Bits 15:8 Reserved, must be kept at reset value.

Bit 7 **TI1S**: TI1 selection

- 0: The TIMx\_CH1 pin is connected to TI1 input
  - 1: The TIMx\_CH1, CH2 and CH3 pins are connected to the TI1 input (XOR combination)
- See also [Section 15.3.18: Interfacing with Hall sensors on page 267](#)

Bits 6:4 **MMS**: Master mode selection

These bits allow to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx\_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter enable signal, CNT\_EN, is used as trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enabled. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode.

When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIMx\_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

011: **Compare Pulse** - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred.  
(TRGO)

100: **Compare** - OC1REF signal is used as trigger output (TRGO)

101: **Compare** - OC2REF signal is used as trigger output (TRGO)

110: **Compare** - OC3REF signal is used as trigger output (TRGO)

111: **Compare** - OC4REF signal is used as trigger output (TRGO)

Bit 3 **CCDS**: Capture/compare DMA selection

0: CCx DMA request sent when CCx event occurs

1: CCx DMA requests sent when update event occurs

Bits 2:0 Reserved, always read as 0.

### 16.4.3 TIM2 and TIM3 slave mode control register (TIM2\_SMCR and TIM3\_SMCR)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ETP	ECE	ETPS[1:0]		ETF[3:0]				MSM	TS[2:0]				OCCS	SMS[2:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 **ETP**: External trigger polarity

This bit selects whether ETR or  $\overline{ETR}$  is used for trigger operations

- 0: ETR is noninverted, active at high level or rising edge
- 1: ETR is inverted, active at low level or falling edge

Bit 14 **ECE**: External clock enable

This bit enables External clock mode 2.

- 0: External clock mode 2 disabled
- 1: External clock mode 2 enabled. The counter is clocked by any active edge on the ETRF signal.
  - 1:** Setting the ECE bit has the same effect as selecting external clock mode 1 with TRGI connected to ETRF (SMS=111 and TS=111).
  - 2:** It is possible to simultaneously use external clock mode 2 with the following slave modes: reset mode, gated mode and trigger mode. Nevertheless, TRGI must not be connected to ETRF in this case (TS bits must not be 111).
  - 3:** If external clock mode 1 and external clock mode 2 are enabled at the same time, the external clock input is ETRF.

Bits 13:12 **ETPS**: External trigger prescaler

External trigger signal ETRP frequency must be at most 1/4 of CK\_INT frequency. A prescaler can be enabled to reduce ETRP frequency. It is useful when inputting fast external clocks.

- 00: Prescaler OFF
- 01: ETRP frequency divided by 2
- 10: ETRP frequency divided by 4
- 11: ETRP frequency divided by 8

Bits 11:8 **ETF[3:0]**: External trigger filter

This bit-field defines the frequency used to sample ETRP signal and the length of the digital filter applied to ETRP. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, sampling is done at  $f_{DTS}$
- 0001:  $f_{SAMPLING} = f_{CK\_INT}$ , N=2
- 0010:  $f_{SAMPLING} = f_{CK\_INT}$ , N=4
- 0011:  $f_{SAMPLING} = f_{CK\_INT}$ , N=8
- 0100:  $f_{SAMPLING} = f_{DTS}/2$ , N=6
- 0101:  $f_{SAMPLING} = f_{DTS}/2$ , N=8
- 0110:  $f_{SAMPLING} = f_{DTS}/4$ , N=6
- 0111:  $f_{SAMPLING} = f_{DTS}/4$ , N=8
- 1000:  $f_{SAMPLING} = f_{DTS}/8$ , N=6
- 1001:  $f_{SAMPLING} = f_{DTS}/8$ , N=8
- 1010:  $f_{SAMPLING} = f_{DTS}/16$ , N=5
- 1011:  $f_{SAMPLING} = f_{DTS}/16$ , N=6
- 1100:  $f_{SAMPLING} = f_{DTS}/16$ , N=8
- 1101:  $f_{SAMPLING} = f_{DTS}/32$ , N=5
- 1110:  $f_{SAMPLING} = f_{DTS}/32$ , N=6
- 1111:  $f_{SAMPLING} = f_{DTS}/32$ , N=8

Bit 7 **MSM:** Master/Slave mode

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between the current timer and its slaves (through TRGO). It is useful if we want to synchronize several timers on a single external event.

Bits 6:4 **TS:** Trigger selection

This bit-field selects the trigger input to be used to synchronize the counter.

000: Internal Trigger 0 (ITR0).

001: Internal Trigger 1 (ITR1).

010: Internal Trigger 2 (ITR2).

011: Internal Trigger 3 (ITR3).

100: TI1 Edge Detector (TI1F\_ED)

101: Filtered Timer Input 1 (TI1FP1)

110: Filtered Timer Input 2 (TI2FP2)

111: External Trigger input (ETRF)

See [Table 47: TIM2 and TIM3 internal trigger connection on page 342](#) for more details on ITRx meaning for each Timer.

*Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.*

Bit 3 **OCCS:** OCREF clear selection.

This bit is used to select the OCREF clear source.

0:OCREF\_CLR\_INT is connected to the OCREF\_CLR input

1: OCREF\_CLR\_INT is connected to ETRF

Bits 2:0 **SMS:** Slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Slave mode disabled - if CEN = '1 then the prescaler is clocked directly by the internal clock.

001: Encoder mode 1 - Counter counts up/down on TI2FP2 edge depending on TI1FP1 level.

010: Encoder mode 2 - Counter counts up/down on TI1FP1 edge depending on TI2FP2 level.

011: Encoder mode 3 - Counter counts up/down on both TI1FP1 and TI2FP2 edges depending on the level of the other input.

100: Reset Mode - Rising edge of the selected trigger input (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger input (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

*Note: The gated mode must not be used if TI1F\_ED is selected as the trigger input (TS=100).*

*Indeed, TI1F\_ED outputs 1 pulse for each transition on TI1F, whereas the gated mode checks the level of the trigger signal.*

Table 47. TIM2 and TIM3 internal trigger connection

Slave TIM	ITR0 (TS = 000)	ITR1 (TS = 001)	ITR2 (TS = 010)	ITR3 (TS = 011)
TIM2	TIM1	TIM15	TIM3	TIM14
TIM3	TIM1	TIM2	TIM15	TIM14

#### 16.4.4 TIM2 and TIM3 DMA/Interrupt enable register (TIM2\_DIER and TIM3\_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TDE	Res.	CC4DE	CC3DE	CC2DE	CC1DE	UDE	Res.	TIE	Res.	CC4IE	CC3IE	CC2IE	CC1IE	UIE
	rw		rw	rw	rw	rw	rw		rw		rw	rw	rw	rw	rw

Bit 15 Reserved, must be kept at reset value.

Bit 14 **TDE**: Trigger DMA request enable

- 0: Trigger DMA request disabled.
- 1: Trigger DMA request enabled.

Bit 13 Reserved, always read as 0

Bit 12 **CC4DE**: Capture/Compare 4 DMA request enable

- 0: CC4 DMA request disabled.
- 1: CC4 DMA request enabled.

Bit 11 **CC3DE**: Capture/Compare 3 DMA request enable

- 0: CC3 DMA request disabled.
- 1: CC3 DMA request enabled.

Bit 10 **CC2DE**: Capture/Compare 2 DMA request enable

- 0: CC2 DMA request disabled.
- 1: CC2 DMA request enabled.

Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable

- 0: CC1 DMA request disabled.
- 1: CC1 DMA request enabled.

Bit 8 **UDE**: Update DMA request enable

- 0: Update DMA request disabled.
- 1: Update DMA request enabled.

Bit 7 Reserved, must be kept at reset value.

Bit 6 **TIE**: Trigger interrupt enable

- 0: Trigger interrupt disabled.
- 1: Trigger interrupt enabled.

Bit 5 Reserved, must be kept at reset value.

Bit 4 **CC4IE**: Capture/Compare 4 interrupt enable

- 0: CC4 interrupt disabled.
- 1: CC4 interrupt enabled.

Bit 3 **CC3IE**: Capture/Compare 3 interrupt enable

- 0: CC3 interrupt disabled
- 1: CC3 interrupt enabled

Bit 2 **CC2IE**: Capture/Compare 2 interrupt enable

- 0: CC2 interrupt disabled
- 1: CC2 interrupt enabled

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

- 0: CC1 interrupt disabled
- 1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

- 0: Update interrupt disabled
- 1: Update interrupt enabled

#### 16.4.5 TIM2 and TIM3 status register (TIM2\_SR and TIM3\_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	CC4OF	CC3OF	CC2OF	CC1OF	Res.	Res.	TIF	Res.	CC4IF	CC3IF	CC2IF	CC1IF	UIF
			rc_w0	rc_w0	rc_w0	rc_w0			rc_w0		rc_w0	rc_w0	rc_w0	rc_w0	rc_w0

Bit 15:13 Reserved, always read as 0.

Bit 12 **CC4OF**: Capture/Compare 4 overcapture flag

Refer to CC1OF description

Bit 11 **CC3OF**: Capture/Compare 3 overcapture flag

Refer to CC1OF description

Bit 10 **CC2OF**: Capture/compare 2 overcapture flag

Refer to CC1OF description

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected

1: The counter value has been captured in TIMx\_CCR1 register while CC1IF flag was already set

Bits 8:7 Reserved, always read as 0.

Bit 6 **TIF**: Trigger interrupt flag

This flag is set by hardware on trigger event (active edge detected on TRGI input when the slave mode controller is enabled in all modes but gated mode. It is set when the counter starts or stops when gated mode is selected. It is cleared by software.

0: No trigger event occurred

1: Trigger interrupt pending

Bit 5 Reserved, always read as 0.

Bit 4 **CC4IF**: Capture/Compare 4 interrupt flag

Refer to CC1IF description

Bit 3 **CC3IF**: Capture/Compare 3 interrupt flag

Refer to CC1IF description

Bit 2 **CC2IF**: Capture/Compare 2 interrupt flag

Refer to CC1IF description

Bit 1 **CC1IF**: Capture/compare 1 interrupt flag

**If channel CC1 is configured as output:**

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx\_CR1 register description). It is cleared by software.

0: No match

1: The content of the counter TIMx\_CNT matches the content of the TIMx\_CCR1 register.

When the contents of TIMx\_CCR1 are greater than the contents of TIMx\_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

**If channel CC1 is configured as input:**

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx\_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx\_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending.

This bit is set by hardware when the registers are updated:

At overflow or underflow and if UDIS=0 in the TIMx\_CR1 register.

When CNT is reinitialized by software using the UG bit in TIMx\_EGR register, if URS=0 and UDIS=0 in the TIMx\_CR1 register.

When CNT is reinitialized by a trigger event (refer to the synchro control register description), if URS=0 and UDIS=0 in the TIMx\_CR1 register.

### 16.4.6 TIM2 and TIM3 event generation register (TIM2\_EGR and TIM3\_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TG	Res.	CC4G	CC3G	CC2G	CC1G	UG								
									w		w	w	w	w	w

Bits 15:7 Reserved, must be kept at reset value.

Bit 6 **TG**: Trigger generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: The TIF flag is set in TIMx\_SR register. Related interrupt or DMA transfer can occur if enabled.

Bit 5 Reserved, must be kept at reset value.

Bit 4 **CC4G**: Capture/compare 4 generation

Refer to CC1G description

Bit 3 **CC3G**: Capture/compare 3 generation

Refer to CC1G description

Bit 2 **CC2G**: Capture/compare 2 generation

Refer to CC1G description

Bit 1 **CC1G**: Capture/compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

**If channel CC1 is configured as output:**

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

**If channel CC1 is configured as input:**

The current value of the counter is captured in TIMx\_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Re-initialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx\_ARR) if DIR=1 (downcounting).

### 16.4.7 TIM2 and TIM3 capture/compare mode register 1 (TIM2\_CCMR1 and TIM3\_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CC<sub>x</sub>S bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OC<sub>xx</sub> describes its function when the channel is configured in output, IC<sub>xx</sub> describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OC2CE	OC2M[2:0]			OC2PE	OC2FE	CC2S[1:0]	OC1CE	OC1M[2:0]			OC1PE	OC1FE	CC1S[1:0]		
IC2F[3:0]			IC2PSC[1:0]				IC1F[3:0]			IC1PSC[1:0]					
RW	RW	RW	RW	RW	RW		RW	RW	RW	RW	RW	RW	RW	RW	RW

#### Output compare mode

Bit 15 **OC2CE**: Output compare 2 clear enable

Bits 14:12 **OC2M[2:0]**: Output compare 2 mode

Bit 11 **OC2PE**: Output compare 2 preload enable

Bit 10 **OC2FE**: Output compare 2 fast enable

Bits 9:8 **CC2S[1:0]**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output

01: CC2 channel is configured as input, IC2 is mapped on TI2

10: CC2 channel is configured as input, IC2 is mapped on TI1

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through the TS bit (TIMx\_SMCR register)

*Note: CC2S bits are writable only when the channel is OFF (CC2E = 0 in TIMx\_CCER).*

Bit 7 **OC1CE**: Output compare 1 clear enable

OC1CE: Output Compare 1 Clear Enable

0: OC1Ref is not affected by the ETRF input

1: OC1Ref is cleared as soon as a High level is detected on ETRF input

Bits 6:4 **OC1M**: Output compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

000: Frozen - The comparison between the output compare register TIMx\_CCR1 and the counter TIMx\_CNT has no effect on the outputs.(this mode is used to generate a timing base).

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).

011: Toggle - OC1REF toggles when TIMx\_CNT=TIMx\_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx\_CNT<TIMx\_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0) as long as TIMx\_CNT>TIMx\_CCR1 else active (OC1REF=1).

111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx\_CNT<TIMx\_CCR1 else active. In downcounting, channel 1 is active as long as TIMx\_CNT>TIMx\_CCR1 else inactive.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S=00 (the channel is configured in output).*

*2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from “frozen” mode to “PWM” mode.*

Bit 3 **OC1PE**: Output compare 1 preload enable

0: Preload register on TIMx\_CCR1 disabled. TIMx\_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx\_CCR1 enabled. Read/Write operations access the preload register. TIMx\_CCR1 preload value is loaded in the active register at each update event.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S=00 (the channel is configured in output).*

*2: The PWM mode can be used without validating the preload register only in one-pulse mode (OPM bit set in TIMx\_CR1 register). Else the behavior is not guaranteed.*

Bit 2 **OC1FE**: Output compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently from the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OCFE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1.

10: CC1 channel is configured as input, IC1 is mapped on TI2.

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx\_CCER).*

## Input capture mode

Bits 15:12 **IC2F**: Input capture 2 filter

Bits 11:10 **IC2PSC[1:0]**: Input capture 2 prescaler

Bits 9:8 **CC2S**: Capture/compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2.

10: CC2 channel is configured as input, IC2 is mapped on TI1.

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC2S bits are writable only when the channel is OFF (CC2E = 0 in TIMx\_CCER).*

Bits 7:4 **IC1F**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

0000: No filter, sampling is done at  $f_{DTS}$

1000:  $f_{SAMPLING} = f_{DTS}/8, N=6$

0001:  $f_{SAMPLING} = f_{CK\_INT}, N=2$

1001:  $f_{SAMPLING} = f_{DTS}/8, N=8$

0010:  $f_{SAMPLING} = f_{CK\_INT}, N=4$

1010:  $f_{SAMPLING} = f_{DTS}/16, N=5$

0011:  $f_{SAMPLING} = f_{CK\_INT}, N=8$

1011:  $f_{SAMPLING} = f_{DTS}/16, N=6$

0100:  $f_{SAMPLING} = f_{DTS}/2, N=6$

1100:  $f_{SAMPLING} = f_{DTS}/16, N=8$

0101:  $f_{SAMPLING} = f_{DTS}/2, N=8$

1101:  $f_{SAMPLING} = f_{DTS}/32, N=5$

0110:  $f_{SAMPLING} = f_{DTS}/4, N=6$

1110:  $f_{SAMPLING} = f_{DTS}/32, N=6$

0111:  $f_{SAMPLING} = f_{DTS}/4, N=8$

1111:  $f_{SAMPLING} = f_{DTS}/32, N=8$

*Note: In the current silicon revision,  $f_{DTS}$  is replaced in the formula by CK\_INT when ICxF[3:0]= 1, 2 or 3.*

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as CC1E=0 (TIMx\_CCER register).

00: no prescaler, capture is done each time an edge is detected on the capture input

01: capture is done once every 2 events

10: capture is done once every 4 events

11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx\_CCER).*

### 16.4.8 TIM2 and TIM3 capture/compare mode register 2 (TIM2\_CCMR2 and TIM3\_CCMR2)

Address offset: 0x1C

Reset value: 0x0000

Refer to the above CCMR1 register description.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
OC4CE	OC4M[2:0]			OC4PE	OC4FE	CC4S[1:0]		OC3CE	OC3M[2:0]			OC3PE	OC3FE	CC3S[1:0]		
IC4F[3:0]			IC4PSC[1:0]		IC3F[3:0]			IC3PSC[1:0]								
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

#### Output compare mode

Bit 15 **OC4CE**: Output compare 4 clear enable

Bits 14:12 **OC4M**: Output compare 4 mode

Bit 11 **OC4PE**: Output compare 4 preload enable

Bit 10 **OC4FE**: Output compare 4 fast enable

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC4S bits are writable only when the channel is OFF (CC4E = 0 in TIMx\_CCER).*

Bit 7 **OC3CE**: Output compare 3 clear enable

Bits 6:4 **OC3M**: Output compare 3 mode

Bit 3 **OC3PE**: Output compare 3 preload enable

Bit 2 **OC3FE**: Output compare 3 fast enable

Bits 1:0 **CC3S**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC3S bits are writable only when the channel is OFF (CC3E = 0 in TIMx\_CCER).*

## Input capture mode

Bits 15:12 **IC4F**: Input capture 4 filter

Bits 11:10 **IC4PSC**: Input capture 4 prescaler

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC4S bits are writable only when the channel is OFF (CC4E = 0 in TIMx\_CCER).*

Bits 7:4 **IC3F**: Input capture 3 filter

Bits 3:2 **IC3PSC**: Input capture 3 prescaler

Bits 1:0 **CC3S**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC3S bits are writable only when the channel is OFF (CC3E = 0 in TIMx\_CCER).*

## 16.4.9 TIM2 and TIM3 capture/compare enable register (TIM2\_CCER and TIM3\_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CC4NP	Res.	CC4P	CC4E	CC3NP	Res.	CC3P	CC3E	CC2NP	Res.	CC2P	CC2E	CC1NP	Res.	CC1P	CC1E
rw		rw	rw												

Bit 15 **CC4NP**: Capture/Compare 4 output Polarity.

Refer to CC1NP description

Bit 14 Reserved, always read as 0.

Bit 13 **CC4P**: Capture/Compare 4 output Polarity.

Refer to CC1P description

Bit 12 **CC4E**: Capture/Compare 4 output enable.

Refer to CC1E description

Bit 13 **CC3NP**: Capture/Compare 3 output Polarity.

Refer to CC1NP description

Bit 12 Reserved, always read as 0.

Bits 11:10 Reserved, always read as 0.

Bit 9 **CC3P**: Capture/Compare 3 output Polarity.

Refer to CC1P description

Bit 8 **CC3E**: *Capture/Compare 3 output enable.*

Refer to CC1E description

Bit 7 **CC2NP**: *Capture/Compare 2 output Polarity.*

Refer to CC1NP description

Bit 6 Reserved, always read as 0.

Bit 5 **CC2P**: *Capture/Compare 2 output Polarity.*

Refer to CC1P description

Bit 4 **CC2E**: *Capture/Compare 2 output enable.*

Refer to CC1E description

Bit 3 **CC1NP**: *Capture/Compare 1 output Polarity.*

**CC1 channel configured as output:**

CC1NP must be kept cleared in this case.

**CC1 channel configured as input:**

This bit is used in conjunction with CC1P to define TI1FP1/TI2FP1 polarity. refer to CC1P description.

Bit 2 Reserved, always read as 0.

Bit 1 **CC1P**: *Capture/Compare 1 output Polarity.*

**CC1 channel configured as output:**

0: OC1 active high

1: OC1 active low

**CC1 channel configured as input:**

CC1NP/CC1P bits select TI1FP1 and TI2FP1 polarity for trigger or capture operations.

00: noninverted/rising edge

Circuit is sensitive to TIxFP1 rising edge (capture, trigger in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger in gated mode, encoder mode).

01: inverted/falling edge

Circuit is sensitive to TIxFP1 falling edge (capture, trigger in reset, external clock or trigger mode), TIxFP1 is inverted (trigger in gated mode, encoder mode).

10: reserved, do not use this configuration.

11: noninverted/both edges

Circuit is sensitive to both TIxFP1 rising and falling edges (capture, trigger in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger in gated mode). This configuration must not be used for encoder mode.

Bit 0 **CC1E**: *Capture/Compare 1 output enable.*

**CC1 channel configured as output:**

0: Off - OC1 is not active

1: On - OC1 signal is output on the corresponding output pin

**CC1 channel configured as input:**

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx\_CCR1) or not.

0: Capture disabled

1: Capture enabled

**Table 48. Output control bit for standard OCx channels**

CCxE bit	OCx output state
0	Output Disabled (OCx=0, OCx_EN=0)
1	OCx=OCxREF + Polarity, OCx_EN=1

**Note:** The state of the external IO pins connected to the standard OCx channels depends on the OCx channel state and the GPIO registers.

#### 16.4.10 TIM2 and TIM3 counter (TIM2\_CNT and TIM3\_CNT)

Address offset: 0x24

Reset value: 0x00000000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CNT[31:16] (TIM2 only)															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 **CNT[31:16]**: High counter value (on TIM2).

Bits 15:0 **CNT[15:0]**: Low counter value

#### 16.4.11 TIM2 and TIM3 prescaler (TIM2\_PSC and TIM3\_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency CK\_CNT is equal to  $f_{CK\_PSC} / (PSC[15:0] + 1)$ .

PSC contains the value to be loaded in the active prescaler register at each update event.

#### 16.4.12 TIM2 and TIM3 auto-reload register (TIM2\_ARR and TIM3\_ARR)

Address offset: 0x2C

Reset value: 0x00000000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ARR[31:16] (TIM2 only)															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 **ARR[31:16]**: High auto-reload value (on TIM2).

Bits 15:0 **ARR[15:0]**: Low Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to [Section 16.3.1: Time-base unit on page 301](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

#### 16.4.13 TIM2 and TIM3 capture/compare register 1 (TIM2\_CCR1 and TIM3\_CCR1)

Address offset: 0x34

Reset value: 0x00000000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CCR1[31:16] (TIM2 only)															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 **CCR1[31:16]**: High Capture/Compare 1 value (on TIM2).

Bits 15:0 **CCR1[15:0]**: Low Capture/Compare 1 value

If channel CC1 is configured as output:

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR1 register (bit OC1PE). Otherwise the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signaled on OC1 output.

If channel CC1 is configured as input:

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

#### 16.4.14 TIM2 and TIM3 capture/compare register 2 (TIM2\_CCR2 and TIM3\_CCR2)

Address offset: 0x38

Reset value: 0x00000000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CCR2[31:16] (TIM2 only)															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR2[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 **CCR2[31:16]**: High Capture/Compare 2 value (on TIM2).

Bits 15:0 **CCR2[15:0]**: Low Capture/Compare 2 value

**If channel CC2 is configured as output:**

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC2 output.

**If channel CC2 is configured as input:**

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

#### 16.4.15 TIM2 and TIM3 capture/compare register 3 (TIM2\_CCR3 and TIM3\_CCR3)

Address offset: 0x3C

Reset value: 0x00000000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CCR3[31:16] (TIM2 only)															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR3[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 **CCR3[31:16]**: High Capture/Compare 3 value (on TIM2).

Bits 15:0 **CCR3[15:0]**: Low Capture/Compare 3 value

**If channel CC3 is configured as output:**

CCR3 is the value to be loaded in the actual capture/compare 3 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR3 register (bit OC3PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC3 output.

**If channel CC3 is configured as input:**

CCR3 is the counter value transferred by the last input capture 3 event (IC3).

### 16.4.16 TIM2 and TIM3 capture/compare register 4 (TIM2\_CCR4 and TIM3\_CCR4)

Address offset: 0x40

Reset value: 0x00000000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CCR4[31:16] (TIM2 only)															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR4[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 **CCR4[31:16]**: High Capture/Compare 4 value (on TIM2)

Bits 15:0 **CCR4[15:0]**: Low Capture/Compare 4 value

1. If CC4 channel is configured as output (CC4S bits):  
CCR4 is the value to be loaded in the actual capture/compare 4 register (preload value). It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR4 register (bit OC4PE). Otherwise, the preload value is copied in the active capture/compare 4 register when an update event occurs.  
The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC4 output.
2. If CC4 channel is configured as input (CC4S bits in TIMx\_CCMR4 register):  
CCR4 is the counter value transferred by the last input capture 4 event (IC4).

### 16.4.17 TIM2 and TIM3 DMA control register (TIM2\_DCR and TIM3\_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	DBA[4:0]					
			rw	rw	rw	rw	rw				rw	rw	rw	rw	rw

Bits 15:13 Reserved, always read as 0.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the number of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx\_DMAR address).

- 00000: 1 transfer,
- 00001: 2 transfers,
- 00010: 3 transfers,
- ...
- 10001: 18 transfers.

Bits 7:5 Reserved, always read as 0.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bit vector defines the base-address for DMA transfers (when read/write access are done through the TIMx\_DMAR address). DBA is defined as an offset starting from the address of the TIMx\_CR1 register.

Example:

- 00000: TIMx\_CR1,
- 00001: TIMx\_CR2,
- 00010: TIMx\_SMCR,
- ...

**Example:** Let us consider the following transfer: DBL = 7 transfers & DBA = TIMx\_CR1. In this case the transfer is done to/from 7 registers starting from the TIMx\_CR1 address..

#### 16.4.18 TIM2 and TIM3 DMA address for full transfer (TIM2\_DMAR and TIM3\_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write operation to the DMAR register accesses the register located at the address (TIMx\_CR1 address) + (DBA + DMA index) x 4

where TIMx\_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx\_DCR register, DMA index is automatically controlled by the DMA transfer, and ranges from 0 to DBL (DBL configured in TIMx\_DCR).

### Example of how to use the DMA burst feature

In this example the timer DMA burst feature is used to update the contents of the CCRx registers ( $x = 2, 3, 4$ ) with the DMA transferring half words into the CCRx registers.

This is done in the following steps:

1. Configure the corresponding DMA channel as follows:
  - DMA channel peripheral address is the DMAR register address
  - DMA channel memory address is the address of the buffer in the RAM containing the data to be transferred by DMA into CCRx registers.
  - Number of data to transfer = 3 (See note below).
  - Circular mode disabled.
2. Configure the DCR register by configuring the DBA and DBL bit fields as follows:  
DBL = 3 transfers, DBA = 0xE.
3. Enable the TIMx update DMA request (set the UDE bit in the DIER register).
4. Enable TIMx
5. Enable the DMA channel

Note:

*This example is for the case where every CCRx register to be updated once. If every CCRx register is to be updated twice for example, the number of data to transfer should be 6. Let us take the example of a buffer in the RAM containing data1, data2, data3, data4, data5 and data6. The data is transferred to the CCRx registers as follows: on the first update DMA request, data1 is transferred to CCR2, data2 is transferred to CCR3, data3 is transferred to CCR4 and on the second update DMA request, data4 is transferred to CCR2, data5 is transferred to CCR3 and data6 is transferred to CCR4.*

#### **16.4.19 TIM2 and TIM3 register map**

TIM2 and TIM3 registers are mapped as described in the table below:

**Table 49. TIM2 and TIM3 register map and reset values**

**Table 49. TIM2 and TIM3 register map and reset values (continued)**

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x2C	<b>TIM2_ARR and TIM3_ARR</b>																																	
		Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x30	<b>Reserved</b>	Res.																																
		Reset value																																
0x34	<b>TIM2_CCR1 and TIM3_CCR1</b>																																	
		Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x38	<b>TIM2_CCR2 and TIM3_CCR2</b>																																	
		Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x3C	<b>TIM2_CCR3 and TIM3_CCR3</b>																																	
		Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x40	<b>TIM2_CCR4 and TIM3_CCR4</b>																																	
		Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x44	<b>Reserved</b>	Res.																																
		Reset value																																
0x48	<b>TIM2_DCR and TIM3_DCR</b>	Res.																																
		Reset value																																
0x4C	<b>TIM2_DMAR and TIM3_DMAR</b>	Res.																																
		Reset value																																

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 17 General-purpose timer (TIM14)

### 17.1 TIM14 introduction

The TIM14 general-purpose timer consists of a 16-bit auto-reload counter driven by a programmable prescaler.

It may be used for a variety of purposes, including measuring the pulse lengths of input signals (input capture) or generating output waveforms (output compare, PWM).

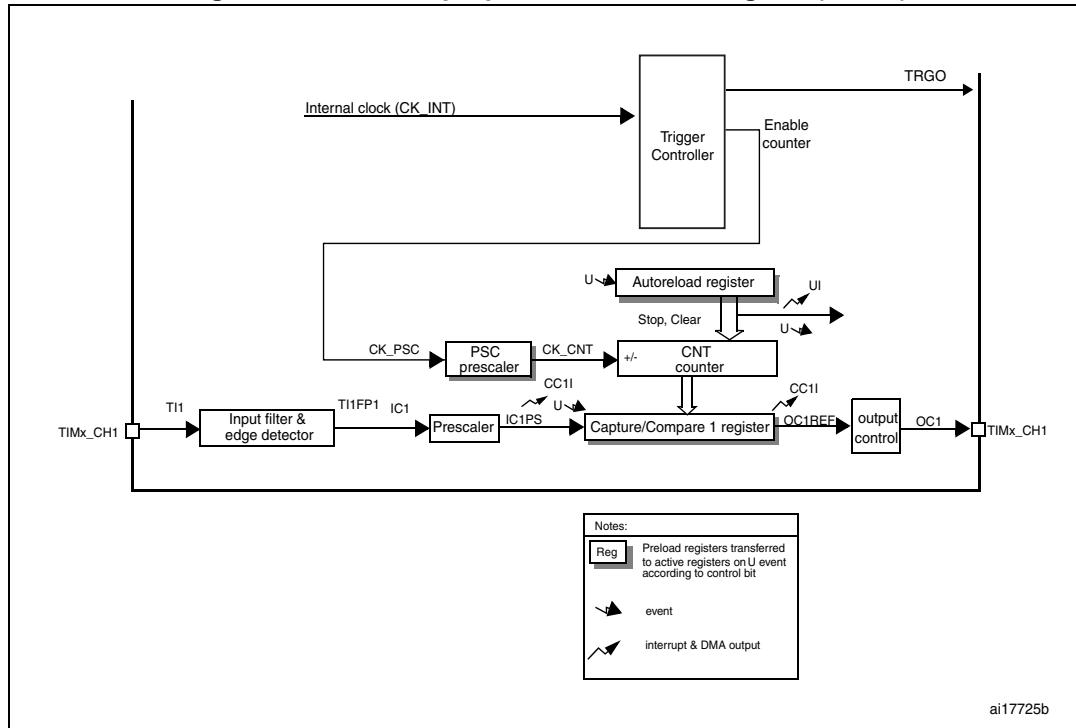
Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

The TIM14 timer is completely independent, and does not share any resources. It can be synchronized together as described in [Section 16.3.15](#).

### 17.2 TIM14 main features

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide the counter clock frequency by any factor between 1 and 65535 (can be changed “on the fly”)
- independent channel for:
  - Input capture
  - Output compare
  - PWM generation (edge-aligned mode)
- Interrupt generation on the following events:
  - Update: counter overflow, counter initialization (by software)
  - Input capture
  - Output compare

Figure 139. General-purpose timer block diagram (TIM14)



## 17.3 TIM14 functional description

### 17.3.1 Time-base unit

The main block of the programmable advanced-control timer is a 16-bit counter with its related auto-reload register. The counter can count up. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter register (TIMx\_CNT)
- Prescaler register (TIMx\_PSC)
- Auto-reload register (TIMx\_ARR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx\_CR1 register. The update event is sent when the counter reaches the overflow and if the UDIS bit equals 0 in the TIMx\_CR1 register. It can also be generated by software. The generation of the update event is described in detailed for each configuration.

The counter is clocked by the prescaler output CK\_CNT, which is enabled only when the counter enable bit (CEN) in TIMx\_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

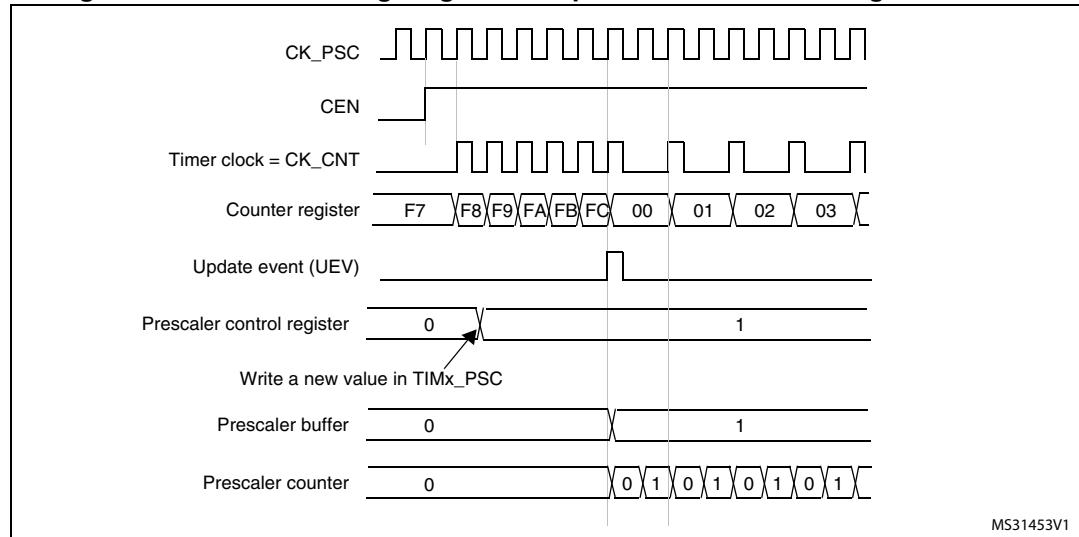
Note that the counter starts counting 1 clock cycle after setting the CEN bit in the TIMx\_CR1 register.

### Prescaler description

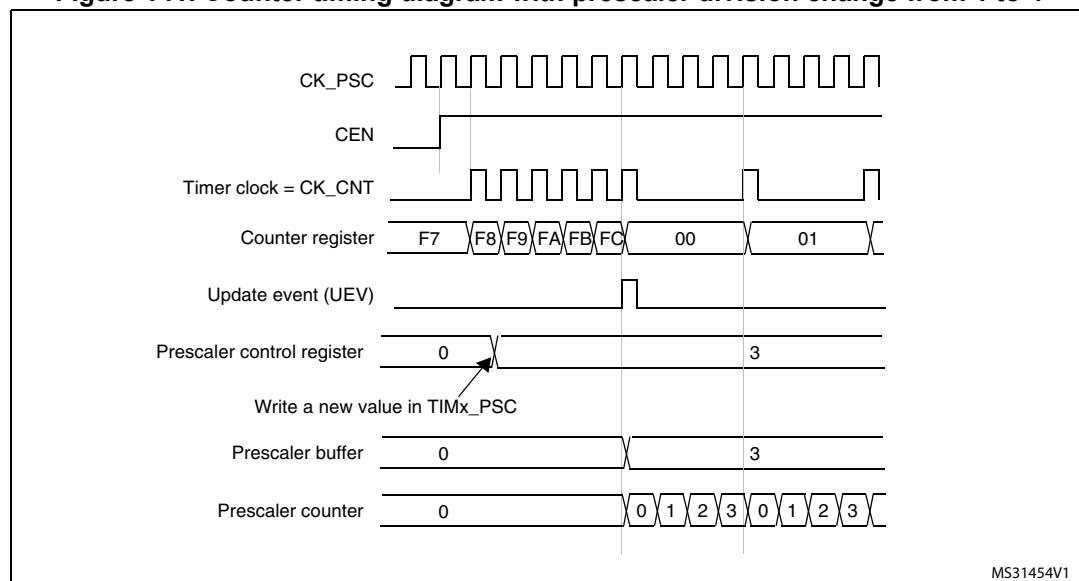
The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx\_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

*Figure 141* and *Figure 142* give some examples of the counter behavior when the prescaler ratio is changed on the fly.

**Figure 140. Counter timing diagram with prescaler division change from 1 to 2**



**Figure 141. Counter timing diagram with prescaler division change from 1 to 4**



### 17.3.2 Counter modes

#### Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx\_ARR register), then restarts from 0 and generates a counter overflow event.

Setting the UG bit in the TIMx\_EGR register also generates an update event.

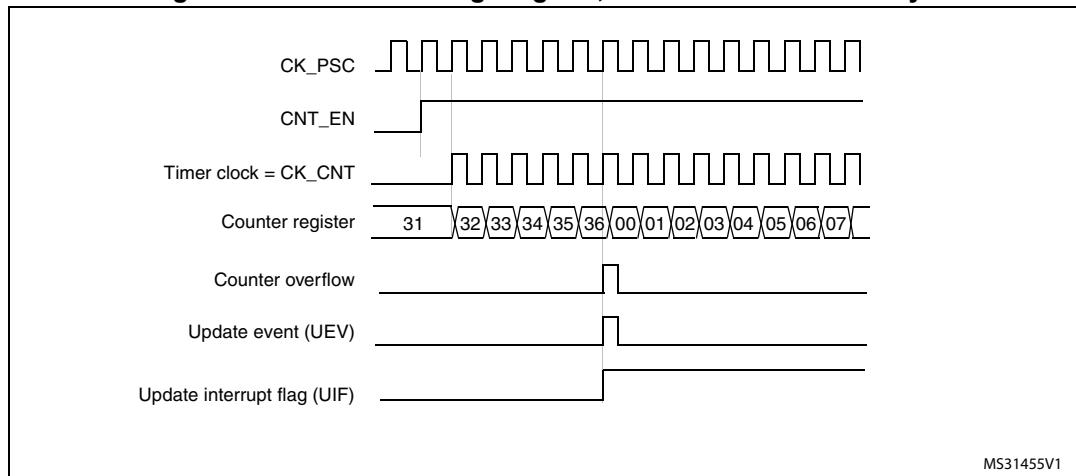
The UEV event can be disabled by software by setting the UDIS bit in the TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

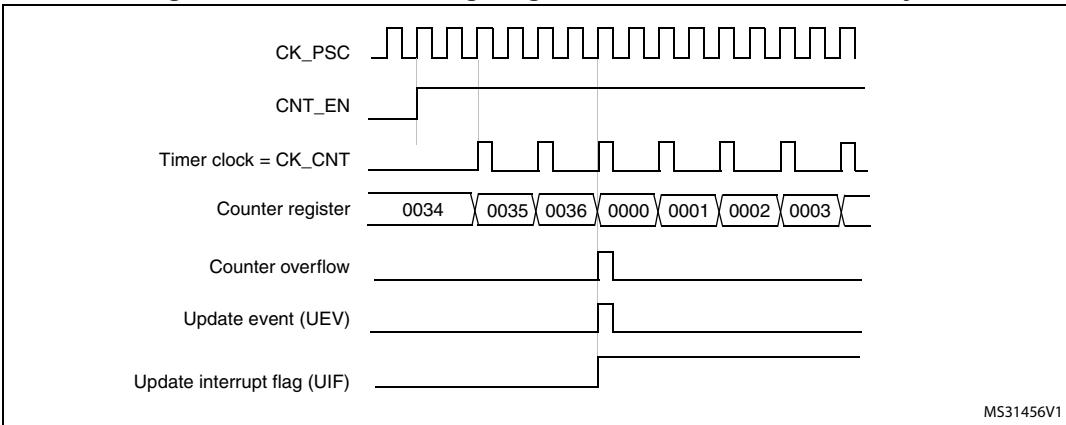
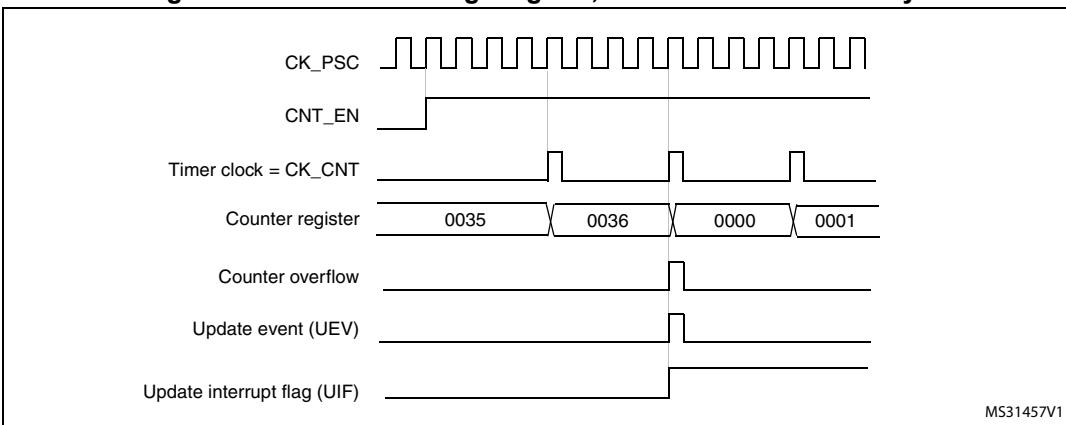
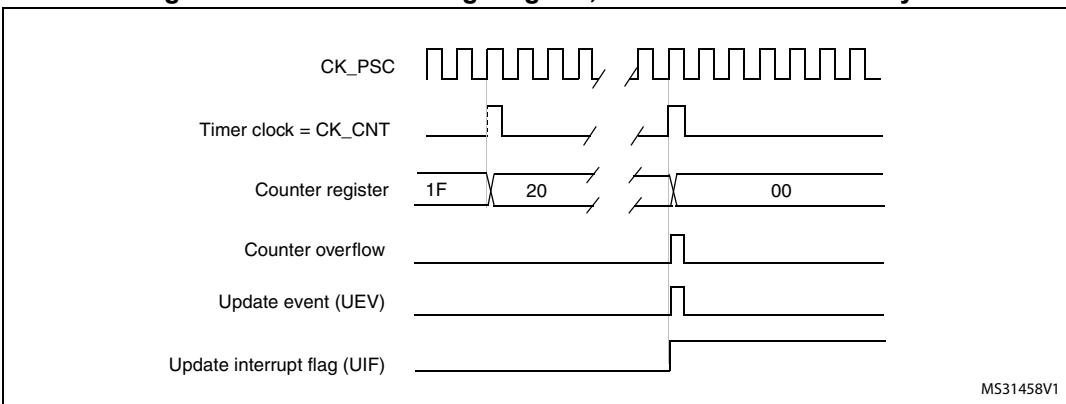
When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

- The auto-reload shadow register is updated with the preload value (TIMx\_ARR),
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register).

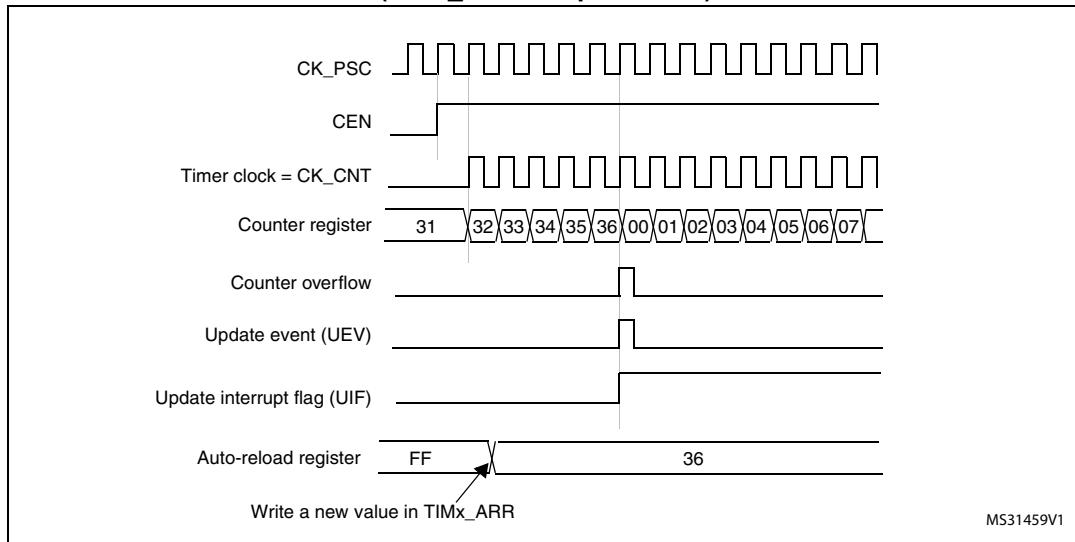
The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR=0x36.

**Figure 142. Counter timing diagram, internal clock divided by 1**

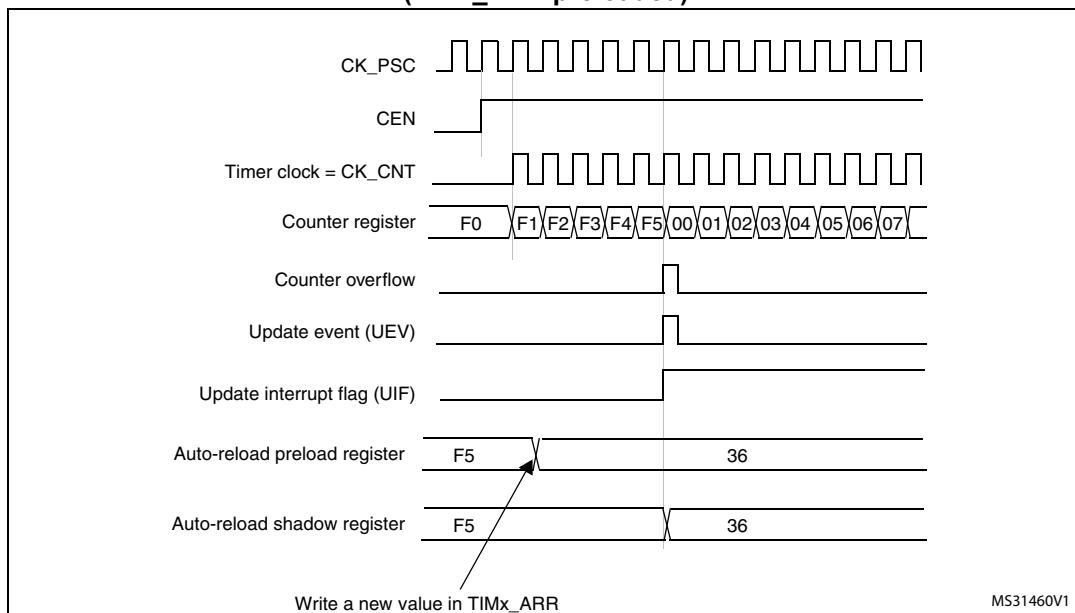


**Figure 143. Counter timing diagram, internal clock divided by 2****Figure 144. Counter timing diagram, internal clock divided by 4****Figure 145. Counter timing diagram, internal clock divided by N**

**Figure 146. Counter timing diagram, update event when ARPE=0  
(TIMx\_ARR not preloaded)**



**Figure 147. Counter timing diagram, update event when ARPE=1  
(TIMx\_ARR preloaded)**



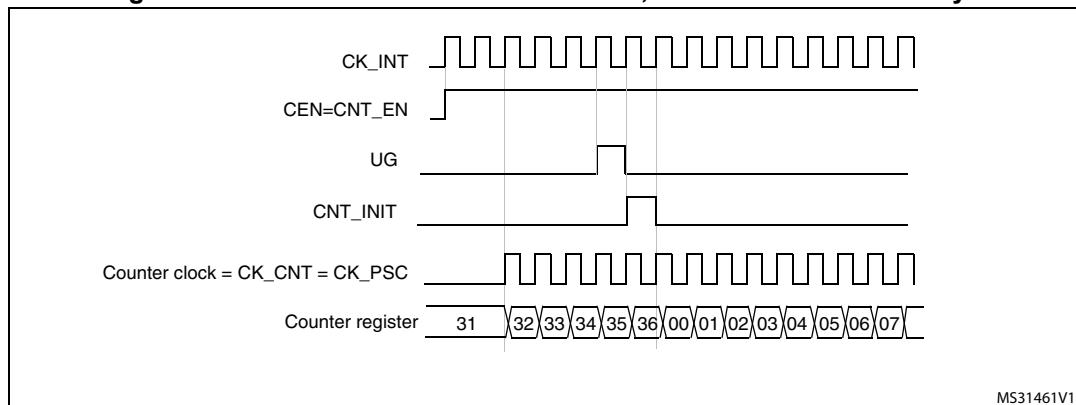
### 17.3.3 Clock source

The counter clock is provided by the Internal clock (CK\_INT) source.

The CEN (in the TIMx\_CR1 register) and UG bits (in the TIMx\_EGR register) are actual control bits and can be changed only by software (except for UG that remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK\_INT.

*Figure 148* shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

**Figure 148. Control circuit in normal mode, internal clock divided by 1**



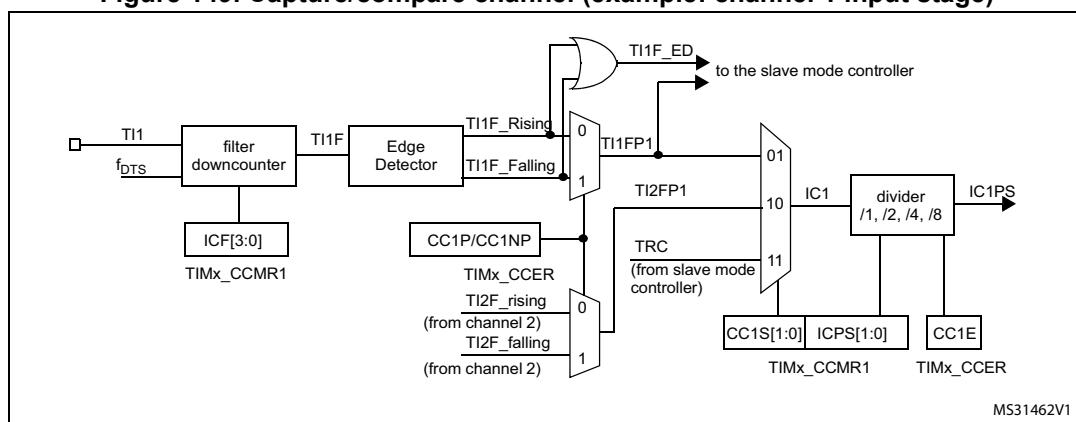
### 17.3.4 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

*Figure 149* to *Figure 151* give an overview of one capture/compare channel.

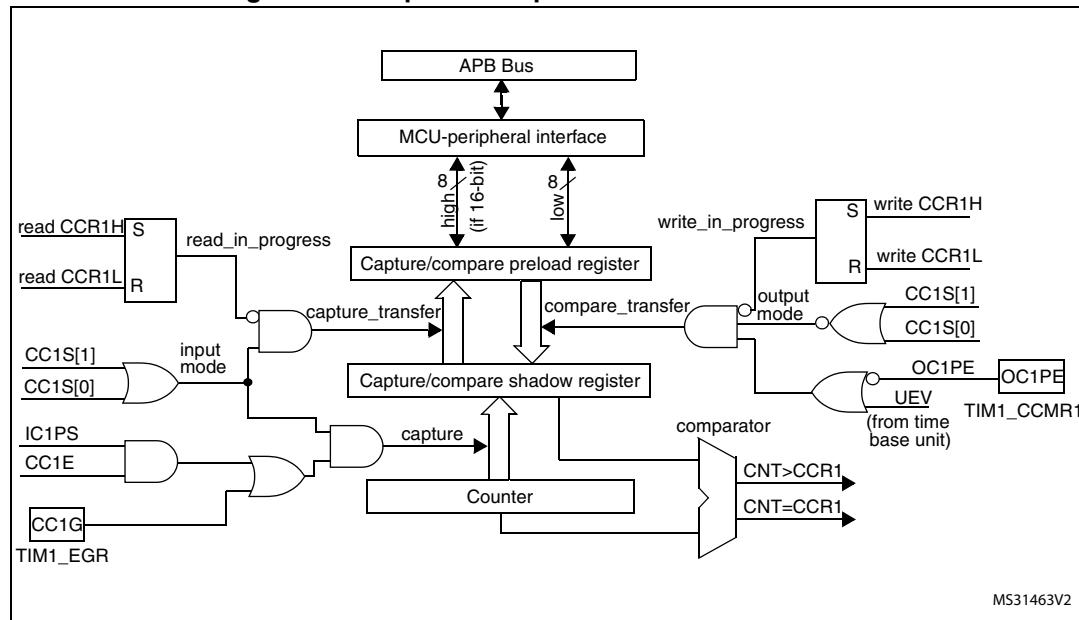
The input stage samples the corresponding TIx input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

**Figure 149. Capture/compare channel (example: channel 1 input stage)**

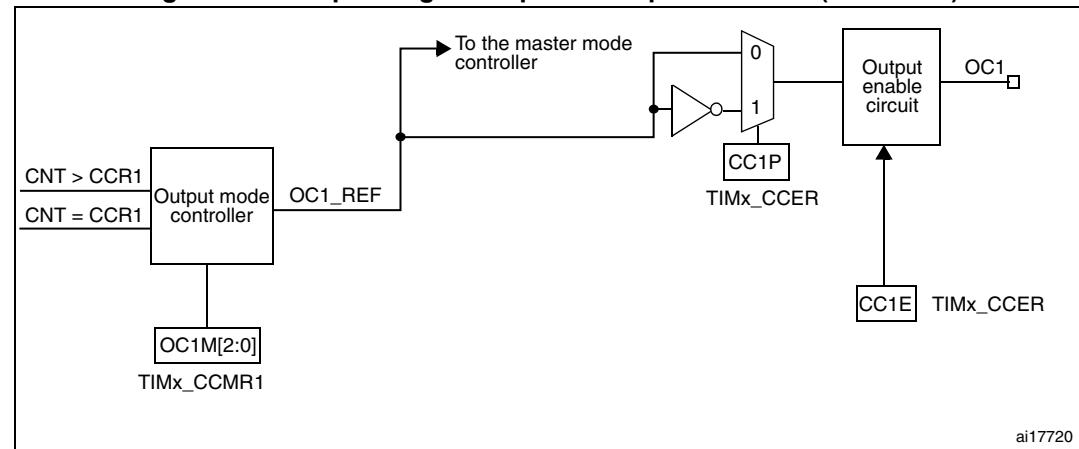


The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

**Figure 150. Capture/compare channel 1 main circuit**



**Figure 151. Output stage of capture/compare channel (channel 1)**



The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

### 17.3.5 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx\_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCXIF flag (TIMx\_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx\_SR register) is set. CCxIF can be cleared by software by writing it to '0' or by reading the captured data stored in the TIMx\_CCRx register. CCxOF is cleared when you write it to '0'.

The following example shows how to capture the counter value in TIMx\_CCR1 when TI1 input rises. To do this, use the following procedure:

1. Select the active input: TIMx\_CCR1 must be linked to the TI1 input, so write the CC1S bits to '01' in the TIMx\_CCMR1 register. As soon as CC1S becomes different from '00', the channel is configured in input mode and the TIMx\_CCR1 register becomes read-only.
2. Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx\_CCMRx register). Let us imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been detected (sampled at  $f_{DTS}$  frequency). Then write IC1F bits to '0011' in the TIMx\_CCMR1 register.
3. Select the edge of the active transition on the TI1 channel by programming CC1P and CC1NP bits to '00' in the TIMx\_CCER register (rising edge in this case).
4. Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to '00' in the TIMx\_CCMR1 register).
5. Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx\_CCER register.
6. If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx\_DIER register.

When an input capture occurs:

- The TIMx\_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

**Note:** *IC interrupt requests can be generated by software by setting the corresponding CCxG bit in the TIMx\_EGR register.*

### 17.3.6 Forced output mode

In output mode (CCxS bits = '00' in the TIMx\_CCMRx register), each output compare signal (OCxREF and then OCx) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (OCXREF/OCx) to its active level, you just need to write '101' in the OCxM bits in the corresponding TIMx\_CCMRx register. Thus OCXREF is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

For example: CCxP='0' (OCx active high) => OCx is forced to high level.

The OCxREF signal can be forced low by writing the OCxM bits to '100' in the TIMx\_CCMRx register.

The comparison between the TIMx\_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt requests can be sent accordingly. This is described in the output compare mode section below.

### 17.3.7 Output compare mode

This function is used to control an output waveform or to indicate when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

1. Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx\_CCMRx register) and the output polarity (CCxP bit in the TIMx\_CCER register). The output pin can keep its level (OCXM='000'), be set active (OCXM='001'), be set inactive (OCXM='010') or can toggle (OCXM='011') on match.
2. Sets a flag in the interrupt status register (CCxIF bit in the TIMx\_SR register).
3. Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx\_DIER register).

The TIMx\_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx\_CCMRx register.

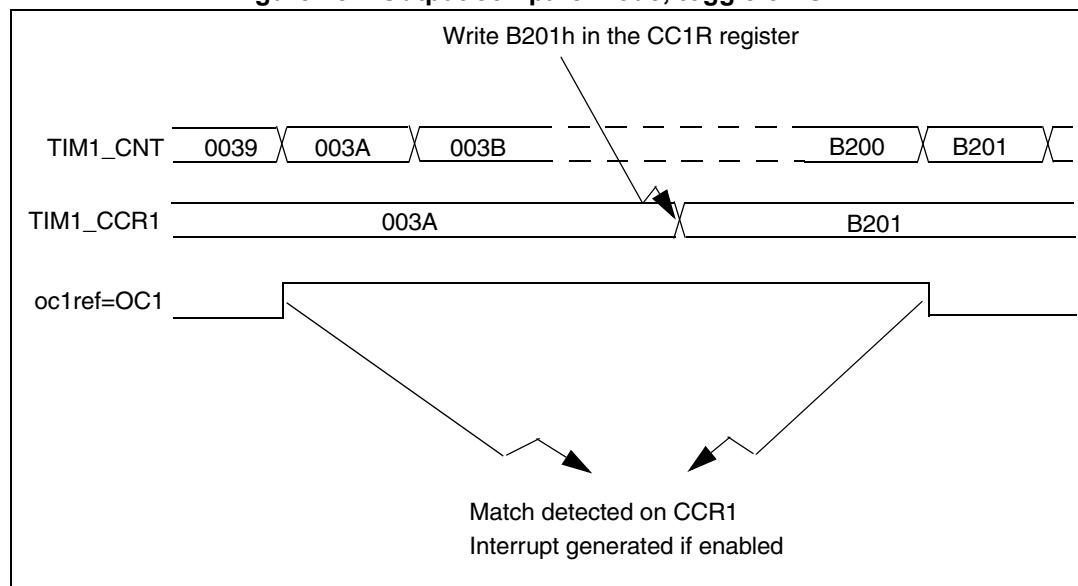
In output compare mode, the update event UEV has no effect on OCxREF and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One-pulse mode).

Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx\_ARR and TIMx\_CCRx registers.
3. Set the CCxIE bit if an interrupt request is to be generated.
4. Select the output mode. For example:
  - Write OCxM = '011' to toggle OCx output pin when CNT matches CCRx
  - Write OCxPE = '0' to disable preload register
  - Write CCxP = '0' to select active high polarity
  - Write CCxE = '1' to enable the output
5. Enable the counter by setting the CEN bit in the TIMx\_CR1 register.

The TIMx\_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE='0', else TIMx\_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 152](#).

**Figure 152. Output compare mode, toggle on OC1.**



### 17.3.8 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx\_ARR register and a duty cycle determined by the value of the TIMx\_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing '110' (PWM mode 1) or '111' (PWM mode 2) in the OCxM bits in the TIMx\_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx\_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx\_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx\_EGR register.

The OCx polarity is software programmable using the CCxP bit in the TIMx\_CCER register. It can be programmed as active high or active low. The OCx output is enabled by the CCxE bit in the TIMx\_CCER register. Refer to the TIMx\_CCERx register description for more details.

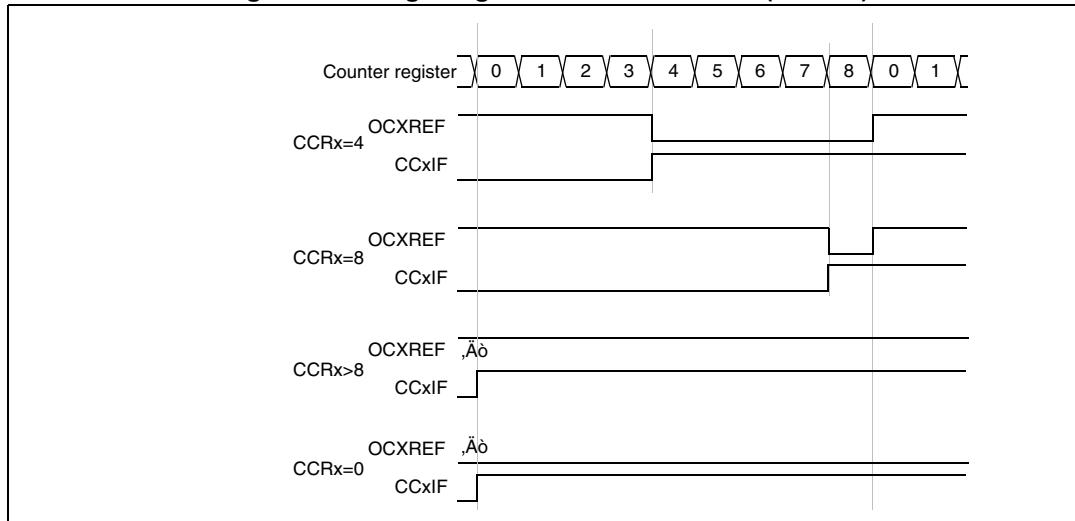
In PWM mode (1 or 2), TIMx\_CNT and TIMx\_CCRx are always compared to determine whether  $\text{TIMx_CNT} \leq \text{TIMx_CCRx}$ .

The timer is able to generate PWM in edge-aligned mode only since the counter is upcounting.

### PWM edge-aligned mode

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as  $\text{TIMx\_CNT} < \text{TIMx\_CCR}_x$  else it becomes low. If the compare value in  $\text{TIMx\_CCR}_x$  is greater than the auto-reload value (in  $\text{TIMx\_ARR}$ ) then OCxREF is held at '1'. If the compare value is 0 then OCxRef is held at '0'. [Figure 153](#) shows some edge-aligned PWM waveforms in an example where  $\text{TIMx\_ARR}=8$ .

**Figure 153. Edge-aligned PWM waveforms (ARR=8)**



### 17.3.9 Debug mode

When the microcontroller enters debug mode (Cortex™-M0 core halted), the TIMx counter either continues to work normally or stops, depending on `DBG_TIMx_STOP` configuration bit in DBG module.

## 17.4 TIM14 registers

### 17.4.1 TIM14 control register 1 (TIM14\_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	Res.	Res.	Res.	Res.	URS	UDIS	CEN

Bits 15:10 Reserved, must be kept at reset value.

Bits 9:8 **CKD**: Clock division

This bit-field indicates the division ratio between the timer clock (CK\_INT) frequency and sampling clock used by the digital filters (ETR, TIx),

- 00:  $t_{DTS} = t_{CK\_INT}$
- 01:  $t_{DTS} = 2 \times t_{CK\_INT}$
- 10:  $t_{DTS} = 4 \times t_{CK\_INT}$
- 11: Reserved

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIMx\_ARR register is not buffered
- 1: TIMx\_ARR register is buffered

Bits 6:3 Reserved, must be kept at reset value.

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the update interrupt (UEV) sources.

- 0: Any of the following events generate an UEV if enabled:
  - Counter overflow
  - Setting the UG bit
- 1: Only counter overflow generates an UEV if enabled.

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable update interrupt (UEV) event generation.

- 0: UEV enabled. An UEV is generated by one of the following events:
  - Counter overflow
  - Setting the UG bit.

Buffered registers are then loaded with their preload values.

- 1: UEV disabled. No UEV is generated, shadow registers keep their value (ARR, PSC, CCRx). The counter and the prescaler are reinitialized if the UG bit is set.

Bit 0 **CEN**: Counter enable

- 0: Counter disabled
- 1: Counter enabled

### 17.4.2 TIM14 interrupt enable register (TIM14\_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	CC1IE	UIE													

Bits 15:2 Reserved, must be kept at reset value.

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

- 0: CC1 interrupt disabled
- 1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

- 0: Update interrupt disabled
- 1: Update interrupt enabled

### 17.4.3 TIM14 status register (TIM14\_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CC1OF	Res.	CC1IF	UIF						

Bit 15:10 Reserved, must be kept at reset value.

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected.

1: The counter value has been captured in TIMx\_CCR1 register while CC1IF flag was already set

Bits 8:2 Reserved, must be kept at reset value.

Bit 1 **CC1IF**: Capture/compare 1 interrupt flag

**If channel CC1 is configured as output:**

This flag is set by hardware when the counter matches the compare value. It is cleared by software.

0: No match.

1: The content of the counter TIMx\_CNT matches the content of the TIMx\_CCR1 register. When the contents of TIMx\_CCR1 are greater than the contents of TIMx\_ARR, the CC1IF bit goes high on the counter overflow.

**If channel CC1 is configured as input:**

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx\_CCR1 register.

0: No input capture occurred.

1: The counter value has been captured in TIMx\_CCR1 register (an edge has been detected on IC1 which matches the selected polarity).

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow and if UDIS='0' in the TIMx\_CR1 register.
- When CNT is reinitialized by software using the UG bit in TIMx\_EGR register, if URS='0' and UDIS='0' in the TIMx\_CR1 register.

#### 17.4.4 TIM14 event generation register (TIM14\_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	CC1G	UG													

Bits 15:2 Reserved, must be kept at reset value.

Bit 1 **CC1G**: Capture/compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

**If channel CC1 is configured as output:**

CC1IF flag is set, Corresponding interrupt or is sent if enabled.

**If channel CC1 is configured as input:**

The current value of the counter is captured in TIMx\_CCR1 register. The CC1IF flag is set, the corresponding interrupt is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Re-initialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared.

### 17.4.5 TIM14 capture/compare mode register 1 (TIM14\_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CC<sub>x</sub>S bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OC<sub>xx</sub> describes its function when the channel is configured in output, IC<sub>xx</sub> describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Res.	OC1M[2:0]				OC1PE	OC1FE	CC1S[1:0]									
Res.	IC1F[3:0]				IC1PSC[1:0]											
								rw	rw	rw	rw	rw	rw	rw	rw	

#### Output compare mode

Bits 15:7 Reserved

Bits 6:4 **OC1M**: Output compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 is derived. OC1REF is active high whereas OC1 active level depends on CC1P bit.

000: Frozen. The comparison between the output compare register TIMx\_CCR1 and the counter TIMx\_CNT has no effect on the outputs.

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).

011: Toggle - OC1REF toggles when TIMx\_CNT = TIMx\_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - Channel 1 is active as long as TIMx\_CNT < TIMx\_CCR1 else inactive.

111: PWM mode 2 - Channel 1 is inactive as long as TIMx\_CNT < TIMx\_CCR1 else active.

*Note:* In PWM mode 1 or 2, the OCREF level changes when the result of the comparison changes or when the output compare mode switches from frozen to PWM mode.

**Bit 3 OC1PE:** Output compare 1 preload enable

0: Preload register on TIMx\_CCR1 disabled. TIMx\_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx\_CCR1 enabled. Read/Write operations access the preload register. TIMx\_CCR1 preload value is loaded in the active register at each update event.

*Note: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx\_CR1 register). Else the behavior is not guaranteed.*

**Bit 2 OC1FE:** Output compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. OC is then set to the compare level independently of the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OC1FE acts only if the channel is configured in PWM1 or PWM2 mode.

**Bits 1:0 CC1S:** Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1.

10: Reserved

11: Reserved

*Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx\_CCER).*

**Input capture mode**

Bits 15:8 Reserved

Bits 7:4 **IC1F**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, sampling is done at  $f_{DTS}$
- 1000:  $f_{SAMPLING} = f_{CK\_INT}$ , N=2
- 0001:  $f_{SAMPLING} = f_{CK\_INT}$ , N=4
- 0010:  $f_{SAMPLING} = f_{CK\_INT}$ , N=8
- 0011:  $f_{SAMPLING} = f_{CK\_INT}$ , N=16
- 0100:  $f_{SAMPLING} = f_{DTS}/2$ , N=32
- 0101:  $f_{SAMPLING} = f_{DTS}/2$ , N=64
- 0110:  $f_{SAMPLING} = f_{DTS}/4$ , N=128
- 0111:  $f_{SAMPLING} = f_{DTS}/4$ , N=256

*Note: In current silicon revision,  $f_{DTS}$  is replaced in the formula by CK\_INT when ICxF[3:0]= 1, 2 or 3.*

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).  
The prescaler is reset as soon as CC1E='0' (TIMx\_CCER register).

- 00: no prescaler, capture is done each time an edge is detected on the capture input
- 01: capture is done once every 2 events
- 10: capture is done once every 4 events
- 11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 0: CC1 channel is configured as output
- 01: CC1 channel is configured as input, IC1 is mapped on TI1
- 10:
- 11:

*Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx\_CCER).*

### 17.4.6 TIM14 capture/compare enable register (TIM14\_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	CC1NP	Res.	CC1P	CC1E											

Bits 15:4 Reserved, must be kept at reset value.

Bit 3 **CC1NP**: Capture/Compare 1 complementary output Polarity.

CC1 channel configured as output: CC1NP must be kept cleared.

CC1 channel configured as input: CC1NP bit is used in conjunction with CC1P to define TI1FP1 polarity (refer to CC1P description).

Bit 2 Reserved, must be kept at reset value.

Bit 1 **CC1P**: Capture/Compare 1 output Polarity.

**CC1 channel configured as output:**

0: OC1 active high

1: OC1 active low

**CC1 channel configured as input:**

The CC1P bit selects TI1FP1 and TI2FP1 polarity for trigger or capture operations.

00: noninverted/rising edge

Circuit is sensitive to TI1FP1 rising edge (capture mode), TI1FP1 is not inverted.

01: inverted/falling edge

Circuit is sensitive to TI1FP1 falling edge (capture mode), TI1FP1 is inverted.

10: reserved, do not use this configuration.

11: noninverted/both edges

Circuit is sensitive to both TI1FP1 rising and falling edges (capture mode), TI1FP1 is not inverted.

Bit 0 **CC1E**: Capture/Compare 1 output enable.

**CC1 channel configured as output:**

0: Off - OC1 is not active

1: On - OC1 signal is output on the corresponding output pin

**CC1 channel configured as input:**

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx\_CCR1) or not.

0: Capture disabled

1: Capture enabled

**Table 50. Output control bit for standard OCx channels**

CCxE bit	OCx output state
0	Output Disabled (OCx='0', OCx_EN='0')
1	OCx=OCxREF + Polarity, OCx_EN='1'

**Note:** The state of the external I/O pins connected to the standard OCx channels depends on the OCx channel state and the GPIO registers.

### 17.4.7 TIM14 counter (TIM14\_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Counter value

### 17.4.8 TIM14 prescaler (TIM14\_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency CK\_CNT is equal to  $f_{CK\_PSC} / (PSC[15:0] + 1)$ .

PSC contains the value to be loaded in the active prescaler register at each update event.

### 17.4.9 TIM14 auto-reload register (TIM14\_ARR)

Address offset: 0x2C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 17.3.1: Time-base unit on page 361](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

### 17.4.10 TIM14 capture/compare register 1 (TIM14\_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

**If channel CC1 is configured as output:**

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signaled on OC1 output.

**If channel CC1 is configured as input:**

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

### 17.4.11 TIM14 option register (TIM14\_OR)

Address offset: 0x50

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TI1_RMP														
														rw	rw

Bits 15:2 Reserved, must be kept at reset value.

Bit 1:0 **TI1\_RMP [1:0]**: Timer Input 1 remap

Set and cleared by software.

00: TIM14 Channel1 is connected to the GPIO. Refer to the alternate function mapping in the device datasheets.

01: TIM14 Channel1 is connected to the RTCCLK.

10: TIM14 Channel1 is connected to the HSE/32 Clock.

11: TIM14 Channel1 is connected to the microcontroller clock output (MCO), this selection is controlled by the MCO[2:0] bits of the Clock configuration register (RCC\_CFGR) (see [Section 7.4.2: Clock configuration register \(RCC\\_CFGR\)](#)).

#### **17.4.12 TIM14 register map**

TIM14 registers are mapped as 16-bit addressable registers as described in the table below:

**Table 51. TIM14 register map and reset values**

**Table 51. TIM14 register map and reset values (continued)**

<b>Offset</b>	<b>Register</b>	
0x38 to 0x4C	<b>Reserved</b>	Res. <b>31</b>
	Reset value	Res. <b>30</b>
0x50	<b>TIM14_OR</b>	Res. <b>29</b>
	Reset value	Res. <b>28</b>
		Res. <b>27</b>
		Res. <b>26</b>
		Res. <b>25</b>
		Res. <b>24</b>
		Res. <b>23</b>
		Res. <b>22</b>
		Res. <b>21</b>
		Res. <b>20</b>
		Res. <b>19</b>
		Res. <b>18</b>
		Res. <b>17</b>
		Res. <b>16</b>
		Res. <b>15</b>
		Res. <b>14</b>
		Res. <b>13</b>
		Res. <b>12</b>
		Res. <b>11</b>
		Res. <b>10</b>
		Res. <b>9</b>
		Res. <b>8</b>
		Res. <b>7</b>
		Res. <b>6</b>
		Res. <b>5</b>
		Res. <b>4</b>
		Res. <b>3</b>
		Res. <b>2</b>
<b>0</b>	<b>T1_RMP</b>	Res. <b>1</b>
<b>0</b>		Res. <b>0</b>

## 18 General-purpose timers (TIM15/16/17)

### 18.1 TIM15/16/17 introduction

The TIM15/16/17 timers consist of a 16-bit auto-reload counter driven by a programmable prescaler.

They may be used for a variety of purposes, including measuring the pulse lengths of input signals (input capture) or generating output waveforms (output compare, PWM, complementary PWM with dead-time insertion).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

The TIM15/16/17 timers are completely independent, and do not share any resources. The TIM15 can be synchronized with other timers.

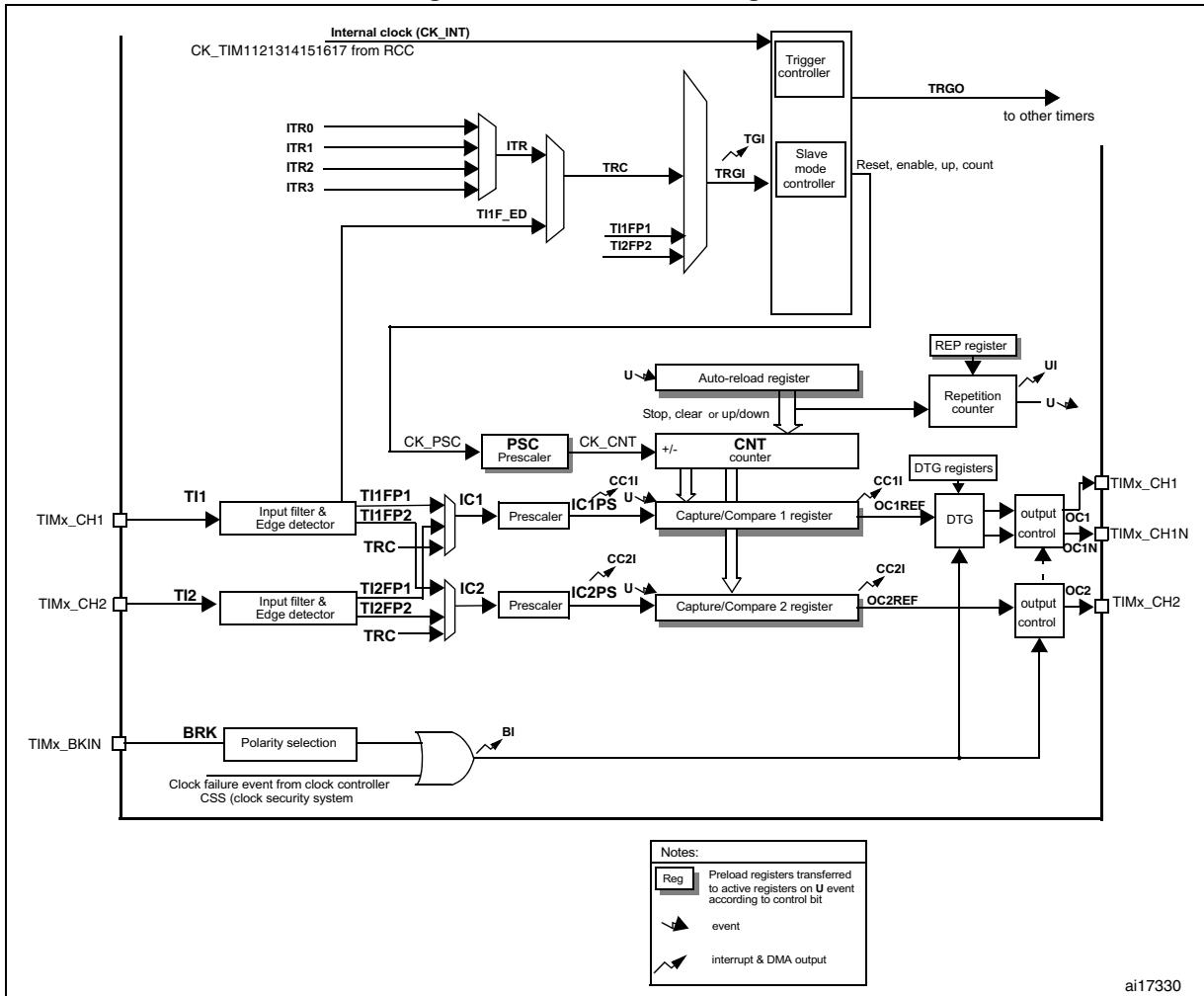
### 18.2 TIM15 main features

This section applies to medium-density devices only.

TIM15 includes the following features:

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535
- Up to 2 independent channels for:
  - Input capture
  - Output compare
  - PWM generation (Edge-aligned mode)
  - One-pulse mode output
- Complementary outputs with programmable dead-time (for channel 1 only)
- Synchronization circuit to control the timer with external signals and to interconnect several timers together
- Repetition counter to update the timer registers only after a given number of cycles of the counter
- Break input to put the timer’s output signals in the reset state or a known state
- Interrupt/DMA generation on the following events:
  - Update: counter overflow, counter initialization (by software or internal/external trigger)
  - Trigger event (counter start, stop, initialization or count by internal/external trigger)
  - Input capture
  - Output compare
  - Break input (interrupt request)

Figure 154. TIM15 block diagram



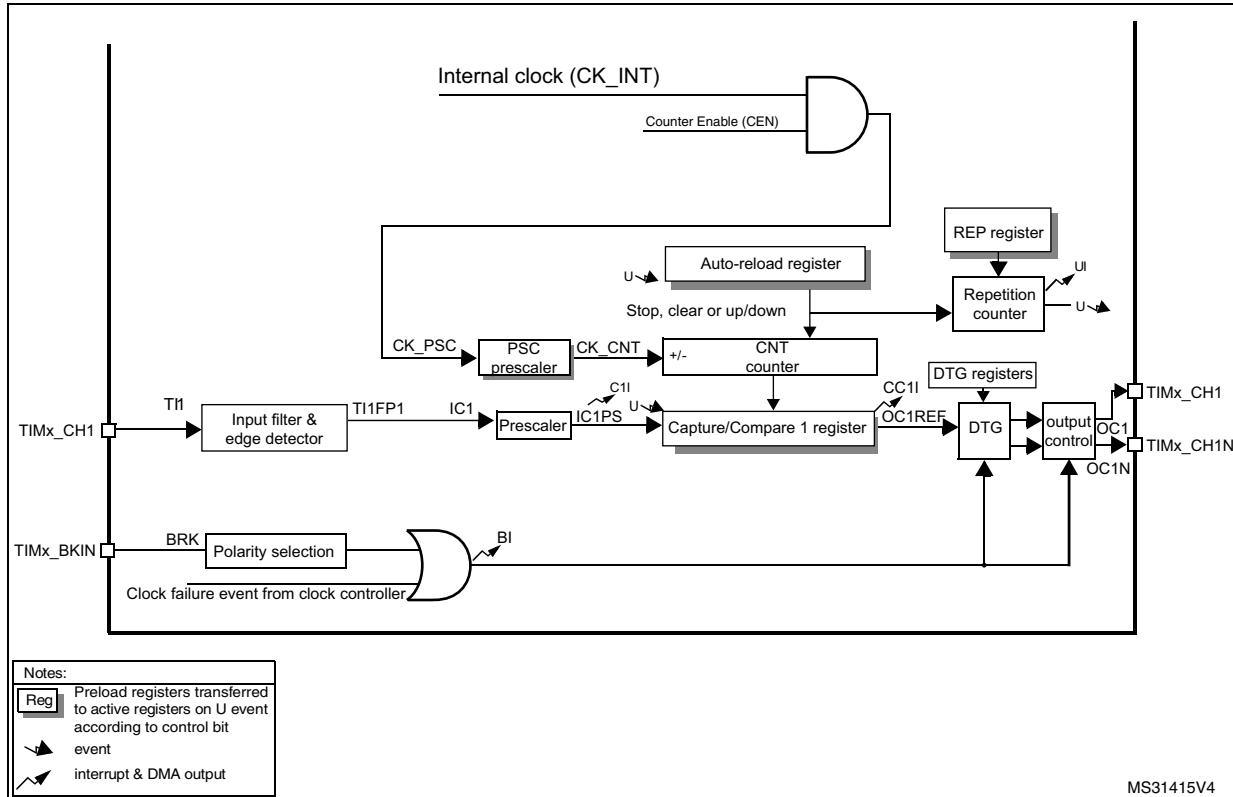
## 18.3 TIM16 and TIM17 main features

The TIM16 and TIM17 timers include the following features:

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535
- One channel for:
  - Input capture
  - Output compare
  - PWM generation (Edge-aligned mode)
  - One-pulse mode output
- Complementary outputs with programmable dead-time
- Repetition counter to update the timer registers only after a given number of cycles of the counter
- Break input to put the timer’s output signals in the reset state or a known state

- Interrupt/DMA generation on the following events:
  - Update: counter overflow
  - Input capture
  - Output compare
  - Break input

Figure 155. TIM16 and TIM17 block diagram



MS31415V4

## 18.4 TIM15/16/17 functional description

### 18.4.1 Time-base unit

The main block of the programmable advanced-control timer is a 16-bit counter with its related auto-reload register. The counter can count up, down or both up and down. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter register (TIMx\_CNT)
- Prescaler register (TIMx\_PSC)
- Auto-reload register (TIMx\_ARR)
- Repetition counter register (TIMx\_RCR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx\_CR1 register. The update event is sent when the counter reaches the overflow (or underflow when downcounting) and if the UDIS bit equals 0 in the TIMx\_CR1 register. It can also be generated by software. The generation of the update event is described in detail for each configuration.

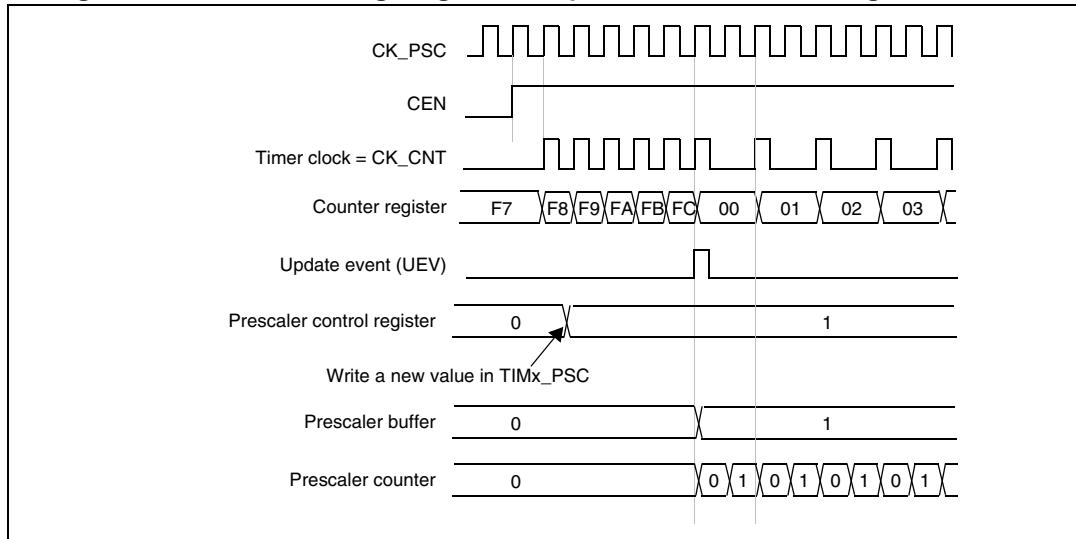
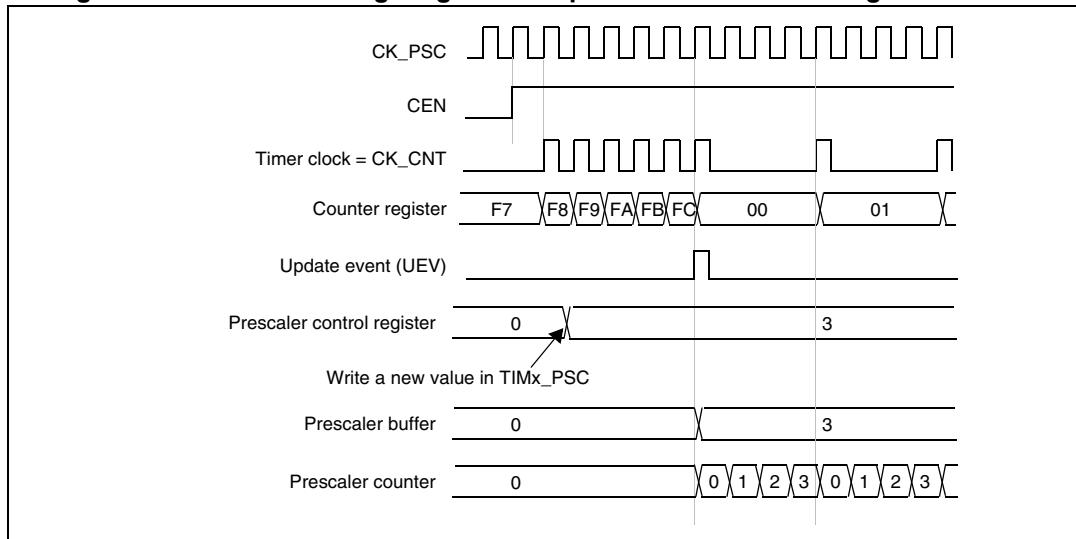
The counter is clocked by the prescaler output CK\_CNT, which is enabled only when the counter enable bit (CEN) in TIMx\_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

Note that the counter starts counting 1 clock cycle after setting the CEN bit in the TIMx\_CR1 register.

#### Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx\_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

*Figure 141* and *Figure 142* give some examples of the counter behavior when the prescaler ratio is changed on the fly:

**Figure 156. Counter timing diagram with prescaler division change from 1 to 2****Figure 157. Counter timing diagram with prescaler division change from 1 to 4**

## 18.4.2 Counter modes

### Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx\_ARR register), then restarts from 0 and generates a counter overflow event.

If the repetition counter is used, the update event (UEV) is generated after upcounting is repeated for the number of times programmed in the repetition counter register (TIMx\_RCR). Else the update event is generated at each counter overflow.

Setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller) also generates an update event.

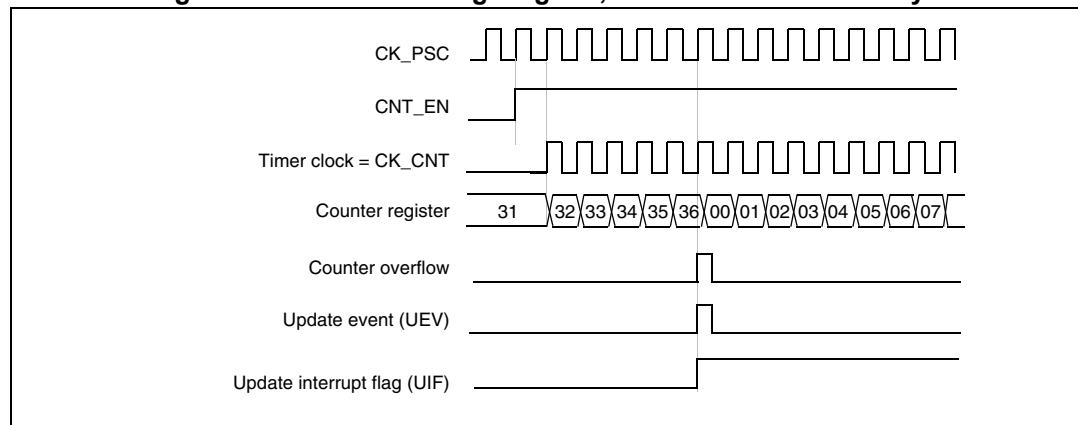
The UEV event can be disabled by software by setting the UDIS bit in the TIMx\_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx\_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx\_SR register) is set (depending on the URS bit):

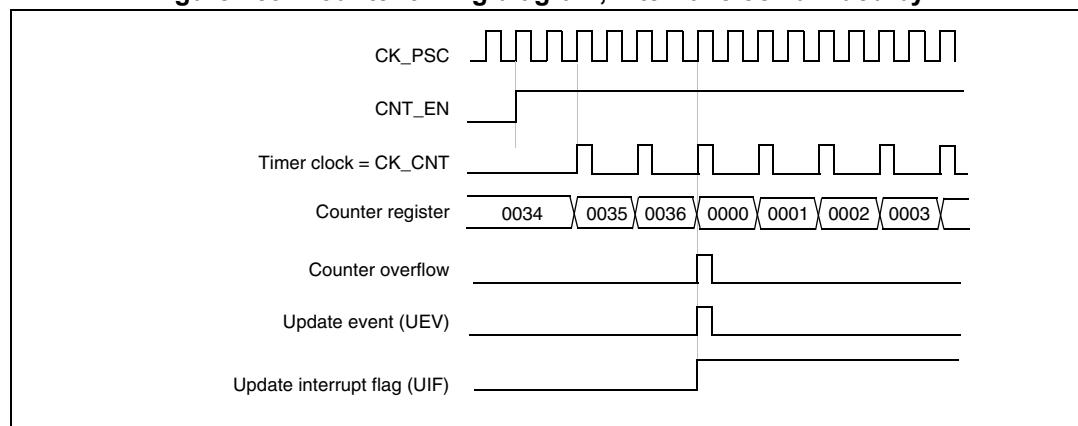
- The repetition counter is reloaded with the content of TIMx\_RCR register,
- The auto-reload shadow register is updated with the preload value (TIMx\_ARR),
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx\_PSC register).

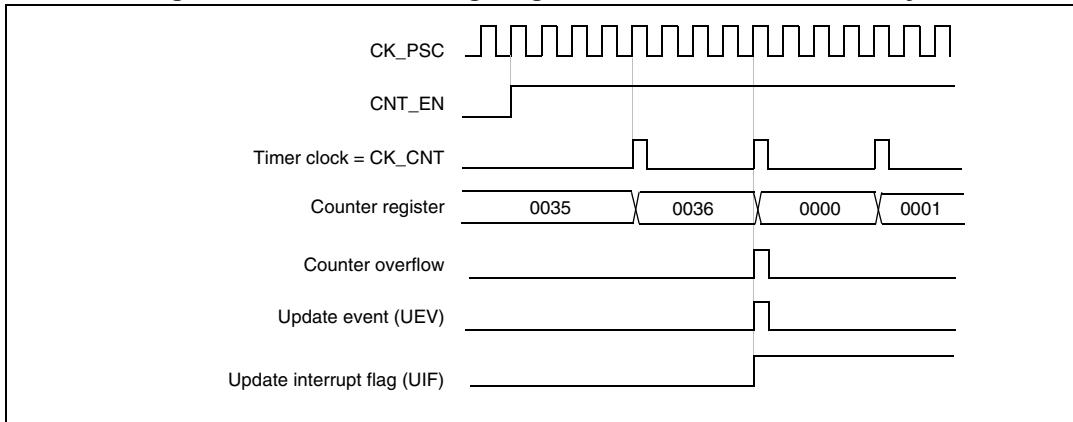
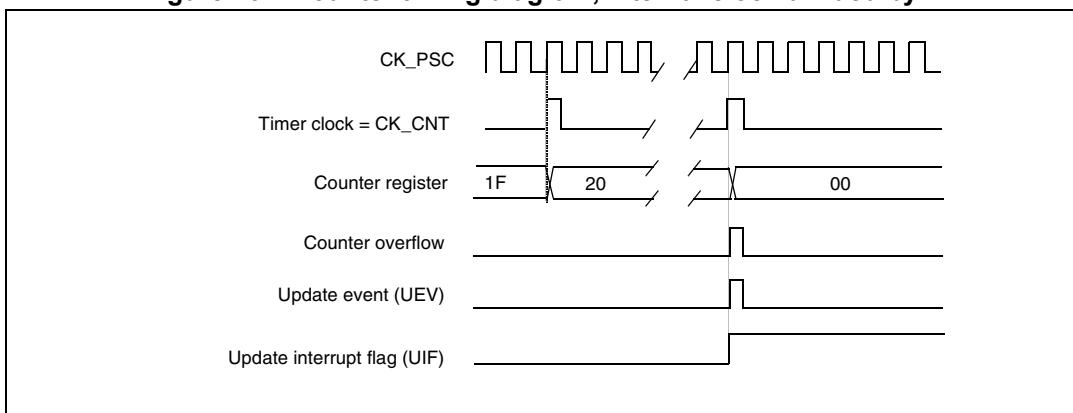
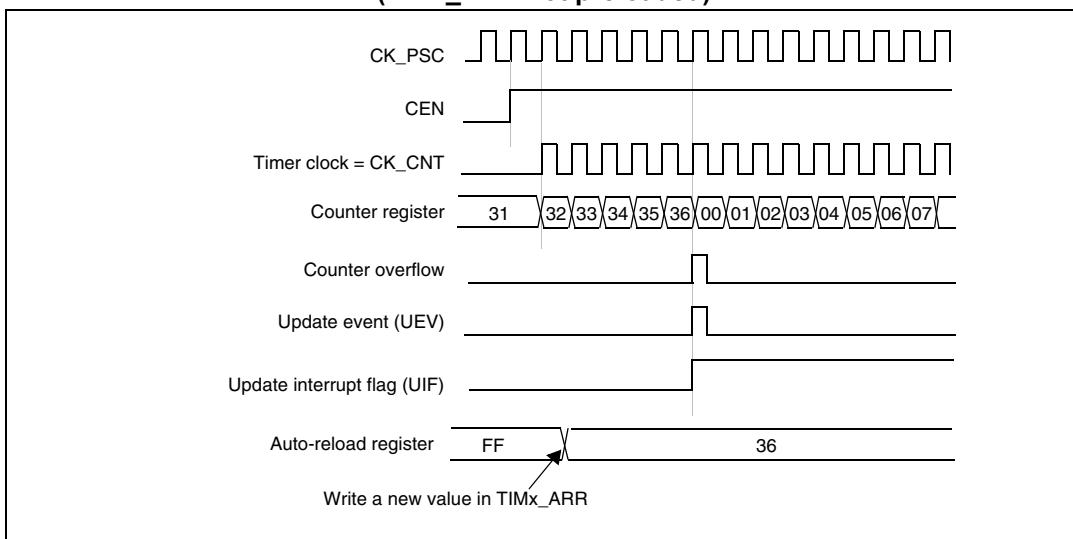
The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR=0x36.

**Figure 158. Counter timing diagram, internal clock divided by 1**

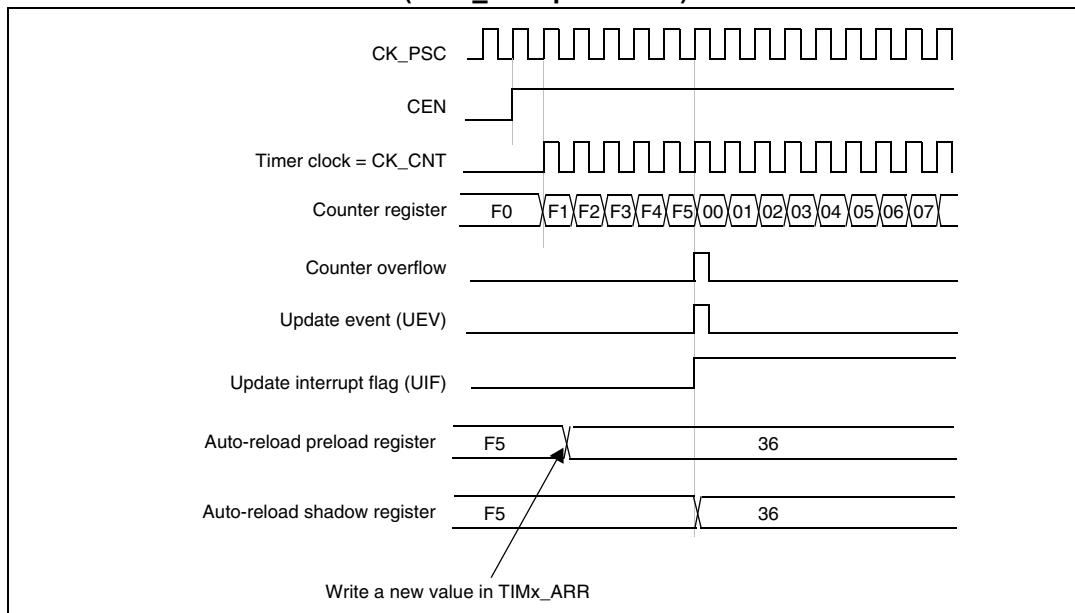


**Figure 159. Counter timing diagram, internal clock divided by 2**



**Figure 160. Counter timing diagram, internal clock divided by 4****Figure 161. Counter timing diagram, internal clock divided by N****Figure 162. Counter timing diagram, update event when ARPE=0  
(TIMx\_ARR not preloaded)**

**Figure 163. Counter timing diagram, update event when ARPE=1  
(TIMx\_ARR preloaded)**



#### 18.4.3 Repetition counter

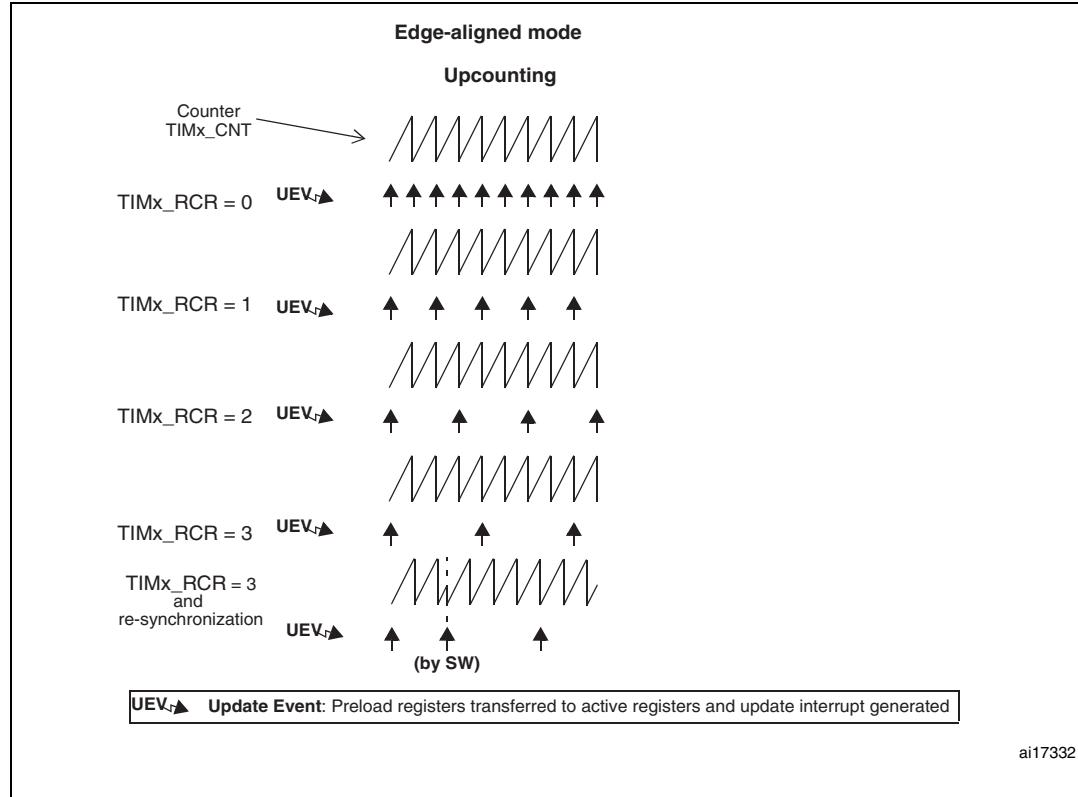
*Section 17.3.1: Time-base unit* describes how the update event (UEV) is generated with respect to the counter overflows/underflows. It is actually generated only when the repetition counter has reached zero. This can be useful when generating PWM signals.

This means that data are transferred from the preload registers to the shadow registers (TIMx\_ARR auto-reload register, TIMx\_PSC prescaler register, but also TIMx\_CCRx capture/compare registers in compare mode) every N counter overflows or underflows, where N is the value in the TIMx\_RCR repetition counter register.

The repetition counter is decremented at each counter overflow in upcounting mode.

The repetition counter is an auto-reload type; the repetition rate is maintained as defined by the TIMx\_RCR register value (refer to [Figure 164](#)). When the update event is generated by software (by setting the UG bit in TIMx\_EGR register) or by hardware through the slave mode controller, it occurs immediately whatever the value of the repetition counter is and the repetition counter is reloaded with the content of the TIMx\_RCR register.

**Figure 164. Update rate examples depending on mode and TIMx\_RCR register settings**



#### 18.4.4 Clock sources

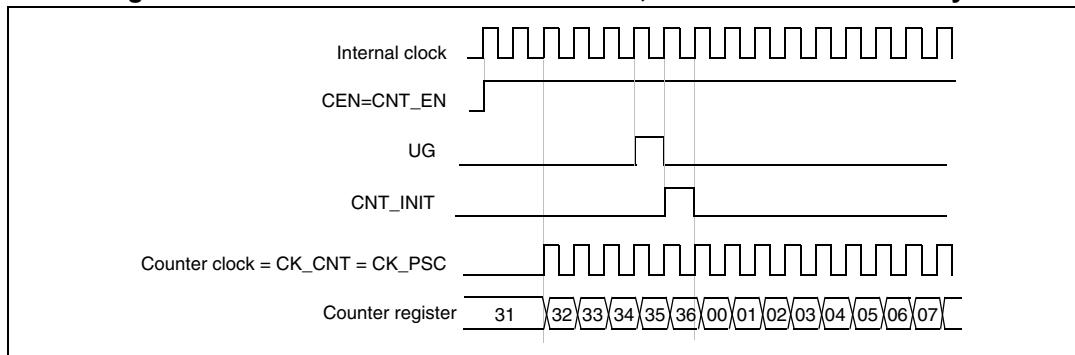
The counter clock can be provided by the following clock sources:

- Internal clock (CK\_INT)
- External clock mode1: external input pin (only for TIM15)
- Internal trigger inputs (ITRx) (only for TIM15): using one timer as the prescaler for another timer, for example, you can configure TIM1 to act as a prescaler for TIM15. Refer to [Using one timer as prescaler for another](#) for more details.

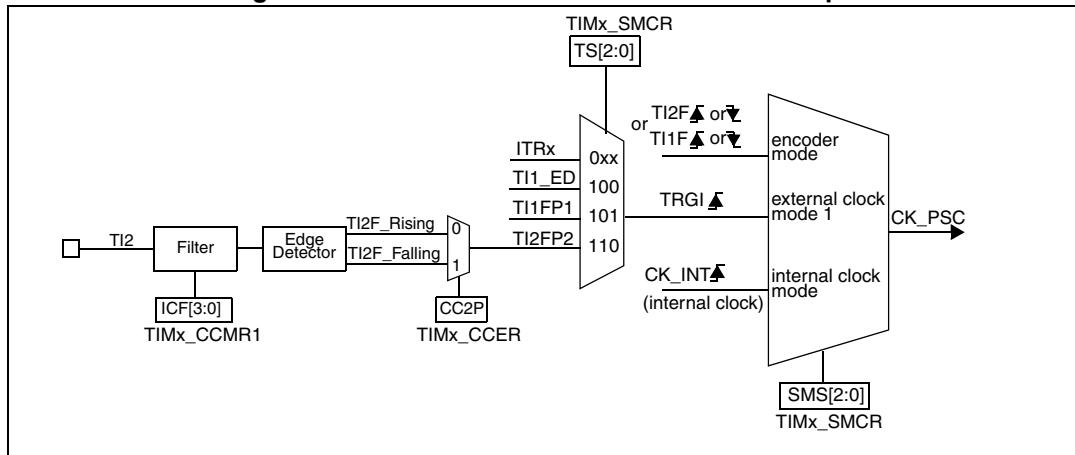
##### Internal clock source (CK\_INT)

For TIM5 if the slave mode controller is disabled (SMS=000), then the CEN, DIR (in the TIMx\_CR1 register) and UG bits (in the TIMx\_EGR register) are actual control bits and can be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK\_INT.

[Figure 17.3.4](#) shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

**Figure 165. Control circuit in normal mode, internal clock divided by 1****External clock source mode 1**

This mode is selected when SMS=111 in the TIMx\_SMCR register. The counter can count at each rising or falling edge on a selected input.

**Figure 166. TI2 external clock connection example**

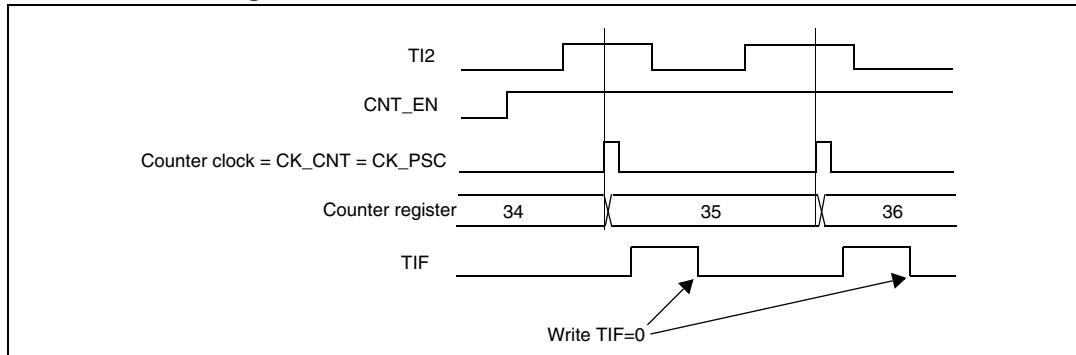
For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S = '01' in the TIMx\_CCMR1 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIMx\_CCMR1 register (if no filter is needed, keep IC2F=0000).
3. Select rising edge polarity by writing CC2P=0 in the TIMx\_CCER register.
4. Configure the timer in external clock mode 1 by writing SMS=111 in the TIMx\_SMCR register.
5. Select TI2 as the trigger input source by writing TS=110 in the TIMx\_SMCR register.
6. Enable the counter by writing CEN=1 in the TIMx\_CR1 register.

*Note:* The capture prescaler is not used for triggering, so you don't need to configure it.

When a rising edge occurs on TI2, the counter counts once and the TIF flag is set.

The delay between the rising edge on TI2 and the actual clock of the counter is due to the resynchronization circuit on TI2 input.

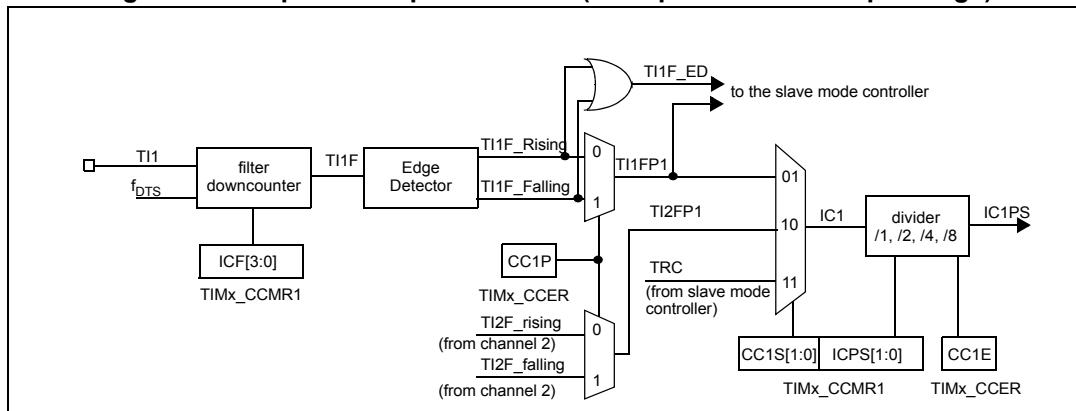
**Figure 167. Control circuit in external clock mode 1**

#### 18.4.5 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

*Figure 149* to *Figure 171* give an overview of one Capture/Compare channel.

The input stage samples the corresponding TI<sub>x</sub> input to generate a filtered signal TI<sub>x</sub>F. Then, an edge detector with polarity selection generates a signal (TI<sub>x</sub>FP<sub>x</sub>) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (IC<sub>x</sub>PS).

**Figure 168. Capture/compare channel (example: channel 1 input stage)**

The output stage generates an intermediate waveform which is then used for reference: OC<sub>x</sub>Ref (active high). The polarity acts at the end of the chain.

Figure 169. Capture/compare channel 1 main circuit

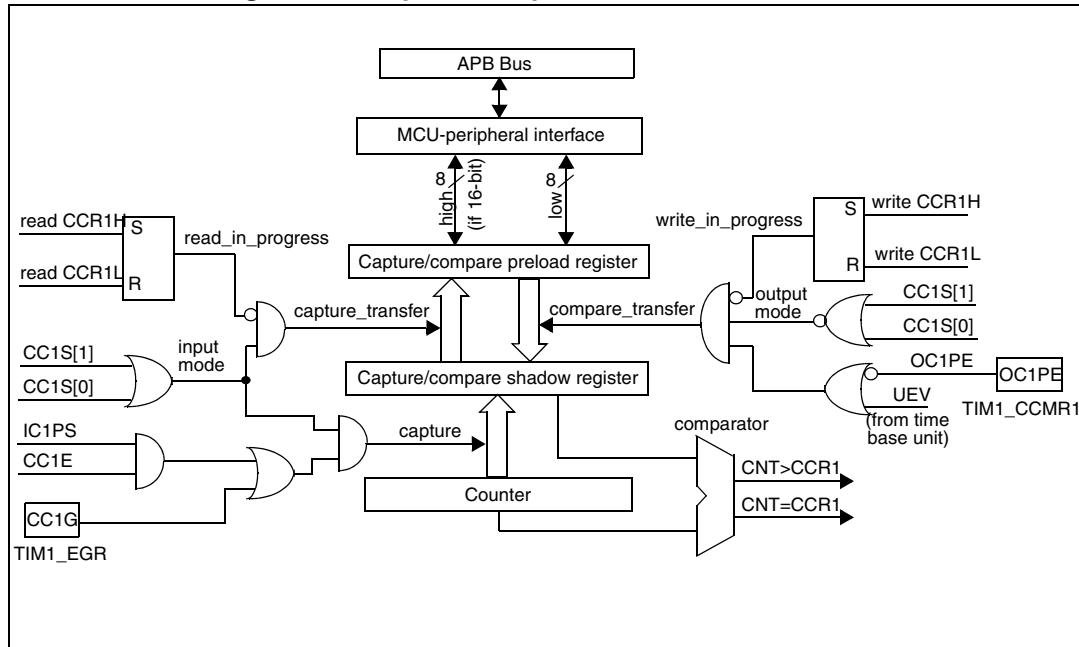


Figure 170. Output stage of capture/compare channel (channel 1)

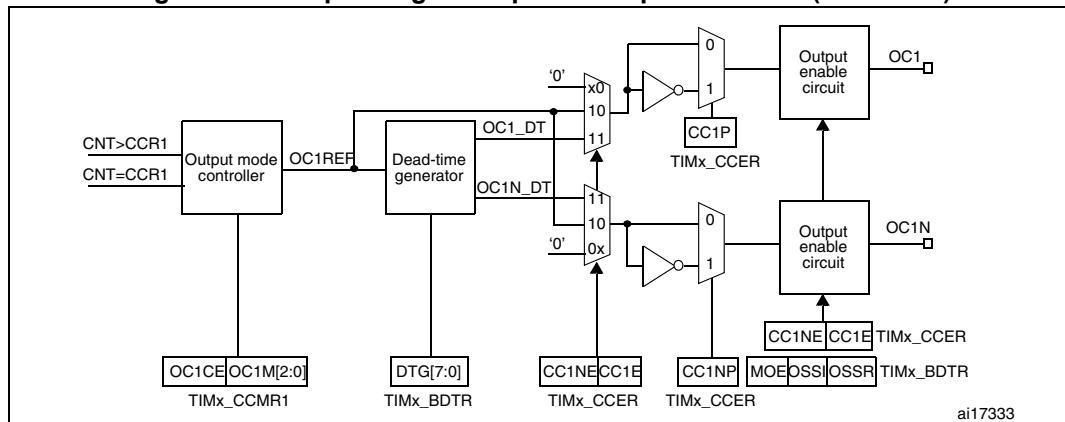
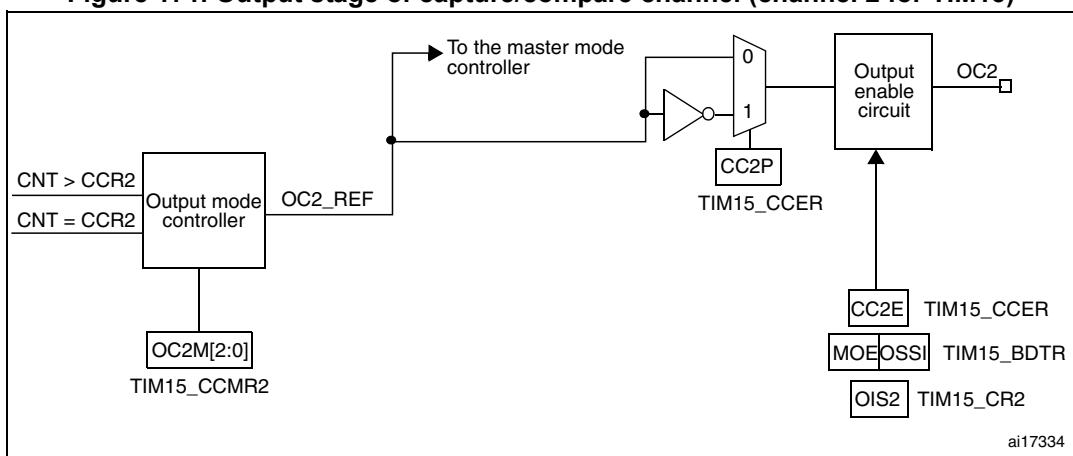


Figure 171. Output stage of capture/compare channel (channel 2 for TIM15)



The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

#### 18.4.6 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx\_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCXIF flag (TIMx\_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx\_SR register) is set. CCxIF can be cleared by software by writing it to '0' or by reading the captured data stored in the TIMx\_CCRx register. CCxOF is cleared when you write it to '0'.

The following example shows how to capture the counter value in TIMx\_CCR1 when TI1 input rises. To do this, use the following procedure:

- Select the active input: TIMx\_CCR1 must be linked to the TI1 input, so write the CC1S bits to 01 in the TIMx\_CCMR1 register. As soon as CC1S becomes different from 00, the channel is configured in input and the TIMx\_CCR1 register becomes read-only.
- Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx\_CCMRx register). Let's imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been detected (sampled at  $f_{DTS}$  frequency). Then write IC1F bits to 0011 in the TIMx\_CCMR1 register.
- Select the edge of the active transition on the TI1 channel by writing CC1P bit to 0 in the TIMx\_CCER register (rising edge in this case).
- Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to '00' in the TIMx\_CCMR1 register).
- Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx\_CCER register.
- If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx\_DIER register, and/or the DMA request by setting the CC1DE bit in the TIMx\_DIER register.

When an input capture occurs:

- The TIMx\_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.
- A DMA request is generated depending on the CC1DE bit.

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

**Note:** IC interrupt and/or DMA requests can be generated by software by setting the corresponding CCxG bit in the TIMx\_EGR register.

### 18.4.7 PWM input mode (only for TIM15)

This section applies to medium-density devices only.

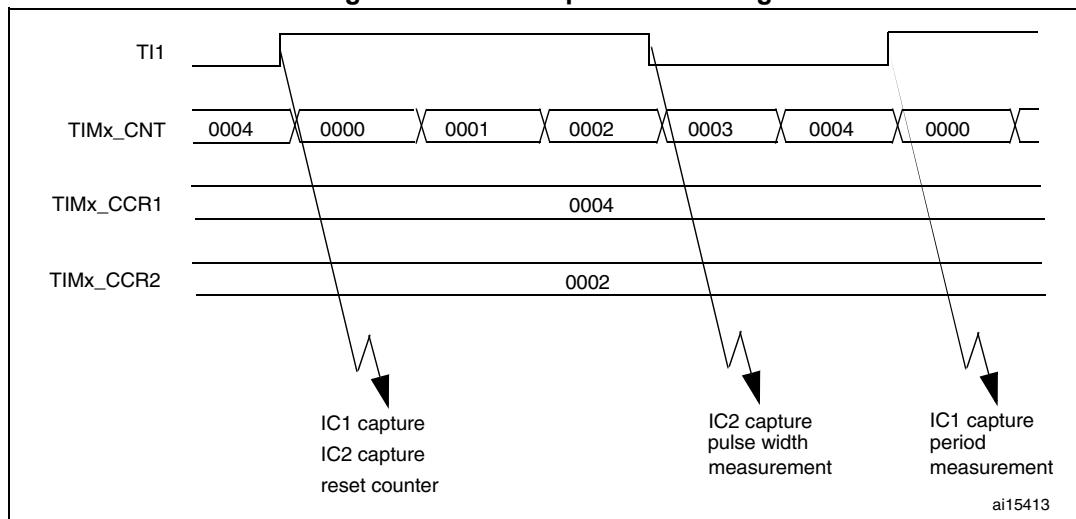
This mode is a particular case of input capture mode. The procedure is the same except:

- Two ICx signals are mapped on the same TIx input.
- These 2 ICx signals are active on edges with opposite polarity.
- One of the two TIxFP signals is selected as trigger input and the slave mode controller is configured in reset mode.

For example, you can measure the period (in TIMx\_CCR1 register) and the duty cycle (in TIMx\_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on CK\_INT frequency and prescaler value):

- Select the active input for TIMx\_CCR1: write the CC1S bits to 01 in the TIMx\_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP1 (used both for capture in TIMx\_CCR1 and counter clear): write the CC1P bit to '0' (active on rising edge).
- Select the active input for TIMx\_CCR2: write the CC2S bits to 10 in the TIMx\_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP2 (used for capture in TIMx\_CCR2): write the CC2P bit to '1' (active on falling edge).
- Select the valid trigger input: write the TS bits to 101 in the TIMx\_SMCR register (TI1FP1 selected).
- Configure the slave mode controller in reset mode: write the SMS bits to 100 in the TIMx\_SMCR register.
- Enable the captures: write the CC1E and CC2E bits to '1' in the TIMx\_CCER register.

Figure 172. PWM input mode timing



1. The PWM input mode can be used only with the TIMx\_CH1/TIMx\_CH2 signals due to the fact that only TI1FP1 and TI2FP2 are connected to the slave mode controller.

### 18.4.8 Forced output mode

In output mode (CCxS bits = 00 in the TIMx\_CCMRx register), each output compare signal (OCxREF and then OCx/OCxN) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (OCXREF/OCx) to its active level, you just need to write 101 in the OCxM bits in the corresponding TIMx\_CCMRx register. Thus OCXREF is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

For example: CCxP=0 (OCx active high) => OCx is forced to high level.

The OCxREF signal can be forced low by writing the OCxM bits to 100 in the TIMx\_CCMRx register.

Anyway, the comparison between the TIMx\_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt and DMA requests can be sent accordingly. This is described in the output compare mode section below.

### 18.4.9 Output compare mode

This function is used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

- Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx\_CCMRx register) and the output polarity (CCxP bit in the TIMx\_CCER register). The output pin can keep its level (OCXM=000), be set active (OCxM=001), be set inactive (OCxM=010) or can toggle (OCxM=011) on match.
- Sets a flag in the interrupt status register (CCxIF bit in the TIMx\_SR register).
- Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx\_DIER register).
- Sends a DMA request if the corresponding enable bit is set (CCxDE bit in the TIMx\_DIER register, CCDS bit in the TIMx\_CR2 register for the DMA request selection).

The TIMx\_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx\_CCMRx register.

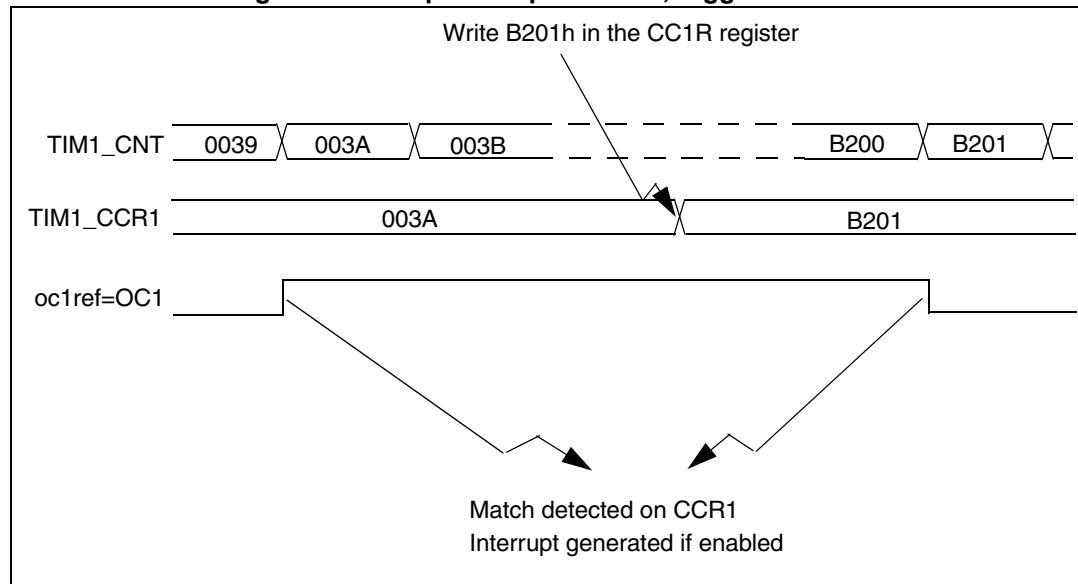
In output compare mode, the update event UEV has no effect on OCxREF and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One-pulse mode).

**Procedure:**

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx\_ARR and TIMx\_CCRx registers.
3. Set the CCxIE bit if an interrupt request is to be generated.
4. Select the output mode. For example:
  - Write OCxM = 011 to toggle OCx output pin when CNT matches CCRx
  - Write OCxPE = 0 to disable preload register
  - Write CCxP = 0 to select active high polarity
  - Write CCxE = 1 to enable the output
5. Enable the counter by setting the CEN bit in the TIMx\_CR1 register.

The TIMx\_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE='0', else TIMx\_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 152](#).

**Figure 173. Output compare mode, toggle on OC1.**



#### 18.4.10 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx\_ARR register and a duty cycle determined by the value of the TIMx\_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing '110' (PWM mode 1) or '111' (PWM mode 2) in the OCxM bits in the TIMx\_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx\_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx\_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx\_EGR register.

OCx polarity is software programmable using the CCxP bit in the TIMx\_CCER register. It can be programmed as active high or active low. OCx output is enabled by a combination of the CCxE, CCxNE, MOE, OSS1 and OSSR bits (TIMx\_CCER and TIMx\_BDTR registers). Refer to the TIMx\_CCER register description for more details.

In PWM mode (1 or 2), TIMx\_CNT and TIMx\_CCRx are always compared to determine whether  $\text{TIMx\_CCRx} \leq \text{TIMx\_CNT}$  or  $\text{TIMx\_CNT} \leq \text{TIMx\_CCRx}$  (depending on the direction of the counter).

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIMx\_CR1 register.

### PWM edge-aligned mode

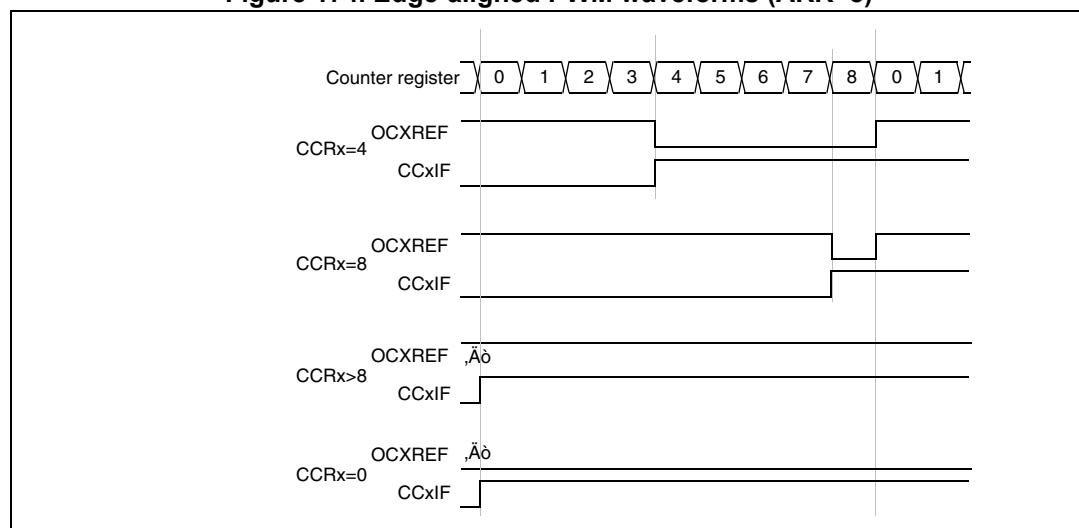
- Upcounting configuration

Upcounting is active when the DIR bit in the TIMx\_CR1 register is low. Refer to the [Upcounting mode on page 363](#).

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as  $\text{TIMx\_CNT} < \text{TIMx\_CCRx}$  else it becomes low. If the compare value in TIMx\_CCRx is greater than the auto-reload value (in TIMx\_ARR) then OCxREF is held at '1'. If the compare value is 0 then OCxRef is held at '0'.

[Figure 153](#) shows some edge-aligned PWM waveforms in an example where TIMx\_ARR=8.

**Figure 174. Edge-aligned PWM waveforms (ARR=8)**



- Downcounting configuration

Downcounting is active when DIR bit in TIMx\_CR1 register is high. Refer to the [Repetition counter on page 390](#).

In PWM mode 1, the reference signal OCxRef is low as long as  $\text{TIMx\_CNT} > \text{TIMx\_CCRx}$  else it becomes high. If the compare value in TIMx\_CCRx is greater than the auto-reload value in TIMx\_ARR, then OCxREF is held at '1'. 0% PWM is not possible in this mode.

### 18.4.11 Complementary outputs and dead-time insertion

The TIM15/16/17 general-purpose timers can output one complementary signal and manage the switching-off and switching-on of the outputs.

This time is generally known as dead-time and you have to adjust it depending on the devices you have connected to the outputs and their characteristics (intrinsic delays of level-shifters, delays due to power switches...)

You can select the polarity of the outputs (main output OC<sub>x</sub> or complementary OC<sub>xN</sub>) independently for each output. This is done by writing to the CC<sub>xP</sub> and CC<sub>xNP</sub> bits in the TIM<sub>x</sub>\_CCER register.

The complementary signals OC<sub>x</sub> and OC<sub>xN</sub> are activated by a combination of several control bits: the CC<sub>xE</sub> and CC<sub>xNE</sub> bits in the TIM<sub>x</sub>\_CCER register and the MOE, OIS<sub>x</sub>, OIS<sub>xN</sub>, OSSI and OSSR bits in the TIM<sub>x</sub>\_BDTR and TIM<sub>x</sub>\_CR2 registers. Refer to [Table 53: Output control bits for complementary OC<sub>x</sub> and OC<sub>xN</sub> channels with break feature on page 422](#) for more details. In particular, the dead-time is activated when switching to the IDLE state (MOE falling down to 0).

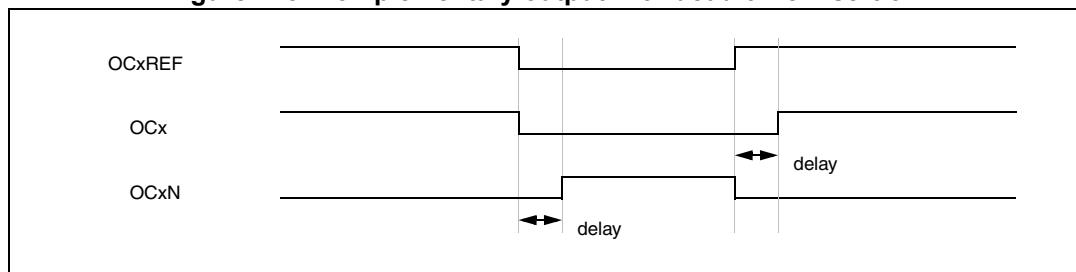
Dead-time insertion is enabled by setting both CC<sub>xE</sub> and CC<sub>xNE</sub> bits, and the MOE bit if the break circuit is present. There is one 10-bit dead-time generator for each channel. From a reference waveform OC<sub>xREF</sub>, it generates 2 outputs OC<sub>x</sub> and OC<sub>xN</sub>. If OC<sub>x</sub> and OC<sub>xN</sub> are active high:

- The OC<sub>x</sub> output signal is the same as the reference signal except for the rising edge, which is delayed relative to the reference rising edge.
- The OC<sub>xN</sub> output signal is the opposite of the reference signal except for the rising edge, which is delayed relative to the reference falling edge.

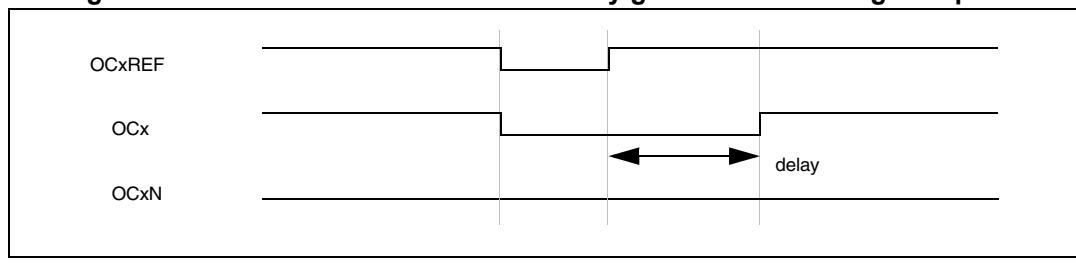
If the delay is greater than the width of the active output (OC<sub>x</sub> or OC<sub>xN</sub>) then the corresponding pulse is not generated.

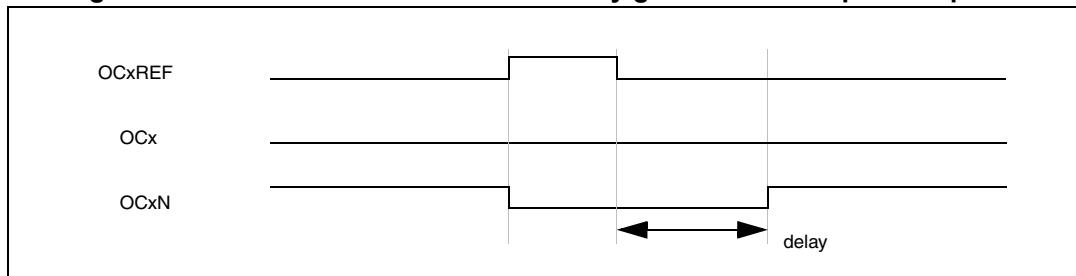
The following figures show the relationships between the output signals of the dead-time generator and the reference signal OC<sub>xREF</sub>. (we suppose CC<sub>xP</sub>=0, CC<sub>xNP</sub>=0, MOE=1, CC<sub>xE</sub>=1 and CC<sub>xNE</sub>=1 in these examples)

**Figure 175. Complementary output with dead-time insertion.**



**Figure 176. Dead-time waveforms with delay greater than the negative pulse.**



**Figure 177. Dead-time waveforms with delay greater than the positive pulse.**

The dead-time delay is the same for each of the channels and is programmable with the DTG bits in the TIMx\_BDTR register. Refer to [Section 18.5.15: TIM15 break and dead-time register \(TIM15\\_BDTR\) on page 425](#) for delay calculation.

#### Re-directing OCxREF to OCx or OCxN

In output mode (forced, output compare or PWM), OCxREF can be re-directed to the OCx output or to OCxN output by configuring the CCxE and CCxNE bits in the TIMx\_CCER register.

This allows you to send a specific waveform (such as PWM or static active level) on one output while the complementary remains at its inactive level. Other alternative possibilities are to have both outputs at inactive level or both outputs active and complementary with dead-time.

**Note:** When only OCxN is enabled (CCxE=0, CCxNE=1), it is not complemented and becomes active as soon as OCxREF is high. For example, if CCxNP=0 then OCxN=OCxRef. On the other hand, when both OCx and OCxN are enabled (CCxE=CCxNE=1) OCx becomes active when OCxREF is high whereas OCxN is complemented and becomes active when OCxREF is low.

#### 18.4.12 Using the break function

When using the break function, the output enable signals and inactive levels are modified according to additional control bits (MOE, OSS1 and OSSR bits in the TIMx\_BDTR register, OISx and OISxN bits in the TIMx\_CR2 register). In any case, the OCx and OCxN outputs cannot be set both to active level at a given time. Refer to [Table 53: Output control bits for complementary OCx and OCxN channels with break feature on page 422](#) for more details.

The break source can be either the break input pin or a clock failure event, generated by the Clock Security System (CSS), from the Reset Clock Controller. For further information on the Clock Security System, refer to [Section 7.2.7: Clock security system \(CSS\)](#).

When exiting from reset, the break circuit is disabled and the MOE bit is low. You can enable the break function by setting the BKE bit in the TIMx\_BDTR register. The break input polarity can be selected by configuring the BKP bit in the same register. BKE and BKP can be modified at the same time. When the BKE and BKP bits are written, a delay of 1 APB clock cycle is applied before the writing is effective. Consequently, it is necessary to wait 1 APB clock period to correctly read back the bit after the write operation.

Because MOE falling edge can be asynchronous, a resynchronization circuit has been inserted between the actual signal (acting on the outputs) and the synchronous control bit (accessed in the TIMx\_BDTR register). It results in some delays between the asynchronous and the synchronous signals. In particular, if you write MOE to 1 whereas it was low, you must insert a delay (dummy instruction) before reading it correctly. This is because you write the asynchronous signal and read the synchronous signal.

When a break occurs (selected level on the break input):

- The MOE bit is cleared asynchronously, putting the outputs in inactive state, idle state or in reset state (selected by the OSS1 bit). This feature functions even if the MCU oscillator is off.
- Each output channel is driven with the level programmed in the OISx bit in the TIMx\_CR2 register as soon as MOE=0. If OSS1=0 then the timer releases the enable output else the enable output remains high.
- When complementary outputs are used:
  - The outputs are first put in reset state inactive state (depending on the polarity). This is done asynchronously so that it works even if no clock is provided to the timer.
  - If the timer clock is still present, then the dead-time generator is reactivated in order to drive the outputs with the level programmed in the OISx and OISxN bits after a dead-time. Even in this case, OCx and OCxN cannot be driven to their active level together. Note that because of the resynchronization on MOE, the dead-time duration is a bit longer than usual (around 2 ck\_tim clock cycles).
  - If OSS1=0 then the timer releases the enable outputs else the enable outputs remain or become high as soon as one of the CCxE or CCxNE bits is high.
- The break status flag (BIF bit in the TIMx\_SR register) is set. An interrupt can be generated if the BIE bit in the TIMx\_DIER register is set. A DMA request can be sent if the BDE bit in the TIMx\_DIER register is set.
- If the AOE bit in the TIMx\_BDTR register is set, the MOE bit is automatically set again at the next update event UEV. This can be used to perform a regulation, for instance. Else, MOE remains low until you write it to '1' again. In this case, it can be used for security and you can connect the break input to an alarm from power drivers, thermal sensors or any security components.

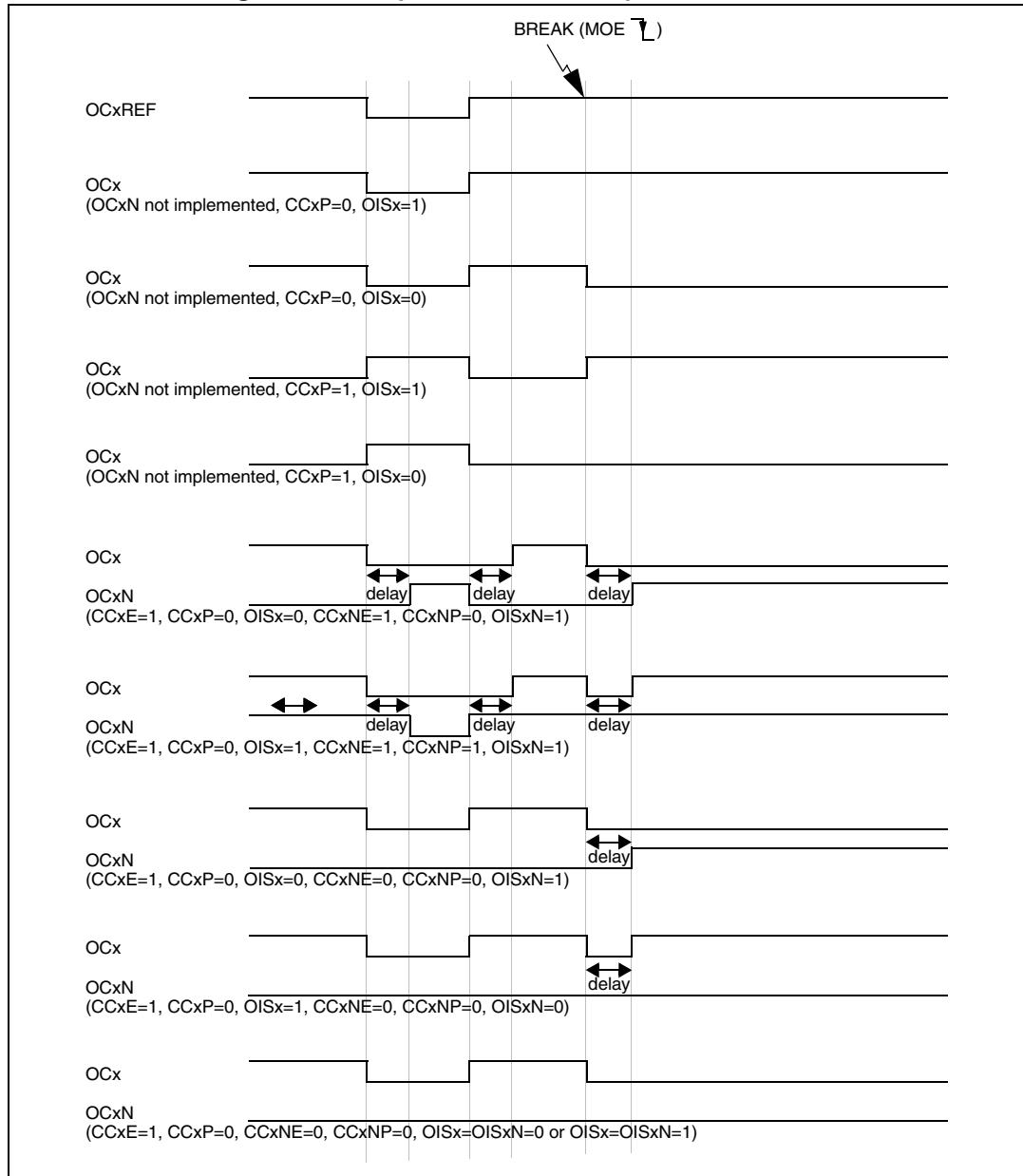
**Note:** *The break inputs is acting on level. Thus, the MOE cannot be set while the break input is active (neither automatically nor by software). In the meantime, the status flag BIF cannot be cleared.*

The break can be generated by the BRK input which has a programmable polarity and an enable bit BKE in the TIMx\_BDTR Register.

In addition to the break input and the output management, a write protection has been implemented inside the break circuit to safeguard the application. It allows you to freeze the configuration of several parameters (dead-time duration, OCx/OCxN polarities and state when disabled, OCxM configurations, break enable and polarity). You can choose from 3 levels of protection selected by the LOCK bits in the TIMx\_BDTR register. Refer to [Section 18.5.15: TIM15 break and dead-time register \(TIM15\\_BDTR\) on page 425](#). The LOCK bits can be written only once after an MCU reset.

The [Figure 178](#) shows an example of behavior of the outputs in response to a break.

Figure 178. Output behavior in response to a break



### 18.4.13 One-pulse mode

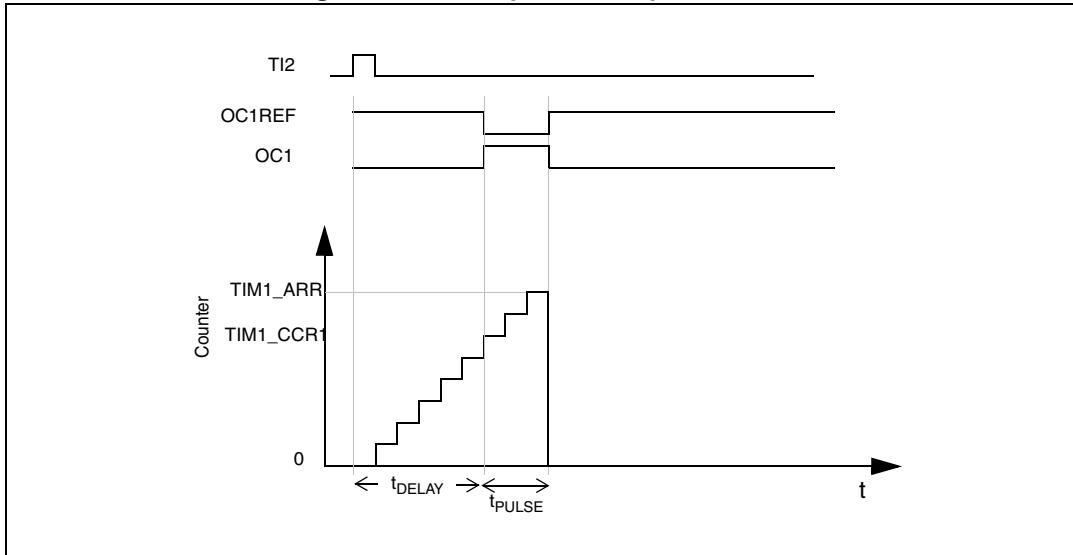
One-pulse mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

Starting the counter can be controlled through the slave mode controller. Generating the waveform can be done in output compare mode or PWM mode. You select One-pulse mode by setting the OPM bit in the TIMx\_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

- In upcounting: CNT < CCRx  $\leq$  ARR (in particular, 0 < CCRx)
- In downcounting: CNT > CCRx

**Figure 179. Example of One-pulse mode**



For example you may want to generate a positive pulse on OC1 with a length of  $t_{PULSE}$  and after a delay of  $t_{DELAY}$  as soon as a positive edge is detected on the TI2 input pin.

Let's use TI2FP2 as trigger 1:

- Map TI2FP2 to TI2 by writing CC2S='01' in the TIMx\_CCMR1 register.
- TI2FP2 must detect a rising edge, write CC2P='0' in the TIMx\_CCER register.
- Configure TI2FP2 as trigger for the slave mode controller (TRGI) by writing TS='110' in the TIMx\_SMCR register.
- TI2FP2 is used to start the counter by writing SMS to '110' in the TIMx\_SMCR register (trigger mode).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The  $t_{DELAY}$  is defined by the value written in the TIMx\_CCR1 register.
- The  $t_{PULSE}$  is defined by the difference between the auto-reload value and the compare value (TIMx\_ARR - TIMx\_CCR1).
- Let's say you want to build a waveform with a transition from '0' to '1' when a compare match occurs and a transition from '1' to '0' when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC1M=111 in the TIMx\_CCMR1 register. You can optionally enable the preload registers by writing OC1PE='1' in the TIMx\_CCMR1 register and ARPE in the TIMx\_CR1 register. In this case you have to write the compare value in the TIMx\_CCR1 register, the auto-reload value in the TIMx\_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0' in this example.

In our example, the DIR and CMS bits in the TIMx\_CR1 register should be low.

You only want 1 pulse, so you write '1' in the OPM bit in the TIMx\_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0).

#### Particular case: OCx fast enable

In One-pulse mode, the edge detection on TIx input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay  $t_{DELAY}$  min we can get.

If you want to output a waveform with the minimum delay, you can set the OCxFE bit in the TIMx\_CCMRx register. Then OCxRef (and OCx) are forced in response to the stimulus, without taking in account the comparison. Its new level is the same as if a compare match had occurred. OCxFE acts only if the channel is configured in PWM1 or PWM2 mode.

### 18.4.14 TIM15 external trigger synchronization

This section applies to medium-density devices only.

The TIM15 timer can be synchronized with an external trigger in several modes: Reset mode, Gated mode and Trigger mode.

#### Slave mode: Reset mode

The counter and its prescaler can be reinitialized in response to an event on a trigger input. Moreover, if the URS bit from the TIMx\_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIMx\_ARR, TIMx\_CCRx) are updated.

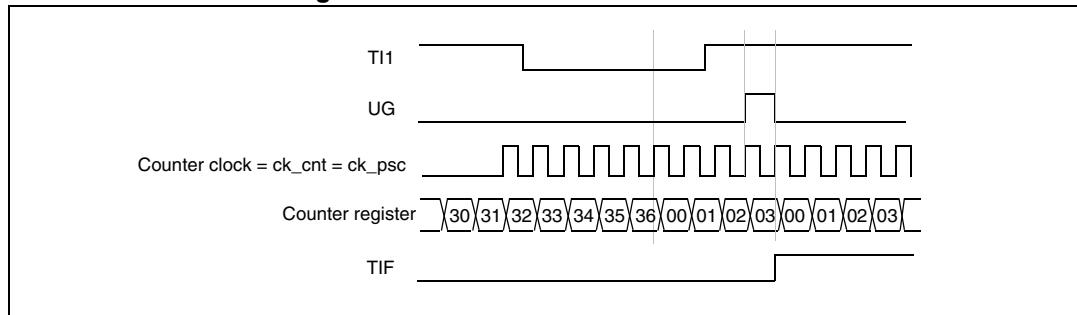
In the following example, the upcounter is cleared in response to a rising edge on TI1 input:

- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S = 01 in the TIMx\_CCMR1 register. Write CC1P=0 in TIMx\_CCER register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.
- Start the counter by writing CEN=1 in the TIMx\_CR1 register.

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIMx\_SR register) and an interrupt request, or a DMA request can be sent if enabled (depending on the TIE and TDE bits in TIMx\_DIER register).

The following figure shows this behavior when the auto-reload register TIMx\_ARR=0x36. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

**Figure 180. Control circuit in reset mode**



### Slave mode: Gated mode

The counter can be enabled depending on the level of a selected input.

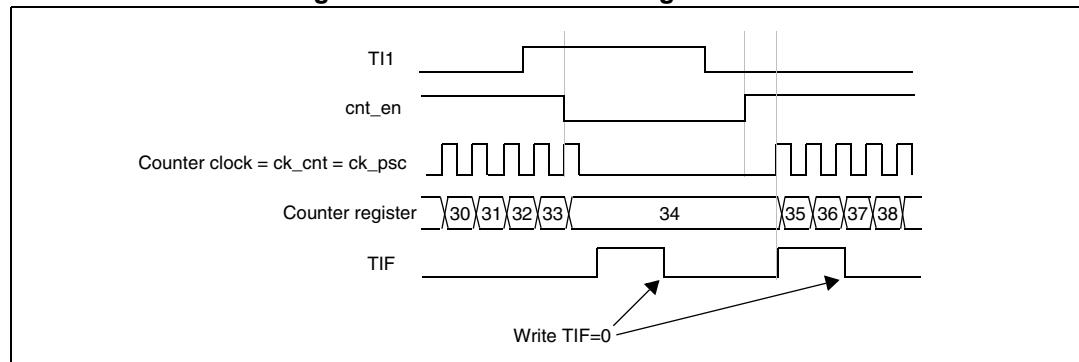
In the following example, the upcounter counts only when TI1 input is low:

- Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S=01 in TIMx\_CCMR1 register. Write CC1P=1 in TIMx\_CCER register to validate the polarity (and detect low level only).
- Configure the timer in gated mode by writing SMS=101 in TIMx\_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx\_SMCR register.
- Enable the counter by writing CEN=1 in the TIMx\_CR1 register (in gated mode, the counter doesn't start if CEN=0, whatever is the trigger input level).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag in the TIMx\_SR register is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual stop of the counter is due to the resynchronization circuit on TI1 input.

**Figure 181. Control circuit in gated mode**



### Slave mode: Trigger mode

The counter can start in response to an event on a selected input.

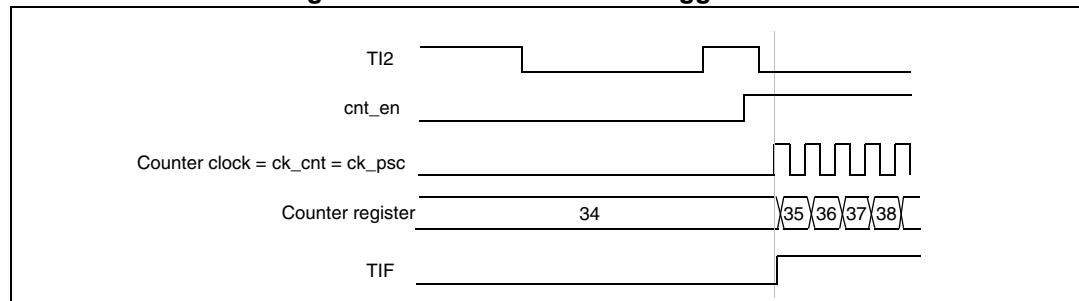
In the following example, the upcounter starts in response to a rising edge on TI2 input:

- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep IC2F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC2S bits are configured to select the input capture source only, CC2S=01 in TIMx\_CCMR1 register. Write CC2P=1 in TIMx\_CCER register to validate the polarity (and detect low level only).
- Configure the timer in trigger mode by writing SMS=110 in TIMx\_SMCR register. Select TI2 as the input source by writing TS=110 in TIMx\_SMCR register.

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual start of the counter is due to the resynchronization circuit on TI2 input.

**Figure 182. Control circuit in trigger mode**



The TIM timers are linked together internally for timer synchronization or chaining. Refer to [Section 16.3.15: Timer synchronization on page 331](#) for details.

#### 18.4.15 Timer synchronization (TIM15)

This section applies to medium-density devices only.

The TIM timers are linked together internally for timer synchronization or chaining. Refer to [Section 13.3.15: Timer synchronization on page 308](#) for details.

#### 18.4.16 Debug mode

When the microcontroller enters debug mode (Cortex<sup>TM</sup>-M0 core halted), the TIMx counter either continues to work normally or stops, depending on DBG\_TIMx\_STOP configuration bit in DBG module. .

## 18.5 TIM15 registers

This section applies to medium-density devices only.

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 18.5.1 TIM15 control register 1 (TIM15\_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN

Bits 15:10 Reserved, always read as 0.

Bits 9:8 **CKD[1:0]**: Clock division

This bitfield indicates the division ratio between the timer clock (CK\_INT) frequency and the dead-time and sampling clock ( $t_{DTS}$ ) used by the dead-time generators and the digital filters (Tlx)

00:  $t_{DTS} = t_{CK\_INT}$

01:  $t_{DTS} = 2*t_{CK\_INT}$

10:  $t_{DTS} = 4*t_{CK\_INT}$

11: Reserved, do not program this value

Bit 7 **ARPE**: Auto-reload preload enable

0: TIMx\_ARR register is not buffered

1: TIMx\_ARR register is buffered

Bits 6:4 Reserved, always read as 0.

Bit 3 **OPM**: One-pulse mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the bit CEN)

**Bit 2 URS:** Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt if enabled. These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt if enabled

**Bit 1 UDIS:** Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

**Bit 0 CEN:** Counter enable

0: Counter disabled

1: Counter enabled

*Note: External clock and gated mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.*

### 18.5.2 TIM15 control register 2 (TIM15\_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	OIS2	OIS1N	OIS1	Res.	MMS[2:0]	CCDS	CCUS	Res.	CCPC		

Bit 15:11 Reserved, always read as 0.

**Bit 10 OIS2:** Output idle state 2 (OC2 output)

0: OC2=0 when MOE=0

1: OC2=1 when MOE=0

*Note: This bit cannot be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in the TIMx\_BKR register).*

**Bit 9 OIS1N:** Output Idle state 1 (OC1N output)

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

*Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BKR register).*

Bit 8 **OIS1**: Output Idle state 1 (OC1 output)

- 0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0
- 1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

*Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BKR register).*

Bit 7 Reserved, always read as 0.

Bits 6:4 **MMS[1:0]**: Master mode selection

These bits allow to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx\_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter Enable signal CNT\_EN is used as trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enable. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIMx\_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

011: **Compare Pulse** - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred. (TRGO).

100: **Compare** - OC1REF signal is used as trigger output (TRGO).

101: **Compare** - OC2REF signal is used as trigger output (TRGO).

Bit 3 **CCDS**: Capture/compare DMA selection

- 0: CCx DMA request sent when CCx event occurs
- 1: CCx DMA requests sent when update event occurs

Bit 2 **CCUS**: Capture/compare control update selection

0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit only.

1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI.

*Note: This bit acts only on channels that have a complementary output.*

Bit 1 Reserved, always read as 0.

Bit 0 **CCPC**: Capture/compare preloaded control

- 0: CCxE, CCxNE and OCxM bits are not preloaded
- 1: CCxE, CCxNE and OCxM bits are preloaded, after having been written, they are updated only when COM bit is set.

*Note: This bit acts only on channels that have a complementary output.*

### 18.5.3 TIM15 slave mode control register (TIM15\_SMCR)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MSM	TS[2:0]	Res.	TS[2:0]	Res.	TS[2:0]	Res.	TS[2:0]							

Bits 15:8 Reserved, always read as 0.

Bit 7 **MSM:** Master/slave mode

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between the current timer and its slaves (through TRGO). It is useful if we want to synchronize several timers on a single external event.

Bits 6:4 **TS[2:0]:** Trigger selection

This bitfield selects the trigger input to be used to synchronize the counter.

000: Internal Trigger 0 (ITR0)

001: Internal Trigger 1 (ITR1)

010: Internal Trigger 2 (ITR2)

011: Internal Trigger 3 (ITR3)

100: TI1 Edge Detector (TI1F\_ED)

101: Filtered Timer Input 1 (TI1FP1)

110: Filtered Timer Input 2 (TI2FP2)

See [Table 52: TIMx Internal trigger connection on page 413](#) for more details on ITRx meaning for each Timer.

*Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.*

Bit 3 Reserved, always read as 0.

Bits 2:0 **SMS:** Slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Slave mode disabled - if CEN = '1' then the prescaler is clocked directly by the internal clock.

001: Encoder mode 1 - Counter counts up/down on TI2FP2 edge depending on TI1FP1 level.

010: Encoder mode 2 - Counter counts up/down on TI1FP1 edge depending on TI2FP2 level.

011: Encoder mode 3 - Counter counts up/down on both TI1FP1 and TI2FP2 edges depending on the level of the other input.

100: Reset Mode - Rising edge of the selected trigger input (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger input (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

*Note: The gated mode must not be used if TI1F\_ED is selected as the trigger input (TS='100'). Indeed, TI1F\_ED outputs 1 pulse for each transition on TI1F, whereas the gated mode checks the level of the trigger signal.*

**Table 52. TIMx Internal trigger connection**

Slave TIM	ITR0 (TS = 000)	ITR1 (TS = 001)	ITR2 (TS = 010)	ITR3 (TS = 011)
TIM15	TIM2	TIM3	TIM16	TIM17

### 18.5.4 TIM15 DMA/interrupt enable register (TIM15\_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TDE	Res.	Res.	Res.	CC2DE	CC1DE	UDE	BIE	TIE	COMIE	Res.	Res.	CC2IE	CC1IE	UIE
	rw				rw	rw	rw	rw	rw	rw			rw	rw	rw

Bit 15 Reserved, always read as 0.

Bit 14 **TDE**: Trigger DMA request enable

- 0: Trigger DMA request disabled
- 1: Trigger DMA request enabled

Bits 13:11 Reserved, always read as 0.

Bit 10 **CC2DE**: Capture/Compare 2 DMA request enable

- 0: CC2 DMA request disabled
- 1: CC2 DMA request enabled

Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable

- 0: CC1 DMA request disabled
- 1: CC1 DMA request enabled

Bit 8 **UDE**: Update DMA request enable

- 0: Update DMA request disabled
- 1: Update DMA request enabled

Bit 7 **BIE**: Break interrupt enable

- 0: Break interrupt disabled
- 1: Break interrupt enabled

Bit 6 **TIE**: Trigger interrupt enable

- 0: Trigger interrupt disabled
- 1: Trigger interrupt enabled

Bit 5 **COMIE**: COM interrupt enable

- 0: COM interrupt disabled
- 1: COM interrupt enabled

Bits 4:3 Reserved, always read as 0.

Bit 2 **CC2IE**: Capture/Compare 2 interrupt enable

- 0: CC2 interrupt disabled
- 1: CC2 interrupt enabled

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

- 0: CC1 interrupt disabled
- 1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

- 0: Update interrupt disabled
- 1: Update interrupt enabled

### 18.5.5 TIM15 status register (TIM15\_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	CC2OF	CC1OF	Res.	BIF	TIF	COMIF	Res.	Res.	CC2IF	CC1IF	UIF

Bits 15:11 Reserved, always read as 0.

Bit 10 **CC2OF**: Capture/Compare 2 overcapture flag  
refer to CC1OF description

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

- 0: No overcapture has been detected
- 1: The counter value has been captured in TIMx\_CCR1 register while CC1IF flag was already set

Bit 8 Reserved, always read as 0.

Bit 7 **BIF**: Break interrupt flag

This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.

- 0: No break event occurred
- 1: An active level has been detected on the break input

Bit 6 **TIF**: Trigger interrupt flag

This flag is set by hardware on trigger event (active edge detected on TRGI input when the slave mode controller is enabled in all modes but gated mode, both edges in case gated mode is selected). It is cleared by software.

- 0: No trigger event occurred
- 1: Trigger interrupt pending

Bit 5 **COMIF**: COM interrupt flag

This flag is set by hardware on a COM event (once the capture/compare control bits –CCxE, CCxNE, OCxM– have been updated). It is cleared by software.

- 0: No COM event occurred
- 1: COM interrupt pending

Bits 5:3 Reserved, always read as 0.

Bit 2 **CC2IF**: Capture/Compare 2 interrupt flag  
refer to CC1IF description

Bit 1 **CC1IF**: Capture/Compare 1 interrupt flag

**If channel CC1 is configured as output:**

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx\_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIMx\_CNT matches the content of the TIMx\_CCR1 register. When the contents of TIMx\_CCR1 are greater than the contents of TIMx\_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

**If channel CC1 is configured as input:**

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx\_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx\_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

–At overflow regarding the repetition counter value (update if repetition counter = 0) and if the UDIS=0 in the TIMx\_CR1 register.

–When CNT is reinitialized by software using the UG bit in TIMx\_EGR register, if URS=0 and UDIS=0 in the TIMx\_CR1 register.

–When CNT is reinitialized by a trigger event (refer to [Section 18.5.3: TIM15 slave mode control register \(TIM15\\_SMCR\)](#)), if URS=0 and UDIS=0 in the TIMx\_CR1 register.

### 18.5.6 TIM15 event generation register (TIM15\_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	BG	TG	COMG	Res.	Res.	CC2G	CC1G	UG							

Bits 15:8 Reserved, always read as 0.

**Bit 7 BG:** Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A break event is generated. MOE bit is cleared and BIF flag is set. Related interrupt or DMA transfer can occur if enabled.

**Bit 6 TG:** Trigger generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: The TIF flag is set in TIMx\_SR register. Related interrupt or DMA transfer can occur if enabled

**Bit 5 COMG:** Capture/Compare control update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: When the CCPC bit is set, it is possible to update the CCxE, CCxNE and OCxM bits

*Note: This bit acts only on channels that have a complementary output.*

Bits 4:3 Reserved, always read as 0.

**Bit 2 CC2G:** Capture/Compare 2 generation

Refer to CC1G description

**Bit 1 CC1G:** Capture/Compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

**If channel CC1 is configured as output:**

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

**If channel CC1 is configured as input:**

The current value of the counter is captured in TIMx\_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

**Bit 0 UG:** Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Reinitialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx\_ARR) if DIR=1 (downcounting).

### 18.5.7 TIM15 capture/compare mode register 1 (TIM15\_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CC<sub>x</sub>S bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OC<sub>xx</sub> describes its function when the channel is configured in output, IC<sub>xx</sub> describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	OC2M[2:0]			OC2 PE	OC2 FE	CC2S[1:0]		Res.	OC1M[2:0]			OC1 PE	OC1 FE	CC1S[1:0]	
	IC2F[3:0]			IC2PSC[1:0]				IC1F[3:0]			IC1PSC[1:0]				
	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW

#### Output compare mode:

Bit 15 Reserved, always read as 0.

Bits 14:12 **OC2M[2:0]**: Output Compare 2 mode

Bit 11 **OC2PE**: Output Compare 2 preload enable

Bit 10 **OC2FE**: Output Compare 2 fast enable

Bits 9:8 **CC2S[1:0]**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2.

10: CC2 channel is configured as input, IC2 is mapped on TI1.

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through the TS bit (TIMx\_SMCR register)

*Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx\_CCER).*

Bit 7 Reserved, always read as 0.

Bits 6:4 **OC1M**: Output Compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

- 000: Frozen - The comparison between the output compare register TIMx\_CCR1 and the counter TIMx\_CNT has no effect on the outputs.
- 001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).
- 010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).
- 011: Toggle - OC1REF toggles when TIMx\_CNT=TIMx\_CCR1.
- 100: Force inactive level - OC1REF is forced low.
- 101: Force active level - OC1REF is forced high.
- 110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx\_CNT<TIMx\_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx\_CNT>TIMx\_CCR1 else active (OC1REF='1').
- 111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx\_CNT<TIMx\_CCR1 else active. In downcounting, channel 1 is active as long as TIMx\_CNT>TIMx\_CCR1 else inactive.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S='00' (the channel is configured in output).*

*2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from “frozen” mode to “PWM” mode.*

Bit 3 **OC1PE**: Output Compare 1 preload enable

- 0: Preload register on TIMx\_CCR1 disabled. TIMx\_CCR1 can be written at anytime, the new value is taken in account immediately.
- 1: Preload register on TIMx\_CCR1 enabled. Read/Write operations access the preload register. TIMx\_CCR1 preload value is loaded in the active register at each update event.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S='00' (the channel is configured in output).*

*2: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx\_CR1 register). Else the behavior is not guaranteed.*

Bit 2 **OC1FE**: Output Compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger input on the CC output.

- 0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.
- 1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently of the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OCFE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC1 channel is configured as output.
- 01: CC1 channel is configured as input, IC1 is mapped on TI1.
- 10: CC1 channel is configured as input, IC1 is mapped on TI2.
- 11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx\_CCER).*

## Input capture mode

Bits 15:12 **IC2F**: Input capture 2 filter

Bits 11:10 **IC2PSC[1:0]**: Input capture 2 prescaler

Bits 9:8 **CC2S**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC2 channel is configured as output
- 01: CC2 channel is configured as input, IC2 is mapped on TI2
- 10: CC2 channel is configured as input, IC2 is mapped on TI1
- 11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx\_CCER).*

Bits 7:4 **IC1F[3:0]**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, sampling is done at  $f_{DTS}$
- 0001:  $f_{SAMPLING} = f_{CK\_INT}$ , N=2
- 0010:  $f_{SAMPLING} = f_{CK\_INT}$ , N=4
- 0011:  $f_{SAMPLING} = f_{CK\_INT}$ , N=8
- 0100:  $f_{SAMPLING} = f_{DTS}/2$ , N=6
- 0101:  $f_{SAMPLING} = f_{DTS}/2$ , N=8
- 0110:  $f_{SAMPLING} = f_{DTS}/4$ , N=6
- 0111:  $f_{SAMPLING} = f_{DTS}/4$ , N=8
- 1000:  $f_{SAMPLING} = f_{DTS}/8$ , N=6
- 1001:  $f_{SAMPLING} = f_{DTS}/8$ , N=8
- 1010:  $f_{SAMPLING} = f_{DTS}/16$ , N=5
- 1011:  $f_{SAMPLING} = f_{DTS}/16$ , N=6
- 1100:  $f_{SAMPLING} = f_{DTS}/16$ , N=8
- 1101:  $f_{SAMPLING} = f_{DTS}/32$ , N=5
- 1110:  $f_{SAMPLING} = f_{DTS}/32$ , N=6
- 1111:  $f_{SAMPLING} = f_{DTS}/32$ , N=8

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as CC1E='0' (TIMx\_CCER register).

- 00: no prescaler, capture is done each time an edge is detected on the capture input
- 01: capture is done once every 2 events
- 10: capture is done once every 4 events
- 11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC1 channel is configured as output
- 01: CC1 channel is configured as input, IC1 is mapped on TI1
- 10: CC1 channel is configured as input, IC1 is mapped on TI2
- 11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx\_CCER).*

### 18.5.8 TIM15 capture/compare enable register (TIM15\_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	CC1NP	Res.	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E							

Bits 15:8 Reserved, always read as 0.

Bit 7 **CC2NP**: Capture/Compare 2 complementary output polarity  
refer to CC1NP description

Bit 6 Reserved, always read as 0.

Bit 5 **CC2P**: Capture/Compare 2 output polarity  
Refer to CC1P description

Bit 4 **CC2E**: Capture/Compare 2 output enable  
Refer to CC1E description

Bit 3 **CC1NP**: Capture/Compare 1 complementary output polarity  
0: OC1N active high  
1: OC1N active low

*Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S="00" (the channel is configured in output).*

Bit 2 **CC1NE**: Capture/Compare 1 complementary output enable

0: Off - OC1N is not active. OC1N level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

Bit 1 **CC1P**: Capture/Compare 1 output polarity

**CC1 channel configured as output:**

0: OC1 active high

1: OC1 active low

**CC1 channel configured as input:**

The CC1NP/CC1P bits select the polarity of TI1FP1 and TI2FP1 for trigger or capture operations.

00: noninverted/rising edge: circuit is sensitive to TIxFP1's rising edge (capture, trigger in reset or trigger mode), TIxFP1 is not inverted (trigger in gated mode).

01: inverted/falling edge: circuit is sensitive to TIxFP1's falling edge (capture, trigger in reset, or trigger mode), TIxFP1 is inverted (trigger in gated mode).

10: reserved, do not use this configuration.

11: noninverted/both edges: circuit is sensitive to both the rising and falling edges of TIxFP1 (capture, trigger in reset or trigger mode), TIxFP1 is not inverted (trigger in gated mode).

*Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register)..*

Bit 0 **CC1E**: Capture/Compare 1 output enable

**CC1 channel configured as output:**

0: Off - OC1 is not active. OC1 level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

**CC1 channel configured as input:**

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx\_CCR1) or not.

0: Capture disabled

1: Capture enabled

**Table 53. Output control bits for complementary OCx and OCxN channels with break feature**

Control bits						Output states <sup>(1)</sup>			
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state			
1	X	0	0	0	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0			
		0	0	1	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1			
		0	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0			
		0	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1			
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0			
		1	0	1	Off-State (output enabled with inactive state) OCx=CCxP, OCx_EN=1	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1			
		1	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Off-State (output enabled with inactive state) OCxN=CCxNP, OCxN_EN=1			
		1	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1			
0	X	0	0	0	Output Disabled (not driven by the timer)				
		0	0	1	Asynchronously: OCx=CCxP, OCx_EN=0, OCxN=CCxNP, OCxN_EN=0				
		0	1	0	Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state.				
		0	1	1					
		1	0	0					
		1	0	1	Off-State (output enabled with inactive state)				
		1	1	0	Asynchronously: OCx=CCxP, OCx_EN=1, OCxN=CCxNP, OCxN_EN=1				
		1	1	1	Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state				

1. When both outputs of a channel are not used (CCxE = CCxNE = 0), the OISx, OISxN, CCxP and CCxNP bits must be kept cleared.

**Note:** The state of the external I/O pins connected to the complementary OCx and OCxN channels depends on the OCx and OCxN channel state and the GPIO and AFIO registers.

### 18.5.9 TIM15 counter (TIM15\_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Counter value

### 18.5.10 TIM15 prescaler (TIM15\_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency ( $f_{CK\_CNT}$ ) is equal to  $f_{CK\_PSC} / (PSC[15:0] + 1)$ .

PSC contains the value to be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx\_EGR register or through trigger controller when configured in “reset mode”).

### 18.5.11 TIM15 auto-reload register (TIM15\_ARR)

Address offset: 0x2C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 17.3.1: Time-base unit on page 361](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

### 18.5.12 TIM15 repetition counter register (TIM15\_RCR)

Address offset: 0x30

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0						
Res.	REP[7:0]																				
								rw	rw	rw	rw	rw	rw	rw	rw						

Bits 15:8 Reserved, always read as 0.

Bits 7:0 **REP[7:0]**: Repetition counter value

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to active registers) when preload registers are enable, as well as the update interrupt generation rate, if this interrupt is enable.

Each time the REP\_CNT related downcounter reaches zero, an update event is generated and it restarts counting from REP value. As REP\_CNT is reloaded with REP value only at the repetition update event U\_RC, any write to the TIMx\_RCR register is not taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to the number of PWM periods in edge-aligned mode.

### 18.5.13 TIM15 capture/compare register 1 (TIM15\_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

**If channel CC1 is configured as output:**

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signaled on OC1 output.

**If channel CC1 is configured as input:**

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

### 18.5.14 TIM15 capture/compare register 2 (TIM15\_CCR2)

Address offset: 0x38

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR2[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR2[15:0]**: Capture/Compare 2 value

**If channel CC2 is configured as output:**

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signalled on OC2 output.

**If channel CC2 is configured as input:**

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

### 18.5.15 TIM15 break and dead-time register (TIM15\_BDTR)

Address offset: 0x44

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DTG[7:0]															
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK[1:0]		rw							

**Note:** As the bits AOE, BKP, BKE, OSSR and DTG[7:0] can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIMx\_BDTR register.

**Bit 15 MOE:** Main output enable

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state

1: OC and OCN outputs are enabled if their respective enable bits are set (CCxE, CCxNE in TIMx\_CCER register)

See OC/OCN enable description for more details ([Section 18.5.8: TIM15 capture/compare enable register \(TIM15\\_CCER\) on page 420](#)).

**Bit 14 AOE:** Automatic output enable

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not active)

*Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).*

**Bit 13 BKP:** Break polarity

0: Break input BRK is active low

1: Break input BRK is active high

*Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).*

*Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.*

**Bit 12 BKE:** Break enable

0: Break inputs (BRK and CCS clock failure event) disabled

1: Break inputs (BRK and CCS clock failure event) enabled

*Note: This bit cannot be modified when LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).*

*Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.*

**Bit 11 OSSR:** Off-state selection for Run mode

This bit is used when MOE=1 on channels having a complementary output which are configured as outputs. OSSR is not implemented if no complementary output is implemented in the timer.

See OC/OCN enable description for more details ([Section 18.5.8: TIM15 capture/compare enable register \(TIM15\\_CCER\) on page 420](#)).

0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)

1: When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCxE=1 or CCxNE=1. Then, OC/OCN enable output signal=1

*Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bit 10 **OSSI**: Off-state selection for Idle mode

This bit is used when MOE=0 on channels configured as outputs.

See OC/OCN enable description for more details ([Section 18.5.8: TIM15 capture/compare enable register \(TIM15\\_CCER\) on page 420](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)
- 1: When inactive, OC/OCN outputs are forced first with their idle level as soon as CCxE=1 or CCxNE=1. OC/OCN enable output signal=1)

*Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx\_BDTR register).*

Bits 9:8 **LOCK[1:0]**: Lock configuration

These bits offer a write protection against software errors.

- 00: LOCK OFF - No bit is write protected
- 01: LOCK Level 1 = DTG bits in TIMx\_BDTR register, OISx and OISxN bits in TIMx\_CR2 register and BKE/BKP/AOE bits in TIMx\_BDTR register can no longer be written
- 10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CCxP/CCxNP bits in TIMx\_CCER register, as long as the related channel is configured in output through the CCxS bits) as well as OSSR and OSSI bits can no longer be written.
- 11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OCxM and OCxPE bits in TIMx\_CCMRx registers, as long as the related channel is configured in output through the CCxS bits) can no longer be written.

*Note: The LOCK bits can be written only once after the reset. Once the TIMx\_BDTR register has been written, their content is frozen until the next reset.*

Bits 7:0 **DTG[7:0]**: Dead-time generator setup

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT correspond to this duration.

- DTG[7:5]=0xx => DT=DTG[7:0]x t<sub>dtg</sub> with t<sub>dtg</sub>=t<sub>DTS</sub>
- DTG[7:5]=10x => DT=(64+DTG[5:0])x t<sub>dtg</sub> with T<sub>dtg</sub>=2x t<sub>DTS</sub>
- DTG[7:5]=110 => DT=(32+DTG[4:0])x t<sub>dtg</sub> with T<sub>dtg</sub>=8x t<sub>DTS</sub>
- DTG[7:5]=111 => DT=(32+DTG[4:0])x t<sub>dtg</sub> with T<sub>dtg</sub>=16x t<sub>DTS</sub>

Example if T<sub>DTS</sub>=125ns (8MHz), dead-time possible values are:

- 0 to 15875 ns by 125 ns steps,
- 16 µs to 31750 ns by 250 ns steps,
- 32 µs to 63 µs by 1 µs steps,
- 64 µs to 126 µs by 2 µs steps

*Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register).*

### 18.5.16 TIM15 DMA control register (TIM15\_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	Res.	DBA[4:0]				
			rw	rw	rw	rw					rw	rw	rw	rw	rw

Bits 15:13 Reserved, always read as 0.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the length of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx\_DMAR address).

00000: 1 transfer,

00001: 2 transfers,

00010: 3 transfers,

...

10001: 18 transfers.

Bits 7:5 Reserved, always read as 0.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bits vector defines the base-address for DMA transfers (when read/write access are done through the TIMx\_DMAR address). DBA is defined as an offset starting from the address of the TIMx\_CR1 register.

Example:

00000: TIMx\_CR1,

00001: TIMx\_CR2,

00010: TIMx\_SMCR,

...

### 18.5.17 TIM15 DMA address for full transfer (TIM15\_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write operation to the DMAR register accesses the register located at the address (TIMx\_CR1 address) + (DBA + DMA index) × 4

where TIMx\_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx\_DCR register, DMA index is automatically controlled by the DMA transfer, and ranges from 0 to DBL (DBL configured in TIMx\_DCR).

### 18.5.18 TIM15 register map

TIM15 registers are mapped as 16-bit addressable registers as described in the table below:

**Table 54. TIM15 register map and reset values**

Offset	Register	Reset value	31
0x00	<b>TIM15_CR1</b>		
0x04	<b>TIM15_CR2</b>		
0x08	<b>TIM15_SMCR</b>		
0x0C	<b>TIM15_DIER</b>		
0x10	<b>TIM15_SR</b>		
0x14	<b>TIM15_EGR</b>		
0x18	<b>TIM15_CCMR1</b> Output compare mode		
	Reset value		
	<b>TIM15_CCMR1</b> Input capture mode		
	Reset value		
0x20	<b>TIM15_CCER</b>		
	Reset value		
0x24	<b>TIM15_CNT</b>		CNT[15:0]
	Reset value		
0x28	<b>TIM15_PSC</b>		PSC[15:0]
	Reset value		
0x2C	<b>TIM15_ARR</b>		ARR[15:0]
	Reset value		
0x30	<b>TIM15_RCR</b>		REP[7:0]
	Reset value		
0x34	<b>TIM15_CCR1</b>		CCR1[15:0]
	Reset value		

**Table 54. TIM15 register map and reset values (continued)**

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x38	<b>TIM15_CCR2</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Reset value																																
0x44	<b>TIM15_BDTR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Reset value																																
0x48	<b>TIM15_DCR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Reset value																																
0x4C	<b>TIM15_DMAR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Reset value																																

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 18.6 TIM16 and TIM17 registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 18.6.1 TIM16 and TIM17 control register 1 (TIM16\_CR1 and TIM17\_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN

Bits 15:10 Reserved, always read as 0.

Bits 9:8 **CKD[1:0]**: Clock division

This bit-field indicates the division ratio between the timer clock (CK\_INT) frequency and the dead-time and sampling clock ( $t_{DTS}$ ) used by the dead-time generators and the digital filters (TIx),

- 00:  $t_{DTS}=t_{CK\_INT}$
- 01:  $t_{DTS}=2*t_{CK\_INT}$
- 10:  $t_{DTS}=4*t_{CK\_INT}$
- 11: Reserved, do not program this value

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIMx\_ARR register is not buffered
- 1: TIMx\_ARR register is buffered

Bits 6:4 Reserved, always read as 0.

Bit 3 **OPM**: One pulse mode

- 0: Counter is not stopped at update event
- 1: Counter stops counting at the next update event (clearing the bit CEN)

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt or DMA request if enabled.

These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 **CEN**: Counter enable

0: Counter disabled

1: Counter enabled

**18.6.2 TIM16 and TIM17 control register 2 (TIM16\_CR2 and TIM17\_CR2)**

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	OIS1N	OIS1	Res.	Res.	Res.	Res.	CCDS	CCUS	Res.	CCPC

Bits 15:10 Reserved, always read as 0.

Bit 9 **OIS1N**: Output Idle state 1 (OC1N output)

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

*Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BKR register).*

Bit 8 **OIS1**: Output Idle state 1 (OC1 output)

0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0

1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

*Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BKR register).*

Bits 7:4 Reserved, always read as 0.

Bit 3 **CCDS**: Capture/compare DMA selection

- 0: CCx DMA request sent when CCx event occurs
- 1: CCx DMA requests sent when update event occurs

Bit 2 **CCUS**: Capture/compare control update selection

- 0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit only.
- 1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI.

*Note: This bit acts only on channels that have a complementary output.*

Bit 1 Reserved, always read as 0.

Bit 0 **CCPC**: Capture/compare preloaded control

- 0: CCxE, CCxNE and OCxM bits are not preloaded
- 1: CCxE, CCxNE and OCxM bits are preloaded, after having been written, they are updated only when COM bit is set.

*Note: This bit acts only on channels that have a complementary output.*

### 18.6.3 TIM16 and TIM17 DMA/interrupt enable register (TIM16\_DIER and TIM17\_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CC1DE	UDE	BIE	Res.	COMIE	Res.	Res.	Res.	CC1IE	UIE

Bit 15 Reserved, always read as 0.

Bit 14 Reserved, always read as 0.

Bit 13:10 Reserved, always read as 0.

Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable

- 0: CC1 DMA request disabled
- 1: CC1 DMA request enabled

Bit 8 **UDE**: Update DMA request enable

- 0: Update DMA request disabled
- 1: Update DMA request enabled

Bit 7 **BIE**: Break interrupt enable

- 0: Break interrupt disabled
- 1: Break interrupt enabled

Bit 6 Reserved, always read as 0.

Bit 5 **COMIE**: COM interrupt enable

- 0: COM interrupt disabled
- 1: COM interrupt enabled

Bits 4:2 Reserved, always read as 0.

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

- 0: CC1 interrupt disabled
- 1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

- 0: Update interrupt disabled
- 1: Update interrupt enabled

#### 18.6.4 TIM16 and TIM17 status register (TIM16\_SR and TIM17\_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CC1OF	Res.	BIF	Res.	COMIF	Res.	Res.	Res.	CC1IF	UIF

Bits 15:10 Reserved, always read as 0.

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

- 0: No overcapture has been detected
- 1: The counter value has been captured in TIMx\_CCR1 register while CC1IF flag was already set

Bit 8 Reserved, always read as 0.

Bit 7 **BIF**: Break interrupt flag

This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.

- 0: No break event occurred
- 1: An active level has been detected on the break input

Bit 6 Reserved, always read as 0.

Bit 5 **COMIF**: COM interrupt flag

This flag is set by hardware on a COM event (once the capture/compare control bits –CCxE, CCxNE, OCxM– have been updated). It is cleared by software.

- 0: No COM event occurred
- 1: COM interrupt pending

Bits 4:2 Reserved, always read as 0.

Bit 1 **CC1IF**: Capture/Compare 1 interrupt flag

**If channel CC1 is configured as output:**

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx\_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIMx\_CNT matches the content of the TIMx\_CCR1 register. When the contents of TIMx\_CCR1 are greater than the contents of TIMx\_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

**If channel CC1 is configured as input:**

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx\_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx\_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow regarding the repetition counter value (update if repetition counter = 0) and if the UDIS=0 in the TIMx\_CR1 register.
- When CNT is reinitialized by software using the UG bit in TIMx\_EGR register, if URS=0 and UDIS=0 in the TIMx\_CR1 register.

### 18.6.5 TIM16 and TIM17 event generation register (TIM16\_EGR and TIM17\_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	BG	Res.	COMG	Res.	Res.	Res.	CC1G	UG							

Bits 15:8 Reserved, always read as 0.

Bit 7 **BG**: Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: A break event is generated. MOE bit is cleared and BIF flag is set. Related interrupt or DMA transfer can occur if enabled.

Bit 6 Reserved, always read as 0.

Bit 5 **COMG**: Capture/Compare control update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: When the CCPC bit is set, it is possible to update the CCxE, CCxNE and OCxM bits

*Note: This bit acts only on channels that have a complementary output.*

Bits 4:2 Reserved, always read as 0.

**Bit 1 CC1G:** Capture/Compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: A capture/compare event is generated on channel 1:

**If channel CC1 is configured as output:**

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

**If channel CC1 is configured as input:**

The current value of the counter is captured in TIMx\_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

**Bit 0 UG:** Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Reinitialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx\_ARR) if DIR=1 (downcounting).

## 18.6.6 TIM16 and TIM17 capture/compare mode register 1 (TIM16\_CCMR1 and TIM17\_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CCxS bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	OC1M[2:0]				OC1PE	OC1FE	CC1S[1:0]								
Res.	IC1F[3:0]				IC1PSC[1:0]										
								rw	rw	rw	rw	rw	rw	rw	rw

### Output compare mode:

Bits 15:7 Reserved, always read as 0.

Bits 6:4 **OC1M**: Output Compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

000: Frozen - The comparison between the output compare register TIMx\_CCR1 and the counter TIMx\_CNT has no effect on the outputs.

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx\_CNT matches the capture/compare register 1 (TIMx\_CCR1).

011: Toggle - OC1REF toggles when TIMx\_CNT=TIMx\_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx\_CNT<TIMx\_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx\_CNT>TIMx\_CCR1 else active (OC1REF='1').

111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx\_CNT<TIMx\_CCR1 else active. In downcounting, channel 1 is active as long as TIMx\_CNT>TIMx\_CCR1 else inactive.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S='00' (the channel is configured in output).*

*2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode.*

**Bit 3 OC1PE:** Output Compare 1 preload enable

0: Preload register on TIMx\_CCR1 disabled. TIMx\_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx\_CCR1 enabled. Read/Write operations access the preload register. TIMx\_CCR1 preload value is loaded in the active register at each update event.

*Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S='00' (the channel is configured in output).*

*2: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx\_CR1 register). Else the behavior is not guaranteed.*

**Bit 2 OC1FE:** Output Compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently of the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OC1FE acts only if the channel is configured in PWM1 or PWM2 mode.

**Bits 1:0 CC1S:** Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx\_CCER).*

**Input capture mode**

Bits 15:8 Reserved, always read as 0.

#### Bits 7:4 **IC1F[3:0]**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, sampling is done at  $f_{DTS}$
- 0001:  $f_{SAMPLING} = f_{CK\_INT}$ , N=2
- 0010:  $f_{SAMPLING} = f_{CK\_INT}$ , N=4
- 0011:  $f_{SAMPLING} = f_{CK\_INT}$ , N=8
- 0100:  $f_{SAMPLING} = f_{DTS}/2$ , N=
- 0101:  $f_{SAMPLING} = f_{DTS}/2$ , N=8
- 0110:  $f_{SAMPLING} = f_{DTS}/4$ , N=6
- 0111:  $f_{SAMPLING} = f_{DTS}/4$ , N=8
- 1000:  $f_{SAMPLING} = f_{DTS}/8$ , N=6
- 1001:  $f_{SAMPLING} = f_{DTS}/8$ , N=8
- 1010:  $f_{SAMPLING} = f_{DTS}/16$ , N=5
- 1011:  $f_{SAMPLING} = f_{DTS}/16$ , N=6
- 1100:  $f_{SAMPLING} = f_{DTS}/16$ , N=8
- 1101:  $f_{SAMPLING} = f_{DTS}/32$ , N=5
- 1110:  $f_{SAMPLING} = f_{DTS}/32$ , N=6
- 1111:  $f_{SAMPLING} = f_{DTS}/32$ , N=8

#### Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as CC1E='0' (TIMx\_CCER register).

- 00: no prescaler, capture is done each time an edge is detected on the capture input.
- 01: capture is done once every 2 events
- 10: capture is done once every 4 events
- 11: capture is done once every 8 events

#### Bits 1:0 **CC1S**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC1 channel is configured as output
- 01: CC1 channel is configured as input, IC1 is mapped on TI1
- 10: CC1 channel is configured as input, IC1 is mapped on TI2
- 11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx\_SMCR register)

*Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx\_CCER).*

### 18.6.7 TIM16 and TIM17 capture/compare enable register (TIM16\_CCER and TIM17\_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	CC1NP	CC1NE	CC1P	CC1E											

Bits 15:4 Reserved, always read as 0.

Bit 3 **CC1NP**: Capture/Compare 1 complementary output polarity

- 0: OC1N active high
- 1: OC1N active low

*Note:* This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register) and CC1S="00" (the channel is configured in output).

Bit 2 **CC1NE**: Capture/Compare 1 complementary output enable

- 0: Off - OC1N is not active. OC1N level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.
- 1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

Bit 1 **CC1P**: Capture/Compare 1 output polarity

**CC1 channel configured as output:**

- 0: OC1 active high
- 1: OC1 active low

**CC1 channel configured as input:**

The CC1NP/CC1P bits select the polarity of TI1FP1 and TI2FP1 for capture operation.

- 00: Non-inverted/rising edge: circuit is sensitive to TIxFP1's rising edge TIxFP1 is not inverted.

- 01: Inverted/falling edge: circuit is sensitive to TIxFP1's falling edge, TIxFP1 is inverted.

- 10: Reserved, do not use this configuration.

- 11: Non-inverted/both edges: circuit is sensitive to both the rising and falling edges of TIxFP1, TIxFP1 is not inverted.

*Note:* This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register)

Bit 0 **CC1E**: Capture/Compare 1 output enable

**CC1 channel configured as output:**

- 0: Off - OC1 is not active. OC1 level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

- 1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

**CC1 channel configured as input:**

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx\_CCR1) or not.

- 0: Capture disabled

- 1: Capture enabled

**Table 55. Output control bits for complementary OCx and OCxN channels with break feature**

Control bits					Output states <sup>(1)</sup>	
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state
1	X	0	0	0	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	0	1	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		0	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		1	0	1	Off-State (output enabled with inactive state) OCx=CCxP, OCx_EN=1	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		1	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Off-State (output enabled with inactive state) OCxN=CCxNP, OCxN_EN=1
		1	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
0	X	0	0	0	Output Disabled (not driven by the timer)	
		0	0	1	Asynchronously: OCx=CCxP, OCx_EN=0, OCxN=CCxNP, OCxN_EN=0	
		0	1	0	Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state.	
		0	1	1		
		0	0	0		
		1	0	1	Off-State (output enabled with inactive state)	
		1	1	0	Asynchronously: OCx=CCxP, OCx_EN=1, OCxN=CCxNP, OCxN_EN=1	
		1	1	1	Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state	

- When both outputs of a channel are not used (CCxE = CCxNE = 0), the OISx, OISxN, CCxP and CCxNP bits must be kept cleared.

**Note:** The state of the external I/O pins connected to the complementary OC<sub>x</sub> and OC<sub>xN</sub> channels depends on the OC<sub>x</sub> and OC<sub>xN</sub> channel state and the GPIO and AFIO registers.

### 18.6.8 TIM16 and TIM17 counter (TIM16\_CNT and TIM17\_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Counter value

### 18.6.9 TIM16 and TIM17 prescaler (TIM16\_PSC and TIM17\_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency (CK\_CNT) is equal to  $f_{CK\_PSC} / (PSC[15:0] + 1)$ .

PSC contains the value to be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx\_EGR register or through trigger controller when configured in “reset mode”).

### 18.6.10 TIM16 and TIM17 auto-reload register (TIM16\_ARR and TIM17\_ARR)

Address offset: 0x2C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 17.3.1: Time-base unit on page 361](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

### 18.6.11 TIM16 and TIM17 repetition counter register (TIM16\_RCR and TIM17\_RCR)

Address offset: 0x30

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	REP[7:0]														
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved, always read as 0.

Bits 7:0 **REP[7:0]**: Repetition counter value

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to active registers) when preload registers are enable, as well as the update interrupt generation rate, if this interrupt is enable.

Each time the REP\_CNT related downcounter reaches zero, an update event is generated and it restarts counting from REP value. As REP\_CNT is reloaded with REP value only at the repetition update event U\_RC, any write to the TIMx\_RCR register is not taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to the number of PWM periods in edge-aligned mode.

### 18.6.12 TIM16 and TIM17 capture/compare register 1 (TIM16\_CCR1 and TIM17\_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

**If channel CC1 is configured as output:**

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx\_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx\_CNT and signaled on OC1 output.

**If channel CC1 is configured as input:**

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

### 18.6.13 TIM16 and TIM17 break and dead-time register (TIM16\_BDTR and TIM17\_BDTR)

Address offset: 0x44

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK[1:0]									DTG[7:0]
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

**Note:** As the bits AOE, BKP, BKE, OSSR, OSSI and DTG[7:0] can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIMx\_BDTR register.

#### Bit 15 **MOE**: Main output enable

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state

1: OC and OCN outputs are enabled if their respective enable bits are set (CCxE, CCxNE in TIMx\_CCER register)

See OC/OCN enable description for more details ([Section 18.5.8: TIM15 capture/compare enable register \(TIM15\\_CCER\) on page 420](#)).

#### Bit 14 **AOE**: Automatic output enable

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not active)

**Note:** This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).

#### Bit 13 **BKP**: Break polarity

0: Break input BRK is active low

1: Break input BRK is active high

**Note:** This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).

**Note:** Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

#### Bit 12 **BKE**: Break enable

0: Break inputs (BRK and CCS clock failure event) disabled

1: Break inputs (BRK and CCS clock failure event) enabled

**Note:** This bit cannot be modified when LOCK level 1 has been programmed (LOCK bits in TIMx\_BDTR register).

**Note:** Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

**Bit 11 OSSR:** Off-state selection for Run mode

This bit is used when MOE=1 on channels having a complementary output which are configured as outputs. OSSR is not implemented if no complementary output is implemented in the timer.

See OC/OCN enable description for more details ([Section 18.5.8: TIM15 capture/compare enable register \(TIM15\\_CCER\) on page 420](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)
- 1: When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCxE=1 or CCxNE=1. Then, OC/OCN enable output signal=1

*Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx\_BDTR register).*

**Bit 10 OSSI:** Off-state selection for Idle mode

This bit is used when MOE=0 on channels configured as outputs.

See OC/OCN enable description for more details ([Section 18.5.8: TIM15 capture/compare enable register \(TIM15\\_CCER\) on page 420](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)
- 1: When inactive, OC/OCN outputs are forced first with their idle level as soon as CCxE=1 or CCxNE=1. OC/OCN enable output signal=1

*Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx\_BDTR register).*

**Bits 9:8 LOCK[1:0]:** Lock configuration

These bits offer a write protection against software errors.

- 00: LOCK OFF - No bit is write protected
- 01: LOCK Level 1 = DTG bits in TIMx\_BDTR register, OISx and OISxN bits in TIMx\_CR2 register and BKE/BKP/AOE bits in TIMx\_BDTR register can no longer be written.
- 10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CCxP/CCxNP bits in TIMx\_CCER register, as long as the related channel is configured in output through the CCxS bits) as well as OSSR and OSSI bits can no longer be written.
- 11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OCxM and OCxPE bits in TIMx\_CCMRx registers, as long as the related channel is configured in output through the CCxS bits) can no longer be written.

*Note: The LOCK bits can be written only once after the reset. Once the TIMx\_BDTR register has been written, their content is frozen until the next reset.*

**Bits 7:0 DTG[7:0]:** Dead-time generator setup

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT correspond to this duration.

- DTG[7:5]=0xx => DT=DTG[7:0]x t<sub>dtg</sub> with t<sub>dtg</sub>=t<sub>DTS</sub>
- DTG[7:5]=10x => DT=(64+DTG[5:0])x t<sub>dtg</sub> with T<sub>dtg</sub>=2x t<sub>DTS</sub>
- DTG[7:5]=110 => DT=(32+DTG[4:0])x t<sub>dtg</sub> with T<sub>dtg</sub>=8x t<sub>DTS</sub>
- DTG[7:5]=111 => DT=(32+DTG[4:0])x t<sub>dtg</sub> with T<sub>dtg</sub>=16x t<sub>DTS</sub>

Example if T<sub>DTS</sub>=125ns (8MHz), dead-time possible values are:

- 0 to 15875 ns by 125 ns steps,
- 16 µs to 31750 ns by 250 ns steps,
- 32 µs to 63 µs by 1 µs steps,
- 64 µs to 126 µs by 2 µs steps

*Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx\_BDTR register).*

### 18.6.14 TIM16 and TIM17 DMA control register (TIM16\_DCR and TIM17\_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]					Res.	Res.	Res.	DBA[4:0]				
			rw	rw	rw	rw	rw				rw	rw	rw	rw	rw

Bits 15:13 Reserved, always read as 0.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the length of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx\_DMAR address), i.e. the number of transfers. Transfers can be in half-words or in bytes (see example below).

00000: 1 transfer,

00001: 2 transfers,

00010: 3 transfers,

...

10001: 18 transfers.

Bits 7:5 Reserved, always read as 0.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bits vector defines the base-address for DMA transfers (when read/write access are done through the TIMx\_DMAR address). DBA is defined as an offset starting from the address of the TIMx\_CR1 register.

Example:

00000: TIMx\_CR1,

00001: TIMx\_CR2,

00010: TIMx\_SMCR,

...

**Example:** Let us consider the following transfer: DBL = 7 transfers and DBA = TIMx\_CR1. In this case the transfer is done to/from 7 registers starting from the TIMx\_CR1 address..

### 18.6.15 TIM16 and TIM17 DMA address for full transfer (TIM16\_DMAR and TIM17\_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write access to the DMAR register accesses the register located at the address: "(TIMx\_CR1 address) + DBA + (DMA index)" in which:

TIMx\_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx\_DCR register, DMA index is the offset automatically controlled by the DMA transfer, depending on the length of the transfer DBL in the TIMx\_DCR register.

### Example of how to use the DMA burst feature

In this example the timer DMA burst feature is used to update the contents of the CCRx registers ( $x = 2, 3, 4$ ) with the DMA transferring half words into the CCRx registers.

This is done in the following steps:

1. Configure the corresponding DMA channel as follows:
  - DMA channel peripheral address is the DMAR register address
  - DMA channel memory address is the address of the buffer in the RAM containing the data to be transferred by DMA into CCRx registers.
  - Number of data to transfer = 3 (See note below).
  - Circular mode disabled.
2. Configure the DCR register by configuring the DBA and DBL bit fields as follows:  
DBL = 3 transfers, DBA = 0xE.
3. Enable the TIMx update DMA request (set the UDE bit in the DIER register).
4. Enable TIMx
5. Enable the DMA channel

Note:

*This example is for the case where every CCRx register to be updated once. If every CCRx register is to be updated twice for example, the number of data to transfer should be 6. Let us take the example of a buffer in the RAM containing data1, data2, data3, data4, data5 and data6. The data is transferred to the CCRx registers as follows: on the first update DMA request, data1 is transferred to CCR2, data2 is transferred to CCR3, data3 is transferred to CCR4 and on the second update DMA request, data4 is transferred to CCR2, data5 is transferred to CCR3 and data6 is transferred to CCR4.*

### **18.6.16 TIM16 and TIM17 register map**

TIM16 and TIM17 registers are mapped as 16-bit addressable registers as described in the table below:

**Table 56. TIM16 and TIM17 register map and reset values**

**Table 56. TIM16 and TIM17 register map and reset values (continued)**

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x48	<b>TIM16_DCR and TIM17_DCR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.			
		Reset value																																
0x4C	<b>TIM16_DMAR and TIM17_DMAR</b>	Res.																																
		Reset value																																

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 19 Basic timer (TIM6)

This section applies to medium-density devices only.

### 19.1 TIM6 introduction

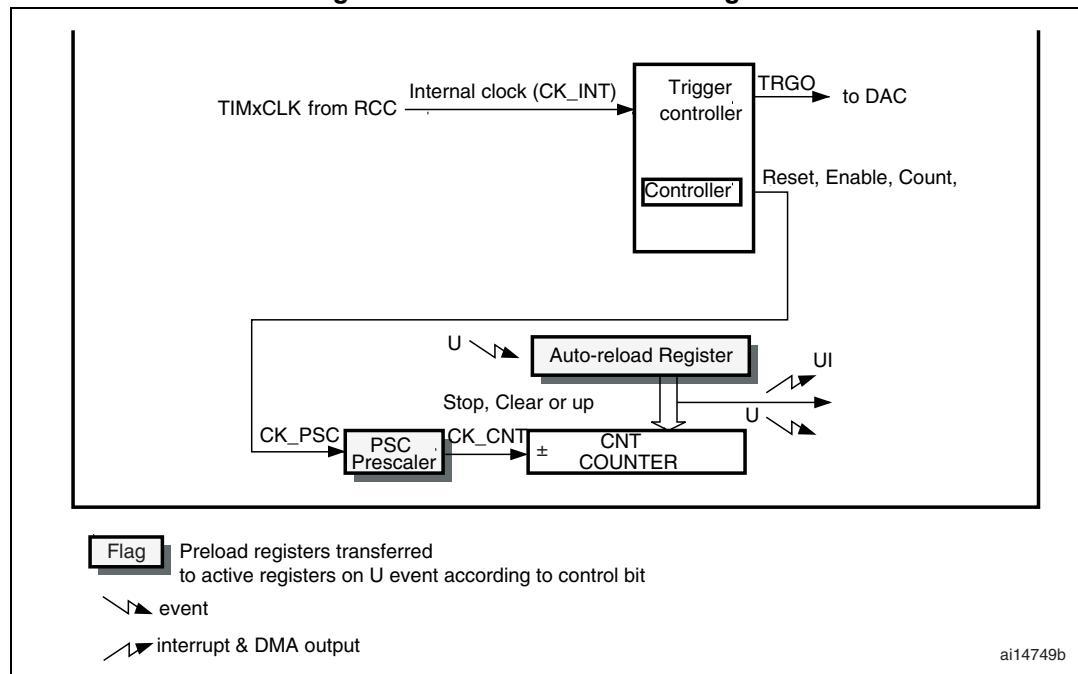
The basic timer TIM6 consists of a 16-bit auto-reload counter driven by a programmable prescaler.

It may be used as a generic timer for time-base generation but it is also specifically used to drive the digital-to-analog converter (DAC). In fact, TIM6 is internally connected to the DAC and is able to drive it through its trigger outputs.

### 19.2 TIM6 main features

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535
- Synchronization circuit to trigger the DAC
- Interrupt/DMA generation on the update event: counter overflow

Figure 183. Basic timer block diagram



## 19.3 TIM6 functional description

### 19.3.1 Time-base unit

The main block of the programmable timer is a 16-bit upcounter with its related auto-reload register. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter Register (TIMx\_CNT)
- Prescaler Register (TIMx\_PSC)
- Auto-Reload Register (TIMx\_ARR)

The auto-reload register is preloaded. The preload register is accessed each time an attempt is made to write or read the auto-reload register. The contents of the preload register are transferred into the shadow register permanently or at each update event UEV, depending on the auto-reload preload enable bit (ARPE) in the TIMx\_CR1 register. The update event is sent when the counter reaches the overflow value and if the UDIS bit equals 0 in the TIMx\_CR1 register. It can also be generated by software. The generation of the update event is described in detail for each configuration.

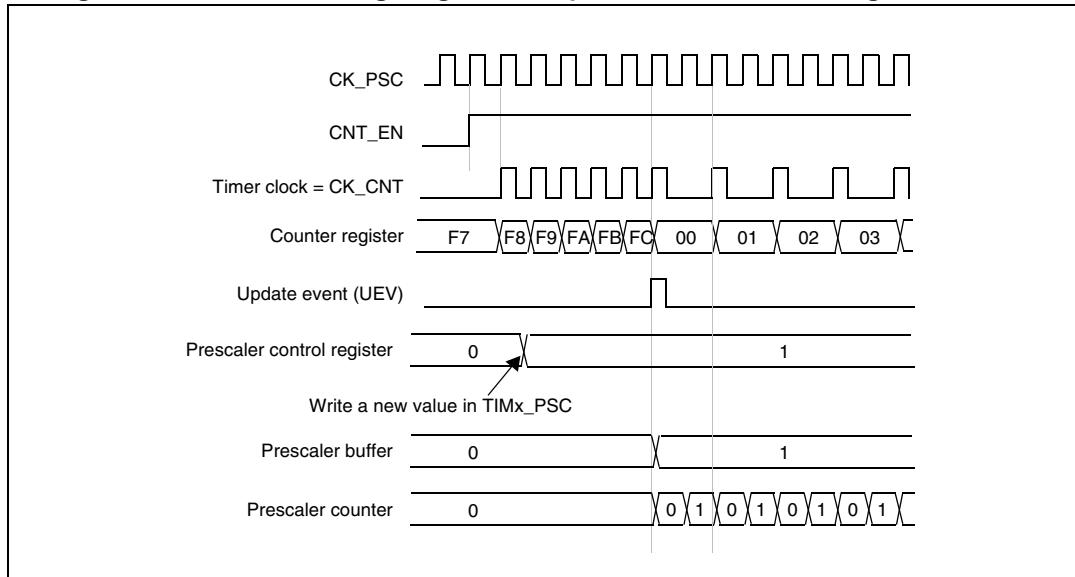
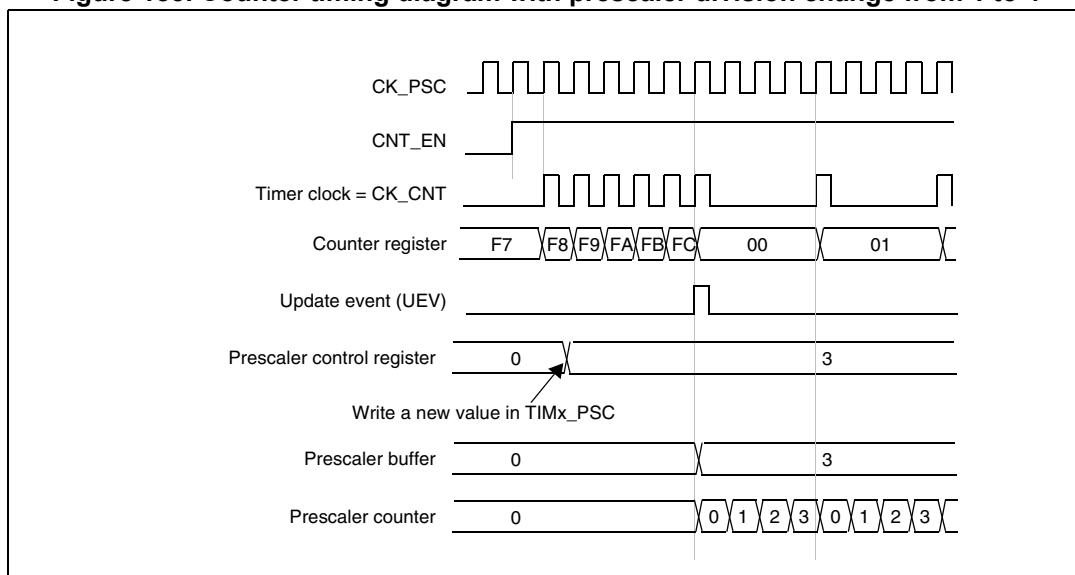
The counter is clocked by the prescaler output CK\_CNT, which is enabled only when the counter enable bit (CEN) in the TIMx\_CR1 register is set.

Note that the actual counter enable signal CNT\_EN is set 1 clock cycle after CEN.

#### Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx\_PSC register). It can be changed on the fly as the TIMx\_PSC control register is buffered. The new prescaler ratio is taken into account at the next update event.

*Figure 184* and *Figure 185* give some examples of the counter behavior when the prescaler ratio is changed on the fly.

**Figure 184. Counter timing diagram with prescaler division change from 1 to 2****Figure 185. Counter timing diagram with prescaler division change from 1 to 4**

### 19.3.2 Counter modes

The counter counts from 0 to the auto-reload value (contents of the TIMx\_ARR register), then restarts from 0 and generates a counter overflow event.

An update event can be generated at each counter overflow or by setting the UG bit in the TIMx\_EGR register (by software or by using the slave mode controller).

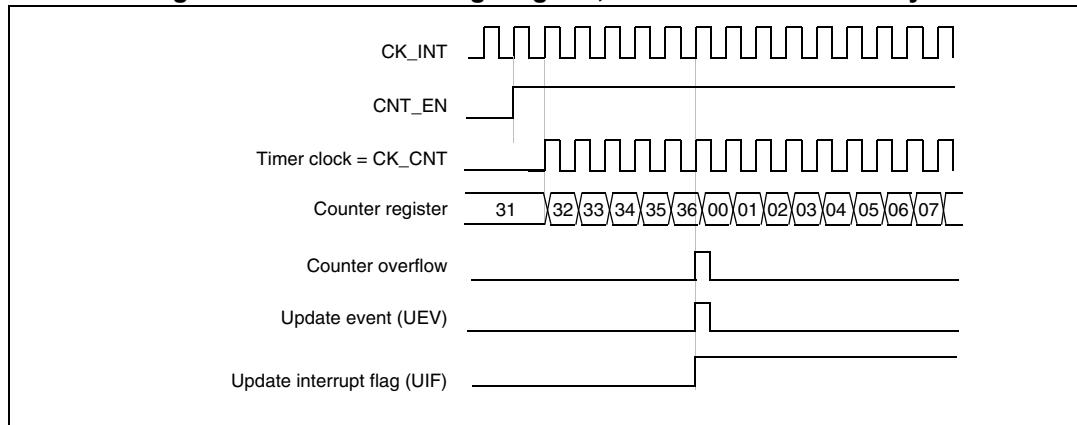
The UEV event can be disabled by software by setting the UDIS bit in the TIMx\_CR1 register. This avoids updating the shadow registers while writing new values into the preload registers. In this way, no update event occurs until the UDIS bit has been written to 0, however, the counter and the prescaler counter both restart from 0 (but the prescale rate does not change). In addition, if the URS (update request selection) bit in the TIMx\_CR1 register is set, setting the UG bit generates an update event UEV, but the UIF flag is not set (so no interrupt or DMA request is sent).

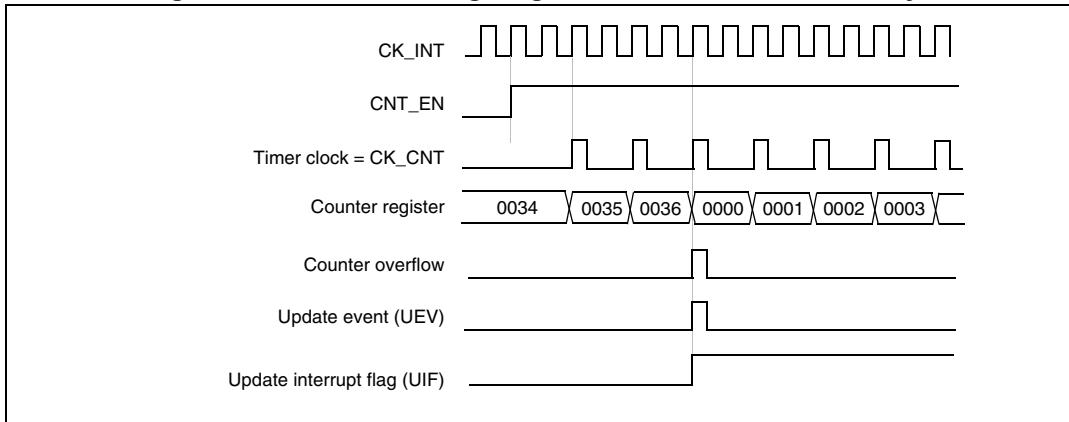
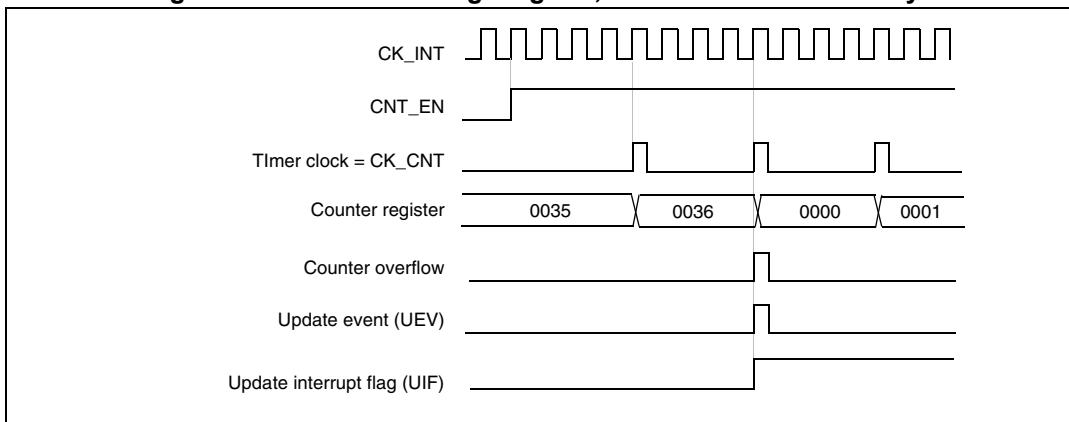
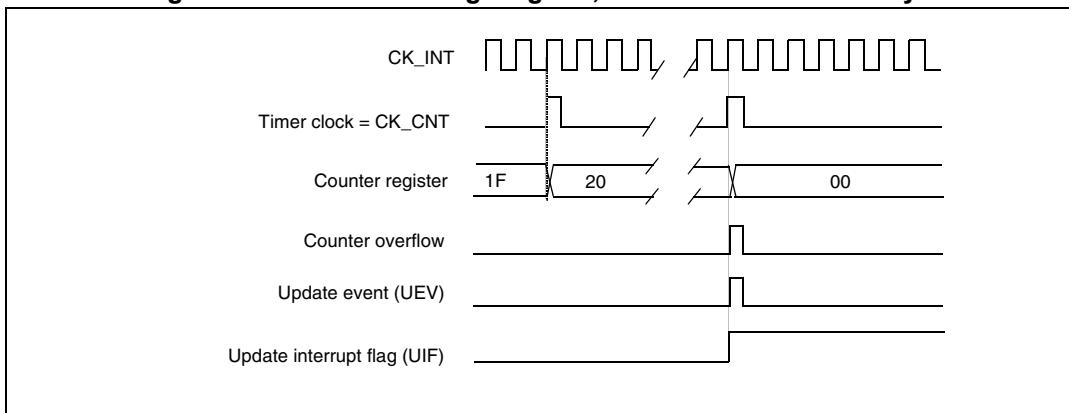
When an update event occurs, all the registers are updated and the update flag (UIF bit in the TIMx\_SR register) is set (depending on the URS bit):

- The buffer of the prescaler is reloaded with the preload value (contents of the TIMx\_PSC register)
- The auto-reload shadow register is updated with the preload value (TIMx\_ARR)

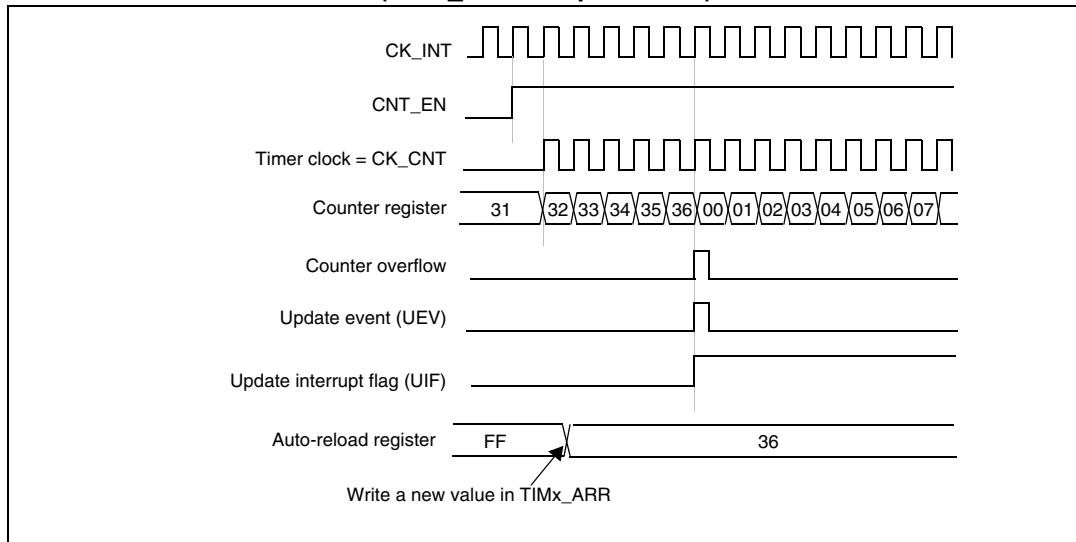
The following figures show some examples of the counter behavior for different clock frequencies when TIMx\_ARR = 0x36.

**Figure 186. Counter timing diagram, internal clock divided by 1**

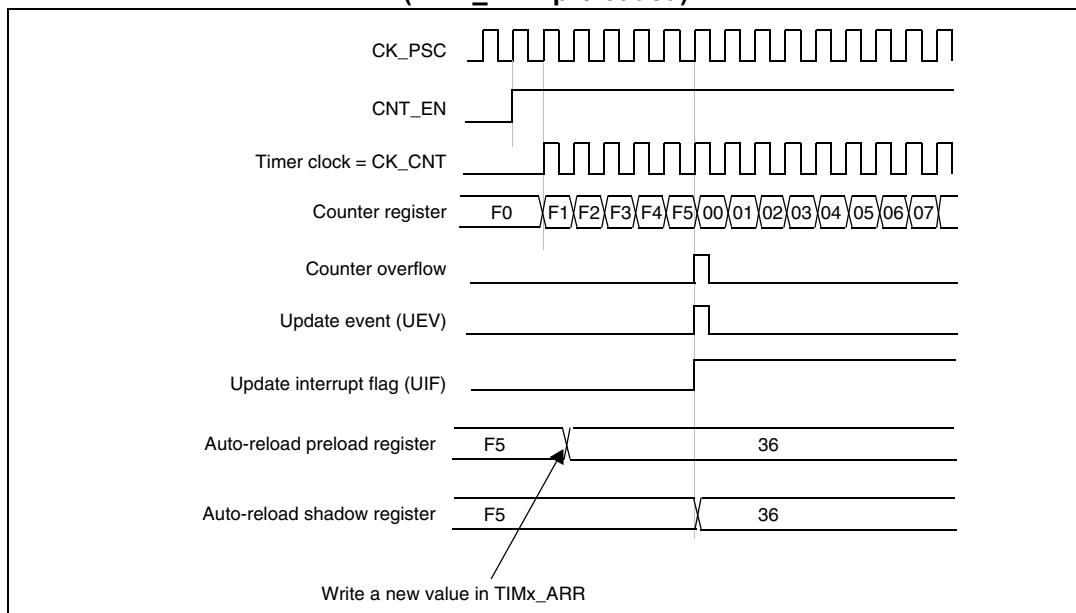


**Figure 187. Counter timing diagram, internal clock divided by 2****Figure 188. Counter timing diagram, internal clock divided by 4****Figure 189. Counter timing diagram, internal clock divided by N**

**Figure 190. Counter timing diagram, update event when ARPE = 0  
(TIMx\_ARR not preloaded)**



**Figure 191. Counter timing diagram, update event when ARPE=1  
(TIMx\_ARR preloaded)**



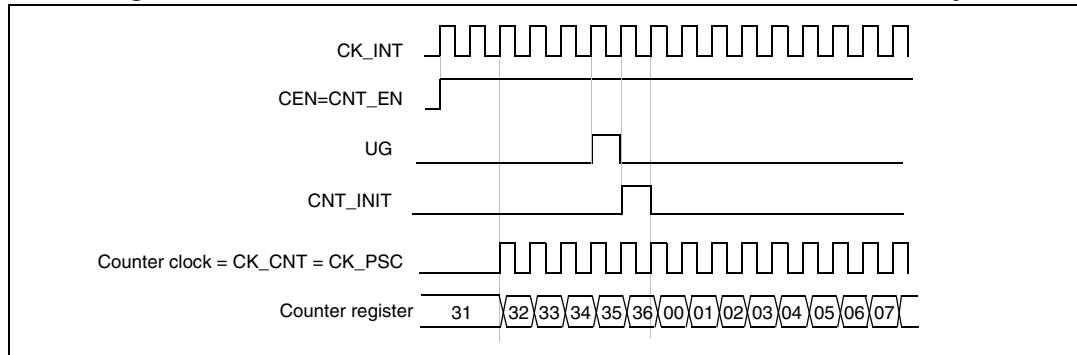
### 19.3.3 Clock source

The counter clock is provided by the Internal clock (CK\_INT) source.

The CEN (in the TIMx\_CR1 register) and UG bits (in the TIMx\_EGR register) are actual control bits and can be changed only by software (except for UG that remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK\_INT.

*Figure 192* shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

**Figure 192. Control circuit in normal mode, internal clock divided by 1**



### 19.3.4 Debug mode

When the microcontroller enters the debug mode (Cortex™-M0 core - halted), the TIMx counter either continues to work normally or stops, depending on the DBG\_TIMx\_STOP configuration bit in the DBG module.

## 19.4 TIM6 registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

### 19.4.1 TIM6 control register 1 (TIM6\_CR1)

Address offset: 0x000

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN							
								rw				rw	rw	rw	rw

Bits 15:8 Reserved, always read as 0.

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIMx\_ARR register is not buffered.
- 1: TIMx\_ARR register is buffered.

Bits 6:4 Reserved, always read as 0.

Bit 3 **OPM**: One-pulse mode

- 0: Counter is not stopped at update event
- 1: Counter stops counting at the next update event (clearing the CEN bit).

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the UEV event sources.

- 0: Any of the following events generates an update interrupt or DMA request if enabled.
- These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

- 1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

- 0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

- 1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 **CEN**: Counter enable

- 0: Counter disabled
- 1: Counter enabled

*Note: Gated mode can work only if the CEN bit has been previously set by software.  
However trigger mode can set the CEN bit automatically by hardware.*

CEN is cleared automatically in one-pulse mode, when an update event occurs.

### 19.4.2 TIM6 control register 2 (TIM6\_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MMS[2:0]	Res.	Res.	Res.	Res.	Res.	Res.								

Bits 15:7 Reserved, must be kept at reset value.

Bits 6:4 **MMS**: Master mode selection

These bits are used to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx\_EGR register is used as a trigger output (TRGO). If reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter enable signal, CNT\_EN, is used as a trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enabled. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode.

When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in the TIMx\_SMCR register).

010: **Update** - The update event is selected as a trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

Bits 3:0 Reserved, always read as 0.

### 19.4.3 TIM6 DMA/Interrupt enable register (TIM6\_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	UDE	Res.	UIE												

Bit 15:9 Reserved, must be kept at reset value.

Bit 8 **UDE**: Update DMA request enable

- 0: Update DMA request disabled.
- 1: Update DMA request enabled.

Bits 7:1 Reserved, must be kept at reset value.

Bit 0 **UIE**: Update interrupt enable

- 0: Update interrupt disabled.
- 1: Update interrupt enabled.

#### 19.4.4 TIM6 status register (TIM6\_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	UIF rc_w0														

Bits 15:1 Reserved, must be kept at reset value.

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow or underflow regarding the repetition counter value and if UDIS = 0 in the TIMx\_CR1 register.

- When CNT is reinitialized by software using the UG bit in the TIMx\_EGR register, if URS = 0 and UDIS = 0 in the TIMx\_CR1 register.

#### 19.4.5 TIM6 event generation register (TIM6\_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	UG w														

Bits 15:1 Reserved, must be kept at reset value.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Re-initializes the timer counter and generates an update of the registers. Note that the prescaler counter is cleared too (but the prescaler ratio is not affected).

#### 19.4.6 TIM6 counter (TIM6\_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0

**CNT[15:0]**: Counter value

### 19.4.7 TIM6 prescaler (TIM6\_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency CK\_CNT is equal to  $f_{CK\_PSC} / (PSC[15:0] + 1)$ .

PSC contains the value to be loaded into the active prescaler register at each update event.

### 19.4.8 TIM6 auto-reload register (TIM6\_ARR)

Address offset: 0x2C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded into the actual auto-reload register.

Refer to [Section 19.3.1: Time-base unit on page 451](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

## 19.4.9 TIM6 register map

TIM6 registers are mapped as 16-bit addressable registers as described in the table below:

**Table 57. TIM6 register map and reset values**

Offset	Register	Reset value
0x00	<b>TIM6_CR1</b>	<b>31</b>
	Reset value	Res.
0x04	<b>TIM6_CR2</b>	<b>30</b>
	Reset value	Res.
0x0C	<b>TIM6_DIER</b>	<b>29</b>
	Reset value	Res.
0x10	<b>TIM6_SR</b>	<b>28</b>
	Reset value	Res.
0x14	<b>TIM6_EGR</b>	<b>27</b>
	Reset value	Res.
0x24	<b>TIM6_CNT</b>	<b>26</b>
	Reset value	Res.
0x28	<b>TIM6_PSC</b>	<b>25</b>
	Reset value	Res.
0x2C	<b>TIM6_ARR</b>	<b>24</b>
	Reset value	Res.
CNT[15:0]		
PSC[15:0]		
ARR[15:0]		
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 MMS[2:0]
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 ARPE 7
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 Res. 6
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 Res. 5
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 Res. 4
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 OPM 3
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 URS 2
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 UDIS 1
0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 CEN 0

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 20 Infrared interface (IRTIM)

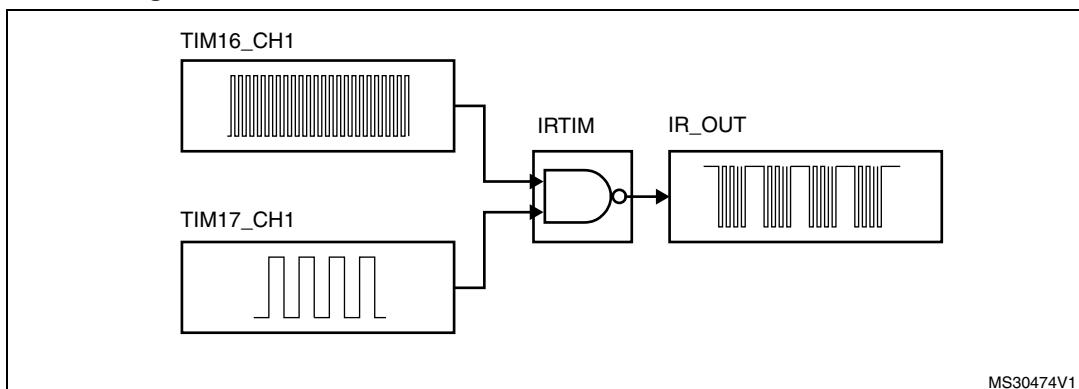
An infrared interface (IRTIM) for remote control is available on the device. It can be used with an infrared LED to perform remote control functions.

It uses internal connections with TIM16 and TIM17 as shown in [Figure 193](#).

To generate the infrared remote control signals, the IR interface must be enabled and TIM16 channel 1 (TIM16\_OC1) and TIM17 channel 1 (TIM17\_OC1) must be properly configured to generate correct waveforms.

The infrared receiver can be implemented easily through a basic input capture mode.

**Figure 193. IR internal hardware connections with TIM16 and TIM17**



### 20.1 Main features

All standard IR pulse modulation modes can be obtained by programming the two timer output compare channels.

TIM16 is used to generate the high frequency carrier signal, while TIM17 generates the modulation envelope.

The infrared function is output on the IR\_OUT pin. The activation of this function is done through the GPIOx\_AFRx register by enabling the related alternate function bit.

The high sink LED driver capability (only available on the PB9 pin) can be activated through the I2C\_PB9\_FM+ bit in the SYS\_CTRL register and used to sink the high current needed to directly control an infrared LED.

## 21 Independent watchdog (IWDG)

### 21.1 Introduction

The devices feature an embedded watchdog peripheral which offers a combination of high safety level, timing accuracy and flexibility of use. The Independent watchdog peripheral serves to detect and resolve malfunctions due to software failure, and to trigger system reset when the counter reaches a given timeout value.

The independent watchdog (IWDG) is clocked by its own dedicated low-speed clock (LSI) and thus stays active even if the main clock fails.

The IWDG is best suited to applications which require the watchdog to run as a totally independent process outside the main application, but have lower timing accuracy constraints. For further information on the window watchdog, refer to [Section 22 on page 471](#).

### 21.2 IWDG main features

- Free-running downcounter
- Clocked from an independent RC oscillator (can operate in Standby and Stop modes)
- Conditional Reset
  - Reset (if watchdog activated) when the downcounter value becomes less than 000h
  - Reset (if watchdog activated) if the downcounter is reloaded outside the window

### 21.3 IWDG functional description

*Figure 194* shows the functional blocks of the independent watchdog module.

When the independent watchdog is started by writing the value 0x0000 CCCC in the Key register (IWDG\_KR), the counter starts counting down from the reset value of 0xFFFF. When it reaches the end of count value (0x000) a reset signal is generated (IWDG reset).

Whenever the key value 0x0000 AAAA is written in the IWDG\_KR register, the IWDG\_RLR value is reloaded in the counter and the watchdog reset is prevented.

#### 21.3.1 Window option

The IWDG can also work as a window watchdog by setting the appropriate window in the IWDG\_WINR register.

If the reload operation is performed while the counter is greater than the value stored in the window register (IWDG\_WINR), then a reset is provided.

The default value of the IWDG\_WINR is 0x0000 0FFF, so if it is not updated, the window option is disabled.

As soon as the window value is changed, a reload operation is performed in order to reset the downcounter to the IWDG\_RLR value and ease the cycle number calculation to generate the next reload.

### Configuring the IWDG when the window option is enabled

1. Enable the IWDG by writing 0x0000 CCCC in the IWDG\_KR register.
2. Enable register access by writing 0x0000 5555 in the IWDG\_KR register.
3. Write the IWDG prescaler by programming IWDG\_PR from 0 to 7.
4. Write the reload register (IWDG\_RLR).
5. Wait for the registers to be updated (IWDG\_SR = 0x0000 0000).
6. Write to the window register IWDG\_WINR. This automatically refreshes the counter value IWDG\_RLR.

*Note:* Writing the window value allows to refresh the Counter value by the RLR when IWDG\_SR to set to 0x0000 0000.

### Configuring the IWDG when the window option is disabled

When the window option it is not used, the IWDG can be configured as follows:

1. Enable register access by writing 0x0000 5555 in the IWDG\_KR register.
2. Write the IWDG prescaler by programming IWDG\_PR from 0 to 7.
3. Write the reload register (IWDG\_RLR).
4. Wait for the registers to be updated (IWDG\_SR = 0x0000 0000).
5. Refresh the counter value with IWDG\_RLR (IWDG\_KR = 0x0000 AAAA).
6. Enable the IWDG by writing 0x0000 CCCC in the IWDG\_KR.

## 21.3.2 Hardware watchdog

If the “Hardware watchdog” feature is enabled through the device option bits, the watchdog is automatically enabled at power-on, and generates a reset unless the Key register is written by the software before the counter reaches end of count or if the downcounter is reloaded inside the window.

## 21.3.3 Register access protection

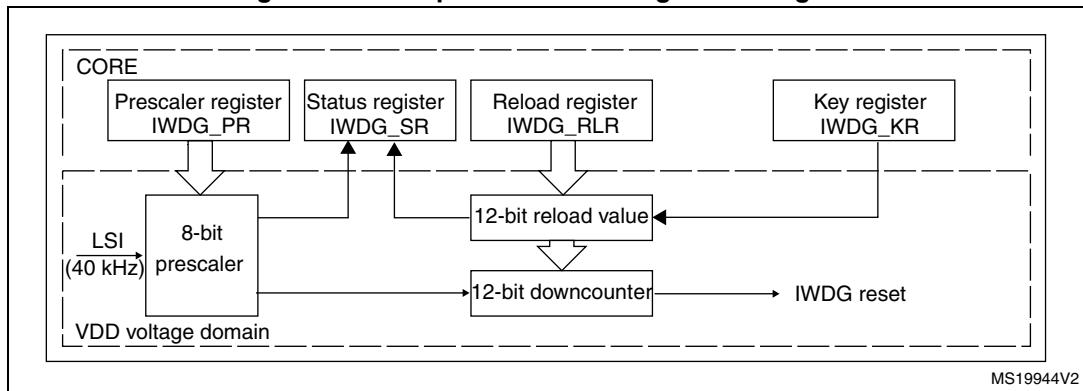
Write access to the IWDG\_PR, IWDG\_RLR and IWDG\_WINR registers is protected. To modify them, you must first write the code 0x0000 5555 in the IWDG\_KR register. A write access to this register with a different value will break the sequence and register access will be protected again. This implies that it is the case of the reload operation (writing 0x0000 AAAA).

A status register is available to indicate that an update of the prescaler or the down-counter reload value or the window value is on going.

## 21.3.4 Debug mode

When the microcontroller enters debug mode (core halted), the IWDG counter either continues to work normally or stops, depending on DBG\_IWDG\_STOP configuration bit in DBG module.

Figure 194. Independent watchdog block diagram



Note: The watchdog function is implemented in the CORE voltage domain that is still functional in Stop and Standby modes.

## 21.4 IWDG registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

### 21.4.1 Key register (IWDG\_KR)

Address offset: 0x00

Reset value: 0x0000 0000 (reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
KEY[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **KEY[15:0]**: Key value (write only, read 0x0000)

These bits must be written by software at regular intervals with the key value 0xAAAA, otherwise the watchdog generates a reset when the counter reaches 0.

Writing the key value 0x5555 to enables access to the IWDG\_PR, IWDG\_RLR and IWDG\_WINR registers (see [Section 21.3.3](#))

Writing the key value CCCCh starts the watchdog (except if the hardware watchdog option is selected)

## 21.4.2 Prescaler register (IWDG\_PR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
Res.	Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Res.	PR[2:0]															
														rw	rw	rw

Bits 31:3 Reserved, must be kept at reset value.

Bits 2:0 **PR[2:0]**: Prescaler divider

These bits are write access protected see [Section 21.3.3](#). They are written by software to select the prescaler divider feeding the counter clock. PVU bit of IWDG\_SR must be reset in order to be able to change the prescaler divider.

- 000: divider /4
- 001: divider /8
- 010: divider /16
- 011: divider /32
- 100: divider /64
- 101: divider /128
- 110: divider /256
- 111: divider /256

*Note: Reading this register returns the prescaler value from the VDD voltage domain. This value may not be up to date/valid if a write operation to this register is ongoing. For this reason the value read from this register is valid only when the PVU bit in the IWDG\_SR register is reset.*

### 21.4.3 Reload register (IWDG\_RLR)

Address offset: 0x08

Reset value: 0x0000 0FFF (reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.												
				rw											
RL[11:0]															

Bits 31:12 Reserved, must be kept at reset value.

Bits11:0 **RL[11:0]**: Watchdog counter reload value

These bits are write access protected see [Section 21.3.3](#). They are written by software to define the value to be loaded in the watchdog counter each time the value 0xAAAA is written in the IWDG\_KR register. The watchdog counter counts down from this value. The timeout period is a function of this value and the clock prescaler. Refer to the datasheet for the timeout information.

The RVU bit in the IWDG\_SR register must be reset in order to be able to change the reload value.

*Note: Reading this register returns the reload value from the VDD voltage domain. This value may not be up to date/valid if a write operation to this register is ongoing on this register. For this reason the value read from this register is valid only when the RVU bit in the IWDG\_SR register is reset.*

## 21.4.4 Status register (IWDG\_SR)

Address offset: 0x0C

Reset value: 0x0000 0000 (not reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	WVU	RVU	PVU												
													r	r	r

Bits 31:3 Reserved, must be kept at reset value.

### Bit 2 **WVU**: Watchdog counter window value update

This bit is set by hardware to indicate that an update of the window value is ongoing. It is reset by hardware when the reload value update operation is completed in the V<sub>DD</sub> voltage domain (takes up to 5 RC 40 kHz cycles).

Window value can be updated only when WVU bit is reset.

This bit is generated only if generic “window” = 1

### Bit 1 **RVU**: Watchdog counter reload value update

This bit is set by hardware to indicate that an update of the reload value is ongoing. It is reset by hardware when the reload value update operation is completed in the V<sub>DD</sub> voltage domain (takes up to 5 RC 40 kHz cycles).

Reload value can be updated only when RVU bit is reset.

### Bit 0 **PVU**: Watchdog prescaler value update

This bit is set by hardware to indicate that an update of the prescaler value is ongoing. It is reset by hardware when the prescaler update operation is completed in the V<sub>DD</sub> voltage domain (takes up to 5 RC 40 kHz cycles).

Prescaler value can be updated only when PVU bit is reset.

### 21.4.5 Window register (IWDG\_WINR)

Address offset: 0x10

Reset value: 0x0000 0FFF (reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	WIN[11:0]											
				rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:12 Reserved, must be kept at reset value.

Bits11:0 **WIN[11:0]**: Watchdog counter window value

These bits are write access protected see [Section 21.3.3](#). These bits contain the high limit of the window value to be compared to the downcounter.

To prevent a reset, the downcounter must be reloaded when its value is lower than the window register value and greater than 0x0

The WVU bit in the IWDG\_SR register must be reset in order to be able to change the reload value.

*Note: Reading this register returns the reload value from the V<sub>DD</sub> voltage domain. This value may not be valid if a write operation to this register is ongoing. For this reason the value read from this register is valid only when the WVU bit in the IWDG\_SR register is reset.*

*Note:* If several reload, prescaler, or window values are used by the application, it is mandatory to wait until RVU bit is reset before changing the reload value, to wait until PVU bit is reset before changing the prescaler value, and to wait until WVU bit is reset before changing the window value. However, after updating the prescaler and/or the reload/window value it is not necessary to wait until RVU or PVU or WVU is reset before continuing code execution except in case of low-power mode entry.

## 21.4.6 IWDG register map

The following table gives the IWDG register map and reset values.

**Table 58. IWDG register map and reset values**

Offset	Register	Reset	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0								
0x00	<b>IWDG_KR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
	Reset value																																									
0x04	<b>IWDG_PR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.				
	Reset value																																									
0x08	<b>IWDG_RLR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.				
	Reset value																																									
0x0C	<b>IWDG_SR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.				
	Reset value																																									
0x10	<b>IWDG_WINR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.				
	Reset value																																									

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 22 System window watchdog (WWDG)

### 22.1 WWDG introduction

The system window watchdog (WWDG) is used to detect the occurrence of a software fault, usually generated by external interference or by unforeseen logical conditions, which causes the application program to abandon its normal sequence. The watchdog circuit generates an MCU reset on expiry of a programmed time period, unless the program refreshes the contents of the downcounter before the T6 bit becomes cleared. An MCU reset is also generated if the 7-bit downcounter value (in the control register) is refreshed before the downcounter has reached the window register value. This implies that the counter must be refreshed in a limited window.

The WWDG clock is prescaled from the APB1 clock and has a configurable time-window that can be programmed to detect abnormally late or early application behavior.

The WWDG is best suited for applications which require the watchdog to react within an accurate timing window.

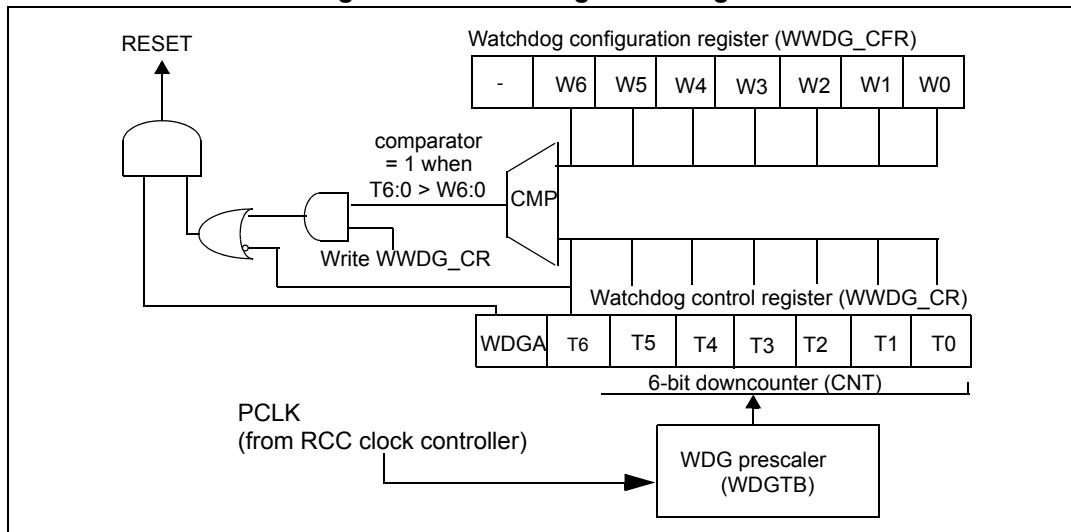
### 22.2 WWDG main features

- Programmable free-running downcounter
- Conditional reset
  - Reset (if watchdog activated) when the downcounter value becomes less than 0x40
  - Reset (if watchdog activated) if the downcounter is reloaded outside the window (see [Figure 196](#))
- Early wakeup interrupt (EWI): triggered (if enabled and the watchdog activated) when the downcounter is equal to 0x40.

### 22.3 WWDG functional description

If the watchdog is activated (the WDGA bit is set in the WWDG\_CR register) and when the 7-bit downcounter (T[6:0] bits) rolls over from 0x40 to 0x3F (T6 becomes cleared), it initiates a reset. If the software reloads the counter while the counter is greater than the value stored in the window register, then a reset is generated.

Figure 195. Watchdog block diagram



The application program must write in the WWDG\_CR register at regular intervals during normal operation to prevent an MCU reset. This operation must occur only when the counter value is lower than the window register value. The value to be stored in the WWDG\_CR register must be between 0xFF and 0xC0:

### Enabling the watchdog

The watchdog is always disabled after a reset. It is enabled by setting the WDGA bit in the WWDG\_CR register, then it cannot be disabled again except by a reset.

### Controlling the downcounter

This downcounter is free-running: It counts down even if the watchdog is disabled. When the watchdog is enabled, the T6 bit must be set to prevent generating an immediate reset.

The T[5:0] bits contain the number of increments which represents the time delay before the watchdog produces a reset. The timing varies between a minimum and a maximum value due to the unknown status of the prescaler when writing to the WWDG\_CR register (see [Figure 196](#)). The Configuration register (WWDG\_CFR) contains the high limit of the window: To prevent a reset, the downcounter must be reloaded when its value is lower than the window register value and greater than 0x3F. [Figure 196](#) describes the window watchdog process.

**Note:** *The T6 bit can be used to generate a software reset (the WDGA bit is set and the T6 bit is cleared).*

### Advanced watchdog interrupt feature

The Early Wakeup Interrupt (EWI) can be used if specific safety operations or data logging must be performed before the actual reset is generated. The EWI interrupt is enabled by setting the EWI bit in the WWDG\_CFR register. When the downcounter reaches the value 0x40, an EWI interrupt is generated and the corresponding interrupt service routine (ISR) can be used to trigger specific actions (such as communications or data logging), before resetting the device.

In some applications, the EWI interrupt can be used to manage a software system check and/or system recovery/graceful degradation, without generating a WWDG reset. In this

case, the corresponding interrupt service routine (ISR) should reload the WWDG counter to avoid the WWDG reset, then trigger the required actions.

The EWI interrupt is cleared by writing '0' to the EWIF bit in the WWDG\_SR register.

**Note:** *When the EWI interrupt cannot be served, e.g. due to a system lock in a higher priority task, the WWDG reset will eventually be generated.*

## 22.4 How to program the watchdog timeout

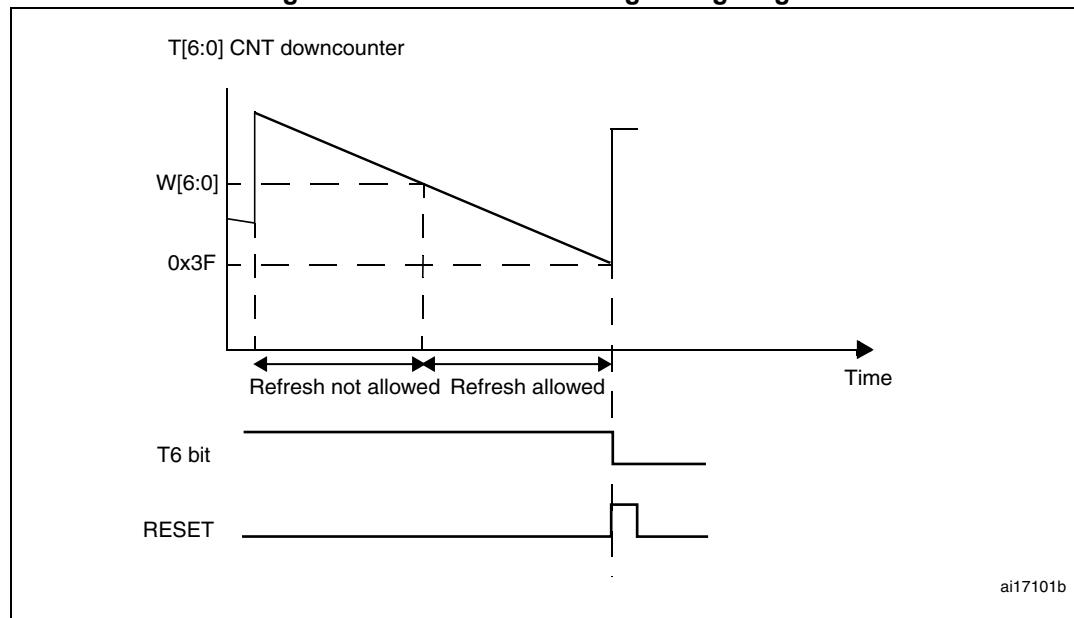
You can use the formula in [Figure 196](#) to calculate the WWDG timeout.

---

**Warning:** **When writing to the WWDG\_CR register, always write 1 in the T6 bit to avoid generating an immediate reset.**

---

**Figure 196. Window watchdog timing diagram**



The formula to calculate the timeout value is given by:

$$t_{\text{WWDG}} = t_{\text{PCLK1}} \times 4096 \times 2^{\text{WDGTB}} \times (t[5:0] + 1) \quad (\text{ms})$$

where:

$t_{\text{WWDG}}$ : WWDG timeout

$t_{\text{PCLK1}}$ : APB1 clock period measured in ms

Refer to the datasheet for the minimum and maximum values of the  $T_{\text{WWDG}}$ .

## 22.5 Debug mode

When the microcontroller enters debug mode (Cortex-M0 core halted), the WWDG counter either continues to work normally or stops, depending on DBG\_WWDG\_STOP configuration bit in DBG module. For more details, refer to [Section 29.9.2: Debug support for timers, watchdog and I2C](#).

## 22.6 WWDG registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

### 22.6.1 Control register (WWDG\_CR)

Address offset: 0x00

Reset value: 0x0000 007F

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	WDGA	T[6:0]													
								rs	rw						

Bits 31:8 Reserved, must be kept at reset value.

#### Bit 7 WDGA: Activation bit

This bit is set by software and only cleared by hardware after a reset. When WDGA = 1, the watchdog can generate a reset.

- 0: Watchdog disabled
- 1: Watchdog enabled

#### Bits 6:0 T[6:0]: 7-bit counter (MSB to LSB)

These bits contain the value of the watchdog counter. It is decremented every  $(4096 \times 2^{\text{WDGTB}})$  PCLK cycles. A reset is produced when it rolls over from 0x40 to 0x3F (T6 becomes cleared).

## 22.6.2 Configuration register (WWDG\_CFR)

Address offset: 0x04

Reset value: 0x0000 007F

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	EWI	WDGTB[1:0]	W[6:0]							
						rs	rw	rw							

Bit 31:10 Reserved, must be kept at reset value.

Bit 9 **EWI**: Early wakeup interrupt

When set, an interrupt occurs whenever the counter reaches the value 0x40. This interrupt is only cleared by hardware after a reset.

Bits 8:7 **WDGTB[1:0]**: Timer base

The time base of the prescaler can be modified as follows:

- 00: CK Counter Clock (PCLK div 4096) div 1
- 01: CK Counter Clock (PCLK div 4096) div 2
- 10: CK Counter Clock (PCLK div 4096) div 4
- 11: CK Counter Clock (PCLK div 4096) div 8

Bits 6:0 **W[6:0]**: 7-bit window value

These bits contain the window value to be compared to the downcounter.

## 22.6.3 Status register (WWDG\_SR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	EWIF														
															rc_w0

Bit 31:1 Reserved, must be kept at reset value.

Bit 0 **EWIF**: Early wakeup interrupt flag

This bit is set by hardware when the counter has reached the value 0x40. It must be cleared by software by writing '0'. A write of '1' has no effect. This bit is also set if the interrupt is not enabled.

#### **22.6.4 WWDG register map**

The following table gives the WWDG register map and reset values.

**Table 59. WWDG register map and reset values**

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 23 Real-time clock (RTC)

### 23.1 Introduction

The real-time clock (RTC) is an independent BCD timer/counter. The RTC provides a time-of-day clock/calendar with programmable alarm interrupt.

The RTC provides an automatic wakeup to manage all low power modes.

Two 32-bit registers contain the seconds, minutes, hours (12- or 24-hour format), day (day of week), date (day of month), month, and year, expressed in binary coded decimal format (BCD). The sub-seconds value is also available in binary format.

Compensations for 28-, 29- (leap year), 30-, and 31-day months are performed automatically. Daylight saving time compensation can also be performed.

Additional 32-bit registers contain the programmable alarm subseconds, seconds, minutes, hours, day, and date.

A digital calibration feature is available to compensate for any deviation in crystal oscillator accuracy.

After backup domain reset, all RTC registers are protected against possible parasitic write accesses.

As long as the supply voltage remains in the operating range, the RTC never stops, regardless of the device status (Run mode, low power mode or under reset).

### 23.2 RTC main features

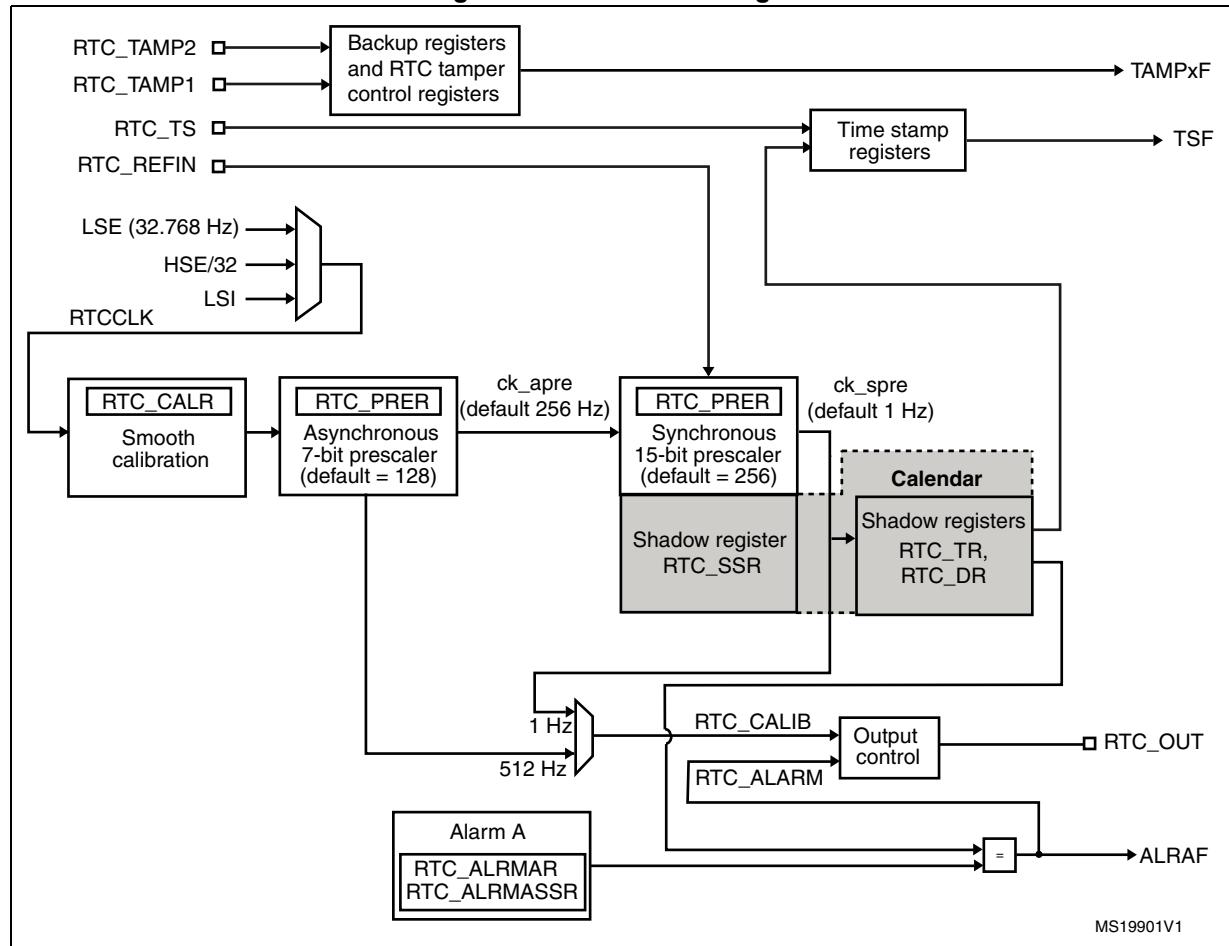
The RTC unit main features are the following (see [Figure 197: RTC block diagram](#)):

- Calendar with subseconds, seconds, minutes, hours (12 or 24 format), day (day of week), date (day of month), month, and year.
- Daylight saving compensation programmable by software.
- Programmable alarm with interrupt function. The alarm can be triggered by any combination of the calendar fields.
- Reference clock detection: a more precise second source clock (50 or 60 Hz) can be used to enhance the calendar precision.
- Accurate synchronization with an external clock using the subsecond shift feature.
- Digital calibration circuit (periodic counter correction): 0.95 ppm accuracy, obtained in a calibration window of several seconds
- Time-stamp function for event saving
- Tamper detection event with configurable filter and internal pull-up
- Maskable interrupts/events:
  - Alarm A
  - Time-stamp
  - Tamper detection
- Backup registers.

## 23.3 RTC functional description

### 23.3.1 RTC block diagram

Figure 197. RTC block diagram



The RTC includes:

- One alarm
- Two tamper events
- Five 32-bit backup registers
- Alternate function outputs: RTC\_OUT which selects one of the following two outputs:
  - RTC\_CALIB: 512 Hz or 1Hz clock output (with an LSE frequency of 32.768 kHz). This output is enabled by setting the COE[23] bit in the RTC\_CR register.
  - RTC\_ALARM: Alarm A. This output is selected by configuring the OSEL[1:0] bits in the RTC\_CR register.
- Alternate function inputs:
  - RTC\_TS : timestamp event
  - RTC\_TAMP1: tamper1 event detection
  - RTC\_TAMP2: tamper2 event detection
  - RTC\_REFIN: 50 or 60 Hz reference clock input

### 23.3.2 GPIOs controlled by the RTC

RTC\_OUT, RTC\_TS and RTC\_TAMP1 are mapped on the same pin (PC13).

The selection of the RTC\_ALARM output is performed through the RTC\_TAFCR register as follows: the PC13VALUE bit is used to select whether the RTC\_ALARM output is configured in push-pull or open drain mode.

When PC13 is not used as RTC alternate function, it can be forced in output push-pull mode by setting the PC13MODE bit in the RTC\_TAFCR. The output data value is then given by the PC13VALUE bit. In this case, PC13 output push-pull state and data are preserved in Standby mode.

The output mechanism follows the priority order shown in [Table 60](#).

When PC14 and PC15 are not used as LSE oscillator, they can be forced in output push-pull mode by setting the PC14MODE and PC15MODE bits in the RTC\_TAFCR register respectively. The output data values are then given by PC14VALUE and PC15VALUE. In this case, the PC14 and PC15 output push-pull states and data values are preserved in Standby mode.

The output mechanism follows the priority order shown in [Table 61](#) and [Table 62](#).

**Table 60. RTC pin PC13 configuration<sup>(1)</sup>**

Pin configuration and function	RTC_ALARM output enabled	RTC_CALIB output enabled	RTC_TAMP1 input enabled	RTC_TS input enabled	PC13MODE bit	PC13VALUE bit
RTC_ALARM output OD	1	Don't care	Don't care	Don't care	Don't care	0
RTC_ALARM output PP	1	Don't care	Don't care	Don't care	Don't care	1
RTC_CALIB output PP	0	1	Don't care	Don't care	Don't care	Don't care
RTC_TAMP1 input floating	0	0	1	0	Don't care	Don't care
RTC_TS and RTC_TAMP1 input floating	0	0	1	1	Don't care	Don't care
RTC_TS input floating	0	0	0	1	Don't care	Don't care
Output PP forced	0	0	0	0	1	PC13 output data value
Wakeup pin or Standard GPIO	0	0	0	0	0	Don't care

1. OD: open drain; PP: push-pull.

Table 61. LSE pin PC14 configuration <sup>(1)</sup>

Pin configuration and function	LSEON bit in RCC_BDCR register	LSEBYP bit in RCC_BDCR register	PC14MODE bit	PC14VALUE bit
LSE oscillator	1	0	Don't care	Don't care
LSE bypass	1	1	Don't care	Don't care
Output PP forced	0	Don't care	1	PC14 output data value
Standard GPIO	0	Don't care	0	Don't care

1. OD: open drain; PP: push-pull.

Table 62. LSE pin PC15 configuration <sup>(1)</sup>

Pin configuration and function	LSEON bit in RCC_BDCR register	LSEBYP bit in RCC_BDCR register	PC15MODE bit	PC15VALUE bit
LSE oscillator	1	0	Don't care	Don't care
Output PP forced	1	1	1	PC15 output data value
	0	Don't care		
Standard GPIO	0	Don't care	0	Don't care

1. OD: open drain; PP: push-pull.

### 23.3.3 Clock and prescalers

The RTC clock source (RTCCLK) is selected through the clock controller among the LSE clock, the LSI oscillator clock, and the HSE clock. For more information on the RTC clock source configuration, refer to [the Reset and clock control \(RCC\) section](#).

A programmable prescaler stage generates a 1 Hz clock which is used to update the calendar. To minimize power consumption, the prescaler is split into 2 programmable prescalers (see [Figure 197: RTC block diagram](#)):

- A 7-bit asynchronous prescaler configured through the PREDIV\_A bits of the RTC\_PRER register.
- A 15-bit synchronous prescaler configured through the PREDIV\_S bits of the RTC\_PRER register.

**Note:** When both prescalers are used, it is recommended to configure the asynchronous prescaler to a high value to minimize consumption.

The asynchronous prescaler division factor is set to 128, and the synchronous division factor to 256, to obtain an internal clock frequency of 1 Hz (ck\_spre) with an LSE frequency of 32.768 kHz.

The minimum division factor is 1 and the maximum division factor is  $2^{22}$ .

This corresponds to a maximum input frequency of around 4 MHz.

$f_{ck\_apre}$  is given by the following formula:

$$f_{CK\_APRE} = \frac{f_{RTCCLK}}{\text{PREDIV\_A} + 1}$$

The ck\_apre clock is used to clock the binary RTC\_SSR subseconds downcounter. When it reaches 0, RTC\_SSR is reloaded with the content of PREDIV\_S.

$f_{ck\_spre}$  is given by the following formula:

$$f_{CK\_SPRE} = \frac{f_{RTCCLK}}{(PREDIV\_S + 1) \times (PREDIV\_A + 1)}$$

### 23.3.4 Real-time clock and calendar

The RTC calendar time and date registers are accessed through shadow registers which are synchronized with PCLK (APB clock). They can also be accessed directly in order to avoid waiting for the synchronization duration.

- RTC\_SSR for the subseconds
- RTC\_TR for the time
- RTC\_DR for the date

Every two RTCCLK periods, the current calendar value is copied into the shadow registers, and the RSF bit of RTC\_ISR register is set (see [Section 23.6.4](#)). The copy is not performed in Stop and Standby mode. When exiting these modes, the shadow registers are updated after up to 2 RTCCLK periods.

When the application reads the calendar registers, it accesses the content of the shadow registers. It is possible to make a direct access to the calendar registers by setting the BYPSHAD control bit in the RTC\_CR register. By default, this bit is cleared, and the user accesses the shadow registers.

When reading the RTC\_SSR, RTC\_TR or RTC\_DR registers in BYPSHAD=0 mode, the frequency of the APB clock ( $f_{APB}$ ) must be at least 7 times the frequency of the RTC clock ( $f_{RTCCLK}$ ).

The shadow registers are reset by system reset.

### 23.3.5 Programmable alarm

The RTC unit provides programmable alarm: Alarm A.

The programmable alarm function is enabled through the ALRAE bit in the RTC\_CR register. The ALRAF is set to 1 if the calendar subseconds, seconds, minutes, hours, date or day match the values programmed in the alarm registers RTC\_ALRMASSR and RTC\_ALRMAR. Each calendar field can be independently selected through the MSKx bits of the RTC\_ALRMAR register, and through the MASKSSx bits of the RTC\_ALRMASSR register. The alarm interrupt is enabled through the ALRAIE bit in the RTC\_CR register.

**Caution:** If the seconds field is selected (MSK0 bit reset in RTC\_ALRMAR), the synchronous prescaler division factor set in the RTC\_PRER register must be at least 3 to ensure correct behavior.

Alarm A (if enabled by bits OSEL[0:1] in RTC\_CR register) can be routed to the RTC\_ALARM output. RTC\_ALARM output polarity can be configured through bit POL the RTC\_CR register.

### 23.3.6 RTC initialization and configuration

#### RTC register access

The RTC registers are 32-bit registers. The APB interface introduces 2 wait-states in RTC register accesses except on read accesses to calendar shadow registers when BYPSHAD=0.

#### RTC register write protection

After system reset, the RTC registers are protected against parasitic write access by clearing the DBP bit in the PWR\_CR register (refer to the power control section). DBP bit must be set in order to enable RTC registers write access.

After backup domain reset, all the RTC registers are write-protected. Writing to the RTC registers is enabled by writing a key into the Write Protection register, RTC\_WPR.

The following steps are required to unlock the write protection on all the RTC registers except for RTC\_ISR[13:8], RTC\_TAFCR, and RTC\_BKPxR.

1. Write '0xCA' into the RTC\_WPR register.
2. Write '0x53' into the RTC\_WPR register.

Writing a wrong key reactivates the write protection.

The protection mechanism is not affected by system reset.

#### Calendar initialization and configuration

To program the initial time and date calendar values, including the time format and the prescaler configuration, the following sequence is required:

1. Set INIT bit to 1 in the RTC\_ISR register to enter initialization mode. In this mode, the calendar counter is stopped and its value can be updated.
2. Poll INITF bit of in the RTC\_ISR register. The initialization phase mode is entered when INITF is set to 1. It takes around 2 RTCCLK clock cycles (due to clock synchronization).
3. To generate a 1 Hz clock for the calendar counter, program both the prescaler factors in RTC\_PRER register.
4. Load the initial time and date values in the shadow registers (RTC\_TR and RTC\_DR), and configure the time format (12 or 24 hours) through the FMT bit in the RTC\_CR register.
5. Exit the initialization mode by clearing the INIT bit. The actual calendar counter value is then automatically loaded and the counting restarts after 4 RTCCLK clock cycles.

When the initialization sequence is complete, the calendar starts counting.

Note:

*After a system reset, the application can read the INITS flag in the RTC\_ISR register to check if the calendar has been initialized or not. If this flag equals 0, the calendar has not been initialized since the year field is set at its backup domain reset default value (0x00).*

*To read the calendar after initialization, the software must first check that the RSF flag is set in the RTC\_ISR register.*

#### Daylight saving time

The daylight saving time management is performed through bits SUB1H, ADD1H, and BKP of the RTC\_CR register.

Using SUB1H or ADD1H, the software can subtract or add one hour to the calendar in one single operation without going through the initialization procedure.

In addition, the software can use the BKP bit to memorize this operation.

### Programming the alarm

A similar procedure must be followed to program or update the programmable alarms.

1. Clear ALRAE in RTC\_CR to disable Alarm A.
2. Program the Alarm A registers (RTC\_ALRMASSR/RTC\_ALRMAR).
3. Set ALRAE in the RTC\_CR register to enable Alarm A again.

*Note:* *Each change of the RTC\_CR register is taken into account after around 2 RTCCLK clock cycles due to clock synchronization.*

### 23.3.7 Reading the calendar

#### When BYPSHAD control bit is cleared in the RTC\_CR register

To read the RTC calendar registers (RTC\_SSR, RTC\_TR and RTC\_DR) properly, the APB1 clock frequency ( $f_{PCLK}$ ) must be equal to or greater than seven times the  $f_{RTCCLK}$  RTC clock frequency. This ensures a secure behavior of the synchronization mechanism.

If the APB1 clock frequency is less than seven times the RTC clock frequency, the software must read the calendar time and date registers twice. If the second read of the RTC\_TR gives the same result as the first read, this ensures that the data is correct. Otherwise a third read access must be done. In any case the APB1 clock frequency must never be lower than the RTC clock frequency.

The RSF bit is set in RTC\_ISR register each time the calendar registers are copied into the RTC\_SSR, RTC\_TR and RTC\_DR shadow registers. The copy is performed every two RTCCLK cycles. To ensure consistency between the 3 values, reading either RTC\_SSR or RTC\_TR locks the values in the higher-order calendar shadow registers until RTC\_DR is read. In case the software makes read accesses to the calendar in a time interval smaller than 2 RTCCLK periods: RSF must be cleared by software after the first calendar read, and then the software must wait until RSF is set before reading again the RTC\_SSR, RTC\_TR and RTC\_DR registers.

After waking up from low power mode (Stop or Standby), RSF must be cleared by software. The software must then wait until it is set again before reading the RTC\_SSR, RTC\_TR and RTC\_DR registers.

The RSF bit must be cleared after wakeup and not before entering low power mode.

After a system reset, the software must wait until RSF is set before reading the RTC\_SSR, RTC\_TR and RTC\_DR registers. Indeed, a system reset resets the shadow registers to their default values.

After an initialization (refer to [Calendar initialization and configuration on page 482](#)): the software must wait until RSF is set before reading the RTC\_SSR, RTC\_TR and RTC\_DR registers.

After synchronization (refer to [Section 23.3.9: RTC synchronization](#)): the software must wait until RSF is set before reading the RTC\_SSR, RTC\_TR and RTC\_DR registers.

### When the BYPSHAD control bit is set in the RTC\_CR register (bypass shadow registers)

Reading the calendar registers gives the values from the calendar counters directly, thus eliminating the need to wait for the RSF bit to be set. This is especially useful after exiting from low power modes (STOP or Standby), since the shadow registers are not updated during these modes.

When the BYPSHAD bit is set to 1, the results of the different registers might not be coherent with each other if an RTCCLK edge occurs between two read accesses to the registers. Additionally, the value of one of the registers may be incorrect if an RTCCLK edge occurs during the read operation. The software must read all the registers twice, and then compare the results to confirm that the data is coherent and correct. Alternatively, the software can just compare the two results of the least-significant calendar register.

**Note:** *While BYPSHAD=1, instructions which read the calendar registers require one extra APB cycle to complete.*

### 23.3.8 Resetting the RTC

The calendar shadow registers (RTC\_SSR, RTC\_TR and RTC\_DR) and some bits of the RTC status register (RTC\_ISR) are reset to their default values by all available system reset sources.

On the contrary, the following registers are reset to their default values by a backup domain reset and are not affected by a system reset: the RTC current calendar registers, the RTC control register (RTC\_CR), the prescaler register (RTC\_PRER), the RTC calibration register (RTC\_CALR), the RTC shift register (RTC\_SHIFTR), the RTC timestamp registers (RTC\_TSSSR, RTC\_TSTR and RTC\_TSDDR), the RTC tamper and alternate function configuration register (RTC\_TAFCR), the RTC backup registers (RTC\_BKPxR), the Alarm A registers (RTC\_ALRMASSR/RTC\_ALRMAR).

In addition, the RTC keeps on running under system reset if the reset source is different from the backup domain reset one. When a backup domain reset occurs, the RTC is stopped and all the RTC registers are set to their reset values.

### 23.3.9 RTC synchronization

The RTC can be synchronized to a remote clock with a high degree of precision. After reading the sub-second field (RTC\_SSR or RTC\_TSSSR), a calculation can be made of the precise offset between the times being maintained by the remote clock and the RTC. The RTC can then be adjusted to eliminate this offset by “shifting” its clock by a fraction of a second using RTC\_SHIFTR.

RTC\_SSR contains the value of the synchronous prescaler’s counter. This allows one to calculate the exact time being maintained by the RTC down to a resolution of  $1 / (\text{PREDIV\_S} + 1)$  seconds. As a consequence, the resolution can be improved by increasing the synchronous prescaler value (PREDIV\_S[14:0]. The maximum resolution allowed (30.52  $\mu$ s with a 32768 Hz clock) is obtained with PREDIV\_S set to 0x7FFF.

However, increasing PREDIV\_S means that PREDIV\_A must be decreased in order to maintain the synchronous prescaler’s output at 1 Hz. In this way, the frequency of the asynchronous prescaler’s output increases, which may increase the RTC dynamic consumption.

The RTC can be finely adjusted using the RTC shift control register (RTC\_SHIFTR). Writing to RTC\_SHIFTR can shift (either delay or advance) the clock by up to a second with a resolution of 1 / (PREDIV\_S + 1) seconds. The shift operation consists of adding the SUBFS[14:0] value to the synchronous prescaler counter SS[15:0]: this will delay the clock. If at the same time the ADD1S bit is set, this results in adding one second and at the same time subtracting a fraction of second, so this will advance the clock.

**Caution:** Before initiating a shift operation, the user must check that SS[15] = 0 in order to ensure that no overflow will occur.

As soon as a shift operation is initiated by a write to the RTC\_SHIFTR register, the SHPF flag is set by hardware to indicate that a shift operation is pending. This bit is cleared by hardware as soon as the shift operation has completed.

**Caution:** This synchronization feature is not compatible with the reference clock detection feature: firmware must not write to RTC\_SHIFTR when REFCKON=1.

### 23.3.10 RTC reference clock detection

The update of the RTC calendar can be synchronized to a reference clock, RTC\_REFIN, which is usually the mains frequency (50 or 60 Hz). The precision of the RTC\_REFIN reference clock should be higher than the 32.768 kHz LSE clock. When the RTC\_REFIN detection is enabled (REFCKON bit of RTC\_CR set to 1), the calendar is still clocked by the LSE, and RTC\_REFIN is used to compensate for the imprecision of the calendar update frequency (1 Hz).

Each 1 Hz clock edge is compared to the nearest RTC\_REFIN clock edge (if one is found within a given time window). In most cases, the two clock edges are properly aligned. When the 1 Hz clock becomes misaligned due to the imprecision of the LSE clock, the RTC shifts the 1 Hz clock a bit so that future 1 Hz clock edges are aligned. Thanks to this mechanism, the calendar becomes as precise as the reference clock.

The RTC detects if the reference clock source is present by using the 256 Hz clock (ck\_apre) generated from the 32.768 kHz quartz. The detection is performed during a time window around each of the calendar updates (every 1 s). The window equals 7 ck\_apre periods when detecting the first reference clock edge. A smaller window of 3 ck\_apre periods is used for subsequent calendar updates.

Each time the reference clock is detected in the window, the asynchronous prescaler which outputs the ck\_apre clock is forced to reload. This has no effect when the reference clock and the 1 Hz clock are aligned because the prescaler is being reloaded at the same moment. When the clocks are not aligned, the reload shifts future 1 Hz clock edges a little for them to be aligned with the reference clock.

If the reference clock halts (no reference clock edge occurred during the 3 ck\_apre window), the calendar is updated continuously based solely on the LSE clock. The RTC then waits for the reference clock using a large 7 ck\_apre period detection window centered on the ck\_spre edge.

When the RTC\_REFIN detection is enabled, PREDIV\_A and PREDIV\_S must be set to their default values:

- PREDIV\_A = 0x007F
- PREDIV\_S = 0x00FF

*Note:* RTC\_REFIN clock detection is not available in Standby mode.

### 23.3.11 RTC smooth digital calibration

The RTC frequency can be digitally calibrated with a resolution of about 0.954 ppm with a range from -487.1 ppm to +488.5 ppm. The correction of the frequency is performed using series of small adjustments (adding and/or subtracting individual RTCCLK pulses). These adjustments are fairly well distributed so that the RTC is well calibrated even when observed over short durations of time.

The smooth digital calibration is performed during a cycle of about  $2^{20}$  RTCCLK pulses, or 32 seconds when the input frequency is 32768 Hz.

The smooth calibration register (RTC\_CALR) specifies the number of RTCCLK clock cycles to be masked during the 32-second cycle:

- Setting the bit CALM[0] to 1 causes exactly one pulse to be masked during the 32-second cycle.
- Setting CALM[1] to 1 causes two additional cycles to be masked
- Setting SMC[2] to 1 causes four additional cycles to be masked
- and so on up to SMC[8] set to 1 which causes 256 clocks to be masked.

While CALM allows the RTC frequency to be reduced by up to 487.1 ppm with fine resolution, the bit CALP can be used to increase the frequency by 488.5 ppm. Setting CALP to '1' effectively inserts an extra RTCCLK pulse every  $2^{11}$  RTCCLK cycles, which means that 512 clocks are added during every 32-second cycle.

Using CALM together with CALP, an offset ranging from -511 to +512 RTCCLK cycles can be added during the 32-second cycle, which translates to a calibration range of -487.1 ppm to +488.5 ppm with a resolution of about 0.954 ppm.

The formula to calculate the effective calibrated frequency ( $F_{CAL}$ ) given the input frequency ( $F_{RTCCLK}$ ) is as follows:

$$F_{CAL} = F_{RTCCLK} \times [1 + (CALP \times 512 - CALM) / (2^{20} + CALM - CALP \times 512)]$$

#### Calibration when PREDIV\_A<3

The CALP bit can not be set to 1 when the asynchronous prescaler value (PREDIV\_A bits in RTC\_PRER register) is less than 3. If CALP was already set to 1 and PREDIV\_A bits are set to a value less than 3, CALP is ignored and the calibration operates as if CALP was equal to 0.

To perform a calibration with PREDIV\_A less than 3, the synchronous prescaler value (PREDIV\_S) should be reduced so that each second is accelerated by 8 RTCCLK clock cycles, which is equivalent to adding 256 clock cycles every 32 seconds. As a result, between 255 and 256 clock pulses (corresponding to a calibration range from 243.3 to 244.1 ppm) can effectively be added during each 32-second cycle using only the CALM bits.

With a nominal RTCCLK frequency of 32768 Hz, when PREDIV\_A equals 1 (division factor of 2), PREDIV\_S should be set to 16379 rather than 16383 (4 less). The only other interesting case is when PREDIV\_A equals 0, PREDIV\_S should be set to 32759 rather than 32767 (8 less).

If PREDIV\_S is reduced in this way, the formula given the effective frequency of the calibrated input clock is as follows:

$$F_{CAL} = F_{RTCCLK} \times [1 + (256 - CALM) / (2^{20} + CALM - 256)]$$

In this case, CALM[7:0] equals 0x100 (the midpoint of the CALM range) is the correct setting if RTCCLK is exactly 32768.00 Hz.

### Verifying the RTC calibration

RTC precision is ensured by measuring the precise frequency of RTCCLK and calculating the correct CALM value and CALP values. An optional 1 Hz output is provided to allow applications to measure and verify the RTC precision.

Measuring the precise frequency of the RTC over a limited interval can result in a measurement error of up to 2 RTCCLK clock cycles over the measurement period, depending on how the digital calibration cycle is aligned with the measurement period.

However, this measurement error can be eliminated if the measurement period is the same length as the calibration cycle period. In this case, the only error observed is the error due to the resolution of the digital calibration.

- By default, the calibration cycle period is 32 seconds.

Using this mode and measuring the accuracy of the 1 Hz output over exactly 32 seconds guarantees that the measure is within 0.477 ppm (0.5 RTCCLK cycles over 32 seconds, due to the limitation of the calibration resolution).

- CALW16 bit of the RTC\_CALR register can be set to 1 to force a 16- second calibration cycle period.

In this case, the RTC precision can be measured during 16 seconds with a maximum error of 0.954 ppm (0.5 RTCCLK cycles over 16 seconds). However, since the calibration resolution is reduced, the long term RTC precision is also reduced to 0.954 ppm: CALM[0] bit is stuck at 0 when CALW16 is set to 1.

- CALW8 bit of the RTC\_CALR register can be set to 1 to force a 8- second calibration cycle period.

In this case, the RTC precision can be measured during 8 seconds with a maximum error of 1.907 ppm (0.5 RTCCLK cycles over 8s). The long term RTC precision is also reduced to 1.907 ppm: CALM[1:0] bits are stuck at 00 when CALW8 is set to 1.

### Re-calibration on-the-fly

The calibration register (RTC\_CALR) can be updated on-the-fly while RTC\_ISR/INITF=0, by using the follow process:

1. Poll the RTC\_ISR/RECALPF (re-calibration pending flag).
2. If it is set to 0, write a new value to RTC\_CALR, if necessary. RECALPF is then automatically set to 1
3. Within three ck\_apre cycles after the write operation to RTC\_CALR, the new calibration settings take effect.

## 23.3.12 Time-stamp function

Time-stamp is enabled by setting the TSE bit of RTC\_CR register to 1.

The calendar is saved in the time-stamp registers (RTC\_TSSSR, RTC\_TSTR, RTC\_TSDR) when a time-stamp event is detected on the RTC\_TS pin. When a time-stamp event occurs, the time-stamp flag bit (TSF) in RTC\_ISR register is set.

By setting the TSIE bit in the RTC\_CR register, an interrupt is generated when a time-stamp event occurs.

If a new time-stamp event is detected while the time-stamp flag (TSF) is already set, the time-stamp overflow flag (TSOVF) flag is set and the time-stamp registers (RTC\_TSTR and RTC\_TSDR) maintain the results of the previous event.

**Note:** *TSF is set 2 ck\_apre cycles after the time-stamp event occurs due to synchronization process.*

*There is no delay in the setting of TSOVF. This means that if two time-stamp events are close together, TSOVF can be seen as '1' while TSF is still '0'. As a consequence, it is recommended to poll TSOVF only after TSF has been set.*

**Caution:** If a time-stamp event occurs immediately after the TSF bit is supposed to be cleared, then both TSF and TSOVF bits are set. To avoid masking a time-stamp event occurring at the same moment, the application must not write '0' into TSF bit unless it has already read it to '1'.

Optionally, a tamper event can cause a time-stamp to be recorded. See the description of the TAMPTS control bit in [Section 23.6.12: RTC time-stamp sub second register \(RTC\\_TSSSR\)](#).

### 23.3.13 Tamper detection

The RTC\_TAMPx input events can be configured either for edge detection, or for level detection with filtering.

#### RTC backup registers

The backup registers (RTC\_BKPxR) are implemented in the V<sub>DD</sub> backup domain that remains powered-on by V<sub>BAT</sub> when the V<sub>DD</sub> power is switched off. They are not reset by system reset, or when the device wakes up from Standby mode. They are reset by a backup domain reset.

The backup registers are reset when a tamper detection event occurs (see [Section 23.6.16: RTC backup registers \(RTC\\_BKPxR\)](#) and [Tamper detection initialization on page 488](#), or when the readout protection of the flash is changed from level 1 to level 0).

#### Tamper detection initialization

Each RTC\_TAMPx tamper detection input is associated with a flag TAMPxF in the RTC\_ISR2 register. Each input can be enabled by setting the corresponding TAMPxE bits to 1 in the RTC\_TAFCR register.

A tamper detection event resets all backup registers (RTC\_BKPxR).

By setting the TAMPIE bit in the RTC\_TAFCR register, an interrupt is generated when a tamper detection event occurs.

#### Timestamp on tamper event

With TAMPTS set to '1', any tamper event causes a timestamp to occur. In this case, either the TSF bit or the TSOVF bit are set in RTC\_ISR, in the same manner as if a normal timestamp event occurs. The affected tamper flag register TAMPxF is set at the same time that TSF or TSOVF is set.

#### Edge detection on tamper inputs

If the TAMPFLT bits are "00", the RTC\_TAMPx pins generate tamper detection events when either a rising edge or a falling edge is observed depending on the corresponding

TAMPxTRG bit. The internal pull-up resistors on the RTC\_TAMPx inputs are deactivated when edge detection is selected.

**Caution:** To avoid losing tamper detection events, the signal used for edge detection is logically ANDed with the corresponding TAMPxE bit in order to detect a tamper detection event in case it occurs before the RTC\_TAMPx pin is enabled.

- When TAMPxTRG = 0: if the RTC\_TAMPx alternate function is already high before tamper detection is enabled (TAMPxE bit set to 1), a tamper event is detected as soon as the RTC\_TAMPx input is enabled, even if there was no rising edge on the RTC\_TAMPx input after TAMPxE was set.
- When TAMPxTRG = 1: if the RTC\_TAMPx alternate function is already low before tamper detection is enabled, a tamper event is detected as soon as the RTC\_TAMPx input is enabled (even if there was no falling edge on the RTC\_TAMPx input after TAMPxE was set).

After a tamper event has been detected and cleared, the RTC\_TAMPx alternate function should be disabled and then re-enabled (TAMPxE set to 1) before re-programming the backup registers (RTC\_BKPxR). This prevents the application from writing to the backup registers while the RTC\_TAMPx input value still indicates a tamper detection. This is equivalent to a level detection on the RTC\_TAMPx alternate function input.

**Note:** *Tamper detection is still active when V<sub>DD</sub> power is switched off. To avoid unwanted resetting of the backup registers, the pin to which the RTC\_TAMPx alternate function is mapped should be externally tied to the correct level.*

### Level detection with filtering on RTC\_TAMPx inputs

Level detection with filtering is performed by setting TAMPFLT to a non-zero value. A tamper detection event is generated when either 2, 4, or 8 (depending on TAMPFLT) consecutive samples are observed at the level designated by the TAMPxTRG bits.

The RTC\_TAMPx inputs are pre-charged through the I/O internal pull-up resistance before its state is sampled, unless disabled by setting TAMPPUDIS to 1. The duration of the precharge is determined by the TAMPPRCH bits, allowing for larger capacitances on the RTC\_TAMPx inputs.

The trade-off between tamper detection latency and power consumption through the pull-up can be optimized by using TAMPFREQ to determine the frequency of the sampling for level detection.

**Note:** *Refer to the datasheets for the electrical characteristics of the pull-up resistors.*

### 23.3.14 Calibration clock output

When the COE bit is set to 1 in the RTC\_CR register, a reference clock is provided on the RTC\_CALIB device output.

If the COSEL bit in the RTC\_CR register is reset and PREDIV\_A = 0x7F, the RTC\_CALIB frequency is  $f_{RTCCLK}/64$ . This corresponds to a calibration output at 512 Hz for an RTCCLK frequency at 32.768 kHz. The RTC\_CALIB duty cycle is irregular: there is a light jitter on falling edges. It is therefore recommended to use rising edges.

When COSEL is set and “PREDIV\_S+1” is a non-zero multiple of 256 (i.e: PREDIV\_S[7:0] = 0xFF), the RTC\_CALIB frequency is  $f_{RTCCLK}/(256 * (PREDIV_A+1))$ . This corresponds to a calibration output at 1 Hz for prescaler default values (PREDIV\_A = 0x7F, PREDIV\_S = 0xFF), with an RTCCLK frequency at 32.768 kHz.

### 23.3.15 Alarm output

The OSEL[1:0] control bits in the RTC\_CR register are used to activate the alarm alternate function output RTC\_ALARM, and to select the function which is output. These functions reflect the contents of the corresponding flags in the RTC\_ISR register.

The polarity of the output is determined by the POL control bit in RTC\_CR so that the opposite of the selected flag bit is output when POL is set to 1.

#### Alarm alternate function output

The RTC\_ALARM pin can be configured in output open drain or output push-pull using the control bit ALARMOUTTYPE in the RTC\_TAFCR register.

**Note:** *Once the RTC\_ALARM output is enabled, it has priority over RTC\_CALIB (COE bit is don't care and must be kept cleared).*

*When the RTC\_CALIB or RTC\_ALARM output is selected, the RTC\_OUT pin is automatically configured in output alternate function.*

## 23.4 RTC low power modes

Table 63. Effect of low power modes on RTC

Mode	Description
Sleep	No effect RTC interrupts cause the device to exit the Sleep mode.
Stop	The RTC remains active when the RTC clock source is LSE or LSI. RTC alarm, RTC tamper event, RTC timestamp event, and RTC Wakeup cause the device to exit the Stop mode.
Standby	The RTC remains active when the RTC clock source is LSE or LSI. RTC alarm, RTC tamper event, RTC timestamp event, and RTC Wakeup cause the device to exit the Standby mode.

## 23.5 RTC interrupts

All RTC interrupts are connected to the EXTI controller. Refer to [the External and internal interrupt/event line mapping section](#).

To enable the RTC Alarm interrupt, the following sequence is required:

1. Configure and enable the EXTI line corresponding to the RTC Alarm event in interrupt mode and select the rising edge sensitivity.
2. Configure and enable the RTC\_ALARM IRQ channel in the NVIC.
3. Configure the RTC to generate RTC alarms (Alarm A).

To enable the RTC Tamper interrupt, the following sequence is required:

1. Configure and enable the EXTI line corresponding to the RTC Tamper event in interrupt mode and select the rising edge sensitivity.
2. Configure and Enable the TAMP\_STAMP IRQ channel in the NVIC.
3. Configure the RTC to detect the RTC tamper event.

To enable the RTC TimeStamp interrupt, the following sequence is required:

1. Configure and enable the EXTI line corresponding to the RTC TimeStamp event in interrupt mode and select the rising edge sensitivity.
2. Configure and Enable the TAMP\_STAMP IRQ channel in the NVIC.
3. Configure the RTC to detect the RTC time-stamp event.

**Table 64. Interrupt control bits**

Interrupt event	Event flag	Enable control bit	Exit the Sleep mode	Exit the Stop mode	Exit the Standby mode
Alarm A	ALRAF	ALRAIE	yes	yes <sup>(1)</sup>	yes <sup>(1)</sup>
RTC_TS input (timestamp)	TSF	TSIE	yes	yes <sup>(1)</sup>	yes <sup>(1)</sup>
RTC_TAMP1 input detection	TAMP1F	TAMPIE	yes	yes <sup>(1)</sup>	yes <sup>(1)</sup>
RTC_TAMP2 input detection	TAMP2F	TAMPIE	yes	yes <sup>(1)</sup>	yes <sup>(1)</sup>

1. Wakeup from STOP and Standby modes is possible only when the RTC clock source is LSE or LSI.

## 23.6 RTC registers

Refer to [Section 1.1 on page 34](#) of the reference manual for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by words (32-bit).

### 23.6.1 RTC time register (RTC\_TR)

The RTC\_TR is the calendar time shadow register. This register must be written in initialization mode only. Refer to [Calendar initialization and configuration on page 482](#) and [Reading the calendar on page 483](#).

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x00

Backup domain reset value: 0x0000 0000

System reset: 0x0000 0000 when BYPSHAD = 0. Not affected when BYPSHAD = 1.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PM	HT[1:0]		HU[3:0]			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MNT[2:0]			MNU[3:0]			Res.	ST[2:0]			SU[3:0]				
	rw	rw	rw	rw	rw	rw	rw		rw	rw	rw	rw	rw	rw	rw

Bits 31-23 Reserved, must be kept at reset value

Bit 22 **PM**: AM/PM notation

- 0: AM or 24-hour format
- 1: PM

Bits 21:20 **HT[1:0]**: Hour tens in BCD format

- Bit 19:16 **HU[3:0]**: Hour units in BCD format  
 Bit 15 Reserved, must be kept at reset value.  
 Bits 14:12 **MNT[2:0]**: Minute tens in BCD format  
 Bit 11:8 **MNU[3:0]**: Minute units in BCD format  
 Bit 7 Reserved, must be kept at reset value.  
 Bits 6:4 **ST[2:0]**: Second tens in BCD format  
 Bit 3:0 **SU[3:0]**: Second units in BCD format

### 23.6.2 RTC date register (RTC\_DR)

The RTC\_DR is the calendar date shadow register. This register must be written in initialization mode only. Refer to [Calendar initialization and configuration on page 482](#) and [Reading the calendar on page 483](#).

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x04

Backup domain reset value: 0x0000 2101

System reset: 0x0000 2101 when BYPSHAD = 0. Not affected when BYPSHAD = 1.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	YT[3:0]				YU[3:0]				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
WDU[2:0]				MT	MU[3:0]				Res.	Res.	DT[1:0]		DU[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw				rw	rw	rw	rw	rw	

Bits 31:24 Reserved, must be kept at reset value

Bits 23:20 **YT[3:0]**: Year tens in BCD format

Bits 19:16 **YU[3:0]**: Year units in BCD format

Bits 15:13 **WDU[2:0]**: Week day units

000: forbidden

001: Monday

...

111: Sunday

Bit 12 **MT**: Month tens in BCD format

Bits 11:8 **MU**: Month units in BCD format

Bits 7:6 Reserved, must be kept at reset value.

Bits 5:4 **DT[1:0]**: Date tens in BCD format

Bits 3:0 **DU[3:0]**: Date units in BCD format

### 23.6.3 RTC control register (RTC\_CR)

Address offset: 0x08

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	COE	OSEL[1:0]	POL	COSEL	BKP	SUB1H	ADD1H	
								rw	rw	rw	rw	rw	rw	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TSIE	Res.	Res.	ALRAIE	TSE	Res.	Res.	ALRAE	Res.	FMT	BYPS HAD	REFCKON	TSEDGE			Res.
rw			rw	rw			rw		rw	rw	rw	rw			

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **COE**: Calibration output enable

This bit enables the RTC\_CALIB output

0: Calibration output disabled

1: Calibration output enabled

Bits 22:21 **OSEL[1:0]**: Output selection

These bits are used to select the flag to be routed to RTC\_ALARM output

00: Output disabled

01: Alarm A output enabled

10: Reserved

11: Reserved

Bit 20 **POL**: Output polarity

This bit is used to configure the polarity of RTC\_ALARM output

0: The pin is high when ALRAF is asserted (depending on OSEL[1:0])

1: The pin is low when ALRAF is asserted (depending on OSEL[1:0]).

Bit 19 **COSEL**: Calibration output selection

When COE=1, this bit selects which signal is output on RTC\_CALIB.

0: Calibration output is 512 Hz

1: Calibration output is 1 Hz

These frequencies are valid for RTCCLK at 32.768 kHz and prescalers at their default values (PREDIV\_A=127 and PREDIV\_S=255). Refer to [Section 23.3.14: Calibration clock output](#)

Bit 18 **BKP**: Backup

This bit can be written by the user to memorize whether the daylight saving time change has been performed or not.

Bit 17 **SUB1H**: Subtract 1 hour (winter time change)

When this bit is set outside initialization mode, 1 hour is subtracted to the calendar time if the current hour is not 0. This bit is always read as 0.

Setting this bit has no effect when current hour is 0.

0: No effect

1: Subtracts 1 hour to the current time. This can be used for winter time change.

Bit 16 **ADD1H**: Add 1 hour (summer time change)

When this bit is set outside initialization mode, 1 hour is added to the calendar time. This bit is always read as 0.

0: No effect

1: Adds 1 hour to the current time. This can be used for summer time change

Bit 15 **TSIE**: Time-stamp interrupt enable

0: Time-stamp Interrupt disable

1: Time-stamp Interrupt enable

Bit 14 Reserved, must be kept at reset value

Bit 13 Reserved, must be kept at reset value

Bit 12 **ALRAIE**: Alarm A interrupt enable

0: Alarm A interrupt disabled

1: Alarm A interrupt enabled

Bit 11 **TSE**: timestamp enable

0: timestamp disable

1: timestamp enable

Bit 10 Reserved, must be kept at reset value

Bit 9 Reserved, must be kept at reset value

Bit 8 **ALRAE**: Alarm A enable

0: Alarm A disabled

1: Alarm A enabled

Bit 7 Reserved, must be kept at reset value.

Bit 6 **FMT**: Hour format

0: 24 hour/day format

1: AM/PM hour format

Bit 5 **BYPSHAD**: Bypass the shadow registers

0: Calendar values (when reading from RTC\_SSR, RTC\_TR, and RTC\_DR) are taken from the shadow registers, which are updated once every two RTCCLK cycles.

1: Calendar values (when reading from RTC\_SSR, RTC\_TR, and RTC\_DR) are taken directly from the calendar counters.

*Note: If the frequency of the APB1 clock is less than seven times the frequency of RTCCLK, BYPSHAD must be set to '1'.*

Bit 4 **REFCKON**: RTC\_REFIN reference clock detection enable (50 or 60 Hz)

0: RTC\_REFIN detection disabled

1: RTC\_REFIN detection enabled

*Note: PREDIV\_S must be 0x00FF.*

Bit 3 **TSEDGE**: Time-stamp event active edge

0: RTC\_TS input rising edge generates a time-stamp event

1: RTC\_TS input falling edge generates a time-stamp event

TSE must be reset when TSEDGE is changed to avoid unwanted TSF setting.

Bits 2:0 Reserved, must be kept at reset value

**Note:** Bits 7, 6 and 4 of this register can be written in initialization mode only (RTC\_ISR/INITF = 1). It is recommended not to change the hour during the calendar hour increment as it could mask the incrementation of the calendar hour.

ADD1H and SUB1H changes are effective in the next second.

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

### 23.6.4 RTC initialization and status register (RTC\_ISR)

This register is write protected (except for RTC\_ISR[13:8] bits). The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x0C

Backup domain reset value: 0x0000 0007

System reset: not affected except INIT, INITF, and RSF bits which are cleared to '0'

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RECALPF
															r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TAMP2F	TAMP1F	TSOVF	TSF	Res.	Res.	ALRAF	INIT	INITF	RSF	INITS	SHPF	Res.	Res.	ALRAWF
	rc_w0	rc_w0	rc_w0	rc_w0			rc_w0	rw	r	rc_w0	r	rc_w0			r

Bits 31:17 Reserved, must be kept at reset value

Bit 16 **RECALPF**: Recalibration pending Flag

The RECALPF status flag is automatically set to '1' when software writes to the RTC\_CALR register, indicating that the RTC\_CALR register is blocked. When the new calibration settings are taken into account, this bit returns to '0'. Refer to [Re-calibration on-the-fly](#).

Bit 15 Reserved, must be kept at reset value

Bit 14 **TAMP2F**: RTC\_TAMP2 detection flag

This flag is set by hardware when a tamper detection event is detected on the RTC\_TAMP2 input.

It is cleared by software writing 0

Bit 13 **TAMP1F**: RTC\_TAMP1 detection flag

This flag is set by hardware when a tamper detection event is detected on the RTC\_TAMP1 input.

It is cleared by software writing 0

Bit 12 **TSOVF**: Time-stamp overflow flag

This flag is set by hardware when a time-stamp event occurs while TSF is already set.

This flag is cleared by software by writing 0. It is recommended to check and then clear TSOVF only after clearing the TSF bit. Otherwise, an overflow might not be noticed if a time-stamp event occurs immediately before the TSF bit is cleared.

Bit 11 **TSF**: Time-stamp flag

This flag is set by hardware when a time-stamp event occurs.

This flag is cleared by software by writing 0.

Bit 10 Reserved, must be kept at reset value.

Bit 9 Reserved, must be kept at reset value.

Bit 8 **ALRAF**: Alarm A flag

This flag is set by hardware when the time/date registers (RTC\_TR and RTC\_DR) match the Alarm A register (RTC\_ALRMAR).

This flag is cleared by software by writing 0.

Bit 7 **INIT**: Initialization mode

0: Free running mode

1: Initialization mode used to program time and date register (RTC\_TR and RTC\_DR), and prescaler register (RTC\_PRER). Counters are stopped and start counting from the new value when INIT is reset.

Bit 6 **INITF**: Initialization flag

When this bit is set to 1, the RTC is in initialization state, and the time, date and prescaler registers can be updated.

0: Calendar registers update is not allowed

1: Calendar registers update is allowed.

Bit 5 **RSF**: Registers synchronization flag

This bit is set by hardware each time the calendar registers are copied into the shadow registers (RTC\_SSRx, RTC\_TRx and RTC\_DRx). This bit is cleared by hardware in initialization mode, while a shift operation is pending (SHPF=1), or when in bypass shadow register mode (BYPSHAD=1). This bit can also be cleared by software.

It is cleared either by software or by hardware in initialization mode.

0: Calendar shadow registers not yet synchronized

1: Calendar shadow registers synchronized

Bit 4 **INITS**: Initialization status flag

This bit is set by hardware when the calendar year field is different from 0 (backup domain reset state).

0: Calendar has not been initialized

1: Calendar has been initialized

Bit 3 **SHPF**: Shift operation pending

0: No shift operation is pending

1: A shift operation is pending

This flag is set by hardware as soon as a shift operation is initiated by a write to the RTC\_SHIFTR register. It is cleared by hardware when the corresponding shift operation has been executed. Writing to the SHPF bit has no effect.

Bit 2 Reserved, must be kept at reset value.

Bit 1 Reserved, must be kept at reset value.

Bit 0 **ALRAWF**: Alarm A write flag

This bit is set by hardware when Alarm A values can be changed, after the ALRAE bit has been set to 0 in RTC\_CR.

It is cleared by hardware in initialization mode.

0: Alarm A update not allowed

1: Alarm A update allowed

*Note:* The bits ALRAF, and TSF are cleared 2 APB clock cycles after programming them to 0.

### 23.6.5 RTC prescaler register (RTC\_PRER)

This register must be written in initialization mode only. The initialization must be performed in two separate write accesses. Refer to [Calendar initialization and configuration on page 482](#).

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x10

Backup domain reset value: 0x007F 00FF

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PREDIV_A[6:0]						
									rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	PREDIV_S[14:0]														
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:23 Reserved, must be kept at reset value

Bits 22:16 **PREDIV\_A[6:0]**: Asynchronous prescaler factor

This is the asynchronous division factor:

$$\text{ck_apre frequency} = \text{RTCCLK frequency}/(\text{PREDIV\_A}+1)$$

Bit 15 Reserved, must be kept at reset value.

Bits 14:0 **PREDIV\_S[14:0]**: Synchronous prescaler factor

This is the synchronous division factor:

$$\text{ck_spres frequency} = \text{ck_apre frequency}/(\text{PREDIV\_S}+1)$$

### 23.6.6 RTC alarm A register (RTC\_ALRMAR)

This register can be written only when ALRAWF is set to 1 in RTC\_ISR, or in initialization mode.

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x1C

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MSK4	WDSEL	DT[1:0]		DU[3:0]				MSK3	PM	HT[1:0]		HU[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSK2	MNT[2:0]			MNU[3:0]				MSK1	ST[2:0]			SU[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

- Bit 31 **MSK4**: Alarm A date mask  
   0: Alarm A set if the date/day match  
   1: Date/day don't care in Alarm A comparison
- Bit 30 **WDSEL**: Week day selection  
   0: DU[3:0] represents the date units  
   1: DU[3:0] represents the week day. DT[1:0] is don't care.
- Bits 29:28 **DT[1:0]**: Date tens in BCD format.
- Bits 27:24 **DU[3:0]**: Date units or day in BCD format.
- Bit 23 **MSK3**: Alarm A hours mask  
   0: Alarm A set if the hours match  
   1: Hours don't care in Alarm A comparison
- Bit 22 **PM**: AM/PM notation  
   0: AM or 24-hour format  
   1: PM
- Bits 21:20 **HT[1:0]**: Hour tens in BCD format.
- Bits 19:16 **HU[3:0]**: Hour units in BCD format.
- Bit 15 **MSK2**: Alarm A minutes mask  
   0: Alarm A set if the minutes match  
   1: Minutes don't care in Alarm A comparison
- Bits 14:12 **MNT[2:0]**: Minute tens in BCD format.
- Bits 11:8 **MNU[3:0]**: Minute units in BCD format.
- Bit 7 **MSK1**: Alarm A seconds mask  
   0: Alarm A set if the seconds match  
   1: Seconds don't care in Alarm A comparison
- Bits 6:4 **ST[2:0]**: Second tens in BCD format.
- Bits 3:0 **SU[3:0]**: Second units in BCD format.

### 23.6.7 RTC write protection register (RTC\_WPR)

Address offset: 0x24

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	KEY														
								w	w	w	w	w	w	w	w

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **KEY**: Write protection key

This byte is written by software.

Reading this byte always returns 0x00.

Refer to [RTC register write protection](#) for a description of how to unlock RTC register write protection.

### 23.6.8 RTC sub second register (RTC\_SSR)

Address offset: 0x28

Backup domain reset value: 0x0000 0000

System reset: 0x0000 0000 when BYPSHAD = 0. Not affected when BYPSHAD = 1.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value

Bits 15:0 **SS**: Sub second value

SS[15:0] is the value in the synchronous prescaler's counter. The fraction of a second is given by the formula below:

Second fraction = ( PREDIV\_S - SS ) / ( PREDIV\_S + 1 )

*Note: SS can be larger than PREDIV\_S only after a shift operation. In that case, the correct time/date is one second less than as indicated by RTC\_TR/RTC\_DR.*

### 23.6.9 RTC shift control register (RTC\_SHIFTR)

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x2C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ADD1S	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
w															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SUBFS[14:0]														
	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bit 31 **ADD1S**: Add one second

0: No effect

1: Add one second to the clock/calendar

This bit is write only and is always read as zero. Writing to this bit has no effect when a shift operation is pending (when SHPF=1, in RTC\_ISR).

This function is intended to be used with SUBFS (see description below) in order to effectively add a fraction of a second to the clock in an atomic operation.

Bits 30:15 Reserved, must be kept at reset value

Bits 14:0 **SUBFS**: Subtract a fraction of a second

These bits are write only and is always read as zero. Writing to this bit has no effect when a shift operation is pending (when SHPF=1, in RTC\_ISR).

The value which is written to SUBFS is added to the synchronous prescaler's counter. Since this counter counts down, this operation effectively subtracts from (delays) the clock by:

Delay (seconds) = SUBFS / ( PREDIV\_S + 1 )

A fraction of a second can effectively be added to the clock (advancing the clock) when the ADD1S function is used in conjunction with SUBFS, effectively advancing the clock by:

Advance (seconds) = ( 1 - ( SUBFS / ( PREDIV\_S + 1 ) ) ).

*Note: Writing to SUBFS causes RSF to be cleared. Software can then wait until RSF=1 to be sure that the shadow registers have been updated with the shifted time.*

### 23.6.10 RTC timestamp time register (RTC\_TSTR)

The content of this register is valid only when TSF is set to 1 in RTC\_ISR. It is cleared when TSF bit is reset.

Address offset: 0x30

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PM	HT[1:0]		HU[3:0]			
15	14	13	12	11	10	9	8	7	6	r	r	r	r	r	r
Res.	MNT[2:0]			MNU[3:0]				Res.	ST[2:0]			SU[3:0]			
	r	r	r	r	r	r	r		r	r	r	r	r	r	r

Bits 31:23 Reserved, must be kept at reset value

Bit 22 **PM**: AM/PM notation

0: AM or 24-hour format

1: PM

Bits 21:20 **HT[1:0]**: Hour tens in BCD format.

Bits 19:16 **HU[3:0]**: Hour units in BCD format.

Bit 15 Reserved, must be kept at reset value

Bits 14:12 **MNT[2:0]**: Minute tens in BCD format.

Bits 11:8 **MNU[3:0]**: Minute units in BCD format.

Bit 7 Reserved, must be kept at reset value

Bits 6:4 **ST[2:0]**: Second tens in BCD format.

Bits 3:0 **SU[3:0]**: Second units in BCD format.

### 23.6.11 RTC timestamp date register (RTC\_TSDR)

The content of this register is valid only when TSF is set to 1 in RTC\_ISR. It is cleared when TSF bit is reset.

Address offset: 0x34

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WDU[1:0]		MT	MU[3:0]				Res.	Res.	DT[1:0]		DU[3:0]				
r	r	r	r	r	r	r	r			r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value

Bits 15:13 **WDU[1:0]**: Week day units

Bit 12 **MT**: Month tens in BCD format

Bits 11:8 **MU[3:0]**: Month units in BCD format

Bits 7:6 Reserved, must be kept at reset value

Bits 5:4 **DT[1:0]**: Date tens in BCD format

Bit 3:0 **DU[3:0]**: Date units in BCD format

### 23.6.12 RTC time-stamp sub second register (RTC\_TSSSR)

The content of this register is valid only when RTC\_ISR/TSF is set. It is cleared when the RTC\_ISR/TSF bit is reset.

Address offset: 0x38

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value

Bits 15:0 **SS**: Sub second value

SS[15:0] is the value of the synchronous prescaler's counter when the timestamp event occurred.

### 23.6.13 RTC calibration register (RTC\_CALR)

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#).

Address offset: 0x3C

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CALP	CALW8	CALW 16	Res.	Res.	Res.	Res.	CALM[8:0]								
rw	rw	rw					rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 31:16 Reserved, must be kept at reset value

Bit 15 **CALP**: Increase frequency of RTC by 488.5 ppm

0: No RTCCLK pulses are added.

1: One RTCCLK pulse is effectively inserted every  $2^{11}$  pulses (frequency increased by 488.5 ppm).

This feature is intended to be used in conjunction with CALM, which lowers the frequency of the calendar with a fine resolution. If the input frequency is 32768 Hz, the number of RTCCLK pulses added during a 32-second window is calculated as follows:  $(512 * \text{CALP}) - \text{CALM}$ .

Refer to [Section 23.3.11: RTC smooth digital calibration](#).

*Note:*

Bit 14 **CALW8**: Use an 8-second calibration cycle period

When CALW8 is set to '1', the 8-second calibration cycle period is selected.

*Note:* CALM[1:0] are stuck at "00" when CALW8='1'. Refer to [Section 23.3.11: RTC smooth digital calibration](#).

Bit 13 **CALW16:** Use a 16-second calibration cycle period

When CALW16 is set to '1', the 16-second calibration cycle period is selected. This bit must not be set to '1' if CALW8=1.

*Note: CALM[0] is stuck at '0' when CALW16='1'. Refer to [Section 23.3.11: RTC smooth digital calibration](#).*

Bits 12:9 Reserved, must be kept at reset value

Bits 8:0 CALM[8:0]: Calibration minus

The frequency of the calendar is reduced by masking CALM out of  $2^{20}$  RTCCLK pulses (32 seconds if the input frequency is 32768 Hz). This decreases the frequency of the calendar with a resolution of 0.9537 ppm.

To increase the frequency of the calendar, this feature should be used in conjunction with CALP. See [Section 23.3.11: RTC smooth digital calibration on page 486](#).

### 23.6.14 RTC tamper and alternate function configuration register (RTC\_TAFCR)

Address offset: 0x40

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PC15 MODE	PC15 VALUE	PC14 MODE	PC14 VALUE	PC13 MODE	PC13 VALUE	Res.	Res.
								rw	rw	rw	rw	rw	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TAMPP UDIS	TAMPPRCH [1:0]	TAMPFLT[1:0]	TAMPFREQ[2:0]	TAMPT S	Res.	Res.	TAMP2 TRG	TAMP2 E	TAMP1 IE	TAMP1 TRG	TAMP1 E				
rw	rw	rw	rw	rw	rw	rw	rw		rw	rw	rw	rw	rw	rw	rw

Bit 31:24 Reserved, must be kept at reset value.

Bit 23 **PC15MODE:** PC15 mode

0: PC15 is controlled by the GPIO configuration registers. Consequently PC15 is floating in Standby mode.

1: PC15 is forced to push-pull output if LSE is disabled.

Bit 22 **PC15VALUE:** PC15 value

If the LSE is disabled and PC15MODE = 1, PC15VALUE configures the PC15 output data.

Bit 21 **PC14MODE:** PC14 mode

0: PC14 is controlled by the GPIO configuration registers. Consequently PC14 is floating in Standby mode.

1: PC14 is forced to push-pull output if LSE is disabled.

Bit 20 **PC14VALUE:** PC14 value

If the LSE is disabled and PC14MODE = 1, PC14VALUE configures the PC14 output data.

Bit 19 **PC13MODE:** PC13 mode

0: PC13 is controlled by the GPIO configuration registers. Consequently PC13 is floating in Standby mode.

1: PC13 is forced to push-pull output if all RTC alternate functions are disabled.

Bit 18 **PC13VALUE**: RTC\_ALARM output type/PC13 value

If PC13 is used to output RTC\_ALARM, PC13VALUE configures the output configuration:

- 0: RTC\_ALARM is an open-drain output
- 1: RTC\_ALARM is a push-pull output

If all RTC alternate functions are disabled and PC13MODE = 1, PC13VALUE configures the PC13 output data.

Bits 17:16 Reserved, must be kept at reset value.

Bit 15 **TAMPPUDIS**: RTC\_TAMPx pull-up disable

This bit determines if each of the RTC\_TAMPx pins are pre-charged before each sample.

- 0: Precharge RTC\_TAMPx pins before sampling (enable internal pull-up)
- 1: Disable precharge of RTC\_TAMPx pins.

Bits 14:13 **TAMPPRCH[1:0]**: RTC\_TAMPx precharge duration

These bit determines the duration of time during which the pull-up/is activated before each sample. TAMPPRCH is valid for each of the RTC\_TAMPx inputs.

- 0x0: 1 RTCCLK cycle
- 0x1: 2 RTCCLK cycles
- 0x2: 4 RTCCLK cycles
- 0x3: 8 RTCCLK cycles

Bits 12:11 **TAMPFLT[1:0]**: RTC\_TAMPx filter count

These bits determines the number of consecutive samples at the specified level (TAMP\*TRG) needed to activate a Tamper event. TAMPFLT is valid for each of the RTC\_TAMPx inputs.

- 0x0: Tamper event is activated on edge of RTC\_TAMPx input transitions to the active level (no internal pull-up on RTC\_TAMPx input).
- 0x1: Tamper event is activated after 2 consecutive samples at the active level.
- 0x2: Tamper event is activated after 4 consecutive samples at the active level.
- 0x3: Tamper event is activated after 8 consecutive samples at the active level.

Bits 10:8 **TAMPFREQ[2:0]**: Tamper sampling frequency

Determines the frequency at which each of the RTC\_TAMPx inputs are sampled.

- 0x0: RTCCLK / 32768 (1 Hz when RTCCLK = 32768 Hz)
- 0x1: RTCCLK / 16384 (2 Hz when RTCCLK = 32768 Hz)
- 0x2: RTCCLK / 8192 (4 Hz when RTCCLK = 32768 Hz)
- 0x3: RTCCLK / 4096 (8 Hz when RTCCLK = 32768 Hz)
- 0x4: RTCCLK / 2048 (16 Hz when RTCCLK = 32768 Hz)
- 0x5: RTCCLK / 1024 (32 Hz when RTCCLK = 32768 Hz)
- 0x6: RTCCLK / 512 (64 Hz when RTCCLK = 32768 Hz)
- 0x7: RTCCLK / 256 (128 Hz when RTCCLK = 32768 Hz)

Bit 7 **TAMPTS**: Activate timestamp on tamper detection event

- 0: Tamper detection event does not cause a timestamp to be saved
- 1: Save timestamp on tamper detection event

TAMPTS is valid even if TSE=0 in the RTC\_CR register.

Bits 6:5 Reserved, must be kept at reset value.

Bit 4 **TAMP2TRG**: Active level for RTC\_TAMP2 input  
 if TAMPFLT != 00:  
 0: RTC\_TAMP2 input staying low triggers a tamper detection event.  
 1: RTC\_TAMP2 input staying high triggers a tamper detection event.  
 if TAMPFLT = 00:  
 0: RTC\_TAMP2 input rising edge triggers a tamper detection event.  
 1: RTC\_TAMP2 input falling edge triggers a tamper detection event.

Bit 3 **TAMP2E**: RTC\_TAMP2 input detection enable  
 0: RTC\_TAMP2 detection disabled  
 1: RTC\_TAMP2 detection enabled

Bit 2 **TAMPIE**: Tamper interrupt enable  
 0: Tamper interrupt disabled  
 1: Tamper interrupt enabled.

Bit 1 **TAMP1TRG**: Active level for RTC\_TAMP1 input  
 If TAMPFLT != 00  
 0: RTC\_TAMP1 input staying low triggers a tamper detection event.  
 1: RTC\_TAMP1 input staying high triggers a tamper detection event.  
 if TAMPFLT = 00:  
 0: RTC\_TAMP1 input rising edge triggers a tamper detection event.  
 1: RTC\_TAMP1 input falling edge triggers a tamper detection event.

Bit 0 **TAMP1E**: RTC\_TAMP1 input detection enable  
 0: RTC\_TAMP1 detection disabled  
 1: RTC\_TAMP1 detection enabled

**Caution:** When TAMPFLT = 0, TAMP1E must be reset when TAMP1TRG is changed to avoid spuriously setting TAMP1F.

### 23.6.15 RTC alarm A sub second register (RTC\_ALRMASSR)

This register can be written only when ALRAE is reset in RTC\_CR register, or in initialization mode.

This register is write protected. The write access procedure is described in [RTC register write protection on page 482](#)

Address offset: 0x44

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	MASKSS[3:0]				Res.							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SS[14:0]														
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	w	rw	rw	rw

Bits 31:28 Reserved, must be kept at reset value.

Bits 27:24 MASKSS[3:0]: Mask the most-significant bits starting at this bit

0: No comparison on sub seconds for Alarm A. The alarm is set when the seconds unit is incremented (assuming that the rest of the fields match).

1: SS[14:1] are don't care in Alarm A comparison. Only SS[0] is compared.

2: SS[14:2] are don't care in Alarm A comparison. Only SS[1:0] are compared.

3: SS[14:3] are don't care in Alarm A comparison. Only SS[2:0] are compared.

...

12: SS[14:12] are don't care in Alarm A comparison. SS[11:0] are compared.

13: SS[14:13] are don't care in Alarm A comparison. SS[12:0] are compared.

14: SS[14] is don't care in Alarm A comparison. SS[13:0] are compared.

15: All 15 SS bits are compared and must match to activate alarm.

The overflow bits of the synchronous counter (bits 15) is never compared. This bit can be different from 0 only after a shift operation.

Bits 23:15 Reserved, must be kept at reset value.

Bits 14:0 SS[14:0]: Sub seconds value

This value is compared with the contents of the synchronous prescaler's counter to determine if Alarm A is to be activated. Only bits 0 up MASKSS-1 are compared.

### 23.6.16 RTC backup registers (RTC\_BKPxR)

Address offset: 0x50 to 0x60

Backup domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
BKP[31:16]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BKP[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	w	rw	rw

Bits 31:0 **BKP[31:0]**

The application can write or read data to and from these registers.

They are powered-on by  $V_{BAT}$  when  $V_{DD}$  is switched off, so that they are not reset by System reset, and their contents remain valid when the device operates in low-power mode. This register is reset on a tamper detection event, as long as TAMPxF=1. or when the Flash readout protection is disabled.

### 23.6.17 RTC register map

**Table 65. RTC register map and reset values**

Offset	Register	Field	Description
0x00	RTC_TR	RESERVED[31:0]	Reset value
0x04	RTC_DR	RESERVED[30:0]	Reset value
0x08	RTC_CR	RESERVED[29:0]	Reset value
0x0C	RTC_ISR	RESERVED[28:0]	Reset value
0x10	RTC_PRER	RESERVED[27:0]	Reset value
0x10	RTC_PRER	PREDIV_A[6:0]	
0x10	RTC_PRER	PREDIV_S[14:0]	
0x1C	RTC_ALRMA_R	MSK4[31:0]	Reset value
0x1C	RTC_ALRMA_R	WDSEL[31:0]	Reset value
0x1C	RTC_WPR	DU[3:0]	Reset value
0x1C	RTC_WPR	HT[1:0]	Reset value
0x24	RTC_WPR	HU[3:0]	Reset value
0x24	RTC_WPR	YU[3:0]	Reset value
0x24	RTC_WPR	YTF[3:0]	Reset value
0x28	RTC_SSR	PREDIV_A[6:0]	Reset value
0x28	RTC_SSR	PREDIV_S[14:0]	Reset value
0x2C	RTC_SHIFTR	MSK3[31:0]	Reset value
0x2C	RTC_SHIFTR	PM[31:0]	Reset value
0x30	RTC_TSTR	HT[1:0]	Reset value
0x30	RTC_TSTR	HU[3:0]	Reset value
0x30	RTC_TSTR	SS[15:0]	Reset value
0x34	RTC_TSDR	MNT[2:0]	Reset value
0x34	RTC_TSDR	WDU[1:0]	Reset value
0x34	RTC_TSDR	MNU[3:0]	Reset value
0x38	RTC_TSSSR	MNU[3:0]	Reset value
0x38	RTC_TSSSR	ST[2:0]	Reset value
0x38	RTC_TSSSR	SU[3:0]	Reset value

Table 65. RTC register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
0x3C	<b>RTC_CALR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.				
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
0x40	<b>RTC_TAFCR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
		Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
0x44	<b>RTC_ALRMASSR</b>	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
		Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
0x50 to 0x60	<b>RTC_BKP0R</b>	BKP[31:0]																																			
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	to <b>RTC_BKP4R</b>	BKP[31:0]																																			
0x50 to 0x60	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	TAMP_PUDIS	0	TAMP_PUDIS	0	CALP	0	CALW8	0	CALW16	0	TAMP_PUDIS	0	TAMP_PUDIS	0	TAMP_PUDIS																						
SS[14:0]																																					
CALM[8:0]																																					

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 24 Inter-integrated circuit (I<sup>2</sup>C) interface

### 24.1 I<sup>2</sup>C introduction

The I<sup>2</sup>C (inter-integrated circuit) bus interface handles communications between the microcontroller and the serial I<sup>2</sup>C bus. It provides multimaster capability, and controls all I<sup>2</sup>C bus-specific sequencing, protocol, arbitration and timing. It supports standard speed mode, Fast Mode and Fast Mode Plus.

It is also SMBus (system management bus) and PMBus (power management bus) compatible.

DMA can be used to reduce CPU overload.

### 24.2 I<sup>2</sup>C main features

- I<sup>2</sup>C bus specification rev03 compatibility:
  - Slave and master modes
  - Multimaster capability
  - Standard mode (up to 100 kHz)
  - Fast Mode (up to 400 kHz)
  - Fast Mode Plus (up to 1 MHz)
  - 7-bit and 10-bit addressing mode
  - Multiple 7-bit slave addresses (2 addresses, 1 with configurable mask)
  - All 7-bit addresses acknowledge mode
  - General call
  - Programmable setup and hold times
  - Easy to use event management
  - Optional clock stretching
  - Software reset
- 1-byte buffer with DMA capability
- Programmable analog and digital noise filters

The following additional features are also available depending on the product implementation (see [Section 24.3: I<sup>2</sup>C implementation](#)):

- SMBus specification rev 2.0 compatibility:
  - Hardware PEC (Packet Error Checking) generation and verification with ACK control
  - Command and data acknowledge control
  - Address resolution protocol (ARP) support
  - Host and Device support
  - SMBus alert
  - Timeouts and idle condition detection
- PMBus rev 1.1 standard compatibility
- Independent clock: a choice of independent clock sources allowing the I<sup>2</sup>C communication speed to be independent from the PCLK reprogramming
- Wakeup from Stop on address match.

## 24.3 I<sup>2</sup>C implementation

This manual describes the full set of features implemented in I<sup>2</sup>C1. I<sup>2</sup>C2 supports a smaller set of features, but is otherwise identical to I<sup>2</sup>C1. The differences are listed in the following table.

**Table 66. STM32F05xxx I<sup>2</sup>C implementation**

I <sup>2</sup> C features <sup>(1)</sup>	I <sup>2</sup> C1	I <sup>2</sup> C2
Independent clock	X	
SMBus	X	
Wakeup from Stop	X	
20 mA output drive for FM+ mode	X	

1. X = supported.

## 24.4 I<sup>2</sup>C functional description

In addition to receiving and transmitting data, this interface converts it from serial to parallel format and vice versa. The interrupts are enabled or disabled by software. The interface is connected to the I<sup>2</sup>C bus by a data pin (SDA) and by a clock pin (SCL). It can be connected with a standard (up to 100 kHz), Fast Mode (up to 400 kHz) or Fast Mode Plus (up to 1 MHz) I<sup>2</sup>C bus.

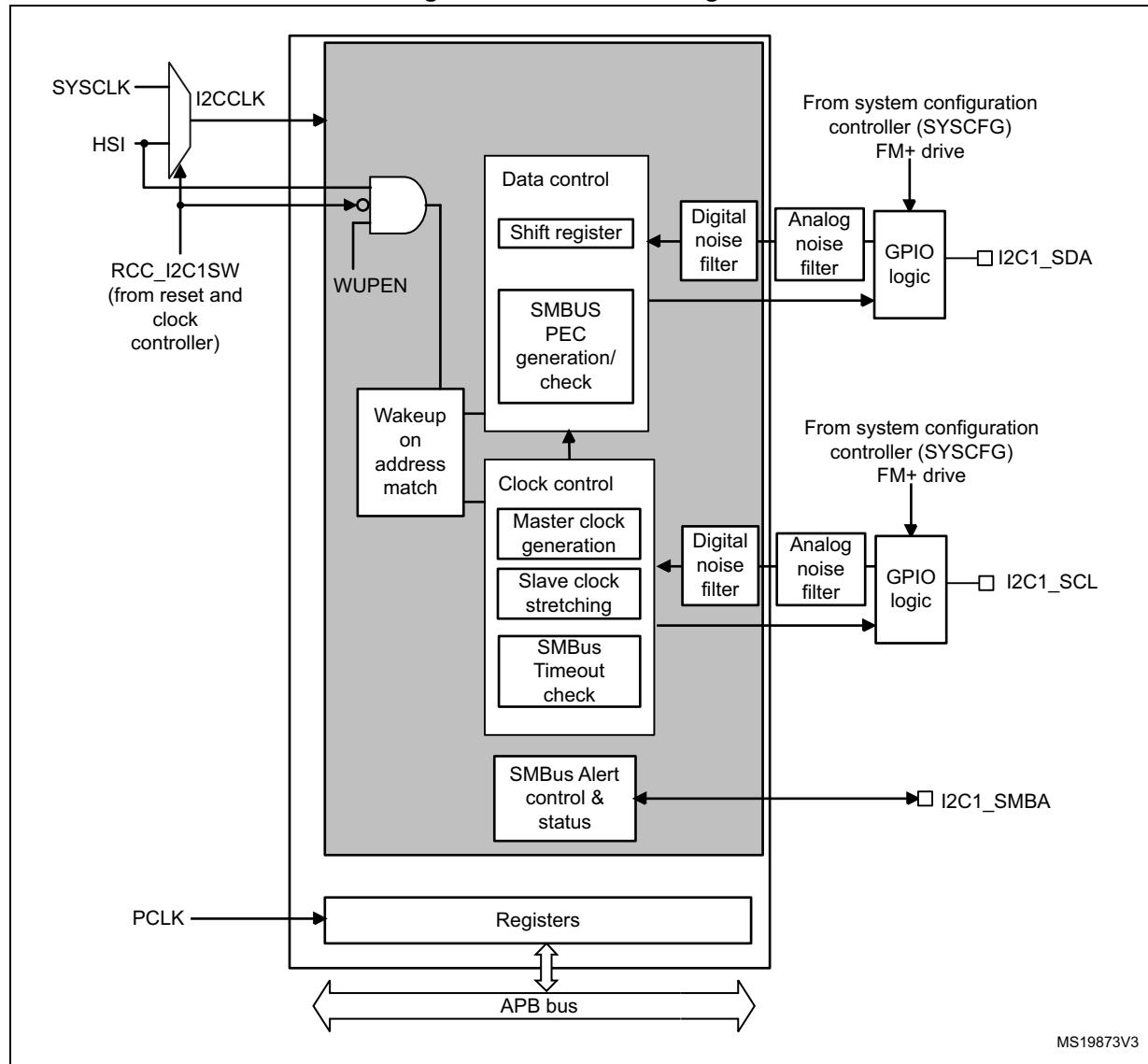
This interface can also be connected to a SMBus with the data pin (SDA) and clock pin (SCL).

If SMBus feature is supported: the additional optional SMBus Alert pin (SMBA) is also available.

#### 24.4.1 I<sup>2</sup>C1 block diagram

The block diagram of the I<sup>2</sup>C1 interface is shown in [Figure 198](#).

**Figure 198. I<sup>2</sup>C1 block diagram**



MS19873V3

The I<sup>2</sup>C1 is clocked by an independent clock source which allows the I<sup>2</sup>C to operate independently from the PCLK frequency.

This independent clock source can be selected for either of the following two clock sources:

- HSI: high speed internal oscillator (default value)
- SYSCLK: system clock

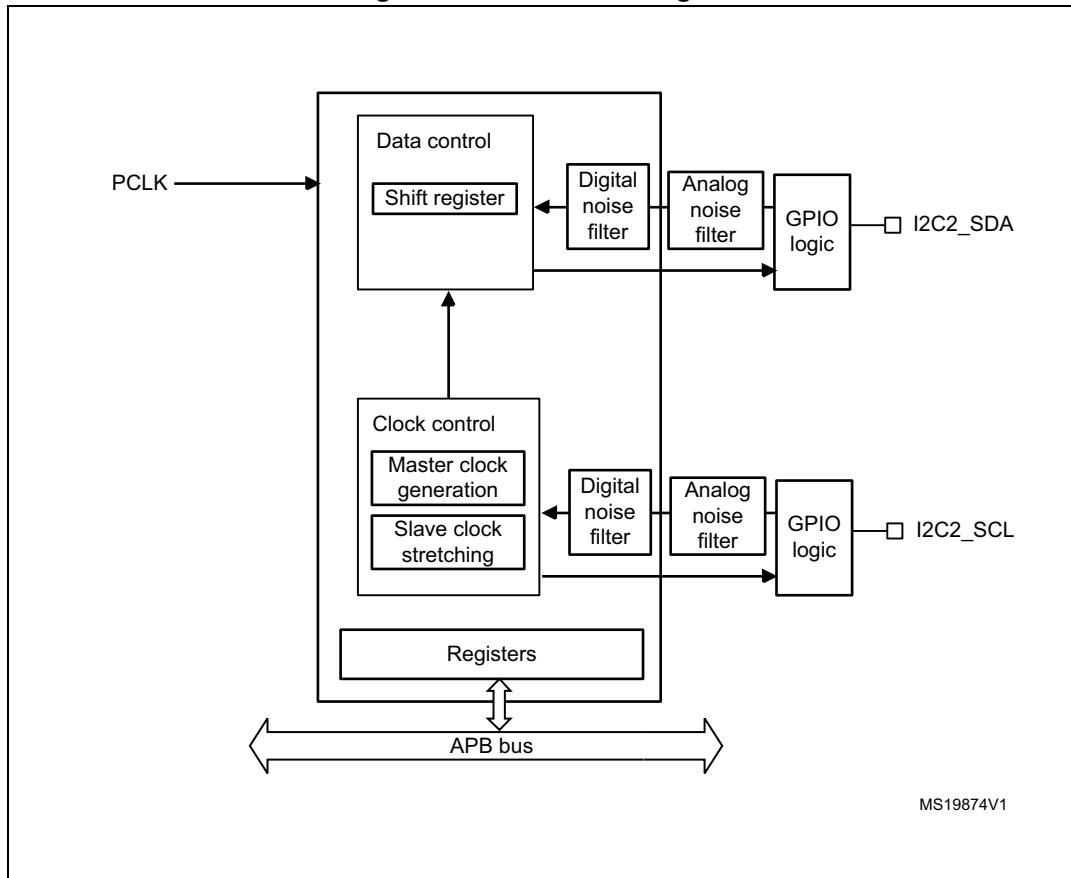
Refer to [Section 7: Reset and clock control \(RCC\)](#) for more details.

I<sup>2</sup>C1 I/Os support 20 mA output current drive for Fast Mode Plus operation. This is enabled by setting the driving capability control bits for SCL and SDA in the [Section 10.1.1: SYSCFG configuration register 1 \(SYSCFG\\_CFGR1\)](#).

#### 24.4.2 I<sup>2</sup>C2 block diagram

The block diagram of the I<sup>2</sup>C interface is shown in [Figure 199](#).

**Figure 199. I<sup>2</sup>C2 block diagram**



#### 24.4.3 I<sup>2</sup>C clock requirements

The I<sup>2</sup>C kernel is clocked by I<sub>2</sub>CCLK.

The I<sub>2</sub>CCLK period  $t_{I2CCLK}$  must respect the following conditions:

$$t_{I2CCLK} < (t_{LOW} - t_{filters}) / 4 \text{ and } t_{I2CCLK} < t_{HIGH}$$

with:

$t_{LOW}$ : SCL low time and  $t_{HIGH}$ : SCL high time

$t_{filters}$ : when enabled, sum of the delays brought by the analog filter and by the digital filter.

Analog filter delay is maximum 260 ns. Digital filter delay is DNF  $\times t_{I2CCLK}$ .

The PCLK clock period  $t_{PCLK}$  must respect the following condition:

$$t_{PCLK} < 4/3 t_{SCL}$$

with  $t_{SCL}$ : SCL period

**Caution:** When the I<sup>2</sup>C kernel is clocked by PCLK. PCLK must respect the conditions for  $t_{I2CCLK}$ .

#### 24.4.4 Mode selection

The interface can operate in one of the four following modes:

- Slave transmitter
- Slave receiver
- Master transmitter
- Master receiver

By default, it operates in slave mode. The interface automatically switches from slave to master when it generates a START condition, and from master to slave if an arbitration loss or a STOP generation occurs, allowing multimaster capability.

#### Communication flow

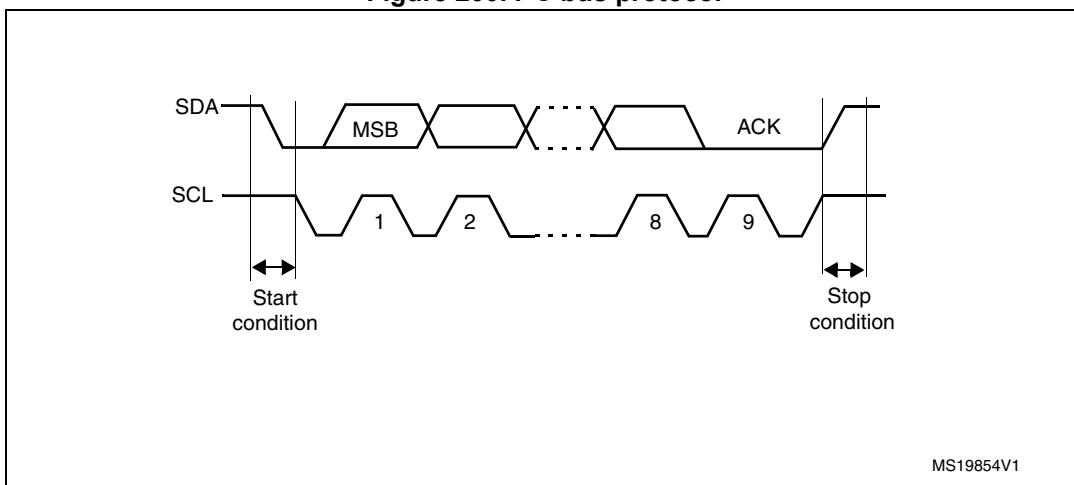
In Master mode, the  $I^2C$  interface initiates a data transfer and generates the clock signal. A serial data transfer always begins with a START condition and ends with a STOP condition. Both START and STOP conditions are generated in master mode by software.

In Slave mode, the interface is capable of recognizing its own addresses (7 or 10-bit), and the General Call address. The General Call address detection can be enabled or disabled by software. The reserved SMBus addresses can also be enabled by software.

Data and addresses are transferred as 8-bit bytes, MSB first. The first byte(s) following the START condition contain the address (one in 7-bit mode, two in 10-bit mode). The address is always transmitted in Master mode.

A 9th clock pulse follows the 8 clock cycles of a byte transfer, during which the receiver must send an acknowledge bit to the transmitter. Refer to the following figure.

**Figure 200.  $I^2C$  bus protocol**



Acknowledge can be enabled or disabled by software. The  $I^2C$  interface addresses can be selected by software.

## 24.4.5 I<sup>2</sup>C initialization

### Enabling and disabling the peripheral

The I<sup>2</sup>C peripheral clock must be configured and enabled in the clock controller (refer to [Section 7: Reset and clock control \(RCC\)](#)).

Then the I<sup>2</sup>C can be enabled by setting the PE bit in the I2Cx\_CR1 register.

When the I<sup>2</sup>C is disabled (PE=0), the I<sup>2</sup>C performs a software reset. Refer to [Section 24.4.6: Software reset](#) for more details.

### Noise filters

Before you enable the I<sup>2</sup>C peripheral by setting the PE bit in I2Cx\_CR1 register, you must configure the noise filters, if needed. By default, an analog noise filter is present on the SDA and SCL inputs. This analog filter is compliant with the I<sup>2</sup>C specification which requires the suppression of spikes with a pulse width up to 50 ns in Fast Mode and Fast Mode Plus. You can disable this analog filter by setting the ANFOFF bit, and/or select a digital filter by configuring the DNF[3:0] bit in the I2Cx\_CR1 register.

When the digital filter is enabled, the level of the SCL or the SDA line is internally changed only if it remains stable for more than DNF x I2CCLK periods. This allows to suppress spikes with a programmable length of 1 to 15 I2CCLK periods.

**Table 67. Comparison of analog vs. digital filters**

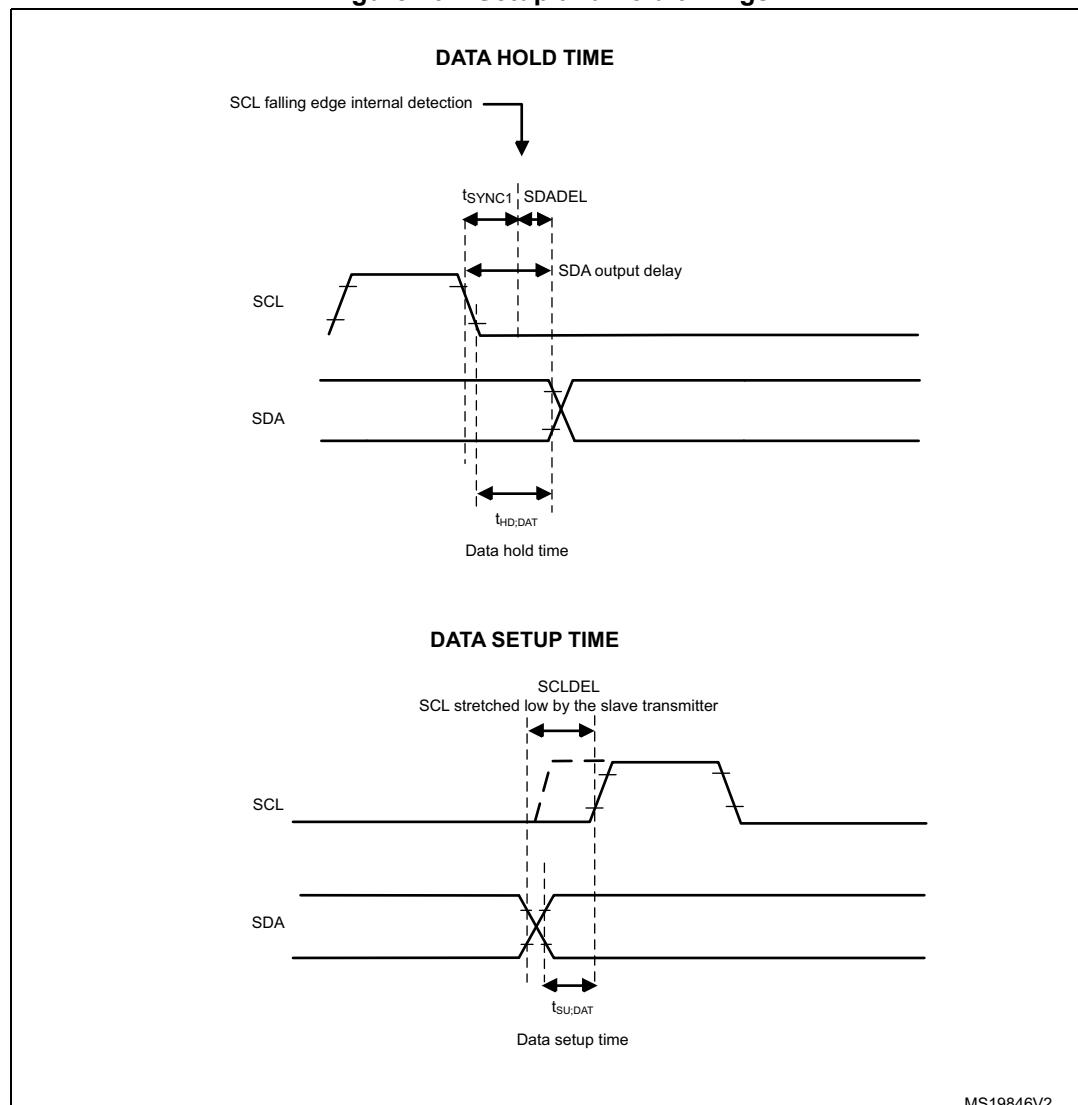
	Analog filter	Digital filter
Pulse width of suppressed spikes	≥ 50 ns	Programmable length from 1 to 15 I <sup>2</sup> C peripheral clocks
Benefits	Available in Stop mode	<ul style="list-style-type: none"> <li>– Programmable length: extra filtering capability vs. standard requirements</li> <li>– Stable length</li> </ul>
Drawbacks	Variation vs. temperature, voltage, process	Wakeup from Stop on address match is not available when digital filter is enabled

**Caution:** Changing the filter configuration is not allowed when the I<sup>2</sup>C is enabled.

## I<sup>2</sup>C timings

The timings must be configured in order to guarantee a correct data hold and setup time, used in master and slave modes. This is done by programming the PRESC[3:0], SCLDEL[3:0] and SDADEL[3:0] bits in the I2Cx\_TIMINGR register.

**Figure 201. Setup and hold timings**



- When the SCL falling edge is internally detected, a delay is inserted before sending SDA output. This delay is  $t_{SDADEL} = SDADEL \times t_{PRESC} + t_{I2CCLK}$  where  $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$ .

$T_{SDADEL}$  impacts the hold time  $t_{HD,DAT}$ .

The total SDA output delay is:

$$t_{SYNC1} + \{ [SDADEL \times (PRESC+1) + 1] \times t_{I2CCLK} \}$$

$t_{SYNC1}$  duration depends on these parameters:

- SCL falling slope
- When enabled, input delay brought by the analog filter:  $t_{AF}$ .  $50\text{ns} < t_{AF} < 260\text{ ns}$ .
- When enabled, input delay brought by the digital filter:  $t_{DNF} = DNF \times t_{I2CCLK}$
- Delay due to SCL synchronization to I2CCLK clock (2 to 3 I2CCLK periods)

In order to bridge the undefined region of the SCL falling edge, you must program SDADEL in such a way that:

$$\{t_f(\max) + t_{HD;DAT}(\min) - 50\text{ns} - [(DNF+3) \times t_{I2CCLK}] \} / \{(PRESC+1) \times t_{I2CCLK}\} \leq SDADEL$$

$$SDADEL \leq \{t_{HD;DAT}(\max) - 260\text{ ns} - [(DNF+4) \times t_{I2CCLK}] \} / \{(PRESC+1) \times t_{I2CCLK}\}$$

Note:

-50 ns / -260 ns are part of the equation only when the analog filter is enabled.

The maximum  $t_{HD;DAT}$  could be 3.45  $\mu\text{s}$ , 0.9  $\mu\text{s}$  and 0.45  $\mu\text{s}$  for Standard-mode, Fast-mode and Fast-mode Plus, but must be less than the maximum of  $t_{VD;DAT}$  by a transition time. This maximum must only be met if the device does not stretch the LOW period ( $t_{LOW}$ ) of the SCL signal. If the clock stretches the SCL, the data must be valid by the set-up time before it releases the clock.

The SDA rising edge is usually the worst case, so in this case the previous equation becomes :

$$SDADEL \leq \{t_{VD;DAT}(\max) - t_r(\max) - 260\text{ ns} - [(DNF+4) \times t_{I2CCLK}] \} / \{(PRESC+1) \times t_{I2CCLK}\}.$$

Note:

This condition can be violated when NOSTRETCH=0, because the device stretches SCL low to guarantee the set-up time, according to the SDADEL value.

Refer to [Table 68: I2C-SMBUS specification data setup and hold times](#) for  $t_f$ ,  $t_r$ ,  $t_{HD;DAT}$  and  $t_{VD;DAT}$  standard values.

- After sending SDA output, SCL line is kept at low level during the setup time. This setup time is  $t_{SCLDEL} = (SCLDEL+1) \times t_{PRESC}$  where  $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$ .  $t_{SCLDEL}$  impacts the setup time  $t_{SU;DAT}$ .

In order to bridge the undefined region of the SDA transition (rising edge usually worst case), you must program SCLDEL in such a way that:

$$\{t_r(\max) + t_{SU;DAT}(\min)\} / \{(PRESC+1) \times t_{I2CCLK}\} - 1 \leq SCLDEL$$

Refer to [Table 68: I2C-SMBUS specification data setup and hold times](#) for  $t_r$  and  $t_{SU;DAT}$  standard values.

The SDA and SCL transition time values to be used are the ones in the application. Using the maximum values from the standard increases the constraints for the SDADEL and SCLDEL calculation, but ensures the functionality whatever the application.

**Table 68. I2C-SMBUS specification data setup and hold times**

	Parameter	Standard		Fast Mode		Fast Mode Plus		SMBUS	
		Min.	Max	Min.	Max	Min.	Max	Min.	Max
t <sub>HD;DAT</sub> (us)	Data hold time	0		0		0		300	
t <sub>VD;DAT</sub>	Data valid time		3.45		0.9		0.45		
t <sub>SU;DAT</sub> (ns)	Data setup time	250		100		50		250	
t <sub>r(ns)</sub>	Rise time of both SDA and SCL signals		1000		300		120		1000
t <sub>f(ns)</sub>	Fall time of both SDA and SCL signals		300		300		120		300

Additionally, in master mode, the SCL clock high and low levels must be configured by programming the PRESC[3:0], SCLH[7:0] and SCLL[7:0] bits in the I2Cx\_TIMINGR register.

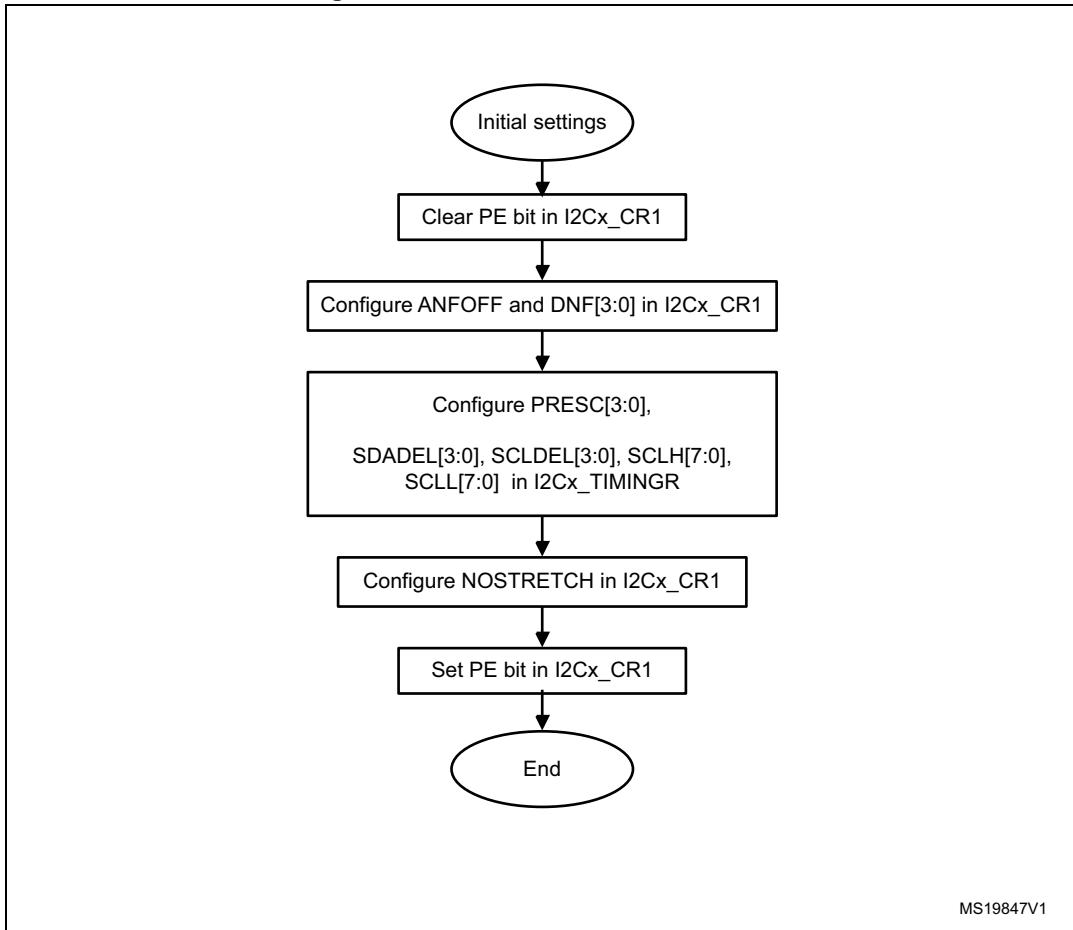
- When the SCL falling edge is internally detected, a delay is inserted before releasing the SCL output. This delay is  $t_{SCLL} = (SCLL+1) \times t_{PRESC}$  where  $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$ .  $t_{SCLL}$  impacts the SCL low time  $t_{LOW}$ .
- When the SCL rising edge is internally detected, a delay is inserted before forcing the SCL output to low level. This delay is  $t_{SCLH} = (SCLH+1) \times t_{PRESC}$  where  $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$ .  $t_{SCLH}$  impacts the SCL high time  $t_{HIGH}$ .

Refer to section : [I2C master initialization](#) for more details.

**Caution:** Changing the timing configuration is not allowed when the I2C is enabled.

The I2C slave NOSTRETCH mode must also be configured before enabling the peripheral. Refer to : [I2C slave initialization](#) for more details.

**Caution:** Changing the NOSTRETCH configuration is not allowed when the I2C is enabled.

Figure 202. I<sup>2</sup>C initialization flowchart

#### 24.4.6 Software reset

A software reset can be performed by clearing the PE bit in the I2Cx\_CR1 register. In that case I<sup>2</sup>C lines SCL and SDA are released. Internal states machines are reset and communication control bits, as well as status bits come back to their reset value. The configuration registers are not impacted.

Here is the list of impacted register bits:

1. I2Cx\_CR2 register: START, STOP, NACK
2. I2Cx\_ISR register: BUSY, TXE, TXIS, RXNE, ADDR, NACKF, TCR, TC, STOPF, BERR, ARLO, OVR

and in addition when the SMBus feature is supported:

1. I2Cx\_CR2 register: PECBYTE
2. I2Cx\_ISR register: PECERR, TIMEOUT, ALERT

PE must be kept low during at least 3 APB clock cycles in order to perform the software reset. This is ensured by writing the following software sequence : - Write PE=0 - Check PE=0 - Write PE=1

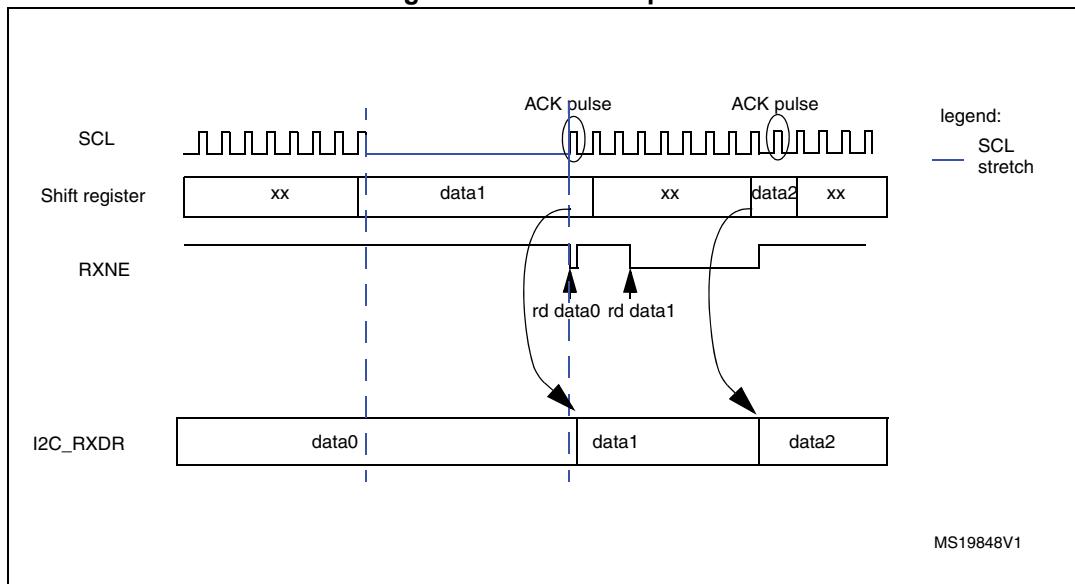
#### 24.4.7 Data transfer

The data transfer is managed through transmit and receive data registers and a shift register.

##### Reception

The SDA input fills the shift register. After the 8th SCL pulse (when the complete data byte is received), the shift register is copied into I<sub>2</sub>C<sub>x</sub>\_RXDR register if it is empty (RXNE=0). If RXNE=1, meaning that the previous received data byte has not yet been read, the SCL line is stretched low until I<sub>2</sub>C<sub>x</sub>\_RXDR is read. The stretch is inserted between the 8th and 9th SCL pulse (before the Acknowledge pulse).

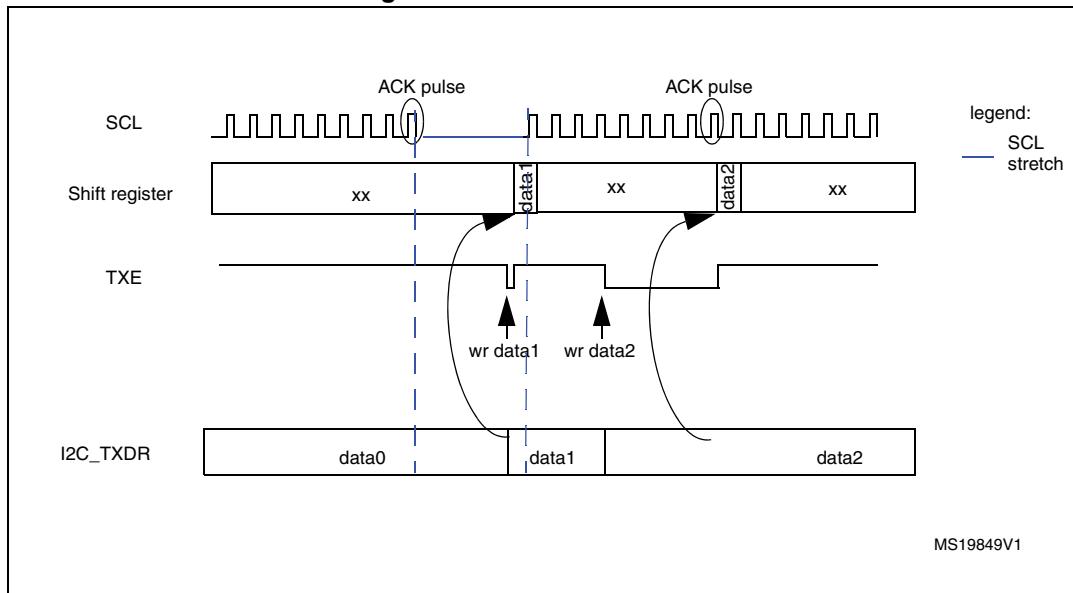
**Figure 203. Data reception**



##### Transmission

If the I<sub>2</sub>C<sub>x</sub>\_TXDR register is not empty (TXE=0), its content is copied into the shift register after the 9th SCL pulse (the Acknowledge pulse). Then the shift register content is shifted out on SDA line. If TXE=1, meaning that no data is written yet in I<sub>2</sub>C<sub>x</sub>\_TXDR, SCL line is stretched low until I<sub>2</sub>C<sub>x</sub>\_TXDR is written. The stretch is done after the 9th SCL pulse.

Figure 204. Data transmission



### Hardware transfer management

The I<sup>2</sup>C has a byte counter embedded in hardware in order to manage byte transfer and to close the communication in various modes such as:

- NACK, STOP and ReSTART generation in master mode
- ACK control in slave receiver mode
- PEC generation/checking when SMBus feature is supported

The byte counter is always used in master mode. By default it is disabled in slave mode, but it can be enabled by software by setting the SBC (Slave Byte Control) bit in the I2Cx\_CR2 register.

The number of bytes to be transferred is programmed in the NBYTES[7:0] bit field in the I2Cx\_CR2 register. If the number of bytes to be transferred (NBYTES) is greater than 255, or if a receiver wants to control the acknowledge value of a received data byte, the reload mode must be selected by setting the RELOAD bit in the I2Cx\_CR2 register. In this mode, TCR flag is set when the number of bytes programmed in NBYTES has been transferred, and an interrupt is generated if TCIE is set. SCL is stretched as long as TCR flag is set. TCR is cleared by software when NBYTES is written to a non-zero value.

When the NBYTES counter is reloaded with the last number of bytes, RELOAD bit must be cleared.

When RELOAD=0 in master mode, the counter can be used in 2 modes:

- **Automatic end mode** (AUTOEND = '1' in the I2Cx\_CR2 register). In this mode, the master automatically sends a STOP condition once the number of bytes programmed in the NBYTES[7:0] bit field has been transferred.
- **Software end mode** (AUTOEND = '0' in the I2Cx\_CR2 register). In this mode, software action is expected once the number of bytes programmed in the NBYTES[7:0] bit field has been transferred; the TC flag is set and an interrupt is generated if the TCIE bit is set. The SCL signal is stretched as long as the TC flag is set. The TC flag is cleared by software when the START or STOP bit is set in the I2Cx\_CR2 register. This mode must be used when the master wants to send a RESTART condition.

**Caution:** The AUTOEND bit has no effect when the RELOAD bit is set.

**Table 69. I<sup>2</sup>C Configuration table**

Function	SBC bit	RELOAD bit	AUTOEND bit
Master Tx/Rx NBYTES + STOP	x	0	1
Master Tx/Rx + NBYTES + RESTART	x	0	0
Slave Tx/Rx all received bytes ACKed	0	x	x
Slave Rx with ACK control	1	1	x

## 24.4.8 I<sup>2</sup>C slave mode

### I<sup>2</sup>C slave initialization

In order to work in slave mode, you must enable at least one slave address. Two registers I2Cx\_OAR1 and I2Cx\_OAR2 are available in order to program the slave own addresses OA1 and OA2.

- OA1 can be configured either in 7-bit mode (by default) or in 10-bit addressing mode by setting the OA1MODE bit in the I2Cx\_OAR1 register.  
OA1 is enabled by setting the OA1EN bit in the I2Cx\_OAR1 register.
- If additional slave addresses are required, you can configure the 2nd slave address OA2. Up to 7 OA2 LSB can be masked by configuring the OA2MSK[2:0] bits in the I2Cx\_OAR2 register. Therefore for OA2MSK configured from 1 to 6, only OA2[7:2], OA2[7:3], OA2[7:4], OA2[7:5], OA2[7:6] or OA2[7] are compared with the received address. As soon as OA2MSK is not equal to 0, the address comparator for OA2 excludes the I<sup>2</sup>C reserved addresses (0000 XXX and 1111 XXX), which are not acknowledged. If OA2MSK=7, all received 7-bit addresses are acknowledged (except reserved addresses). OA2 is always a 7-bit address.

These reserved addresses can be acknowledged if they are enabled by the specific enable bit, if they are programmed in the I2Cx\_OAR1 or I2Cx\_OAR2 register with OA2MSK=0.

OA2 is enabled by setting the OA2EN bit in the I2Cx\_OAR2 register.

- The General Call address is enabled by setting the GCEN bit in the I2Cx\_CR1 register.

When the I<sup>2</sup>C is selected by one of its enabled addresses, the ADDR interrupt status flag is set, and an interrupt is generated if the ADDRIE bit is set.

By default, the slave uses its clock stretching capability, which means that it stretches the SCL signal at low level when needed, in order to perform software actions. If the master does not support clock stretching, the I<sup>2</sup>C must be configured with NOSTRETCH=1 in the I2Cx\_CR1 register.

After receiving an ADDR interrupt, if several addresses are enabled you must read the ADDCODE[6:0] bits in the I2Cx\_ISR register in order to check which address matched. DIR flag must also be checked in order to know the transfer direction.

### Slave clock stretching (NOSTRETCH = 0)

In default mode, the I<sup>2</sup>C slave stretches the SCL clock in the following situations:

- When the ADDR flag is set: the received address matches with one of the enabled slave addresses. This stretch is released when the ADDR flag is cleared by software setting the ADDRCF bit.
- In transmission, if the previous data transmission is completed and no new data is written in I2Cx\_TXDR register, or if the first data byte is not written when the ADDR flag is cleared (TXE=1). This stretch is released when the data is written to the I2Cx\_TXDR register.
- In reception when the I2Cx\_RXDR register is not read yet and a new data reception is completed. This stretch is released when I2Cx\_RXDR is read.
- When TCR = 1 in Slave Byte Control mode, reload mode (SBC=1 and RELOAD=1), meaning that the last data byte has been transferred. This stretch is released when then TCR is cleared by writing a non-zero value in the NBYTES[7:0] field.
- After SCL falling edge detection, the I<sup>2</sup>C stretches SCL low during  $[(SDADEL+SCLDEL+1) \times (PRESC+1) + 1] \times t_{I2CCLK}$ .

### Slave without clock stretching (NOSTRETCH = 1)

When NOSTRETCH = 1 in the I2Cx\_CR1 register, the I<sup>2</sup>C slave does not stretch the SCL signal.

- The SCL clock is not stretched while the ADDR flag is set.
- In transmission, the data must be written in the I2Cx\_TXDR register before the first SCL pulse corresponding to its transfer occurs. If not, an underrun occurs, the OVR flag is set in the I2Cx\_ISR register and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register. The OVR flag is also set when the first data transmission starts and the STOPF bit is still set (has not been cleared). Therefore, if you clear the STOPF flag of the previous transfer only after writing the first data to be transmitted in the next transfer, you ensure that the OVR status is provided, even for the first data to be transmitted.
- In reception, the data must be read from the I2Cx\_RXDR register before the 9th SCL pulse (ACK pulse) of the next data byte occurs. If not an overrun occurs, the OVR flag is set in the I2Cx\_ISR register and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

### Slave Byte Control Mode

In order to allow byte ACK control in slave reception mode, Slave Byte Control mode must be enabled by setting the SBC bit in the I2Cx\_CR1 register. This is required to be compliant with SMBus standards.

Reload mode must be selected in order to allow byte ACK control in slave reception mode (RELOAD=1). To get control of each byte, NBYTES must be initialized to 0x1 in the ADDR interrupt subroutine, and reloaded to 0x1 after each received byte. When the byte is received, the TCR bit is set, stretching the SCL signal low between the 8th and 9th SCL pulses. You can read the data from the I2Cx\_RXDR register, and then decide to acknowledge it or not by configuring the ACK bit in the I2Cx\_CR2 register. The SCL stretch is released by programming NBYTES to a non-zero value: the acknowledge or not-acknowledge is sent and next byte can be received.

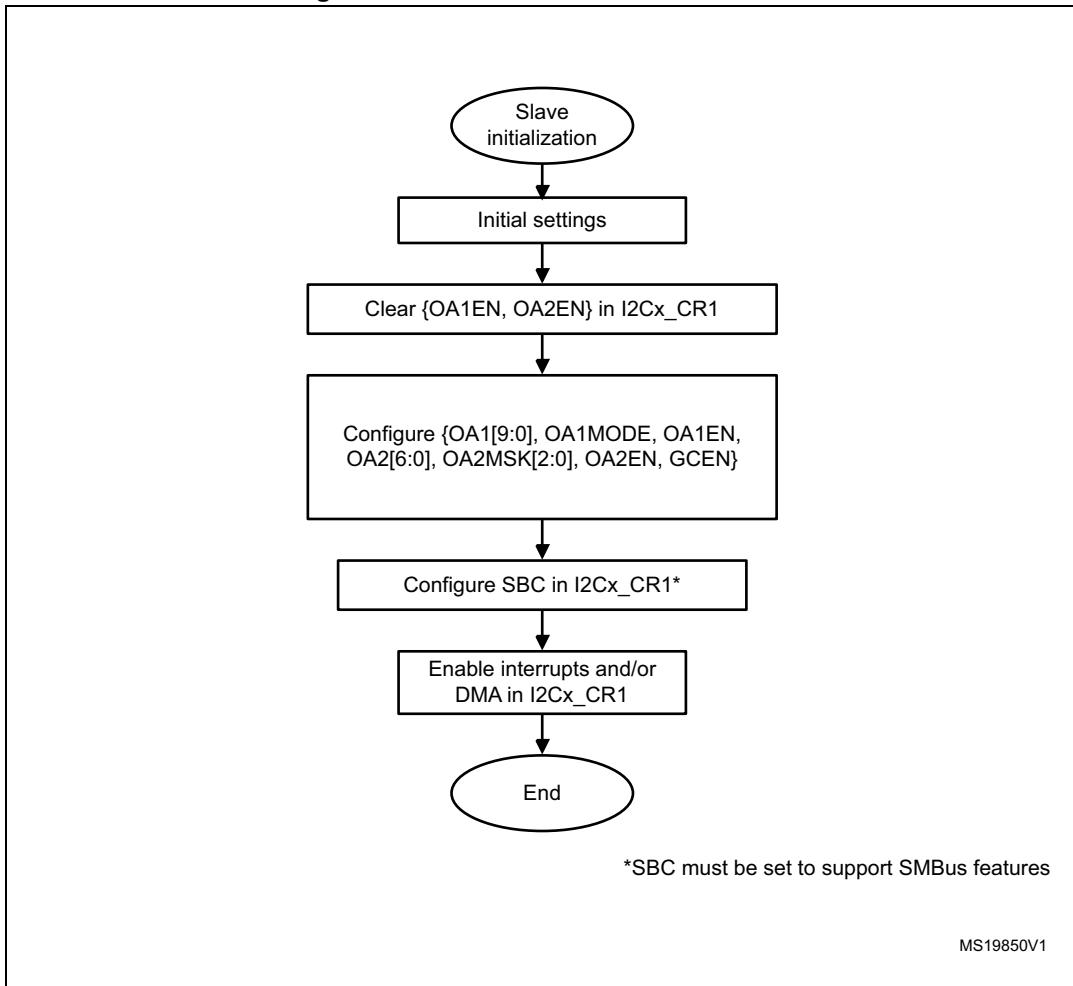
NBYTES can be loaded with a value greater than 0x1, and in this case, the reception flow is continuous during NBYTES data reception.

**Note:** The SBC bit must be configured when the I $^2$ C is disabled, or when the slave is not addressed, or when ADDR=1.

The RELOAD bit value can be changed when ADDR=1, or when TCR=1.

**Caution:** Slave Byte Control mode is not compatible with NOSTRETCH mode. Setting SBC when NOSTRETCH=1 is not allowed.

Figure 205. Slave initialization flowchart



### Slave transmitter

A transmit interrupt status (TXIS) is generated when the I $^2$ Cx\_TXDR register becomes empty. An interrupt is generated if the TXIE bit is set in the I $^2$ Cx\_CR1 register.

The TXIS bit is cleared when the I $^2$ Cx\_TXDR register is written with the next data byte to be transmitted.

When a NACK is received, the NACKF bit is set in the I $^2$ Cx\_ISR register and an interrupt is generated if the NACKIE bit is set in the I $^2$ Cx\_CR1 register. The slave automatically releases the SCL and SDA lines in order to let the master perform a STOP or a RESTART condition. The TXIS bit is not set when a NACK is received.

When a STOP is received and the STOPIE bit is set in the I2Cx\_CR1 register, the STOPF flag is set in the I2Cx\_ISR register and an interrupt is generated. In most applications, the SBC bit is usually programmed to '0'. In this case, If TXE = 0 when the slave address is received (ADDR=1), you can choose either to send the content of the I2Cx\_TXDR register as the first data byte, or to flush the I2Cx\_TXDR register by setting the TXE bit in order to program a new data byte.

In Slave Byte Control mode (SBC=1), the number of bytes to be transmitted must be programmed in NBYTES in the address match interrupt subroutine (ADDR=1). In this case, the number of TXIS events during the transfer corresponds to the value programmed in NBYTES.

**Caution:** When NOSTRETCH=1, the SCL clock is not stretched while the ADDR flag is set, so you cannot flush the I2Cx\_TXDR register content in the ADDR subroutine, in order to program the first data byte. The first data byte to be sent must be previously programmed in the I2Cx\_TXDR register:

- This data can be the data written in the last TXIS event of the previous transmission message.
- If this data byte is not the one to be sent, the I2Cx\_TXDR register can be flushed by setting the TXE bit in order to program a new data byte. The STOPF bit must be cleared only after these actions, in order to guarantee that they are executed before the first data transmission starts, following the address acknowledge.

If STOPF is still set when the first data transmission starts, an underrun error will be generated (the OVR flag is set).

If you need a TXIS event, (Transmit Interrupt or Transmit DMA request), you must set the TXIS bit in addition to the TXE bit, in order to generate a TXIS event.

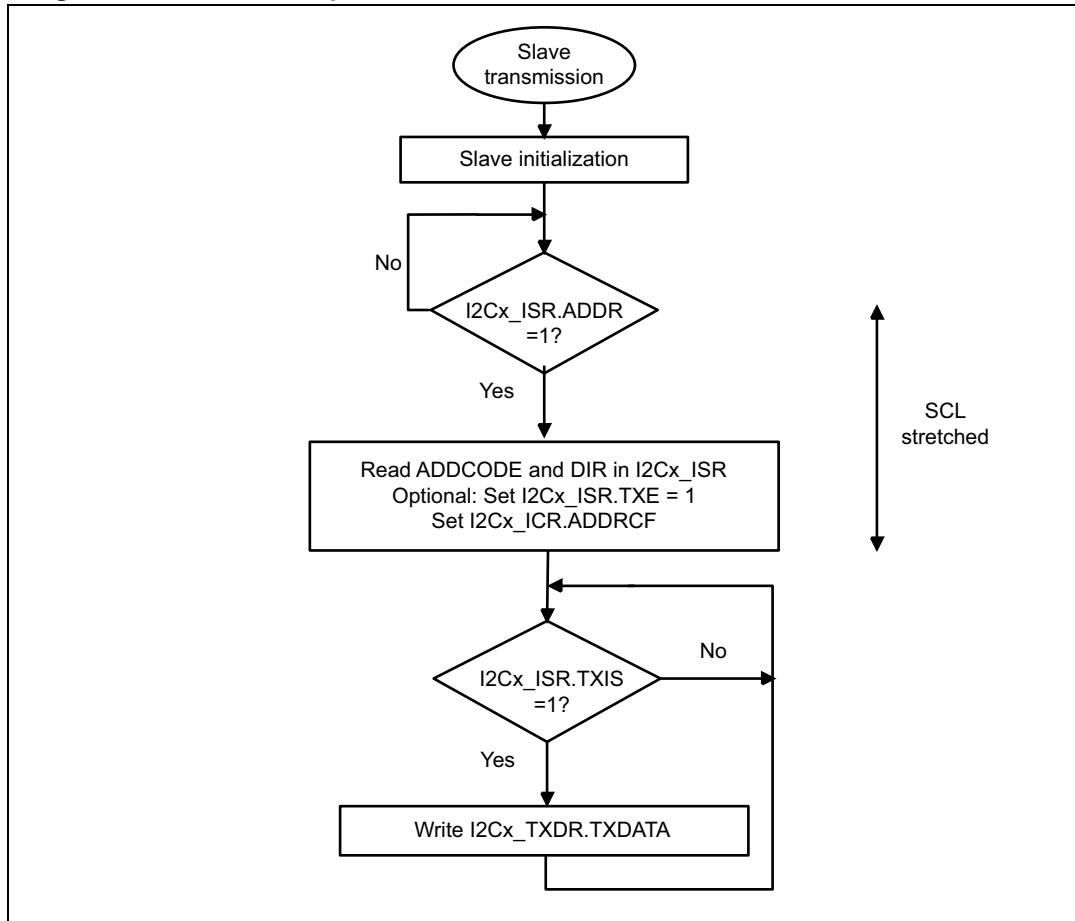
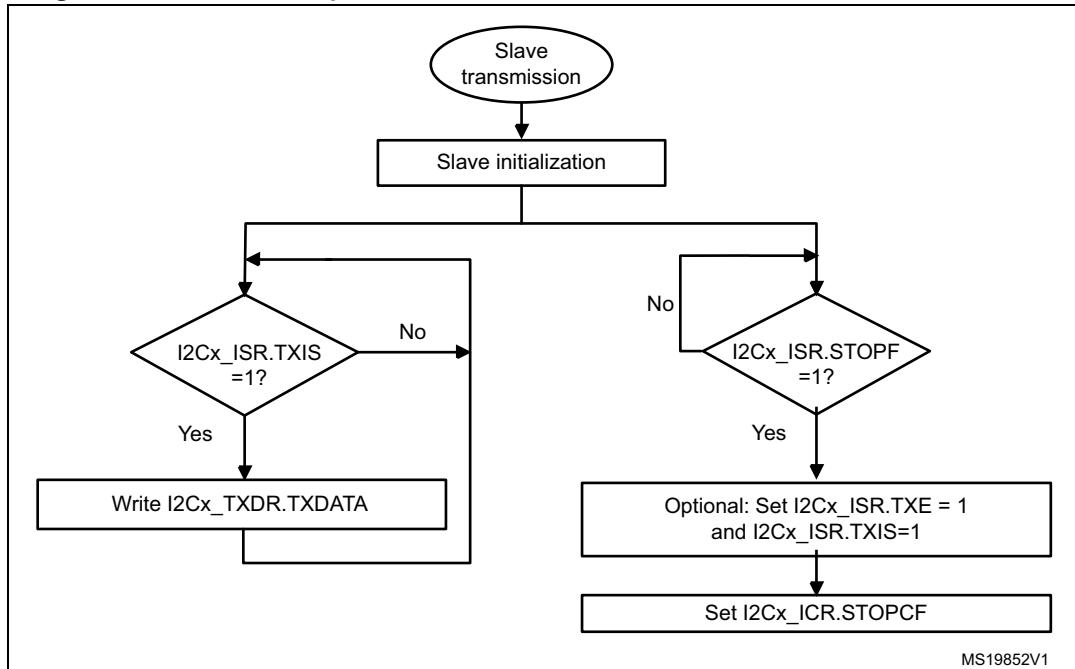
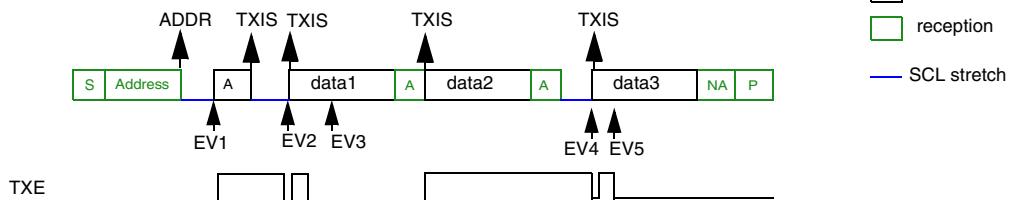
**Figure 206. Transfer sequence flowchart for I<sup>2</sup>C slave transmitter, NOSTRETCH=0****Figure 207. Transfer sequence flowchart for I<sup>2</sup>C slave transmitter, NOSTRETCH=1**

Figure 208. Transfer bus diagrams for I<sup>2</sup>C slave transmitter

Example I<sup>2</sup>C slave transmitter 3 bytes with 1st data flushed,  
NOSTRETCH=0:



EV1: ADDR ISR: check ADDCODE and DIR, set TXE, set ADDRCF

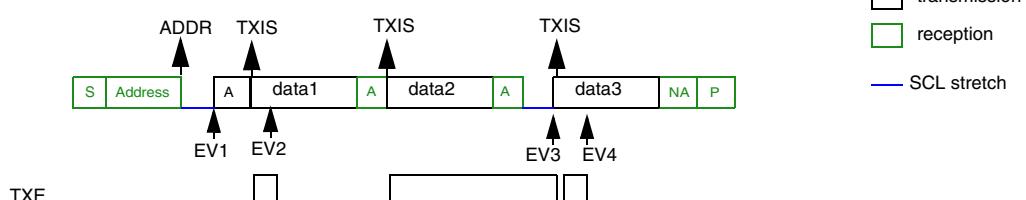
EV2: TXIS ISR: wr data1

EV3: TXIS ISR: wr data2

EV4: TXIS ISR: wr data3

EV5: TXIS ISR: wr data4 (not sent)

Example I<sup>2</sup>C slave transmitter 3 bytes without 1st data flush,  
NOSTRETCH=0:



EV1: ADDR ISR: check ADDCODE and DIR, set ADDRCF

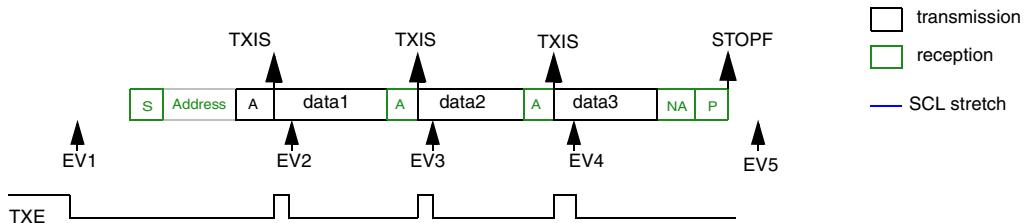
EV2: TXIS ISR: wr data1

EV3: TXIS ISR: wr data2

EV4: TXIS ISR: wr data3

EV5: TXIS ISR: wr data4 (not sent)

Example I<sup>2</sup>C slave transmitter 3 bytes, NOSTRETCH=1:



EV1: wr data1

EV2: TXIS ISR: wr data2

EV3: TXIS ISR: wr data3

EV4: TXIS ISR: wr data4 (not sent)

EV5: STOPF ISR: (optional: set TXE and TXIS), set STOPCF

legend:

□ transmission

□ reception

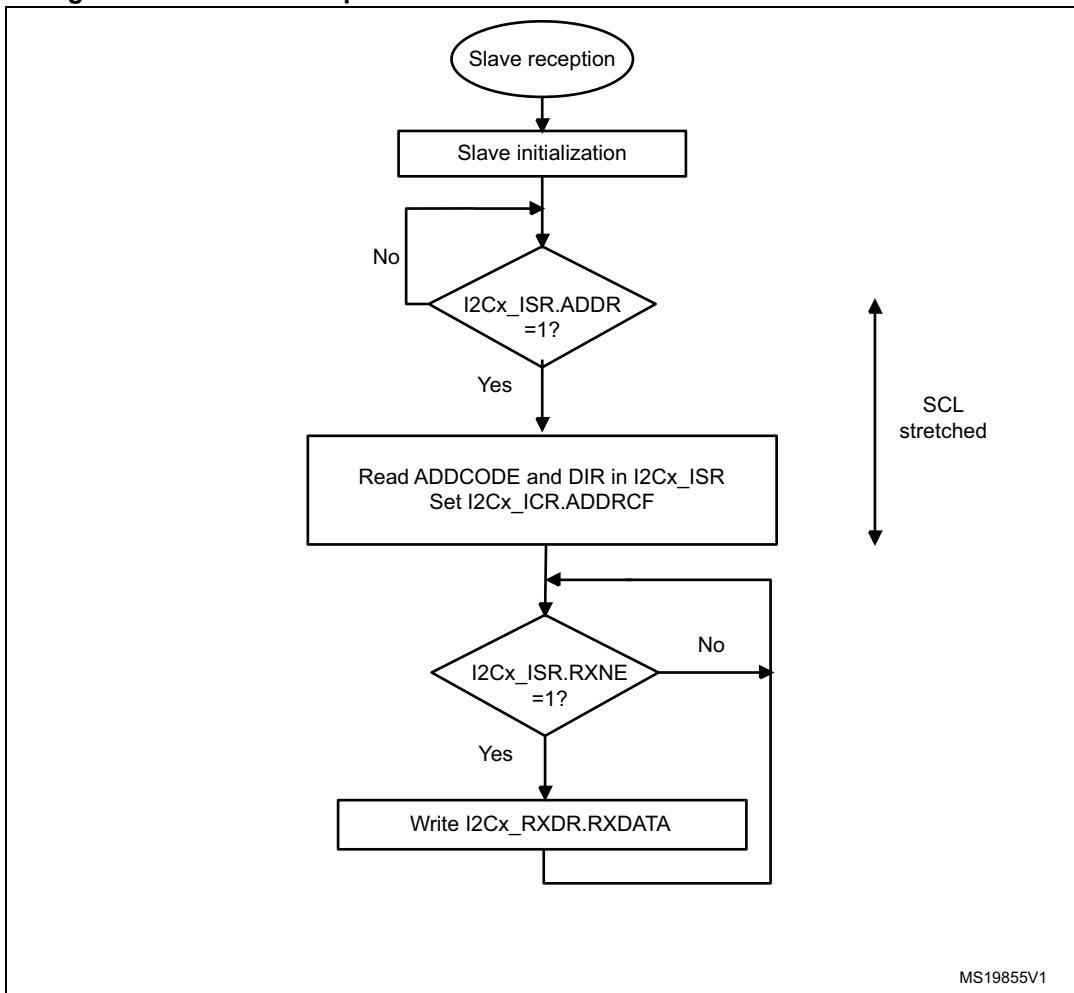
— SCL stretch

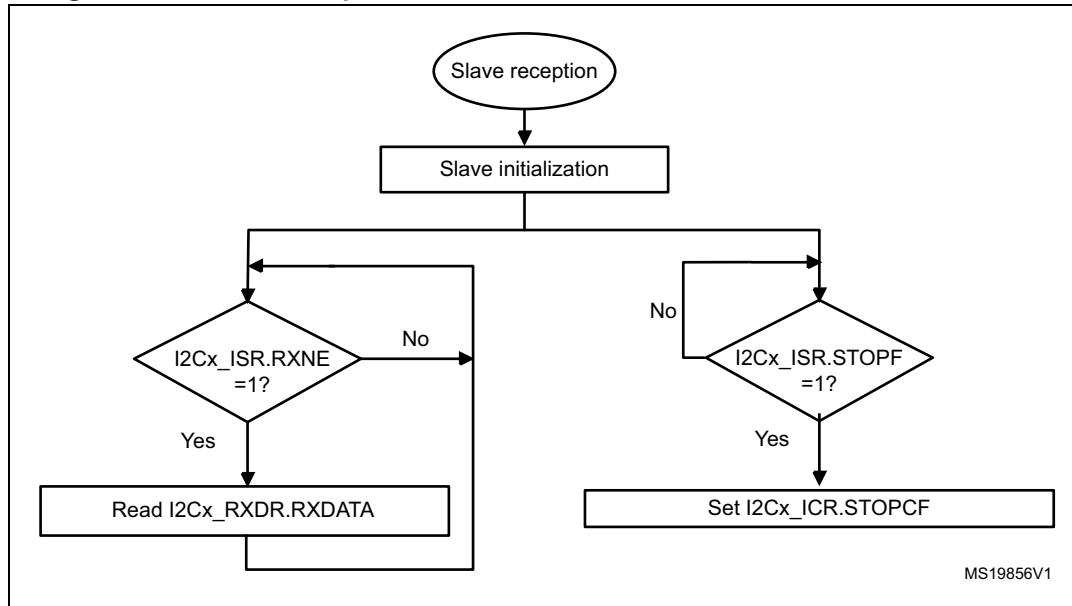
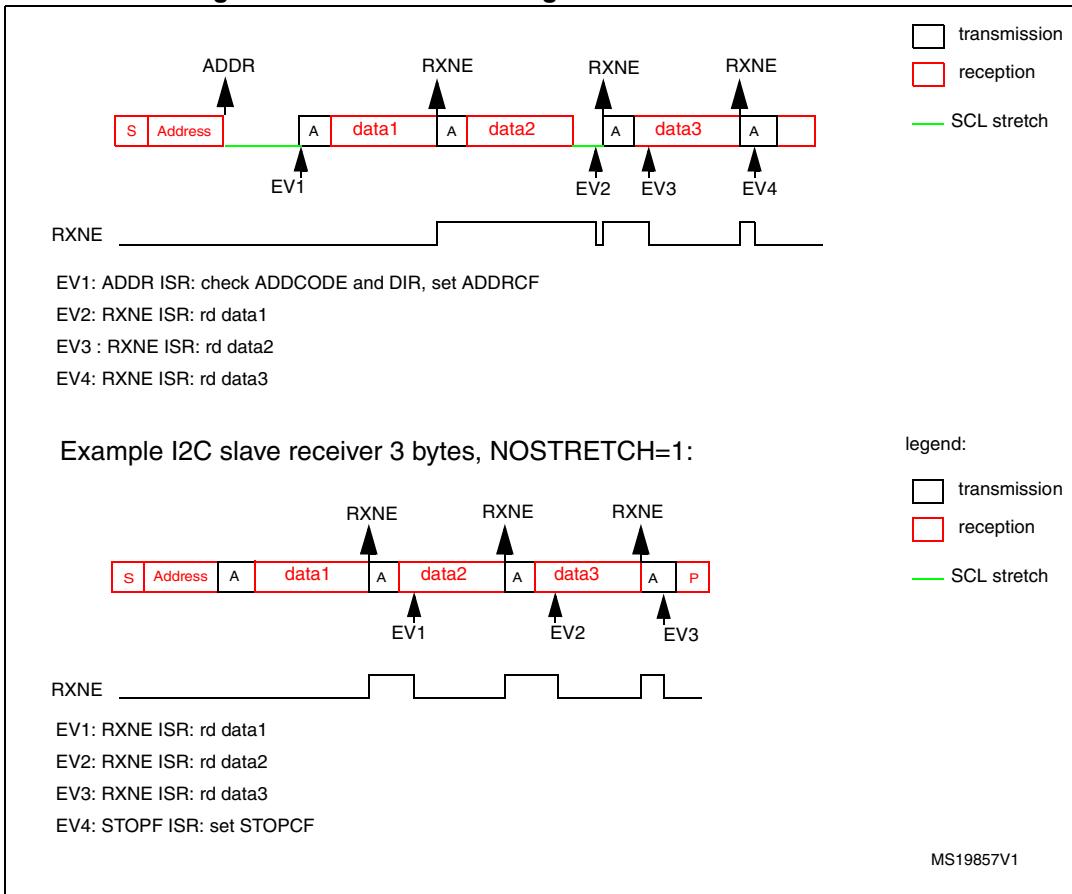
### Slave receiver

RXNE is set in I<sub>2</sub>Cx\_ISR when the I<sub>2</sub>Cx\_RXDR is full, and generates an interrupt if RXIE is set in I<sub>2</sub>Cx\_CR1. RXNE is cleared when I<sub>2</sub>Cx\_RXDR is read.

When a STOP is received and STOPIE is set in I<sub>2</sub>Cx\_CR1, STOPF is set in I<sub>2</sub>Cx\_ISR and an interrupt is generated.

**Figure 209. Transfer sequence flowchart for slave receiver with NOSTRETCH=0**



**Figure 210. Transfer sequence flowchart for slave receiver with NOSTRETCH=1****Figure 211. Transfer bus diagrams for I2C slave receiver**

## 24.4.9 I<sup>2</sup>C master mode

### I<sup>2</sup>C master initialization

Before enabling the peripheral, the I<sup>2</sup>C master clock must be configured by setting the SCLH and SCLL bits in the I<sup>2</sup>Cx\_TIMINGR register.

A clock synchronization mechanism is implemented in order to support multi-master environment and slave clock stretching.

In order to allow clock synchronization:

- The low level of the clock is counted using the SCLL counter, starting from the SCL low level internal detection.
- The high level of the clock is counted using the SCLH counter, starting from the SCL high level internal detection.

The I<sup>2</sup>C detects its own SCL low level after a  $t_{SYNC1}$  delay depending on the SCL falling edge, SCL input noise filters (analog + digital) and SCL synchronization to the I<sup>2</sup>CxCLK clock. The I<sup>2</sup>C releases SCL to high level once the SCLL counter reaches the value programmed in the SCLL[7:0] bits in the I<sup>2</sup>Cx\_TIMINGR register.

The I<sup>2</sup>C detects its own SCL high level after a  $t_{SYNC2}$  delay depending on the SCL rising edge, SCL input noise filters (analog + digital) and SCL synchronization to I<sup>2</sup>CxCLK clock. The I<sup>2</sup>C ties SCL to low level once the SCLH counter is reached reaches the value programmed in the SCLH[7:0] bits in the I<sup>2</sup>Cx\_TIMINGR register.

Consequently the master clock period is:

$$t_{SCL} = t_{SYNC1} + t_{SYNC2} + \{ [(SCLH+1) + (SCLL+1)] \times (PRESC+1) \times t_{I2CCLK} \}$$

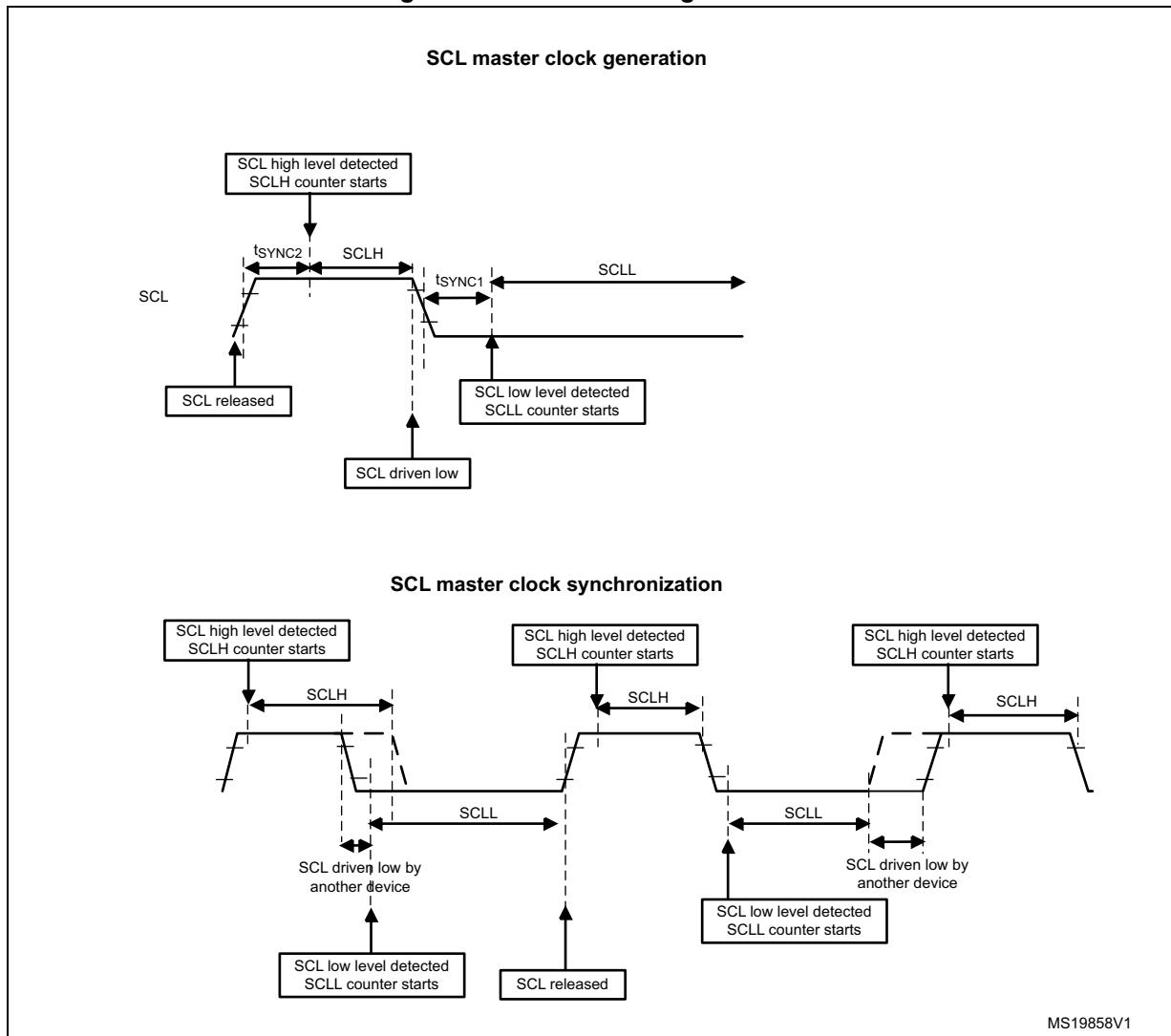
The duration of  $t_{SYNC1}$  depends on these parameters:

- SCL falling slope
- When enabled, input delay induced by the analog filter.
- When enabled, input delay induced by the digital filter: DNF  $\times t_{I2CCLK}$
- Delay due to SCL synchronization with I<sup>2</sup>CCLK clock (2 to 3 I<sup>2</sup>CCLK periods)

The duration of  $t_{SYNC2}$  depends on these parameters:

- SCL rising slope
- When enabled, input delay induced by the analog filter.
- When enabled, input delay induced by the digital filter: DNF  $\times t_{I2CCLK}$
- Delay due to SCL synchronization with I<sup>2</sup>CCLK clock (2 to 3 I<sup>2</sup>CCLK periods)

Figure 212. Master clock generation



**Caution:** In order to be I<sup>2</sup>C or SMBus compliant, the master clock must respect the timings given below:

Table 70. I<sup>2</sup>C-SMBUS specification clock timings

Symbol	Parameter	Standard		Fast Mode		Fast Mode Plus		SMBUS		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	
$f_{SCL}$	SCL clock frequency		100		400		1000		100	kHz
$t_{HD:STA}$	Hold time (repeated) START condition	4.0		0.6		0.26		4.0		μs
$t_{SU:STA}$	Set-up time for a repeated START condition	4.7		0.6		0.26		4.7		μs
$t_{SU:STO}$	Set-up time for STOP condition	4.0		0.6		0.26		4.0		μs

**Table 70. I2C-SMBUS specification clock timings (continued)**

Symbol	Parameter	Standard		Fast Mode		Fast Mode Plus		SMBUS		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	
t <sub>BUF</sub>	Bus free time between a STOP and START condition	4.7		1.3		0.5		4.7		μs
t <sub>LOW</sub>	Low period of the SCL clock	4.7		1.3		0.5		4.7		μs
t <sub>HIGH</sub>	Period of the SCL clock	4.0		0.6		0.26		4.0	50	μs
t <sub>r</sub>	Rise time of both SDA and SCL signals		1000		300		120		1000	ns
t <sub>f</sub>	Fall time of both SDA and SCL signals		300		300		120		300	ns

**Note:** *SCLL is also used to generate the t<sub>BUF</sub> and t<sub>SU:STA</sub> timings.*

*SCLH is also used to generate the t<sub>HD:STA</sub> and t<sub>SU:STO</sub> timings.*

Refer to [Section 24.4.10: I2Cx\\_TIMINGR register configuration examples](#) for examples of I2Cx\_TIMINGR settings vs. I2CCLK frequency.

### Master communication initialization (address phase)

In order to initiate the communication, you must program the following parameters for the addressed slave in the I2Cx\_CR2 register:

- Addressing mode (7-bit or 10-bit): ADD10
- Slave address to be sent: SADD[9:0]
- Transfer direction: RD\_WRN
- In case of 10-bit address read: HEAD10R bit. HEAD10R must be configure to indicate if the complete address sequence must be sent, or only the header in case of a direction change.
- The number of bytes to be transferred: NBYTES[7:0]. If the number of bytes is equal to or greater than 255 bytes, NBYTES[7:0] must initially be filled with 0xFF.

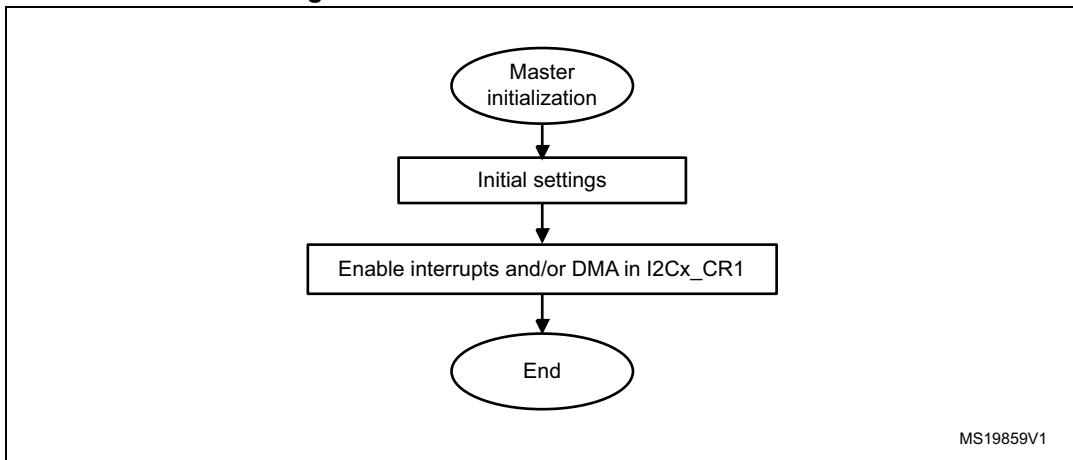
You must then set the START bit in I2Cx\_CR2 register. Changing all the above bits is not allowed when START bit is set.

Then the master automatically sends the START condition followed by the slave address as soon as it detects that the bus is free (BUSY = 0) and after a delay of t<sub>BUF</sub>.

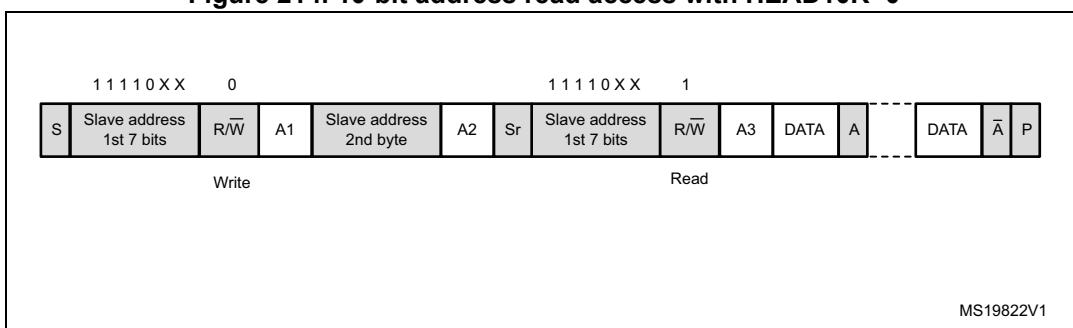
In case of an arbitration loss, the master automatically switches back to slave mode and can acknowledge its own address if it is addressed as a slave.

**Note:** *The START bit is reset by hardware when the slave address has been sent on the bus, whatever the received acknowledge value. The START bit is also reset by hardware if an arbitration loss occurs. If the I2C is addressed as a slave (ADDR=1) while the START bit is set, the I2C switches to slave mode and the START bit is cleared when the ADDRCF bit is set.*

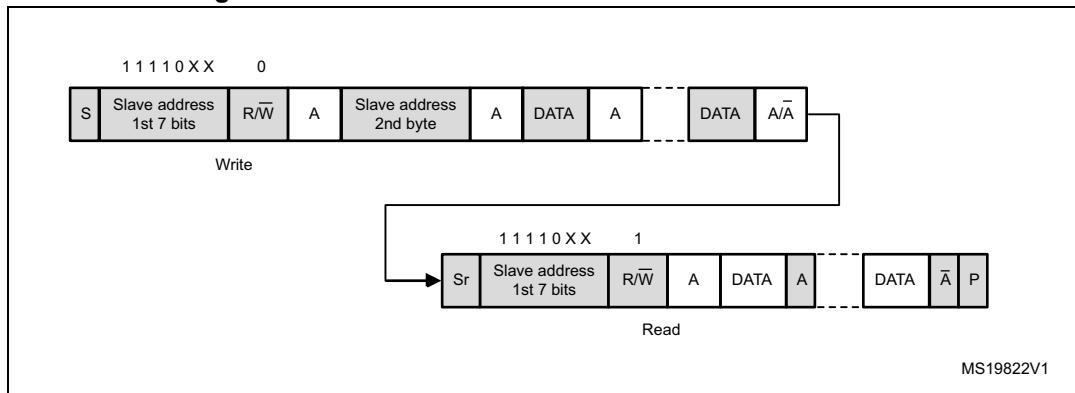
**Note:** *The same procedure is applied for a Repeated Start condition. In this case BUSY=1.*

**Figure 213. Master initialization flowchart****Initialization of a master receiver addressing a 10-bit address slave**

- If the slave address is in 10-bit format, you can choose to send the complete read sequence by clearing the HEAD10R bit in the I2Cx\_CR2 register. In this case the master automatically sends the following complete sequence after the START bit is set: (Re)Start + Slave address 10-bit header Write + Slave address 2nd byte + REStart + Slave address 10-bit header Read

**Figure 214. 10-bit address read access with HEAD10R=0**

- If the master addresses a 10-bit address slave, transmits data to this slave and then reads data from the same slave, a master transmission flow must be done first. Then a repeated start is set with the 10 bit slave address configured with HEAD10R=1. In this case the master sends this sequence: ReStart + Slave address 10-bit header Read

**Figure 215. 10-bit address read access with HEAD10R=1**

### Master transmitter

In the case of a write transfer, the TXIS flag is set after each byte transmission, after the 9th SCL pulse when an ACK is received.

A TXIS event generates an interrupt if the TXIE bit is set in the I2Cx\_CR1 register. The flag is cleared when the I2Cx\_TXDR register is written with the next data byte to be transmitted.

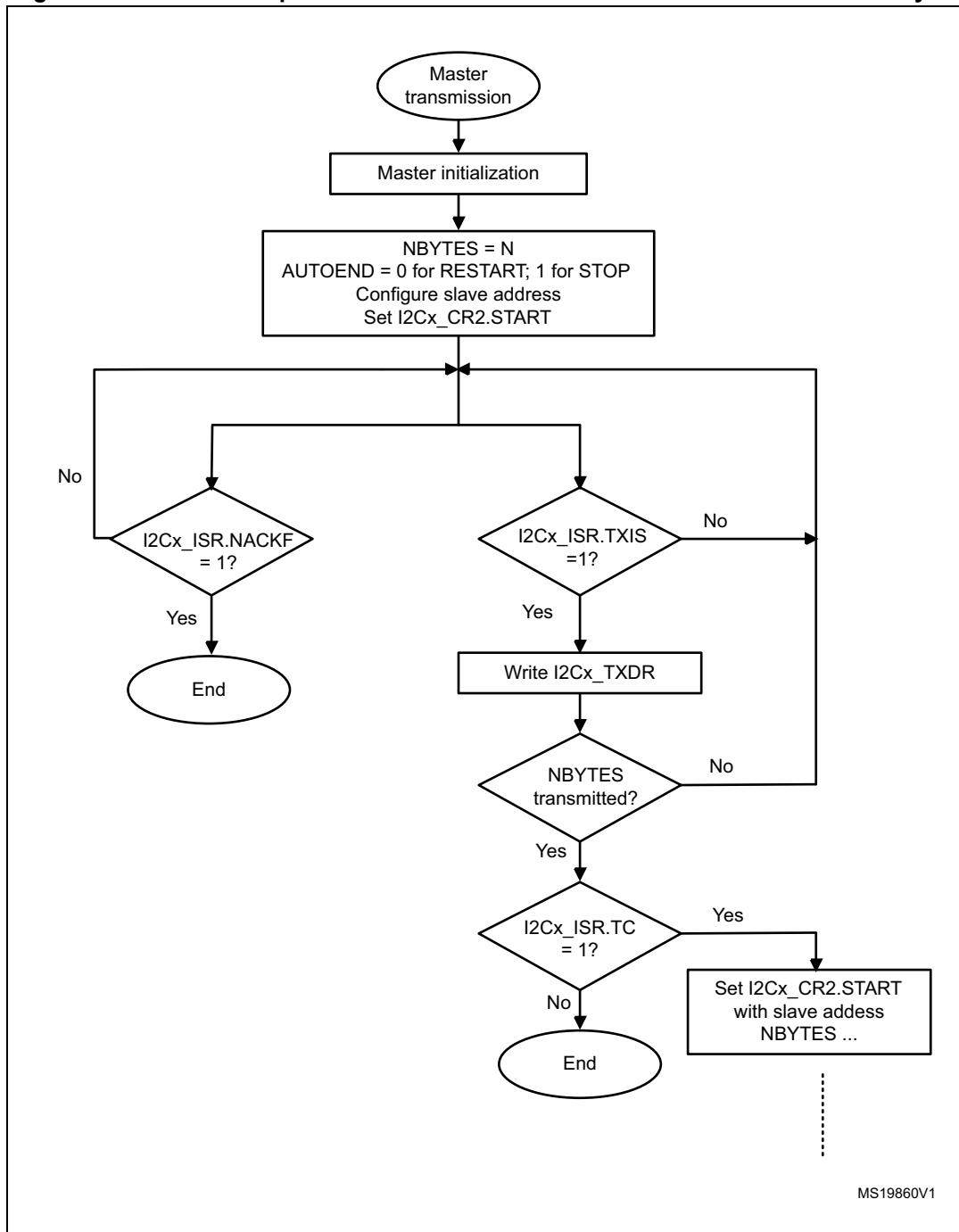
The number of TXIS events during the transfer corresponds to the value programmed in NBYTES[7:0]. If the total number of data bytes to be sent is greater than 255, reload mode must be selected by setting the RELOAD bit in the I2Cx\_CR2 register. In this case, when NBYTES data have been transferred, the TCR flag is set and the SCL line is stretched low until NBYTES[7:0] is written to a non-zero value.

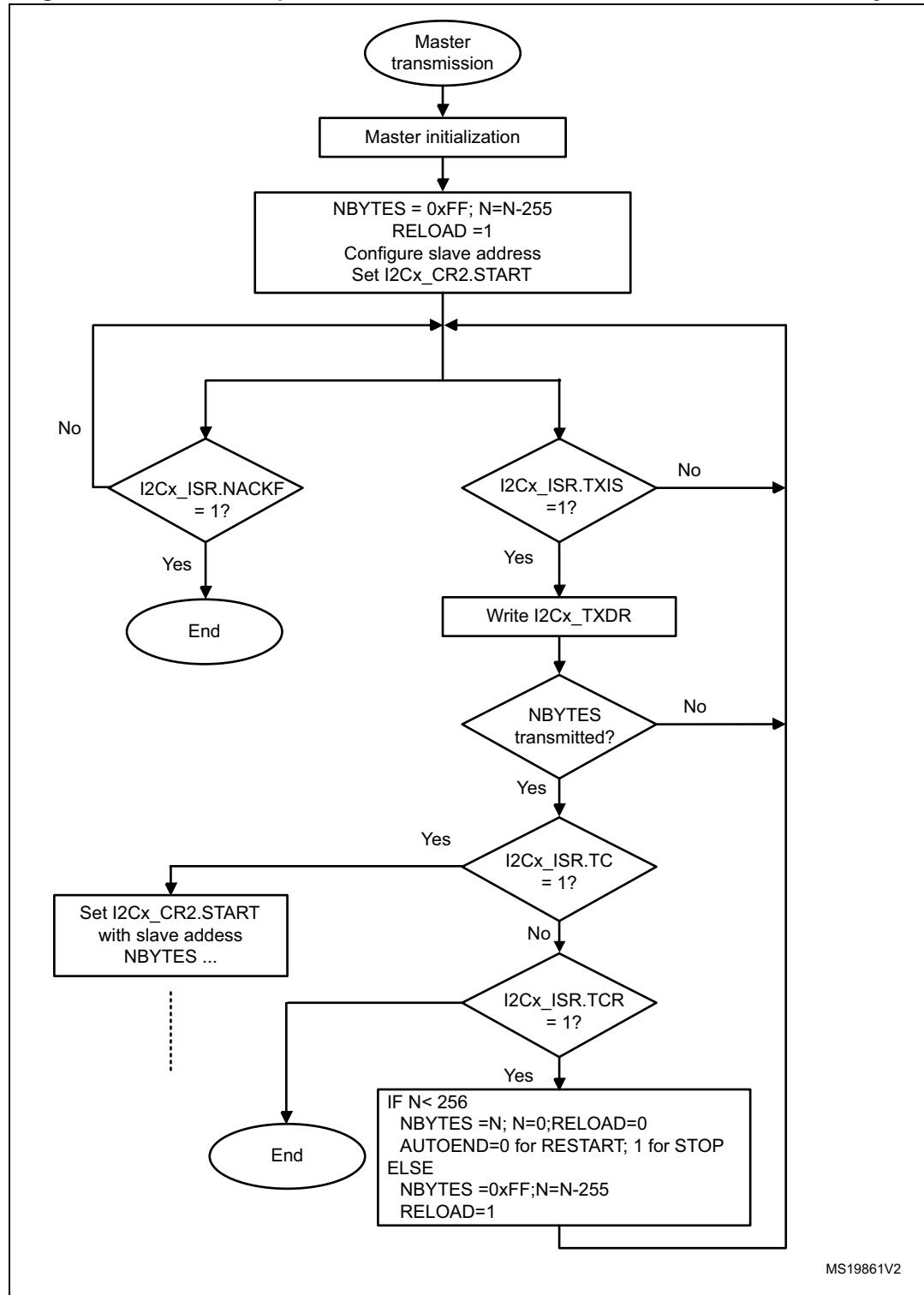
The TXIS flag is not set when a NACK is received.

- When RELOAD=0 and NBYTES data have been transferred:
  - In automatic end mode (AUTOEND=1), a STOP is automatically sent.
  - In software end mode (AUTOEND=0), the TC flag is set and the SCL line is stretched low in order to perform software actions:
 

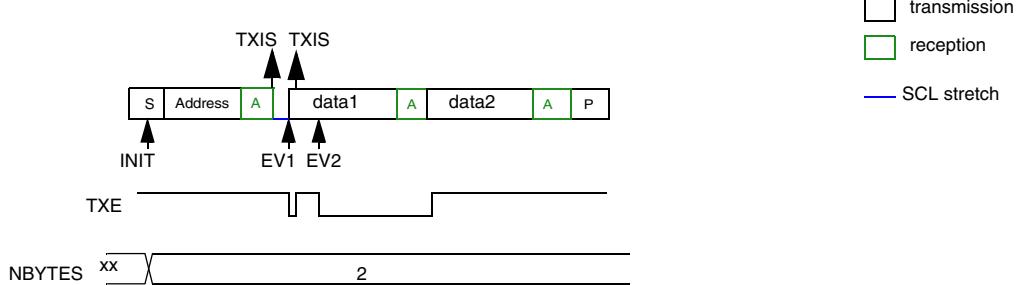
A RESTART condition can be requested by setting the START bit in the I2Cx\_CR2 register with the proper slave address configuration, and number of bytes to be transferred. Setting the START bit clears the TC flag and the START condition is sent on the bus.

A STOP condition can be requested by setting the STOP bit in the I2Cx\_CR2 register. Setting the STOP bit clears the TC flag and the STOP condition is sent on the bus.
- If a NACK is received: the TXIS flag is not set, and a STOP condition is automatically sent after the NACK reception. the NACKF flag is set in the I2Cx\_ISR register, and an interrupt is generated if the NACKIE bit is set.

Figure 216. Transfer sequence flowchart for I<sup>2</sup>C master transmitter for N<=255 bytes

**Figure 217. Transfer sequence flowchart for I<sup>2</sup>C master transmitter for N>255 bytes**

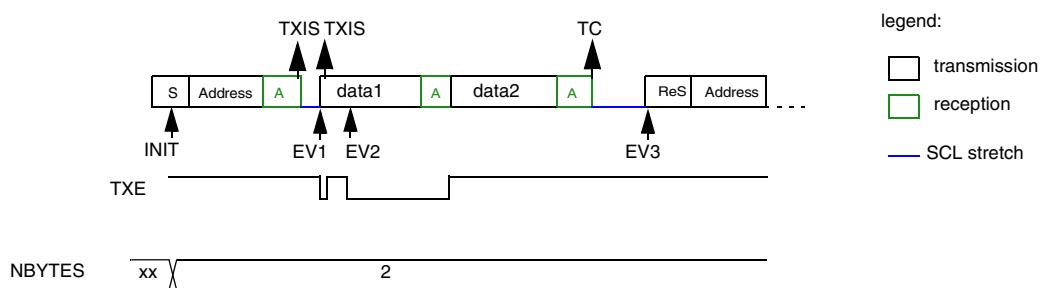
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**Figure 218. Transfer bus diagrams for I<sup>2</sup>C master transmitter****Example I<sup>2</sup>C master transmitter 2 bytes, automatic end mode (STOP)**

INIT: program Slave address, program NBYTES = 2, AUTOEND=1, set START

EV1: TXIS ISR: wr data1

EV2: TXIS ISR: wr data2

**Example I<sup>2</sup>C master transmitter 2 bytes, software end mode (RESTART)**

INIT: program Slave address, program NBYTES = 2, AUTOEND=0, set START

### Master receiver

In the case of a read transfer, the RXNE flag is set after each byte reception, after the 8th SCL pulse. An RXNE event generates an interrupt if the RXIE bit is set in the I2Cx\_CR1 register. The flag is cleared when I2Cx\_RXDR is read.

If the total number of data bytes to be received is greater than 255, reload mode must be selected by setting the RELOAD bit in the I2Cx\_CR2 register. In this case, when NBYTES[7:0] data have been transferred, the TCR flag is set and the SCL line is stretched low until NBYTES[7:0] is written to a non-zero value.

- When RELOAD=0 and NBYTES[7:0] data have been transferred:
  - In automatic end mode (AUTOEND=1), a NACK and a STOP are automatically sent after the last received byte.
  - In software end mode (AUTOEND=0), a NACK is automatically sent after the last received byte, the TC flag is set and the SCL line is stretched low in order to allow software actions:  
A RESTART condition can be requested by setting the START bit in the I2Cx\_CR2 register with the proper slave address configuration, and number of bytes to be transferred. Setting the START bit clears the TC flag and the START condition, followed by slave address, are sent on the bus.  
A STOP condition can be requested by setting the STOP bit in the I2Cx\_CR2 register. Setting the STOP bit clears the TC flag and the STOP condition is sent on the bus.

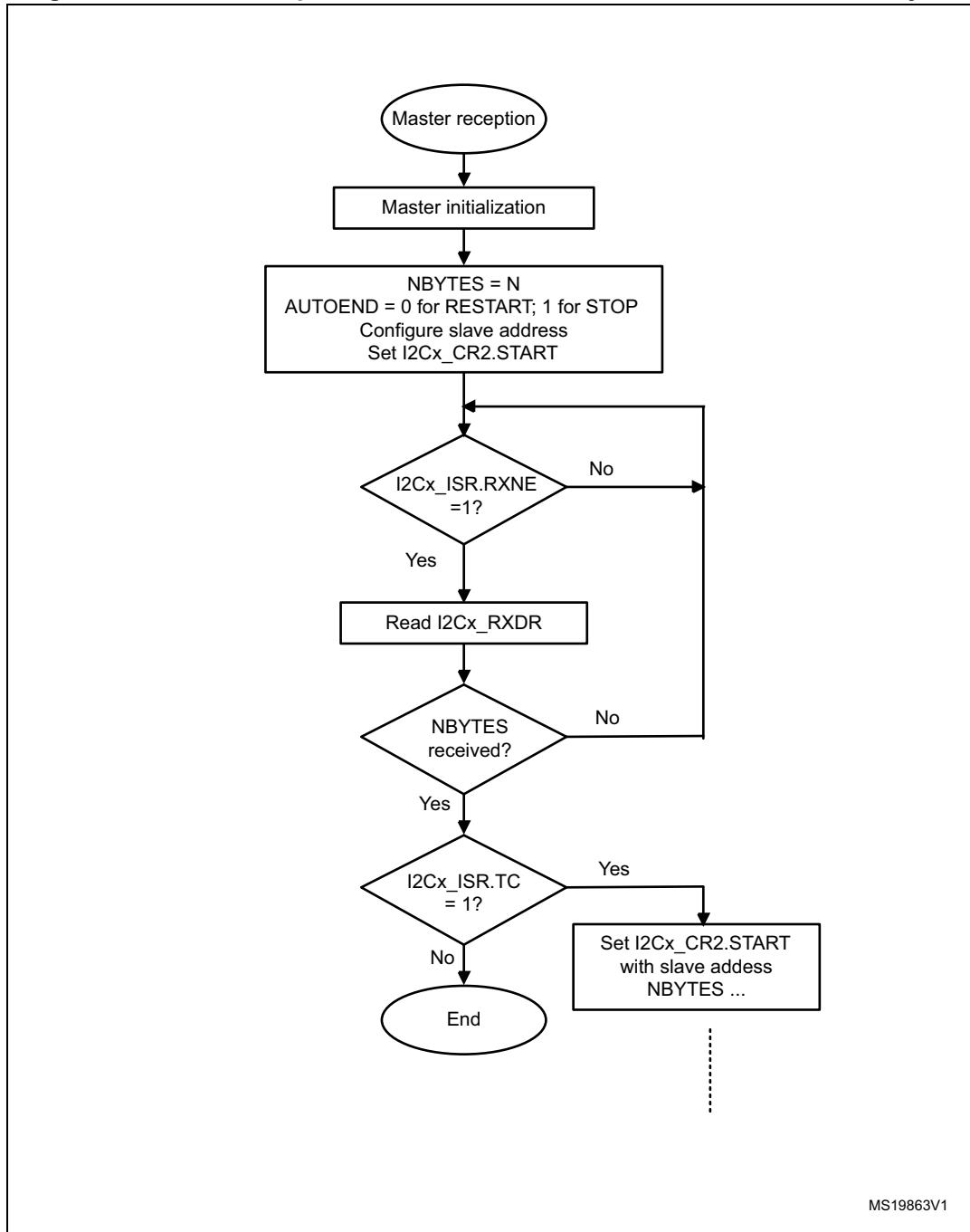
Figure 219. Transfer sequence flowchart for I<sup>2</sup>C master receiver for N<=255 bytes

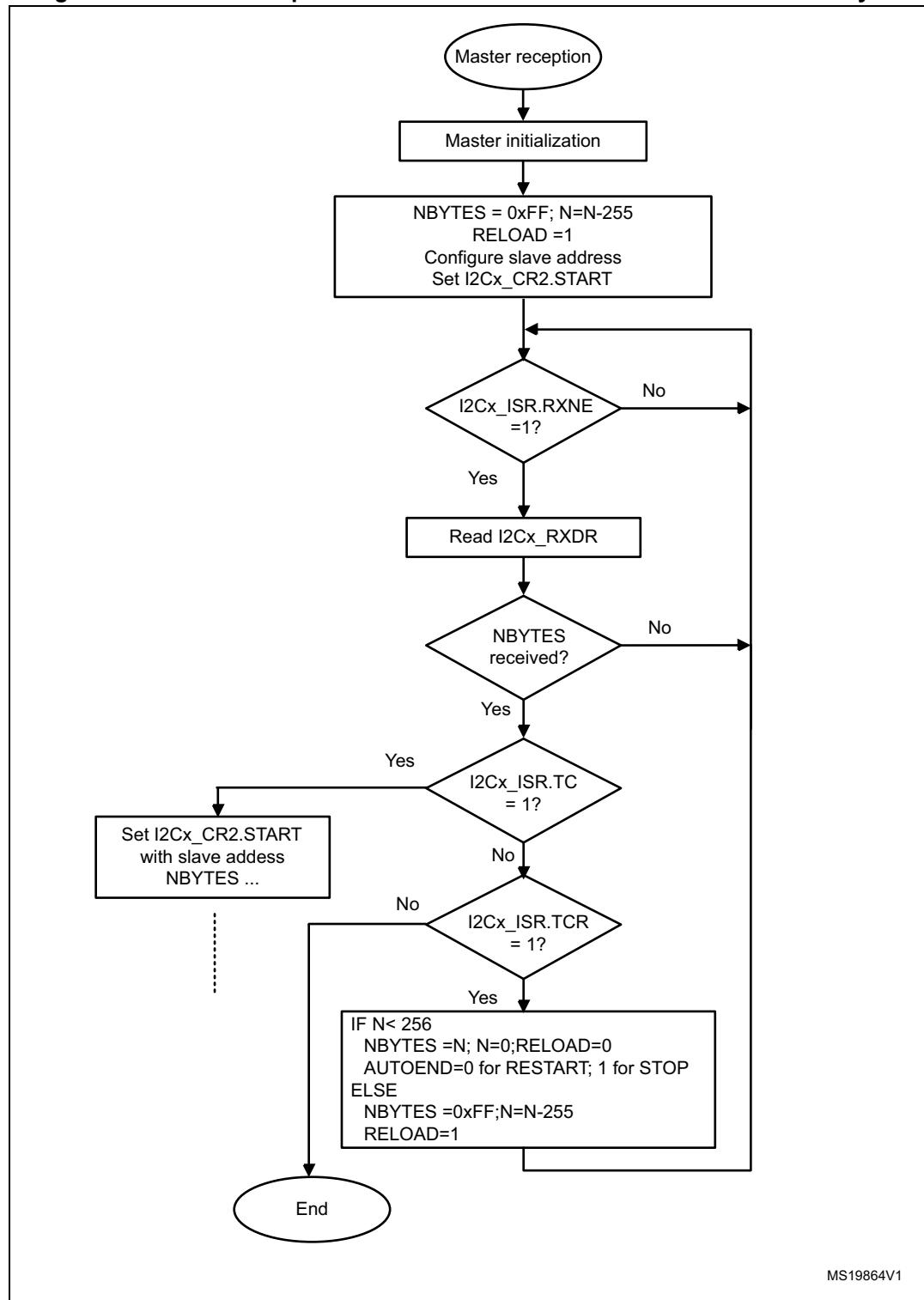
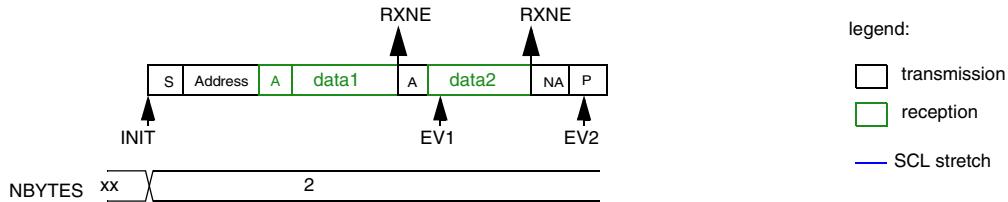
Figure 220. Transfer sequence flowchart for I<sup>2</sup>C master receiver for N>255 bytes

Figure 221. Transfer bus diagrams for I<sup>2</sup>C master receiver

Example I<sup>2</sup>C master receiver 2 bytes, automatic end mode (STOP)

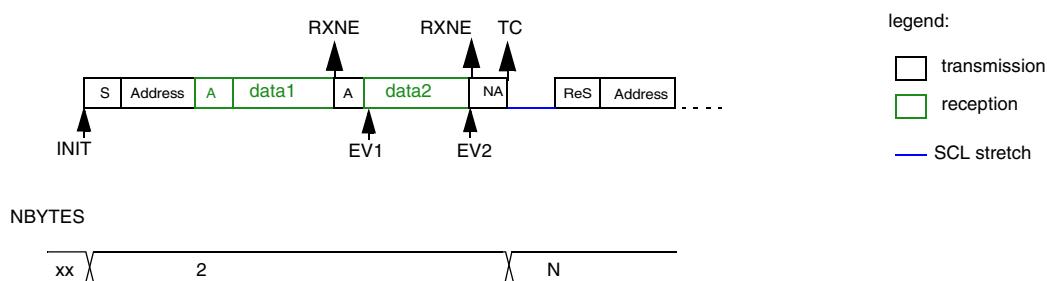


INIT: program Slave address, program NBYTES = 2, AUTOEND=1, set START

EV1: RXNE ISR: rd data1

EV2: RXNE ISR: rd data2

Example I<sup>2</sup>C master receiver 2 bytes, software end mode (RESTART)



INIT: program Slave address, program NBYTES = 2, AUTOEND=0, set START

EV1: RXNE ISR: rd data1

EV2: RXNE ISR: read data2

EV3: TC ISR: program Slave address, program NBYTES = N, set START

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#### 24.4.10 I2Cx\_TIMINGR register configuration examples

**Table 71. Examples of timings settings for f<sub>I2CCLK</sub> = 8 MHz**

Parameter	Standard mode		Fast Mode	Fast Mode Plus
	10 kHz	100 kHz	400 kHz	500 kHz
PRESC	1	1	0	0
SCLL	0xC7	0x13	0x9	0x6
t <sub>SCLL</sub>	200x250 ns = 50 µs	20x250 ns = 5.0 µs	10x125 ns = 1250 ns	7x125 ns = 875 ns
SCLH	0xC3	0xF	0x3	0x3
t <sub>SCLH</sub>	196x250 ns = 49 µs	16x250 ns = 4.0 µs	4x125 ns = 500 ns	4x125 ns = 500 ns
t <sub>SCL</sub> <sup>(1)</sup>	~100 µs <sup>(2)</sup>	~10 µs <sup>(2)</sup>	~2500 ns <sup>(3)</sup>	~2000 ns <sup>(4)</sup>
SDADEL	0x2	0x2	0x1	0x0
t <sub>SDADEL</sub>	2x250 ns = 500 ns	2x250 ns = 500 ns	1x125 ns = 125 ns	0 ns
SCLDEL	0x4	0x4	0x3	0x1
t <sub>SCLDEL</sub>	5x250 ns = 1250 ns	5x250 ns = 1250 ns	4x125 ns = 500 ns	2x125 ns = 250 ns

1. SCL period t<sub>SCL</sub> is greater than t<sub>SCLL</sub> + t<sub>SCLH</sub> due to SCL internal detection delay. Values provided for t<sub>SCL</sub> are examples only.

2. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4 x t<sub>I2CCLK</sub> = 500 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 1000 ns

3. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4 x t<sub>I2CCLK</sub> = 500 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 750 ns

4. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4 x t<sub>I2CCLK</sub> = 500 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 655 ns

**Table 72. Examples of timings settings for f<sub>I2CCLK</sub> = 16 MHz**

Parameter	Standard mode		Fast Mode	Fast Mode Plus
	10 kHz	100 kHz	400 kHz	1000 kHz
PRESC	3	3	1	0
SCLL	0xC7	0x13	0x9	0x4
t <sub>SCLL</sub>	200 x 250 ns = 50 µs	20 x 250 ns = 5.0 µs	10 x 125 ns = 1250 ns	5 x 62.5 ns = 312.5 ns
SCLH	0xC3	0xF	0x3	0x2
t <sub>SCLH</sub>	196 x 250 ns = 49 µs	16 x 250 ns = 4.0 µs	4 x 125 ns = 500 ns	3 x 62.5 ns = 187.5 ns
t <sub>SCL</sub> <sup>(1)</sup>	~100 µs <sup>(2)</sup>	~10 µs <sup>(2)</sup>	~2500 ns <sup>(3)</sup>	~1000 ns <sup>(4)</sup>
SDADEL	0x2	0x2	0x2	0x0
t <sub>SDADEL</sub>	2 x 250 ns = 500 ns	2 x 250 ns = 500 ns	2 x 125 ns = 250 ns	0 ns
SCLDEL	0x4	0x4	0x3	0x2
t <sub>SCLDEL</sub>	5 x 250 ns = 1250 ns	5 x 250 ns = 1250 ns	4 x 125 ns = 500 ns	3 x 62.5 ns = 187.5 ns

1. SCL period t<sub>SCL</sub> is greater than t<sub>SCLL</sub> + t<sub>SCLH</sub> due to SCL internal detection delay. Values provided for t<sub>SCL</sub> are examples only.

2. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4 x t<sub>I2CCLK</sub> = 250 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 1000 ns

3. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4 x t<sub>I2CCLK</sub> = 250 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 750 ns

4. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4 x t<sub>I2CCLK</sub> = 250 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 500 ns

**Table 73. Examples of timings settings for f<sub>I<sup>2</sup>CCLK</sub> = 48 MHz**

Parameter	Standard mode		Fast Mode	Fast Mode Plus
	10 kHz	100 kHz	400 kHz	1000 kHz
PRESC	0xB	0xB	5	5
SCLL	0xC7	0x13	0x9	0x3
t <sub>SCLL</sub>	200 × 250 ns = 50 µs	20 × 250 ns = 5.0 µs	10 × 125 ns = 1250 ns	4 × 125 ns = 500 ns
SCLH	0xC3	0xF	0x3	0x1
t <sub>SCLH</sub>	196 × 250 ns = 49 µs	16 × 250 ns = 4.0 µs	4 × 125 ns = 500 ns	2 × 125 ns = 250 ns
t <sub>SCL</sub> <sup>(1)</sup>	~100 µs <sup>(2)</sup>	~10 µs <sup>(2)</sup>	~2500 ns <sup>(3)</sup>	~875 ns <sup>(4)</sup>
SDADEL	0x2	0x2	0x3	0x0
t <sub>SDADEL</sub>	2 × 250 ns = 500 ns	2 × 250 ns = 500 ns	3 × 125 ns = 375 ns	0 ns
SCLDEL	0x4	0x4	0x3	0x1
t <sub>SCLDEL</sub>	5 × 250 ns = 1250 ns	5 × 250 ns = 1250 ns	4 × 125 ns = 500 ns	2 × 125 ns = 250 ns

1. The SCL period t<sub>SCL</sub> is greater than t<sub>SCLL</sub> + t<sub>SCLH</sub> due to the SCL internal detection delay. Values provided for t<sub>SCL</sub> are only examples.
2. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4x t<sub>I<sup>2</sup>CCLK</sub> = 83.3 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 1000 ns
3. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4x t<sub>I<sup>2</sup>CCLK</sub> = 83.3 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 750 ns
4. t<sub>SYNC1</sub> + t<sub>SYNC2</sub> minimum value is 4x t<sub>I<sup>2</sup>CCLK</sub> = 83.3 ns. Example with t<sub>SYNC1</sub> + t<sub>SYNC2</sub> = 250 ns

#### 24.4.11 SMBus specific features

This section is relevant only when SMBus feature is supported. Please refer to [Table 24.3: I<sup>2</sup>C implementation](#).

##### Introduction

The System Management Bus (SMBus) is a two-wire interface through which various devices can communicate with each other and with the rest of the system. It is based on I<sup>2</sup>C principles of operation. SMBus provides a control bus for system and power management related tasks.

This peripheral is compatible with the SMBUS specification rev 2.0 (<http://smbus.org/specs/>).

The System Management Bus Specification refers to three types of devices.

- A slave is a device that receives or responds to a command.
- A master is a device that issues commands, generates the clocks and terminates the transfer.
- A host is a specialized master that provides the main interface to the system's CPU. A host must be a master-slave and must support the SMBus host notify protocol. Only one host is allowed in a system.

This peripheral can be configured as master or slave device, and also as a host.

## SMBUS is based on I<sup>2</sup>C specification rev 2.1.

### Bus protocols

There are eleven possible command protocols for any given device. A device may use any or all of the eleven protocols to communicate. The protocols are Quick Command, Send Byte, Receive Byte, Write Byte, Write Word, Read Byte, Read Word, Process Call, Block Read, Block Write and Block Write-Block Read Process Call. These protocols should be implemented by the user software.

For more details of these protocols, refer to SMBus specification ver. 2.0 (<http://smbus.org/specs/>).

### Address resolution protocol (ARP)

SMBus slave address conflicts can be resolved by dynamically assigning a new unique address to each slave device. In order to provide a mechanism to isolate each device for the purpose of address assignment each device must implement a unique device identifier (UDID). This 128-bit number is implemented by software.

This peripheral supports the Address Resolution Protocol (ARP). The SMBus Device Default Address (0b1100 001) is enabled by setting SMBDEN bit in I2Cx\_CR1 register. The ARP commands should be implemented by the user software.

Arbitration is also performed in slave mode for ARP support.

For more details of the SMBus Address Resolution Protocol, refer to SMBus specification ver. 2.0 (<http://smbus.org/specs/>).

### Received Command and Data acknowledge control

A SMBus receiver must be able to NACK each received command or data. In order to allow the ACK control in slave mode, the Slave Byte Control mode must be enabled by setting SBC bit in I2Cx\_CR1 register. Refer to *Slave Byte Control Mode on page 522* section for more details.

### Host Notify protocol

This peripheral supports the Host Notify protocol by setting the SMBHEN bit in the I2Cx\_CR1 register. In this case the host will acknowledge the SMBus Host address (0b0001 000).

When this protocol is used, the device acts as a master and the host as a slave.

### SMBus alert

The SMBus ALERT optional signal is supported. A slave-only device can signal the host through the SMBALERT# pin that it wants to talk. The host processes the interrupt and simultaneously accesses all SMBALERT# devices through the Alert Response Address (0b0001 100). Only the device(s) which pulled SMBALERT# low will acknowledge the Alert Response Address.

When configured as a slave device(SMBHEN=0), the SMBA pin is pulled low by setting the ALERTEN bit in the I2Cx\_CR1 register. The Alert Response Address is enabled at the same time.

When configured as a host (SMBHEN=1), the ALERT flag is set in the I2Cx\_ISR register when a falling edge is detected on the SMBA pin and ALERTEN=1. An interrupt is

generated if the ERRIE bit is set in the I2Cx\_CR1 register. When ALERTEN=0, the ALERT line is considered high even if the external SMBA pin is low.

*If the SMBus ALERT pin is not needed, the SMBA pin can be used as a standard GPIO if ALERTEN=0.*

### Packet error checking

A packet error checking mechanism has been introduced in the SMBus specification to improve reliability and communication robustness. Packet Error Checking is implemented by appending a Packet Error Code (PEC) at the end of each message transfer. The PEC is calculated by using the  $C(x) = x^8 + x^2 + x + 1$  CRC-8 polynomial on all the message bytes (including addresses and read/write bits).

The peripheral embeds a hardware PEC calculator and allows to send a Not Acknowledge automatically when the received byte does not match with the hardware calculated PEC.

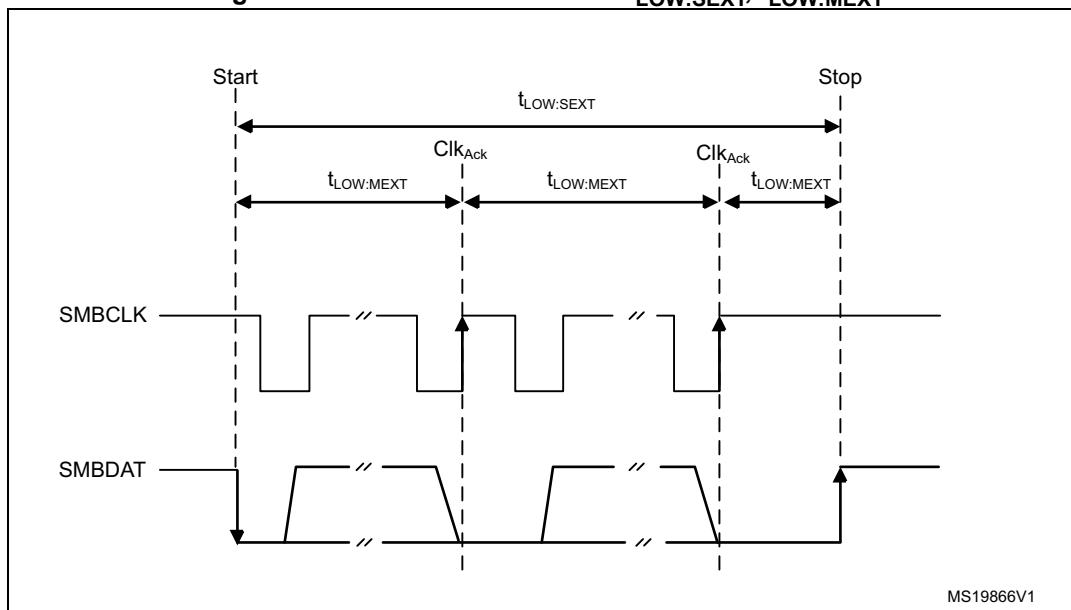
### Timeouts

This peripheral embeds hardware timers in order to be compliant with the 3 timeouts defined in SMBus specification ver. 2.0.

**Table 74. SMBus timeout specifications**

Symbol	Parameter	Limits		Unit
		Min	Max	
t <sub>TIMEOUT</sub>	Detect clock low timeout	25	35	ms
t <sub>LOW:SEXT</sub> <sup>(1)</sup>	Cumulative clock low extend time (slave device)		25	ms
t <sub>LOW:MEXT</sub> <sup>(2)</sup>	Cumulative clock low extend time (master device)		10	ms

1. t<sub>LOW:SEXT</sub> is the cumulative time a given slave device is allowed to extend the clock cycles in one message from the initial START to the STOP. It is possible that, another slave device or the master will also extend the clock causing the combined clock low extend time to be greater than t<sub>LOW:SEXT</sub>. Therefore, this parameter is measured with the slave device as the sole target of a full-speed master.
2. t<sub>LOW:MEXT</sub> is the cumulative time a master device is allowed to extend its clock cycles within each byte of a message as defined from START-to-ACK, ACK-to-ACK, or ACK-to-STOP. It is possible that a slave device or another master will also extend the clock causing the combined clock low time to be greater than t<sub>LOW:MEXT</sub> on a given byte. Therefore, this parameter is measured with a full speed slave device as the sole target of the master.

Figure 222. Timeout intervals for  $t_{LOW:SEXT}$ ,  $t_{LOW:MEXT}$ 

### Bus idle detection

A master can assume that the bus is free if it detects that the clock and data signals have been high for  $t_{IDLE}$  greater than  $t_{HIGH,MAX}$ . (refer to [Table 70: I<sup>2</sup>C-SMBUS specification clock timings](#))

This timing parameter covers the condition where a master has been dynamically added to the bus and may not have detected a state transition on the SMBCLK or SMBDAT lines. In this case, the master must wait long enough to ensure that a transfer is not currently in progress. The peripheral supports a hardware bus idle detection.

#### 24.4.12 SMBus initialization

This section is relevant only when SMBus feature is supported. Please refer to [Section 24.3: I<sup>2</sup>C implementation](#).

In addition to I<sup>2</sup>C initialization, some other specific initialization must be done in order to perform SMBus communication:

##### Received Command and Data Acknowledge control (Slave mode)

A SMBus receiver must be able to NACK each received command or data. In order to allow ACK control in slave mode, the Slave Byte Control mode must be enabled by setting the SBC bit in the I<sup>2</sup>Cx\_CR1 register. Refer to [Slave Byte Control Mode on page 522](#) for more details.

### Specific address (Slave mode)

The specific SMBus addresses should be enabled if needed. Refer to [Bus idle detection on page 545](#) for more details.

- The SMBus Device Default address (0b1100 001) is enabled by setting the SMBDEN bit in the I2Cx\_CR1 register.
- The SMBus Host address (0b0001 000) is enabled by setting the SMBHEN bit in the I2Cx\_CR1 register.
- The Alert Response Address (0b0001100) is enabled by setting the ALERTEN bit in the I2Cx\_CR1 register.

### Packet error checking

PEC calculation is enabled by setting the PECEN bit in the I2Cx\_CR1 register. Then the PEC transfer is managed with the help of a hardware byte counter: NBYTES[7:0] in the I2Cx\_CR2 register. The PECEN bit must be configured before enabling the I2C.

The PEC transfer is managed with the hardware byte counter, so the SBC bit must be set when interfacing the SMBus in slave mode. The PEC is transferred after NBYTES-1 data have been transferred when the PECBYTE bit is set and the RELOAD bit is cleared. If RELOAD is set, PECBYTE has no effect.

**Caution:** Changing the PECEN configuration is not allowed when the I2C is enabled.

**Table 75. SMBUS with PEC configuration table**

Mode	SBC bit	RELOAD bit	AUTOEND bit	PECBYTE bit
Master Tx/Rx NBYTES + PEC+ STOP	x	0	1	1
Master Tx/Rx NBYTES + PEC + ReSTART	x	0	0	1
Slave Tx/Rx with PEC	1	0	x	1

### Timeout detection

The timeout detection is enabled by setting the TIMOUTEN and TEXTEN bits in the I2Cx\_TIMEOUTR register. The timers must be programmed in such a way that they detect a timeout before the maximum time given in the SMBus specification ver. 2.0.

- $t_{TIMEOUT}$  check

In order to enable the  $t_{TIMEOUT}$  check, the 12-bit TIMEOUTA[11:0] bits must be programmed with the timer reload value in order to check the  $t_{TIMEOUT}$  parameter. The TIDLE bit must be configured to '0' in order to detect the SCL low level timeout.

Then the timer is enabled by setting the TIMOUTEN in the I2Cx\_TIMEOUTR register. If SCL is tied low for a time greater than (TIMEOUTA+1) x 2048 x  $t_{I2CCLK}$ , the TIMEOUT flag is set in the I2Cx\_ISR register.

Refer to [Table 76: Examples of TIMEOUTA settings for various I2CCLK frequencies \(max tTIMEOUT = 25 ms\)](#)

**Caution:** Changing the TIMEOUTA[11:0] bits and TIDLE bit configuration is not allowed when the TIMEOUTEN bit is set.

- $t_{LOW:SEXT}$  and  $t_{LOW:MEXT}$  check

Depending on if the peripheral is configured as a master or as a slave, The 12-bit TIMEOUTB timer must be configured in order to check  $t_{LOW:SEXT}$  for a slave and  $t_{LOW:MEXT}$  for a master. As the standard specifies only a maximum, you can choose the same value for the both.

Then the timer is enabled by setting the TEXTEN bit in the I2Cx\_TIMEOUTTR register.

If the SMBus peripheral performs a cumulative SCL stretch for a time greater than  $(TIMEOUTB+1) \times 2048 \times t_{I2CCLK}$ , and in the timeout interval described in [Bus idle detection on page 545](#) section, the TIMEOUT flag is set in the I2Cx\_ISR register.

Refer to [Table 77: Examples of TIMEOUTB settings for various I2CCLK frequencies](#)

**Caution:** Changing the TIMEOUTB configuration is not allowed when the TEXTEN bit is set.

#### Bus Idle detection

In order to enable the  $t_{IDLE}$  check, the 12-bit TIMEOUTA[11:0] field must be programmed with the timer reload value in order to obtain the  $t_{IDLE}$  parameter. The TIDLE bit must be configured to '1' in order to detect both SCL and SDA high level timeout.

Then the timer is enabled by setting the TIMOUTEN bit in the I2Cx\_TIMEOUTTR register.

If both the SCL and SDA lines remain high for a time greater than  $(TIMEOUTA+1) \times 4 \times t_{I2CCLK}$ , the TIMEOUT flag is set in the I2Cx\_ISR register.

Refer to [Table 78: Examples of TIMEOUTA settings for various I2CCLK frequencies \(max tIDLE = 50 µs\)](#)

**Caution:** Changing the TIMEOUTA and TIDLE configuration is not allowed when the TIMEOUTEN is set.

### 24.4.13 SMBus: I2Cx\_TIMEOUTTR register configuration examples

This section is relevant only when SMBus feature is supported. Please refer to [Section 24.3: I2C implementation](#).

- Configuring the maximum duration of  $t_{TIMEOUT}$  to 25 ms:

**Table 76. Examples of TIMEOUTA settings for various I2CCLK frequencies (max  $t_{TIMEOUT} = 25$  ms)**

$f_{I2CCLK}$	TIMEOUTA[11:0] bits	TIDLE bit	TIMEOUTEN bit	$t_{TIMEOUT}$
8 MHz	0x61	0	1	$98 \times 2048 \times 125$ ns = 25 ms
16 MHz	0xC3	0	1	$196 \times 2048 \times 62.5$ ns = 25 ms
48 MHz	0x249	0	1	$586 \times 2048 \times 20.08$ ns = 25 ms

- Configuring the maximum duration of  $t_{LOW:SEXT}$  and  $t_{LOW:MEXT}$  to 8 ms:

**Table 77. Examples of TIMEOUTB settings for various I2CCLK frequencies**

$f_{I2CCLK}$	TIMEOUTB[11:0] bits	TEXTEN bit	$t_{LOW:EXT}$
8 MHz	0x1F	1	$32 \times 2048 \times 125 \text{ ns} = 8 \text{ ms}$
16 MHz	0x3F	1	$64 \times 2048 \times 62.5 \text{ ns} = 8 \text{ ms}$
48 MHz	0xBB	1	$188 \times 2048 \times 20.08 \text{ ns} = 8 \text{ ms}$

- Configuring the maximum duration of  $t_{IDLE}$  to 50  $\mu\text{s}$

**Table 78. Examples of TIMEOUTA settings for various I2CCLK frequencies  
(max  $t_{IDLE} = 50 \mu\text{s}$ )**

$f_{I2CCLK}$	TIMEOUTA[11:0] bits	TIDLE bit	TIMEOUTEN bit	$t_{TIDLE}$
8 MHz	0x63	1	1	$100 \times 4 \times 125 \text{ ns} = 50 \mu\text{s}$
16 MHz	0xC7	1	1	$200 \times 4 \times 62.5 \text{ ns} = 50 \mu\text{s}$
48 MHz	0x257	1	1	$600 \times 4 \times 20.08 \text{ ns} = 50 \mu\text{s}$

#### 24.4.14 SMBus slave mode

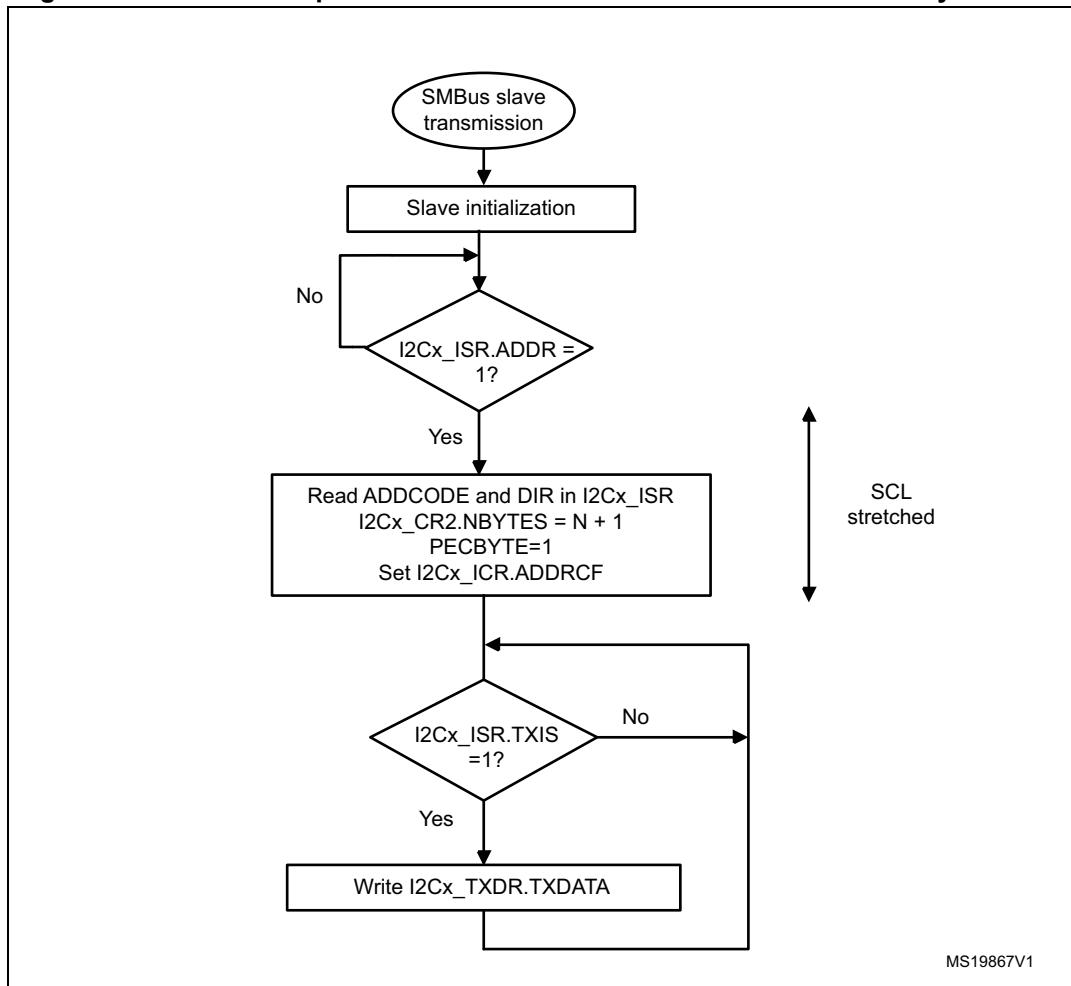
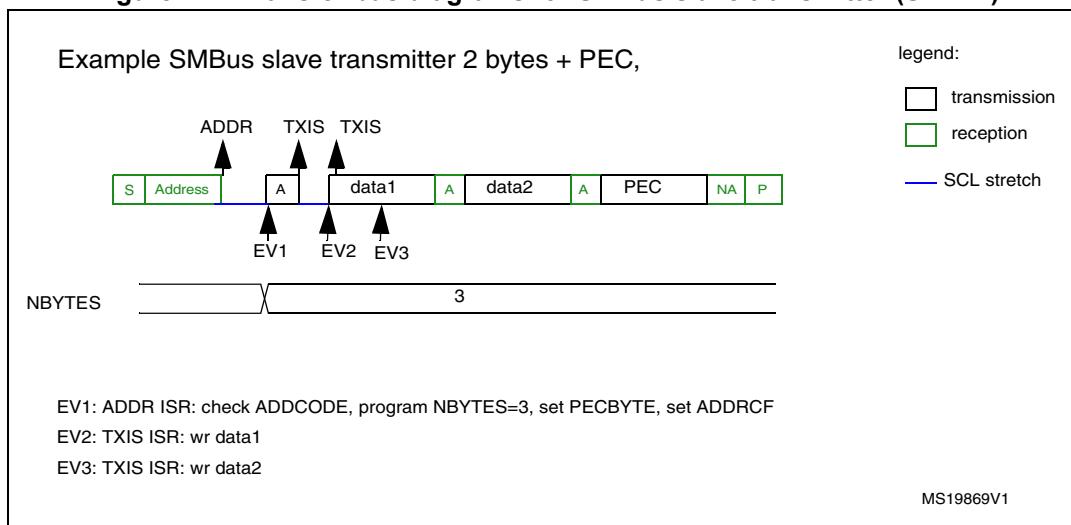
This section is relevant only when SMBus feature is supported. Please refer to [Section 24.3: I2C implementation](#).

In addition to I2C slave transfer management (refer to [Section 24.4.8: I2C slave mode](#)) some additional software flowcharts are provided to support SMBus.

##### SMBus Slave transmitter

When the IP is used in SMBus, SBC must be programmed to '1' in order to allow the PEC transmission at the end of the programmed number of data bytes. When the PECPBYTE bit is set, the number of bytes programmed in NBYTES[7:0] includes the PEC transmission. In that case the total number of TXIS interrupts will be NBYTES-1 and the content of the I2Cx\_PECR register is automatically transmitted if the master requests an extra byte after the NBYTES-1 data transfer.

**Caution:** The PECPBYTE bit has no effect when the RELOAD bit is set.

**Figure 223. Transfer sequence flowchart for SMBus slave transmitter N bytes + PEC****Figure 224. Transfer bus diagrams for SMBus slave transmitter (SBC=1)**

### SMBus Slave receiver

When the I2C is used in SMBus mode, SBC must be programmed to '1' in order to allow the PEC checking at the end of the programmed number of data bytes. In order to allow the ACK control of each byte, the reload mode must be selected (RELOAD=1). Refer to [Slave Byte Control Mode on page 522](#) for more details.

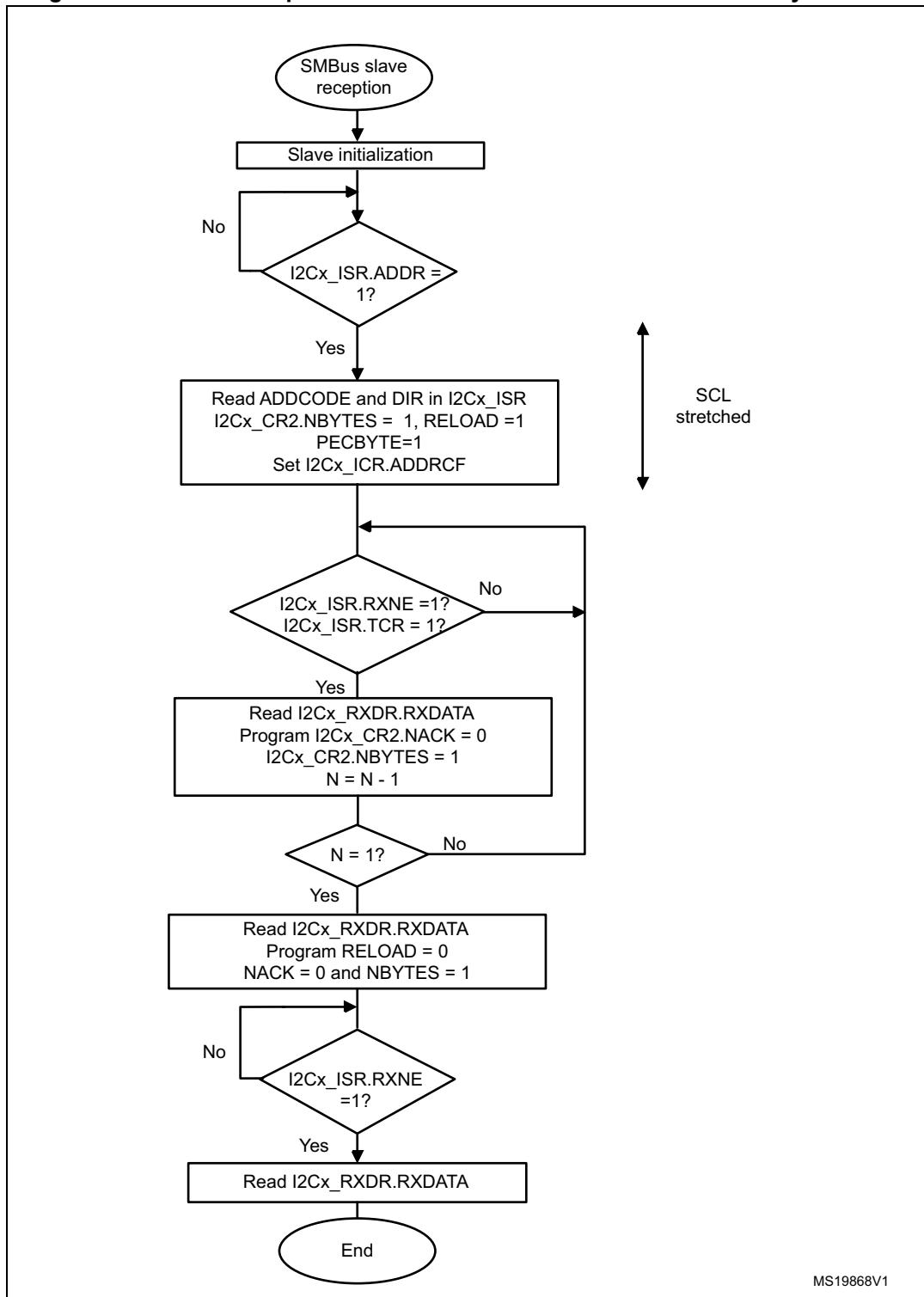
In order to check the PEC byte, the RELOAD bit must be cleared and the PECPBYTE bit must be set. In this case, after NBYTES-1 data have been received, the next received byte is compared with the internal I2Cx\_PECR register content. A NACK is automatically generated if the comparison does not match, and an ACK is automatically generated if the comparison matches, whatever the ACK bit value. Once the PEC byte is received, it is copied into the I2Cx\_RXDR register like any other data, and the RXNE flag is set.

In the case of a PEC mismatch, the PECPERR flag is set and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

If no ACK software control is needed, you can program PECPBYTE=1 and, in the same write operation, program NBYTES with the number of bytes to be received in a continuous flow. After NBYTES-1 are received, the next received byte is checked as being the PEC.

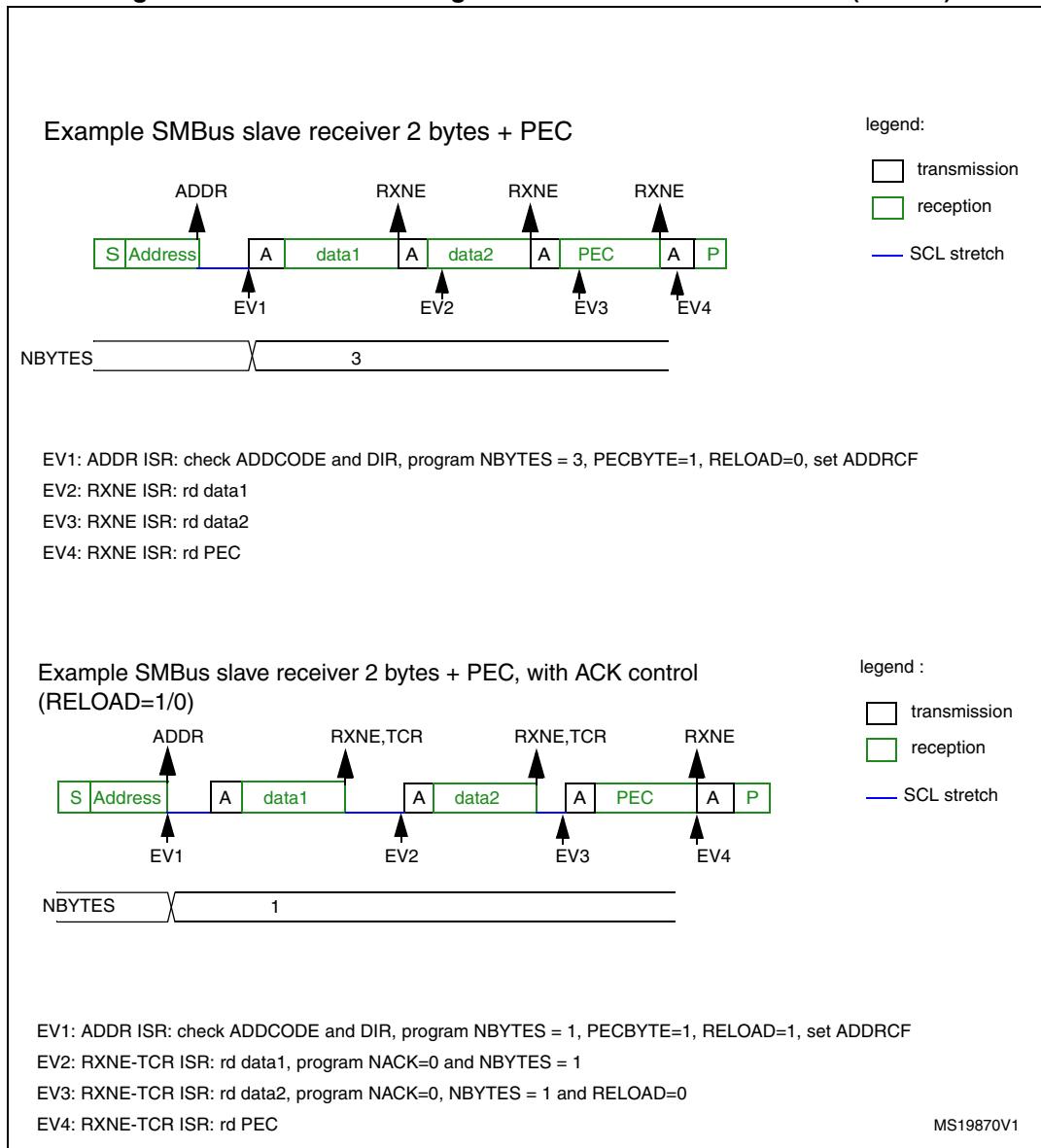
**Caution:** The PECPBYTE bit has no effect when the RELOAD bit is set.

Figure 225. Transfer sequence flowchart for SMBus slave receiver N Bytes + PEC



MS19868V1

Figure 226. Bus transfer diagrams for SMBus slave receiver (SBC=1)



This section is relevant only when SMBus feature is supported. Please refer to [Section 24.3: I<sup>2</sup>C implementation](#).

In addition to I<sup>2</sup>C master transfer management (refer to [Section 24.4.9: I<sup>2</sup>C master mode](#)) some additional software flowcharts are provided to support SMBus.

### SMBus Master transmitter

When the SMBus master wants to transmit the PEC, the PECBYTE bit must be set and the number of bytes must be programmed in the NBYTES[7:0] field, before setting the START bit. In this case the total number of TXIS interrupts will be NBYTES-1. So if the PECBYTE bit is set when NBYTES=0x1, the content of the I2Cx\_PECR register is automatically transmitted.

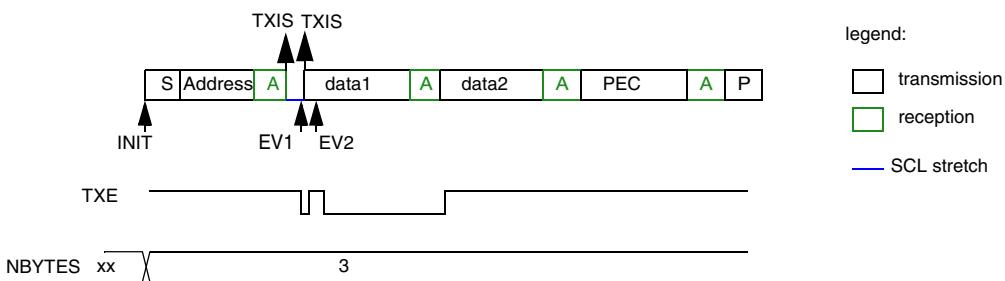
If the SMBus master wants to send a STOP condition after the PEC, automatic end mode should be selected (AUTOEND=1). In this case, the STOP condition automatically follows the PEC transmission.

When the SMBus master wants to send a RESTART condition after the PEC, software mode must be selected (AUTOEND=0). In this case, once NBYTES-1 have been transmitted, the I<sub>2</sub>C<sub>x</sub>\_PECR register content is transmitted and the TC flag is set after the PEC transmission, stretching the SCL line low. The RESTART condition must be programmed in the TC interrupt subroutine.

**Caution:** The PECBYTE bit has no effect when the RELOAD bit is set.

**Figure 227. Bus transfer diagrams for SMBus master transmitter**

Example SMBus master transmitter 2 bytes + PEC, automatic end mode (STOP)

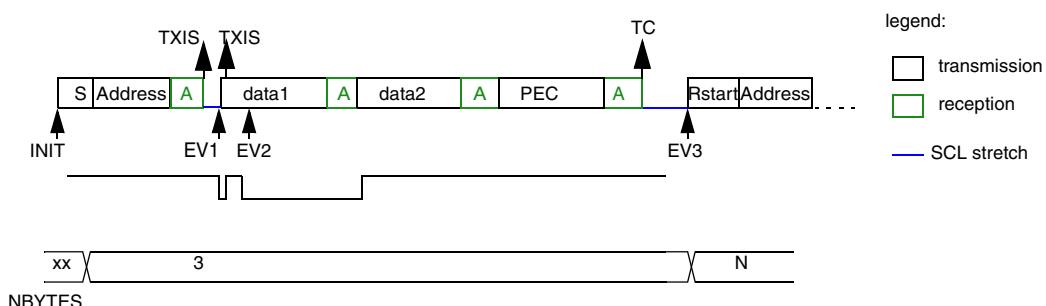


INIT: program Slave address, program NBYTES = 3, AUTOEND=1, set PECBYTE, set START

EV1: TXIS ISR: wr data1

EV2: TXIS ISR: wr data2

Example SMBus master transmitter 2 bytes + PEC, software end mode (RESTART)



INIT: program Slave address, program NBYTES = 3, AUTOEND=0, set PECBYTE, set START

EV1: TXIS ISR: wr data1

EV2: TXIS ISR: wr data2

EV3: TC ISR: program Slave address, program NBYTES = N, set START

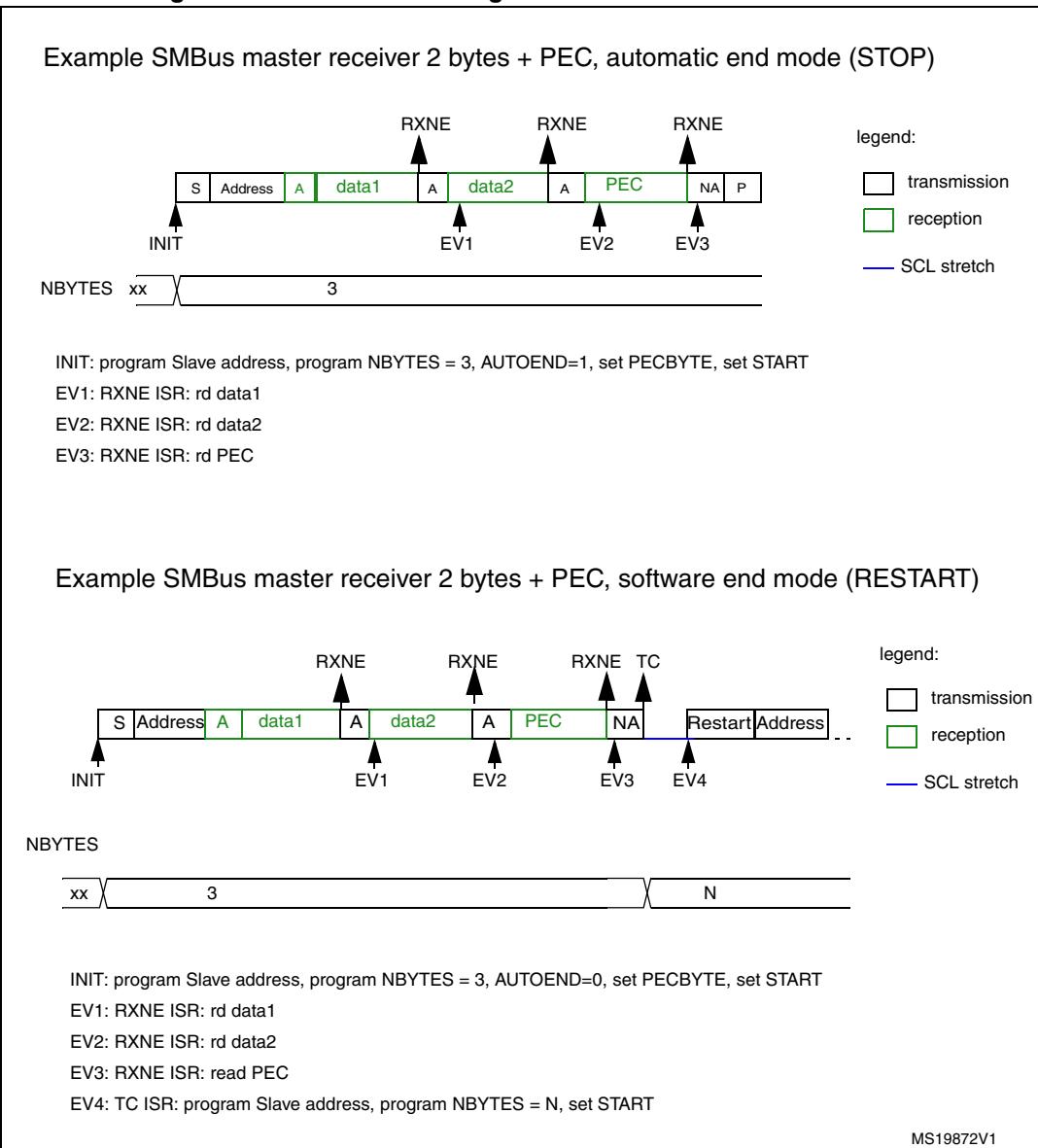
MS19871V1

### SMBus Master receiver

When the SMBus master wants to receive the PEC followed by a STOP at the end of the transfer, automatic end mode can be selected (AUTOEND=1). The PECBYTE bit must be set and the slave address must be programmed, before setting the START bit. In this case, after NBYTES-1 data have been received, the next received byte is automatically checked versus the I2Cx\_PECR register content. A NACK response is given to the PEC byte, followed by a STOP condition.

When the SMBus master receiver wants to receive the PEC byte followed by a RESTART condition at the end of the transfer, software mode must be selected (AUTOEND=0). The PECBYTE bit must be set and the slave address must be programmed, before setting the START bit. In this case, after NBYTES-1 data have been received, the next received byte is automatically checked versus the I2Cx\_PECR register content. The TC flag is set after the PEC byte reception, stretching the SCL line low. The RESTART condition can be programmed in the TC interrupt subroutine.

**Caution:** The PECBYTE bit has no effect when the RELOAD bit is set.

**Figure 228. Bus transfer diagrams for SMBus master receiver**

#### 24.4.15 Wakeup from STOP on address match

This section is relevant only when Wakeup from STOP feature is supported. Please refer to [Section 24.3: I<sup>2</sup>C implementation](#).

The I<sup>2</sup>C is able to wakeup the MCU from Stop mode (APB clock is off), when it is addressed. All addressing modes are supported.

Wakeup from STOP is enabled by setting the WUPEN bit in the I2Cx\_CR1 register. The HSI oscillator must be selected as the clock source for I2CCLK in order to allow wakeup from STOP.

During Stop mode, the HSI is switched off. When a START is detected, the I<sup>2</sup>C interface switches the HSI on, and stretches SCL low until HSI is woken up.

HSI is then used for the address reception.

In case of an address match, the I<sup>2</sup>C stretches SCL low during MCU wakeup time. The stretch is released when ADDR flag is cleared by software, and the transfer goes on normally.

If the address does not match, the HSI is switched off again and the MCU is not woken up.

**Note:** *If the I<sup>2</sup>C clock is the system clock, or if WUPEN = 0, the HSI oscillator is not switched on after a START is received.*

*Only an ADDR interrupt can wakeup the MCU. Therefore do not enter Stop mode when the I<sup>2</sup>C is performing a transfer as a master, or as an addressed slave after the ADDR flag is set. This can be managed by clearing SLEEPDEEP bit in the ADDR interrupt routine and setting it again only after the STOPF flag is set.*

**Caution:** The digital filter is not compatible with the wakeup from STOP feature. If the DNF bit is not equal to 0, setting the WUPEN bit has no effect.

**Caution:** This feature is available only when the I<sup>2</sup>C clock source is the HSI oscillator.

**Caution:** Clock stretching must be enabled (NOSTRETCH=0) to ensure proper operation of the wakeup from STOP feature.

**Caution:** If wakeup from Stop is disabled (WUPEN=0), the I<sup>2</sup>C peripheral must be disabled before entering Stop mode (PE=0).

#### 24.4.16 Error conditions

The following are the error conditions which may cause communication to fail.

##### Bus error (BERR)

A bus error is detected when a START or a STOP condition is detected and is not located after a multiple of 9 SCL clock pulses. A START or a STOP condition is detected when a SDA edge occurs while SCL is high.

The bus error flag is set only if the I<sup>2</sup>C is involved in the transfer as master or addressed slave (i.e not during the address phase in slave mode).

In case of a misplaced START or RESTART detection in slave mode, the I<sup>2</sup>C enters address recognition state like for a correct START condition.

When a bus error is detected, the BERR flag is set in the I2Cx\_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

##### Arbitration lost (ARLO)

An arbitration loss is detected when a high level is sent on the SDA line, but a low level is sampled on the SCL rising edge.

- In master mode, arbitration loss is detected during the address phase, data phase and data acknowledge phase. In this case, the SDA and SCL lines are released, the START control bit is cleared by hardware and the master switches automatically to slave mode.
- In slave mode, arbitration loss is detected during data phase and data acknowledge phase. In this case, the transfer is stopped, and the SCL and SDA lines are released.

When an arbitration loss is detected, the ARLO flag is set in the I2Cx\_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

### Overrun/underrun error (OVR)

An overrun or underrun error is detected in slave mode when NOSTRETCH=1 and:

- In reception when a new byte is received and the RXDR register has not been read yet.  
The new received byte is lost, and a NACK is automatically sent as a response to the new byte.
- In transmission:
  - When STOPF=1 and the first data byte should be sent. The content of the I2Cx\_TXDR register is sent if TXE=0, 0xFF if not.
  - When a new byte should be sent and the I2Cx\_TXDR register has not been written yet, 0xFF is sent.

When an overrun or underrun error is detected, the OVR flag is set in the I2Cx\_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

### Packet Error Checking Error (PECERR)

This section is relevant only when the SMBus feature is supported. Please refer to [Section 24.3: I2C implementation](#).

A PEC error is detected when the received PEC byte does not match with the I2Cx\_PECR register content. A NACK is automatically sent after the wrong PEC reception.

When an PEC error is detected, the PECERR flag is set in the I2Cx\_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

### Timeout Error (TIMEOUT)

This section is relevant only when the SMBus feature is supported. Please refer to [Section 24.3: I2C implementation](#).

A timeout error occurs for any of these conditions:

- TIDLE=0 and SCL remained low for the time defined in the TIMEOUTA[11:0] bits: this is used to detect a SMBus timeout.
- TIDLE=1 and both SDA and SCL remained high for the time defined in the TIMEOUTA [11:0] bits: this is used to detect a bus idle condition.
- Master cumulative clock low extend time reached the time defined in the TIMEOUTB[11:0] bits (SMBus t<sub>LOW:MEXT</sub> parameter)
- Slave cumulative clock low extend time reached the time defined in TIMEOUTB[11:0] bits (SMBus t<sub>LOW:SEXT</sub> parameter)

When a timeout violation is detected in master mode, a STOP condition is automatically sent.

When a timeout violation is detected in slave mode, SDA and SCL lines are automatically released.

When an timeout error is detected, the TIMEOUT flag is set in the I2Cx\_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

### Alert (ALERT)

This section is relevant only when the SMBus feature is supported. Please refer to [Section 24.3: I2C implementation](#).

The ALERT flag is set when the I<sup>2</sup>C interface is configured as a Host (SMBHEN=1), the alert pin detection is enabled (ALERTEN=1) and a falling edge is detected on the SMBA pin. An interrupt is generated if the ERRIE bit is set in the I2Cx\_CR1 register.

#### 24.4.17 DMA requests

##### Transmission using DMA

DMA (Direct Memory Access) can be enabled for transmission by setting the TXDMAEN bit in the I2Cx\_CR1 register. Data is loaded from an SRAM area configured using the DMA peripheral (see [Section 10: Direct memory access controller \(DMA\) on page 148](#)) to the I2Cx\_TXDR register whenever the TXIS bit is set.

Only the data are transferred with DMA.

- In master mode: the initialization, the slave address, direction, number of bytes and START bit are programmed by software (the transmitted slave address cannot be transferred with DMA). When all data are transferred using DMA, the DMA must be initialized before setting the START bit. The end of transfer is managed with the NBYTES counter. Refer to [Master transmitter on page 533](#).
- In slave mode:
  - With NOSTRETCH=0, when all data are transferred using DMA, the DMA must be initialized before the address match event, or in ADDR interrupt subroutine, before clearing ADDR.
  - With NOSTRETCH=1, the DMA must be initialized before the address match event.
- For instances supporting SMBus: the PEC transfer is managed with NBYTES counter. Refer to [SMBus Slave transmitter on page 548](#) and [SMBus Master transmitter on page 552](#).

*Note:* If DMA is used for transmission, the TXIE bit does not need to be enabled.

##### Reception using DMA

DMA (Direct Memory Access) can be enabled for reception by setting the RXDMAEN bit in the I2Cx\_CR1 register. Data is loaded from the I2Cx\_RXDR register to an SRAM area configured using the DMA peripheral (refer to [Section 10: Direct memory access controller \(DMA\) on page 148](#)) whenever the RXNE bit is set. Only the data (including PEC) are transferred with DMA.

- In master mode, the initialization, the slave address, direction, number of bytes and START bit are programmed by software. When all data are transferred using DMA, the DMA must be initialized before setting the START bit. The end of transfer is managed with the NBYTES counter. Refer to [Master receiver on page 537](#).
- In slave mode with NOSTRETCH=0, when all data are transferred using DMA, the DMA must be initialized before the address match event, or in the ADDR interrupt subroutine, before clearing the ADDR flag.
- If SMBus is supported (see [Section 24.3: I<sup>2</sup>C implementation](#)): the PEC transfer is managed with the NBYTES counter. Refer to [SMBus Slave receiver on page 550](#) and [SMBus Master receiver on page 554](#).

*Note:* If DMA is used for reception, the RXIE bit does not need to be enabled.

#### 24.4.18 Debug mode

When the microcontroller enters debug mode (core halted), the SMBus timeout either continues to work normally or stops, depending on the DBG\_I2Cx\_SMBUS\_TIMEOUT configuration bits in the DBG module.

### 24.5 I<sup>2</sup>C low power modes

**Table 79. Low power modes**

Mode	Description
Sleep	No effect I2C interrupts cause the device to exit the Sleep mode.
Stop	The I2C registers content is kept. If WUPEN=1: the address recognition is functional. The I2C address match condition causes the device to exit the Stop mode. If WUPEN=0: the I2C must be disabled before entering Stop mode.
Standby	The I2C peripheral is powered down and must be reinitialized after exiting Standby.

### 24.6 I<sup>2</sup>C interrupts

The table below gives the list of I<sup>2</sup>C interrupt requests.

**Table 80. I<sup>2</sup>C Interrupt requests**

Interrupt event	Event flag	Event flag/Interrupt clearing method	Interrupt enable control bit
Receive buffer not empty	RXNE	Read I2Cx_RXDR register	RXIE
Transmit buffer interrupt status	TXIS	Write I2Cx_TXDR register	TXIE
Stop detection interrupt flag	STOPF	Write STOPCF=1	STOPIE
Transfer Complete Reload	TCR	Write I2Cx_CR2 with NBYTES[7:0] ≠ 0	TCIE
Transfer complete	TC	Write START=1 or STOP=1	
Address matched	ADDR	Write ADDRCF=1	ADDRIE
NACK reception	NACKF	Write NACKCF=1	NACKIE
Bus error	BERR	Write BERRCF=1	ERRIE
Arbitration loss	ARLO	Write ARLOCF=1	
Overrun/Underrun	OVR	Write OVRCF=1	
PEC error	PECERR	Write PECERRCF=1	
Timeout/t <sub>LOW</sub> error	TIMEOUT	Write TIMEOUTCF=1	
SMBus Alert	ALERT	Write ALERTCF=1	

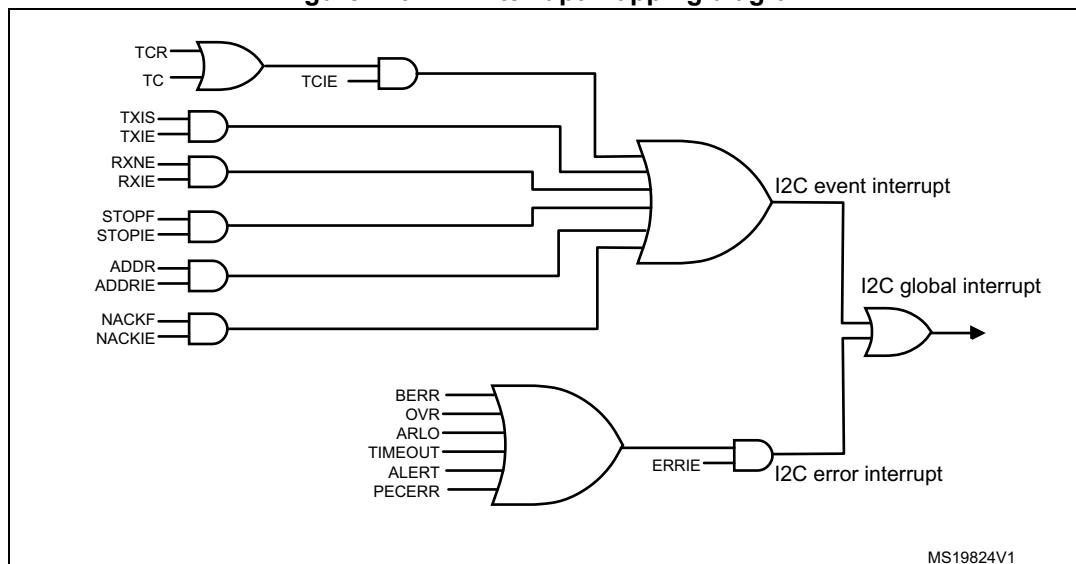
Depending on the product implementation, all these interrupt events can either share the same interrupt vector (I<sup>2</sup>C global interrupt), or be grouped into 2 interrupt vectors (I<sup>2</sup>C event interrupt and I<sup>2</sup>C error interrupt). Refer to the [Vector table in the Interrupts and events section](#) for details.

In order to enable the I<sup>2</sup>C interrupts, the following sequence is required:

1. Configure and enable the I<sup>2</sup>C IRQ channel in the NVIC.
2. Configure the I<sup>2</sup>C to generate interrupts.

The I<sup>2</sup>C wakeup event is connected to the EXTI controller (refer to [the External and internal interrupt/event line mapping section](#)).

**Figure 229. I<sup>2</sup>C interrupt mapping diagram**



## 24.7 I<sup>2</sup>C registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

The peripheral registers are accessed by words (32-bit).

### 24.7.1 Control register 1 (I<sup>2</sup>Cx\_CR1)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PECEN	ALERT EN	SMBD EN	SMBH EN	GCEN	WUP EN	NOSTR ETCH	SBC
								rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RXDMA EN	TXDMA EN	Res.	ANF OFF	DNF				ERRIE	TCIE	STOP IE	NACK IE	ADDR IE	RXIE	TXIE	PE
rw	rw		rw	rw				rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **PECEN**: PEC enable

- 0: PEC calculation disabled
- 1: PEC calculation enabled

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 22 **ALERTEN**: SMBus alert enable

**Device mode (SMBHEN=0):**

- 0: Releases SMBA pin high and Alert Response Address Header disabled: 0001100x followed by NACK.
- 1: Drives SMBA pin low and Alert Response Address Header enables: 0001100x followed by ACK.

**Host mode (SMBHEN=1):**

- 0: SMBus Alert pin (SMBA) not supported.
- 1: SMBus Alert pin (SMBA) supported.

*Note: When ALERTEN=0, the SMBA pin can be used as a standard GPIO.*

*If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 21 **SMBDEN**: SMBus Device Default address enable

- 0: Device default address disabled. Address 0b1100001x is NACKed.
- 1: Device default address enabled. Address 0b1100001x is ACKed.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 20 **SMBHEN**: SMBus Host address enable

- 0: Host address disabled. Address 0b0001000x is NACKed.
- 1: Host address enabled. Address 0b0001000x is ACKed.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 19 **GCEN**: General call enable

- 0: General call disabled. Address 0b00000000 is NACKed.
- 1: General call enabled. Address 0b00000000 is ACKed.

Bit 18 **WUPEN**: Wakeup from STOP enable

- 0: Wakeup from STOP disable.
- 1: Wakeup from STOP enable.

*Note: If the Wakeup from STOP feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

*Note: WUPEN can be set only when DNF = '0000'*

Bit 17 **NOSTRETCH**: Clock stretching disable

This bit is used to disable clock stretching in slave mode.

- 0: Clock stretching enabled
- 1: Clock stretching disabled

*Note: This bit can only be programmed when the I2C is disabled (PE = 0).*

Bit 16 **SBC**: Slave byte control

This bit is used to enable hardware byte control in slave mode.

- 0: Slave byte control disabled
- 1: Slave byte control enabled

Bit 15 **RXDMAEN**: DMA reception requests enable

- 0: DMA mode disabled for reception
- 1: DMA mode enabled for reception

Bit 14 **TXDMAEN**: DMA transmission requests enable

- 0: DMA mode disabled for transmission
- 1: DMA mode enabled for transmission

Bit 13 Reserved, must be kept at reset value.

Bit 12 **ANFOFF**: Analog noise filter OFF

- 0: Analog noise filter enabled
- 1: Analog noise filter disabled

*Note: This bit can only be programmed when the I2C is disabled (PE = 0).*

Bits 11:8 **DNF[3:0]**: Digital noise filter

These bits are used to configure the digital noise filter on SDA and SCL input. The digital filter will filter spikes with a length of up to DNF[3:0] \* t<sub>I2CCLK</sub>

0000: Digital filter disabled

0001: Digital filter enabled and filtering capability up to 1 t<sub>I2CCLK</sub>

...  
1111: digital filter enabled and filtering capability up to 15 t<sub>I2CCLK</sub>

*Note: If the analog filter is also enabled, the digital filter is added to the analog filter.*

*This filter can only be programmed when the I2C is disabled (PE = 0).*

Bit 7 **ERRIE**: Error interrupts enable

- 0: Error detection interrupts disabled
- 1: Error detection interrupts enabled

*Note: Any of these errors generate an interrupt:*

*Arbitration Loss (ARLO)*

*Bus Error detection (BERR)*

*Overrun/Underrun (OVR)*

*Timeout detection (TIMEOUT)*

*PEC error detection (PECERR)*

*Alert pin event detection (ALERT)*

Bit 6 **TCIE**: Transfer Complete interrupt enable

- 0: Transfer Complete interrupt disabled
- 1: Transfer Complete interrupt enabled

*Note: Any of these events will generate an interrupt:*

*Transfer Complete (TC)*

*Transfer Complete Reload (TCR)*

Bit 5 **STOPIE**: STOP detection Interrupt enable

- 0: Stop detection (STOPF) interrupt disabled
- 1: Stop detection (STOPF) interrupt enabled

Bit 4 **NACKIE**: Not acknowledge received Interrupt enable

- 0: Not acknowledge (NACKF) received interrupts disabled
- 1: Not acknowledge (NACKF) received interrupts enabled

Bit 3 **ADDRIE**: Address match Interrupt enable (slave only)

- 0: Address match (ADDR) interrupts disabled
- 1: Address match (ADDR) interrupts enabled

Bit 2 **RXIE**: RX Interrupt enable

- 0: Receive (RXNE) interrupt disabled
- 1: Receive (RXNE) interrupt enabled

Bit 1 **TXIE**: TX Interrupt enable

- 0: Transmit (TXIS) interrupt disabled
- 1: Transmit (TXIS) interrupt enabled

Bit 0 **PE**: Peripheral enable

- 0: Peripheral disable
- 1: Peripheral enable

*Note:* When PE=0, the I<sup>2</sup>C SCL and SDA lines are released. Internal state machines and status bits are put back to their reset value. When cleared, PE must be kept low for at least 3 APB clock cycles.

## 24.7.2 Control register 2 (I<sup>2</sup>Cx\_CR2)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16						
Res.	Res.	Res.	Res.	Res.	PEC BYTE	AUTO END	RE LOAD	NBYTES[7:0]													
					rs	rw	rw	rw													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0						
NACK	STOP	START	HEAD 10R	ADD10	RD_W RN	SADD[9:0]															
rs	rs	rs	rw	rw	rw	rw															

Bits 31:27 Reserved, must be kept at reset value.

Bit 26 **PECBYTE**: Packet error checking byte

This bit is set by software, and cleared by hardware when the PEC is transferred, or when a STOP condition or an Address Matched is received, also when PE=0.

- 0: No PEC transfer.

- 1: PEC transmission/reception is requested

*Note:* Writing '0' to this bit has no effect.

*This bit has no effect when RELOAD is set.*

*This bit has no effect in slave mode when SBC=0.*

*If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to Section 24.3: I<sup>2</sup>C implementation.*

Bit 25 **AUTOEND**: Automatic end mode (master mode)

This bit is set and cleared by software.

- 0: software end mode: TC flag is set when NBYTES data are transferred, stretching SCL low.

- 1: Automatic end mode: a STOP condition is automatically sent when NBYTES data are transferred.

*Note:* This bit has no effect in slave mode or when the RELOAD bit is set.

Bit 24 **RELOAD**: NBYTES reload mode

This bit is set and cleared by software.

- 0: The transfer is completed after the NBYTES data transfer (STOP or RESTART will follow).
- 1: The transfer is not completed after the NBYTES data transfer (NBYTES will be reloaded). TCR flag is set when NBYTES data are transferred, stretching SCL low.

Bits 23:16 **NBYTES[7:0]**: Number of bytes

The number of bytes to be transmitted/received is programmed there. This field is don't care in slave mode with SBC=0.

*Note: Changing these bits when the START bit is set is not allowed.*

Bit 15 **NACK**: NACK generation (slave mode)

The bit is set by software, cleared by hardware when the NACK is sent, or when a STOP condition or an Address Matched is received, or when PE=0.

- 0: an ACK is sent after current received byte.
- 1: a NACK is sent after current received byte.

*Note: Writing '0' to this bit has no effect.*

*This bit is used in slave mode only: in master receiver mode, NACK is automatically generated after last byte preceding STOP or RESTART condition, whatever the NACK bit value.*

*When an overrun occurs in slave receiver NOSTRETCH mode, a NACK is automatically generated whatever the NACK bit value.*

*When hardware PEC checking is enabled (PECBYTE=1), the PEC acknowledge value does not depend on the NACK value.*

Bit 14 **STOP**: Stop generation (master mode)

The bit is set by software, cleared by hardware when a Stop condition is detected, or when PE = 0.

**In Master Mode:**

- 0: No Stop generation.
- 1: Stop generation after current byte transfer.

*Note: Writing '0' to this bit has no effect.*

Bit 13 **START**: Start generation

This bit is set by software, and cleared by hardware after the Start followed by the address sequence is sent, by an arbitration loss, by a timeout error detection, or when PE = 0. It can also be cleared by software by writing '1' to the ADDRCF bit in the I2Cx\_ICR register.

- 0: No Start generation.
- 1: Restart/Start generation:
  - If the I2C is already in master mode with AUTOEND = 0, setting this bit generates a Repeated Start condition when RELOAD=0, after the end of the NBYTES transfer.
  - Otherwise setting this bit will generate a START condition once the bus is free.

*Note: Writing '0' to this bit has no effect.*

*The START bit can be set even if the bus is BUSY or I2C is in slave mode.*

*This bit has no effect when RELOAD is set.*

Bit 12 **HEAD10R**: 10-bit address header only read direction (master receiver mode)

- 0: The master sends the complete 10 bit slave address read sequence: Start + 2 bytes 10bit address in write direction + Restart + 1st 7 bits of the 10 bit address in read direction.
- 1: The master only sends the 1st 7 bits of the 10 bit address, followed by Read direction.

*Note: Changing this bit when the START bit is set is not allowed.*

Bit 11 **ADD10**: 10-bit addressing mode (master mode)

- 0: The master operates in 7-bit addressing mode,
- 1: The master operates in 10-bit addressing mode

*Note: Changing this bit when the START bit is set is not allowed.*

Bit 10 **RD\_WRN**: Transfer direction (master mode)

- 0: Master requests a write transfer.
- 1: Master requests a read transfer.

*Note: Changing this bit when the START bit is set is not allowed.*

Bits 9:8 **SADD[9:8]**: Slave address bit 9:8 (master mode)

**In 7-bit addressing mode (ADD10 = 0):**

These bits are don't care

**In 10-bit addressing mode (ADD10 = 1):**

These bits should be written with bits 9:8 of the slave address to be sent

*Note: Changing these bits when the START bit is set is not allowed.*

Bits 7:1 **SADD[7:1]**: Slave address bit 7:1 (master mode)

**In 7-bit addressing mode (ADD10 = 0):**

These bits should be written with the 7-bit slave address to be sent

**In 10-bit addressing mode (ADD10 = 1):**

These bits should be written with bits 7:1 of the slave address to be sent.

*Note: Changing these bits when the START bit is set is not allowed.*

Bit 0 **SADD0**: Slave address bit 0 (master mode)

**In 7-bit addressing mode (ADD10 = 0):**

This bit is don't care

**In 10-bit addressing mode (ADD10 = 1):**

This bit should be written with bit 0 of the slave address to be sent

*Note: Changing these bits when the START bit is set is not allowed.*

### 24.7.3 Own address 1 register (I<sup>2</sup>Cx\_OAR1)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OA1EN	Res.	Res.	Res.	Res.	Res.	OA1 MODE	OA1[9:8]	OA1[7:1]						OA1[0]	
rw						rw	rw	rw						rw	

Bits 31:16 Reserved, must be kept at reset value.

Bit 15 **OA1EN**: Own Address 1 enable

- 0: Own address 1 disabled. The received slave address OA1 is NACKed.
- 1: Own address 1 enabled. The received slave address OA1 is ACKed.

Bits 14:11 Reserved, must be kept at reset value.

Bit 10 **OA1MODE** Own Address 1 10-bit mode

- 0: Own address 1 is a 7-bit address.
- 1: Own address 1 is a 10-bit address.

*Note: This bit can be written only when OA1EN=0.*

Bits 9:8 **OA1[9:8]**: Interface address

- 7-bit addressing mode: don't care
- 10-bit addressing mode: bits 9:8 of address

*Note: These bits can be written only when OA1EN=0.*

Bits 7:1 **OA1[7:1]**: Interface address

- bits 7:1 of address

*Note: These bits can be written only when OA1EN=0.*

Bit 0 **OA1[0]**: Interface address

- 7-bit addressing mode: don't care
- 10-bit addressing mode: bit 0 of address

*Note: This bit can be written only when OA1EN=0.*

#### 24.7.4 Own address 2 register (I<sup>2</sup>Cx\_OAR2)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OA2EN	Res.	Res.	Res.	Res.	Res.	OA2MSK[2:0]			OA2[7:1]						Res.
rw						rw			rw						

Bits 31:16 Reserved, must be kept at reset value.

Bit 15 **OA2EN**: Own Address 2 enable

- 0: Own address 2 disabled. The received slave address OA2 is NACKed.
- 1: Own address 2 enabled. The received slave address OA2 is ACKed.

Bits 14:11 Reserved, must be kept at reset value.

Bits 10:8 **OA2MSK[2:0]**: Own Address 2 masks

- 000: No mask
- 001: OA2[1] is masked and don't care. Only OA2[7:2] are compared.
- 010: OA2[2:1] are masked and don't care. Only OA2[7:3] are compared.
- 011: OA2[3:1] are masked and don't care. Only OA2[7:4] are compared.
- 100: OA2[4:1] are masked and don't care. Only OA2[7:5] are compared.
- 101: OA2[5:1] are masked and don't care. Only OA2[7:6] are compared.
- 110: OA2[6:1] are masked and don't care. Only OA2[7] is compared.
- 111: OA2[7:1] are masked and don't care. No comparison is done, and all (except reserved) 7-bit received addresses are acknowledged.

*Note: These bits can be written only when OA2EN=0.*

*As soon as OA2MSK is not equal to 0, the reserved I<sup>2</sup>C addresses (0b0000xxx and 0b1111xxx) are not acknowledged even if the comparison matches.*

Bits 7:1 **OA2[7:1]**: Interface address

bits 7:1 of address

*Note:* These bits can be written only when OA2EN=0.

Bit 0 Reserved, must be kept at reset value.

### 24.7.5 Timing register (I2Cx\_TIMINGR)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PRESC[3:0]				Res.	Res.	Res.	Res.	SCLDEL[3:0]				SDADEL[3:0]			
rw				rw				rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCLH[7:0]				SCLL[7:0]				rw				rw			

Bits 31:28 **PRESC[3:0]**: Timing prescaler

This field is used to prescale I2CCLK in order to generate the clock period  $t_{PRESC}$  used for data setup and hold counters (refer to [I2C timings on page 515](#)) and for SCL high and low level counters (refer to [I2C master initialization on page 529](#)).

$$t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$$

Bits 27:24 Reserved, must be kept at reset value.

Bits 23:20 **SCLDEL[3:0]**: Data setup time

This field is used to generate a delay  $t_{SCLDEL}$  between SDA edge and SCL rising edge in transmission mode.

$$t_{SCLDEL} = (SCLDEL+1) \times t_{PRESC}$$

*Note:*  $t_{SCLDEL}$  is used to generate  $t_{SU:DAT}$  timing.

Bits 19:16 **SDADEL[3:0]**: Data hold time

This field is used to generate the delay  $t_{SDADEL}$  between SCL falling edge SDA edge in transmission mode.

$$t_{SDADEL} = SDADEL \times t_{PRESC}$$

*Note:*  $SDADEL$  is used to generate  $t_{HD:DAT}$  timing.

Bits 15:8 **SCLH[7:0]**: SCL high period (master mode)

This field is used to generate the SCL high period in master mode.

$$t_{SCLH} = (SCLH+1) \times t_{PRESC}$$

*Note:*  $SCLH$  is also used to generate  $t_{SU:STO}$  and  $t_{HD:STA}$  timing.

Bits 7:0 **SCLL[7:0]**: SCL low period (master mode)

This field is used to generate the SCL low period in master mode.

$$t_{SCLL} = (SCLL+1) \times t_{PRESC}$$

*Note:*  $SCLL$  is also used to generate  $t_{BUF}$  and  $t_{SU:STA}$  timings.

*Note:* This register must be configured when the I2C is disabled (PE = 0).

### 24.7.6 Timeout register (I2Cx\_TIMEOUTTR)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TEXTEN	Res.	Res.	Res.												TIMEOUTB [11:0]
rw															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TIMOUTEN	Res.	Res.	TIDLE												TIMEOUTA [11:0]
rw			rw												rw

Bit 31 **TEXTEN**: Extended clock timeout enable

0: Extended clock timeout detection is disabled

1: Extended clock timeout detection is enabled. When a cumulative SCL stretch for more than  $t_{LOW:EXT}$  is **done by the I<sup>2</sup>C interface**, a timeout error is detected (TIMEOUT=1).

Bits 30:29 Reserved, must be kept at reset value.

Bits 27:16 **TIMEOUTB[11:0]**: Bus timeout B

This field is used to configure the cumulative clock extension timeout:

In master mode, the master cumulative clock low extend time ( $t_{LOW:MEXT}$ ) is detected

In slave mode, the slave cumulative clock low extend time ( $t_{LOW:SEXT}$ ) is detected

$t_{LOW:EXT} = (TIMEOUTB+1) \times 2048 \times t_{I2CCLK}$

*Note: These bits can be written only when TEXTEN=0.*

Bit 15 **TIMOUTEN**: Clock timeout enable

0: SCL timeout detection is disabled

1: SCL timeout detection is enabled: when SCL is low for more than  $t_{TIMEOUT}$  (TIDLE=0) or high for more than  $t_{IDLE}$  (TIDLE=1), a timeout error is detected (TIMEOUT=1).

Bits 14:13 Reserved, must be kept at reset value.

Bit 12 **TIDLE**: Idle clock timeout detection

0: TIMEOUTA is used to detect SCL low timeout

1: TIMEOUTA is used to detect both SCL and SDA high timeout (bus idle condition)

*Note: This bit can be written only when TIMOUTEN=0.*

Bits 11:0 **TIMEOUTA[11:0]**: Bus Timeout A

This field is used to configure:

- The SCL low timeout condition  $t_{TIMEOUT}$  when TIDLE=0

$t_{TIMEOUT} = (TIMEOUTA+1) \times 2048 \times t_{I2CCLK}$

- The bus idle condition (both SCL and SDA high) when TIDLE=1

$t_{IDLE} = (TIMEOUTA+1) \times 4 \times t_{I2CCLK}$

*Note: These bits can be written only when TIMOUTEN=0.*

**Note:** If the SMBus feature is not supported, this register is reserved and forced by hardware to “0x00000000”. Please refer to Section 24.3: I<sup>2</sup>C implementation.

### 24.7.7 Interrupt and Status register (I2Cx\_ISR)

Address offset: 0x18

Reset value: 0x0000 0001

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ADD CODE[6:0]						DIR	
								r						r	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BUSY	Res.	ALERT	TIME OUT	PEC ERR	OVR	ARLO	BERR	TCR	TC	STOPF	NACKF	ADDR	RXNE	TXIS	TXE
r		r	r	r	r	r	r	r	r	r	r	r	r	r_w1	r_w1

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:17 ADDCODE[6:0]: Address match code (Slave mode)

These bits are updated with the received address when an address match event occurs (ADDR = 1).

In the case of a 10-bit address, ADDCODE provides the 10-bit header followed by the 2 MSBs of the address.

Bit 16 DIR: Transfer direction (Slave mode)

This flag is updated when an address match event occurs (ADDR=1).

0: Write transfer, slave enters receiver mode.

1: Read transfer, slave enters transmitter mode.

Bit 15 BUSY: Bus busy

This flag indicates that a communication is in progress on the bus. It is set by hardware when a START condition is detected. It is cleared by hardware when a Stop condition is detected, or when PE=0.

Bit 14 Reserved, must be kept at reset value.

Bit 13 ALERT: SMBus alert

This flag is set by hardware when SMBHEN=1 (SMBus host configuration), ALERTEN=1 and a SMBALERT event (falling edge) is detected on SMBA pin. It is cleared by software by setting the ALERTCF bit.

*Note: This bit is cleared by hardware when PE=0.*

*If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 12 TIMEOUT: Timeout or t<sub>LOW</sub> detection flag

This flag is set by hardware when a timeout or extended clock timeout occurred. It is cleared by software by setting the TIMEOUTCF bit.

*Note: This bit is cleared by hardware when PE=0.*

*If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 11 PECERR: PEC Error in reception

This flag is set by hardware when the received PEC does not match with the PEC register content. A NACK is automatically sent after the wrong PEC reception. It is cleared by software by setting the PECCF bit.

*Note: This bit is cleared by hardware when PE=0.*

*If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

**Bit 10 OVR:** Overrun/Underrun (slave mode)

This flag is set by hardware in slave mode with NOSTRETCH=1, when an overrun/underrun error occurs. It is cleared by software by setting the OVRCF bit.

*Note: This bit is cleared by hardware when PE=0.*

**Bit 9 ARLO:** Arbitration lost

This flag is set by hardware in case of arbitration loss. It is cleared by software by setting the ARLOCF bit.

*Note: This bit is cleared by hardware when PE=0.*

**Bit 8 BERR:** Bus error

This flag is set by hardware when a misplaced Start or Stop condition is detected whereas the peripheral is involved in the transfer. The flag is not set during the address phase in slave mode. It is cleared by software by setting the BERRCF bit.

*Note: This bit is cleared by hardware when PE=0.*

**Bits 7 TCR:** Transfer Complete Reload

This flag is set by hardware when RELOAD=1 and NBYTES data have been transferred. It is cleared by software when NBYTES is written to a non-zero value.

*Note: This bit is cleared by hardware when PE=0.*

*This flag is only for master mode, or for slave mode when the SBC bit is set.*

**Bit 6 TC:** Transfer Complete (master mode)

This flag is set by hardware when RELOAD=0, AUTOEND=0 and NBYTES data have been transferred. It is cleared by software when START bit or STOP bit is set.

*Note: This bit is cleared by hardware when PE=0.*

**Bit 5 STOPF:** Stop detection flag

This flag is set by hardware when a Stop condition is detected on the bus and the peripheral is involved in this transfer:

- either as a master, provided that the STOP condition is generated by the peripheral.
- or as a slave, provided that the peripheral has been addressed previously during this transfer.

It is cleared by software by setting the STOPCF bit.

*Note: This bit is cleared by hardware when PE=0.*

**Bit 4 NACKF:** Not Acknowledge received flag

This flag is set by hardware when a NACK is received after a byte transmission. It is cleared by software by setting the NACKCF bit.

*Note: This bit is cleared by hardware when PE=0.*

**Bit 3 ADDR:** Address matched (slave mode)

This bit is set by hardware as soon as the received slave address matched with one of the enabled slave addresses. It is cleared by software by setting the ADDRCF bit.

*Note: This bit is cleared by hardware when PE=0.*

Bit 2 **RXNE**: Receive data register not empty (receivers)

This bit is set by hardware when the received data is copied into the I2Cx\_RXDR register, and is ready to be read. It is cleared when I2Cx\_RXDR is read.

*Note: This bit is cleared by hardware when PE=0.*

Bit 1 **TXIS**: Transmit interrupt status (transmitters)

This bit is set by hardware when the I2Cx\_TXDR register is empty and the data to be transmitted must be written in the I2Cx\_TXDR register. It is cleared when the next data to be sent is written in the I2Cx\_TXDR register.

This bit can be written to '1' by software when NOSTRETCH=1 only, in order to generate a TXIS event (interrupt if TXIE=1 or DMA request if TXDMAEN=1).

*Note: This bit is cleared by hardware when PE=0.*

Bit 0 **TXE**: Transmit data register empty (transmitters)

This bit is set by hardware when the I2Cx\_TXDR register is empty. It is cleared when the next data to be sent is written in the I2Cx\_TXDR register.

This bit can be written to '1' by software in order to flush the transmit data register I2Cx\_TXDR.

*Note: This bit is set by hardware when PE=0.*

## 24.7.8 Interrupt clear register (I2Cx\_ICR)

Address offset: 0x1C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	ALERT CF	TIM OUTCF	PECCF	OVRCF	ARLO CF	BERR CF	Res.	Res.	STOP CF	NACK CF	ADDR CF	Res.	Res.	Res.
		w	w	w	w	w	w			w	w	w			

Bits 31:14 Reserved, must be kept at reset value.

Bit 13 **ALERTCF**: Alert flag clear

Writing 1 to this bit clears the ALERT flag in the I2Cx\_ISR register.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 12 **TIMOUTCF**: Timeout detection flag clear

Writing 1 to this bit clears the TIMEOUT flag in the I2Cx\_ISR register.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 11 **PECCF**: PEC Error flag clear

Writing 1 to this bit clears the PECERR flag in the I2Cx\_ISR register.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 24.3: I2C implementation](#).*

Bit 10 **OVRCF**: Overrun/Underrun flag clear

Writing 1 to this bit clears the OVR flag in the I2Cx\_ISR register.

- Bit 9 **ARLOCF**: Arbitration Lost flag clear  
Writing 1 to this bit clears the ARLO flag in the I2Cx\_ISR register.
- Bit 8 **BERRCF**: Bus error flag clear  
Writing 1 to this bit clears the BERRF flag in the I2Cx\_ISR register.
- Bits 7:6 Reserved, must be kept at reset value.
- Bit 5 **STOPCF**: Stop detection flag clear  
Writing 1 to this bit clears the STOPF flag in the I2Cx\_ISR register.
- Bit 4 **NACKCF**: Not Acknowledge flag clear  
Writing 1 to this bit clears the ACKF flag in I2Cx\_ISR register.
- Bit 3 **ADDRCF**: Address Matched flag clear  
Writing 1 to this bit clears the ADDR flag in the I2Cx\_ISR register. Writing 1 to this bit also clears the START bit in the I2Cx\_CR2 register.
- Bits 2:0 Reserved, must be kept at reset value.

#### 24.7.9 PEC register (I2Cx\_PECR)

Address offset: 0x20

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	PEC[7:0]														
															r

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **PEC[7:0]** Packet error checking register

This field contains the internal PEC when PECEN=1.

The PEC is cleared by hardware when PE=0.

**Note:** If the SMBus feature is not supported, this register is reserved and forced by hardware to “0x00000000”. Please refer to [Section 24.3: I2C implementation](#).

### 24.7.10 Receive data register (I2Cx\_RXDR)

Address offset: 0x24

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.								RXDATA[7:0]							
															r

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **RXDATA[7:0]** 8-bit receive data

Data byte received from the  $I^2C$  bus.

### 24.7.11 Transmit data register (I2Cx\_TXDR)

Address offset: 0x28

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.							TXDATA[7:0]								
															rw

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **TXDATA[7:0]** 8-bit transmit data

Data byte to be transmitted to the  $I^2C$  bus.

*Note:* These bits can be written only when TXE=1.

## 24.7.12 I<sup>2</sup>C register map

The table below provides the I<sup>2</sup>C register map and reset values.

**Table 81. I<sup>2</sup>C register map and reset values**

Offset	Register								
0x0	I2Cx_CR1								
0x4	Reset value								
0x8	I2Cx_CR2								
0xC	Reset value								
0x10	I2Cx_OAR1								
0x10	Reset value								
0x14	I2Cx_OAR2								
0x14	Reset value								
0x18	I2Cx_TIMINGR								
0x18	Reset value								
0x1C	I2Cx_TIMEOUTR								
0x1C	Reset value								
0x20	I2Cx_ISR								
0x20	Reset value								
0x24	I2Cx_ICR								
0x24	Reset value								
0x28	I2Cx_PECR								
0x28	Reset value								
0x2C	I2Cx_RXDR								
0x2C	Reset value								
0x30	I2Cx_TXDR								
0x30	Reset value								
0x34	RXDATA								
0x34	Reset value								
0x38	TXDATA								
0x38	Reset value								

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 25 Universal synchronous asynchronous receiver transmitter (USART)

### 25.1 USART introduction

The universal synchronous asynchronous receiver transmitter (USART) offers a flexible means of full-duplex data exchange with external equipment requiring an industry standard NRZ asynchronous serial data format. The USART offers a very wide range of baud rates using a baud rate generator.

It supports synchronous one-way communication and half-duplex single wire communication. It also supports the LIN (local interconnection network), Smartcard Protocol and IrDA (infrared data association) SIR ENDEC specifications, and modem operations (CTS/RTS). It allows multiprocessor communication.

High speed data communication is possible by using the DMA for multibuffer configuration.

## 25.2 USART main features

- Full duplex, asynchronous communications
- NRZ standard format (mark/space)
- Configurable oversampling method by 16 or by 8 to give flexibility between speed and clock tolerance
- Baud rate generator systems
  - A common programmable transmit and receive baud rate of up to 6 Mbit/s when the clock frequency is 48 MHz and oversampling is by 8
- Dual clock domain allowing
  - UART functionality and wakeup from Stop mode
  - Convenient baud rate programming independent from the PCLK reprogramming
- Auto baud rate detection
- Programmable data word length (8 or 9 bits)
- Programmable data order with MSB-first or LSB-first shifting
- Configurable stop bits - support for 1 or 2 stop bits
- Synchronous mode and clock output for synchronous communication
- Single-wire half-duplex communication
- Continuous communication using DMA (direct memory access)
  - Buffering of received/transmitted bytes in reserved SRAM using centralized DMA
- Separate enable bits for transmitter and receiver
- Separate signal polarity control for transmission and reception
- Swappable Tx/Rx pin configuration
- Hardware flow control for modem and RS-485 transceiver
- Transfer detection flags:
  - Receive buffer full
  - Transmit buffer empty
  - Busy and end of transmission flags
- Parity control:
  - Transmits parity bit
  - Checks parity of received data byte
- Four error detection flags:
  - Overrun error
  - Noise detection
  - Frame error
  - Parity error
- Fourteen interrupt sources with flags
  - CTS changes
  - LIN break detection
  - Transmit data register empty
  - Transmission complete
  - Receive data register full
  - Idle line received

- Overrun error
- Framing error
- Noise error
- Parity error
- Address/character match
- Receiver timeout interrupt
- End of block interrupt
- Wakeup from Stop mode
- Multiprocessor communication - enter mute mode if address match does not occur
- Wakeup from mute mode (by idle line detection or address mark detection)
- Two receiver wakeup modes: Address bit (MSB, 9<sup>th</sup> bit), Idle line

## 25.3 USART extended features

- LIN master synchronous break send capability and LIN slave break detection capability
  - 13-bit break generation and 10/11 bit break detection when USART is hardware configured for LIN
- IrDA SIR encoder decoder
  - Support for 3/16 bit duration for normal mode
- Smartcard mode
  - Supports the T=0 and T=1 asynchronous protocols for Smartcards as defined in the ISO/IEC 7816-3 standard
  - 1.5 stop bits for Smartcard operation
- Support for ModBus communication
  - Timeout feature
  - CR/LF character recognition

## 25.4 USART implementation

This manual describes the full set of features implemented in USART1. USART2 supports a smaller set of features, but is otherwise identical to USART1. The differences are listed in the following table.

**Table 82. STM32F05xxx USART features**

USART modes/features <sup>(1)</sup>	USART1	USART2
Hardware flow control for modem	X	X
Continuous communication using DMA	X	X
Multiprocessor communication	X	X
Synchronous mode	X	X
Smartcard mode	X	
Single-wire half-duplex communication	X	X
IrDA SIR ENDEC block	X	

**Table 82. STM32F05xxx USART features (continued)**

USART modes/features <sup>(1)</sup>	USART1	USART2
LIN mode	X	
Dual clock domain and wakeup from Stop mode	X	
Receiver timeout interrupt	X	
Modbus communication	X	
Auto baud rate detection	X	
Driver Enable	X	X

1. X = supported.

## 25.5 USART functional description

Any USART bidirectional communication requires a minimum of two pins: Receive Data In (RX) and Transmit Data Out (TX):

**RX:** Receive Data Input is the serial data input. Oversampling techniques are used for data recovery by discriminating between valid incoming data and noise.

**TX:** Transmit Data Output. When the transmitter is disabled, the output pin returns to its I/O port configuration. When the transmitter is enabled and nothing is to be transmitted, the TX pin is at high level. In single-wire and Smartcard modes, this I/O is used to transmit and receive the data.

Through these pins, serial data is transmitted and received in normal USART mode as frames comprising:

- An Idle Line prior to transmission or reception
- A start bit
- A data word (8 or 9 bits) least significant bit first
- 1, 1.5, 2 Stop bits indicating that the frame is complete
- This interface uses a baud rate generator
- A status register (USART\_ISR)
- Receive and transmit data registers (USART\_RDR, USART\_TDR)
- A baud rate register (USART\_BRR)
- A guardtime register (USART\_GTPR) in case of Smartcard mode.

Refer to [Section 25.7: USART registers on page 615](#) for the definitions of each bit.

The following pin is required to interface in synchronous mode and Smartcard mode:

- **SCLK:** Clock output. This pin outputs the transmitter data clock for synchronous transmission corresponding to SPI master mode (no clock pulses on start bit and stop bit, and a software option to send a clock pulse on the last data bit). In parallel, data can be received synchronously on RX. This can be used to control peripherals that have shift registers (e.g. LCD drivers). The clock phase and polarity are software programmable. In Smartcard mode, SCLK output can provide the clock to the Smartcard.

The following pins are required in Hardware flow control mode:

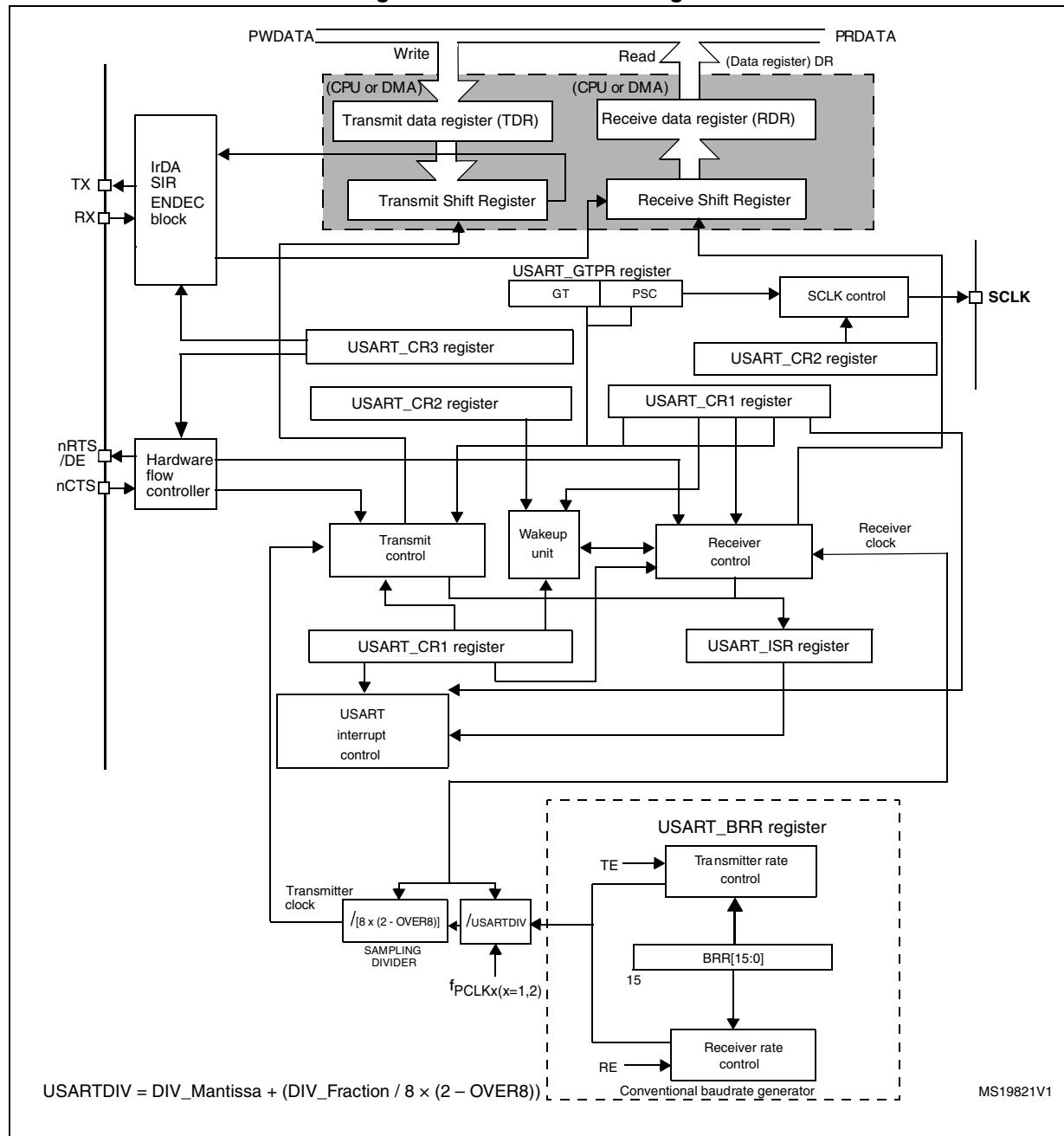
- **nCTS**: Clear To Send blocks the data transmission at the end of the current transfer when high
- **nRTS**: Request to send indicates that the USART is ready to receive data (when low).

The following pin is required in RS485 Hardware control mode:

- **DE**: Driver Enable activates the transmission mode of the external transceiver.

*Note:* DE and nRTS share the same pin.

Figure 230. USART block diagram



$$\text{USARTDIV} = \text{DIV\_Mantissa} + (\text{DIV\_Fraction} / 8 \times (2 - \text{OVER8}))$$

MS19821V1

### 25.5.1 USART character description

Word length may be selected as being either 8 or 9 bits by programming the M bit in the USART\_CR1 register (see [Figure 231](#)).

In default configuration, the signal (TX or RX) is in low state during the start bit. It is in high state during the stop bit.

These values can be inverted, separately for each signal, through polarity configuration control.

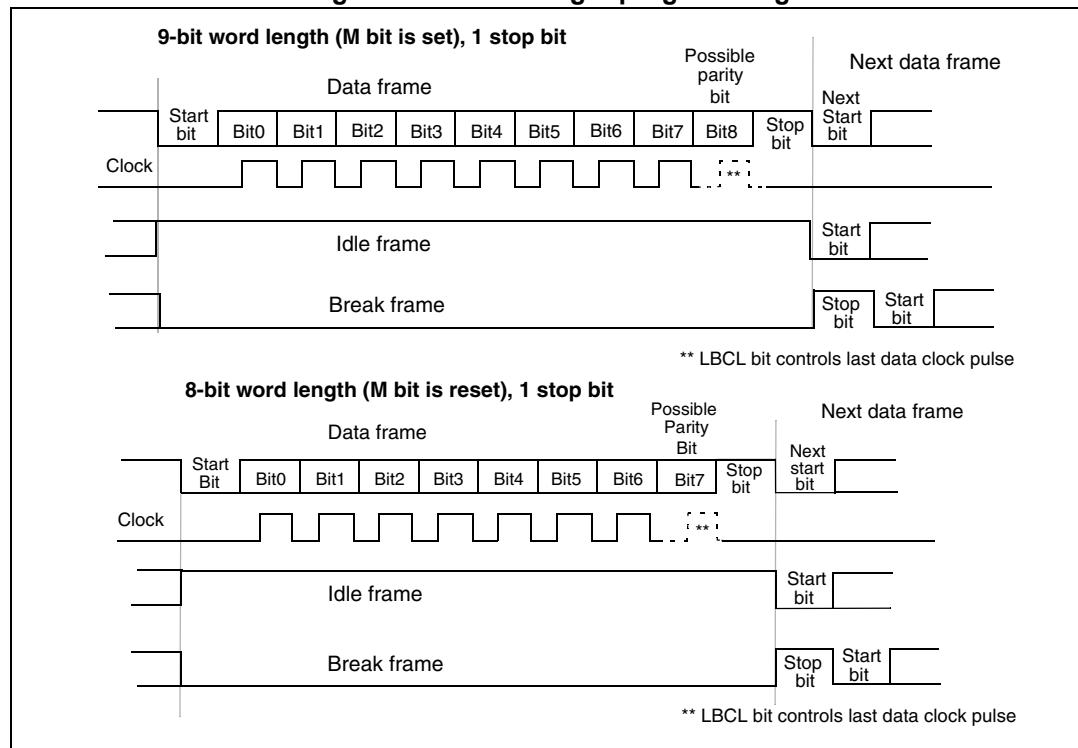
An ***Idle character*** is interpreted as an entire frame of “1”s followed by the start bit of the next frame which contains data (The number of “1” ‘s will include the number of stop bits).

A ***Break character*** is interpreted on receiving “0”s for a frame period. At the end of the break frame the transmitter inserts 2 stop bits.

Transmission and reception are driven by a common baud rate generator, the clock for each is generated when the enable bit is set respectively for the transmitter and receiver.

The details of each block is given below.

**Figure 231. Word length programming**



## 25.5.2 Transmitter

The transmitter can send data words of either 8 or 9 bits depending on the M bit status. The Transmit Enable bit (TE) must be set in order to activate the transmitter function. The data in the transmit shift register is output on the TX pin and the corresponding clock pulses are output on the SCLK pin.

### Character transmission

During an USART transmission, data shifts out least significant bit first (default configuration) on the TX pin. In this mode, the USART\_TDR register consists of a buffer (TDR) between the internal bus and the transmit shift register (see [Figure 230](#)).

Every character is preceded by a start bit which is a logic level low for one bit period. The character is terminated by a configurable number of stop bits.

The following stop bits are supported by USART: 1, 1.5 and 2 stop bits.

**Note:** *The TE bit must be set before writing the data to be transmitted to the USART\_TDR. An idle frame will be sent after the TE bit is enabled.*

### Configurable stop bits

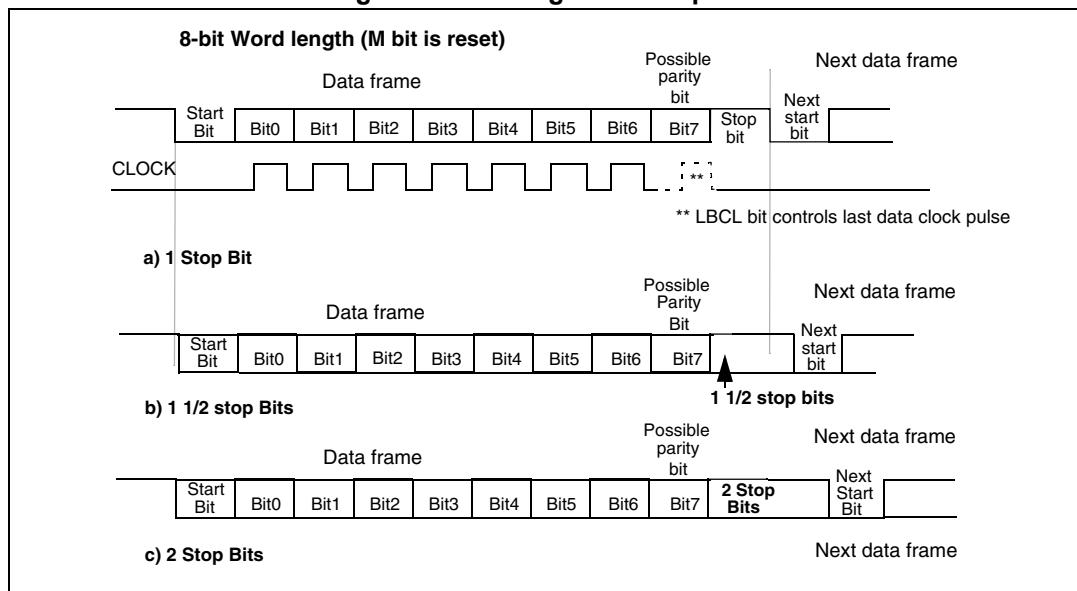
The number of stop bits to be transmitted with every character can be programmed in Control register 2, bits 13,12.

1. **1 stop bit:** This is the default value of number of stop bits.
2. **2 Stop bits:** This will be supported by normal USART, single-wire and modem modes.
3. **1.5 stop bits:** To be used in Smartcard mode.

An idle frame transmission will include the stop bits.

A break transmission will be 10 low bits (when m = 0) or 11 low bits (when m = 1) followed by 2 stop bits. It is not possible to transmit long breaks (break of length greater than 10/11 low bits).

**Figure 232. Configurable stop bits**



**Procedure:**

1. Program the M bit in USART\_CR1 to define the word length.
2. Select the desired baud rate using the USART\_BRR register.
3. Program the number of stop bits in USART\_CR2.
4. Enable the USART by writing the UE bit in USART\_CR1 register to 1.
5. Select DMA enable (DMAT) in USART\_CR3 if Multi buffer Communication is to take place. Configure the DMA register as explained in multibuffer communication.
6. Set the TE bit in USART\_CR1 to send an idle frame as first transmission.
7. Write the data to send in the USART\_TDR register (this clears the TXE bit). Repeat this for each data to be transmitted in case of single buffer.
8. After writing the last data into the USART\_TDR register, wait until TC=1. This indicates that the transmission of the last frame is complete. This is required for instance when the USART is disabled or enters the Halt mode to avoid corrupting the last transmission.

**Single byte communication**

Clearing the TXE bit is always performed by a write to the transmit data register.

The TXE bit is set by hardware and it indicates:

- The data has been moved from the USART\_TDR register to the shift register and the data transmission has started.
- The USART\_TDR register is empty.
- The next data can be written in the USART\_TDR register without overwriting the previous data.

This flag generates an interrupt if the TXEIE bit is set.

When a transmission is taking place, a write instruction to the USART\_TDR register stores the data in the TDR register and which is copied in the shift register at the end of the current transmission.

When no transmission is taking place, a write instruction to the USART\_TDR register places the data in the shift register, the data transmission starts, and the TXE bit is set.

If a frame is transmitted (after the stop bit) and the TXE bit is set, the TC bit goes high. An interrupt is generated if the TCIE bit is set in the USART\_CR1 register.

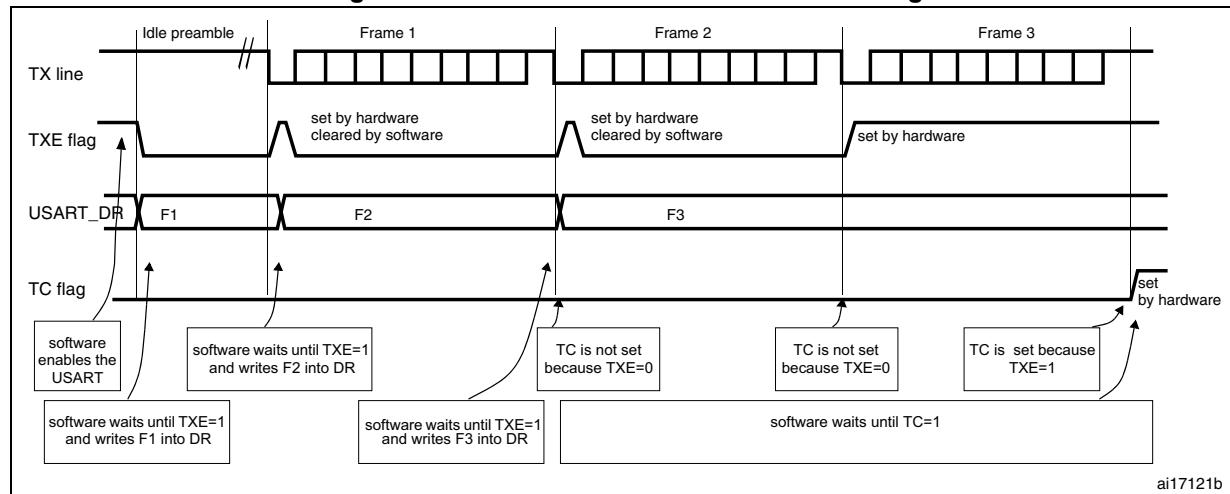
After writing the last data in the USART\_TDR register, it is mandatory to wait for TC=1 before disabling the USART or causing the microcontroller to enter the low power mode (see [Figure 233: TC/TXE behavior when transmitting](#)).

**Note:**

*The correct procedure to disable the USART is:*

- clear the TE bit (if a transmission is ongoing or a data word is in the USART\_TDR register, it will be sent before effectively disabling the transmission)
- the TC is set either immediately or at the end of the pending transmission
- clear the UE bit after TC=1

Figure 233. TC/TXE behavior when transmitting



### Break characters

Setting the SBKRQ bit transmits a break character. The break frame length depends on the M bit (see [Figure 231](#)).

If a ‘1’ is written to the SBKRQ bit, a break character is sent on the TX line after completing the current character transmission. The SBKF bit is set by the write operation and it is reset by hardware when the break character is completed (during the stop bits after the break character). The USART inserts a logic 1 signal (STOP) for the duration of 2 bits at the end of the break frame to guarantee the recognition of the start bit of the next frame.

### Idle characters

Setting the TE bit drives the USART to send an idle frame before the first data frame.

## 25.5.3 Receiver

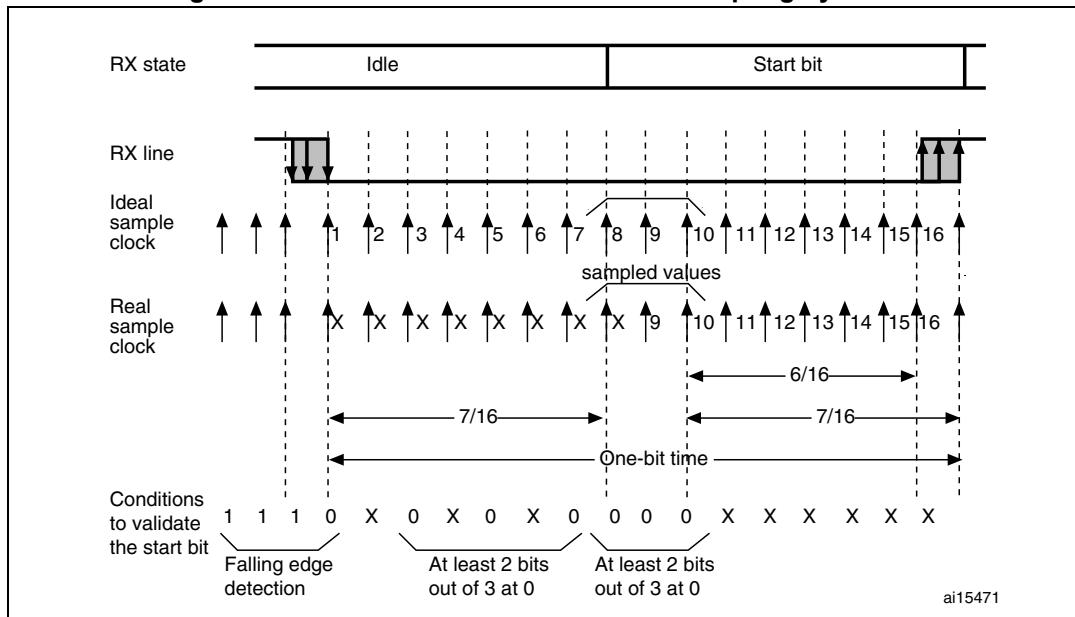
The USART can receive data words of either 8 or 9 bits depending on the M bit in the USART\_CR1 register.

### Start bit detection

The start bit detection sequence is the same when oversampling by 16 or by 8.

In the USART, the start bit is detected when a specific sequence of samples is recognized. This sequence is: 1 1 1 0 X 0 X 0X 0X 0 X 0X 0.

Figure 234. Start bit detection when oversampling by 16 or 8



Note: If the sequence is not complete, the start bit detection aborts and the receiver returns to the idle state (no flag is set), where it waits for a falling edge.

The start bit is confirmed (RXNE flag set, interrupt generated if RXNEIE=1) if the 3 sampled bits are at 0 (first sampling on the 3rd, 5th and 7th bits finds the 3 bits at 0 and second sampling on the 8th, 9th and 10th bits also finds the 3 bits at 0).

The start bit is validated (RXNE flag set, interrupt generated if RXNEIE=1) but the NE noise flag is set if, for both samplings, at least 2 out of the 3 sampled bits are at 0 (sampling on the 3rd, 5th and 7th bits and sampling on the 8th, 9th and 10th bits). If this condition is not met, the start detection aborts and the receiver returns to the idle state (no flag is set).

If, for one of the samplings (sampling on the 3rd, 5th and 7th bits or sampling on the 8th, 9th and 10th bits), 2 out of the 3 bits are found at 0, the start bit is validated but the NE noise flag bit is set.

### Character reception

During an USART reception, data shifts in least significant bit first (default configuration) through the RX pin. In this mode, the USART\_RDR register consists of a buffer (RDR) between the internal bus and the received shift register.

Procedure:

1. Program the M bit in USART\_CR1 to define the word length.
2. Select the desired baud rate using the baud rate register USART\_BRR
3. Program the number of stop bits in USART\_CR2.
4. Enable the USART by writing the UE bit in USART\_CR1 register to 1.
5. Select DMA enable (DMAR) in USART\_CR3 if multibuffer communication is to take place. Configure the DMA register as explained in multibuffer communication. STEP 3
6. Set the RE bit USART\_CR1. This enables the receiver which begins searching for a start bit.

When a character is received

- The RXNE bit is set. It indicates that the content of the shift register is transferred to the RDR. In other words, data has been received and can be read (as well as its associated error flags).
- An interrupt is generated if the RXNEIE bit is set.
- The error flags can be set if a frame error, noise or an overrun error has been detected during reception. PE flag can also be set with RXNE.
- In multibuffer, RXNE is set after every byte received and is cleared by the DMA read of the Receive Data Register.
- In single buffer mode, clearing the RXNE bit is performed by a software read to the USART\_RDR register. The RXNE flag can also be cleared by writing 1 to the RXFRQ in the USART\_RQR register. The RXNE bit must be cleared before the end of the reception of the next character to avoid an overrun error.

### **Break character**

When a break character is received, the USART handles it as a framing error.

### **Idle character**

When an idle frame is detected, there is the same procedure as for a received data character plus an interrupt if the IDLEIE bit is set.

### **Overrun error**

An overrun error occurs when a character is received when RXNE has not been reset. Data can not be transferred from the shift register to the RDR register until the RXNE bit is cleared.

The RXNE flag is set after every byte received. An overrun error occurs if RXNE flag is set when the next data is received or the previous DMA request has not been serviced. When an overrun error occurs:

- The ORE bit is set.
- The RDR content will not be lost. The previous data is available when a read to USART\_RDR is performed.
- The shift register will be overwritten. After that point, any data received during overrun is lost.
- An interrupt is generated if either the RXNEIE bit is set or EIE bit is set.
- The ORE bit is reset by setting the ORECF bit in the ICR register.

*Note:*

*The ORE bit, when set, indicates that at least 1 data has been lost. There are two possibilities:*

- if RXNE=1, then the last valid data is stored in the receive register RDR and can be read,
- if RXNE=0, then it means that the last valid data has already been read and thus there is nothing to be read in the RDR. This case can occur when the last valid data is read in the RDR at the same time as the new (and lost) data is received.

## Selecting the clock source and the proper oversampling method

The choice of the clock source is done through the Clock Control system (see the [Reset and clock control \(RCC\) section](#)). The clock source must be chosen before enabling the USART (by setting the UE bit).

The choice of the clock source must be done according to two criteria:

- Possible use of the USART in low power mode
- Communication speed

The clock source frequency is  $f_{CK}$ .

When the dual clock domain and the wakeup from Stop mode features are supported, the clock source can be one of the following sources:  $f_{PCLK}$  (default),  $f_{LSE}$ ,  $f_{HSI}$  or  $f_{SYS}$ . Otherwise, the USART clock source is  $f_{PCLK}$ .

Choosing  $f_{LSE}$ ,  $f_{HSI}$  as clock source may allow the USART to receive data while the MCU is in low power mode. Depending on the received data and wakeup mode selection, the USART wakes up the MCU, when needed, in order to transfer the received data by software reading the USART\_RDR register or by DMA.

For the other clock sources, the system must be active in order to allow USART communication.

The communication speed range (specially the maximum communication speed) is also determined by the clock source.

The receiver implements different user-configurable oversampling techniques (except in synchronous mode) for data recovery by discriminating between valid incoming data and noise. This allows a trade off between the maximum communication speed and noise/clock inaccuracy immunity.

The oversampling method can be selected by programming the OVER8 bit in the USART\_CR1 register and can be either 16 or 8 times the baud rate clock ([Figure 235](#) and [Figure 236](#)).

Depending on the application:

- Select oversampling by 8 (OVER8=1) to achieve higher speed (up to  $f_{CK}/8$ ). In this case the maximum receiver tolerance to clock deviation is reduced (refer to [Section 25.5.5: Tolerance of the USART receiver to clock deviation on page 591](#))
- Select oversampling by 16 (OVER8=0) to increase the tolerance of the receiver to clock deviations. In this case, the maximum speed is limited to maximum  $f_{CK}/16$

, where  $f_{CK}$  is the clock source frequency.

Programming the ONEBIT bit in the USART\_CR3 register selects the method used to evaluate the logic level. There are two options:

- The majority vote of the three samples in the center of the received bit. In this case, when the 3 samples used for the majority vote are not equal, the NF bit is set
- A single sample in the center of the received bit

Depending on the application:

- select the three samples' majority vote method (ONEBIT=0) when operating in a noisy environment and reject the data when a noise is detected (refer to [Figure 83](#)) because this indicates that a glitch occurred during the sampling.
- select the single sample method (ONEBIT=1) when the line is noise-free to increase the receiver's tolerance to clock deviations (see [Section 25.5.5: Tolerance of the USART receiver to clock deviation on page 591](#))

*Tolerance of the USART receiver to clock deviation on page 591*). In this case the NF bit will never be set.

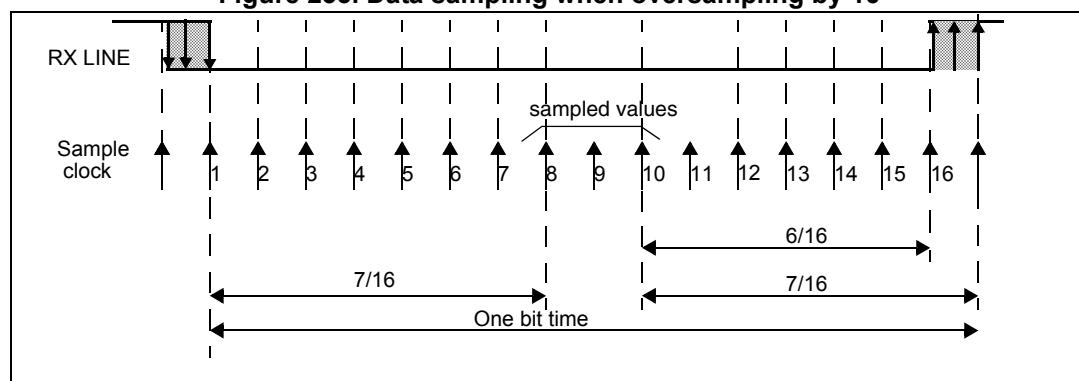
When noise is detected in a frame:

- The NF bit is set at the rising edge of the RXNE bit.
- The invalid data is transferred from the Shift register to the USART\_RDR register.
- No interrupt is generated in case of single byte communication. However this bit rises at the same time as the RXNE bit which itself generates an interrupt. In case of multibuffer communication an interrupt will be issued if the EIE bit is set in the USART\_CR3 register.

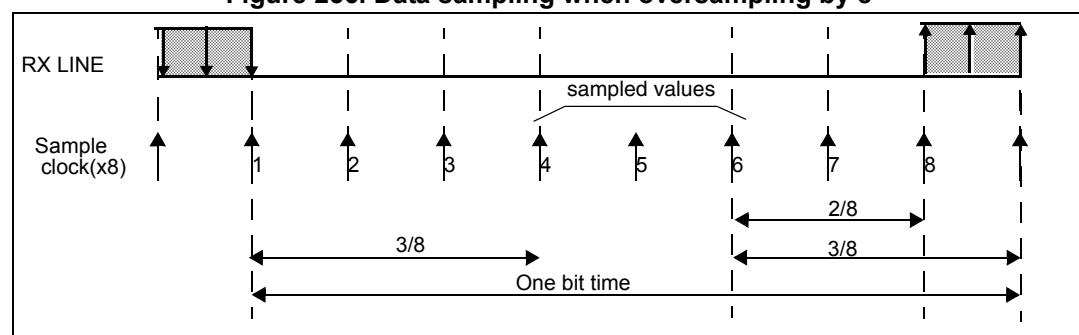
The NF bit is reset by setting NFCF bit in ICR register.

**Note:** *Oversampling by 8 is not available in the Smartcard, IrDA and LIN modes. In those modes, the OVER8 bit is forced to '0' by hardware.*

**Figure 235. Data sampling when oversampling by 16**



**Figure 236. Data sampling when oversampling by 8**



**Table 83. Noise detection from sampled data**

Sampled value	NE status	Received bit value
000	0	0
001	1	0
010	1	0
011	1	1
100	1	0
101	1	1

**Table 83. Noise detection from sampled data (continued)**

Sampled value	NE status	Received bit value
110	1	1
111	0	1

### Framing error

A framing error is detected when:

The stop bit is not recognized on reception at the expected time, following either a de-synchronization or excessive noise.

When the framing error is detected:

- The FE bit is set by hardware
- The invalid data is transferred from the Shift register to the USART\_RDR register.
- No interrupt is generated in case of single byte communication. However this bit rises at the same time as the RXNE bit which itself generates an interrupt. In case of multibuffer communication an interrupt will be issued if the EIE bit is set in the USART\_CR3 register.

The FE bit is reset by writing 1 to the FECF in the USART\_ICR register.

### Configurable stop bits during reception

The number of stop bits to be received can be configured through the control bits of Control Register 2 - it can be either 1 or 2 in normal mode and 1.5 in Smartcard mode.

1. **1 stop bit:** Sampling for 1 stop Bit is done on the 8th, 9th and 10th samples.
2. **1.5 stop bits (Smartcard mode):** When transmitting in Smartcard mode, the device must check that the data is correctly sent. Thus the receiver block must be enabled (RE =1 in the USART\_CR1 register) and the stop bit is checked to test if the Smartcard has detected a parity error. In the event of a parity error, the Smartcard forces the data signal low during the sampling - NACK signal-, which is flagged as a framing error. Then, the FE flag is set with the RXNE at the end of the 1.5 stop bit. Sampling for 1.5 stop bits is done on the 16th, 17th and 18th samples (1 baud clock period after the beginning of the stop bit). The 1.5 stop bit can be decomposed into 2 parts: one 0.5 baud clock period during which nothing happens, followed by 1 normal stop bit period during which sampling occurs halfway through. Refer to [Section 25.5.13: Smartcard mode on page 601](#) for more details.
3. **2 stop bits:** Sampling for 2 stop bits is done on the 8th, 9th and 10th samples of the first stop bit. If a framing error is detected during the first stop bit the framing error flag will be set. The second stop bit is not checked for framing error. The RXNE flag will be set at the end of the first stop bit.

### 25.5.4 Baud rate generation

The baud rate for the receiver and transmitter (Rx and Tx) are both set to the same value as programmed in the USART\_BRR register.

#### Equation 1: Baud rate for standard USART (SPI mode included)

In case of oversampling by 16, the equation is:

$$\text{Tx/Rx baud} = \frac{f_{CK}}{\text{USARTDIV}}$$

In case of oversampling by 8, the equation is:

$$\text{Tx/Rx baud} = \frac{2 \times f_{CK}}{\text{USARTDIV}}$$

#### Equation 2: Baud rate in Smartcard, LIN and IrDA modes

$$\text{Tx/Rx baud} = \frac{f_{CK}}{\text{USARTDIV}}$$

USARTDIV is an unsigned fixed point number that is coded on the USART\_BRR register.

- When OVER8=0, BRR = USARTDIV
- When OVER8=1
  - BRR[2:0] = USARTDIV[3:0] shifted 1 bit to the right.
  - BRR3 must be kept cleared.
  - BRR[15:4] = USARTDIV[15:4]

Note:

*The baud counters are updated to the new value in the baud registers after a write operation to USART\_BRR. Hence the baud rate register value should not be changed during communication.*

*In case of oversampling by 16, USARTDIV must be greater than or equal to 16d.*

*In case of oversampling by 8, USARTDIV must be greater than or equal to 8d.*

#### How to derive USARTDIV from USART\_BRR register values when OVER8=0

Example 1

To obtain 9600 baud with  $f_{CK}$  = 8 MHz.

- In case of oversampling by 16:  
 $\text{USARTDIV} = 8\ 000\ 000/9600$   
 $\text{BRR}[31:0] = \text{USARTDIV} = 833d = 0x0341$
- In case of oversampling by 8:  
 $\text{USARTDIV} = 2 * 8\ 000\ 000/9600$   
 $\text{USARTDIV} = 1666,66$  ( $1667d = 0x683$ )  
 $\text{BRR}[3:0] = 0x3 << 1 = 0x1$   
 $\text{BRR} = 0x681$

## Example 2

To obtain 921.6 Kbaud with  $f_{CK} = 48$  MHz.

- In case of oversampling by 16:

$$\text{USARTDIV} = 48\ 000\ 000 / 921\ 600$$

$$\text{BRR} = \text{USARTDIV} = 52d = 0x34$$

- In case of oversampling by 8:

$$\text{USARTDIV} = 2 * 48\ 000\ 000 / 921\ 600$$

$$\text{USARTDIV} = 104\ (104d = 0x68)$$

$$\text{BRR}[3:0] = \text{USARTDIV}[3:0] >> 1 = 0x8 >> 1 = 0x4$$

$$\text{BRR} = 0x64$$

**Table 84. Error calculation for programmed baud rates at  $f_{CK} = 48$  MHz for oversampling by 16 and by 8**

Baudrate		Oversampling by 16 (OVER8 = 0)			Oversampling by 8 (OVER8 = 1)		
S.No	Desired	Actual	USART_BRR value	% Error = (calculated - Desired baudrate)/Desired baudrate	Actual	USART_BRR value	% Error = (calculated - Desired baudrate)/Desired baudrate
2	2.4	2.4	0x4E20	0	2.4	0x9C40	0
3	9.6	9.6	0x1388	0	9.6	0x2710	0
4	19.2	19.2	0x9C4	0	19.2	0x1384	0
5	38.4	38.4	0x4E2	0	38.4	0x9C2	0
6	57.6	57.62	0x341	0.03	57.59	0x681	0.02
7	115.2	115.11	0x1A1	0.08	115.25	0x340	0.04
8	230.4	230.76	0xD0	0.16	230.21	0x1A0	0.08
9	460.8	461.54	0x68	0.16	461.54	0xD0	0.16
10	921.6	923.07	0x34	0.16	923.07	0x64	0.16
11	2000	2000	0x18	0	2000	0x30	0
12	3000	3000	0x10	0	3000	0x20	0
13	4000	N.A	N.A	N.A	4000	0x14	0
14	5000	N.A	N.A	N.A	5052.63	0x11	1.05
15	6000	N.A	N.A	N.A	6000	0x10	0

### 25.5.5 Tolerance of the USART receiver to clock deviation

The asynchronous receiver of the USART works correctly only if the total clock system deviation is less than the tolerance of the USART receiver. The causes which contribute to the total deviation are:

- DTRA: Deviation due to the transmitter error (which also includes the deviation of the transmitter's local oscillator)
- DQUANT: Error due to the baud rate quantization of the receiver
- DREC: Deviation of the receiver's local oscillator
- DTCL: Deviation due to the transmission line (generally due to the transceivers which can introduce an asymmetry between the low-to-high transition timing and the high-to-low transition timing)

$$DTRA + DQUANT + DREC + DTCL + DWU < \text{USART receiver's tolerance}$$

Where

DWU is the error due to sampling point deviation when the wakeup from Stop mode is used.

when M = 1:

$$DWU = \frac{t_{WUSTOP}}{(11 \times Tbit)}$$

when M=0:

$$DWU = \frac{t_{WUSTOP}}{(10 \times Tbit)}$$

$t_{WUSTOP}$  is the wakeup time from Stop mode, which is specified in the product datasheet.

The USART receiver can receive data correctly at up to the maximum tolerated deviation specified in [Table 85](#) and [Table 86](#), depending on the following choices:

- 10- or 11-bit character length defined by the M bit in the USART\_CR1 register
- Oversampling by 8 or 16 defined by the OVER8 bit in the USART\_CR1 register
- Bits BRR[3:0] of USART\_BRR register are equal to or different from 0000.
- Use of 1 bit or 3 bits to sample the data, depending on the value of the ONEBIT bit in the USART\_CR3 register

**Table 85. Tolerance of the USART receiver when BRR[3:0] = 0000**

M bit	OVER8 bit = 0		OVER8 bit = 1	
	ONEBIT=0	ONEBIT=1	ONEBIT=0	ONEBIT=1
0	3.75%	4.375%	2.50%	3.75%
1	3.41%	3.97%	2.27%	3.41%

**Table 86. Tolerance of the USART receiver when BRR[3:0] is different from 0000**

M bit	OVER8 bit = 0		OVER8 bit = 1	
	ONEBIT=0	ONEBIT=1	ONEBIT=0	ONEBIT=1
0	3.33%	3.88%	2%	3%
1	3.03%	3.53%	1.82%	2.73%

**Note:** The data specified in [Table 85](#) and [Table 86](#) may slightly differ in the special case when the received frames contain some Idle frames of exactly 10-bit times when M=0 (11-bit times when M=1).

### 25.5.6 Auto baud rate detection

The USART is able to detect and automatically set the USART\_BRR register value based on the reception of one character. Automatic baud rate detection is useful under two circumstances:

- The communication speed of the system is not known in advance
- The system is using a relatively low accuracy clock source and this mechanism allows the correct baud rate to be obtained without measuring the clock deviation

The clock source frequency must be compatible with the expected communication speed (oversampling by 16 selected and baudrate between  $f_{CK}/65535$  and  $f_{CK}/16$ ).

Before activating the auto baud rate detection, the character pattern must be chosen. There are two possible character patterns, which can be chosen through the ABRMOD[1:0] field in the USART\_CR2 register. These patterns are:

1. Any character starting with a bit at 1. In this case the USART will measure the duration of the Start bit (falling edge to rising edge).
2. Any character starting with a 10xx bit pattern. In this case, the USART will measure the duration of the Start and of the 1st data bit. The measure is done falling edge to falling edge, ensuring a better accuracy in the case of slow signal slopes.

In addition, prior to activating auto baud rate detection, the USART\_BRR register must be initialized by writing a non-zero baud rate value.

The automatic baud rate detection is activated by setting the ABREN bit in the USART\_CR2 register. The USART will then wait for the first character on the RX line. The auto baud rate operation completion is indicated by the setting of the ABRF flag in the USART\_ISR register.

If the line is noisy, the correct baud rate detection cannot be guaranteed. In this case the BRR value may be corrupted and/or the ABRE error flag may be set. This also happens if the communication speed is not compatible with the automatic baud rate detection range (bit duration not between 16 to 65536 clock periods).

The RXNE interrupt will signal the end of the operation.

At any later time, the auto baud rate detection may be relaunched by resetting the ABRF flag (by writing a 0).

If the USART is disabled (UE=0) during an auto baud rate operation, the BRR value may be corrupted.

### 25.5.7 Multiprocessor communication

It is possible to perform multiprocessor communication with the USART (with several USARTs connected in a network). For instance one of the USARTs can be the master, its TX output connected to the RX inputs of the other USARTs. The others are slaves, their respective TX outputs are logically ANDed together and connected to the RX input of the master.

In multiprocessor configurations it is often desirable that only the intended message recipient should actively receive the full message contents, thus reducing redundant USART service overhead for all non addressed receivers.

The non addressed devices may be placed in mute mode by means of the muting function. In order to use the mute mode feature, the MME bit must be set in the USART\_CR1 register.

In mute mode:

- None of the reception status bits can be set.
- All the receive interrupts are inhibited.
- The RWU bit in USART\_ISR register is set to 1. RWU can be controlled automatically by hardware or by software, through the MMRQ bit in the USART\_RQR register, under certain conditions.

The USART can enter or exit from mute mode using one of two methods, depending on the WAKE bit in the USART\_CR1 register:

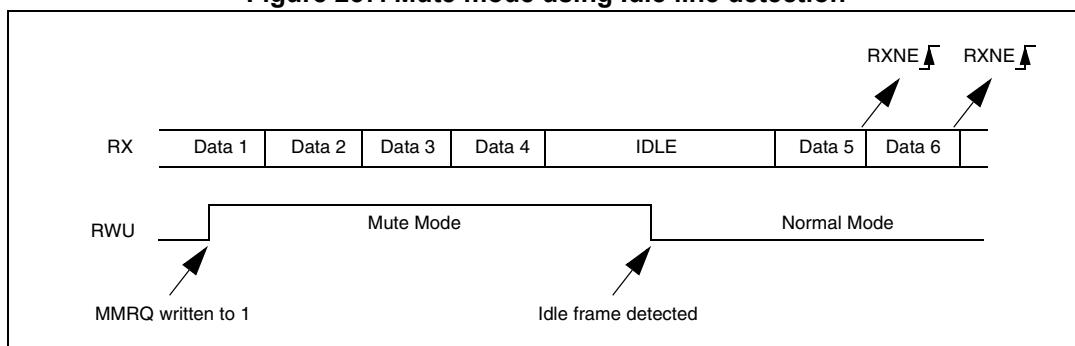
- Idle Line detection if the WAKE bit is reset,
- Address Mark detection if the WAKE bit is set.

#### Idle line detection (WAKE=0)

The USART enters mute mode when the MMRQ bit is written to 1 and the RWU is automatically set.

It wakes up when an Idle frame is detected. Then the RWU bit is cleared by hardware but the IDLE bit is not set in the USART\_ISR register. An example of mute mode behavior using Idle line detection is given in [Figure 237](#).

**Figure 237. Mute mode using Idle line detection**



**Note:** If the MMRQ is set while the IDLE character has already elapsed, mute mode will not be entered (RWU is not set).

If the USART is activated while the line is IDLE, the idle state is detected after the duration of one IDLE frame (not only after the reception of one character frame).

#### 4-bit/7-bit address mark detection (WAKE=1)

In this mode, bytes are recognized as addresses if their MSB is a '1' otherwise they are considered as data. In an address byte, the address of the targeted receiver is put in the 4 or 7 LSBs. The choice of 7 or 4 bit address detection is done using the ADDM7 bit. This 4-bit/7-bit word is compared by the receiver with its own address which is programmed in the ADD bits in the USART\_CR2 register.

**Note:** *In 7-bit and 9-bit data modes, address detection is done on 6-bit and 8-bit addresses (ADD[5:0] and ADD[7:0]) respectively.*

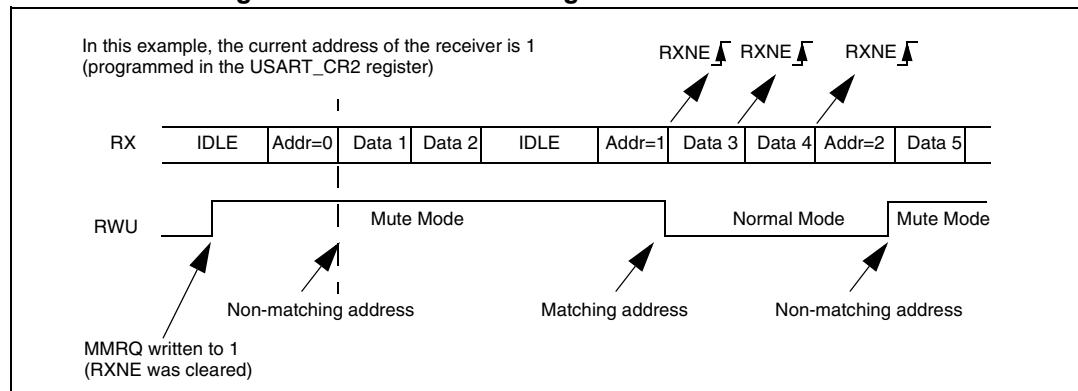
The USART enters mute mode when an address character is received which does not match its programmed address. In this case, the RWU bit is set by hardware. The RXNE flag is not set for this address byte and no interrupt or DMA request is issued when the USART enters mute mode.

The USART also enters mute mode when the MMRQ bit is written to 1. The RWU bit is also automatically set in this case.

The USART exits from mute mode when an address character is received which matches the programmed address. Then the RWU bit is cleared and subsequent bytes are received normally. The RXNE bit is set for the address character since the RWU bit has been cleared.

An example of mute mode behavior using address mark detection is given in [Figure 238](#).

**Figure 238. Mute mode using address mark detection**



#### 25.5.8 ModBus communication

The USART offers basic support for the implementation of Modbus/RTU and Modbus/ASCII protocols. Modbus/RTU is a half duplex, block transfer protocol. The control part of the protocol (address recognition, block integrity control and command interpretation) must be implemented in software.

The USART offers basic support for the end of the block detection, without software overhead or other resources.

##### Modbus/RTU

In this mode, the end of one block is recognized by a "silence" (idle line) for more than 2 character times. This function is implemented through the programmable timeout function.

The timeout function and interrupt must be activated, through the RTOEN bit in the USART\_CR2 register and the RTOIE in the USART\_CR1 register. The value corresponding to a timeout of 2 character times (for example 22 x bit time) must be programmed in the RTO register. When the receive line is idle for this duration, after the last stop bit is received, an interrupt is generated, informing the software that the current block reception is completed.

### Modbus/ASCII

In this mode, the end of a block is recognized by a specific (CR/LF) character sequence. The USART manages this mechanism using the character match function.

By programming the LF ASCII code in the ADD[7:0] field and by activating the character match interrupt (CMIE=1), the software is informed when a LF has been received and can check the CR/LF in the DMA buffer.

## 25.5.9 Parity control

Parity control (generation of parity bit in transmission and parity checking in reception) can be enabled by setting the PCE bit in the USART\_CR1 register. Depending on the frame length defined by the M bit, the possible USART frame formats are as listed in [Table 87](#).

**Table 87. Frame formats**

M bit	PCE bit	USART frame <sup>(1)</sup>
0	0	SB   8 bit data   STB
0	1	SB   7-bit data   PB   STB
1	0	SB   9-bit data   STB
1	1	SB   8-bit data PB   STB

1. Legends: SB: start bit, STB: stop bit, PB: parity bit.
2. In the data register, the PB is always taking the MSB position (8th or 7th, depending on the M bit value).

### Even parity

The parity bit is calculated to obtain an even number of “1s” inside the frame made of the 7 or 8 LSB bits (depending on whether M is equal to 0 or 1) and the parity bit.

E.g.: data=00110101; 4 bits set => parity bit will be 0 if even parity is selected (PS bit in USART\_CR1 = 0).

### Odd parity

The parity bit is calculated to obtain an odd number of “1s” inside the frame made of the 7 or 8 LSB bits (depending on whether M is equal to 0 or 1) and the parity bit.

E.g.: data=00110101; 4 bits set => parity bit will be 1 if odd parity is selected (PS bit in USART\_CR1 = 1).

### Parity checking in reception

If the parity check fails, the PE flag is set in the USART\_ISR register and an interrupt is generated if PEIE is set in the USART\_CR1 register. The PE flag is cleared by software writing 1 to the PECF in the USART\_ICR register.

### Parity generation in transmission

If the PCE bit is set in USART\_CR1, then the MSB bit of the data written in the data register is transmitted but is changed by the parity bit (even number of "1s" if even parity is selected (PS=0) or an odd number of "1s" if odd parity is selected (PS=1)).

## 25.5.10 LIN (local interconnection network) mode

This section is relevant only when LIN mode is supported. Please refer to [Section 25.4: USART implementation on page 577](#).

The LIN mode is selected by setting the LINEN bit in the USART\_CR2 register. In LIN mode, the following bits must be kept cleared:

- STOP[1:0], CLKEN in the USART\_CR2 register
- SCEN, HDSEL and IREN in the USART\_CR3 register.

### LIN transmission

The procedure explained in [Section 25.5.2](#) has to be applied for LIN Master transmission. It must be the same as for normal USART transmission with the following differences:

- Clear the M bit to configure 8-bit word length.
- Set the LINEN bit to enter LIN mode. In this case, setting the SBKRQ bit sends 13 '0' bits as a break character. Then 2 bits of value '1' are sent to allow the next start detection.

### LIN reception

When LIN mode is enabled, the break detection circuit is activated. The detection is totally independent from the normal USART receiver. A break can be detected whenever it occurs, during Idle state or during a frame.

When the receiver is enabled (RE=1 in USART\_CR1), the circuit looks at the RX input for a start signal. The method for detecting start bits is the same when searching break characters or data. After a start bit has been detected, the circuit samples the next bits exactly like for the data (on the 8th, 9th and 10th samples). If 10 (when the LBDL = 0 in USART\_CR2) or 11 (when LBDL=1 in USART\_CR2) consecutive bits are detected as '0', and are followed by a delimiter character, the LBDF flag is set in USART\_ISR. If the LBDIE bit=1, an interrupt is generated. Before validating the break, the delimiter is checked for as it signifies that the RX line has returned to a high level.

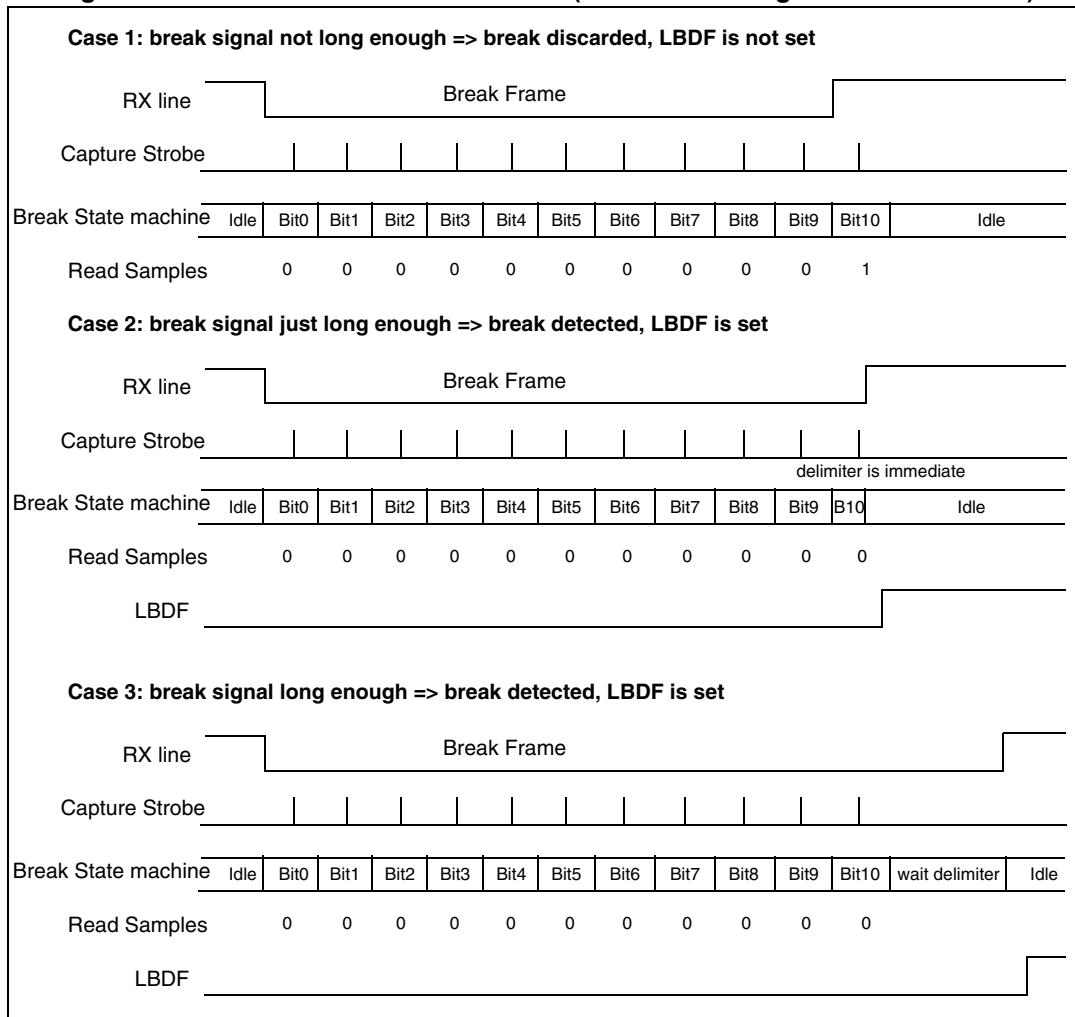
If a '1' is sampled before the 10 or 11 have occurred, the break detection circuit cancels the current detection and searches for a start bit again.

If the LIN mode is disabled (LINEN=0), the receiver continues working as normal USART, without taking into account the break detection.

If the LIN mode is enabled (LINEN=1), as soon as a framing error occurs (i.e. stop bit detected at '0, which will be the case for any break frame), the receiver stops until the break detection circuit receives either a '1, if the break word was not complete, or a delimiter character if a break has been detected.

The behavior of the break detector state machine and the break flag is shown on the [Figure 239: Break detection in LIN mode \(11-bit break length - LBDL bit is set\) on page 597](#).

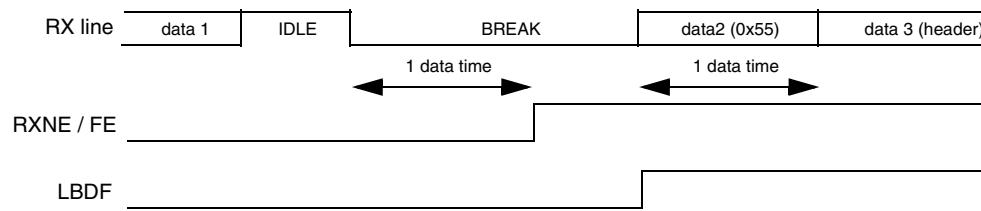
Examples of break frames are given on [Figure 240: Break detection in LIN mode vs. Framing error detection on page 598](#).

**Figure 239. Break detection in LIN mode (11-bit break length - LBDL bit is set)**

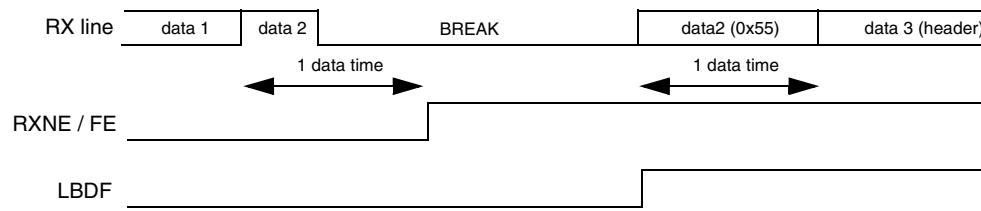
**Figure 240. Break detection in LIN mode vs. Framing error detection**

In these examples, we suppose that LBDL=1 (11-bit break length), M=0 (8-bit data)

**Case 1: break occurring after an Idle**



**Case 1: break occurring while data is being received**



### 25.5.11 USART synchronous mode

The synchronous mode is selected by writing the CLKEN bit in the USART\_CR2 register to 1. In synchronous mode, the following bits must be kept cleared:

- LINEN bit in the USART\_CR2 register,
- SCEN, HDSEL and IREN bits in the USART\_CR3 register.

In this mode, the USART can be used to control bidirectional synchronous serial communications in master mode. The SCLK pin is the output of the USART transmitter clock. No clock pulses are sent to the SCLK pin during start bit and stop bit. Depending on the state of the LBCL bit in the USART\_CR2 register, clock pulses are, or are not, generated during the last valid data bit (address mark). The CPOL bit in the USART\_CR2 register is used to select the clock polarity, and the CPHA bit in the USART\_CR2 register is used to select the phase of the external clock (see [Figure 241](#), [Figure 242](#) & [Figure 243](#)).

During the Idle state, preamble and send break, the external SCLK clock is not activated.

In synchronous mode the USART transmitter works exactly like in asynchronous mode. But as SCLK is synchronized with TX (according to CPOL and CPHA), the data on TX is synchronous.

In this mode the USART receiver works in a different manner compared to the asynchronous mode. If RE=1, the data is sampled on SCLK (rising or falling edge, depending on CPOL and CPHA), without any oversampling. A setup and a hold time must be respected (which depends on the baud rate: 1/16 bit time).

*Note:*

*The SCLK pin works in conjunction with the TX pin. Thus, the clock is provided only if the transmitter is enabled (TE=1) and data is being transmitted (the data register USART\_DR written). This means that it is not possible to receive synchronous data without transmitting data.*

*The LBCL, CPOL and CPHA bits have to be selected when the USART is disabled (UE=0) to ensure that the clock pulses function correctly.*

Figure 241. USART example of synchronous transmission

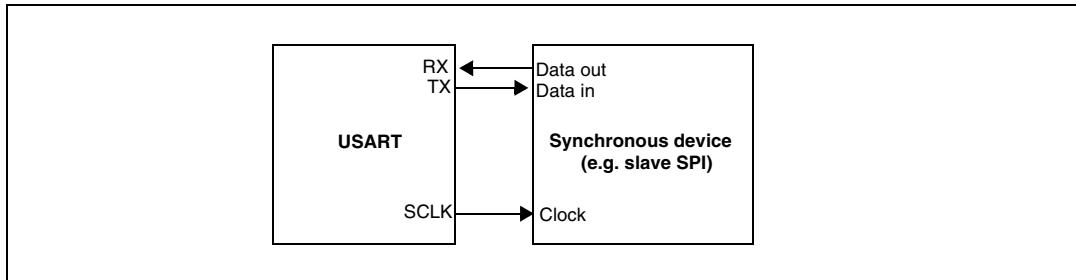


Figure 242. USART data clock timing diagram (M=0)

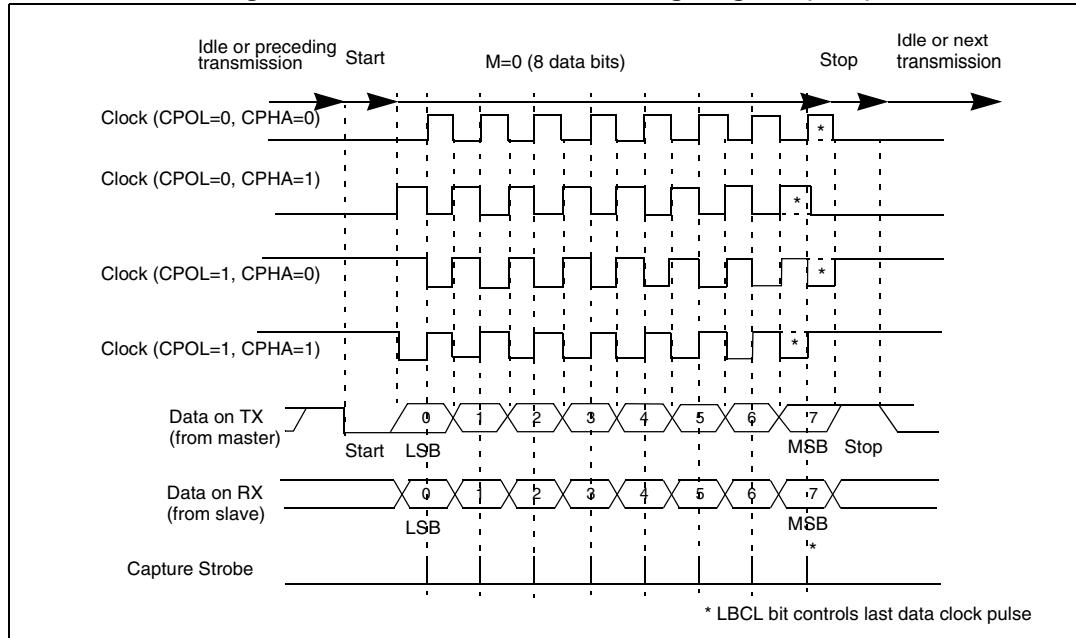


Figure 243. USART data clock timing diagram (M=1)

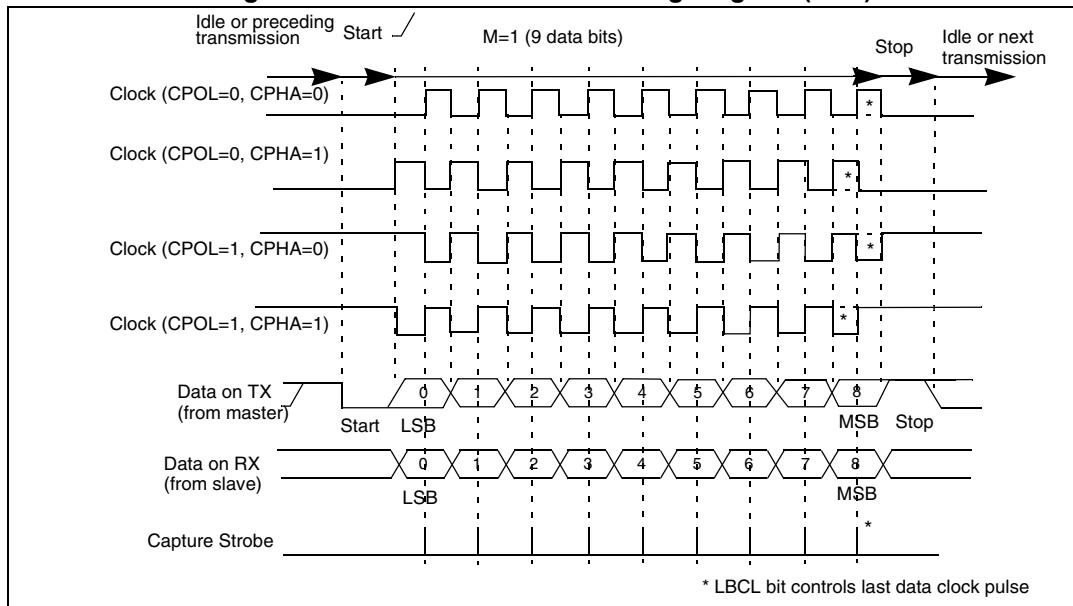
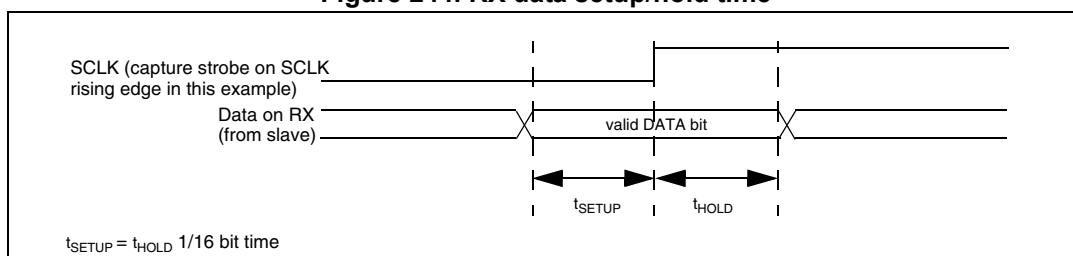


Figure 244. RX data setup/hold time



Note: The function of SCLK is different in Smartcard mode. Refer to [Section 25.5.13: Smartcard mode](#) for more details.

### 25.5.12 Single-wire half-duplex communication

Single-wire half-duplex mode is selected by setting the HDSEL bit in the USART\_CR3 register. In this mode, the following bits must be kept cleared:

- LINEN and CLKEN bits in the USART\_CR2 register,
- SCEN and IREN bits in the USART\_CR3 register.

The USART can be configured to follow a single-wire half-duplex protocol where the TX and RX lines are internally connected. The selection between half- and full-duplex communication is made with a control bit 'HALF DUPLEX SEL' (HDSEL in USART\_CR3).

As soon as HDSEL is written to 1:

- The TX and RX lines are internally connected
- The RX pin is no longer used
- The TX pin is always released when no data is transmitted. Thus, it acts as a standard I/O in idle or in reception. It means that the I/O must be configured so that TX is configured as alternate function open-drain with an external pull-up.

Apart from this, the communication protocol is similar to normal USART mode. Any conflicts on the line must be managed by software (by the use of a centralized arbiter, for instance). In particular, the transmission is never blocked by hardware and continues as soon as data is written in the data register while the TE bit is set.

### 25.5.13 Smartcard mode

This section is relevant only when Smartcard mode is supported. Please refer to [Section 25.4: USART implementation on page 577](#).

Smartcard mode is selected by setting the SCEN bit in the USART\_CR3 register. In Smartcard mode, the following bits must be kept cleared:

- LINEN bit in the USART\_CR2 register,
- HDSEL and IREN bits in the USART\_CR3 register.

Moreover, the CLKEN bit may be set in order to provide a clock to the Smartcard.

The Smartcard interface is designed to support asynchronous protocol Smartcards as defined in the ISO 7816-3 standard. Both T=0 (character mode) and T=1 (block mode) are supported.

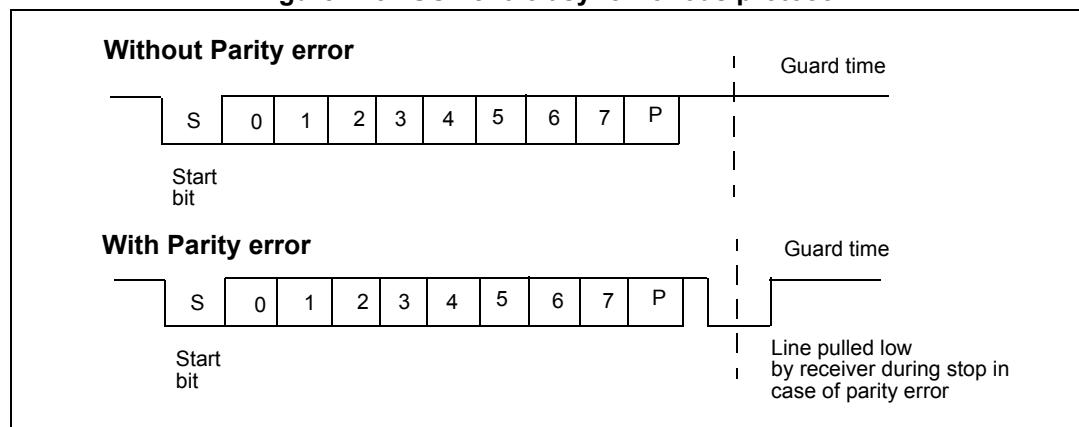
The USART should be configured as:

- 8 bits plus parity: where M=1 and PCE=1 in the USART\_CR1 register
- 1.5 stop bits: where STOP=11 in the USART\_CR2 register.

In T=0 (character) mode, the parity error is indicated at the end of each character during the guard time period.

[Figure 245](#) shows examples of what can be seen on the data line with and without parity error.

**Figure 245. ISO 7816-3 asynchronous protocol**



When connected to a Smartcard, the TX output of the USART drives a bidirectional line that is also driven by the Smartcard. The TX pin must be configured as open drain.

Smartcard mode implements a single wire half duplex communication protocol.

- Transmission of data from the transmit shift register is guaranteed to be delayed by a minimum of 1/2 baud clock. In normal operation a full transmit shift register starts

shifting on the next baud clock edge. In Smartcard mode this transmission is further delayed by a guaranteed 1/2 baud clock.

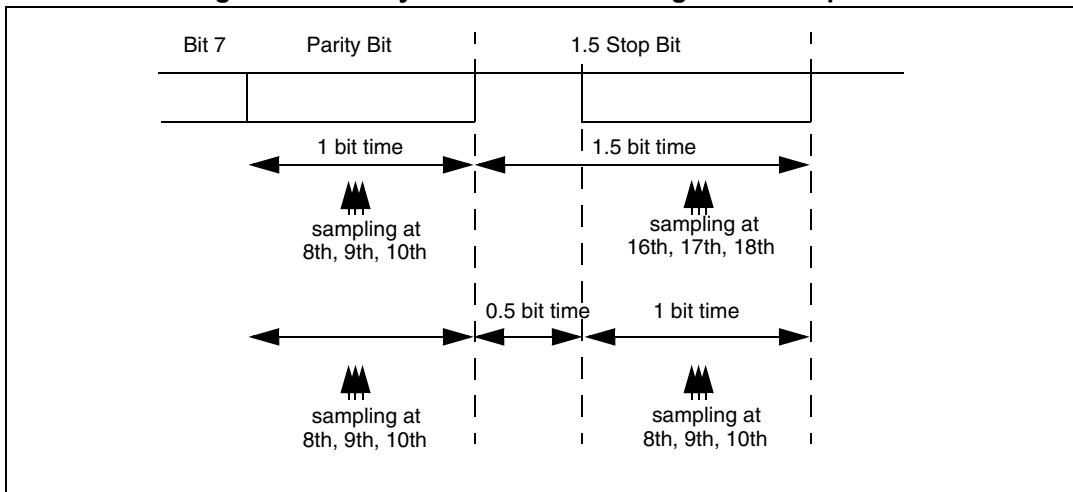
- In transmission, if the Smartcard detects a parity error, it signals this condition to the USART by driving the line low (NACK). This NACK signal (pulling transmit line low for 1 baud clock) causes a framing error on the transmitter side (configured with 1.5 stop bits). The USART can handle automatic re-sending of data according to the protocol. The number of retries is programmed in the SCARCNT bit field. If the USART continues receiving the NACK after the programmed number of retries, it stops transmitting and signals the error as a framing error. The TXE bit may be cleared using the TXFRQ bit in the USART\_RQR register.
- Smartcard auto-retry in transmission: A delay of 2.5 baud periods is inserted between the NACK detection by the USART and the start bit of the repeated character. The TC bit is set immediately at the end of reception of the last repeated character (no guardtime). If the software wants to repeat it again, it must insure the minimum 2 baud periods required by the standard.
- If a parity error is detected during reception of a frame programmed with a 1.5 stop bit period, the transmit line is pulled low for a baud clock period after the completion of the receive frame. This is to indicate to the Smartcard that the data transmitted to the USART has not been correctly received. A parity error is NACKed by the receiver if the NACK control bit is set, otherwise a NACK is not transmitted (to be used in T=1 mode). If the received character is erroneous, the RXNE/receive DMA request is not activated. According to the protocol specification, the Smartcard must resend the same character. If the received character is still erroneous after the maximum number of retries specified in the SCARCNT bit field, the USART stops transmitting the NACK and signals the error as a parity error.
- Smartcard auto-retry in reception: the BUSY flag remains set if the USART NACKs the card but the card doesn't repeat the character.
- In transmission, the USART inserts the Guard Time (as programmed in the Guard Time register) between two successive characters. As the Guard Time is measured after the stop bit of the previous character, the GT[7:0] register must be programmed to the desired CGT (Character Guard Time, as defined by the 7816-3 specification) minus 12 (the duration of one character).
- The assertion of the TC flag can be delayed by programming the Guard Time register. In normal operation, TC is asserted when the transmit shift register is empty and no further transmit requests are outstanding. In Smartcard mode an empty transmit shift register triggers the Guard Time counter to count up to the programmed value in the Guard Time register. TC is forced low during this time. When the Guard Time counter reaches the programmed value TC is asserted high.
- The de-assertion of TC flag is unaffected by Smartcard mode.
- If a framing error is detected on the transmitter end (due to a NACK from the receiver), the NACK is not detected as a start bit by the receive block of the transmitter. According to the ISO protocol, the duration of the received NACK can be 1 or 2 baud clock periods.
- On the receiver side, if a parity error is detected and a NACK is transmitted the receiver does not detect the NACK as a start bit.

*Note:* A break character is not significant in Smartcard mode. A 0x00 data with a framing error is treated as data and not as a break.

*No Idle frame is transmitted when toggling the TE bit. The Idle frame (as defined for the other configurations) is not defined by the ISO protocol.*

**Figure 246** details how the NACK signal is sampled by the USART. In this example the USART is transmitting data and is configured with 1.5 stop bits. The receiver part of the USART is enabled in order to check the integrity of the data and the NACK signal.

**Figure 246. Parity error detection using the 1.5 stop bits**



The USART can provide a clock to the Smartcard through the SCLK output. In Smartcard mode, SCLK is not associated to the communication but is simply derived from the internal peripheral input clock through a 5-bit prescaler. The division ratio is configured in the prescaler register USART\_GTPR. SCLK frequency can be programmed from  $f_{CK}/2$  to  $f_{CK}/62$ , where  $f_{CK}$  is the peripheral input clock.

#### Block mode (T=1)

In T=1 (block) mode, the parity error transmission is deactivated, by clearing the NACK bit in the UART\_CR3 register.

When requesting a read from the Smartcard, in block mode, the software must program the RTOR register to the BWT (block wait time) - 11 value. If no answer is received from the card before the expiration of this period, a timeout interrupt will be generated. If the first character is received before the expiration of the period, it is signaled by the RXNE interrupt.

**Note:** *The RXNE interrupt must be enabled even when using the USART in DMA mode to read from the Smartcard in block mode. In parallel, the DMA must be enabled only after the first received byte.*

After the reception of the first character (RXNE interrupt), the RTO register must be programmed to the CWT (character wait time) - 11 value, in order to allow the automatic check of the maximum wait time between two consecutive characters. This time is expressed in baudtime units. If the Smartcard doesn't send a new character in less than the CWT period after the end of the previous character, the USART signals this to the software through the RTOF flag and interrupt (when RTOIE bit is set).

**Note:** *The RTO counter starts counting from the end of the first stop bit of the last character in cases STOP = 00, 10. In case of STOP = 11, the RTO counter starts counting 1 bit time after the beginning of the STOP bit. As in the Smartcard protocol definition, the BWT/CWT values are defined from the beginning (start bit) of the last character. The RTO register must be programmed to BWT -11 or CWT -11, respectively, taking into account the length of the last character itself.*

A block length counter is used to count all the characters received by the USART. This counter is reset when the USART is transmitting (TXE=0). The length of the block is communicated by the Smartcard in the third byte of the block (prologue field). This value must be programmed to the BLEN field in the USART\_RTOR register. When using DMA mode, before the start of the block, this register field must be programmed to the minimum value (0x0). With this value, an interrupt is generated after the 4th received character. The software must read the LEN field (third byte), its value must be read from the receive buffer.

In interrupt driven receive mode, the length of the block may be checked by software or by programming the BLEN value. However, before the start of the block, the maximum value of BLEN (0xFF) may be programmed. The real value will be programmed after the reception of the third character.

If the block is using the LRC longitudinal redundancy check (1 epilogue byte), the BLEN=LEN. If the block is using the CRC mechanism (2 epilog bytes), BLEN=LEN+1 must be programmed. The total block length (including prologue, epilogue and information fields) equals BLEN+4. The end of the block is signaled to the software through the EOBF flag and interrupt (when EOBI bit is set).

In case of an error in the block length, the end of the block is signaled by the RTO interrupt (Character Wait Time overflow).

*Note:* *The error checking code (LRC/CRC) must be computed/verified by software.*

### Direct and inverse convention

The Smartcard protocol defines two conventions: direct and inverse.

The direct convention is defined as: LSB first, logical bit value of 1 corresponds to a H state of the line and parity is even. In order to use this convention, the following control bits must be programmed: MSBFIRST=0, DATAINV=0 (default values).

The inverse convention is defined as: MSB first, logical bit value 1 corresponds to an L state on the signal line and parity is even. In order to use this convention, the following control bits must be programmed: MSBFIRST=1, DATAINV=1.

*Note:* *When logical data values are inverted (0=H, 1=L), the parity bit is also inverted in the same way.*

In order to recognize the card convention, the card sends the initial character, TS, as the first character of the ATR (Answer To Reset) frame. The two possible patterns for the TS are: LHHL LLL LLH and LHHL HHH LLH.

- (H) LHHL LLL LLH sets up the inverse convention: state L encodes value 1 and moment 2 conveys the most significant bit (MSB first). When decoded by inverse convention, the conveyed byte is equal to '3F'.
- (H) LHHL HHH LLH sets up the direct convention: state H encodes value 1 and moment 2 conveys the least significant bit (LSB first). When decoded by direct convention, the conveyed byte is equal to '3B'.

Character parity is correct when there is an even number of bits set to 1 in the nine moments 2 to 10.

As the USART does not know which convention is used by the card, it needs to be able to recognize either pattern and act accordingly. The pattern recognition is not done in hardware, but through a software sequence. Moreover, supposing that the USART is configured in direct convention (default) and the card answers with the inverse convention, TS = LHHL LLL LLH => the USART received character will be '03' and the parity will be odd.

Therefore, two methods are available for TS pattern recognition:

**Method 1:** The USART is programmed in standard Smartcard mode/direct convention. In this case, the TS pattern reception generates a parity error interrupt and error signal to the card.

- The parity error interrupt informs the software that the card didn't answer correctly in direct convention. Software then reprograms the USART for inverse convention
- In response to the error signal, the card retries the same TS character, and it will be correctly received this time, by the reprogrammed USART

Alternatively, in answer to the parity error interrupt, the software may decide to reprogram the USART and to also generate a new reset command to the card, then wait again for the TS.

**Method 2:** The USART is programmed in 9-bit/no-parity mode, no bit inversion. In this mode it receives any of the two TS patterns as:

- (H) LHHL LLL LLH = 0x103 -> inverse convention to be chosen
- (H) LHHL HHH LLH = 0x13B -> direct convention to be chosen

The software checks the received character against these two patterns and, if any of them match, then programs the USART accordingly for the next character reception.

If none of the two is recognized, a card reset may be generated in order to restart the negotiation.

#### 25.5.14 IrDA SIR ENDEC block

This section is relevant only when IrDA mode is supported. Please refer to [Section 25.4: USART implementation on page 577](#).

IrDA mode is selected by setting the IREN bit in the USART\_CR3 register. In IrDA mode, the following bits must be kept cleared:

- LINEN, STOP and CLKEN bits in the USART\_CR2 register,
- SCEN and HDSEL bits in the USART\_CR3 register.

The IrDA SIR physical layer specifies use of a Return to Zero, Inverted (RZI) modulation scheme that represents logic 0 as an infrared light pulse (see [Figure 247](#)).

The SIR Transmit encoder modulates the Non Return to Zero (NRZ) transmit bit stream output from USART. The output pulse stream is transmitted to an external output driver and infrared LED. USART supports only bit rates up to 115.2 Kbps for the SIR ENDEC. In normal mode the transmitted pulse width is specified as 3/16 of a bit period.

The SIR receive decoder demodulates the return-to-zero bit stream from the infrared detector and outputs the received NRZ serial bit stream to the USART. The decoder input is normally high (marking state) in the Idle state. The transmit encoder output has the opposite polarity to the decoder input. A start bit is detected when the decoder input is low.

- IrDA is a half duplex communication protocol. If the Transmitter is busy (when the USART is sending data to the IrDA encoder), any data on the IrDA receive line is ignored by the IrDA decoder and if the Receiver is busy (when the USART is receiving decoded data from the USART), data on the TX from the USART to IrDA is not

encoded. While receiving data, transmission should be avoided as the data to be transmitted could be corrupted.

- A 0 is transmitted as a high pulse and a 1 is transmitted as a 0. The width of the pulse is specified as 3/16th of the selected bit period in normal mode (see [Figure 248](#)).
- The SIR decoder converts the IrDA compliant receive signal into a bit stream for USART.
- The SIR receive logic interprets a high state as a logic one and low pulses as logic zeros.
- The transmit encoder output has the opposite polarity to the decoder input. The SIR output is in low state when Idle.
- The IrDA specification requires the acceptance of pulses greater than 1.41  $\mu$ s. The acceptable pulse width is programmable. Glitch detection logic on the receiver end filters out pulses of width less than 2 PSC periods (PSC is the prescaler value programmed in the USART\_GTPR register). Pulses of width less than 1 PSC period are always rejected, but those of width greater than one and less than two periods may be accepted or rejected, those greater than 2 periods will be accepted as a pulse. The IrDA encoder/decoder doesn't work when PSC=0.
- The receiver can communicate with a low-power transmitter.
- In IrDA mode, the STOP bits in the USART\_CR2 register must be configured to "1 stop bit".

## IrDA low-power mode

### *Transmitter:*

In low-power mode the pulse width is not maintained at 3/16 of the bit period. Instead, the width of the pulse is 3 times the low-power baud rate which can be a minimum of 1.42 MHz. Generally, this value is 1.8432 MHz ( $1.42 \text{ MHz} < \text{PSC} < 2.12 \text{ MHz}$ ). A low-power mode programmable divisor divides the system clock to achieve this value.

### *Receiver:*

Receiving in low-power mode is similar to receiving in normal mode. For glitch detection the USART should discard pulses of duration shorter than  $1/\text{PSC}$ . A valid low is accepted only if its duration is greater than 2 periods of the IrDA low-power Baud clock (PSC value in the USART\_GTPR register).

**Note:** *A pulse of width less than two and greater than one PSC period(s) may or may not be rejected.*

*The receiver set up time should be managed by software. The IrDA physical layer specification specifies a minimum of 10 ms delay between transmission and reception (IrDA is a half duplex protocol).*

Figure 247. IrDA SIR ENDEC- block diagram

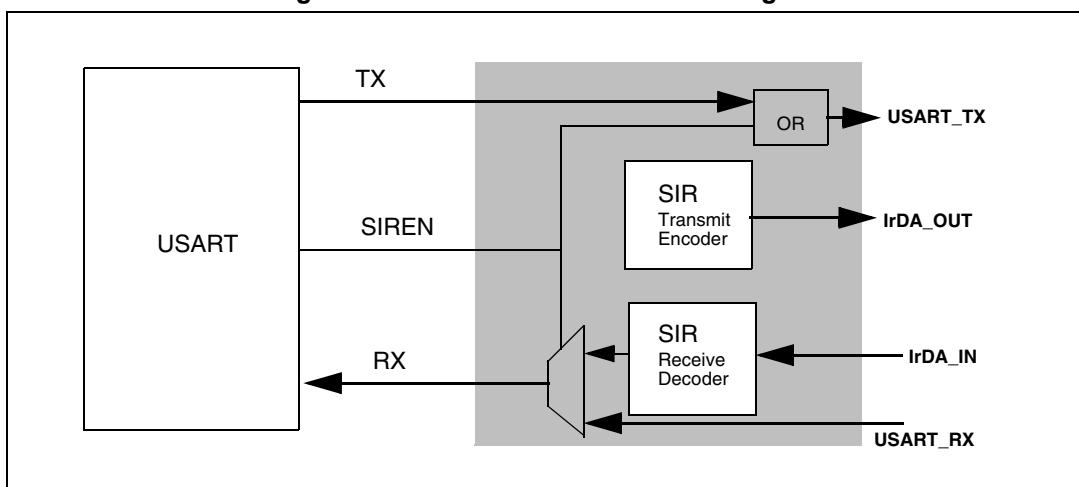
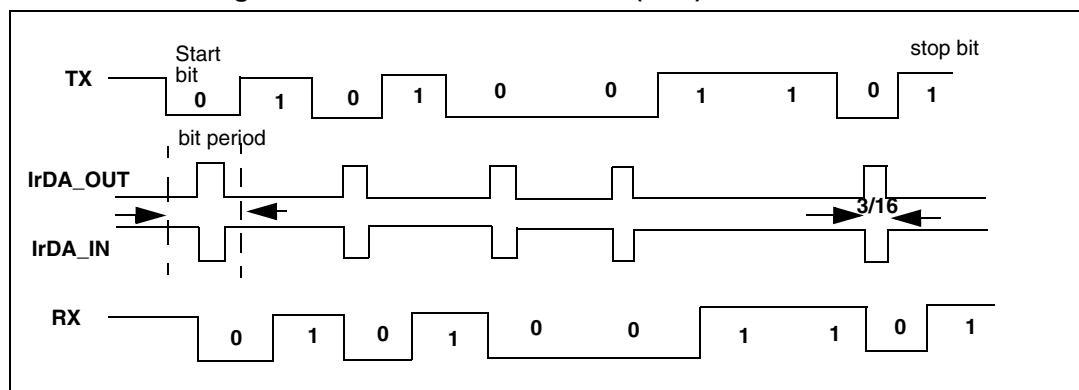


Figure 248. IrDA data modulation (3/16) -Normal Mode



### 25.5.15 Continuous communication using DMA

The USART is capable of performing continuous communication using the DMA. The DMA requests for Rx buffer and Tx buffer are generated independently.

**Note:** Please refer to [Section 25.4: USART implementation on page 577](#) to determine if the DMA mode is supported. If DMA is not supported, use the USART as explained in [Section 25.5.2](#) or [25.5.3](#). To perform continuous communication, you can clear the TXE/ RXNE flags in the USART\_ISR register.

#### Transmission using DMA

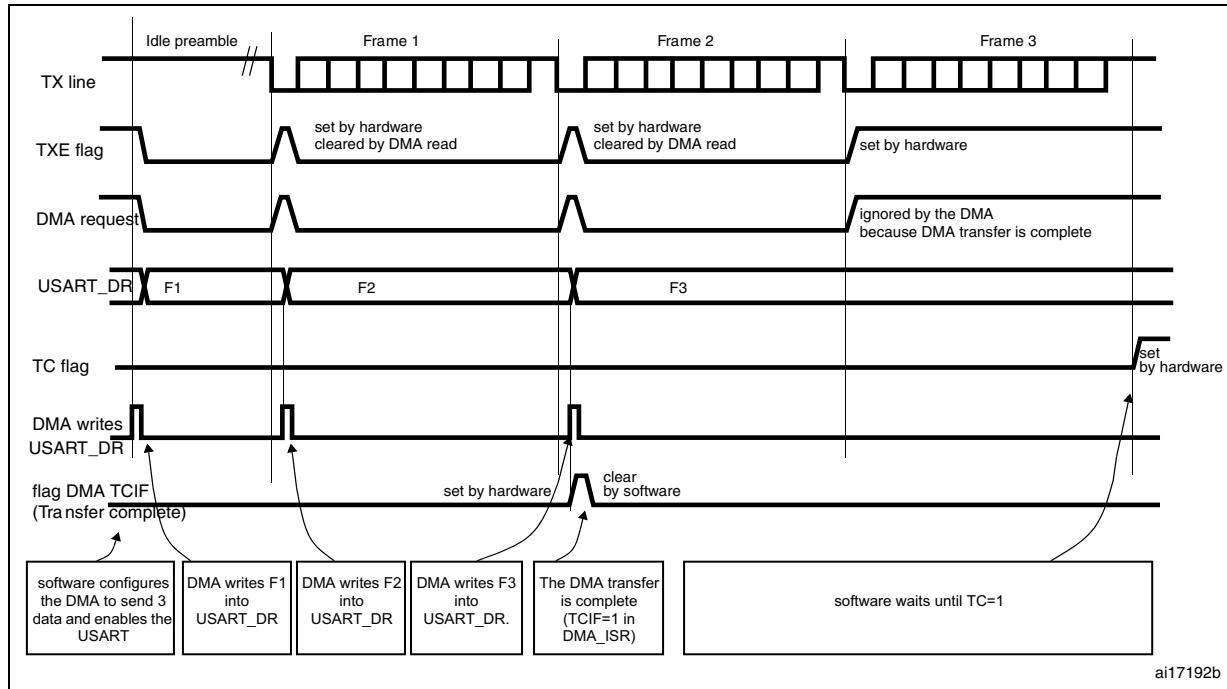
DMA mode can be enabled for transmission by setting DMAT bit in the USART\_CR3 register. Data is loaded from a SRAM area configured using the DMA peripheral (refer to [Section 10: Direct memory access controller \(DMA\) on page 148](#)) to the USART\_TDR register whenever the TXE bit is set. To map a DMA channel for USART transmission, use the following procedure (x denotes the channel number):

1. Write the USART\_TDR register address in the DMA control register to configure it as the destination of the transfer. The data is moved to this address from memory after each TXE event.
2. Write the memory address in the DMA control register to configure it as the source of the transfer. The data is loaded into the USART\_TDR register from this memory area after each TXE event.
3. Configure the total number of bytes to be transferred to the DMA control register.
4. Configure the channel priority in the DMA register
5. Configure DMA interrupt generation after half/ full transfer as required by the application.
6. Clear the TC flag in the USART\_ISR register by setting the TCCF bit in the USART\_ICR register.
7. Activate the channel in the DMA register.

When the number of data transfers programmed in the DMA Controller is reached, the DMA controller generates an interrupt on the DMA channel interrupt vector.

In transmission mode, once the DMA has written all the data to be transmitted (the TCIF flag is set in the DMA\_ISR register), the TC flag can be monitored to make sure that the USART communication is complete. This is required to avoid corrupting the last transmission before disabling the USART or entering Stop mode. Software must wait until TC=1. The TC flag remains cleared during all data transfers and it is set by hardware at the end of transmission of the last frame.

Figure 249. Transmission using DMA



ai17192b

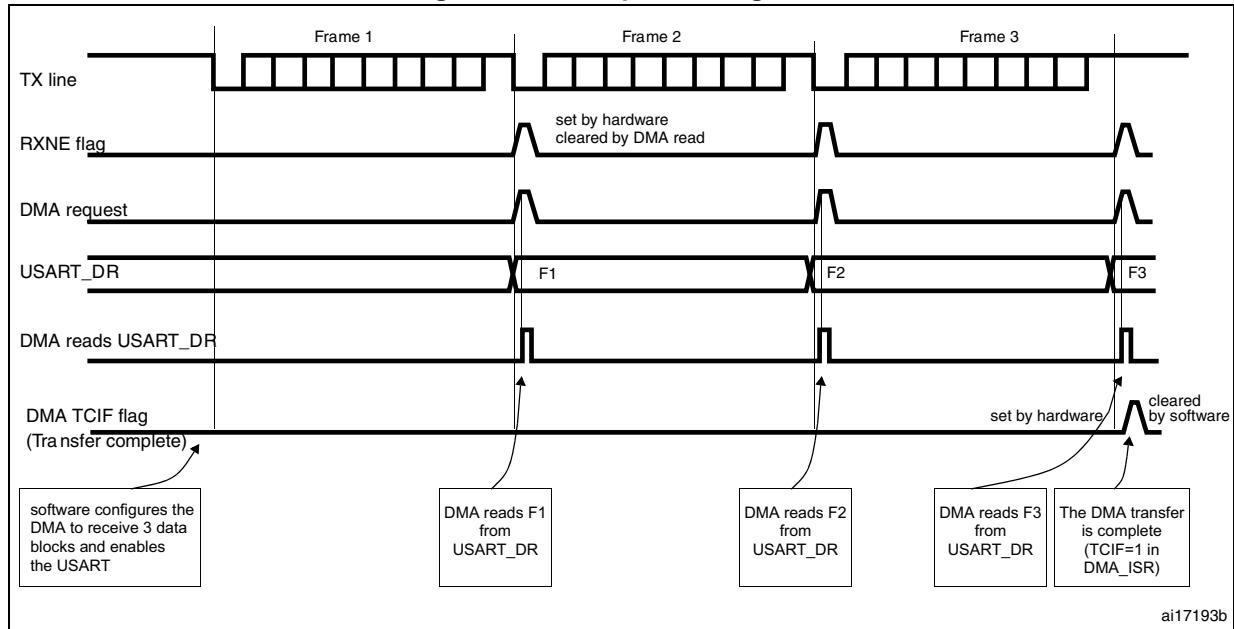
### Reception using DMA

DMA mode can be enabled for reception by setting the DMAR bit in USART\_CR3 register. Data is loaded from the USART\_RDR register to a SRAM area configured using the DMA peripheral (refer [Section 10: Direct memory access controller \(DMA\) on page 148](#)) whenever a data byte is received. To map a DMA channel for USART reception, use the following procedure:

1. Write the USART\_RDR register address in the DMA control register to configure it as the source of the transfer. The data is moved from this address to the memory after each RXNE event.
2. Write the memory address in the DMA control register to configure it as the destination of the transfer. The data is loaded from USART\_RDR to this memory area after each RXNE event.
3. Configure the total number of bytes to be transferred to the DMA control register.
4. Configure the channel priority in the DMA control register
5. Configure interrupt generation after half/ full transfer as required by the application.
6. Activate the channel in the DMA control register.

When the number of data transfers programmed in the DMA Controller is reached, the DMA controller generates an interrupt on the DMA channel interrupt vector.

Figure 250. Reception using DMA



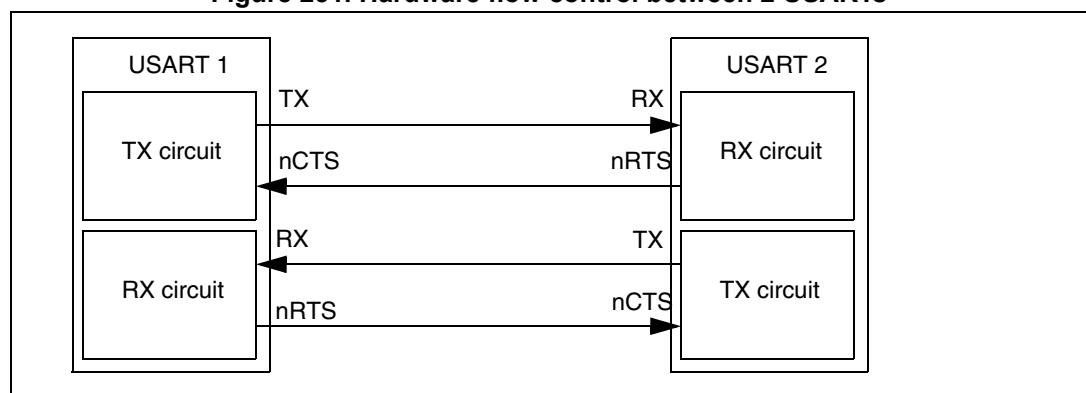
### Error flagging and interrupt generation in multibuffer communication

In multibuffer communication if any error occurs during the transaction the error flag is asserted after the current byte. An interrupt is generated if the interrupt enable flag is set. For framing error, overrun error and noise flag which are asserted with RXNE in single byte reception, there is a separate error flag interrupt enable bit (EIE bit in the USART\_CR3 register), which, if set, enables an interrupt after the current byte if any of these errors occur.

### 25.5.16 Hardware flow control and RS485 Driver Enable

It is possible to control the serial data flow between 2 devices by using the nCTS input and the nRTS output. The [Figure 251](#) shows how to connect 2 devices in this mode:

Figure 251. Hardware flow control between 2 USARTs

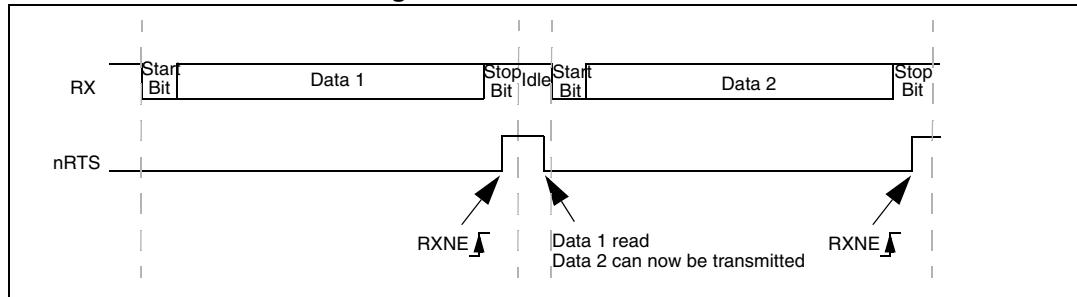


RTS and CTS flow control can be enabled independently by writing the RTSE and CTSE bits respectively to 1 (in the USART\_CR3 register).

### RTS flow control

If the RTS flow control is enabled ( $RTSE=1$ ), then nRTS is asserted (tied low) as long as the USART receiver is ready to receive a new data. When the receive register is full, nRTS is deasserted, indicating that the transmission is expected to stop at the end of the current frame. [Figure 252](#) shows an example of communication with RTS flow control enabled.

**Figure 252. RTS flow control**

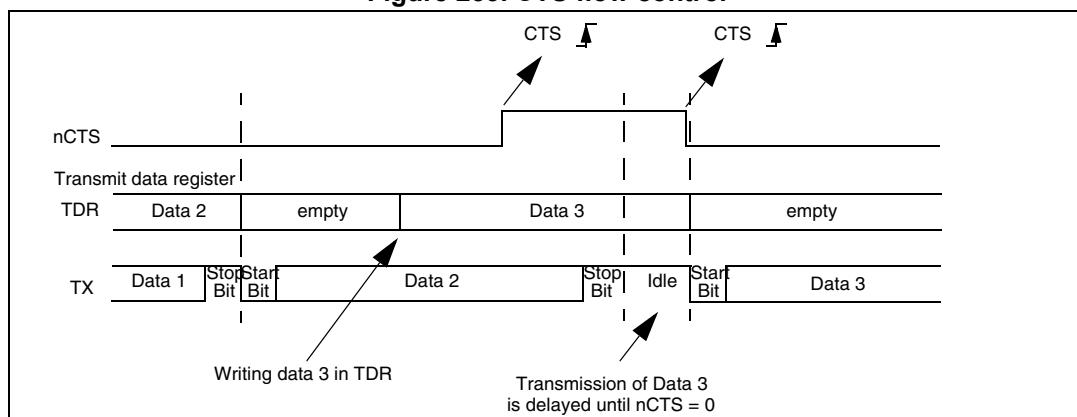


### CTS flow control

If the CTS flow control is enabled ( $CTSE=1$ ), then the transmitter checks the nCTS input before transmitting the next frame. If nCTS is asserted (tied low), then the next data is transmitted (assuming that data is to be transmitted, in other words, if  $TXE=0$ ), else the transmission does not occur. When nCTS is deasserted during a transmission, the current transmission is completed before the transmitter stops.

When  $CTSE=1$ , the CTSIF status bit is automatically set by hardware as soon as the nCTS input toggles. It indicates when the receiver becomes ready or not ready for communication. An interrupt is generated if the CTSIE bit in the USART\_CR3 register is set. [Figure 253](#) shows an example of communication with CTS flow control enabled.

**Figure 253. CTS flow control**



Note:

For correct behavior, nCTS must be asserted at least 3 USART clock source periods before the end of the current character. In addition it should be noted that the CTSCF flag may not be set for pulses shorter than 2 x PCLK periods.

## RS485 Driver Enable

The driver enable feature is enabled by setting bit DEM in the USART\_CR3 control register. This allows the user to activate the external transceiver control, through the DE (Driver Enable) signal. The assertion time is the time between the activation of the DE signal and the beginning of the START bit. It is programmed using the DEAT [4:0] bit fields in the USART\_CR1 control register. The de-assertion time is the time between the end of the last stop bit, in a transmitted message, and the de-activation of the DE signal. It is programmed using the DEDT [4:0] bit fields in the USART\_CR1 control register. The polarity of the DE signal can be configured using the DEP bit in the USART\_CR3 control register.

### 25.5.17 Wakeup from Stop mode

This section is relevant only when the Wakeup from Stop feature is supported. Please refer to [Table 82: STM32F05xxx USART features on page 577](#).

The USART is able to wake up the MCU from Stop mode when the UESM bit is set and the USART clock is set to HSI or LSE (refer to the [Reset and clock control \(RCC\) section](#)).

The MCU wakeup from Stop mode can be done using the standard RXNE interrupt. In this case, the RXNEIE bit must be set before entering Stop mode.

Alternatively, a specific interrupt may be selected through the WUS bit fields.

In order to be able to wake up the MCU from Stop mode, the UESM bit in the USART\_CR1 control register must be set prior to entering Stop mode.

When the wakeup event is detected, the WUF flag is set by hardware and a wakeup interrupt is generated if the WUFIE bit is set.

**Note:**

*Before entering Stop mode, software must check that the USART is not performing a transfer, by checking the BUSY flag in the USART\_SR register.*

*The WUF flag is set when a wakeup event is detected, independently of whether the MCU is in Stop or in an active mode.*

*When entering Stop mode just after having initialized and enabled the receiver, the REACK bit must be checked to ensure the USART is actually enabled.*

*When DMA is used for reception, it must be disabled before entering Stop mode and re-enabled upon exit from Stop mode.*

*The minimum bit duration to wake up properly from Stop mode is  $t_{WUSTOP} / (DWU \text{ (max)} * 11)$  when M equals 1 and  $t_{WUSTOP} / (DWU \text{ (max)} * 10)$  when M equals 0.*

**Caution:**

The wakeup from Stop mode feature is not available for all modes. For example it doesn't work in SPI mode because the SPI operates in master mode only.

## Using Mute mode with Stop mode

If the USART is put into Mute mode before entering Stop mode:

- Wakeup from Mute mode on idle detection must not be used, because idle detection cannot work in Stop mode.
- If the wakeup from Mute mode on address match is used, then the source of wake-up from Stop mode must also be the address match.
- If the USART is configured to wake up the MCU from Stop mode on START bit detection, the WUF flag is set, but the RXNE flag is not set.

## 25.6 USART interrupts

Table 88. USART interrupt requests

Interrupt event	Event flag	Enable Control bit
Transmit data register empty	TXE	TXEIE
CTS interrupt	CTSIF	CTSIE
Transmission Complete	TC	TCIE
Receive data register not empty (data ready to be read)	RXNE	RXNEIE
Overrun error detected	ORE	
Idle line detected	IDLE	IDLEIE
Parity error	PE	PEIE
LIN break	LBDF	LBDIE
Noise Flag, Overrun error and Framing Error in multibuffer communication.	NF or ORE or FE	EIE
Character match	CMF	CMIE
Receiver timeout error	RTOF	RTOIE
End of Block	EOBF	EOBIE
Wakeup from Stop mode	WUF <sup>(1)</sup>	WUFIE

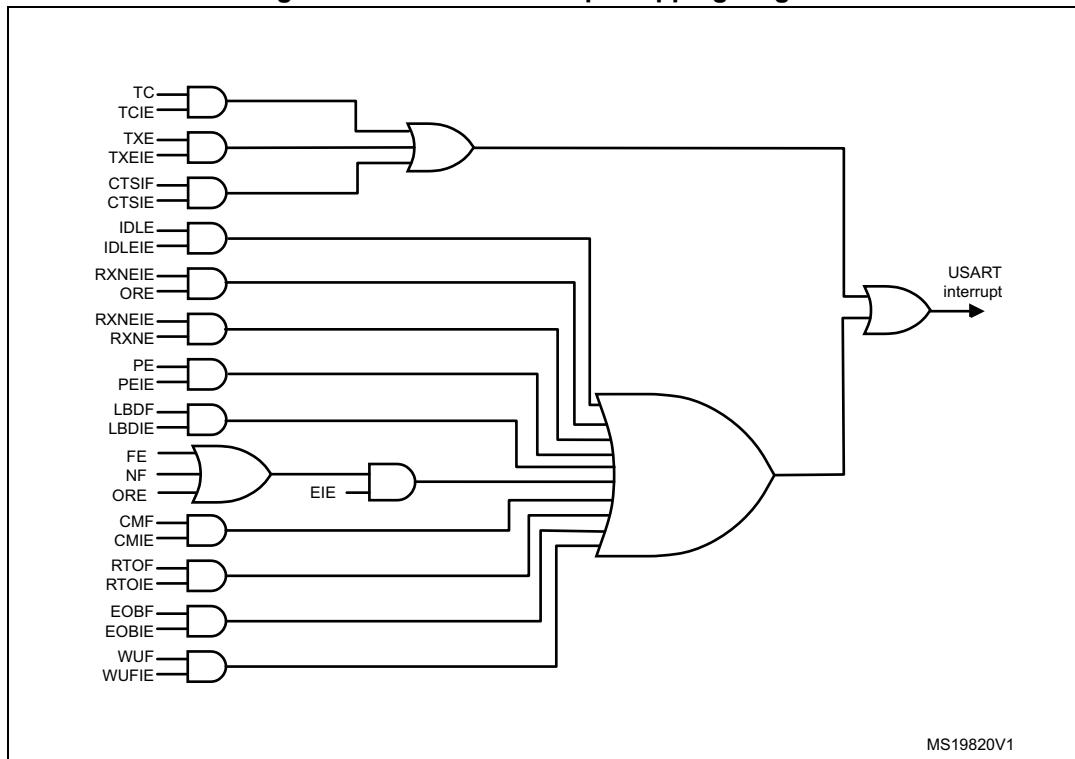
1. The WUF interrupt is active only in Stop mode.

The USART interrupt events are connected to the same interrupt vector (see [Figure 254](#)).

- During transmission: Transmission Complete, Clear to Send, Transmit Data Register empty or Framing error (in Smartcard mode) interrupt.
- During reception: Idle Line detection, Overrun error, Receive data register not empty, Parity error, LIN break detection, Noise Flag (only in multi buffer communication), Framing Error (only in multi buffer communication), Character match, etc.

These events generate an interrupt if the corresponding Enable Control Bit is set.

Figure 254. USART interrupt mapping diagram



## 25.7 USART registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 25.7.1 Control register 1 (USART\_CR1)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	EOBIE	RTOIE	DEAT[4:0]						DEDT[4:0]			
				rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OVER <sub>8</sub>	CMIE	MME	M	WAKE	PCE	PS	PEIE	TXEIE	TCIE	RXNEI <sub>E</sub>	IDLEIE	TE	RE	UESM	UE
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:28 Reserved, must be kept at reset value

Bit 27 EOBIE: End of Block interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated when the EOBF flag is set in the USART\_ISR register

*Note:* If the USART does not support Smartcard mode, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).

Bit 26 RTOIE: Receiver timeout interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated when the RTOF bit is set in the USART\_ISR register.

*Note:* If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'. [Section 25.4: USART implementation on page 577](#).

Bits 25:21 DEAT[4:0]: Driver Enable assertion time

This 5-bit value defines the time between the activation of the DE (Driver Enable) signal and the beginning of the start bit. It is expressed in sample time units (1/8 or 1/16 bit time, depending on the oversampling rate)

*Note:* If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. Please refer to [Section 25.4: USART implementation on page 577](#).

This bit field can only be written when the USART is disabled (UE=0).

Bits 20:16 DEDT[4:0]: Driver Enable deassertion time

This 5-bit value defines the time between the end of the last stop bit, in a transmitted message, and the de-activation of the DE (Driver Enable) signal. It is expressed in sample time units (1/8 or 1/16 bit time, depending on the oversampling rate).

If the USART\_TDR register is written during the DEDT time, the new data is transmitted only when the DEDT and DEAT times have both elapsed.

*Note:* If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. Please refer to [Section 25.4: USART implementation on page 577](#).

This bit field can only be written when the USART is disabled (UE=0).

Bit 15 **OVER8**: Oversampling mode

- 0: Oversampling by 16
- 1: Oversampling by 8

*Note: In LIN, IrDA and Smartcard modes, this bit must be kept cleared.*

This bit can only be written when the USART is disabled (UE=0).

Bit 14 **CME**: Character match interrupt enable

This bit is set and cleared by software.

- 0: Interrupt is inhibited
- 1: A USART interrupt is generated when the CMF bit is set in the USART\_ISR register.

Bit 13 **MME**: Mute mode enable

This bit activates the mute mode function of the USART. When set, the USART can switch between the active and mute modes, as defined by the WAKE bit. It is set and cleared by software.

- 0: Receiver in active mode permanently
- 1: Receiver can switch between mute mode and active mode.

Bit 12 **M**: Word length

This bit determines the word length. It is set or cleared by software.

- 0: 1 Start bit, 8 Data bits, n Stop bit
- 1: 1 Start bit, 9 Data bits, n Stop bit

This bit can only be written when the USART is disabled (UE=0).

Bit 11 **WAKE**: Receiver wakeup method

This bit determines the USART wakeup method from Mute mode. It is set or cleared by software.

- 0: Idle line
- 1: Address mark

This bit field can only be written when the USART is disabled (UE=0).

Bit 10 **PCE**: Parity control enable

This bit selects the hardware parity control (generation and detection). When the parity control is enabled, the computed parity is inserted at the MSB position (9th bit if M=1; 8th bit if M=0) and parity is checked on the received data. This bit is set and cleared by software. Once it is set, PCE is active after the current byte (in reception and in transmission).

- 0: Parity control disabled
- 1: Parity control enabled

This bit field can only be written when the USART is disabled (UE=0).

Bit 9 **PS**: Parity selection

This bit selects the odd or even parity when the parity generation/detection is enabled (PCE bit set). It is set and cleared by software. The parity will be selected after the current byte.

- 0: Even parity
- 1: Odd parity

This bit field can only be written when the USART is disabled (UE=0).

Bit 8 **PEIE**: PE interrupt enable

This bit is set and cleared by software.

- 0: Interrupt is inhibited
- 1: A USART interrupt is generated whenever PE=1 in the USART\_ISR register

**Bit 7 TXEIE:** interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever TXE=1 in the USART\_ISR register

**Bit 6 TCIE:** Transmission complete interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever TC=1 in the USART\_ISR register

**Bit 5 RXNEIE:** RXNE interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever ORE=1 or RXNE=1 in the USART\_ISR register

**Bit 4 IDLEIE:** IDLE interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever IDLE=1 in the USART\_ISR register

**Bit 3 TE:** Transmitter enable

This bit enables the transmitter. It is set and cleared by software.

0: Transmitter is disabled

1: Transmitter is enabled

*Note:* 1: During transmission, a “0” pulse on the TE bit (“0” followed by “1”) sends a preamble (idle line) after the current word, except in Smartcard mode. In order to generate an idle character, the TE must not be immediately written to 1. In order to ensure the required duration, the software can poll the TEACK bit in the USART\_ISR register.

2: When TE is set there is a 1 bit-time delay before the transmission starts.

**Bit 2 RE:** Receiver enable

This bit enables the receiver. It is set and cleared by software.

0: Receiver is disabled

1: Receiver is enabled and begins searching for a start bit

**Bit 1 UESM:** USART enable in Stop mode

When this bit is cleared, the USART is not able to wake up the MCU from Stop mode.

When this bit is set, the USART is able to wake up the MCU from Stop mode, provided that the USART clock selection is HSI or LSE in the RCC.

This bit is set and cleared by software.

0: USART not able to wake up the MCU from Stop mode.

1: USART able to wake up the MCU from Stop mode. When this function is active, the clock source for the USART must be HSI or LSE (see RCC chapter)

*Note: 1: It is recommended to set the UESM bit just before entering Stop mode and clear it on exit from Stop mode.*

*2: If the USART does not support the wakeup from Stop feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

**Bit 0 UE:** USART enable

When this bit is cleared, the USART prescalers and outputs are stopped immediately, and current operations are discarded. The configuration of the USART is kept, but all the status flags, in the USART\_ISR are reset. This bit is set and cleared by software.

0: USART prescaler and outputs disabled, low power mode

1: USART enabled

*Note: 1: In order to go into low power mode without generating errors on the line, the TE bit must be reset before and the software must wait for the TC bit in the USART\_ISR to be set before resetting the UE bit.*

*2: The DMA requests are also reset when UE = 0 so the DMA channel must be disabled before resetting the UE bit.*

## 25.7.2 Control register 2 (USART\_CR2)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ADD[7:4]				ADD[3:0]				RTOEN	ABRMOD[1:0]		ABREN	MSBFIRST	DATAINV	TXINV	RXINV
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SWAP	LINEN	STOP[1:0]		CLKEN	CPOL	CPHA	LBCL	Res.	LBDIE	LBDL	ADDM7	Res.	Res.	Res.	Res.
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw				

Bits 31:28 **ADD[7:4]: Address of the USART node**

This bit-field gives the address of the USART node or a character code to be recognized.

This is used in multiprocessor communication during Mute mode or Stop mode, for wakeup with 7-bit address mark detection. The MSB of the character sent by the transmitter should be equal to 1. It may also be used for character detection during normal reception, Mute mode inactive (for example, end of block detection in ModBus protocol). In this case, the whole received character (8-bit) is compared to the ADD[7:0] value and CMF flag is set on match.

This bit field can only be written when reception is disabled (RE = 0) or the USART is disabled (UE=0)

Bits 27:24 **ADD[3:0]: Address of the USART node**

This bit-field gives the address of the USART node or a character code to be recognized.

This is used in multiprocessor communication during Mute mode or Stop mode, for wakeup with address mark detection.

This bit field can only be written when reception is disabled (RE = 0) or the USART is disabled (UE=0)

Bit 23 **RTOEN: Receiver timeout enable**

This bit is set and cleared by software.

0: Receiver timeout feature disabled.

1: Receiver timeout feature enabled.

When this feature is enabled, the RTOF flag in the USART\_ISR register is set if the RX line is idle (no reception) for the duration programmed in the RTOR (receiver timeout register).

*Note: If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'. Please refer to Section 25.4: USART implementation on page 577.*

Bits 22:21 **ABRMODE[1:0]: Auto baud rate mode**

These bits are set and cleared by software.

00: Measurement of the start bit is used to detect the baud rate.

01: Falling edge to falling edge measurement. (the received frame must start with a single bit = 1 -> Frame = Start1xxxxxx)

10: Reserved.

11: Reserved

*Note: If DATAINV=1 and/or MSBFIRST=1 the patterns must be the same on the line, for example 0xAA for MSBFIRST)*

*Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'. Please refer to Section 25.4: USART implementation on page 577.*

This bit field can only be written when ABREN = 0 or the USART is disabled (UE=0).

Bit 20 **ABREN**: Auto baud rate enable

This bit is set and cleared by software.

0: Auto baud rate detection is disabled.

1: Auto baud rate detection is enabled.

*Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'. Please refer to Section 25.4: USART implementation on page 577.*

Bit 19 **MSBFIRST**: Most significant bit first

This bit is set and cleared by software.

0: data is transmitted/received with data bit 0 first, following the start bit.

1: data is transmitted/received with the MSB (bit 7/8) first, following the start bit.

This bit field can only be written when the USART is disabled (UE=0).

Bit 18 **DATAINV**: Binary data inversion

This bit is set and cleared by software.

0: Logical data from the data register are send/received in positive/direct logic. (1=H, 0=L)

1: Logical data from the data register are send/received in negative/inverse logic. (1=L, 0=H). The parity bit is also inverted.

This bit field can only be written when the USART is disabled (UE=0).

Bit 17 **TXINV**: TX pin active level inversion

This bit is set and cleared by software.

0: TX pin signal works using the standard logic levels ( $V_{DD} =1/\text{idle}$ , Gnd=0/mark)

1: TX pin signal values are inverted. (( $V_{DD} =0/\text{mark}$ , Gnd=1/idle)).

This allows the use of an external inverter on the TX line.

This bit field can only be written when the USART is disabled (UE=0).

Bit 16 **RXINV**: RX pin active level inversion

This bit is set and cleared by software.

0: RX pin signal works using the standard logic levels ( $V_{DD} =1/\text{idle}$ , Gnd=0/mark)

1: RX pin signal values are inverted. (( $V_{DD} =0/\text{mark}$ , Gnd=1/idle)).

This allows the use of an external inverter on the RX line.

This bit field can only be written when the USART is disabled (UE=0).

Bit 15 **SWAP**: Swap TX/RX pins

This bit is set and cleared by software.

0: TX/RX pins are used as defined in standard pinout

1: The TX and RX pins functions are swapped. This allows to work in the case of a cross-wired connection to another USART.

This bit field can only be written when the USART is disabled (UE=0).

Bit 14 **LINEN**: LIN mode enable

This bit is set and cleared by software.

0: LIN mode disabled

1: LIN mode enabled

The LIN mode enables the capability to send LIN Synch Breaks (13 low bits) using the SBKRQ bit in the USART\_CR1 register, and to detect LIN Sync breaks.

This bit field can only be written when the USART is disabled (UE=0).

*Note: If the USART does not support LIN mode, this bit is reserved and forced by hardware to '0'. Please refer to Section 25.4: USART implementation on page 577.*

**Bits 13:12 STOP[1:0]: STOP bits**

These bits are used for programming the stop bits.

- 00: 1 stop bit
- 01: Reserved.
- 10: 2 stop bits
- 11: 1.5 stop bit

This bit field can only be written when the USART is disabled (UE=0).

**Bit 11 CLKEN: Clock enable**

This bit allows the user to enable the SCLK pin.

- 0: SCLK pin disabled
- 1: SCLK pin enabled

This bit can only be written when the USART is disabled (UE=0).

*Note: If neither synchronous mode nor Smartcard mode is supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

**Bit 10 CPOL: Clock polarity**

This bit allows the user to select the polarity of the clock output on the SCLK pin in synchronous mode. It works in conjunction with the CPHA bit to produce the desired clock/data relationship

- 0: Steady low value on SCLK pin outside transmission window
- 1: Steady high value on SCLK pin outside transmission window

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

**Bit 9 CPHA: Clock phase**

This bit is used to select the phase of the clock output on the SCLK pin in synchronous mode. It works in conjunction with the CPOL bit to produce the desired clock/data relationship (see [Figure 242](#) and [Figure 243](#))

- 0: The first clock transition is the first data capture edge
- 1: The second clock transition is the first data capture edge

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

**Bit 8 LBCL: Last bit clock pulse**

This bit is used to select whether the clock pulse associated with the last data bit transmitted (MSB) has to be output on the SCLK pin in synchronous mode.

- 0: The clock pulse of the last data bit is not output to the SCLK pin
- 1: The clock pulse of the last data bit is output to the SCLK pin

**Caution:** The last bit is the 8th or 9th data bit transmitted depending on the 8 or 9 bit format selected by the M bit in the USART\_CR1 register.

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

**Bit 7 Reserved, must be kept at reset value.****Bit 6 LBDIE: LIN break detection interrupt enable**

Break interrupt mask (break detection using break delimiter).

- 0: Interrupt is inhibited
- 1: An interrupt is generated whenever LBDF=1 in the USART\_ISR register

*Note: If LIN mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

**Bit 5 LBDL:** LIN break detection length

This bit is for selection between 11 bit or 10 bit break detection.

0: 10-bit break detection

1: 11-bit break detection

This bit can only be written when the USART is disabled (UE=0).

*Note: If LIN mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to Section 25.4: USART implementation on page 577.*

**Bit 4 ADDM7:7-bit Address Detection/4-bit Address Detection**

This bit is for selection between 4-bit address detection or 7-bit address detection.

0: 4-bit address detection

1: 7-bit address detection (in 8-bit data mode)

This bit can only be written when the USART is disabled (UE=0)

*Note: In 7-bit and 9-bit data modes, the address detection is done on 6-bit and 8-bit address (ADD[5:0] and ADD[7:0]) respectively.*

Bits 3:0 Reserved, must be kept at reset value.

*Note: The 3 bits (CPOL, CPHA, LBCL) should not be written while the transmitter is enabled.*

### 25.7.3 Control register 3 (USART\_CR3)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	WUFIE	WUS[2:0]	SCARCNT2:0]	SCARCNT2:0]	Res.		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DEP	DEM	DDRE	OVR DIS	ONE BIT	CTSIE	CTSE	RTSE	DMAT	DMAR	SCEN	NACK	HD SEL	IRLP	IREN	EIE
RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW

Bits 31:23 Reserved, must be kept at reset value.

Bit 22 **WUFIE**: Wakeup from Stop mode interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: An USART interrupt is generated whenever WUF=1 in the USART\_ISR register

*Note:* 1. *WUFIE must be set before entering in Stop mode.*

2. *The WUF interrupt is active only in Stop mode.*

3. *If the USART does not support the wakeup from Stop feature, this bit is reserved and forced by hardware to '0'.*

Bits 21:20 **WUS[1:0]**: Wakeup from Stop mode interrupt flag selection

This bit-field specify the event which activates the WUF (Wakeup from Stop mode flag).

00: WUF active on address match (as defined by ADD[7:0] and ADDM7)

01: Reserved.

10: WUF active on Start bit detection

11: WUF active on RXNE.

This bit field can only be written when the USART is disabled (UE=0).

*Note:* *If the USART does not support the wakeup from Stop feature, this bit is reserved and forced by hardware to '0'.*

Bits 19:17 **SCARCNT[2:0]**: Smartcard auto-retry count

This bit-field specifies the number of retries in transmit and receive, in Smartcard mode.

In transmission mode, it specifies the number of automatic retransmission retries, before generating a transmission error (FE bit set).

In reception mode, it specifies the number of erroneous reception trials, before generating a reception error (RXNE and PE bits set).

This bit field must be programmed only when the USART is disabled (UE=0).

When the USART is enabled (UE=1), this bit field may only be written to 0x0, in order to stop retransmission.

0x0: retransmission disabled - No automatic retransmission in transmit mode.

0x1 to 0x7: number of automatic retransmission attempts (before signaling error)

*Note:* *If Smartcard mode is not supported, this bit is reserved and forced by hardware to '0'.*

*Please refer to Section 25.4: USART implementation on page 577.*

Bit 16 Reserved, must be kept at reset value.

Bit 15 **DEP**: Driver enable polarity selection

- 0: DE signal is active high.
- 1: DE signal is active low.

*Note: If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. Please refer to [Section 25.4: USART implementation on page 577](#).*

This bit can only be written when the USART is disabled (UE=0).

Bit 14 **DEM**: Driver enable mode

This bit allows the user to activate the external transceiver control, through the DE signal.

- 0: DE function is disabled.
- 1: DE function is enabled. The DE signal is output on the RTS pin.

*Note: If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. [Section 25.4: USART implementation on page 577](#).*

This bit can only be written when the USART is disabled (UE=0).

Bit 13 **DDRE**: DMA Disable on Reception Error

0: DMA is not disabled in case of reception error. The corresponding error flag is set but RXNE is kept 0 preventing from overrun. As a consequence, the DMA request is not asserted, so the erroneous data is not transferred (no DMA request), but next correct received data will be transferred. (used for Smartcard mode)

1: DMA is disabled following a reception error. The corresponding error flag is set, as well as RXNE. The DMA request is masked until the error flag is cleared. This means that the software must first disable the DMA request (DMAR = 0) or clear RXNE before clearing the error flag.

This bit can only be written when the USART is disabled (UE=0).

*Note: The reception errors are: parity error, framing error or noise error.*

Bit 12 **OVRDIS**: Overrun Disable

This bit is used to disable the receive overrun detection.

0: Overrun Error Flag, ORE, is set when received data is not read before receiving new data.

1: Overrun functionality is disabled. If new data is received while the RXNE flag is still set the ORE flag is not set and the new received data overwrites the previous content of the USART\_RDR register.

This bit can only be written when the USART is disabled (UE=0).

*Note: This control bit allows checking the communication flow w/o reading the data.*

Bit 11 **ONEBIT**: One sample bit method enable

This bit allows the user to select the sample method. When the one sample bit method is selected the noise detection flag (NF) is disabled.

- 0: Three sample bit method
- 1: One sample bit method

This bit can only be written when the USART is disabled (UE=0).

Bit 10 **CTSIE**: CTS interrupt enable

0: Interrupt is inhibited

1: An interrupt is generated whenever CTSIF=1 in the USART\_ISR register

*Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 9 **CTSE**: CTS enable

0: CTS hardware flow control disabled

1: CTS mode enabled, data is only transmitted when the nCTS input is asserted (tied to 0). If the nCTS input is deasserted while data is being transmitted, then the transmission is completed before stopping. If data is written into the data register while nCTS is asserted, the transmission is postponed until nCTS is asserted.

This bit can only be written when the USART is disabled (UE=0)

*Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 8 **RTSE**: RTS enable

0: RTS hardware flow control disabled

1: RTS output enabled, data is only requested when there is space in the receive buffer. The transmission of data is expected to cease after the current character has been transmitted.

The nRTS output is asserted (pulled to 0) when data can be received.

This bit can only be written when the USART is disabled (UE=0).

*Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 7 **DMAT**: DMA enable transmitter

This bit is set/reset by software

1: DMA mode is enabled for transmission

0: DMA mode is disabled for transmission

*Note: If the USART does not support DMA, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 6 **DMAR**: DMA enable receiver

This bit is set/reset by software

1: DMA mode is enabled for reception

0: DMA mode is disabled for reception

*Note: If the USART does not support DMA, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 5 **SCEN**: Smartcard mode enable

This bit is used for enabling Smartcard mode.

0: Smartcard Mode disabled

1: Smartcard Mode enabled

This bit field can only be written when the USART is disabled (UE=0).

*Note: If the USART does not support Smartcard mode, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 4 **NACK**: Smartcard NACK enable

0: NACK transmission in case of parity error is disabled

1: NACK transmission during parity error is enabled

This bit field can only be written when the USART is disabled (UE=0).

*Note: If the USART does not support Smartcard mode, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 3 **HDSEL**: Half-duplex selection

Selection of Single-wire Half-duplex mode

0: Half duplex mode is not selected

1: Half duplex mode is selected

This bit can only be written when the USART is disabled (UE=0).

Bit 2 **IRLP**: IrDA low-power

This bit is used for selecting between normal and low-power IrDA modes

0: Normal mode

1: Low-power mode

This bit can only be written when the USART is disabled (UE=0).

*Note: If IrDA mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 1 **IREN**: IrDA mode enable

This bit is set and cleared by software.

0: IrDA disabled

1: IrDA enabled

This bit can only be written when the USART is disabled (UE=0).

*Note: If IrDA mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 0 **EIE**: Error interrupt enable

Error Interrupt Enable Bit is required to enable interrupt generation in case of a framing error, overrun error or noise flag (FE=1 or ORE=1 or NF=1 in the USART\_ISR register).

0: Interrupt is inhibited

1: An interrupt is generated when FE=1 or ORE=1 or NF=1 in the USART\_ISR register.

**25.7.4 Baud rate register (USART\_BRR)**

*This register can only be written when the USART is disabled (UE=0). It may be automatically updated by hardware in auto baud rate detection mode.*

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BRR[15:4]														BRR[3:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:4 BRR[15:4]

BRR[15:4] = USARTDIV[15:4]

Bits 3:0 BRR[3:0]

When OVER8 = 0, BRR [3:0] = USARTDIV [3:0]

When OVER8 = 1, BRR [2:0] = USARTDIV [3:0] shifted 1 bit to the right. BRR [3] must be kept cleared.

### 25.7.5 Guard time and prescaler register (USART\_GTPR)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GT[7:0]								PSC[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value

Bits 15:8 **GT[7:0]:** Guard time value

This bit-field is used to program the Guard time value in terms of number of baud clock periods.

This is used in Smartcard mode. The Transmission Complete flag is set after this guard time value.

This bit field can only be written when the USART is disabled (UE=0).

*Note:* If Smartcard mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).

Bits 7:0 **PSC[7:0]:** Prescaler value

– In IrDA Low-power and normal IrDA mode:

**PSC[7:0] = IrDA Normal and Low-Power Baud Rate**

Used for programming the prescaler for dividing the USART source clock to achieve the low-power frequency:

The source clock is divided by the value given in the register (8 significant bits):

00000000: Reserved - do not program this value

00000001: divides the source clock by 1

00000010: divides the source clock by 2

...

– In Smartcard mode:

**PSC[4:0]:** Prescaler value

Used for programming the prescaler for dividing the USART source clock to provide the Smartcard clock.

The value given in the register (5 significant bits) is multiplied by 2 to give the division factor of the source clock frequency:

00000: Reserved - do not program this value

00001: divides the source clock by 2

00010: divides the source clock by 4

00011: divides the source clock by 6

...

This bit field can only be written when the USART is disabled (UE=0).

*Note:* Bits [7:5] must be kept cleared if Smartcard mode is used.

*This bit field is reserved and forced by hardware to '0' when the Smartcard and IrDA modes are not supported. Please refer to [Section 25.4: USART implementation on page 577](#).*

## 25.7.6 Receiver timeout register (USART\_RTOR)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
BLEN[7:0]								RTO[23:16]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RTO[15:0]								RTO[15:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

### Bits 31:24 BLEN[7:0]: Block Length

This bit-field gives the Block length in Smartcard T=1 Reception. Its value equals the number of information characters + the length of the Epilogue Field (1-LEC/2-CRC) - 1.

Examples:

BLEN = 0 -> 0 information characters + LEC

BLEN = 1 -> 0 information characters + CRC

BLEN = 255 -> 254 information characters + CRC (total 256 characters))

In Smartcard mode, the Block length counter is reset when TXE=0.

This bit-field can be used also in other modes. In this case, the Block length counter is reset when RE=0 (receiver disabled) and/or when the EOBCF bit is written to 1.

*Note: This value can be programmed after the start of the block reception (using the data from the LEN character in the Prologue Field). It must be programmed only once per received block.*

### Bits 23:0 RTO[23:0]: Receiver timeout value

This bit-field gives the Receiver timeout value in terms of number of baud clocks.

In standard mode, the RTOF flag is set if, after the last received character, no new start bit is detected for more than the RTO value.

In Smartcard mode, this value is used to implement the CWT and BWT. See Smartcard chapter for more details.

In this case, the timeout measurement is done starting from the Start Bit of the last received character.

*Note: This value must only be programmed once per received character.*

*Note: RTOR can be written on the fly. If the new value is lower than or equal to the counter, the RTOF flag is set.*

*This register is reserved and forced by hardware to “0x00000000” when the Receiver timeout feature is not supported. Please refer to Section 25.4: USART implementation on page 577.*

### 25.7.7 Request register (USART\_RQR)

Address offset: 0x18

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.											
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TXFRQ	RXFRQ	MMRQ	SBKRQ	ABRRQ										

Bits 31:5 Reserved, must be kept at reset value

Bit 4 **TXFRQ**: Transmit data flush request

Writing 1 to this bit sets the TXE flag.

This allows to discard the transmit data. This bit must be used only in Smartcard mode, when data has not been sent due to errors (NACK) and the FE flag is active in the USART\_ISR register.

If the USART does not support Smartcard mode, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).

Bit 3 **RXFRQ**: Receive data flush request

Writing 1 to this bit clears the RXNE flag.

This allows to discard the received data without reading it, and avoid an overrun condition.

Bit 2 **MMRQ**: Mute mode request

Writing 1 to this bit puts the USART in mute mode and resets the RWU flag.

Bit 1 **SBKRQ**: Send break request

Writing 1 to this bit sets the SBKF flag and request to send a BREAK on the line, as soon as the transmit machine is available.

Bit 0 **ABRRQ**: Auto baud rate request

Writing 1 to this bit resets the ABRF flag in the USART\_ISR and request an automatic baud rate measurement on the next received data frame.

*Note: : If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

## 25.7.8 Interrupt & status register (USART\_ISR)

Address offset: 0x1C

Reset value: 0x0000 00C0

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	RE ACK	TE ACK	WUF	RWU	SBKF	CMF	BUSY						
									r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ABRF	ABRE	Res.	EOBF	RTOF	CTS	CTSIF	LBDF	TXE	TC	RXNE	IDLE	ORE	NF	FE	PE
r	r		r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:23 Reserved, must be kept at reset value.

Bit 22 **REACK**: Receive enable acknowledge flag

This bit is set/reset by hardware, when the Receive Enable value is taken into account by the USART.

It can be used to verify that the USART is ready for reception before entering Stop mode.

*Note: If the USART does not support the wakeup from Stop feature, this bit is reserved and forced by hardware to '0'.*

Bit 21 **TEACK**: Transmit enable acknowledge flag

This bit is set/reset by hardware, when the Transmit Enable value is taken into account by the USART.

It can be used when an idle frame request is generated by writing TE=0, followed by TE=1 in the USART\_CR1 register, in order to respect the TE=0 minimum period.

Bit 20 **WUF**: Wakeup from Stop mode flag

This bit is set by hardware, when a wakeup event is detected. The event is defined by the WUS bit field. It is cleared by software, writing a 1 to the WUCF in the USART\_ICR register.

An interrupt is generated if WUFIE=1 in the USART\_CR3 register.

*Note: 1. When UESM is cleared, WUF flag is also cleared.*

*2. The WUF interrupt is active only in Stop mode.*

*3. If the USART does not support the wakeup from Stop feature, this bit is reserved and forced by hardware to '0'.*

Bit 19 **RWU**: Receiver wakeup from Mute mode

This bit indicates if the USART is in mute mode. It is cleared/set by hardware when a wakeup/mute sequence is recognized. The mute mode control sequence (address or IDLE) is selected by the WAKE bit in the USART\_CR1 register.

When wakeup on IDLE mode is selected, this bit can only be set by software, writing 1 to the MMRQ bit in the USART\_RQR register.

0: Receiver in active mode

1: Receiver in mute mode

Bit 18 **SBKF**: Send break flag

This bit indicates that a send break character was requested. It is set by software, by writing 1 to the SBKRQ bit in the USART\_CR3 register. It is automatically reset by hardware during the stop bit of break transmission.

0: No break character is transmitted

1: Break character will be transmitted

Bit 17 **CMF**: Character match flag

This bit is set by hardware, when a the character defined by ADD[7:0] is received. It is cleared by software, writing 1 to the CMCF in the USART\_ICR register.

An interrupt is generated if CMIE=1in the USART\_CR1 register.

0: No Character match detected

1: Character Match detected

Bit 16 **BUSY**: Busy flag

This bit is set and reset by hardware. It is active when a communication is ongoing on the RX line (successful start bit detected). It is reset at the end of the reception (successful or not).

0: USART is idle (no reception)

1: Reception on going

Bit 15 **ABRF**: Auto baud rate flag

This bit is set by hardware when the automatic baud rate has been set (RXNE will also be set, generating an interrupt if RXNEIE = 1) or when the auto baud rate operation was completed without success (ABRE=1) (ABRE, RXNE and FE are also set in this case)

It is cleared by software, in order to request a new auto baud rate detection, by writing 1 to the ABRRQ in the USART\_RQR register.

*Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'.*

Bit 14 **ABRE**: Auto baud rate error

This bit is set by hardware if the baud rate measurement failed (baud rate out of range or character comparison failed)

It is cleared by software, by writing 1 to the ABRRQ bit in the USART\_CR3 register.

*Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'.*

## Bit 13 Reserved, must be kept at reset value.

Bit 12 **EOBF**: End of block flag

This bit is set by hardware when a complete block has been received (for example T=1 Smartcard mode). The detection is done when the number of received bytes (from the start of the block, including the prologue) is equal or greater than BLEN + 4.

An interrupt is generated if the EOBIIE=1 in the USART\_CR2 register.

It is cleared by software, writing 1 to the EOBCF in the USART\_ICR register.

0: End of Block not reached

1: End of Block (number of characters) reached

*Note: If Smartcard mode is not supported, this bit is reserved and forced by hardware to '0'.*

*Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 11 **RTOF**: Receiver timeout

This bit is set by hardware when the timeout value, programmed in the RTOR register has lapsed, without any communication. It is cleared by software, writing 1 to the RTOCF bit in the USART\_ICR register.

An interrupt is generated if RTOIE=1 in the USART\_CR2 register.

In Smartcard mode, the timeout corresponds to the CWT or BWT timings.

0: Timeout value not reached

1: Timeout value reached without any data reception

*Note:* 1. If a time equal to the value programmed in RTOR register separates 2 characters, RTOF is not set. If this time exceeds this value + 2 sample times (2/16 or 2/8, depending on the oversampling method), RTOF flag is set.

2. The counter counts even if RE = 0 but RTOF is set only when RE = 1. If the timeout has already elapsed when RE is set, then RTOF will be set.

3. If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'.

Bit 10 **CTS**: CTS flag

This bit is set/reset by hardware. It is an inverted copy of the status of the nCTS input pin.

0: nCTS line set

1: nCTS line reset

*Note:* If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'.

Bit 9 **CTSIF**: CTS interrupt flag

This bit is set by hardware when the nCTS input toggles, if the CTSE bit is set. It is cleared by software, by writing 1 to the CTSCF bit in the USART\_ICR register.

An interrupt is generated if CTSIE=1 in the USART\_CR3 register.

0: No change occurred on the nCTS status line

1: A change occurred on the nCTS status line

*Note:* If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'.

Bit 8 **LBDF**: LIN break detection flag

This bit is set by hardware when the LIN break is detected. It is cleared by software, by writing 1 to the LBDCF in the USART\_ICR.

An interrupt is generated if LBDIE = 1 in the USART\_CR2 register.

0: LIN Break not detected

1: LIN break detected

*Note:* If the USART does not support LIN mode, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).

Bit 7 **TXE**: Transmit data register empty

This bit is set by hardware when the content of the USART\_TDR register has been transferred into the shift register. It is cleared by a write to the USART\_TDR register.

The TXE flag can also be cleared by writing 1 to the TXFRQ in the USART\_RQR register, in order to discard the data (only in Smartcard T=0 mode, in case of transmission failure).

An interrupt is generated if the TXEIE bit =1 in the USART\_CR1 register.

0: Data is not transferred to the shift register

1: Data is transferred to the shift register)

*Note:* This bit is used during single buffer transmission.

**Bit 6 TC:** Transmission complete

This bit is set by hardware if the transmission of a frame containing data is complete and if TXE is set. An interrupt is generated if TCIE=1 in the USART\_CR1 register. It is cleared by software, writing 1 to the TCCF in the USART\_ICR register or by a write to the USART\_TDR register.

An interrupt is generated if TCIE=1 in the USART\_CR1 register.

- 0: Transmission is not complete
- 1: Transmission is complete

*Note: If TE bit is reset and no transmission is on going, the TC bit will be set immediately.*

**Bit 5 RXNE:** Read data register not empty

This bit is set by hardware when the content of the RDR shift register has been transferred to the USART\_RDR register. It is cleared by a read to the USART\_RDR register. The RXNE flag can also be cleared by writing 1 to the RXFRQ in the USART\_RQR register.

An interrupt is generated if RXNEIE=1 in the USART\_CR1 register.

- 0: Data is not received
- 1: Received data is ready to be read.

**Bit 4 IDLE:** Idle line detected

This bit is set by hardware when an Idle Line is detected. An interrupt is generated if IDLEIE=1 in the USART\_CR1 register. It is cleared by software, writing 1 to the IDLECF in the USART\_ICR register.

- 0: No Idle line is detected
- 1: Idle line is detected

*Note: 1. The IDLE bit will not be set again until the RXNE bit has been set (i.e. a new idle line occurs).*

*2. If mute mode is enabled (MME=1), IDLE is set if the USART is not mute (RWU=0), whatever the mute mode selected by the WAKE bit. If RWU=1, IDLE is not set.*

**Bit 3 ORE:** Overrun error

This bit is set by hardware when the data currently being received in the shift register is ready to be transferred into the RDR register while RXNE=1. It is cleared by a software, writing 1 to the ORECF, in the USART\_ICR register.

An interrupt is generated if RXNEIE=1 or EIE = 1 in the USART\_CR1 register.

- 0: No overrun error
- 1: Overrun error is detected

*Note: 1. When this bit is set, the RDR register content is not lost but the shift register is overwritten. An interrupt is generated if the ORE flag is set during multi buffer communication if the EIE bit is set.*

*2. This bit is permanently forced to 0 (no overrun detection) when the OVRDIS bit is set in the USART\_CR3 register.*

**Bit 2 NF:** Noise detected flag

This bit is set by hardware when noise is detected on a received frame. It is cleared by software, writing 1 to the NFCF bit in the USART\_ICR register.

- 0: No noise is detected
- 1: Noise is detected

*Note:* 1. This bit does not generate an interrupt as it appears at the same time as the RXNE bit which itself generates an interrupt. An interrupt is generated when the NF flag is set during multi buffer communication if the EIE bit is set.

2. When the line is noise-free, the NF flag can be disabled by programming the ONEBIT bit to 1 to increase the USART tolerance to deviations (Refer to [Section 25.5.5: Tolerance of the USART receiver to clock deviation on page 591](#)).

**Bit 1 FE:** Framing error

This bit is set by hardware when a de-synchronization, excessive noise or a break character is detected. It is cleared by software, writing 1 to the FECF bit in the USART\_ICR register.

In Smartcard mode, in transmission, this bit is set when the maximum number of transmit attempts is reached without success (the card NACKs the data frame).

An interrupt is generated if EIE = 1 in the USART\_CR1 register.

- 0: No Framing error is detected
- 1: Framing error or break character is detected

**Bit 0 PE:** Parity error

This bit is set by hardware when a parity error occurs in receiver mode. It is cleared by software, writing 1 to the PECF in the USART\_ICR register.

An interrupt is generated if PEIE = 1 in the USART\_CR1 register.

- 0: No parity error
- 1: Parity error

**25.7.9 Interrupt flag clear register (USART\_ICR)**

Address offset: 0x20

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	WUCF	Res.	Res.	CMCF	Res.
											w			w	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	EOBCF	RTOCF	Res.	CTSCF	LBDCF	Res.	TCCF	Res.	IDLEC F	ORECF	NCF	FECF	PECF
			w	w		w	w		w		w	w	w	w	w

Bits 31:21 Reserved, must be kept at reset value.

**Bit 20 WUCF:** Wakeup from Stop mode clear flag

Writing 1 to this bit clears the WUF flag in the USART\_ISR register.

*Note:* If the USART does not support the wakeup from Stop feature, this bit is reserved and forced by hardware to '0'.

Bits 19:18 Reserved, must be kept at reset value.

**Bit 17 CMCF:** Character match clear flag

Writing 1 to this bit clears the CMF flag in the USART\_ISR register.

Bits 16:13 Reserved, must be kept at reset value.

Bit 12 **EOBCF**: End of timeout clear flag

Writing 1 to this bit clears the EOBF flag in the USART\_ISR register.

*Note: If the USART does not support Smartcard mode, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 11 **RTOCF**: Receiver timeout clear flag

Writing 1 to this bit clears the RTOF flag in the USART\_ISR register.

*Note: If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 10 Reserved, must be kept at reset value.

Bit 9 **CTSCF**: CTS clear flag

Writing 1 to this bit clears the CTSIF flag in the USART\_ISR register.

*Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 8 **LBDCF**: LIN break detection clear flag

Writing 1 to this bit clears the LBDF flag in the USART\_ISR register.

*Note: If LIN mode is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 25.4: USART implementation on page 577](#).*

Bit 7 Reserved, must be kept at reset value.

Bit 6 **TCCF**: Transmission complete clear flag

Writing 1 to this bit clears the TC flag in the USART\_ISR register.

Bit 5 Reserved, must be kept at reset value.

Bit 4 **IDLECF**: Idle line detected clear flag

Writing 1 to this bit clears the IDLE flag in the USART\_ISR register.

Bit 3 **ORECF**: Overrun error clear flag

Writing 1 to this bit clears the ORE flag in the USART\_ISR register.

Bit 2 **NCF**: Noise detected clear flag

Writing 1 to this bit clears the NF flag in the USART\_ISR register.

Bit 1 **FECF**: Framing error clear flag

Writing 1 to this bit clears the FE flag in the USART\_ISR register.

Bit 0 **PECF**: Parity error clear flag

Writing 1 to this bit clears the PE flag in the USART\_ISR register.

### 25.7.10 Receive data register (USART\_RDR)

Address offset: 0x24

Reset value: Undefined

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.									RDR[8:0]						
							r	r	r	r	r	r	r	r	r

Bits 31:9 Reserved, must be kept at reset value.

Bits 8:0 **RDR[8:0]**: Receive data value

Contains the received data character.

The RDR register provides the parallel interface between the input shift register and the internal bus (see [Figure 230](#)).

When receiving with the parity enabled, the value read in the MSB bit is the received parity bit.

### 25.7.11 Transmit data register (USART\_TDR)

Address offset: 0x28

Reset value: Undefined

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.								TDR[8:0]							
							rw								

Bits 31:9 Reserved, must be kept at reset value.

Bits 8:0 **TDR[8:0]**: Transmit data value

Contains the data character to be transmitted.

The TDR register provides the parallel interface between the internal bus and the output shift register (see [Figure 230](#)).

When transmitting with the parity enabled (PCE bit set to 1 in the USART\_CR1 register), the value written in the MSB (bit 7 or bit 8 depending on the data length) has no effect because it is replaced by the parity.

*Note:* This register must be written only when TXE=1.

### 25.7.12 USART register map

The table below gives the USART register map and reset values.

**Table 89. USART register map and reset values**

Offset	Register	Reset value	31
0x00	<b>USART_CR1</b>		Res. 30
	Reset value		Res. 29
0x04	<b>USART_CR2</b>	ADD[7:4]	Res. 28
	Reset value	0	EOBIE 27
0x08	<b>USART_CR3</b>	ADD[3:0]	Res. 26
	Reset value	0	RTOIE 26
0x0C	<b>USART_BRR</b>	ABRN	DEAT4 25
	Reset value	0	DEAT3 24
0x10	<b>USART_GTPR</b>	WUS[1:0]	DEAT2 23
	Reset value	0	DEDT4 20
0x14	<b>USART_RTOR</b>	SCAR CNT2:0]	DEDT3 19
	Reset value	0	DATAINV 18
0x18	<b>USART_RQR</b>	TXINV	DEDT1 17
	Reset value	0	RXINV 16
0x1C	<b>USART_ISR</b>	DDRE	SWAP 15
	Reset value	0	OVER8 15
0x20	<b>USART_ICR</b>	OVRDIS	M 12
	Reset value	0	ONEBIT 11
0x24	<b>USART_RDR</b>	CLKEN	WAKE 11
	Reset value	0	CTSIE 10
0x28	<b>USART_TDR</b>	CPOL	PCE 10
	Reset value	0	PS 9
		CTSE	TCIE 6
		LBDL	RXNEIE 5
		NACK	IDLEIE 4
		ADDM7	HDSEL 3
		RTS	TE 3
		DMAT	IRLP 2
		DMAR	IREN 1
		SCEN	RES 1
		LBCL	PEIE 8
		RTSE	TXEIE 7
		DMAT	RES 0
		DMAR	EIE 0
		SCEN	UESM 0
		LBCL	UE 0

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 26 Serial peripheral interface / inter-IC sound (SPI/I<sup>2</sup>S)

### 26.1 Introduction

The SPI/I<sup>2</sup>S interface can be used to communicate with external devices using the SPI protocol or the I<sup>2</sup>S audio protocol. SPI or I<sup>2</sup>S mode is selectable by software. SPI mode is selected by default after a device reset.

The serial peripheral interface (SPI) protocol supports half-duplex, full-duplex and simplex synchronous, serial communication with external devices. The interface can be configured as master and in this case it provides the communication clock (SCK) to the external slave device. The interface is also capable of operating in multimaster configuration.

The Inter-IC sound (I<sup>2</sup>S) protocol is also a synchronous serial communication interface. It can operate in slave or master mode with full duplex and half-duplex communication. It can address four different audio standards including the Philips I<sup>2</sup>S standard, the MSB- and LSB-justified standards and the PCM standard.

#### 26.1.1 SPI main features

- Master or slave operation
- Full-duplex synchronous transfers on three lines
- Half-duplex synchronous transfer on two lines (with bidirectional data line)
- Simplex synchronous transfers on two lines (with unidirectional data line)
- 4-bit to 16-bit data size selection
- Multimaster mode capability
- 8 master mode baud rate prescalers up to  $f_{PCLK}/2$ .
- Slave mode frequency up to  $f_{PCLK}/2$ .
- NSS management by hardware or software for both master and slave: dynamic change of master/slave operations
- Programmable clock polarity and phase
- Programmable data order with MSB-first or LSB-first shifting
- Dedicated transmission and reception flags with interrupt capability
- SPI bus busy status flag
- SPI Motorola support
- Hardware CRC feature for reliable communication:
  - CRC value can be transmitted as last byte in Tx mode
  - Automatic CRC error checking for last received byte
- Master mode fault, overrun flags with interrupt capability
- CRC Error flag
- Two 32-bit embedded Rx and Tx FIFOs with DMA capability

### 26.1.2 SPI extended features

- SPI TI mode support

### 26.1.3 I<sup>2</sup>S features

- Half-duplex communication (only transmitter or receiver)
- Master or slave operations
- 8-bit programmable linear prescaler to reach accurate audio sample frequencies (from 8 kHz to 192 kHz)
- Data format may be 16-bit, 24-bit or 32-bit
- Packet frame is fixed to 16-bit (16-bit data frame) or 32-bit (16-bit, 24-bit, 32-bit data frame) by audio channel
- Programmable clock polarity (steady state)
- Underrun flag in slave transmission mode, overrun flag in reception mode (master and slave) and Frame Error Flag in reception and transmitter mode (slave only)
- 16-bit register for transmission and reception with one data register for both channel sides
- Supported I<sup>2</sup>S protocols:
  - I<sup>2</sup>S Philips standard
  - MSB-Justified standard (Left-Justified)
  - LSB-Justified standard (Right-Justified)
  - PCM standard (with short and long frame synchronization on 16-bit channel frame or 16-bit data frame extended to 32-bit channel frame)
- Data direction is always MSB first
- DMA capability for transmission and reception (16-bit wide)
- Master clock can be output to drive an external audio component. Ratio is fixed at  $256 \times F_S$  (where  $F_S$  is the audio sampling frequency)

## 26.2 SPI/I2S implementation

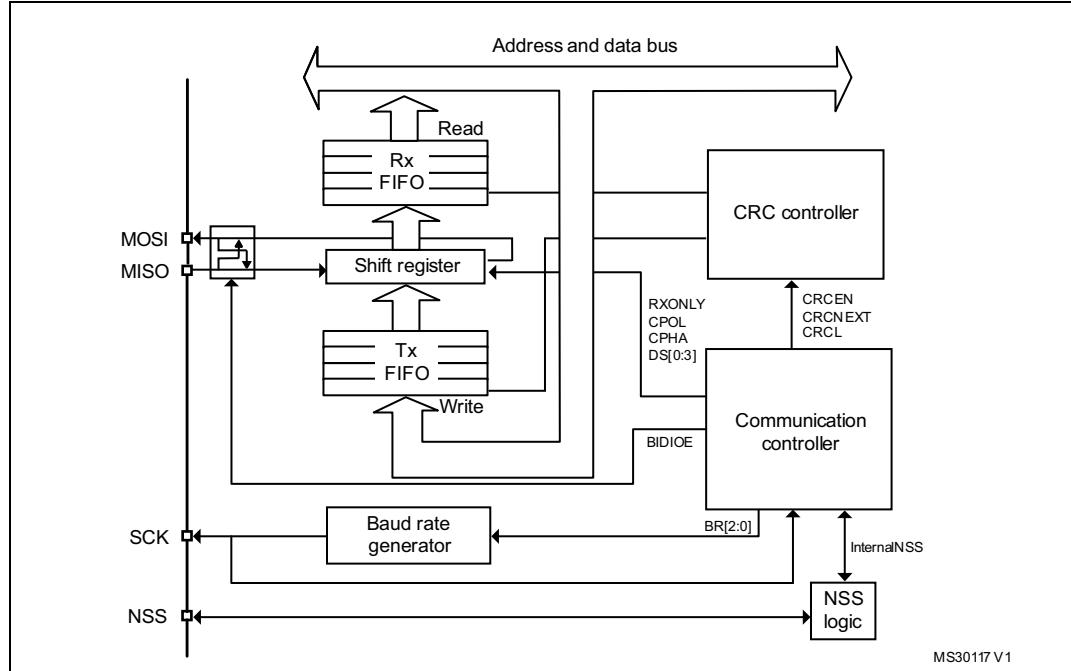
This manual describes the full set of features implemented in SPI1. SPI2 supports all the features except I<sup>2</sup>S mode.

## 26.3 SPI functional description

### 26.3.1 General description

The SPI allows synchronous, serial communication between the MCU and external devices. Application software can manage the communication by polling the status flag or using dedicated SPI interrupt. The main elements of SPI and their interactions are shown in the following block diagram [Figure 255](#).

**Figure 255. SPI block diagram**



Four I/O pins are dedicated to SPI communication with external devices.

- **MISO:** Master In / Slave Out data. In the general case, this pin is used to transmit data in slave mode and receive data in master mode.
- **MOSI:** Master Out / Slave In data. In the general case, this pin is used to transmit data in master mode and receive data in slave mode.
- **SCK:** Serial Clock output pin for SPI masters and input pin for SPI slaves.
- **NSS:** Slave select pin. Depending on the SPI and NSS settings, this pin can be used to either:
  - select an individual slave device for communication
  - synchronize the data frame or
  - detect a conflict between multiple masters

See [Section 26.3.4: Slave select \(NSS\) pin management](#) for details.

The SPI bus allows the communication between one master device and one or more slave devices. The bus consists of at least two wires - one for the clock signal and the other for synchronous data transfer. Other signals can be added depending on the data exchange between SPI nodes and their slave select signal management.

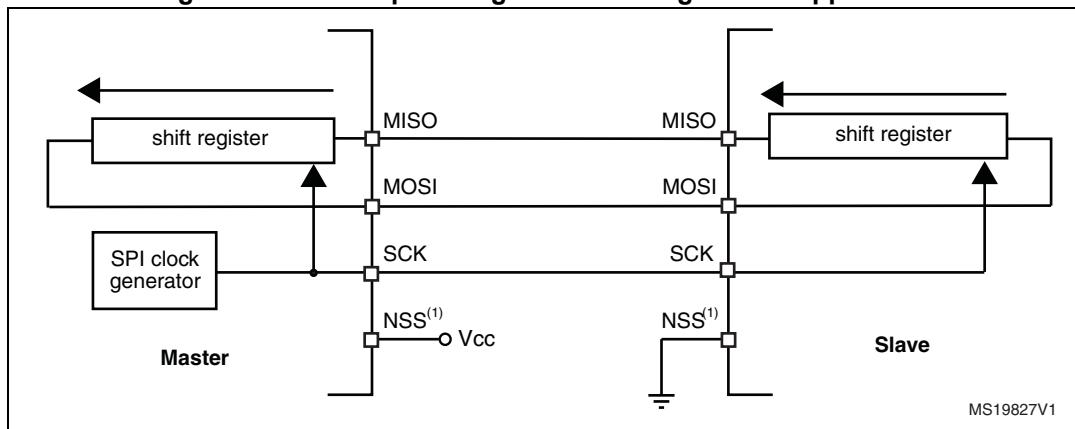
### 26.3.2 Communications between one master and one slave

The SPI allows the MCU to communicate using different configurations, depending on the device targeted and the application requirements. These configurations use 2 or 3 wires (with software NSS management) or 3 or 4 wires (with hardware NSS management). Communication is always initiated by the master.

#### Full-duplex communication

By default, the SPI is configured for full-duplex communication. In this configuration, the shift registers of the master and slave are linked using two unidirectional lines between the MOSI and the MISO pins. During SPI communication, data is shifted synchronously on the SCK clock edges provided by the master. The master transmits the data to be sent to the slave via the MOSI line and receives data from the slave via the MISO line. When the data frame transfer is complete (all the bits are shifted) the information between the master and slave is exchanged.

**Figure 256. Full-duplex single master/ single slave application**

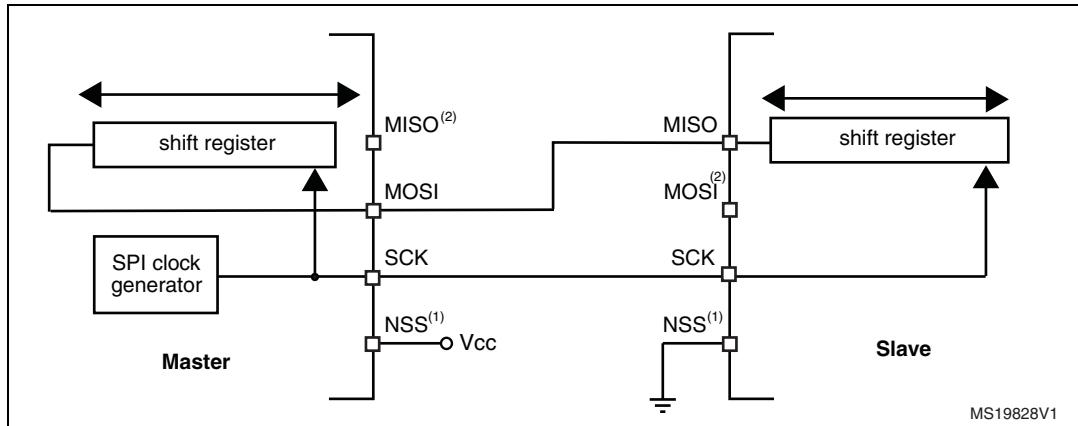


1. The NSS pin is configured as an input in this case.

#### Half-duplex communication

The SPI can communicate in half-duplex mode by setting the BIDIMODE bit in the SPIx\_CR1 register. In this configuration, one single cross connection line is used to link the shift registers of the master and slave together. During this communication, the data is synchronously shifted between the shift registers on the SCK clock edge in the transfer direction selected reciprocally by both master and slave with the BDIOE bit in their SPIx\_CR1 registers. In this configuration, the master's MISO pin and the slave's MOSI pin are free for other application uses and act as GPIOs.

Figure 257. Half-duplex single master/ single slave application



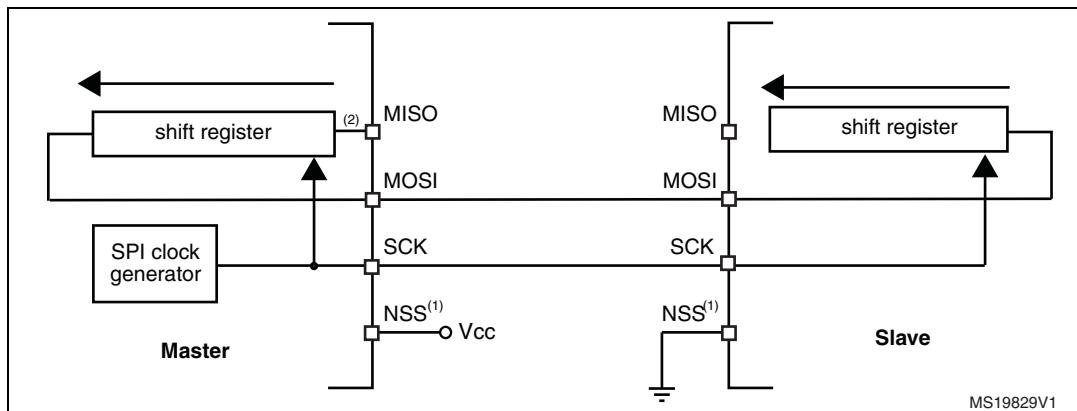
1. The NSS pin is configured as an input in this case.
2. In this configuration, the master's MISO pin and the slave's MOSI pin can be used as GPIOs.

### Simplex communications

The SPI can communicate in simplex mode by setting the SPI in transmit-only or in receive-only using the RXONLY bit in the SPIx\_CR2 register. In this configuration, only one line is used for the transfer between the shift registers of the master and slave. The remaining MISO and MOSI pins pair is not used for communication and can be used as standard GPIOs.

- **Transmit-only mode (RXONLY=0):** The configuration settings are the same as for full-duplex. The application has to ignore the information captured on the unused input pin. This pin can be used as a standard GPIO.
- **Receive-only mode (RXONLY=1):** The application can disable the SPI output function by setting the RXONLY bit. In slave configuration, the MISO output is disabled and the pin can be used as a GPIO. The slave continues to receive data from the MOSI pin while its slave select signal is active (see [26.3.4 Slave select \(NSS\) pin management](#)). Received data events appear depending on the data buffer configuration. In the master configuration, the MOSI output is disabled and the pin can be used as a GPIO. The clock signal is generated continuously as long as the SPI is enabled. The only way to stop the clock is to clear the RXONLY bit or the SPE bit and wait until the incoming pattern from the MISO pin is finished and fills the data buffer structure, depending on its configuration.

**Figure 258. Simplex single master/single slave application (master in transmit-only/slave in receive-only mode)**



1. The NSS pin is configured as an input in this case.
2. The input information is captured in the shift register and must be ignored in standard transmit only mode (for example, OVF flag).
3. In this configuration, both the MISO pins can be used as GPIOs.

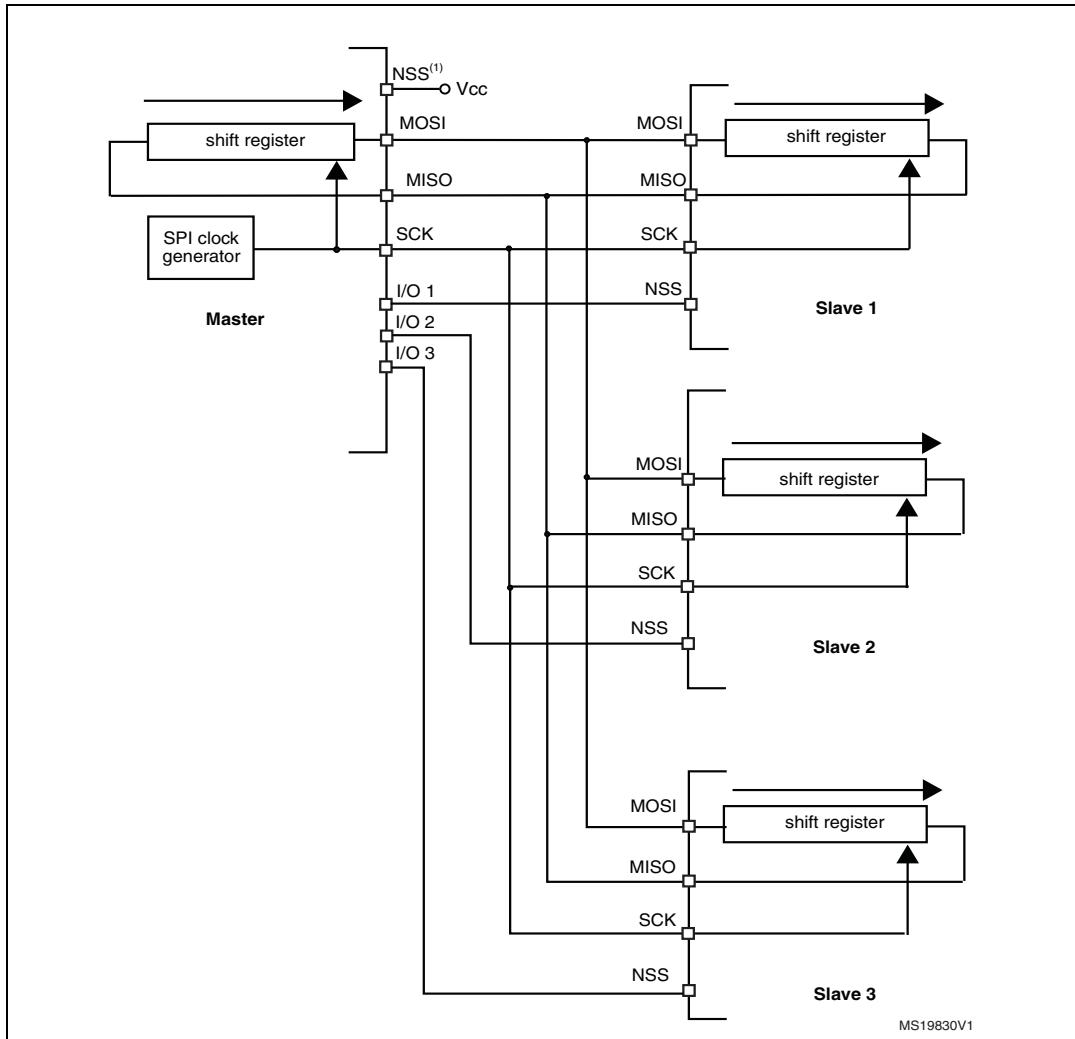
**Note:**

*Any simplex communication can be alternatively replaced by a variant of the half duplex communication with a constant setting of the transaction direction (bidirectional mode is enabled while BDIO bit is not changed).*

### 26.3.3 Standard multi-slave communication

In a configuration with two or more independent slaves, the master uses GPIO pins to manage the chip select lines for each slave (see [Figure 259](#)). The master must select one of the slaves individually by pulling low the GPIO connected to the slave NSS input. When this is done, a standard master and dedicated slave communication is established.

Figure 259. Master and three independent slaves



1. As MISO pins of the slaves are connected together, all slaves must have the GPIO configuration of their MISO pin set as alternate function open-drain (see [Section 8.3.7: I/O alternate function input/output on page 129](#)).

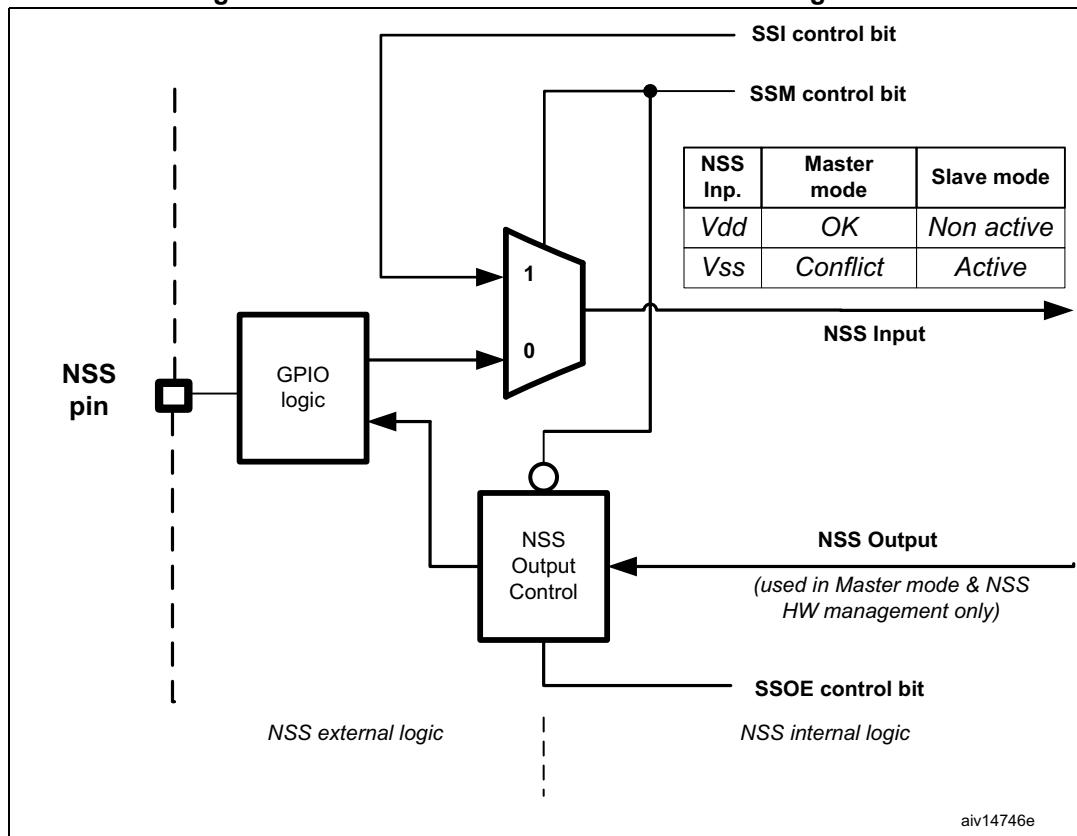
#### 26.3.4 Slave select (NSS) pin management

In slave mode, the NSS works as a standard “chip select” input and lets the slave communicate with the master. In master mode, NSS can be used either as output or input. As an input it can prevent multimaster bus collision, and as an output it can drive a slave select signal of a single slave.

Hardware or software slave select management can be set using the SSM bit in the SPIx\_CR1 register:

- **Software NSS management (SSM = 1):** in this configuration, slave select information is driven internally by the SSI bit value in register SPIx\_CR1. The external NSS pin is free for other application uses.
- **Hardware NSS management (SSM = 0):** in this case, there are two possible configurations. The configuration used depends on the NSS output configuration (SSOE bit in register SPIx\_CR1).
  - **NSS output enable (SSM=0,SSOE = 1):** this configuration is only used when the MCU is set as master. The NSS pin is managed by the hardware. The NSS signal is driven low as soon as the SPI is enabled in master mode (SPE=1), and is kept low until the SPI is disabled (SPE =0). A pulse can be generated between continuous communications if NSS pulse mode is activated (NSSP=1). The SPI cannot work in multimaster configuration with this NSS setting.
  - **NSS output disable (SSM=0, SSOE = 0):** if the microcontroller is acting as the master on the bus, this configuration allows multimaster capability. If the NSS pin is pulled low in this mode, the SPI enters master mode fault state and the device is automatically reconfigured in slave mode. In slave mode, the NSS pin works as a standard “chip select” input and the slave is selected while NSS line is at low level.

**Figure 260. Hardware/software slave select management**



### 26.3.5 Communication formats

During SPI communication, receive and transmit operations are performed simultaneously. The serial clock (SCK) synchronizes the shifting and sampling of the information on the data lines. The communication format depends on the clock phase, the clock polarity and the data frame format. To be able to communicate together, the master and slaves devices must follow the same communication format.

#### Clock phase and polarity controls

Four possible timing relationships may be chosen by software, using the CPOL and CPHA bits in the SPIx\_CR1 register. The CPOL (clock polarity) bit controls the idle state value of the clock when no data is being transferred. This bit affects both master and slave modes. If CPOL is reset, the SCK pin has a low-level idle state. If CPOL is set, the SCK pin has a high-level idle state.

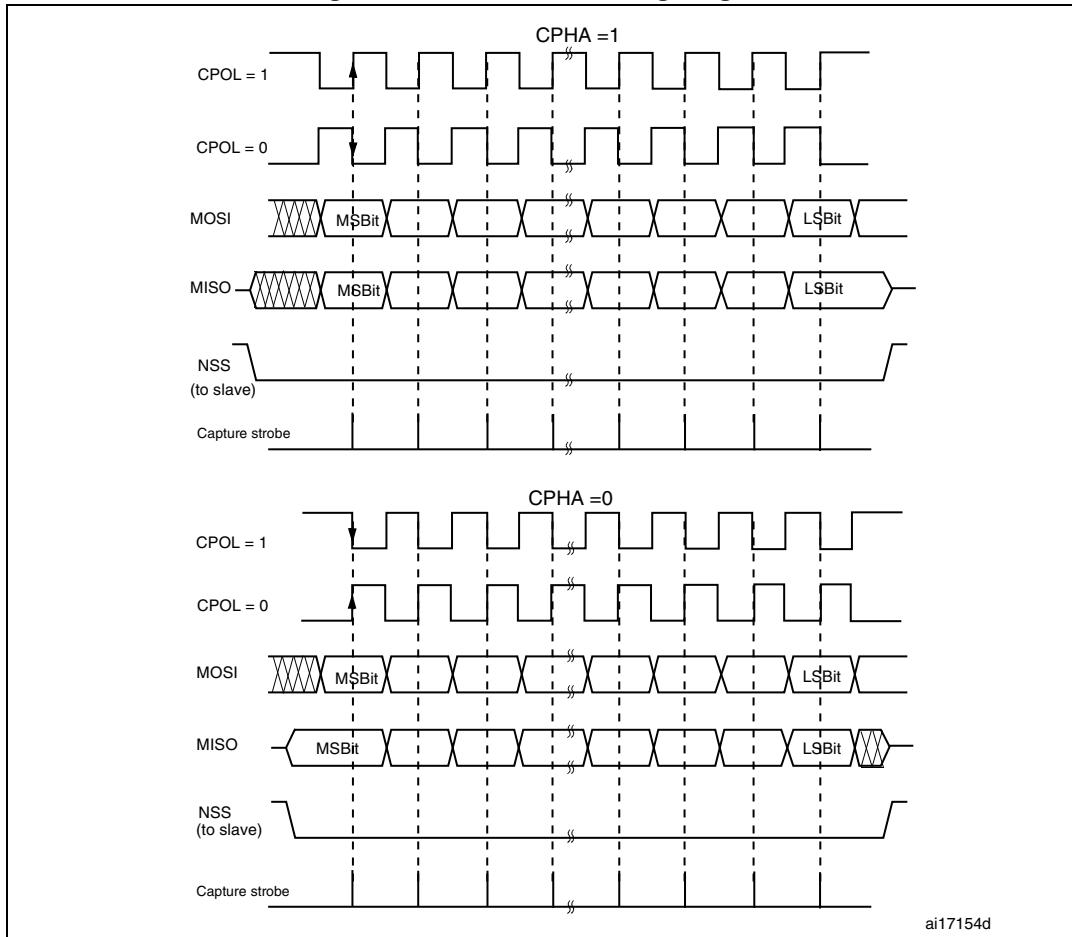
If the CPHA bit is set, the second edge on the SCK pin captures the first data bit transacted (falling edge if the CPOL bit is reset, rising edge if the CPOL bit is set). Data are latched on each occurrence of this clock transition type. If the CPHA bit is reset, the first edge on the SCK pin captures the first data bit transacted (falling edge if the CPOL bit is set, rising edge if the CPOL bit is reset). Data are latched on each occurrence of this clock transition type.

The combination of CPOL (clock polarity) and CPHA (clock phase) bits selects the data capture clock edge.

*Figure 261*, shows an SPI full-duplex transfer with the four combinations of the CPHA and CPOL bits.

**Note:** *Prior to changing the CPOL/CPHA bits the SPI must be disabled by resetting the SPE bit. The idle state of SCK must correspond to the polarity selected in the SPIx\_CR1 register (by pulling up SCK if CPOL=1 or pulling down SCK if CPOL=0).*

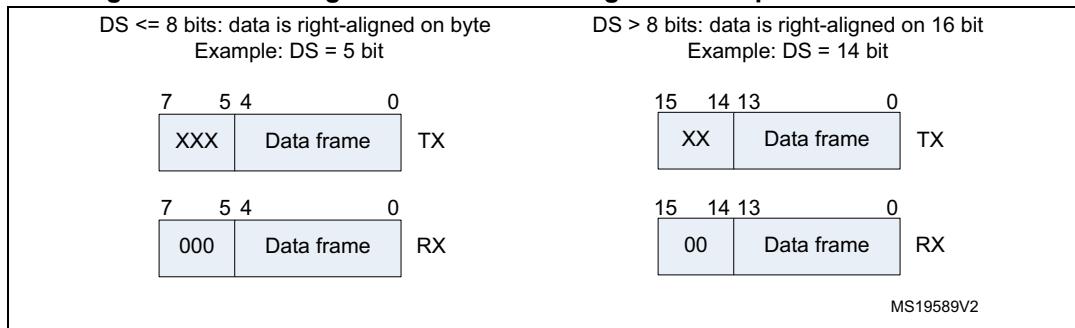
Figure 261. Data clock timing diagram



1. The order of data bits depends on LSBFIRST bit setting.

### Data frame format

The SPI shift register can be set up to shift out MSB-first or LSB-first, depending on the value of the LSBFIRST bit. The data frame size is chosen by using the DS bits. It can be set from 4-bit up to 16-bit length and the setting applies for both transmission and reception. Whatever the selected data frame size, read access to the FIFO must be aligned with the FRXTH level. When the SPIx\_DR register is accessed, data frames are always right-aligned into either a byte (if the data fits into a byte) or a half-word (see [Figure 262](#)). During communication, only bits within the data frame are clocked and transferred.

**Figure 262. Data alignment when data length is not equal to 8-bit or 16-bit**

**Note:** The minimum data length is 4 bits. If a data length of less than 4 bits is selected, it is forced to an 8-bit data frame size.

### 26.3.6 Configuration of SPI

The configuration procedure is almost the same for master and slave. For specific mode setups, follow the dedicated chapters. When a standard communication is to be initialized, perform these steps:

1. Write proper GPIO registers: Configure GPIO for MOSI, MISO and SCK pins.
2. Write to the SPI\_CR1 register:
  - a) Configure the serial clock baud rate using the BR[2:0] bits (*Note*: 4).
  - b) Configure the CPOL and CPHA bits combination to define one of the four relationships between the data transfer and the serial clock (CPHA must be cleared in NSSP mode). (*Note*: 2).
  - c) Select simplex or half-duplex mode by configuring RXONLY or BIDIMODE and BIDIOE (RXONLY and BIDIMODE can't be set at the same time).
  - d) Configure the LSBFIRST bit to define the frame format (*Note*: 2).
  - e) Configure the CRCL and CRCEN bits if CRC is needed (while SCK clock signal is at idle state).
  - f) Configure SSM and SSI (*Note*: 2 & 3).
  - g) Configure the MSTR bit (in multimaster NSS configuration, avoid conflict state on NSS if master is configured to prevent MODF error).
3. Write to SPI\_CR2 register:
  - a) Configure the DS[3:0] bits to select the data length for the transfer.
  - b) Configure SSOE (*Note*: 1 & 2 & 3).
  - c) Set the FRF bit if the TI protocol is required (keep NSSP bit cleared in TI mode).
  - d) Set the NSSP bit if the NSS pulse mode between two data units is required (keep CHPA and TI bits cleared in NSSP mode).
  - e) Configure the FRXTH bit. The RXFIFO threshold must be aligned to the read access size for the SPIx\_DR register.
  - f) Initialize LDMA\_TX and LDMA\_RX bits if DMA is used in packed mode.
4. Write to SPI\_CRCPR register: Configure the CRC polynomial if needed.
5. Write proper DMA registers: Configure DMA streams dedicated for SPI Tx and Rx in DMA registers if the DMA streams are used.

- Note:
- (1) Step is not required in slave mode.
  - (2) Step is not required in TI mode.
  - (3) Step is not required in NSSP mode.
  - (4) The step is not required in slave mode except slave working at TI mode

### 26.3.7 Procedure for enabling SPI

It is recommended to enable the SPI slave before the master sends the clock. If not, undesired data transmission might occur. The data register of the slave must already contain data to be sent before starting communication with the master (either on the first edge of the communication clock, or before the end of the ongoing communication if the clock signal is continuous). The SCK signal must be settled at an idle state level corresponding to the selected polarity before the SPI slave is enabled.

The master at full duplex (or in any transmit-only mode) starts to communicate when the SPI is enabled and TXFIFO is not empty, or with the next write to TXFIFO.

In any master receive only mode (RXONLY=1 or BIDIMODE=1 & BIDIOE=0), master starts to communicate and the clock starts running immediately after SPI is enabled.

For handling DMA, follow the dedicated chapter.

### 26.3.8 Data transmission and reception procedures

#### RXFIFO and TXFIFO

All SPI data transactions pass through the 32-bit embedded FIFOs. This enables the SPI to work in a continuous flow, and prevents overruns when the data frame size is short. Each direction has its own FIFO called TXFIFO and RXFIFO. These FIFOs are used in all SPI modes except for receiver-only mode (slave or master) with CRC calculation enabled (see [Section 26.4.3: CRC calculation](#)).

The handling of FIFOs depends on the data exchange mode (duplex, simplex), data frame format (number of bits in the frame), access size performed on the FIFO data registers (8-bit or 16-bit), and whether or not data packing is used when accessing the FIFOs (see [Section 26.4.2: TI mode](#)).

A read access to the SPIx\_DR register returns the oldest value stored in RXFIFO that has not been read yet. A write access to the SPIx\_DR stores the written data in the TXFIFO at the end of a send queue. The read access must be always aligned with the RXFIFO threshold configured by the FRXTH bit in SPIx\_CR2 register. FTLVL[1:0] and FRLVL[1:0] bits indicate the current occupancy level of both FIFOs.

A read access to the SPIx\_DR register must be managed by the RXNE event. This event is triggered when data is stored in RXFIFO and the threshold (defined by FRXTH bit) is reached. When RXNE is cleared, RXFIFO is considered to be empty. In a similar way, write access of a data frame to be transmitted is managed by the TXE event. This event is triggered when the TXFIFO level is less than or equal to half of its capacity. Otherwise TXE is cleared and the TXFIFO is considered as full. In this way, RXFIFO can store up to four data frames, whereas TXFIFO can only store up to three when the data frame format is not greater than 8 bits. This difference prevents possible corruption of 3x 8-bit data frames already stored in the TXFIFO when software tries to write more data in 16-bit mode into TXFIFO. Both TXE and RXNE events can be polled or handled by interrupts. See [Figure 264](#) through [Figure 267](#).

Another way to manage the data exchange is to use DMA (see [Section 26.6.9: DMA features](#)).

If the next data is received when the RXFIFO is full, an overrun event occurs (see description of OVR flag at [Section 26.3.9: SPI status flags](#)). An overrun event can be polled or handled by an interrupt.

The BSY bit being set indicates ongoing transaction of a current data frame. When the clock signal runs continuously, the BSY flag stays set between data frames at master but becomes low for a minimum duration of one SPI clock at slave between each data frame transfer.

### Sequence handling

A few data frames can be passed at single sequence to complete a message. When transmission is enabled, a sequence begins and continues while any data is present in the TXFIFO of the master. The clock signal is provided continuously by the master until TXFIFO becomes empty, then it stops waiting for additional data.

In receive-only modes, half duplex (BIDIMODE=1, BIDIOE=0) or simplex (BIDIMODE=0, RXONLY=1) the master starts the sequence immediately when both SPI is enabled and receive-only mode is activated. The clock signal is provided by the master and it does not stop until either SPI or receive-only mode is disabled by the master. The master receives data frames continuously up to this moment.

While the master can provide all the transactions in continuous mode (SCK signal is continuous) it has to respect slave capability to handle data flow and its content at anytime. When necessary, the master must slow down the communication and provide either a slower clock or separate frames or data sessions with sufficient delays. Be aware there is no underflow error signal for master or slave in SPI mode, and data from the slave is always transacted and processed by the master even if the slave could not prepare it correctly in time. It is preferable for the slave to use DMA, especially when data frames are shorter and bus rate is high.

Each sequence must be encased by the NSS pulse in parallel with the multislide system to select just one of the slaves for communication. In a single slave system it is not necessary to control the slave with NSS, but it is often better to provide the pulse here too, to synchronize the slave with the beginning of each data sequence. NSS can be managed by both software and hardware (see [Section 26.3.4: Slave select \(NSS\) pin management](#)).

When the BSY bit is set it signifies an ongoing data frame transaction. When the dedicated frame transaction is finished, the RXNE flag is raised. The last bit is just sampled and the complete data frame is stored in the RXFIFO.

### Procedure for disabling the SPI

When SPI is disabled, it is mandatory to follow the disable procedures described in this paragraph. It is important to do this before the system enters a low power mode when the peripheral clock is stopped. Ongoing transactions can be corrupted in this case. In some modes the disable procedure is the only way to stop continuous communication running.

Master in full duplex or transmit only mode can finish any transaction when it stops providing data for transmission. In this case, the clock stops after the last data transaction. Special care must be taken in packing mode when an odd number of data frames are transacted to prevent some dummy byte exchange (refer to Data packing section below). Before the SPI is disabled in these modes, the user must follow standard disable procedure. When the SPI

is disabled at the master transmitter while a frame transaction is ongoing or next data frame is stored in TXFIFO, the SPI behavior is not guaranteed.

When the master is in any receive only mode, the only way to stop the continuous clock is to disable the peripheral by SPE=0. This must occur in specific time window within last data frame transaction just between the sampling time of its first bit and before its last bit transfer starts (in order to receive a complete number of expected data frames and to prevent any additional "dummy" data reading after the last valid data frame). Specific procedure must be followed when disabling SPI in this mode.

Data received but not read remains stored in RXFIFO when the SPI is disabled, and must be processed the next time the SPI is enabled, before starting a new sequence. To prevent having unread data, ensure that RXFIFO is empty when disabling the SPI, by using the correct disabling procedure, or by initializing all the SPI registers with a software reset via the control of a specific register dedicated to peripheral reset (see the SPIiRST bits in the RCC\_APBiRSTR registers).

Standard disable procedure is based on pulling BSY status together with FTLVL[1:0] to check if a transmission session is fully completed. This check can be done in specific cases, too, when it is necessary to identify the end of ongoing transactions, for example:

- When NSS signal is managed by software and master has to provide proper end of NSS pulse for slave, or
- When transactions' streams from DMA or FIFO are completed while the last data frame or CRC frame transaction is still ongoing in the peripheral bus.

The correct disable procedure is (except when receive only mode is used):

1. Wait until FTLVL[1:0] = 00 (no more data to transmit).
2. Wait until BSY=0 (the last data frame is processed).
3. Disable the SPI (SPE=0).
4. Read data until FRLVL[1:0] = 00 (read all the received data).

The correct disable procedure for certain receive only modes is:

1. Interrupt the receive flow by disabling SPI (SPE=0) in the specific time window while the last data frame is ongoing.
2. Wait until BSY=0 (the last data frame is processed).
3. Read data until FRLVL[1:0] = 00 (read all the received data).

**Note:**

*If packing mode is used and an odd number of data frames with a format less than or equal to 8 bits (fitting into one byte) has to be received, FRXTH must be set when FRLVL[1:0] = 01, in order to generate the RXNE event to read the last odd data frame and to keep good FIFO pointer alignment.*

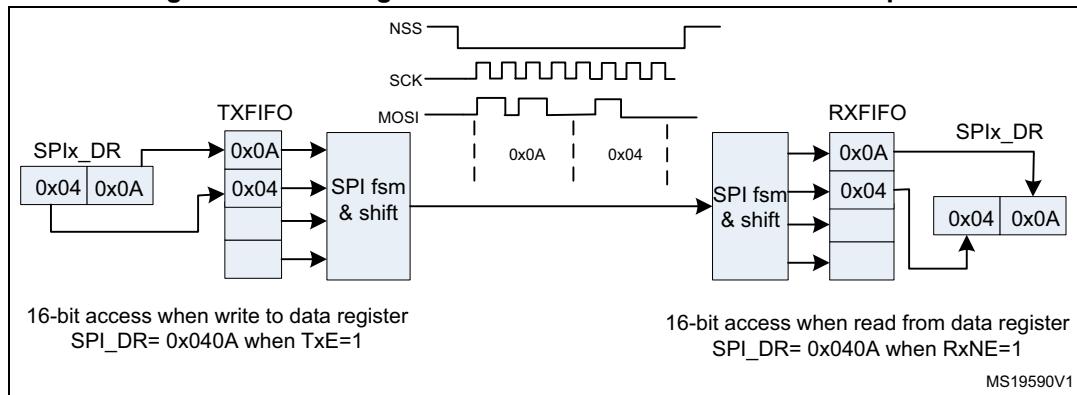
### Data packing

When the data frame size fits into one byte (less than or equal to 8 bits), data packing is used automatically when any read or write 16-bit access is performed on the SPIx\_DR register. The double data frame pattern is handled in parallel in this case. At first, the SPI operates using the pattern stored in the LSB of the accessed word, then with the other half stored in the MSB. [Figure 263](#) provides an example of data packing mode sequence handling. Two data frames are sent after the single 16-bit access the SPIx\_DR register of the transmitter. This sequence can generate just one RXNE event in the receiver if the RXFIFO threshold is set to 16 bits (FRXTH=0). The receiver then has to access both data frames by a single 16-bit read of SPIx\_DR as a response to this single RXNE event. The

RxFIFO threshold setting and the following read access must be always kept aligned at the receiver side, as data can be lost if it is not in line.

A specific problem appears if an odd number of such “fit into one byte” data frames must be handled. On the transmitter side, writing the last data frame of any odd sequence with an 8-bit access to SPIx\_DR is enough. The receiver has to change the Rx\_FIFO threshold level for the last data frame received in the odd sequence of frames in order to generate the RXNE event.

**Figure 263. Packing data in FIFO for transmission and reception**



### Communication using DMA (direct memory addressing)

To operate at its maximum speed and to facilitate the data register read/write process required to avoid overrun, the SPI features a DMA capability, which implements a simple request/acknowledge protocol.

A DMA access is requested when the TXE or RXNE enable bit in the SPIx\_CR2 register is set. Separate requests must be issued to the Tx and Rx buffers.

- In transmission, a DMA request is issued each time TXE is set to 1. The DMA then writes to the SPIx\_DR register.
- In reception, a DMA request is issued each time RXNE is set to 1. The DMA then reads the SPIx\_DR register.

See [Figure 264](#) through [Figure 267](#).

When the SPI is used only to transmit data, it is possible to enable only the SPI Tx DMA channel. In this case, the OVR flag is set because the data received is not read. When the SPI is used only to receive data, it is possible to enable only the SPI Rx DMA channel.

In transmission mode, when the DMA has written all the data to be transmitted (the TCIF flag is set in the DMA\_ISR register), the BSY flag can be monitored to ensure that the SPI communication is complete. This is required to avoid corrupting the last transmission before disabling the SPI or entering the Stop mode. The software must first wait until FTLVL[1:0]=00 and then until BSY=0.

When starting communication using DMA, to prevent DMA channel management raising error events, these steps must be followed in order:

1. Enable DMA Rx buffer in the RXDMAEN bit in the SPI\_CR2 register, if DMA Rx is used.
2. Enable DMA streams for Tx and Rx in DMA registers, if the streams are used.
3. Enable DMA Tx buffer in the TXDMAEN bit in the SPI\_CR2 register, if DMA Tx is used.
4. Enable the SPI by setting the SPE bit.

To close communication it is mandatory to follow these steps in order:

1. Disable DMA streams for Tx and Rx in the DMA registers, if the streams are used.
2. Disable the SPI by following the SPI disable procedure.
3. Disable DMA Tx and Rx buffers by clearing the TXDMAEN and RXDMAEN bits in the SPI\_CR2 register, if DMA Tx and/or DMA Rx are used.

#### Packing with DMA

If the transfers are managed by DMA (TXDMAEN and RXDMAEN set in the SPIx\_CR2 register) packing mode is enabled/disabled automatically depending on the PSIZE value configured for SPI TX and the SPI RX DMA channel. If the DMA channel PSIZE value is equal to 16-bit and SPI data size is less than or equal to 8-bit, then packing mode is enabled. The DMA then automatically manages the write operations to the SPIx\_DR register.

If data packing mode is used and the number of data to transfer is not a multiple of two, the LDMA\_TX/LDMA\_RX bits must be set. The SPI then considers only one data for the transmission or reception to serve the last DMA transfer (for more details refer to [Data packing on page 651](#).)

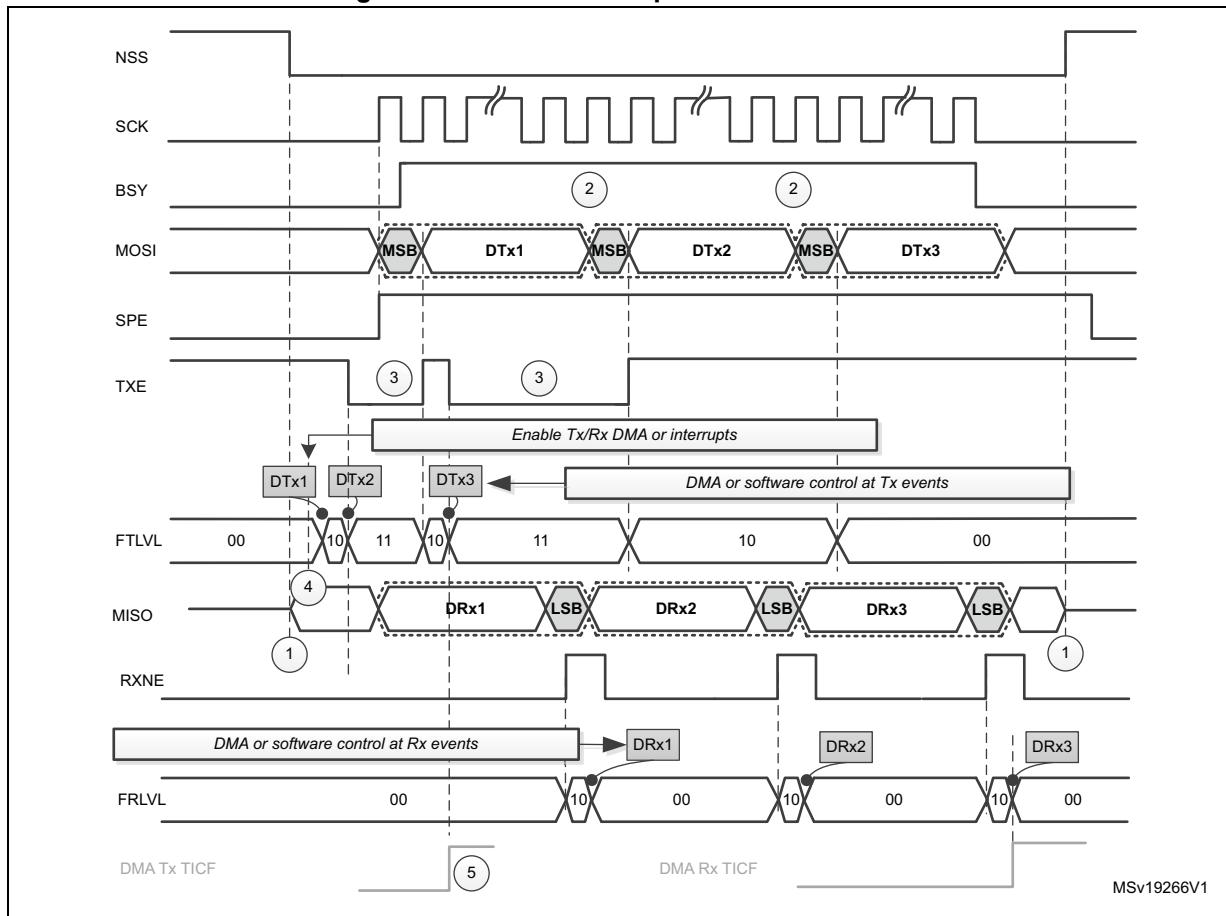
## Communication diagrams

Some typical timing schemes are explained in this section. These schemes are valid no matter if the SPI events are handled by pulling, interrupts or DMA. For simplicity, the LSBFIRST=0, CPOL=0 and CPHA=1 setting is used as a common assumption here. No complete configuration of DMA streams is provided.

The following numbered notes are common for [Figure 264 on page 655](#) through [Figure 267 on page 658](#).

1. The slave starts to control MISO line as NSS is active and SPI is enabled, and is disconnected from the line when one of them is released. Sufficient time must be provided for the slave to prepare data dedicated to the master in advance before its transaction starts.  
At the master, the SPI peripheral takes control at MOSI and SCK signals (occasionally at NSS signal as well) only if SPI is enabled. If SPI is disabled the SPI peripheral is disconnected from GPIO logic, so the levels at these lines depends on GPIO setting exclusively.
2. At the master, BSY stays active between frames if the communication (clock signal) is continuous. At the slave, BSY signal always goes down for at least one clock cycle between data frames.
3. The TXE signal is cleared only if TXFIFO is full.
4. The DMA arbitration process starts just after the TXDMAEN bit is set. The TXE interrupt is generated just after the TXEIE is set. As the TXE signal is at an active level, data transfers to TxFIFO start, until TxFIFO becomes full or the DMA transfer completes.
5. If all the data to be sent can fit into TxFIFO, the DMA Tx TCIF flag can be raised even before communication on the SPI bus starts. This flag always rises before the SPI transaction is completed.
6. The CRC value for a package is calculated continuously frame by frame in the SPIx\_TxCRCR and SPIx\_RxCRCR registers. The CRC information is processed after the entire data package has completed, either automatically by DMA (Tx channel must be set to the number of data frames to be processed) or by SW (the user must handle CRCNEXT bit during the last data frame processing).  
While the CRC value calculated in SPIx\_TxCRCR is simply sent out by transmitter, received CRC information is loaded into Rx FIFO and then compared with the SPIx\_RxCRCR register content (CRC error flag can be raised here if any difference). This is why the user must take care to flush this information from the FIFO, either by software reading out all the stored content of Rx FIFO, or by DMA when the proper number of data frames is preset for Rx channel (number of data frames + number of CRC frames) (see the settings at the example assumption).
7. In data packed mode, TxE and RxNE events are paired and each read/write access to the FIFO is 16 bits wide until the number of data frames are even. If the Tx FIFO is  $\frac{3}{4}$  full FTLVL status stays at FIFO full level. That is why the last odd data frame cannot be stored before the Tx FIFO becomes  $\frac{1}{2}$  full. This frame is stored into Tx FIFO within 8-bit access either by software or automatically by DMA when LDMA\_TX control is set.
8. To receive the last odd data frame in packed mode, the Rx threshold must be changed to 8-bit when the last data frame is processed, either by software setting FRXTH=1 or automatically by a DMA internal signal when LDMA\_RX is set.

Figure 264. Master full duplex communication



Assumptions for master full duplex communication example:

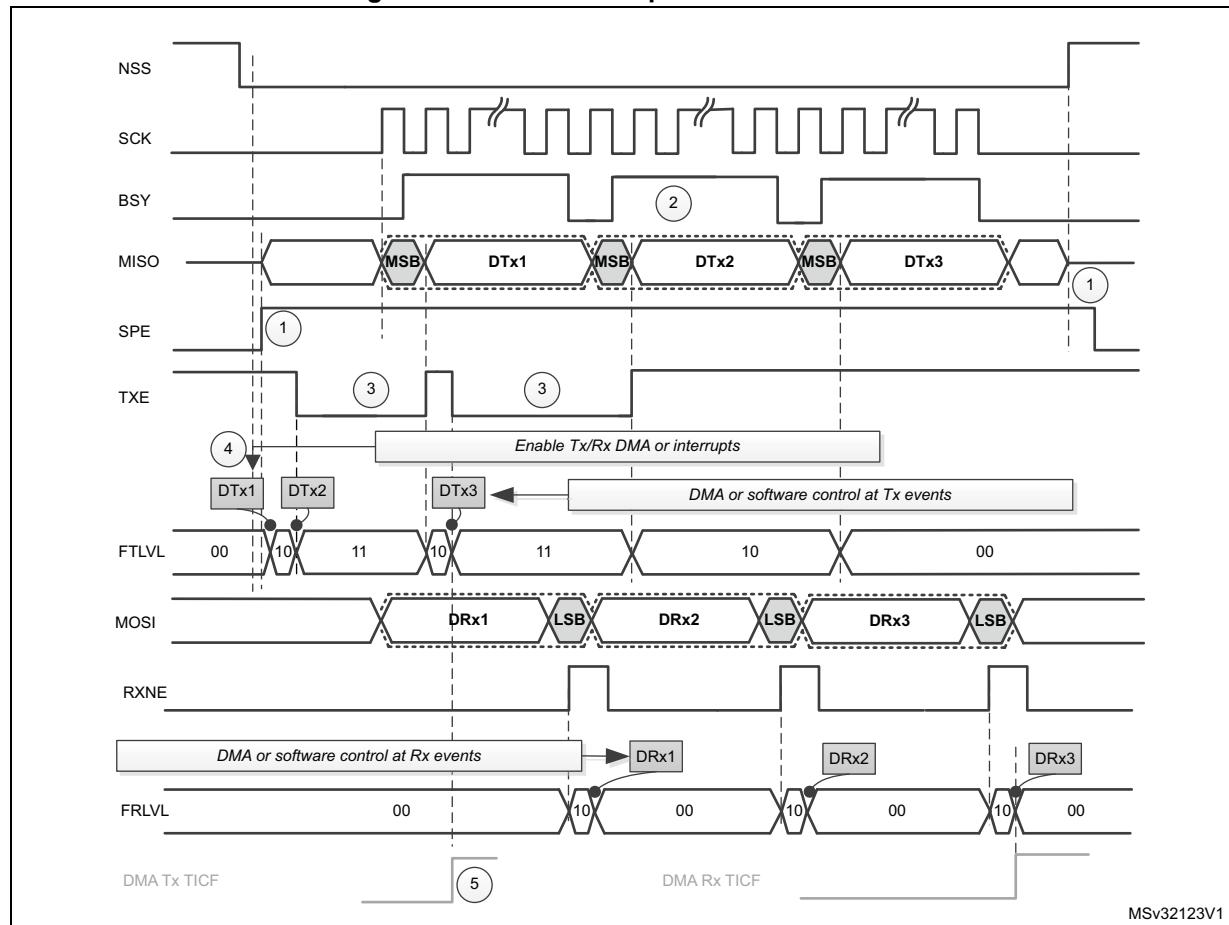
- Data size > 8 bit

If DMA is used:

- Number of Tx frames transacted by DMA is set to 3
- Number of Rx frames transacted by DMA is set to 3

See also [Communication diagrams on page 654](#) for details about common assumptions and notes.

Figure 265. Slave full duplex communication



Assumptions for slave full duplex communication example:

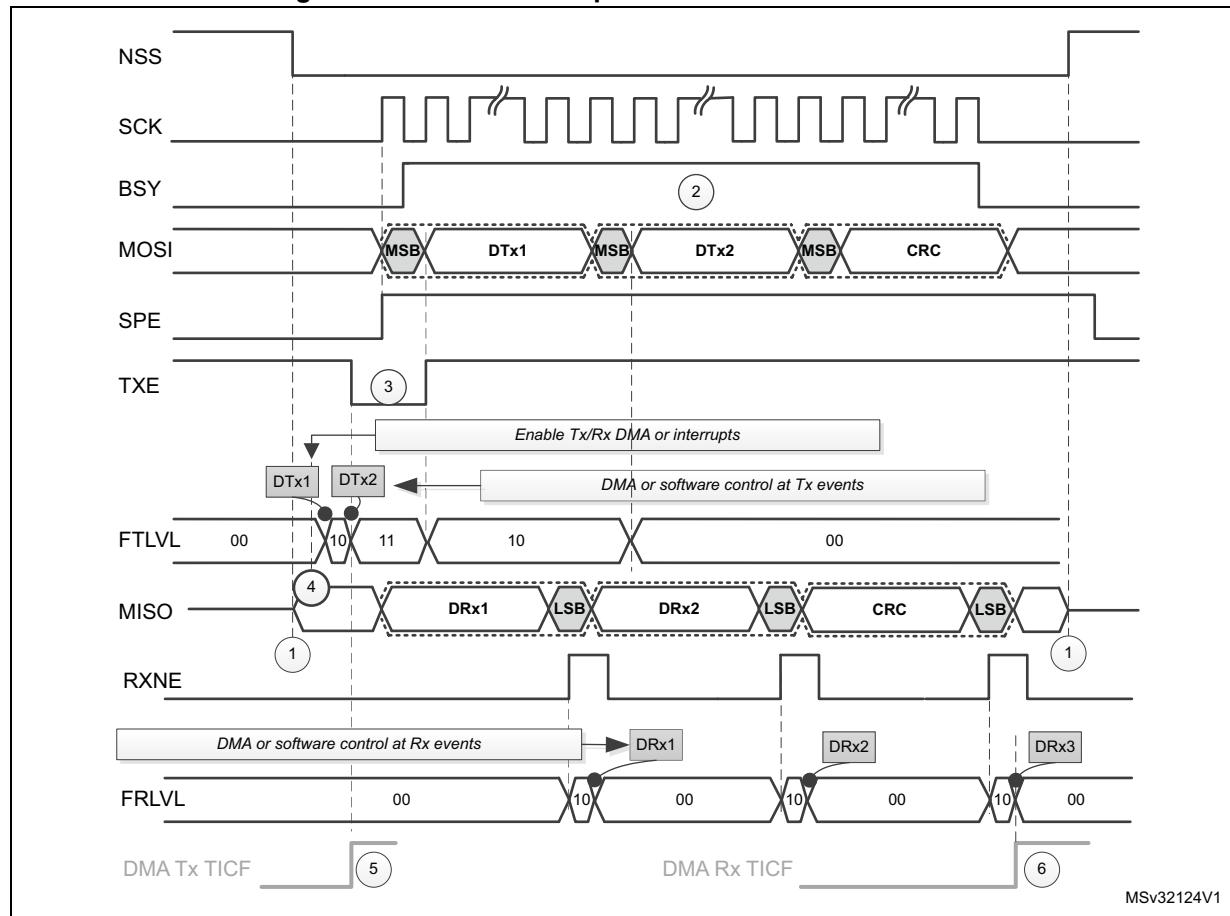
- Data size > 8 bit

If DMA is used:

- Number of Tx frames transacted by DMA is set to 3
- Number of Rx frames transacted by DMA is set to 3

See also [Communication diagrams on page 654](#) for details about common assumptions and notes.

Figure 266. Master full duplex communication with CRC



Assumptions for master full duplex communication with CRC example:

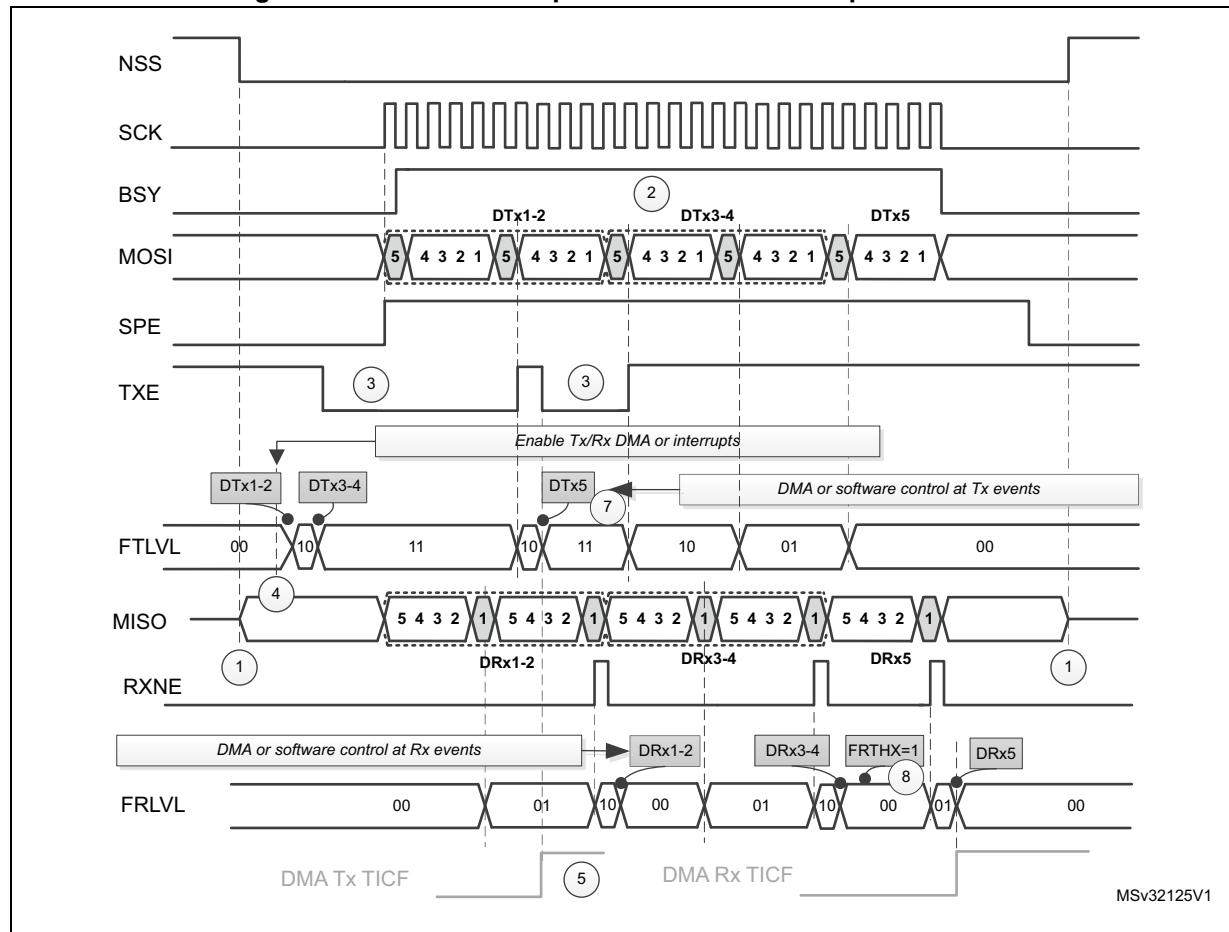
- Data size = 16 bit
- CRC enabled

If DMA is used:

- Number of Tx frames transacted by DMA is set to 2
- Number of Rx frames transacted by DMA is set to 3

See also [Communication diagrams on page 654](#) for details about common assumptions and notes.

Figure 267. Master full duplex communication in packed mode



Assumptions for master full duplex communication in packed mode example:

- Data size = 5 bit
- Read/write FIFO is performed mostly by 16-bit access
- FRXTH=0

If DMA is used:

- Number of Tx frames to be transacted by DMA is set to 3
- Number of Rx frames to be transacted by DMA is set to 3
- PSIZE for both Tx and Rx DMA channel is set to 16-bit
- LDMA\_TX=1 and LDMA\_RX=1

See also [Communication diagrams on page 654](#) for details about common assumptions and notes.

### 26.3.9 SPI status flags

Three status flags are provided for the application to completely monitor the state of the SPI bus.

#### Tx buffer empty flag (TXE)

The TXE flag is set when transmission TXFIFO has enough space to store data to send. TXE flag is linked to the TXFIFO level. The flag goes high and stays high until the TXFIFO level is lower or equal to 1/2 of the FIFO depth. An interrupt can be generated if the TXEIE bit in the SPIx\_CR2 register is set. The bit is cleared automatically when the TXFIFO level becomes greater than 1/2.

#### Rx buffer not empty (RXNE)

The RXNE flag is set depending on the FRXTH bit value in the SPIx\_CR2 register:

- If FRXTH is set, RXNE goes high and stays high until the RXFIFO level is greater or equal to 1/4 (8-bit).
- If FRXTH is cleared, RXNE goes high and stays high until the RXFIFO level is greater than or equal to 1/2 (16-bit).

An interrupt can be generated if the RXNEIE bit in the SPIx\_CR2 register is set.

The RXNE is cleared by hardware automatically when the above conditions are no longer true.

#### Busy flag (BSY)

The BSY flag is set and cleared by hardware (writing to this flag has no effect).

When BSY is set, it indicates that a data transfer is in progress on the SPI (the SPI bus is busy).

The BSY flag can be used in certain modes to detect the end of a transfer so that the software can disable the SPI or its peripheral clock before entering a low power mode which does not provide a clock for the peripheral. This avoids corrupting the last transfer.

The BSY flag is also useful for preventing write collisions in a multimaster system.

The BSY flag is cleared under any one of the following conditions:

- When the SPI is correctly disabled
- When a fault is detected in Master mode (MODF bit set to 1)
- In Master mode, when it finishes a data transmission and no new data is ready to be sent
- In Slave mode, when the BSY flag is set to '0' for at least one SPI clock cycle between each data transfer.

**Note:**

*When the next transmission can be handled immediately by the master (e.g. if the master is in Receive-only mode or its Transmit FIFO is not empty), communication is continuous and the BSY flag remains set to '1' between transfers on the master side. Although this is not the case with a slave, it is recommended to use always the TXE and RXNE flags (instead of the BSY flags) to handle data transmission or reception operations.*

### 26.3.10 SPI error flags

An SPI interrupt is generated if one of the following error flags is set and interrupt is enabled by setting the ERRIE bit.

#### Overrun flag (OVR)

An overrun condition occurs when data is received by a master or slave and the RXFIFO has not enough space to store this received data. This can happen if the software or the DMA did not have enough time to read the previously received data (stored in the RXFIFO) or when space for data storage is limited e.g. the RXFIFO is not available when CRC is enabled in receive only mode so in this case the reception buffer is limited into a single data frame buffer (see [Section 26.4.3: CRC calculation](#)).

When an overrun condition occurs, the newly received value does not overwrite the previous one in the RXFIFO. The newly received value is discarded and all data transmitted subsequently is lost. Clearing the OVR bit is done by a read access to the SPI\_DR register followed by a read access to the SPI\_SR register.

#### Mode fault (MODF)

Mode fault occurs when the master device has its internal NSS signal (NSS pin in NSS hardware mode, or SSI bit in NSS software mode) pulled low. This automatically sets the MODF bit. Master mode fault affects the SPI interface in the following ways:

- The MODF bit is set and an SPI interrupt is generated if the ERRIE bit is set.
- The SPE bit is cleared. This blocks all output from the device and disables the SPI interface.
- The MSTR bit is cleared, thus forcing the device into slave mode.

Use the following software sequence to clear the MODF bit:

1. Make a read or write access to the SPIx\_SR register while the MODF bit is set.
2. Then write to the SPIx\_CR1 register.

To avoid any multiple slave conflicts in a system comprising several MCUs, the NSS pin must be pulled high during the MODF bit clearing sequence. The SPE and MSTR bits can be restored to their original state after this clearing sequence. As a security, hardware does not allow the SPE and MSTR bits to be set while the MODF bit is set. In a slave device the MODF bit cannot be set except as the result of a previous multimaster conflict.

#### CRC error (CRCERR)

This flag is used to verify the validity of the value received when the CRCEN bit in the SPIx\_CR1 register is set. The CRCERR flag in the SPIx\_SR register is set if the value received in the shift register does not match the receiver SPIx\_RXCRCR value. The flag is cleared by the software.

#### TI mode frame format error (FRE)

A TI mode frame format error is detected when an NSS pulse occurs during an ongoing communication when the SPI is operating in slave mode and configured to conform to the TI mode protocol. When this error occurs, the FRE flag is set in the SPIx\_SR register. The SPI is not disabled when an error occurs, the NSS pulse is ignored, and the SPI waits for the next NSS pulse before starting a new transfer. The data may be corrupted since the error detection may result in the loss of two data bytes.

The FRE flag is cleared when SPIx\_SR register is read. If the ERRIE bit is set, an interrupt is generated on the NSS error detection. In this case, the SPI should be disabled because data consistency is no longer guaranteed and communications should be reinitiated by the master when the slave SPI is enabled again.

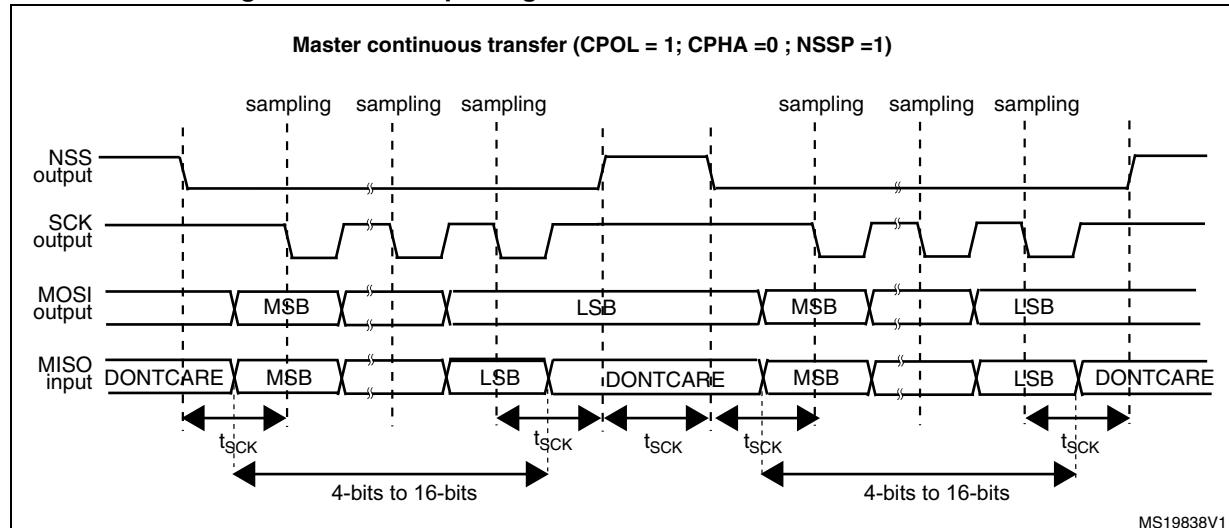
## 26.4 SPI special features

### 26.4.1 NSS pulse mode

This mode is activated by the NSSP bit in the SPIx\_CR1 register and it takes effect only if the SPI interface is configured as Motorola SPI master (FRF=0) with capture on the first edge (SPIx\_CR1 CPHA = 0, CPOL setting is ignored). When activated, an NSS pulse is generated between two consecutive data frame transfers when NSS stays at high level for the duration of one clock period at least. This mode allows the slave to latch data. NSSP pulse mode is designed for applications with a single master-slave pair.

*Figure 268* illustrates NSS pin management when NSSP pulse mode is enabled.

**Figure 268. NSSP pulse generation in Motorola SPI master mode**



**Note:** Similar behavior is encountered when CPOL = 0. In this case the sampling edge is the *rising* edge of SCK, and NSS assertion and deassertion refer to this sampling edge.

### 26.4.2 TI mode

#### TI protocol in master mode

The SPI interface is compatible with the TI protocol. The FRF bit of the SPIx\_CR2 register can be used to configure the SPI to be compliant with this protocol.

The clock polarity and phase are forced to conform to the TI protocol requirements whatever the values set in the SPIx\_CR1 register. NSS management is also specific to the TI protocol which makes the configuration of NSS management through the SPIx\_CR1 and SPIx\_CR2 registers (SSM, SSI, SSOE) impossible in this case.

In slave mode, the SPI baud rate prescaler is used to control the moment when the MISO pin state changes to HiZ when the current transaction finishes (see [Figure 269](#)). Any baud rate can be used, making it possible to determine this moment with optimal flexibility. However, the baud rate is generally set to the external master clock baud rate. The delay for the MISO signal to become HiZ ( $t_{release}$ ) depends on internal resynchronization and on the baud rate value set in through the BR[2:0] bits in the SPIx\_CR1 register. It is given by the formula:

$$\frac{t_{baud\_rate}}{2} + 4 \times t_{pclk} < t_{release} < \frac{t_{baud\_rate}}{2} + 6 \times t_{pclk}$$

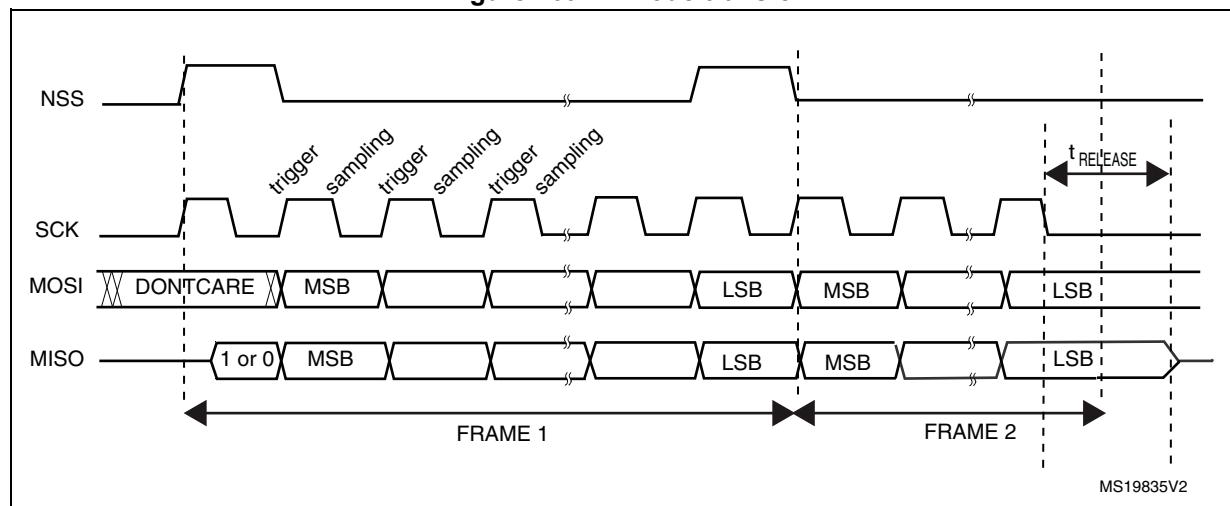
If the slave detects a misplaced NSS pulse during a data frame transaction the TIFRE flag is set.

If the data size is equal to 4-bits or 5-bits, the master in full-duplex mode or transmit-only mode uses a protocol with one more dummy data bit added after LSB. TI NSS pulse is generated above this dummy bit clock cycle instead of the LSB in each period.

This feature is not available for Motorola SPI communications (FRF bit set to 0).

[Figure 269: TI mode transfer](#) shows the SPI communication waveforms when TI mode is selected.

**Figure 269. TI mode transfer**



### 26.4.3 CRC calculation

Two separate CRC calculators are implemented in order to check the reliability of transmitted and received data. The SPI offers CRC8 or CRC16 calculation independently of the frame data length, which can be fixed to 8-bit or 16-bit. For all the other data frame lengths, no CRC is available.

#### CRC principle

CRC calculation is enabled by setting the CRCEN bit in the SPIx\_CR1 register before the SPI is enabled (SPE = 1). The CRC value is calculated using an odd programmable polynomial on each bit. The calculation is processed on the sampling clock edge defined by the CPHA and CPOL bits in the SPIx\_CR1 register. The calculated CRC value is checked

automatically at the end of the data block as well as for transfer managed by CPU or by the DMA. When a mismatch is detected between the CRC calculated internally on the received data and the CRC sent by the transmitter, a CRCERR flag is set to indicate a data corruption error. The right procedure for handling the CRC calculation depends on the SPI configuration and the chosen transfer management.

*Note:* *The polynomial value should only be odd. No even values are supported.*

### CRC transfer managed by CPU

Communication starts and continues normally until the last data frame has to be sent or received in the SPIx\_DR register. Then CRCNEXT bit has to be set in the SPIx\_CR1 register to indicate that the CRC frame transaction will follow after the transaction of the currently processed data frame. The CRCNEXT bit must be set before the end of the last data frame transaction. CRC calculation is frozen during CRC transaction.

The received CRC is stored in the RXFIFO like a data byte or word. That is why in CRC mode only, the reception buffer has to be considered as a single 16-bit buffer used to receive only one data frame at a time.

A CRC-format transaction usually takes one more data frame to communicate at the end of data sequence. However, when setting an 8-bit data frame checked by 16-bit CRC, two more frames are necessary to send the complete CRC.

When the last CRC data is received, an automatic check is performed comparing the received value and the value in the SPIx\_RXCRC register. Software has to check the CRCERR flag in the SPIx\_SR register to determine if the data transfers were corrupted or not. Software clears the CRCERR flag by writing '0' to it.

After the CRC reception, the CRC value is stored in the RXFIFO and must be read in the SPIx\_DR register in order to clear the RXNE flag.

### CRC transfer managed by DMA

When SPI communication is enabled with CRC communication and DMA mode, the transmission and reception of the CRC at the end of communication is automatic (with the exception of reading CRC data in receive only mode). The CRCNEXT bit does not have to be handled by the software. The counter for the SPI transmission DMA channel has to be set to the number of data frames to transmit excluding the CRC frame. On the receiver side, the received CRC value is handled automatically by DMA at the end of the transaction but user must take care to flush out received CRC information from RXFIFO as it is always loaded into it. In full duplex mode, the counter of the reception DMA channel can be set to the number of data frames to receive including the CRC, which means, for example, in the specific case of an 8-bit data frame checked by 16-bit CRC:

$$\text{DMA\_RX} = \text{Numb\_of\_data} + 2$$

In receive only mode, the DMA reception channel counter should contain only the amount of data transferred, excluding the CRC calculation. Then based on the complete transfer from DMA, all the CRC values must be read back by software from FIFO as it works as a single buffer in this mode.

At the end of the data and CRC transfers, the CRCERR flag in the SPIx\_SR register is set if corruption occurred during the transfer.

If packing mode is used, the LDMA\_RX bit needs managing if the number of data is odd.

### Resetting the SPI<sub>x</sub>\_TXCRC and SPI<sub>x</sub>\_RXCRC values

The SPI<sub>x</sub>\_TXCRC and SPI<sub>x</sub>\_RXCRC values are cleared automatically when new data is sampled after a CRC phase. This allows the use of DMA circular mode (not available in receive-only mode) in order to transfer data without any interruption, (several data blocks covered by intermediate CRC checking phases).

If the SPI is disabled during a communication the following sequence must be followed:

1. Disable the SPI
2. Clear the CRCEN bit
3. Enable the CRCEN bit
4. Enable the SPI

*Note:* When the SPI is in slave mode, the CRC calculator is sensitive to the SCK slave input clock as soon as the CRCEN bit is set, and this is the case whatever the value of the SPE bit. In order to avoid any wrong CRC calculation, the software must enable CRC calculation only when the clock is stable (in steady state). When the SPI interface is configured as a slave, the NSS internal signal needs to be kept low between the data phase and the CRC phase.

## 26.5 SPI interrupts

During SPI communication an interrupts can be generated by the following events:

- Transmit TXFIFO ready to be loaded
- Data received in Receive RXFIFO
- Master mode fault
- Overrun error
- TI frame format error

Interrupts can be enabled and disabled separately.

Table 90. SPI interrupt requests

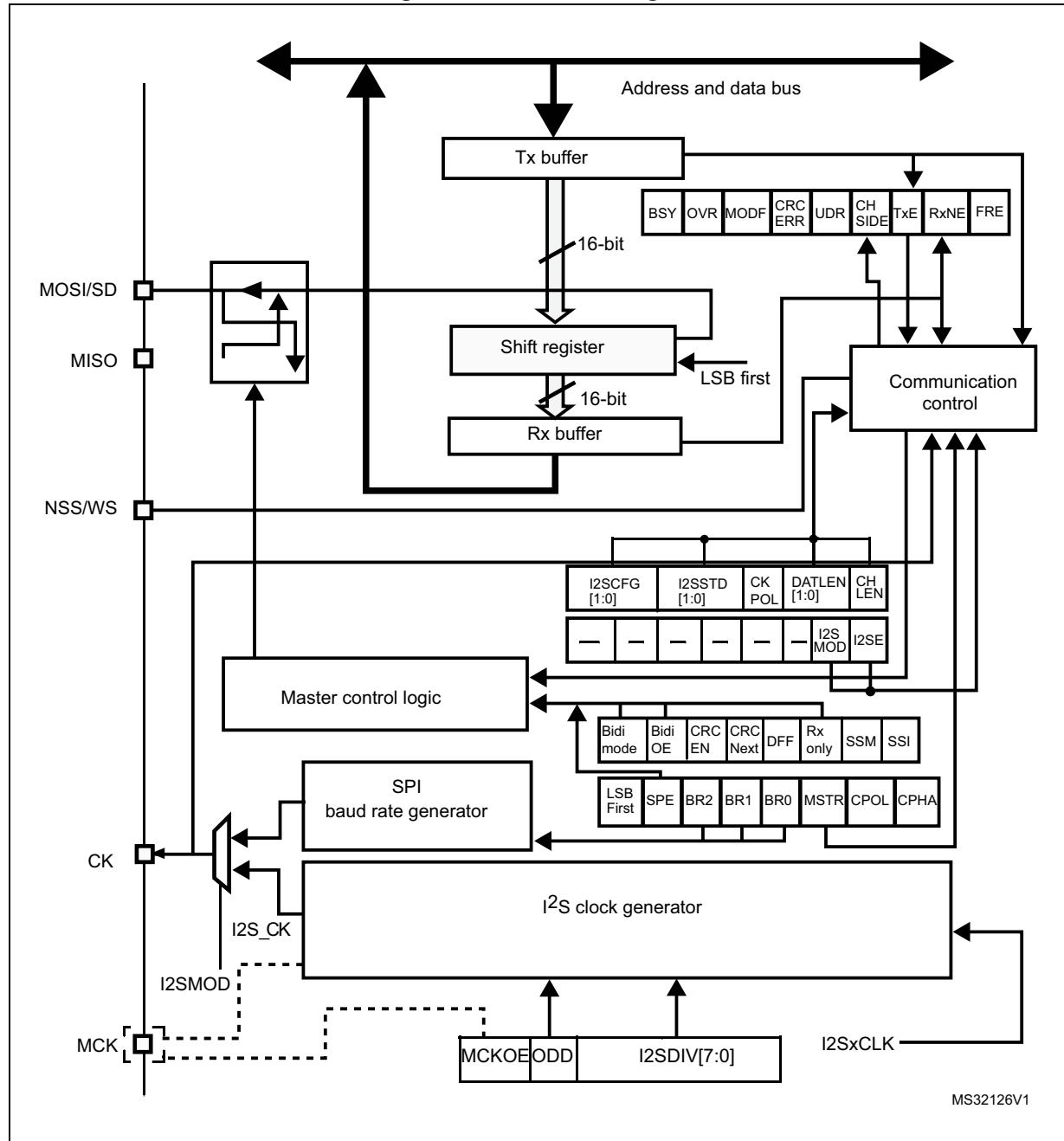
Interrupt event	Event flag	Enable Control bit
Transmit TXFIFO ready to be loaded	TXE	TXEIE
Data received in RXFIFO	RXNE	RXNEIE
Master Mode fault event	MODF	
Overrun error	OVR	ERRIE
TI frame format error	FRE	

## 26.6 I<sup>2</sup>S functional description

### 26.6.1 I<sup>2</sup>S general description

The block diagram of the I<sup>2</sup>S is shown in [Figure 270](#).

**Figure 270. I<sup>2</sup>S block diagram**



1. MCK is mapped on the MISO pin.

The SPI can function as an audio I<sup>2</sup>S interface when the I<sup>2</sup>S capability is enabled (by setting the I2SMOD bit in the SPIx\_I2SCFGR register). This interface mainly uses the same pins, flags and interrupts as the SPI.

The I<sup>2</sup>S shares three common pins with the SPI:

- SD: Serial Data (mapped on the MOSI pin) to transmit or receive the two time-multiplexed data channels (in half-duplex mode only).
- WS: Word Select (mapped on the NSS pin) is the data control signal output in master mode and input in slave mode.
- CK: Serial Clock (mapped on the SCK pin) is the serial clock output in master mode and serial clock input in slave mode.

An additional pin can be used when a master clock output is needed for some external audio devices:

- MCK: Master Clock (mapped separately) is used, when the I<sup>2</sup>S is configured in master mode (and when the MCKOE bit in the SPIx\_I2SPR register is set), to output this additional clock generated at a preconfigured frequency rate equal to  $256 \times f_S$ , where  $f_S$  is the audio sampling frequency.

The I<sup>2</sup>S uses its own clock generator to produce the communication clock when it is set in master mode. This clock generator is also the source of the master clock output. Two additional registers are available in I<sup>2</sup>S mode. One is linked to the clock generator configuration SPIx\_I2SPR and the other one is a generic I<sup>2</sup>S configuration register SPIx\_I2SCFGR (audio standard, slave/master mode, data format, packet frame, clock polarity, etc.).

The SPIx\_CR1 register and all CRC registers are not used in the I<sup>2</sup>S mode. Likewise, the SSOE bit in the SPIx\_CR2 register and the MODF and CRCERR bits in the SPIx\_SR are not used.

The I<sup>2</sup>S uses the same SPI register for data transfer (SPIx\_DR) in 16-bit wide mode.

## 26.6.2

### Supported audio protocols

The three-line bus has to handle only audio data generally time-multiplexed on two channels: the right channel and the left channel. However there is only one 16-bit register for transmission or reception. So, it is up to the software to write into the data register the appropriate value corresponding to each channel side, or to read the data from the data register and to identify the corresponding channel by checking the CHSIDE bit in the SPIx\_SR register. Channel left is always sent first followed by the channel right (CHSIDE has no meaning for the PCM protocol).

Four data and packet frames are available. Data may be sent with a format of:

- 16-bit data packed in a 16-bit frame
- 16-bit data packed in a 32-bit frame
- 24-bit data packed in a 32-bit frame
- 32-bit data packed in a 32-bit frame

When using 16-bit data extended on 32-bit packet, the first 16 bits (MSB) are the significant bits, the 16-bit LSB is forced to 0 without any need for software action or DMA request (only one read/write operation).

The 24-bit and 32-bit data frames need two CPU read or write operations to/from the SPIx\_DR register or two DMA operations if the DMA is preferred for the application. For 24-

bit data frame specifically, the 8 nonsignificant bits are extended to 32 bits with 0-bits (by hardware).

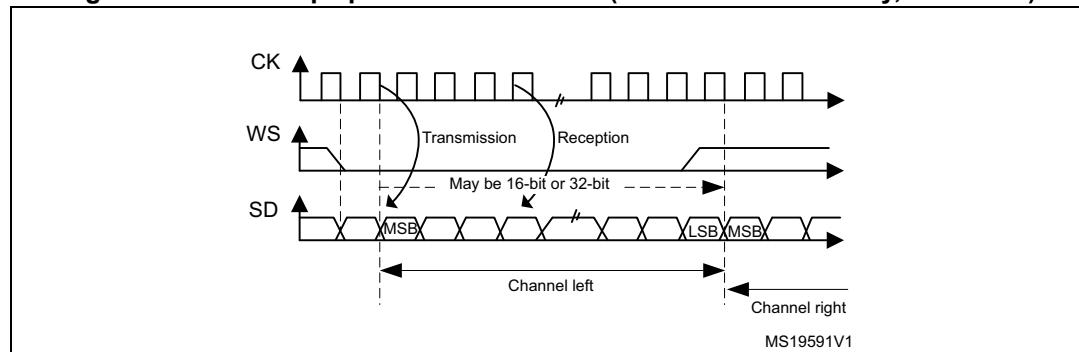
For all data formats and communication standards, the most significant bit is always sent first (MSB first).

The I<sup>2</sup>S interface supports four audio standards, configurable using the I2SSTD[1:0] and PCMSYNC bits in the SPIx\_I2SCFGR register.

### I<sup>2</sup>S Philips standard

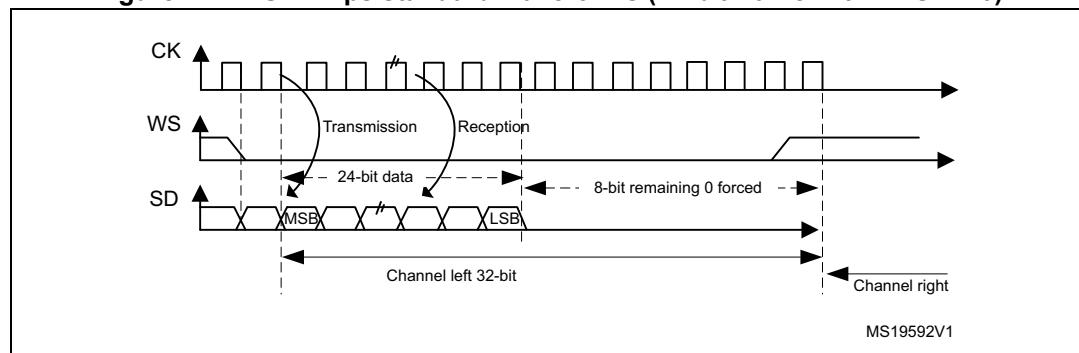
For this standard, the WS signal is used to indicate which channel is being transmitted. It is activated one CK clock cycle before the first bit (MSB) is available.

**Figure 271. I<sup>2</sup>S Philips protocol waveforms (16/32-bit full accuracy, CPOL = 0)**



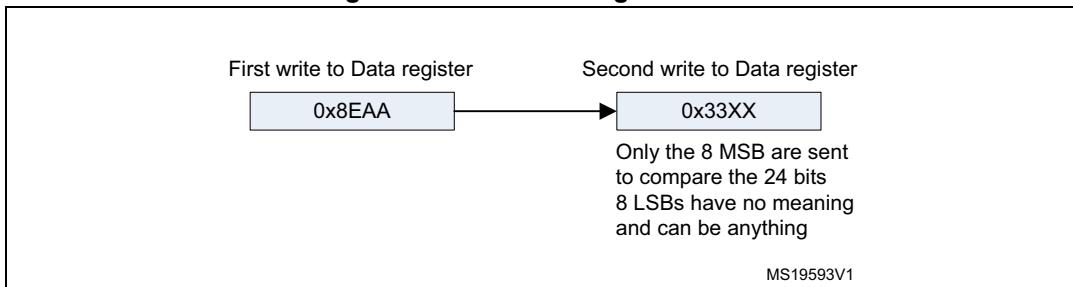
Data are latched on the falling edge of CK (for the transmitter) and are read on the rising edge (for the receiver). The WS signal is also latched on the falling edge of CK.

**Figure 272. I<sup>2</sup>S Philips standard waveforms (24-bit frame with CPOL = 0)**

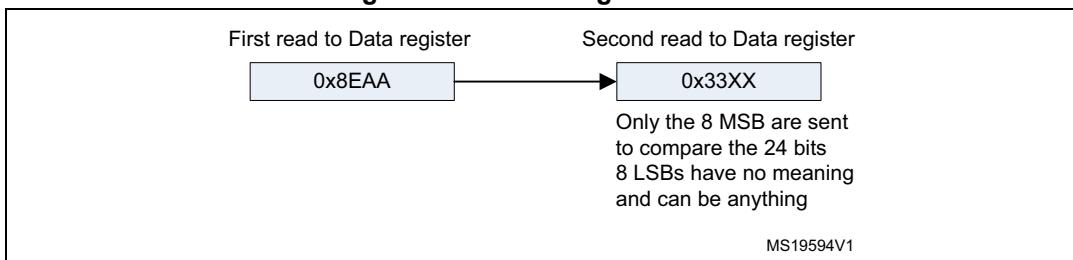
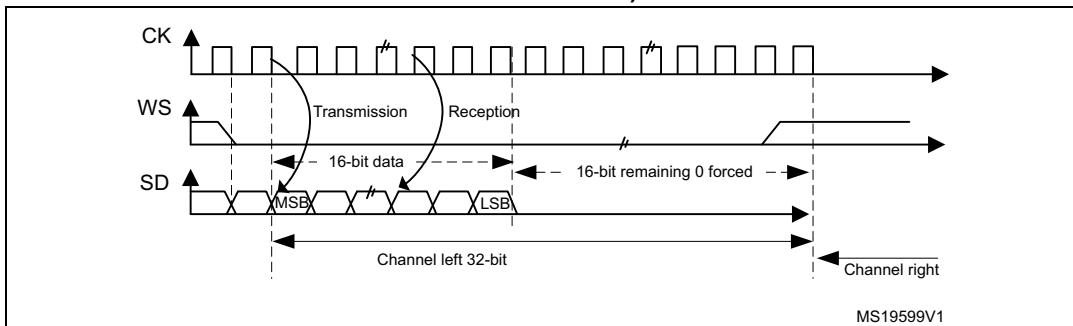


This mode needs two write or read operations to/from the SPIx\_DR register.

- In transmission mode:  
If 0x8EAA33 has to be sent (24-bit):

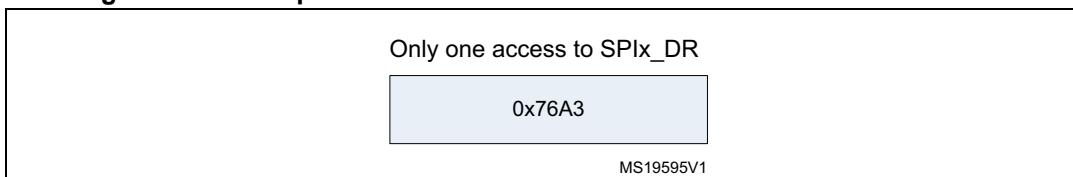
**Figure 273. Transmitting 0x8EAA33**

- In reception mode:  
If data 0x8EAA33 is received:

**Figure 274. Receiving 0x8EAA33****Figure 275. I<sup>2</sup>S Philips standard (16-bit extended to 32-bit packet frame with CPOL = 0)**

When 16-bit data frame extended to 32-bit channel frame is selected during the I<sup>2</sup>S configuration phase, only one access to the SPIx\_DR register is required. The 16 remaining bits are forced by hardware to 0x0000 to extend the data to 32-bit format.

If the data to transmit or the received data are 0x76A3 (0x76A30000 extended to 32-bit), the operation shown in [Figure 276](#) is required.

**Figure 276. Example of 16-bit data frame extended to 32-bit channel frame**

For transmission, each time an MSB is written to SPIx\_DR, the TXE flag is set and its interrupt, if allowed, is generated to load the SPIx\_DR register with the new value to send. This takes place even if 0x0000 have not yet been sent because it is done by hardware.

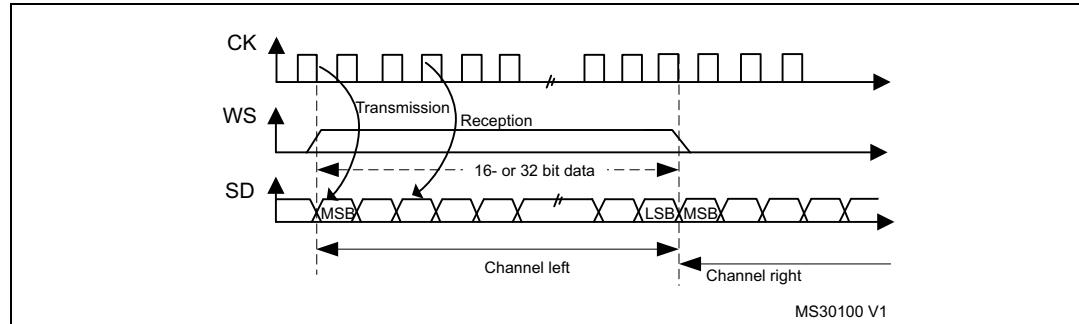
For reception, the RXNE flag is set and its interrupt, if allowed, is generated when the first 16 MSB half-word is received.

In this way, more time is provided between two write or read operations, which prevents underrun or overrun conditions (depending on the direction of the data transfer).

### MSB justified standard

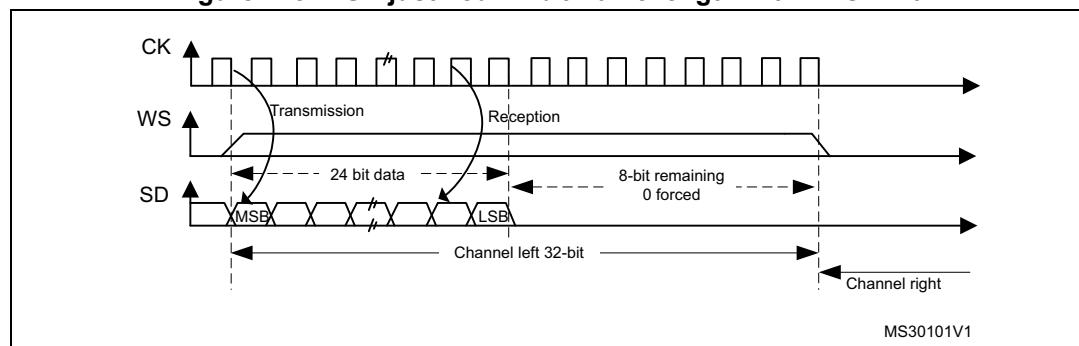
For this standard, the WS signal is generated at the same time as the first data bit, which is the MSBit.

**Figure 277. MSB Justified 16-bit or 32-bit full-accuracy length with CPOL = 0**

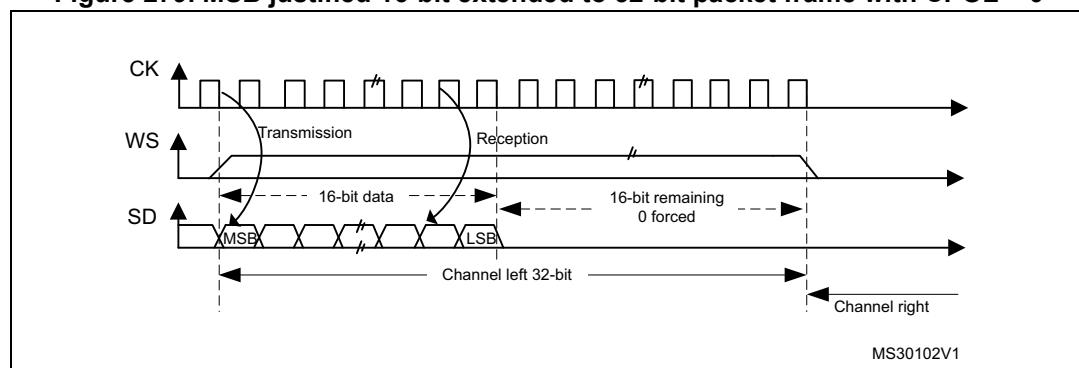


Data are latched on the falling edge of CK (for transmitter) and are read on the rising edge (for the receiver).

**Figure 278. MSB justified 24-bit frame length with CPOL = 0**



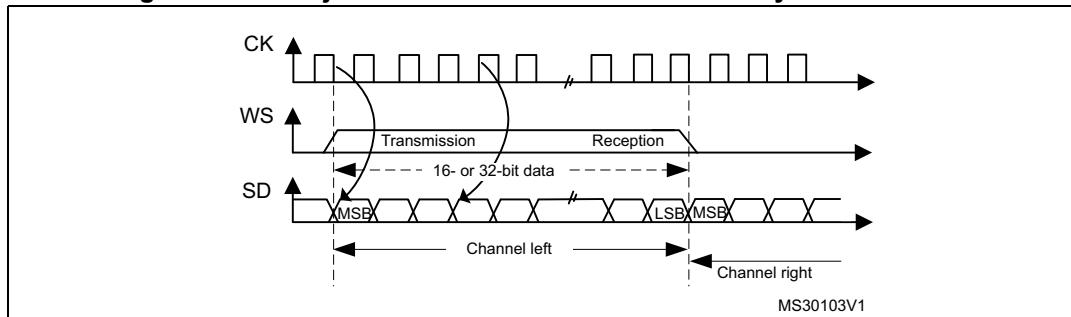
**Figure 279. MSB justified 16-bit extended to 32-bit packet frame with CPOL = 0**



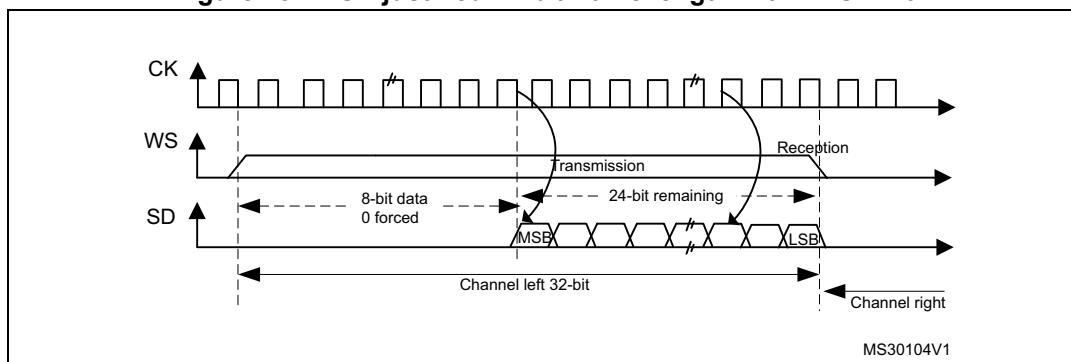
### LSB justified standard

This standard is similar to the MSB justified standard (no difference for the 16-bit and 32-bit full-accuracy frame formats).

**Figure 280. LSB justified 16-bit or 32-bit full-accuracy with CPOL = 0**



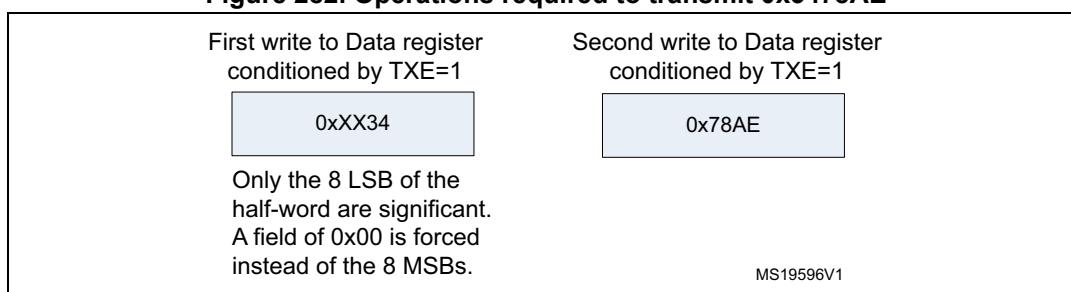
**Figure 281. LSB justified 24-bit frame length with CPOL = 0**



- In transmission mode:

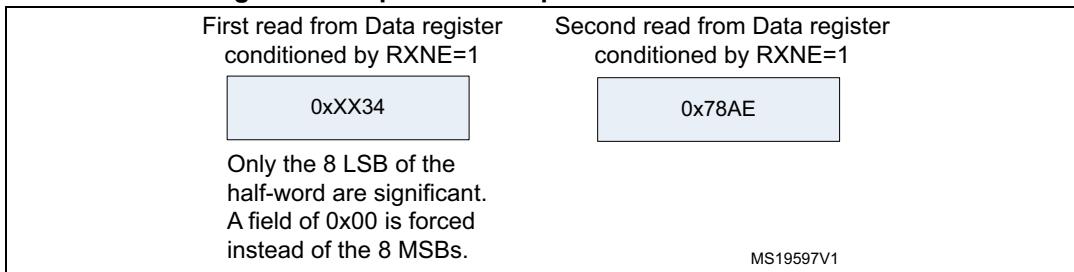
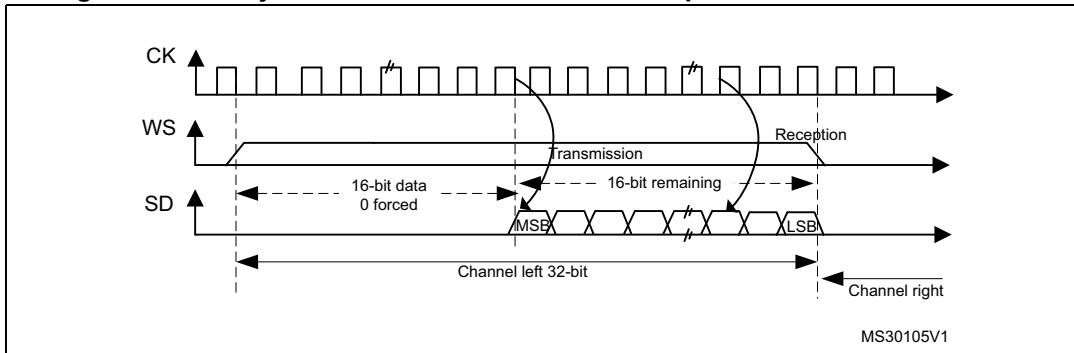
If data 0x3478AE have to be transmitted, two write operations to the SPIx\_DR register are required by software or by DMA. The operations are shown below.

**Figure 282. Operations required to transmit 0x3478AE**



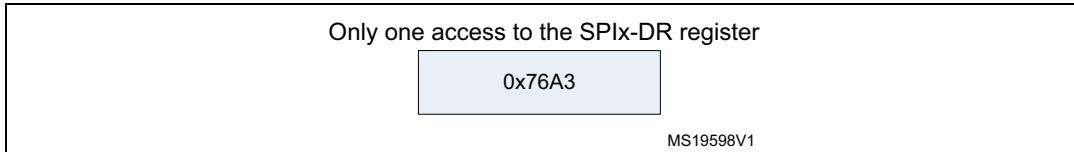
- In reception mode:

If data 0x3478AE are received, two successive read operations from the SPIx\_DR register are required on each RXNE event.

**Figure 283. Operations required to receive 0x3478AE****Figure 284. LSB justified 16-bit extended to 32-bit packet frame with CPOL = 0**

When 16-bit data frame extended to 32-bit channel frame is selected during the I<sup>2</sup>S configuration phase, Only one access to the SPIx\_DR register is required. The 16 remaining bits are forced by hardware to 0x0000 to extend the data to 32-bit format. In this case it corresponds to the half-word MSB.

If the data to transmit or the received data are 0x76A3 (0x0000 76A3 extended to 32-bit), the operation shown in [Figure 285](#) is required.

**Figure 285. Example of 16-bit data frame extended to 32-bit channel frame**

In transmission mode, when a TXE event occurs, the application has to write the data to be transmitted (in this case 0x76A3). The 0x000 field is transmitted first (extension on 32-bit). The TXE flag is set again as soon as the effective data (0x76A3) is sent on SD.

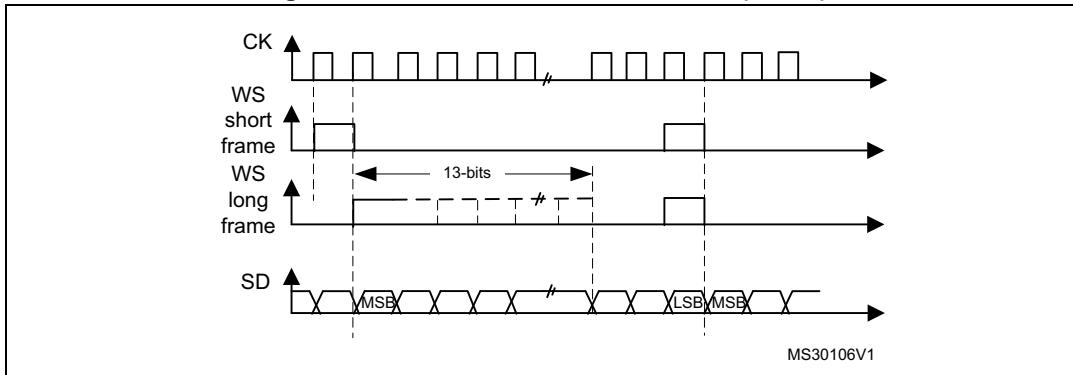
In reception mode, RXNE is asserted as soon as the significant half-word is received (and not the 0x0000 field).

In this way, more time is provided between two write or read operations to prevent underrun or overrun conditions.

### PCM standard

For the PCM standard, there is no need to use channel-side information. The two PCM modes (short and long frame) are available and configurable using the PCMSYNC bit in SPIx\_I2SCFGR register.

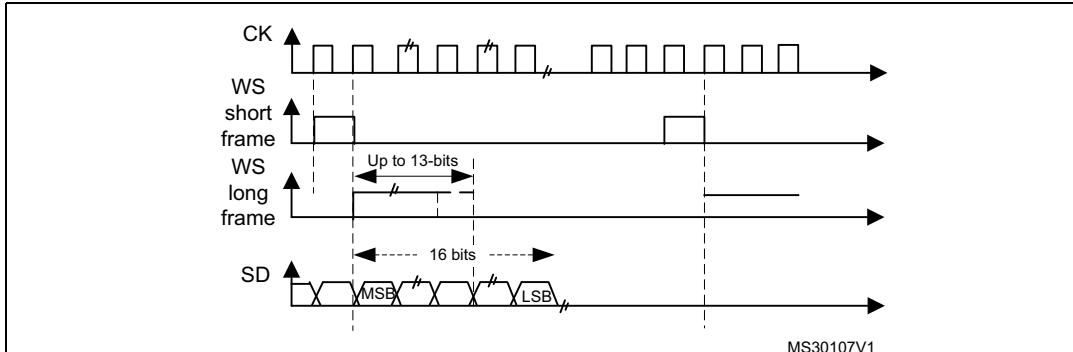
Figure 286. PCM standard waveforms (16-bit)



For long frame synchronization, the WS signal assertion time is fixed to 13 bits in master mode.

For short frame synchronization, the WS synchronization signal is only one cycle long.

Figure 287. PCM standard waveforms (16-bit extended to 32-bit packet frame)



Note: For both modes (master and slave) and for both synchronizations (short and long), the number of bits between two consecutive pieces of data (and so two synchronization signals) needs to be specified (DATLEN and CHLEN bits in the SPIx\_I2SCFGR register) even in slave mode.

### 26.6.3 Clock generator

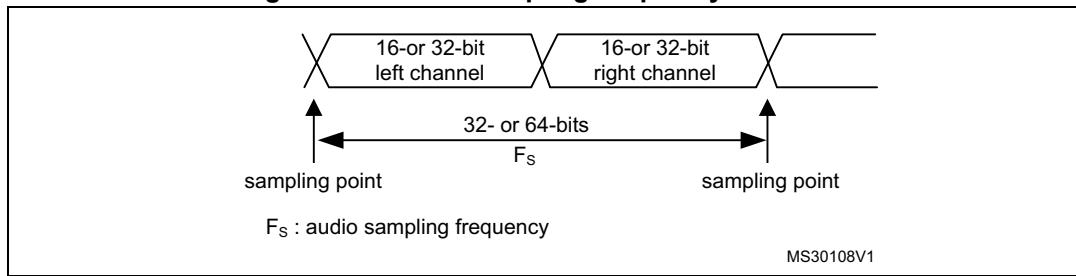
The I<sup>2</sup>S bitrate determines the dataflow on the I<sup>2</sup>S data line and the I<sup>2</sup>S clock signal frequency.

I<sup>2</sup>S bitrate = number of bits per channel × number of channels × sampling audio frequency

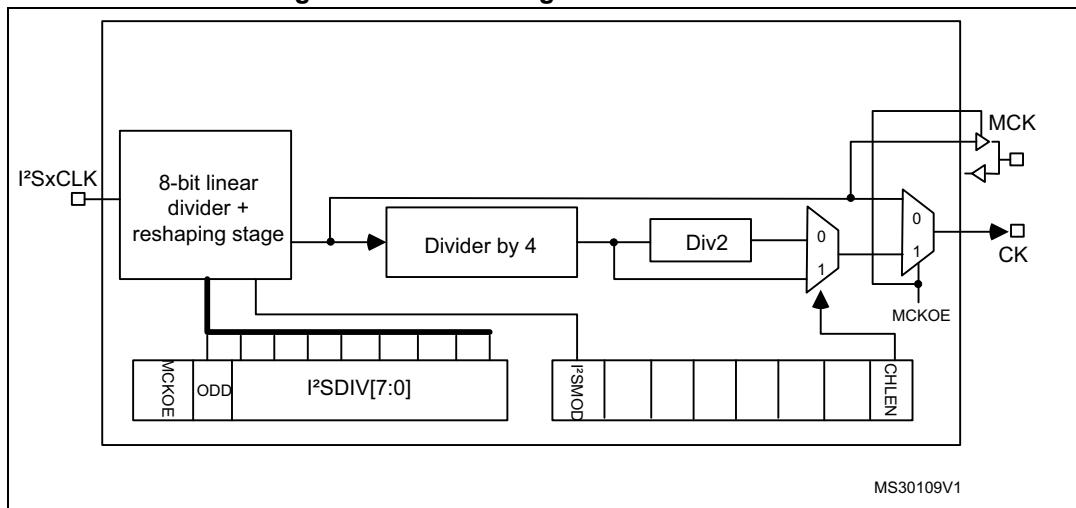
For a 16-bit audio, left and right channel, the I<sup>2</sup>S bitrate is calculated as follows:

$$\text{I}^2\text{S bitrate} = 16 \times 2 \times f_S$$

It will be: I<sup>2</sup>S bitrate = 32 × 2 × f<sub>S</sub> if the packet length is 32-bit wide.

**Figure 288. Audio sampling frequency definition**

When the master mode is configured, a specific action needs to be taken to properly program the linear divider in order to communicate with the desired audio frequency.

**Figure 289. I<sup>2</sup>S clock generator architecture**

1. Where x can be 2 or 3.

*Figure 289* presents the communication clock architecture. The I<sup>2</sup>Sx clock is always the system clock.

The audio sampling frequency may be 192 KHz, 96 kHz, 48 kHz, 44.1 kHz, 32 kHz, 22.05 kHz, 16 kHz, 11.025 kHz or 8 kHz (or any other value within this range). In order to reach the desired frequency, the linear divider needs to be programmed according to the formulas below:

When the master clock is generated (MCKOE in the SPIx\_I2SPR register is set):

$$f_S = I^{2}SxCLK / [(16*2)*(2*I2SDIV)+ODD)*8]] \text{ when the channel frame is 16-bit wide}$$

$$f_S = I^{2}SxCLK / [(32*2)*(2*I2SDIV)+ODD)*4]] \text{ when the channel frame is 32-bit wide}$$

When the master clock is disabled (MCKOE bit cleared):

$$f_S = I^{2}SxCLK / [(16*2)*(2*I2SDIV)+ODD)] \text{ when the channel frame is 16-bit wide}$$

$$f_S = I^{2}SxCLK / [(32*2)*(2*I2SDIV)] \text{ when the channel frame is 32-bit wide}$$

*Table 91* provides example precision values for different clock configurations.

*Note:*

*Other configurations are possible that allow optimum clock precision.*

**Table 91. Audio-frequency precision using standard 8 MHz HSE<sup>(1)</sup>**

<b>SYSCLK (MHz)</b>	<b>Data length</b>	<b>I2SDIV</b>	<b>I2SODD</b>	<b>MCLK</b>	<b>Target fs (Hz)</b>	<b>Real fs (KHz)</b>	<b>Error</b>
48	16	8	0	No	96000	93750	2.3438%
48	32	4	0	No	96000	93750	2.3438%
48	16	15	1	No	48000	48387.0968	0.8065%
48	32	8	0	No	48000	46875	2.3438%
48	16	17	0	No	44100	44117.647	0.0400%
48	32	8	1	No	44100	44117.647	0.0400%
48	16	23	1	No	32000	31914.8936	0.2660%
48	32	11	1	No	32000	32608.696	1.9022%
48	16	34	0	No	22050	22058.8235	0.0400%
48	32	17	0	No	22050	22058.8235	0.0400%
48	16	47	0	No	16000	15957.4468	0.2660%
48	32	23	1	No	16000	15957.447	0.2660%
48	16	68	0	No	11025	11029.4118	0.0400%
48	32	34	0	No	11025	11029.412	0.0400%
48	16	94	0	No	8000	7978.7234	0.2660%
48	32	47	0	No	8000	7978.7234	0.2660%
48	16	2	0	Yes	48000	46875	2.3430%
48	32	2	0	Yes	48000	46875	2.3430%
48	16	2	0	Yes	44100	46875	6.2925%
48	32	2	0	Yes	44100	46875	6.2925%
48	16	3	0	Yes	32000	31250	2.3438%
48	32	3	0	Yes	32000	31250	2.3438%
48	16	4	1	Yes	22050	20833.333	5.5178%
48	32	4	1	Yes	22050	20833.333	5.5178%
48	16	6	0	Yes	16000	15625	2.3438%
48	32	6	0	Yes	16000	15625	2.3438%
48	16	8	1	Yes	11025	11029.4118	0.0400%
48	32	8	1	Yes	11025	11029.4118	0.0400%
48	16	11	1	Yes	8000	8152.17391	1.9022%
48	32	11	1	Yes	8000	8152.17391	1.9022%

1. This table gives only example values for different clock configurations. Other configurations allowing optimum clock precision are possible.

## 26.6.4 I<sup>2</sup>S master mode

The I<sup>2</sup>S can be configured in master mode. This means that the serial clock is generated on the CK pin as well as the Word Select signal WS. Master clock (MCK) may be output or not, controlled by the MCKOE bit in the SPIx\_I2SPR register.

### Procedure

1. Select the I2SDIV[7:0] bits in the SPIx\_I2SPR register to define the serial clock baud rate to reach the proper audio sample frequency. The ODD bit in the SPIx\_I2SPR register also has to be defined.
2. Select the CKPOL bit to define the steady level for the communication clock. Set the MCKOE bit in the SPIx\_I2SPR register if the master clock MCK needs to be provided to the external DAC/ADC audio component (the I2SDIV and ODD values should be computed depending on the state of the MCK output, for more details refer to [Section 26.6.3: Clock generator](#)).
3. Set the I2SMOD bit in the SPIx\_I2SCFGR register to activate the I<sup>2</sup>S functions and choose the I<sup>2</sup>S standard through the I2SSTD[1:0] and PCMSYNC bits, the data length through the DATLEN[1:0] bits and the number of bits per channel by configuring the CHLEN bit. Select also the I<sup>2</sup>S master mode and direction (Transmitter or Receiver) through the I2SCFG[1:0] bits in the SPIx\_I2SCFGR register.
4. If needed, select all the potential interrupt sources and the DMA capabilities by writing the SPIx\_CR2 register.
5. The I2SE bit in SPIx\_I2SCFGR register must be set.

WS and CK are configured in output mode. MCK is also an output, if the MCKOE bit in SPIx\_I2SPR is set.

### Transmission sequence

The transmission sequence begins when a half-word is written into the Tx buffer.

Lets assume the first data written into the Tx buffer corresponds to the left channel data. When data are transferred from the Tx buffer to the shift register, TXE is set and data corresponding to the right channel have to be written into the Tx buffer. The CHSIDE flag indicates which channel is to be transmitted. It has a meaning when the TXE flag is set because the CHSIDE flag is updated when TXE goes high.

A full frame has to be considered as a left channel data transmission followed by a right channel data transmission. It is not possible to have a partial frame where only the left channel is sent.

The data half-word is parallel loaded into the 16-bit shift register during the first bit transmission, and then shifted out, serially, to the MOSI/SD pin, MSB first. The TXE flag is set after each transfer from the Tx buffer to the shift register and an interrupt is generated if the TXEIE bit in the SPIx\_CR2 register is set.

For more details about the write operations depending on the I<sup>2</sup>S standard mode selected, refer to [Section 26.6.2: Supported audio protocols](#)).

To ensure a continuous audio data transmission, it is mandatory to write the SPIx\_DR register with the next data to transmit before the end of the current transmission.

To switch off the I<sup>2</sup>S, by clearing I2SE, it is mandatory to wait for TXE = 1 and BSY = 0.

### Reception sequence

The operating mode is the same as for transmission mode except for the point 3 (refer to the procedure described in [Section 26.6.4: I<sup>2</sup>S master mode](#)), where the configuration should set the master reception mode through the I2SCFG[1:0] bits.

Whatever the data or channel length, the audio data are received by 16-bit packets. This means that each time the Rx buffer is full, the RXNE flag is set and an interrupt is generated if the RXNEIE bit is set in SPIx\_CR2 register. Depending on the data and channel length configuration, the audio value received for a right or left channel may result from one or two receptions into the Rx buffer.

Clearing the RXNE bit is performed by reading the SPIx\_DR register.

CHSIDE is updated after each reception. It is sensitive to the WS signal generated by the I<sup>2</sup>S cell.

For more details about the read operations depending on the I<sup>2</sup>S standard mode selected, refer to [Section 26.6.2: Supported audio protocols](#).

If data are received while the previously received data have not been read yet, an overrun is generated and the OVR flag is set. If the ERRIE bit is set in the SPIx\_CR2 register, an interrupt is generated to indicate the error.

To switch off the I<sup>2</sup>S, specific actions are required to ensure that the I<sup>2</sup>S completes the transfer cycle properly without initiating a new data transfer. The sequence depends on the configuration of the data and channel lengths, and on the audio protocol mode selected. In the case of:

- 16-bit data length extended on 32-bit channel length (DATLEN = 00 and CHLEN = 1) using the LSB justified mode (I2SSTD = 10)
  - a) Wait for the second to last RXNE = 1 (n – 1)
  - b) Then wait 17 I<sup>2</sup>S clock cycles (using a software loop)
  - c) Disable the I<sup>2</sup>S (I2SE = 0)
- 16-bit data length extended on 32-bit channel length (DATLEN = 00 and CHLEN = 1) in MSB justified, I<sup>2</sup>S or PCM modes (I2SSTD = 00, I2SSTD = 01 or I2SSTD = 11, respectively)
  - a) Wait for the last RXNE
  - b) Then wait 1 I<sup>2</sup>S clock cycle (using a software loop)
  - c) Disable the I<sup>2</sup>S (I2SE = 0)
- For all other combinations of DATLEN and CHLEN, whatever the audio mode selected through the I2SSTD bits, carry out the following sequence to switch off the I<sup>2</sup>S:
  - a) Wait for the second to last RXNE = 1 (n – 1)
  - b) Then wait one I<sup>2</sup>S clock cycle (using a software loop)
  - c) Disable the I<sup>2</sup>S (I2SE = 0)

*Note:* The BSY flag is kept low during transfers.

### 26.6.5 I<sup>2</sup>S slave mode

For the slave configuration, the I<sup>2</sup>S can be configured in transmission or reception mode. The operating mode is following mainly the same rules as described for the I<sup>2</sup>S master configuration. In slave mode, there is no clock to be generated by the I<sup>2</sup>S interface. The

clock and WS signals are input from the external master connected to the I<sup>2</sup>S interface. There is then no need, for the user, to configure the clock.

The configuration steps to follow are listed below:

1. Set the I2SMOD bit in the SPIx\_I2SCFGR register to select I<sup>2</sup>S mode and choose the I<sup>2</sup>S standard through the I2SSTD[1:0] bits, the data length through the DATLEN[1:0] bits and the number of bits per channel for the frame configuring the CHLEN bit. Select also the mode (transmission or reception) for the slave through the I2SCFG[1:0] bits in SPIx\_I2SCFGR register.
2. If needed, select all the potential interrupt sources and the DMA capabilities by writing the SPIx\_CR2 register.
3. The I2SE bit in SPIx\_I2SCFGR register must be set.

### Transmission sequence

The transmission sequence begins when the external master device sends the clock and when the NSS\_WS signal requests the transfer of data. The slave has to be enabled before the external master starts the communication. The I<sup>2</sup>S data register has to be loaded before the master initiates the communication.

For the I<sup>2</sup>S, MSB justified and LSB justified modes, the first data item to be written into the data register corresponds to the data for the left channel. When the communication starts, the data are transferred from the Tx buffer to the shift register. The TXE flag is then set in order to request the right channel data to be written into the I<sup>2</sup>S data register.

The CHSIDE flag indicates which channel is to be transmitted. Compared to the master transmission mode, in slave mode, CHSIDE is sensitive to the WS signal coming from the external master. This means that the slave needs to be ready to transmit the first data before the clock is generated by the master. WS assertion corresponds to left channel transmitted first.

**Note:** *The I2SE has to be written at least two PCLK cycles before the first clock of the master comes on the CK line.*

The data half-word is parallel-loaded into the 16-bit shift register (from the internal bus) during the first bit transmission, and then shifted out serially to the MOSI/SD pin MSB first. The TXE flag is set after each transfer from the Tx buffer to the shift register and an interrupt is generated if the TXIE bit in the SPIx\_CR2 register is set.

Note that the TXE flag should be checked to be at 1 before attempting to write the Tx buffer.

For more details about the write operations depending on the I<sup>2</sup>S standard mode selected, refer to [Section 26.6.2: Supported audio protocols](#).

To secure a continuous audio data transmission, it is mandatory to write the SPIx\_DR register with the next data to transmit before the end of the current transmission. An underrun flag is set and an interrupt may be generated if the data are not written into the SPIx\_DR register before the first clock edge of the next data communication. This indicates to the software that the transferred data are wrong. If the ERRIE bit is set into the SPIx\_CR2 register, an interrupt is generated when the UDR flag in the SPIx\_SR register goes high. In this case, it is mandatory to switch off the I<sup>2</sup>S and to restart a data transfer starting from the left channel.

To switch off the I<sup>2</sup>S, by clearing the I2SE bit, it is mandatory to wait for TXE = 1 and BSY = 0.

### Reception sequence

The operating mode is the same as for the transmission mode except for the point 1 (refer to the procedure described in [Section 26.6.5: I<sup>2</sup>S slave mode](#)), where the configuration should set the master reception mode using the I2SCFG[1:0] bits in the SPIx\_I2SCFGR register.

Whatever the data length or the channel length, the audio data are received by 16-bit packets. This means that each time the RX buffer is full, the RXNE flag in the SPIx\_SR register is set and an interrupt is generated if the RXNEIE bit is set in the SPIx\_CR2 register. Depending on the data length and channel length configuration, the audio value received for a right or left channel may result from one or two receptions into the RX buffer.

The CHSIDE flag is updated each time data are received to be read from the SPIx\_DR register. It is sensitive to the external WS line managed by the external master component.

Clearing the RXNE bit is performed by reading the SPIx\_DR register.

For more details about the read operations depending the I<sup>2</sup>S standard mode selected, refer to [Section 26.6.2: Supported audio protocols](#).

If data are received while the preceding received data have not yet been read, an overrun is generated and the OVR flag is set. If the bit ERRIE is set in the SPIx\_CR2 register, an interrupt is generated to indicate the error.

To switch off the I<sup>2</sup>S in reception mode, I2SE has to be cleared immediately after receiving the last RXNE = 1.

*Note:* *The external master components should have the capability of sending/receiving data in 16-bit or 32-bit packets via an audio channel.*

## 26.6.6 I<sup>2</sup>S status flags

Three status flags are provided for the application to fully monitor the state of the I<sup>2</sup>S bus.

### Busy flag (BSY)

The BSY flag is set and cleared by hardware (writing to this flag has no effect). It indicates the state of the communication layer of the I<sup>2</sup>S.

When BSY is set, it indicates that the I<sup>2</sup>S is busy communicating. There is one exception in master receive mode (I2SCFG = 11) where the BSY flag is kept low during reception.

The BSY flag is useful to detect the end of a transfer if the software needs to disable the I<sup>2</sup>S. This avoids corrupting the last transfer. For this, the procedure described below must be strictly respected.

The BSY flag is set when a transfer starts, except when the I<sup>2</sup>S is in master receiver mode.

The BSY flag is cleared:

- When a transfer completes (except in master transmit mode, in which the communication is supposed to be continuous)
- When the I<sup>2</sup>S is disabled

When communication is continuous:

- In master transmit mode, the BSY flag is kept high during all the transfers
- In slave mode, the BSY flag goes low for one I<sup>2</sup>S clock cycle between each transfer

**Note:** *Do not use the BSY flag to handle each data transmission or reception. It is better to use the TXE and RXNE flags instead.*

### Tx buffer empty flag (TXE)

When set, this flag indicates that the Tx buffer is empty and the next data to be transmitted can then be loaded into it. The TXE flag is reset when the Tx buffer already contains data to be transmitted. It is also reset when the I<sup>2</sup>S is disabled (I<sup>2</sup>SE bit is reset).

### RX buffer not empty (RXNE)

When set, this flag indicates that there are valid received data in the RX Buffer. It is reset when SPIx\_DR register is read.

### Channel Side flag (CHSIDE)

In transmission mode, this flag is refreshed when TXE goes high. It indicates the channel side to which the data to transfer on SD has to belong. In case of an underrun error event in slave transmission mode, this flag is not reliable and I<sup>2</sup>S needs to be switched off and switched on before resuming the communication.

In reception mode, this flag is refreshed when data are received into SPIx\_DR. It indicates from which channel side data have been received. Note that in case of error (like OVR) this flag becomes meaningless and the I<sup>2</sup>S should be reset by disabling and then enabling it (with configuration if it needs changing).

This flag has no meaning in the PCM standard (for both Short and Long frame modes).

**When the OVR or UDR flag in the SPIx\_SR is set and the ERRIE bit in SPIx\_CR2 is also set, an interrupt is generated. This interrupt can be cleared by reading the SPIx\_SR status register (once the interrupt source has been cleared).**

## 26.6.7 I<sup>2</sup>S error flags

There are three error flags for the I<sup>2</sup>S cell.

### Underrun flag (UDR)

In slave transmission mode this flag is set when the first clock for data transmission appears while the software has not yet loaded any value into SPIx\_DR. It is available when the I2SMOD bit in the SPIx\_I2SCFGR register is set. An interrupt may be generated if the ERRIE bit in the SPIx\_CR2 register is set.

The UDR bit is cleared by a read operation on the SPIx\_SR register.

### Overrun flag (OVR)

This flag is set when data are received and the previous data have not yet been read from the SPIx\_DR register. As a result, the incoming data are lost. An interrupt may be generated if the ERRIE bit is set in the SPIx\_CR2 register.

In this case, the receive buffer contents are not updated with the newly received data from the transmitter device. A read operation to the SPIx\_DR register returns the previous correctly received data. All other subsequently transmitted half-words are lost.

Clearing the OVR bit is done by a read operation on the SPIx\_DR register followed by a read access to the SPIx\_SR register.

#### Frame error flag (FRE)

This flag can be set by hardware only if the I<sup>2</sup>S is configured in Slave mode. It is set if the external master is changing the WS line while the slave is not expecting this change. If the synchronization is lost, the following steps are required to recover from this state and resynchronize the external master device with the I<sup>2</sup>S slave device:

1. Disable the I<sup>2</sup>S.
2. Enable it again when the correct level is detected on the WS line (WS line is high in I<sup>2</sup>S mode or low for MSB- or LSB-justified or PCM modes).

Desynchronization between master and slave devices may be due to noisy environment on the SCK communication clock or on the WS frame synchronization line. An error interrupt can be generated if the ERRIE bit is set. The desynchronization flag (FRE) is cleared by software when the status register is read.

### 26.6.8 I<sup>2</sup>S interrupts

[Table 92](#) provides the list of I<sup>2</sup>S interrupts.

**Table 92. I<sup>2</sup>S interrupt requests**

Interrupt event	Event flag	Enable control bit
Transmit buffer empty flag	TXE	TXEIE
Receive buffer not empty flag	RXNE	RXNEIE
Overrun error	OVR	ERRIE
Underrun error	UDR	
Frame error flag	FRE	

### 26.6.9 DMA features

In I<sup>2</sup>S mode, the DMA works in exactly the same way as it does in SPI mode. There is no difference except that the CRC feature is not available in I<sup>2</sup>S mode since there is no data transfer protection system.

## 26.7 SPI and I<sup>2</sup>S registers

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit). SPI\_DR in addition by can be accessed by 8-bit access.

### 26.7.1 SPI control register 1 (SPIx\_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BIDI MODE	BIDI OE	CRC EN	CRC NEXT	CRCL	RX ONLY	SSM	SSI	LSB FIRST	SPE	BR [2:0]			MSTR	CPOL	CPHA
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

*Bit 15 BIDIMODE:* Bidirectional data mode enable. This bit enables half-duplex communication using common single bidirectional data line. Keep RXONLY bit clear when bidirectional mode is active.

0: 2-line unidirectional data mode selected

1: 1-line bidirectional data mode selected

*Note:* This bit is not used in I<sup>2</sup>S mode.

*Bit 14 BIDIOE:* Output enable in bidirectional mode

This bit combined with the BIDIMODE bit selects the direction of transfer in bidirectional mode

0: Output disabled (receive-only mode)

1: Output enabled (transmit-only mode)

*Note:* 1. In master mode, the MOSI pin is used and in slave mode, the MISO pin is used.

2. This bit is not used in I<sup>2</sup>S mode.

*Bit 13 CRCEN:* Hardware CRC calculation enable

0: CRC calculation disabled

1: CRC calculation Enabled

*Note:* 1. This bit should be written only when SPI is disabled (SPE = '0') for correct operation.

2. This bit is not used in I<sup>2</sup>S mode.

*Bit 12 CRCNEXT:* Transmit CRC next

0: Next transmit value is from Tx buffer

1: Next transmit value is from Tx CRC register

*Note:* 1. This bit has to be written as soon as the last data is written in the SPIx\_DR register.

2. This bit is not used in I<sup>2</sup>S mode.

*Bit 11 CRCL:* CRC length

This bit is set and cleared by software to select the CRC length.

0: 8-bit CRC length

1: 16-bit CRC length

*Note:* 1. This bit should be written only when SPI is disabled (SPE = '0') for correct operation.

2. This bit is not used in I<sup>2</sup>S mode.

**Bit 10 RXONLY:** Receive only mode enabled.

This bit enables simplex communication using a single unidirectional line to receive data exclusively. Keep BIDIMODE bit clear when receive only mode is active. This bit is also useful in a multislave system in which this particular slave is not accessed, the output from the accessed slave is not corrupted.

- 0: Full duplex (Transmit and receive)
- 1: Output disabled (Receive-only mode)

*Note: This bit is not used in I<sup>2</sup>S mode.*

**Bit 9 SSM:** Software slave management

When the SSM bit is set, the NSS pin input is replaced with the value from the SSI bit.

- 0: Software slave management disabled
- 1: Software slave management enabled

*Note: This bit is not used in I<sup>2</sup>S mode and SPI TI mode.*

**Bit 8 SSI:** Internal slave select

This bit has an effect only when the SSM bit is set. The value of this bit is forced onto the NSS pin and the I/O value of the NSS pin is ignored.

*Note: This bit is not used in I<sup>2</sup>S mode and SPI TI mode.*

**Bit 7 LSBFIRST:** Frame format

- 0: MSB transmitted first
- 1: LSB transmitted first

*Note: 1. This bit should not be changed when communication is ongoing.*

*2. This bit is not used in I<sup>2</sup>S mode and SPI TI mode.*

**Bit 6 SPE:** SPI enable

- 0: Peripheral disabled
- 1: Peripheral enabled

*Note: 1. This bit is not used in I<sup>2</sup>S mode.*

*2. When disabling the SPI, follow the procedure described in [Procedure for disabling the SPI on page 650](#).*

**Bits 5:3 BR[2:0]:** Baud rate control

- 000: f<sub>PCLK</sub>/2
- 001: f<sub>PCLK</sub>/4
- 010: f<sub>PCLK</sub>/8
- 011: f<sub>PCLK</sub>/16
- 100: f<sub>PCLK</sub>/32
- 101: f<sub>PCLK</sub>/64
- 110: f<sub>PCLK</sub>/128
- 111: f<sub>PCLK</sub>/256

*Note: 1. These bits should not be changed when communication is ongoing.*

*2. This bit is not used in I<sup>2</sup>S mode.*

Bit 2 **MSTR:** Master selection

- 0: Slave configuration
- 1: Master configuration

*Note:* 1. This bit should not be changed when communication is ongoing.  
2. This bit is not used in I<sup>2</sup>S mode.

Bit1 **CPOL:** Clock polarity

- 0: CK to 0 when idle
- 1: CK to 1 when idle

*Note:* 1. This bit should not be changed when communication is ongoing.  
2. This bit is not used in I<sup>2</sup>S mode and SPI TI mode.

Bit 0 **CPHA:** Clock phase

- 0: The first clock transition is the first data capture edge
- 1: The second clock transition is the first data capture edge

*Note:* 1. This bit should not be changed when communication is ongoing.  
2. This bit is not used in I<sup>2</sup>S mode and SPI TI mode.

## 26.7.2 SPI control register 2 (SPIx\_CR2)

Address offset: 0x04

Reset value: 0x0000

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	LDMA_TX	LDMA_RX	FRXT H	DS [3:0]				TXEIE	RXNEIE	ERRIE	FRF	NSSP	SSOE	TXDMAEN	RXDMAEN	
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 Reserved, must be kept at reset value.

Bit 14 **LDMA\_TX:** Last DMA transfer for transmission

This bit is used in data packing mode, to define if the total number of data to transmit by DMA is odd or even. It has significance only if the TXDMAEN bit in the SPIx\_CR2 register is set and if packing mode is used (data length =< 8-bit and write access to SPIx\_DR is 16-bit wide). It has to be written when the SPI is disabled (SPE = 0 in the SPIx\_CR1 register).

- 0: Number of data to transfer is even
- 1: Number of data to transfer is odd

*Note:* 1. Refer to [Procedure for disabling the SPI on page 650](#) if the CRCEN bit is set.  
2. This bit is not used in I<sup>2</sup>S mode.

Bit 13 **LDMA\_RX:** Last DMA transfer for reception

This bit is used in data packing mode, to define if the total number of data to receive by DMA is odd or even. It has significance only if the RXDMAEN bit in the SPIx\_CR2 register is set and if packing mode is used (data length =< 8-bit and write access to SPIx\_DR is 16-bit wide). It has to be written when the SPI is disabled (SPE = 0 in the SPIx\_CR1 register).

- 0: Number of data to transfer is even
- 1: Number of data to transfer is odd

*Note:* 1. Refer to [Procedure for disabling the SPI on page 650](#) if the CRCEN bit is set.  
2. This bit is not used in I<sup>2</sup>S mode.

**Bit 12 FRXTH:** FIFO reception threshold

This bit is used to set the threshold of the RXFIFO that triggers an RXNE event

0: RXNE event is generated if the FIFO level is greater than or equal to 1/2 (16-bit)

1: RXNE event is generated if the FIFO level is greater than or equal to 1/4 (8-bit)

*Note: This bit is not used in I<sup>2</sup>S mode.*

**Bit 11:8 DS [3:0]:** Data size

These bits configure the data length for SPI transfers:

0000: Not used

0001: Not used

0010: Not used

0011: 4-bit

0100: 5-bit

0101: 6-bit

0110: 7-bit

0111: 8-bit

1000: 9-bit

1001: 10-bit

1010: 11-bit

1011: 12-bit

1100: 13-bit

1101: 14-bit

1110: 15-bit

1111: 16-bit

If software attempts to write one of the “Not used” values, they are forced to the value “0111”(8-bit).

*Note: These bits are not used in I<sup>2</sup>S mode.*

**Bit 7 TXEIE:** Tx buffer empty interrupt enable

0: TXE interrupt masked

1: TXE interrupt not masked. Used to generate an interrupt request when the TXE flag is set.

**Bit 6 RXNEIE:** RX buffer not empty interrupt enable

0: RXNE interrupt masked

1: RXNE interrupt not masked. Used to generate an interrupt request when the RXNE flag is set.

**Bit 5 ERRIE:** Error interrupt enable

This bit controls the generation of an interrupt when an error condition occurs (CRCERR, OVR, MODF in SPI mode, FRE at TI mode and UDR, OVR, and FRE in I<sup>2</sup>S mode).

0: Error interrupt is masked

1: Error interrupt is enabled

**Bit 4 FRF:** Frame format

0: SPI Motorola mode

1 SPI TI mode

*Note: 1. This bit must be written only when the SPI is disabled (SPE=0).*

*2. This bit is not used in I<sup>2</sup>S mode.*

**Bit 3 NSSP:** NSS pulse management

This bit is used in master mode only. It allows the SPI to generate an NSS pulse between two consecutive data when doing continuous transfers. In the case of a single data transfer, it forces the NSS pin high level after the transfer.

It has no meaning if CPHA = '1', or FRF = '1'.

0: No NSS pulse

1: NSS pulse generated

*Note:* 1. This bit must be written only when the SPI is disabled (SPE=0).

2. This bit is not used in I<sup>2</sup>S mode and SPI TI mode.

**Bit 2 SSOE:** SS output enable

0: SS output is disabled in master mode and the SPI interface can work in multimaster configuration

1: SS output is enabled in master mode and when the SPI interface is enabled. The SPI interface cannot work in a multimaster environment.

*Note:* This bit is not used in I<sup>2</sup>S mode and SPI TI mode.

**Bit 1 TXDMAEN:** Tx buffer DMA enable

When this bit is set, a DMA request is generated whenever the TXE flag is set.

0: Tx buffer DMA disabled

1: Tx buffer DMA enabled

**Bit 0 RXDMAEN:** Rx buffer DMA enable

When this bit is set, a DMA request is generated whenever the RXNE flag is set.

0: Rx buffer DMA disabled

1: Rx buffer DMA enabled

### 26.7.3 SPI status register (SPIx\_SR)

Address offset: 0x08

Reset value: 0x0002

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	FTLVL[1:0]		FRLVL[2:0]		FRE	BSY	OVR	MODF	CRC ERR	UDR	CHSIDE	TXE	RXNE
			r	r	r	r	r	r	r	r	rc_w0	r	r	r	r

Bits 15:13 Reserved, must be kept at reset value.

Bits 12:11 **FTLVL[1:0]: FIFO Transmission Level**

These bits are set and cleared by hardware.

00: FIFO empty

01: 1/4 FIFO

10: 1/2 FIFO

11: FIFO full (considered as FULL when the FIFO threshold is greater than 1/2)

*Note: These bits are not used in I<sup>2</sup>S mode.*

Bits 10:9 **FRLVL[1:0]: FIFO reception level**

These bits are set and cleared by hardware.

00: FIFO empty

01: 1/4 FIFO

10: 1/2 FIFO

11: FIFO full

*Note: These bits are not used in I<sup>2</sup>S mode and in SPI receive-only mode while CRC calculation is enabled.*

Bits 8 **FRE: Frame format error**

This flag is used for SPI in TI slave mode and I<sup>2</sup>S slave mode. Refer to [Section 26.3.10: SPI error flags](#) and [Section 26.6.7: I2S error flags](#).

This flag is set by hardware and reset when SPIx\_SR is read by software.

0: No frame format error

1: A frame format error occurred

**Bit 7 BSY: Busy flag**

0: SPI (or I2S) not busy

1: SPI (or I2S) is busy in communication or Tx buffer is not empty

This flag is set and cleared by hardware.

*Note: The BSY flag must be used with caution: refer to [Section 26.3.9: SPI status flags and Procedure for disabling the SPI](#) on page 650.*

Bit 6 **OVR: Overrun flag**

0: No overrun occurred

1: Overrun occurred

This flag is set by hardware and reset by a software sequence. Refer to [I2S error flags on page 679](#) for the software sequence.

Bit 5 **MODF: Mode fault**

0: No mode fault occurred

1: Mode fault occurred

This flag is set by hardware and reset by a software sequence. Refer to [Section 26.4 on page 661](#) for the software sequence.

*Note: This bit is not used in I<sup>2</sup>S mode.*

**Bit 4 CRCERR:** CRC error flag

- 0: CRC value received matches the SPIx\_RXCRCR value
- 1: CRC value received does not match the SPIx\_RXCRCR value

This flag is set by hardware and cleared by software writing 0.

*Note: This bit is not used in I<sup>2</sup>S mode.*

**Bit 3 UDR:** Underrun flag

- 0: No underrun occurred
- 1: Underrun occurred

This flag is set by hardware and reset by a software sequence. Refer to [I2S error flags on page 679](#) for the software sequence.

*Note: This bit is not used in SPI mode.*

**Bit 2 CHSIDE:** Channel side

- 0: Channel Left has to be transmitted or has been received
- 1: Channel Right has to be transmitted or has been received

*Note: This bit is not used in SPI mode. It has no significance in PCM mode.*

**Bit 1 TXE:** Transmit buffer empty

- 0: Tx buffer not empty
- 1: Tx buffer empty

**Bit 0 RXNE:** Receive buffer not empty

- 0: Rx buffer empty
- 1: Rx buffer not empty

### 26.7.4 SPI data register (SPIx\_DR)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DR[15:0]**: Data register

*Data received or to be transmitted*

The data register serves as an interface between the Rx and Tx FIFOs. When the data register is read, RxFIFO is accessed while the write to data register accesses TxFIFO (See [Section 26.3.8: Data transmission and reception procedures](#)).

*Note:* Data is always right-aligned. Unused bits are ignored when writing to the register, and read as zero when the register is read. The Rx threshold setting must always correspond with the read access currently used.

### 26.7.5 SPI CRC polynomial register (SPIx\_CRCPR)

Address offset: 0x10

Reset value: 0x0007

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRCPOLY[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CRCPOLY[15:0]**: CRC polynomial register

This register contains the polynomial for the CRC calculation.

The CRC polynomial (0007h) is the reset value of this register. Another polynomial can be configured as required.

*Note:* The polynomial value should be odd only. No even value is supported.

## 26.7.6 SPI Rx CRC register (SPIx\_RXCRCR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RxCRC[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 15:0 **RXCRC[15:0]**: Rx CRC register

When CRC calculation is enabled, the RxCRC[15:0] bits contain the computed CRC value of the subsequently received bytes. This register is reset when the CRCEN bit in SPIx\_CR1 register is written to 1. The CRC is calculated serially using the polynomial programmed in the SPIx\_CRCPR register.

Only the 8 LSB bits are considered when the data frame format is set to be 8-bit data (CRCL bit in the SPIx\_CR1 is cleared). CRC calculation is done based on any CRC8 standard.

The entire 16-bits of this register are considered when a 16-bit data frame format is selected (CRCL bit in the SPIx\_CR1 register is set). CRC calculation is done based on any CRC16 standard.

*Note: A read to this register when the BSY Flag is set could return an incorrect value.*

*These bits are not used in I<sup>2</sup>S mode.*

## 26.7.7 SPI Tx CRC register (SPIx\_TXCRCR)

Address offset: 0x18

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TxCRC[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 15:0 **TxCRC[15:0]**: Tx CRC register

When CRC calculation is enabled, the TxCRC[7:0] bits contain the computed CRC value of the subsequently transmitted bytes. This register is reset when the CRCEN bit of SPIx\_CR1 is written to 1. The CRC is calculated serially using the polynomial programmed in the SPIx\_CRCPR register.

Only the 8 LSB bits are considered when the data frame format is set to be 8-bit data (CRCL bit in the SPIx\_CR1 is cleared). CRC calculation is done based on any CRC8 standard.

The entire 16-bits of this register are considered when a 16-bit data frame format is selected (CRCL bit in the SPIx\_CR1 register is set). CRC calculation is done based on any CRC16 standard.

*Note: A read to this register when the BSY flag is set could return an incorrect value.*

*These bits are not used in I<sup>2</sup>S mode.*

## 26.7.8 SPIx\_I<sup>2</sup>S configuration register (SPIx\_I2SCFGR)

Address offset: 0x1C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	I2SMOD	I2SE	I2SCFG		PCMSYNC	Res.	I2SSTD		CKPOL	DATLEN		CHLEN

Bits 15:12 Reserved: Forced to 0 by hardware

Bit 11 **I2SMOD**: I<sup>2</sup>S mode selection

- 0: SPI mode is selected
- 1: I<sup>2</sup>S mode is selected

*Note:* This bit should be configured when the SPI or I<sup>2</sup>S is disabled.

Bit 10 **I2SE**: I<sup>2</sup>S enable

- 0: I<sup>2</sup>S peripheral is disabled
- 1: I<sup>2</sup>S peripheral is enabled

*Note:* This bit is not used in SPI mode.

Bits 9:8 **I2SCFG**: I<sup>2</sup>S configuration mode

- 00: Slave - transmit
- 01: Slave - receive
- 10: Master - transmit
- 11: Master - receive

*Note:* These bits should be configured when the I<sup>2</sup>S is disabled.

*They are not used in SPI mode.*

Bit 7 **PCMSYNC**: PCM frame synchronization

- 0: Short frame synchronization
- 1: Long frame synchronization

*Note:* This bit has a meaning only if I2SSTD = 11 (PCM standard is used).

*It is not used in SPI mode.*

Bit 6 Reserved: forced at 0 by hardware

Bits 5:4 **I2SSTD**: I<sup>2</sup>S standard selection

- 00: I<sup>2</sup>S Philips standard.
- 01: MSB justified standard (left justified)
- 10: LSB justified standard (right justified)
- 11: PCM standard

For more details on I<sup>2</sup>S standards, refer to [Section 26.6.2 on page 666](#)

*Note:* For correct operation, these bits should be configured when the I<sup>2</sup>S is disabled.

*They are not used in SPI mode.*

Bit 3 **CKPOL**: Steady state clock polarity

- 0: I<sup>2</sup>S clock steady state is low level
- 1: I<sup>2</sup>S clock steady state is high level

*Note: For correct operation, this bit should be configured when the I<sup>2</sup>S is disabled.*

*It is not used in SPI mode.*

Bits 2:1 **DATLEN**: Data length to be transferred

- 00: 16-bit data length
- 01: 24-bit data length
- 10: 32-bit data length
- 11: Not allowed

*Note: For correct operation, these bits should be configured when the I<sup>2</sup>S is disabled.*

*They are not used in SPI mode.*

Bit 0 **CHLEN**: Channel length (number of bits per audio channel)

- 0: 16-bit wide
- 1: 32-bit wide

The bit write operation has a meaning only if DATLEN = 00 otherwise the channel length is fixed to 32-bit by hardware whatever the value filled in.

*Note: For correct operation, this bit should be configured when the I<sup>2</sup>S is disabled.*

*It is not used in SPI mode.*

### 26.7.9 SPIx\_I<sup>2</sup>S prescaler register (SPIx\_I2SPR)

Address offset: 0x20

Reset value: 0x0002

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	MCKOE	ODD								I2SDIV
						rw	rw								rw

Bits 15:10 Reserved: Forced to 0 by hardware

Bit 9 **MCKOE**: Master clock output enable

- 0: Master clock output is disabled
- 1: Master clock output is enabled

*Note:* This bit should be configured when the I<sup>2</sup>S is disabled. It is used only when the I<sup>2</sup>S is in master mode.

*It is not used in SPI mode.*

Bit 8 **ODD**: Odd factor for the prescaler

- 0: Real divider value is = I2SDIV \*2
- 1: Real divider value is = (I2SDIV \* 2)+1

Refer to [Section 26.6.3 on page 672](#)

*Note:* This bit should be configured when the I<sup>2</sup>S is disabled. It is used only when the I<sup>2</sup>S is in master mode.

*It is not used in SPI mode.*

Bits 7:0 **I2SDIV**: I<sup>2</sup>S linear prescaler

I2SDIV [7:0] = 0 or I2SDIV [7:0] = 1 are forbidden values.

Refer to [Section 26.6.3 on page 672](#)

*Note:* These bits should be configured when the I<sup>2</sup>S is disabled. They are used only when the I<sup>2</sup>S is in master mode.

*They are not used in SPI mode.*

### 26.7.10 SPI/I2S register map

*Table 93* shows the SPI/I2S register map and reset values.

**Table 93. SPI register map and reset values**

Offset	Register	Reset value	31
0x00	<b>SPIx_CR1</b>	Res.	Res.
		Res.	Res.
0x04	<b>SPIx_CR2</b>	Res.	Res.
		Res.	Res.
0x08	<b>SPIx_SR</b>	Res.	Res.
		Res.	Res.
0x0C	<b>SPIx_DR</b>	Res.	Res.
		Res.	Res.
0x10	<b>SPIx_CRCPR</b>	Res.	Res.
		Res.	Res.
0x14	<b>SPIx_RXCRCR</b>	Res.	Res.
		Res.	Res.
0x18	<b>SPIx_TXCRCR</b>	Res.	Res.
		Res.	Res.
0x1C	<b>SPIx_I2SCFGR</b>	Res.	Res.
		Res.	Res.
0x20	<b>SPIx_I2SPR</b>	Res.	Res.
		Res.	Res.
			30
			29
			28
			27
			26
			25
			24
			23
			22
			21
			20
			19
			18
			17
			16
			15
			14
			13
			12
			11
			10
			9
			8
			7
			6
			5
			4
			3
			2
			1
			0

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 27 Touch sensing controller (TSC)

This section applies to medium-density devices only.

### 27.1 Introduction

The touch sensing controller provides a simple solution for adding capacitive sensing functionality to any application. Capacitive sensing technology is able to detect finger presence near an electrode which is protected from direct touch by a dielectric (glass, plastic, ...). The capacitive variation introduced by the finger (or any conductive object) is measured using a proven implementation based on a surface charge transfer acquisition principle.

The touch sensing controller is fully supported by the STM Touch touch sensing firmware library which is free to use and allows touch sensing functionality to be implemented reliably in the end application.

### 27.2 TSC main features

The touch sensing controller has the following main features:

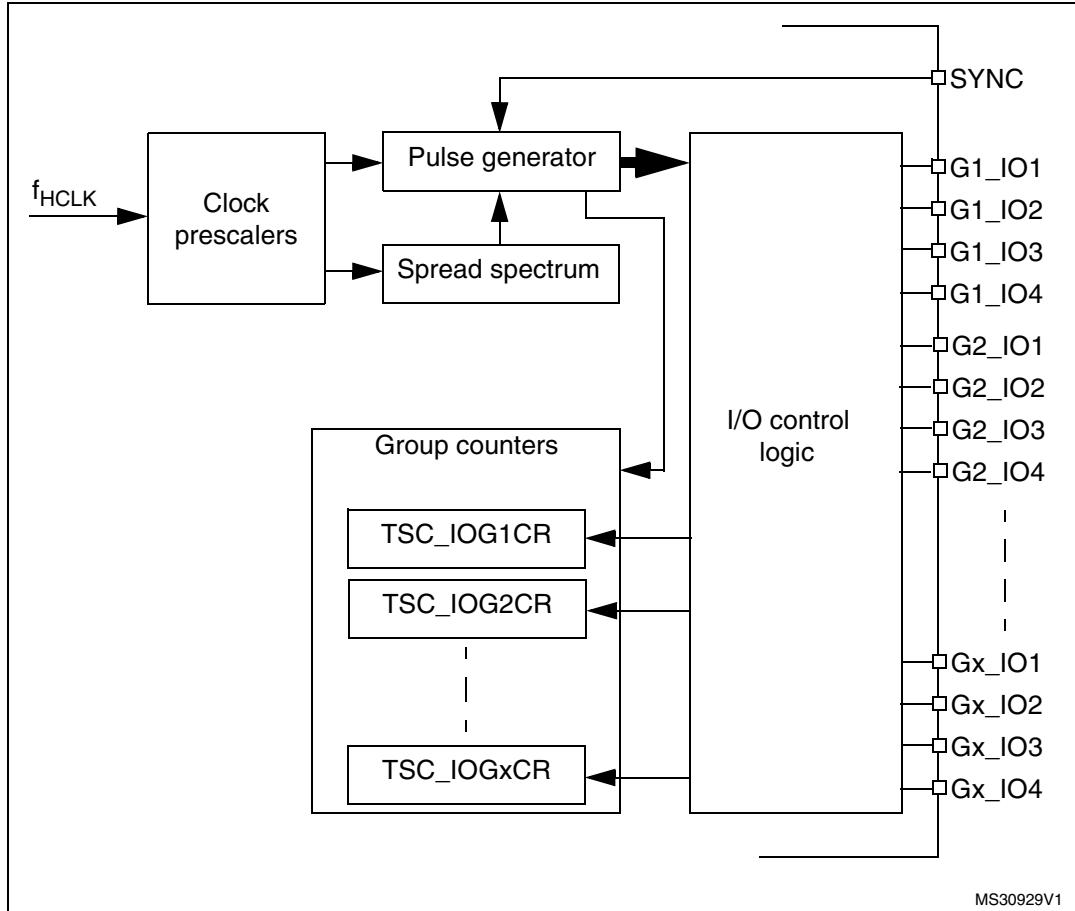
- Proven and robust surface charge transfer acquisition principle
- Supports up to 18 capacitive sensing channels
- Up to 6 capacitive sensing channels can be acquired in parallel offering a very good response time
- Spread spectrum feature to improve system robustness in noisy environments
- Full hardware management of the charge transfer acquisition sequence
- Programmable charge transfer frequency
- Programmable sampling capacitor I/O pin
- Programmable channel I/O pin
- Programmable max count value to avoid long acquisition when a channel is faulty
- Dedicated end of acquisition and max count error flags with interrupt capability
- One sampling capacitor for up to 3 capacitive sensing channels to reduce the system components
- Compatible with proximity, touchkey, linear and rotary touch sensor implementation
- Designed to operate with STM Touch touch sensing firmware library

## 27.3 TSC functional description

### 27.3.1 TSC block diagram

The block diagram of the touch sensing controller is shown in [Figure 290: TSC block diagram](#).

**Figure 290. TSC block diagram**



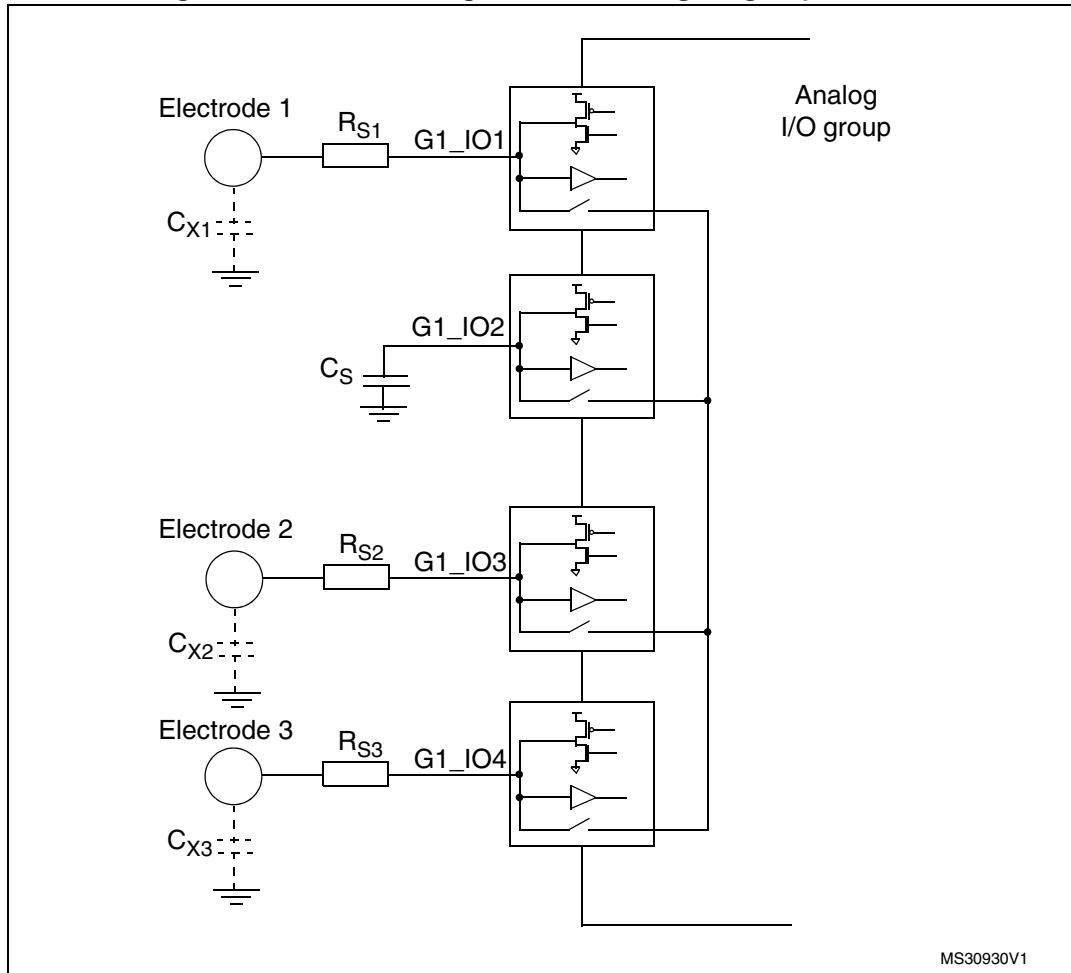
### 27.3.2 Surface charge transfer acquisition overview

The surface charge transfer acquisition is a proven, robust and efficient way to measure a capacitance. It uses a minimum number of external components to operate with a single ended electrode type. This acquisition is designed around an analog I/O group which is composed of four GPIOs (see [Figure 291](#)). Several analog I/O groups are available to allow the acquisition of several capacitive sensing channels simultaneously and to support a larger number of capacitive sensing channels. Within a same analog I/O group, the acquisition of the capacitive sensing channels is sequential.

One of the GPIOs is dedicated to the sampling capacitor  $C_S$ . Only one sampling capacitor I/O per analog I/O group must be enabled at a time.

The remaining GPIOs are dedicated to the electrodes and are commonly called channels. For some specific needs (such as proximity detection), it is possible to simultaneously enable more than one channel per analog I/O group.

**Figure 291. Surface charge transfer analog I/O group structure**



**Note:**  $Gx\_Io_y$  where  $x$  is the analog I/O group number and  $y$  the GPIO number within the selected group.

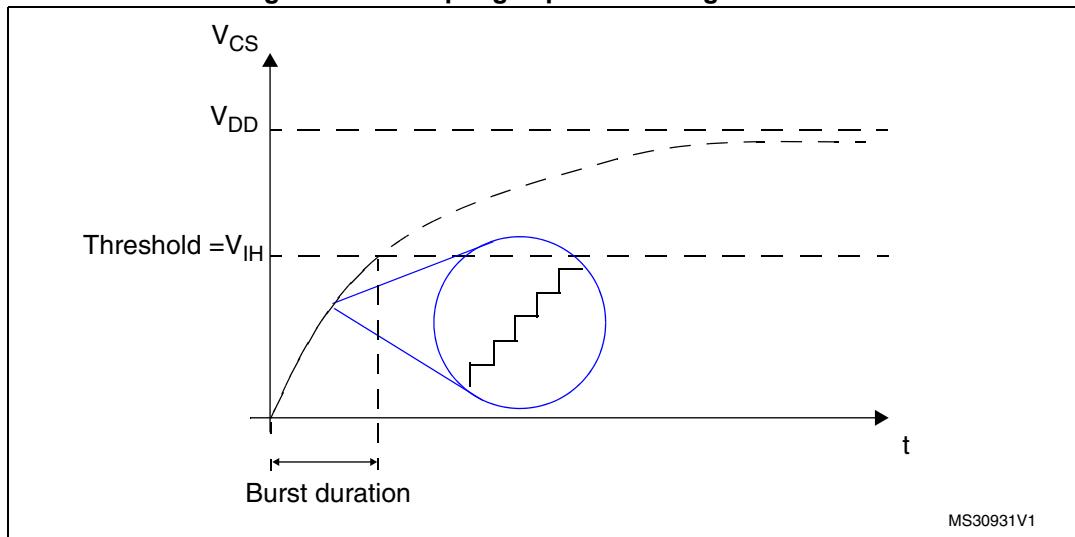
The surface charge transfer acquisition principle consists of charging an electrode capacitance ( $C_X$ ) and transferring a part of the accumulated charge into a sampling capacitor ( $C_S$ ). This sequence is repeated until the voltage across  $C_S$  reaches a given threshold ( $V_{IH}$  in our case). The number of charge transfers required to reach the threshold is a direct representation of the size of the electrode capacitance.

The [Table 94](#) details the charge transfer acquisition sequence of the capacitive sensing channel 1. States 3 to 7 are repeated until the voltage across  $C_S$  reaches the given threshold. The same sequence applies to the acquisition of the other channels. The electrode serial resistor  $R_S$  improves the ESD immunity of the solution.

**Table 94. Acquisition sequence summary**

State	G1_IO1 (electrode)	G1_IO2 (sampling)	G1_IO3 (electrode)	G1_IO4 (electrode)	State description		
#1	Input floating with analog switch closed	Output open-drain low with analog switch closed	Input floating with analog switch closed		Discharge all $C_X$ and $C_S$		
#2	Input floating				Dead time		
#3	Output push-pull high	Input floating				Charge $C_{X1}$	
#4	Input floating				Dead time		
#5	Input floating with analog switch closed	Input floating			Charge transfer from $C_{X1}$ to $C_S$		
#6	Input floating				Dead time		
#7	Input floating				Measure $C_S$ voltage		

The voltage variation over the time on the sampling capacitor  $C_S$  is detailed below:

**Figure 292. Sampling capacitor voltage variation**

### 27.3.3 Reset and clocks

The TSC clock source is the AHB clock ( $f_{HCLK}$ ). Two programmable prescalers are used to generate the pulse generator and the spread spectrum internal clocks:

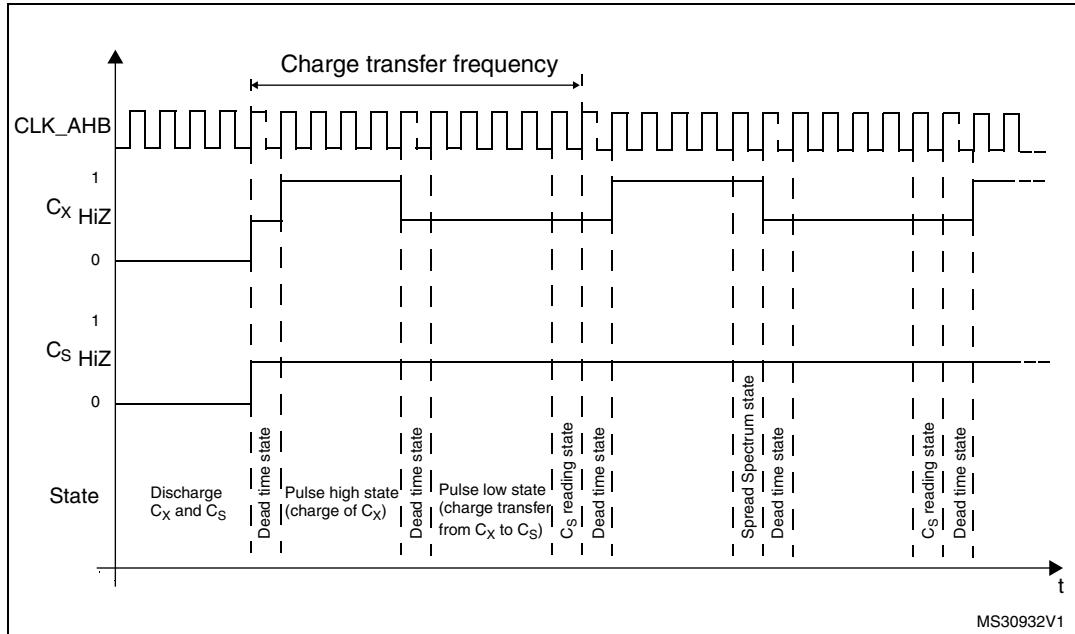
- The pulse generator clock ( $f_{PGCLK}$ ) is defined using the PGPSC[2:0] bits of the TSC\_CR register
- The spread spectrum clock ( $f_{SSCLK}$ ) is defined using the SSPSC bit of the TSC\_CR register

The Reset and Clock Controller (RCC) provides dedicated bits to enable the touch sensing controller clock and to reset this peripheral. For more information, please refer to [the Reset and clock control \(RCC\) section](#).

### 27.3.4 Charge transfer acquisition sequence

An example of a charge transfer acquisition sequence is detailed in [Figure 293](#).

**Figure 293. Charge transfer acquisition sequence**



For higher flexibility, the charge transfer frequency is fully configurable. Both the pulse high state (charge of  $C_X$ ) and the pulse low state (transfer of charge from  $C_X$  to  $C_S$ ) duration can be defined using the CTPH[3:0] and CTPL[3:0] bits in the TSC\_CR register. The standard range for the pulse high and low states duration is 500 ns to 2  $\mu$ s. To ensure a correct measurement of the electrode capacitance, the pulse high state duration must be set to ensure that  $C_X$  is always fully charged.

A dead time where both the sampling capacitor I/O and the channel I/O are in input floating state is inserted between the pulse high and low states to ensure an optimum charge transfer acquisition sequence. This state duration is 2 periods of  $f_{HCLK}$ .

At the end of the pulse high state and if the spread spectrum feature is enabled, a variable number of periods of  $f_{SSCLK}$  are added.

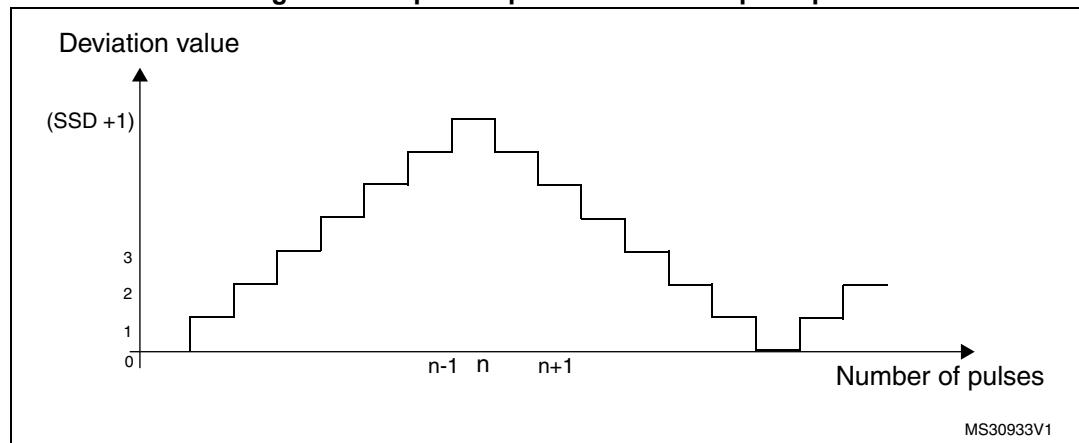
The reading of the sampling capacitor I/O, to determine if the voltage across  $C_S$  has reached the given threshold, is performed at the end of the pulse low state and its duration is one period of  $f_{HCLK}$ .

### 27.3.5 Spread spectrum feature

The spread spectrum feature allows to generate a variation of the charge transfer frequency. This is done to improve the robustness of the charge transfer acquisition in noisy environments and also to reduce the induced emission. The maximum frequency variation is in the range of 10 % to 50 % of the nominal charge transfer period. For instance, for a nominal charge transfer frequency of 250 KHz (4  $\mu$ s), the typical spread spectrum deviation is 10 % (400 ns) which leads to a minimum charge transfer frequency of ~227 KHz.

In practice, the spread spectrum consists of adding a variable number of  $f_{SSCLK}$  periods to the pulse high state using the principle shown below:

**Figure 294. Spread spectrum variation principle**



The table below details the maximum frequency deviation with different  $f_{HCLK}$  settings:

**Table 95. Spread spectrum deviation versus AHB clock frequency**

$f_{HCLK}$	Spread spectrum step	Maximum spread spectrum deviation
24 MHz	41.6 ns	10666.6 ns
48 MHz	20.8 ns	5333.3 ns

The spread spectrum feature can be disabled/enabled using the SSE bit in the TSC\_CR register. The frequency deviation is also configurable to accommodate the device HCLK clock frequency and the selected charge transfer frequency through the SSPSC and SSD[6:0] bits in the TSC\_CR register.

### 27.3.6 Max count error

The max count error prevents long acquisition times resulting from a faulty capacitive sensing channel. It consists of specifying a maximum count value for the analog I/O group counters. This maximum count value is specified using the MCV[2:0] bits in the TSC\_CR register. As soon as an acquisition group counter reaches this maximum value, the on-going acquisition is stopped and the end of acquisition (EOAF bit) and max count error (MCEF bit) flags are both set. An interrupt can also be generated if the corresponding end of acquisition (EOAIE bit) or/and max count error (MCEIE bit) interrupt enable bits are set.

### 27.3.7 Sampling capacitor I/O and channel I/O mode selection

To allow the GPIOs to be controlled by the touch sensing controller, the corresponding alternate function must be enabled through the standard GPIO registers and the GPIOxAFR registers.

The GPIOs modes controlled by the TSC are defined using the TSC\_IOSCR and TSC\_IOCCR register.

When there is no on-going acquisition, all the I/Os controlled by the touch sensing controller are in default state. While an acquisition is on-going, only unused I/Os (neither defined as sampling capacitor I/O nor as channel I/O) are in default state. The IODEF bit in the TSC\_CR register defines the configuration of the I/Os which are in default state. The table below summarizes the configuration of the I/O depending on its mode.

**Table 96. I/O state depending on its mode and IODEF bit value**

IODEF bit	Acquisition status	Unused I/O mode	Electrode I/O mode	Sampling capacitor I/O mode
0 (output push-pull low)	No	Output push-pull low	Output push-pull low	Output push-pull low
0 (output push-pull low)	On-going	Output push-pull low	-	-
1 (input floating)	No	Input floating	Input floating	Input floating
1 (input floating)	On-going	Input floating	-	-

#### Unused I/O mode

An unused I/O corresponds to a GPIO controlled by the TSC peripheral but not defined as an electrode I/O nor as a sampling capacitor I/O.

#### Sampling capacitor I/O mode

To allow the control of the sampling capacitor I/O by the TSC peripheral, the corresponding GPIO must be first set to alternate output open drain mode and then the corresponding Gx\_IOy bit in the TSC\_IOSCR register must be set.

Only one sampling capacitor per analog I/O group must be enabled at a time.

#### Channel I/O mode

To allow the control of the channel I/O by the TSC peripheral, the corresponding GPIO must be first set to alternate output push-pull mode and the corresponding Gx\_IOy bit in the TSC\_IOCCR register must be set.

For proximity detection where a higher equivalent electrode surface is required or to speed-up the acquisition process, it is possible to enable and simultaneously acquire several channels belonging to the same analog I/O group.

#### Note:

*During the acquisition phase and even if the TSC peripheral alternate function is not enabled, as soon as the TSC\_IOSCR or TSC\_IOCCR bit is set, the corresponding GPIO analog switch is automatically controlled by the touch sensing controller.*

### 27.3.8 Acquisition mode

The touch sensing controller offers two acquisition modes:

- Normal acquisition mode: the acquisition starts as soon as the START bit in the TSC\_CR register is set.
- Synchronized acquisition mode: the acquisition is enabled by setting the START bit in the TSC\_CR register but only starts upon the detection of a falling edge or a rising edge and high level on the SYNC input pin. This mode is useful for synchronizing the capacitive sensing channels acquisition with an external signal without additional CPU load.

The GxE bits in the TSC\_IOGCSR registers specify which analog I/O groups are enabled (corresponding counter is counting). The  $C_S$  voltage of a disabled analog I/O group is not monitored and this group does not participate in the triggering of the end of acquisition flag. However, if the disabled analog I/O group contains some channels, they will be pulsed.

When the  $C_S$  voltage of an enabled analog I/O group reaches the given threshold, the corresponding GxS bit of the TSC\_IOGCSR register is set. When the acquisition of all enabled analog I/O groups is complete (all GxS bits of all enabled analog I/O groups are set), the EOAF flag in the TSC\_ISR register is set. An interrupt request is generated if the EOAIE bit in the TSC\_IER register is set.

In the case that a max count error is detected, the on-going acquisition is stopped and both the EOAF and MCEF flags in the TSC\_ISR register are set. Interrupt requests can be generated for both events if the corresponding bits (EOAIE and MCEIE bits of the TSCIER register) are set. Note that when the max count error is detected the remaining GxS bits in the enabled analog I/O groups are not set.

To clear the interrupt flags, the corresponding EOAC and MCEIC bits in the TSC\_ICR register must be set.

The analog I/O group counters are cleared when a new acquisition is started. They are updated with the number of charge transfer cycles generated on the corresponding channel(s) upon the completion of the acquisition.

### 27.3.9 I/O hysteresis and analog switch control

In order to offer a higher flexibility, the touch sensing controller also allows to take the control of the Schmitt trigger hysteresis and analog switch of each Gx\_IOy. This control is available whatever the I/O control mode is (controlled by standard GPIO registers or other peripherals, ...) assuming that the touch sensing controller is enabled. This may be useful to perform a different acquisition sequence or for other purposes.

In order to improve the system immunity, the Schmitt trigger hysteresis of the GPIOs controlled by the TSC must be disabled by resetting the corresponding Gx\_IOy bit in the TSC\_IOHCR register.

### 27.3.10 Capacitive sensing GPIOs

The table below provides an overview of the capacitive sensing GPIOs available on medium-density devices.

**Table 97. Capacitive sensing GPIOs available on medium-density devices**

Pin name	Capacitive sensing group name	Pin name	Capacitive sensing group name
PA0	G1_IO1	PA9	G4_IO1
PA1	G1_IO2	PA10	G4_IO2
PA2	G1_IO3	PA11	G4_IO3
PA3	G1_IO4	PA12	G4_IO4
PA4	G2_IO1	PB3	G5_IO1
PA5	G2_IO2	PB4	G5_IO2
PA6	G2_IO3	PB6	G5_IO3
PA7	G2_IO4	PB7	G5_IO4
PC5	G3_IO1	PB11	G6_IO1
PB0	G3_IO2	PB12	G6_IO2
PB1	G3_IO3	PB13	G6_IO3
PB2	G3_IO4	PB14	G6_IO4

## 27.4 TSC low power modes

**Table 98. Effect of low power modes on TSC**

Mode	Description
Sleep	No effect TSC interrupts cause the device to exit Sleep mode.
Stop	TSC registers are frozen
Standby	The TSC stops its operation until the Stop or Standby mode is exited.

## 27.5 TSC interrupts

**Table 99. Interrupt control bits**

Interrupt event	Enable control bit	Event flag	Clear flag bit	Exit the Sleep mode	Exit the Stop mode	Exit the Standby mode
End of acquisition	EOAIE	EOAIF	EOAIC	yes	no	no
Max count error	MCEIE	MCEIF	MCEIC	yes	no	no

## 27.6 TSC registers

Refer to [Section 1.1 on page 34](#) of the reference manual for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by words (32-bit).

### 27.6.1 TSC control register (TSC\_CR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	
CTPH[3:0]				CTPL[3:0]				SSD[6:0]								SSE
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
SSPSC	PGPSC[2:0]				Res.	Res.	Res.	MCV[2:0]				IODEF	SYNC POL	AM	START	TSCE
rw	rw	rw	rw					rw	rw	rw	rw	rw	rw	rw	rw	rw

#### Bits 31:28 CTPH[3:0]: Charge transfer pulse high

These bits are set and cleared by software. They define the duration of the high state of the charge transfer pulse (charge of  $C_X$ ).

0000: 1x  $t_{PGCLK}$   
0001: 2x  $t_{PGCLK}$   
...

1111: 16x  $t_{PGCLK}$

*Note: These bits must not be modified when an acquisition is on-going.*

#### Bits 27:24 CTPL[3:0]: Charge transfer pulse low

These bits are set and cleared by software. They define the duration of the low state of the charge transfer pulse (transfer of charge from  $C_X$  to  $C_S$ ).

0000: 1x  $t_{PGCLK}$   
0001: 2x  $t_{PGCLK}$   
...

1111: 16x  $t_{PGCLK}$

*Note: These bits must not be modified when an acquisition is on-going.*

#### Bits 23:17 SSD[6:0]: Spread spectrum deviation

These bits are set and cleared by software. They define the spread spectrum deviation which consists in adding a variable number of period at  $f_{SSCLK}$  to the charge transfer pulse high state.

0000000: 1x  $t_{SSCLK}$   
0000001: 2x  $t_{SSCLK}$   
...

1111111: 128x  $t_{SSCLK}$

*Note: These bits must not be modified when an acquisition is on-going.*

#### Bit 16 SSE: Spread spectrum enable

This bit is set and cleared by software to enable/disable the spread spectrum feature.

0: Spread spectrum disabled  
1: Spread spectrum enabled

*Note: This bit must not be modified when an acquisition is on-going.*

Bit 15 **SSPSC**: Spread spectrum prescaler

This bit is set and cleared by software. It selects the AHB clock divider used to generate the spread spectrum clock ( $f_{SSCLK}$ ).

- 0:  $f_{HCLK}$
- 1:  $f_{HCLK} /2$

*Note: This bit must not be modified when an acquisition is on-going.*

Bits 14:12 **PGPSC[2:0]**: pulse generator prescaler

These bits are set and cleared by software. They select the AHB clock divider used to generate the pulse generator clock ( $f_{PGCLK}$ ).

- 000:  $f_{HCLK}$
- 001:  $f_{HCLK} /2$
- 010:  $f_{HCLK} /4$
- 011:  $f_{HCLK} /8$
- 100:  $f_{HCLK} /16$
- 101:  $f_{HCLK} /32$
- 110:  $f_{HCLK} /64$
- 111:  $f_{HCLK} /128$

*Note: These bits must not be modified when an acquisition is on-going.*

## Bits 11:8 Reserved, must be kept at reset value.

Bits 7:5 **MCV[2:0]**: Max count value

These bits are set and cleared by software. They define the maximum number of charge transfer pulses that can be generated before a max count error is generated.

- 000: 255
- 001: 511
- 010: 1023
- 011: 2047
- 100: 4095
- 101: 8191
- 110: 16383
- 111: reserved

*Note: These bits must not be modified when an acquisition is on-going.*

Bit 4 **IODEF**: I/O Default mode

This bit is set and cleared by software. It defines the configuration of all the TSC I/Os when there is no on-going acquisition. When there is an on-going acquisition, it defines the configuration of all unused I/Os (not defined as sampling capacitor I/O or as channel I/O).

- 0: I/Os are forced to output push-pull low
- 1: I/Os are in input floating

*Note: This bit must not be modified when an acquisition is on-going.*

Bit 3 **SYNPOL**: Synchronization pin polarity

This bit is set and cleared by software to select the polarity of the synchronization input pin.

- 0: Falling edge only
- 1: Rising edge and high level

Bit 2 **AM**: Acquisition mode

This bit is set and cleared by software to select the acquisition mode.

- 0: Normal acquisition mode (acquisition starts as soon as START bit is set)
- 1: Synchronized acquisition mode (acquisition starts if START bit is set and when the selected signal is detected on the SYNC input pin)

*Note: This bit must not be modified when an acquisition is on-going.*

Bit 1 **START**: Start a new acquisition

This bit is set by software to start a new acquisition. It is cleared by hardware as soon as the acquisition is complete or by software to cancel the on-going acquisition.

- 0: Acquisition not started
- 1: Start a new acquisition

Bit 0 **TSC\_E**: Touch sensing controller enable

This bit is set and cleared by software to enable/disable the touch sensing controller.

- 0: Touch sensing controller disabled
- 1: Touch sensing controller enabled

*Note: When the touch sensing controller is disabled, TSC registers settings have no effect.*

**27.6.2 TSC interrupt enable register (TSC\_IER)**

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.														
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MCEIE	EOAIE													
														rw	rw

Bits 31:2 Reserved, must be kept at reset value.

Bit 1 **MCEIE**: Max count error interrupt enable

This bit is set and cleared by software to enable/disable the max count error interrupt.

- 0: Max count error interrupt disabled
- 1: Max count error interrupt enabled

Bit 0 **EOAIE**: End of acquisition interrupt enable

This bit is set and cleared by software to enable/disable the end of acquisition interrupt.

- 0: End of acquisition interrupt disabled
- 1: End of acquisition interrupt enabled

**27.6.3 TSC interrupt clear register (TSC\_ICR)**

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.														
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MCEIC	EOAIC													
														rw	rw

Bits 31:2 Reserved, must be kept at reset value.

**Bit 1 MCEIC:** Max count error interrupt clear

This bit is set by software to clear the max count error flag and it is cleared by hardware when the flag is reset. Writing a '0' has no effect.

0: No effect

1: Clears the corresponding MCEF of the TSC\_ISR register

**Bit 0 EOAC:** End of acquisition interrupt clear

This bit is set by software to clear the end of acquisition flag and it is cleared by hardware when the flag is reset. Writing a '0' has no effect.

0: No effect

1: Clears the corresponding EOAF of the TSC\_ISR register

#### 27.6.4 TSC interrupt status register (TSC\_ISR)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MCEF	EOAF													
														rw	rw

Bits 31:2 Reserved, must be kept at reset value.

**Bit 1 MCEF:** Max count error flag

This bit is set by hardware as soon as an analog I/O group counter reaches the max count value specified. It is cleared by software writing 1 to the bit MCEIC of the TSC\_ICR register.

0: No max count error (MCE) detected

1: Max count error (MCE) detected

**Bit 0 EOAF:** End of acquisition flag

This bit is set by hardware when the acquisition of all enabled group is complete (all GxS bits of all enabled analog I/O groups are set or when a max count error is detected). It is cleared by software writing 1 to the bit EOAC of the TSC\_ICR register.

0: Acquisition is on-going or not started

1: Acquisition is complete

### 27.6.5 TSC I/O hysteresis control register (TSC\_IOHCR)

Address offset: 0x10

Reset value: 0xFFFF FFFF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	G6_IO4	G6_IO3	G6_IO2	G6_IO1	G5_IO4	G5_IO3	G5_IO2	G5_IO1							
								rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
G4_IO4	G4_IO3	G4_IO2	G4_IO1	G3_IO4	G3_IO3	G3_IO2	G3_IO1	G2_IO4	G2_IO3	G2_IO2	G2_IO1	G1_IO4	G1_IO3	G1_IO2	G1_IO1
rw															

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:0 **Gx\_IOy**: Gx\_IOy Schmitt trigger hysteresis mode

These bits are set and cleared by software to enable/disable the Gx\_IOy Schmitt trigger hysteresis.

0: Gx\_IOy Schmitt trigger hysteresis disabled

1: Gx\_IOy Schmitt trigger hysteresis enabled

*Note:* These bits control the I/O Schmitt trigger hysteresis whatever the I/O control mode is (even if controlled by standard GPIO registers).

### 27.6.6 TSC I/O analog switch control register (TSC\_IOASCR)

Address offset: 0x18

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	G6_IO4	G6_IO3	G6_IO2	G6_IO1	G5_IO4	G5_IO3	G5_IO2	G5_IO1							
								rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
G4_IO4	G4_IO3	G4_IO2	G4_IO1	G3_IO4	G3_IO3	G3_IO2	G3_IO1	G2_IO4	G2_IO3	G2_IO2	G2_IO1	G1_IO4	G1_IO3	G1_IO2	G1_IO1
rw															

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:0 **Gx\_IOy**: Gx\_IOy analog switch enable

These bits are set and cleared by software to enable/disable the Gx\_IOy analog switch.

0: Gx\_IOy analog switch disabled (opened)

1: Gx\_IOy analog switch enabled (closed)

*Note:* These bits control the I/O analog switch whatever the I/O control mode is (even if controlled by standard GPIO registers).

### 27.6.7 TSC I/O sampling control register (TSC\_IOSCR)

Address offset: 0x20

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	G6_IO4	G6_IO3	G6_IO2	G6_IO1	G5_IO4	G5_IO3	G5_IO2	G5_IO1							
								rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
G4_IO4	G4_IO3	G4_IO2	G4_IO1	G3_IO4	G3_IO3	G3_IO2	G3_IO1	G2_IO4	G2_IO3	G2_IO2	G2_IO1	G1_IO4	G1_IO3	G1_IO2	G1_IO1
rw															

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:0 **Gx\_IOy**: Gx\_IOy sampling mode

These bits are set and cleared by software to configure the Gx\_IOy as a sampling capacitor I/O. Only one I/O per analog I/O group must be defined as sampling capacitor.

0: Gx\_IOy unused

1: Gx\_IOy used as sampling capacitor

*Note: These bits must not be modified when an acquisition is on-going.*

*During the acquisition phase and even if the TSC peripheral alternate function is not enabled, as soon as the TSC\_IOSCR bit is set, the corresponding GPIO analog switch is automatically controlled by the touch sensing controller.*

### 27.6.8 TSC I/O channel control register (TSC\_IOCCR)

Address offset: 0x28

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	G6_IO4	G6_IO3	G6_IO2	G6_IO1	G5_IO4	G5_IO3	G5_IO2	G5_IO1							
								rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
G4_IO4	G4_IO3	G4_IO2	G4_IO1	G3_IO4	G3_IO3	G3_IO2	G3_IO1	G2_IO4	G2_IO3	G2_IO2	G2_IO1	G1_IO4	G1_IO3	G1_IO2	G1_IO1
rw															

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:0 **Gx\_IOy**: Gx\_IOy channel mode

These bits are set and cleared by software to configure the Gx\_IOy as a channel I/O.

0: Gx\_IOy unused

1: Gx\_IOy used as channel

*Note: These bits must not be modified when an acquisition is on-going.*

*During the acquisition phase and even if the TSC peripheral alternate function is not enabled, as soon as the TSC\_IOCCR bit is set, the corresponding GPIO analog switch is automatically controlled by the touch sensing controller.*

### 27.6.9 TSC I/O group control status register (TSC\_IOGCSR)

Address offset: 0x30

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	G6S	G5S	G4S	G3S	G2S	G1S									
										r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	G6E	G5E	G4E	G3E	G2E	G1E									
										rw	rw	rw	rw	rw	rw

Bits 31:22 Reserved, must be kept at reset value.

Bits 21:16 **GxS**: Analog I/O group x status

These bits are set by hardware when the acquisition on the corresponding enabled analog I/O group x is complete. They are cleared by hardware when a new acquisition is started.

0: Acquisition on analog I/O group x is on-going or not started

1: Acquisition on analog I/O group x is complete

*Note: When a max count error is detected the remaining GxS bits of the enabled analog I/O groups are not set.*

Bits 15:6 Reserved, must be kept at reset value.

Bits 5:0 **GxE**: Analog I/O group x enable

These bits are set and cleared by software to enable/disable the acquisition (counter is counting) on the corresponding analog I/O group x.

0: Acquisition on analog I/O group x disabled

1: Acquisition on analog I/O group x enabled

### 27.6.10 TSC I/O group x counter register (TSC\_IOGxCR) (x=1..6)

Address offset: 0x30 + 0x04 x Analog I/O group number

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	CNT[13:0]													
		r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:14 Reserved, must be kept at reset value.

Bits 13:0 **CNT[13:0]**: Counter value

These bits represent the number of charge transfer cycles generated on the analog I/O group x to complete its acquisition (voltage across  $C_S$  has reached the threshold).

## 27.6.11 TSC register map

**Table 100. TSC register map and reset values**

**Table 100. TSC register map and reset values (continued)**

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 28 HDMI-CEC controller (HDMI-CEC)

This section applies to medium-density devices only.

### 28.1 Introduction

Consumer Electronics Control (CEC) is part of HDMI (High-Definition Multimedia Interface) standard as *appendix supplement 1*.

It consists of a protocol that provides high-level control functions between all of the various audiovisual products in a user environment. It has been specified to operate at low speeds with minimal processing and memory overhead.

The HDMI-CEC controller provides hardware support for this protocol.

## 28.2 HDMI-CEC controller main features

- Complies with HDMI-CEC v1.4 Specification
- 32 KHz CEC kernel with 2 clock source options
  - HSI RC oscillator with fixed prescaler (HSI/244)
  - LSE oscillator
- Works in Stop mode for ultra low-power applications
- Configurable Signal Free Time before start of transmission
  - Automatic by hardware, according to CEC state and transmission history
  - Fixed by software (7 timing options)
- Configurable Peripheral Address (OAR)
- Supports Listen mode
  - Enables reception of CEC messages sent to destination address different from OAR without interfering with the CEC line
- Configurable Rx-tolerance margin
  - Standard tolerance
  - Extended tolerance
- Receive-Error detection
  - Bit rising error (BRE), with optional stop of reception (BRESTP)
  - Short bit period error (SBPE)
  - Long bit period error (LBPE)
- Configurable error-bit generation
  - on BRE detection (BREGEN)
  - on LBPE detection (LBPEGEN)
  - always generated on SBPE detection
- Transmission error detection (TXERR)
- Arbitration Lost detection (ARBLST)
  - With automatic transmission retry
- Transmission underrun detection (TXUDR)
- Reception overrun detection (RXOVR)

## 28.3 HDMI-CEC functional description

### 28.3.1 HDMI-CEC pin

The CEC bus consists of a single bidirectional line that is used to transfer data in and out of the device. It is connected to a +3.3 V supply voltage via a 27 kΩ pull-up resistor. The output stage of the device must have an open-drain or open-collector to allow a wired-and connection.

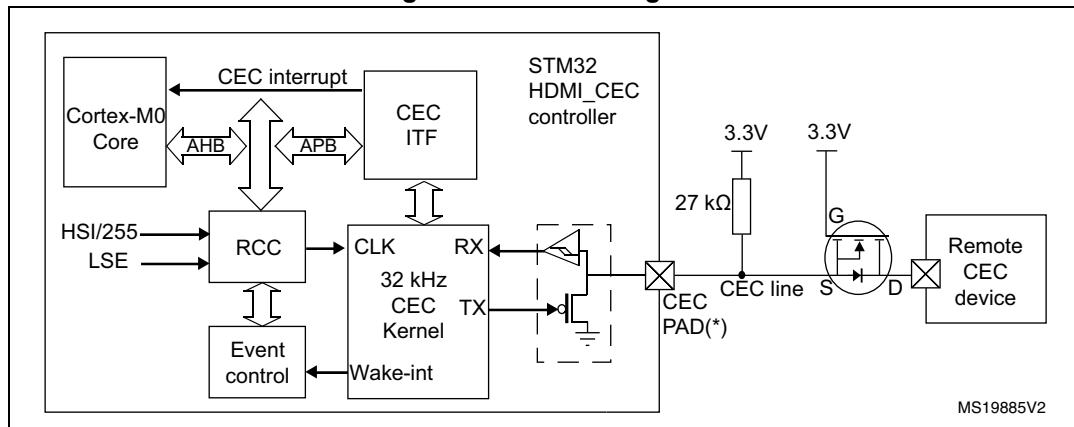
The HDMI-CEC controller manages the CEC bidirectional line as an alternate function of a standard GPIO, assuming that it is configured as Alternate Function Open Drain. The 27 kΩ pull-up must be added externally to the STM32.

To not interfere with the CEC bus when the application power is removed, it is mandatory to isolate the CEC pin from the bus in such conditions. This could be done by using a MOS transistor, as shown on [Figure 295](#).

Table 101. HDMI pin

Name	Signal type	Remarks
CEC	bidirectional	two states: 1 = high impedance 0 = low impedance A $27\text{ k}\Omega$ must be added externally.

Figure 295. Block diagram



1. GPIO configured as output open-drain alternate function
2. When configured as output open-drain alternate function, the schmit trigger is still activated.

### 28.3.2 Message description

All transactions on the CEC line consist of an initiator and one or more followers. The initiator is responsible for sending the message structure and the data. The follower is the recipient of any data and is responsible for setting any acknowledgement bits.

A message is conveyed in a single frame which consists of a start bit followed by a header block and optionally an opcode and a variable number of operand blocks.

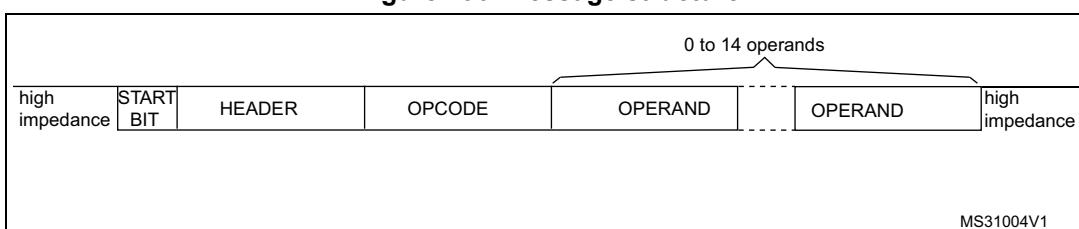
All these blocks are made of a 8-bit payload - most significant bit is transmitted first - followed by an end of message (EOM) bit and an acknowledge (ACK) bit.

The EOM bit is set in the last block of a message and kept reset in all others. In the event that a message contains additional blocks after an EOM is indicated, those additional blocks should be ignored. The EOM bit may be set in the header block to 'ping' other devices, to make sure they are active.

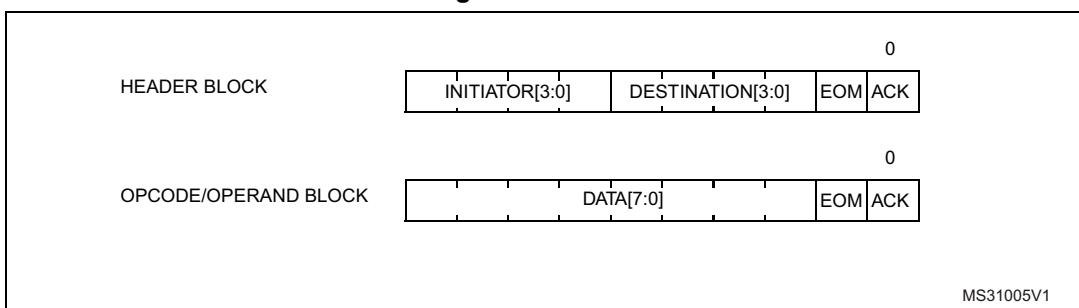
The acknowledge bit is always set to high impedance by the initiator so that it can be driven low either by the follower which has read its own address in the header or by the follower which needs to reject a broadcast message.

The header consists of the source logical address field, and the destination logical address field. Note that the special address 0xF is used for broadcast messages.

**Figure 296. Message structure**



**Figure 297. Blocks**

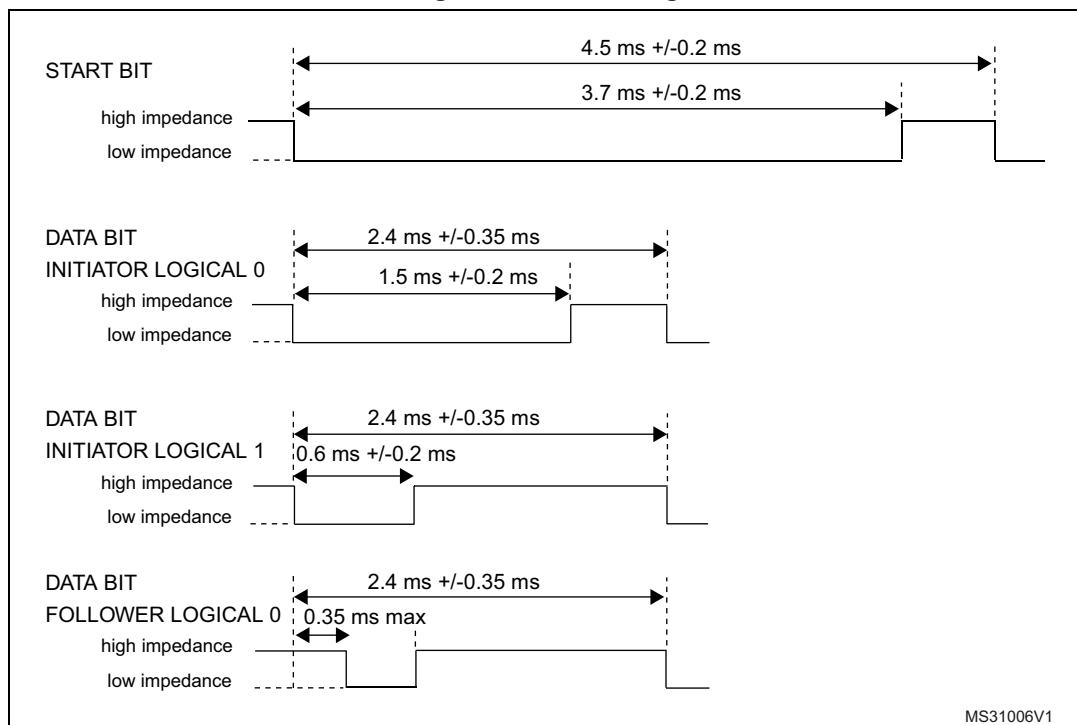


### 28.3.3 Bit timing

The format of the start bit is unique and identifies the start of a message. It should be validated by its low duration and its total duration.

All remaining data bits in the message, after the start bit, have consistent timing. The high to low transition at the end of the data bit is the start of the next data bit except for the final bit where the CEC line remains high.

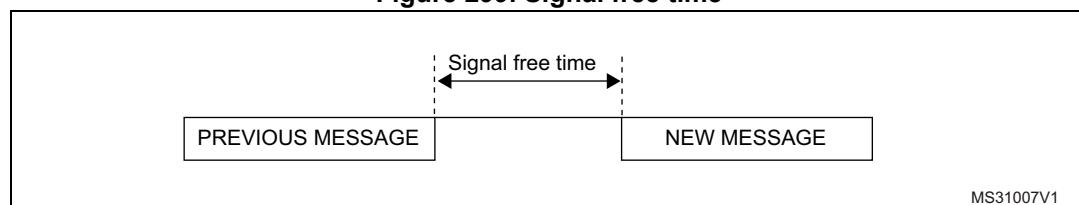
Figure 298. Bit timings



## 28.4 Arbitration

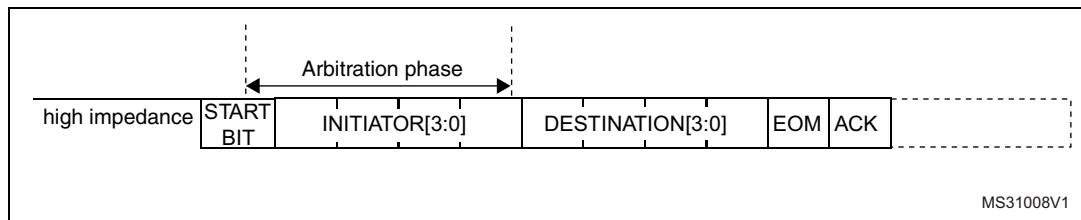
All devices that have to transmit - or retransmit - a message onto the CEC line have to ensure that it has been inactive for a number of bit periods. This signal free time is defined as the time starting from the final bit of the previous frame and depends on the initiating device and the current status as shown in the table below.

Figure 299. Signal free time



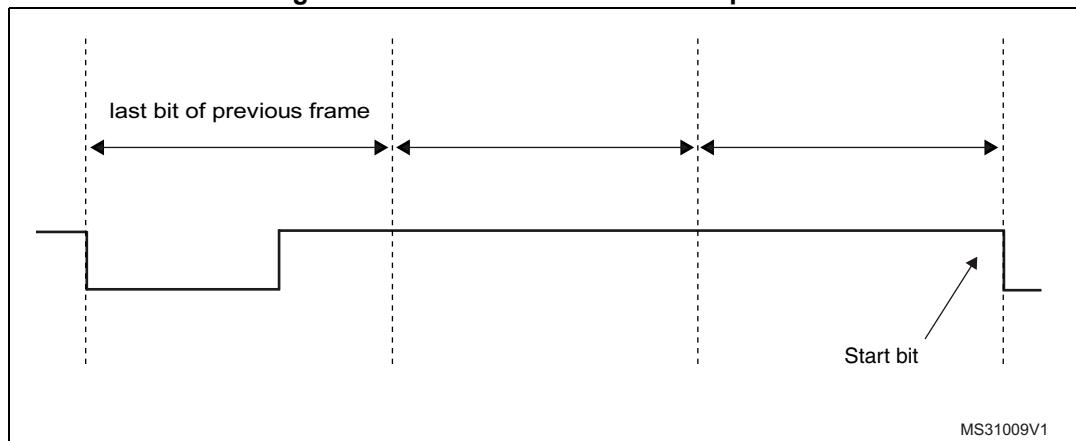
Since only one initiator is allowed at any one time, an arbitration mechanism is provided to avoid conflict when more than one initiator begins transmitting at the same time.

CEC line arbitration commences with the leading edge of the start bit and continues until the end of the initiator address bits within the header block. During this period, the initiator shall monitor the CEC line, if whilst driving the line to high impedance it reads it back to 0, it then assumes it has lost arbitration, stops transmitting and becomes a follower.

**Figure 300. Arbitration phase**

MS31008V1

The [Figure 301](#) shows an example for a SFT of three nominal bit periods

**Figure 301. SFT of three nominal bit periods**

MS31009V1

A configurable time window is counted before starting the transmission.

In the SFT=0x0 configuration the HDMI-CEC device performs automatic SFT calculation ensuring compliancy to the HDMI-CEC Standard:

- 2.5 data bit periods if the CEC is the last bus initiator with unsuccessful transmission
- 4 data bit periods if the CEC is the new bus initiator
- 6 data bit periods if the CEC is the last bus initiator with successful transmission

This is done to guarantee the maximum priority to a failed transmission and the lowest one to the last initiator that completed successfully its transmission.

Otherwise there is the possibility to configure the SFTbits to count a fixed timing value. Possible values are 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 6.5 data bit periods.

#### 28.4.1 SFT option bit

In case of SFTOPT=0 configuration SFT starts being counted when the start-of-transmission command is set by software (TXSOM=1).

In case of SFTOPT=1, SFT starts automatically being counted by the HDMI-CEC device when a bus-idle or line error condition is detected. If the SFT timer is completed at the time TXSOM command is set then transmission starts immediately without latency. If the SFT

timer is still running instead, the system waits until the timer elapses before transmission can start.

SFTOPT=1 bus-event condition starting the SFT timer is detected in the following cases:

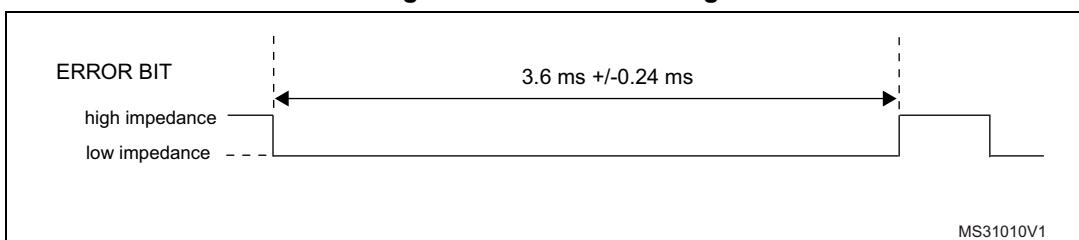
- In case of a regular end of transmission/reception, when TXEND/RXEND bits are set at the minimum nominal data bit duration of the last bit in the message (ACK bit).
- In case of a transmission error detection, SFT timer starts when the TXERR transmission error is detected (TXERR=1).
- In case of a missing acknowledge from the CEC follower, the SFT timer starts when the TXACKE bit is set, that is at the nominal sampling time of the ACK bit.
- In case of a transmission underrun error, the SFT timer starts when the TXUDR bit is set at the end of the ACK bit.
- In case of a receive error detection implying reception abort, the SFT timer starts at the same time the error is detected. If an error bit is generated, then SFT starts being counted at the end of the error bit.
- In case of a wrong start bit or of any un-codified low impedance bus state from idle, the SFT timer is restarted as soon as the bus comes back to hi-impedance idleness.

## 28.5 Error handling

### 28.5.1 Bit error

If a data bit - excluding the start bit - is considered invalid, the follower is expected to notify such error by generating a low bit period on the CEC line of 1.4 to 1.6 times the nominal data bit period, i.e. 3.6 ms nominally.

**Figure 302. Error bit timing**



### 28.5.2 Message error

A message is considered lost and therefore may be retransmitted under the following conditions:

- a message is not acknowledged in a directly addressed message
- a message is negatively acknowledged in a broadcast message
- a low impedance is detected on the CEC line while it is not expected (line error)

Three kinds of error flag can be detected when the CEC interface is receiving a data bit:

### 28.5.3 Bit Rising Error (BRE)

BRE (bit rising error): is set when a bit rising edge is detected outside the windows where it is expected (see [Figure 303](#)). BRE flag also generates a CEC interrupt if the BREIE=1.

In the case of a BRE detection, the message reception can be stopped according to the BRESTP bit value and an error bit can be generated if BREGEN bit is set.

When BRE is detected in a broadcast message with BRESTP=1 an error bit is generated even if BREGEN=0 to enforce initiator's retry of the failed transmission. Error bit generation can be disabled by configuring BREGEN=0, BRDNOGEN=1.

#### 28.5.4 Short Bit Period Error (SBPE)

SBPE is set when a bit falling edge is detected earlier than expected (see [Figure 303](#)). SBPE flag also generates a CEC interrupt if the SBPEIE=1.

An error bit is always generated on the line in case of a SBPE error detection. An Error Bit is not generated upon SBPE detection only for the following cases:

- Broadcast message is received containing SBPE
- Listen mode is set (LSTN=1)
- BRDNOGEN=1

#### 28.5.5 Long Bit Period Error (LBPE)

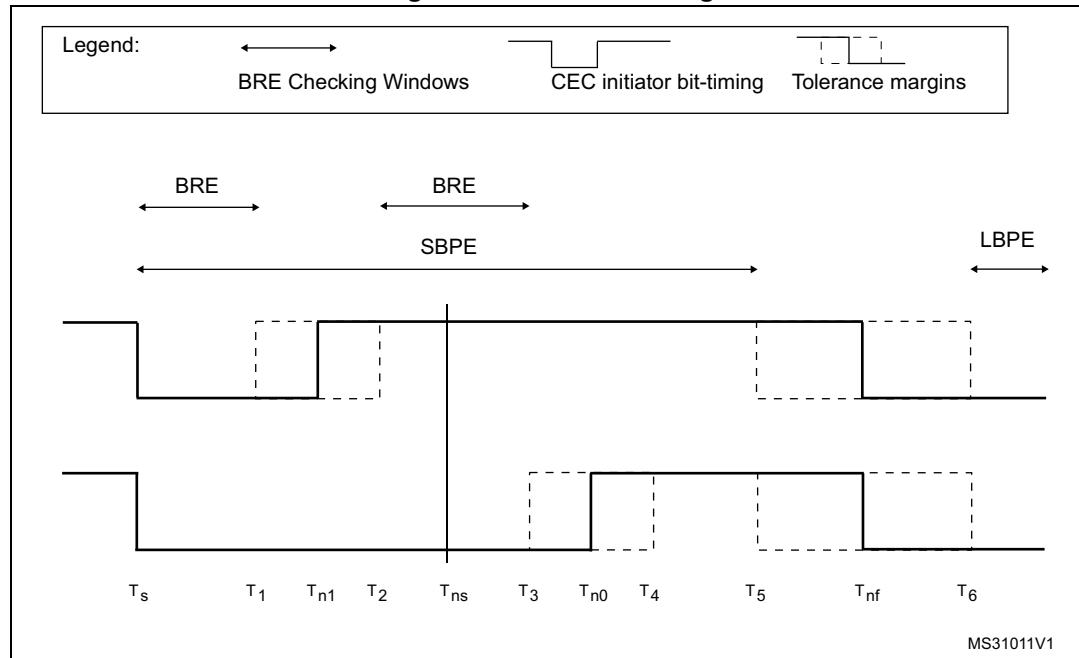
LBPE is set when a bit falling edge is not detected in a valid window (see [Figure 303](#)). LBPE flag also generates a CEC interrupt if the LBPEIE=1.

LBPE always stops the reception, an error bit is generated on the line when LBPEGEN bit is set.

When LBPE is detected in a broadcast message an error bit is generated even if LBPEGEN=0 to enforce initiator's retry of the failed transmission. Error bit generation can be disabled by configuring LBPEGEN=0, BRDNOGEN=1.

*Note:* The BREGEN=1, BRESTP=0 configuration must be avoided

**Figure 303. Error handling**



**Table 102. Error handling timing parameters**

Time	RXTOL	ms	Description
T <sub>s</sub>	x	0	Bit start event.
T <sub>1</sub>	1	0.3	The earliest time for a low - high transition when indicating a logical 1.
	0	0.4	
T <sub>n1</sub>	x	0.6	The nominal time for a low - high transition when indicating a logical 1.
T <sub>2</sub>	0	0.8	The latest time for a low - high transition when indicating a logical 1.
	1	0.9	
T <sub>ns</sub>	x	1.05	Nominal sampling time.
T <sub>3</sub>	1	1.2	The earliest time a device is permitted return to a high impedance state (logical 0).
	0	1.3	
T <sub>n0</sub>	x	1.5	The nominal time a device is permitted return to a high impedance state (logical 0).
T <sub>4</sub>	0	1.7	The latest time a device is permitted return to a high impedance state (logical 0).
	1	1.8	
T <sub>5</sub>	1	1.85	The earliest time for the start of a following bit.
	0	2.05	
T <sub>nf</sub>	x	2.4	The nominal data bit period.
T <sub>6</sub>	0	2.75	The latest time for the start of a following bit.
	1	2.95	

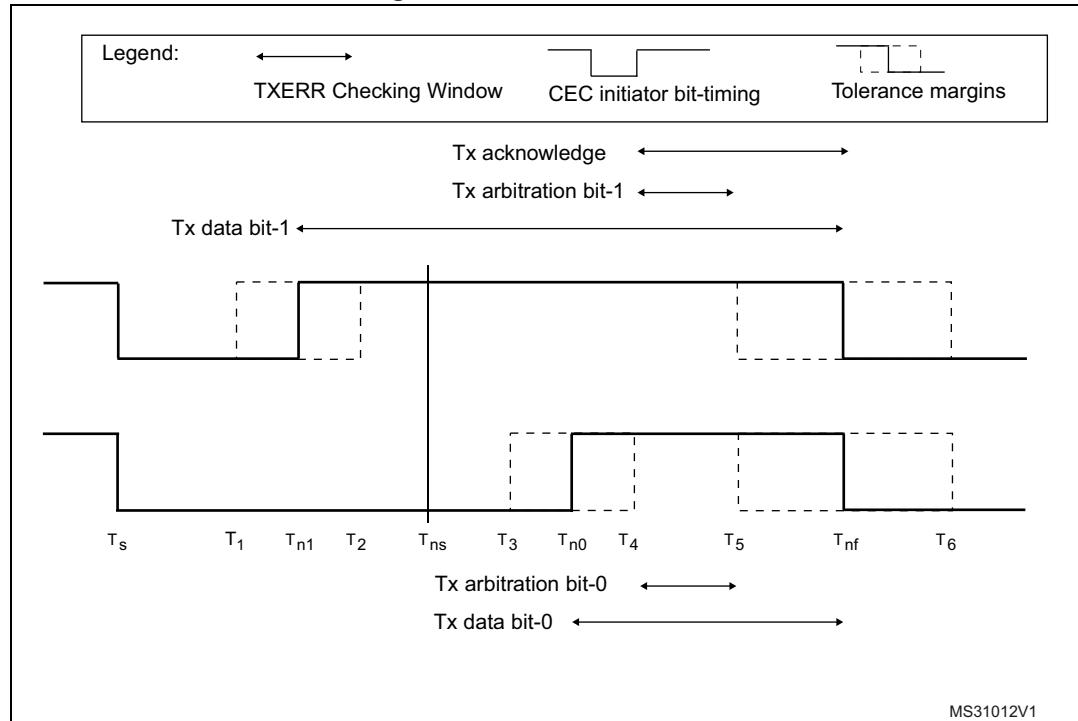
### 28.5.6 Transmission Error Detection (TXERR)

The CEC initiator sets the TXERR flag if detecting low impedance on the CEC line when it is transmitting high impedance and is not expecting a follower asserted bit. TXERR flag also generates a CEC interrupt if the TXERRIE=1.

TXERR assertion stops the message transmission. Application is in charge to retry the failed transmission up to 5 times.

TXERR checks are performed differently depending on the different states of the CEC line and on the RX tolerance configuration.

**Figure 304. TXERR detection**



**Table 103. TXERR timing parameters**

Time	RXTOL	ms	Description
$T_s$	x	0	Bit start event.
$T_1$	1	0.3	The earliest time for a low - high transition when indicating a logical 1.
	0	0.4	
$T_{n1}$	x	0.6	The nominal time for a low - high transition when indicating a logical 1.
$T_2$	0	0.8	The latest time for a low - high transition when indicating a logical 1.
	1	0.9	
$T_{ns}$	x	1.05	Nominal sampling time.
$T_3$	1	1.2	The earliest time a device is permitted return to a high impedance state (logical 0).
	0	1.3	

**Table 103. TXERR timing parameters (continued)**

Time	RXTOL	ms	Description
T <sub>n0</sub>	x	1.5	The nominal time a device is permitted return to a high impedance state (logical 0).
T <sub>4</sub>	0	1.7	The latest time a device is permitted return to a high impedance state (logical 0).
	1	1.8	
T <sub>5</sub>	1	1.85	The earliest time for the start of a following bit.
	0	2.05	
T <sub>nf</sub>	x	2.4	The nominal data bit period.
T <sub>6</sub>	0	2.75	The latest time for the start of a following bit.
	1	2.95	

## 28.6 HDMI-CEC interrupts

An interrupt can be produced:

- during reception if a Receive Block Transfer is finished or if a Receive Error occurs.
- during transmission if a Transmit Block Transfer is finished or if a Transmit Error occurs.

**Table 104. HDMI-CEC interrupts**

Interrupt event	Event flag	Enable Control bit
Rx-Byte Received	RXBR	RXBRIE
End of reception	RXEND	RXENDIE
Rx-Overrun	RXOVR	RXOVRIE
RxBit Rising Error	BRE	BREIE
Rx-Short Bit Period Error	SBPE	SBPEIE
Rx-Long Bit Period Error	LBPE	LBPEIE
Rx-Missing Acknowledge Error	RXACKE	RXACKEIE
Arbitration lost	ARBLST	ARBLSTIE
Tx-Byte Request	TXBR	TXBRIE
End of transmission	TXEND	TXENDIE
Tx-Buffer Underrun	TXUDR	TXUDRIE
Tx-Error	TXERR	TXERRIE
Tx-Missing Acknowledge Error	TXACKE	TXACKEIE

## 28.7 HDMI-CEC registers

Refer to [Section 1.1 on page 34](#) for a list of abbreviations used in register descriptions.

### 28.7.1 CEC control register (CEC\_CR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.													
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TX EOM	TX SOM	CEC ON												
													rs	rs	rw

Bits 31:3 Reserved, must be kept at reset value.

#### Bit 2 TXEOM: Tx End Of Message

The TXEOM bit is set by software to command transmission of the last byte of a CEC message.

TXEOM is cleared by hardware at the same time and under the same conditions as for TXSOM.

0: TXDR data byte is transmitted with EOM=0

1: TXDR data byte is transmitted with EOM=1

*Note:* TXEOM must be set when CECEN=1

*TXEOM must be set before writing transmission data to TXDR*

*If TXEOM is set when TXSOM=0, transmitted message will consist of 1 byte (HEADER) only (PING message)*

#### Bit 1 TXSOM: Tx Start Of Message

TXSOM is set by software to command transmission of the first byte of a CEC message. If the CEC message consists of only one byte, TXEOM must be set before TXSOM.

Start-Bit is effectively started on the CEC line after SFT is counted. If TXSOM is set while a message reception is ongoing, transmission will start after the end of reception.

TXSOM is cleared by hardware after the last byte of the message is sent with a positive acknowledge (TXEND=1), in case of transmission underrun (TXUDR=1), negative acknowledge (TXACKE=1), and transmission error (TXERR=1). It is also cleared by CECEN=0. It is not cleared and transmission is automatically retried in case of arbitration lost (ARBLST=1).

TXSOM can be also used as a status bit informing application whether any transmission request is pending or under execution. The application can abort a transmission request at any time by clearing the CECEN bit.

0: No CEC transmission is on-going

1: CEC transmission command

*Note:* TXSOM must be set when CECEN=1

*TXSOM must be set when transmission data is available into TXDR*

*HEADER's first four bits containing own peripheral address are taken from TXDR[7:4], not from CEC\_CFGR.OAR which is used only for reception*

#### Bit 0 **CECEN**: CEC Enable

The CECEN bit is set and cleared by software. CECEN=1 starts message reception and enables the TXSOM control. CECEN=0 disables the CEC peripheral, clears all bits of CEC\_CR register and aborts any on-going reception or transmission.

0: CEC peripheral is off

1: CEC peripheral is on

### 28.7.2 CEC configuration register (CEC\_CFGR)

This register is used to configure the HDMI-CEC controller.

Address offset: 0x04

Reset value: 0x0000 0000

**Caution:** It is mandatory to write CEC\_CFGR only when CECEN=0.

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LSTN	OAR[14:0]															
rw	rw															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	SFT OPT	BRDN OGEN	LBPE GEN	BRE GEN	BRE STP	RX TOL	SFT[2:0]			
							rw	rw	rw	rw	rw	rw	rw			

Reserved, must be kept at reset value.

**Bit 31 LSTN:** Listen mode

LSTN bit is set and cleared by software.

0: CEC peripheral receives only message addressed to its own address (OAR). Messages addressed to different destination are ignored. Broadcast messages are always received.

1: CEC peripheral receives messages addressed to its own address (OAR) with positive acknowledge. Messages addressed to different destination are received, but without interfering with the CEC bus: no acknowledge sent.

**Bits 30:16 OAR:** Own Address

OAR bits are set by software to configure the own address of the CEC device. It is used in receive mode only. At the end of HEADER reception OAR is compared with received destination address. In case of matching address message is received. In case of not-matching address message is received only in listen mode (LSTN=1), but without acknowledge sent. Broadcast messages are always received.

This register can handle multiple OAR, a logic 1 value on each bit of this reg corresponds to the CEC address identified by the bit position.

Example:

OAR = 00000000100001 means that CEC has as address 0x0 and 0x5. Consequently, each message directed to one of these addresses is received.

*Note: It is possible to configure OAR=0xF: in this case only broadcast messages are received if LSTN=0, while all messages are received and never acknowledged if LSTN=1.*

**Bits 15:9 Reserved,** must be kept at reset value.

**Bit 8 SFTOP:** SFT Option Bit

The SFTOPT bit is set and cleared by software.

0: SFT timer starts when TXSOM is set by software

1: SFT timer starts automatically at the end of message transmission/reception.

**Bit 7 BRDNOGEN:** Avoid Error-Bit Generation in Broadcast

The BRDNOGEN bit is set and cleared by software.

0: BRE detection with BRESTP=1 and BREGEN=0 on a broadcast message generates an Error-Bit on the CEC line. LBPE detection with LBPEGEN=0 on a broadcast message generates an Error-Bit on the CEC line

1: Error-Bit is not generated in the same condition as above. An Error-Bit is not generated even in case of an SBPE detection in a broadcast message if listen mode is set.

**Bit 6 LBPEGEN:** Generate Error-Bit on Long Bit Period Error

The LBPEGEN bit is set and cleared by software.

0: LBPE detection does not generate an Error-Bit on the CEC line

1: LBPE detection generates an Error-Bit on the CEC line

*Note: If BRDNOGEN=0, an Error-bit is generated upon LBPE detection in broadcast even if LBPEGEN=0*

**Bit 5 BREGEN:** Generate Error-Bit on Bit Rising Error

The BREGEN bit is set and cleared by software.

0: BRE detection does not generate an Error-Bit on the CEC line

1: BRE detection generates an Error-Bit on the CEC line (if BRESTP is set)

*Note: If BRDNOGEN=0, an Error-bit is generated upon BRE detection with BRESTP=1 in broadcast even if BREGEN=0*

**Bit 4 BRESTP: Rx-Stop on Bit Rising Error**

The BRESTP bit is set and cleared by software.

0: BRE detection does not stop reception of the CEC message. Data bit is sampled at 1.05 ms.

1: BRE detection stops message reception

**Bit 3 RXTOL: Rx-Tolerance**

The RXTOL bit is set and cleared by software.

0: Standard tolerance margin:

- Start-Bit, +/- 200 µs rise, +/- 200 µs fall.
- Data-Bit: +/- 200 µs rise, +/- 350 µs fall.

1: Extended Tolerance

- Start-Bit: +/- 400 µs rise, +/- 400 µs fall
- Data-Bit: +/-300 µs rise, +/- 500 µs fall

**Bits 2:0 SFT: Signal Free Time**

SFT bits are set by software. In the SFT=0x0 configuration the number of nominal data bit periods waited before transmission is ruled by hardware according to the transmission history. In all the other configurations the SFT number is determined by software.

" 0x0

- 2.5 Data-Bit periods if CEC is the last bus initiator with unsuccessful transmission (ARBLST=1, TXERR=1, TXUDR=1 or TXACKE= 1)
- 4 Data-Bit periods if CEC is the new bus initiator
- 6 Data-Bit periods if CEC is the last bus initiator with successful transmission (TXEOM=1)

" 0x1: 0.5 nominal data bit periods

" 0x2: 1.5 nominal data bit periods

" 0x3: 2.5 nominal data bit periods

" 0x4: 3.5 nominal data bit periods

" 0x5: 4.5 nominal data bit periods

" 0x6: 5.5 nominal data bit periods

" 0x7: 6.5 nominal data bit periods

### 28.7.3 CEC Tx data register (CEC\_TXDR)

Address offset: 0x8

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.															
								w	w	w	w	w	w	w	w

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **TXD[7:0]**: Tx Data register.

TXD is a write-only register containing the data byte to be transmitted.

*Note:* TXD must be written when TXSTART=1

### 28.7.4 CEC Rx Data Register (CEC\_RXDR)

Address offset: 0xC

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.			r	r	r	r	r	r							
										r	r	r	r	r	r

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **RXD[7:0]**: Rx Data register.

RXD is read-only and contains the last data byte which has been received from the CEC line.

### 28.7.5 CEC Interrupt and Status Register (CEC\_ISR)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	TX ACKE	TX ERR	TX UDR	TX END	TXBR	ARB LST	RX ACKE	LBPE	SBPE	BRE	RX OVR	RX END	RXBR
			rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1

Bits 31:13 Reserved, must be kept at reset value.

**Bit 12 TXACKE:** Tx-Missing Acknowledge Error

In transmission mode, TXACKE is set by hardware to inform application that no acknowledge was received. In case of broadcast transmission, TXACKE informs application that a negative acknowledge was received. TXACKE aborts message transmission and clears TXSOM and TXEOM controls.

TXACKE is cleared by software write at 1.

**Bit 11 TXERR:** Tx-Error

In transmission mode, TXERR is set by hardware if the CEC initiator detects low impedance on the CEC line while it is released. TXERR aborts message transmission and clears TXSOM and TXEOM controls.

TXERR is cleared by software write at 1.

**Bit 10 TXUDR:** Tx-Buffer Underrun

In transmission mode, TXUDR is set by hardware if application was not in time to load TXDR before of next byte transmission. TXUDR aborts message transmission and clears TXSOM and TXEOM control bits.

TXUDR is cleared by software write at 1

**Bit 9 TXEND:** End of Transmission

TXEND is set by hardware to inform application that the last byte of the CEC message has been successfully transmitted. TXEND clears the TXSOM and TXEOM control bits.

TXBYTE is cleared by software write at 1.

**Bit 8 TXBR:** Tx-Byte Request

TXBR is set by hardware to inform application that the next transmission data has to be written to TXDR. TXBR is set when the 4th bit of currently transmitted byte is sent. Application must write the next byte to TXDR within 6 nominal data-bit periods before transmission underrun error occurs (TXUDR).

TXBR is cleared by software write at 1.

**Bit 7 ARBLST:** Arbitration Lost

ARBLST is set by hardware to inform application that CEC device is switching to reception due to arbitration lost event following the TXSOM command. ARBLST can be due either to a contending CEC device starting earlier or starting at the same time but with higher HEADER priority. After ARBLST assertion TXSOM bit keeps pending for next transmission attempt.

ARBLST is cleared by software write at 1.

**Bit 6 RXACKE:** Rx-Missing Acknowledge

In receive mode, RXACKE is set by hardware to inform application that no acknowledge was seen on the CEC line. RXACKE applies for broadcast messages only and in listen mode for not directly addressed messages (OAR different from destination address). RXACKE aborts message reception.

RXACKE is cleared by software write at 1.

**Bit 5 LBPE:** Rx-Long Bit Period Error

LBPE is set by hardware in case a Data-Bit waveform is detected with Long Bit Period Error. LBPE is set at the end of the maximum bit-extension tolerance allowed by RXTOL, in case falling edge is still longing. LBPE always stops reception of the CEC message. LBPE generates an Error-Bit on the CEC line if LBPEGEN=1. In case of broadcast, Error-Bit is generated even in case of LBPEGEN=0.

LBPE is cleared by software write at 1.

**Bit 4 SBPE:** Rx-Short Bit Period Error

SBPE is set by hardware in case a Data-Bit waveform is detected with Short Bit Period Error. SBPE is set at the time the anticipated falling edge occurs. SBPE generates an Error-Bit on the CEC line.

SBPE is cleared by software write at 1.

**Bit 3 BRE:** Rx-Bit Rising Error

BRE is set by hardware in case a Data-Bit waveform is detected with Bit Rising Error. BRE is set either at the time the misplaced rising edge occurs, or at the end of the maximum BRE tolerance allowed by RXTOL, in case rising edge is still longing. BRE stops message reception if BRESTP=1. BRE generates an Error-Bit on the CEC line if BREGEN=1.

BRE is cleared by software write at 1.

**Bit 2 RXOVR:** Rx-Overrun

RXOVR is set by hardware if RXBR is not yet cleared at the time a new byte is received on the CEC line and stored into RXD. RXOVR assertion stops message reception so that no acknowledge is sent. In case of broadcast, a negative acknowledge is sent.

RXOVR is cleared by software write at 1.

**Bit 1 RXEND:** End Of Reception

RXEND is set by hardware to inform application that the last byte of a CEC message is received from the CEC line and stored into the RXD buffer. RXEND is set at the same time of RXBR.

RXEND is cleared by software write at 1.

**Bit 0 RXBR:** Rx-Byte Received

The RXBR bit is set by hardware to inform application that a new byte has been received from the CEC line and stored into the RXD buffer.

RXBR is cleared by software write at 1.

## 28.7.6 CEC interrupt enable register (CEC\_IER)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	TXACKIE	TXERRIE	TXUDRIE	TXENDIE	TXBRIE	ARBLSTIE	RXACKIE	LBPEIE	SBPEIE	BREIE	RXOVRIE	RXENDIE	RXBRIE
			rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:13 Reserved, must be kept at reset value.

**Bit 12 TXACKIE:** Tx-Missing Acknowledge Error Interrupt Enable

The TXACKIE bit is set and cleared by software.

0: TXACKIE interrupt disabled

1: TXACKIE interrupt enabled

**Bit 11 TXERRIE:** Tx-Error Interrupt Enable

The TXERRIE bit is set and cleared by software.

0: TXERRIE interrupt disabled

1: TXERRIE interrupt enabled

**Bit 10 TXUDRIE:** Tx-Underrun Interrupt Enable

The TXUDRIE bit is set and cleared by software.

0: TXUDRIE interrupt disabled

1: TXUDRIE interrupt enabled

**Bit 9 TXENDIE:** Tx-End Of Message Interrupt Enable

The TXENDIE bit is set and cleared by software.

0: TXEND interrupt disabled

1: TXEND interrupt enabled

**Bit 8 TXBRIE:** Tx-Byte Request Interrupt Enable

The TXBRIE bit is set and cleared by software.

0: TXBR interrupt disabled

1: TXBR interrupt enabled

**Bit 7 ARBLSTIE:** Arbitration Lost Interrupt Enable

The ARBLSTIE bit is set and cleared by software.

0: ARBLST interrupt disabled

1: ARBLST interrupt enabled

**Bit 6 RXACKIE:** Rx-Missing Acknowledge Error Interrupt Enable

The RXACKIE bit is set and cleared by software.

0: RXACKE interrupt disabled

1: RXACKE interrupt enabled

**Bit 5 LBPEIE:** Long Bit Period Error Interrupt Enable

The LBPEIE bit is set and cleared by software.

0: LBPE interrupt disabled

1: LBPE interrupt enabled

**Bit 4 SBPEIE:** Short Bit Period Error Interrupt Enable

The SBPEIE bit is set and cleared by software.

0: SBPE interrupt disabled

1: SBPE interrupt enabled

**Bit 3 BREIE:** Bit Rising Error Interrupt Enable

The BREIE bit is set and cleared by software.

0: BRE interrupt disabled

1: BRE interrupt enabled

**Bit 2 RXOVRIE:** Rx-Buffer Overrun Interrupt Enable

The RXOVRIE bit is set and cleared by software.

0: RXOVR interrupt disabled

1: RXOVR interrupt enabled

**Bit 1 RXENDIE:** End Of Reception Interrupt Enable

The RXENDIE bit is set and cleared by software.

0: RXEND interrupt disabled

1: RXEND interrupt enabled

**Bit 0 RXBRIE:** Rx-Byte Received Interrupt Enable

The RXBRIE bit is set and cleared by software.

0: RXBR interrupt disabled

1: RXBR interrupt enabled

**Caution:** (\*) It is mandatory to write CEC\_IER only when CECEN=0

### **28.7.7 HDMI-CEC register map**

The following table summarizes the HDMI-CEC registers.

**Table 105. HDMI-CEC register map and reset values**

Refer to [Section 2.2.2 on page 38](#) for the register boundary addresses.

## 29 Debug support (DBG)

### 29.1 Overview

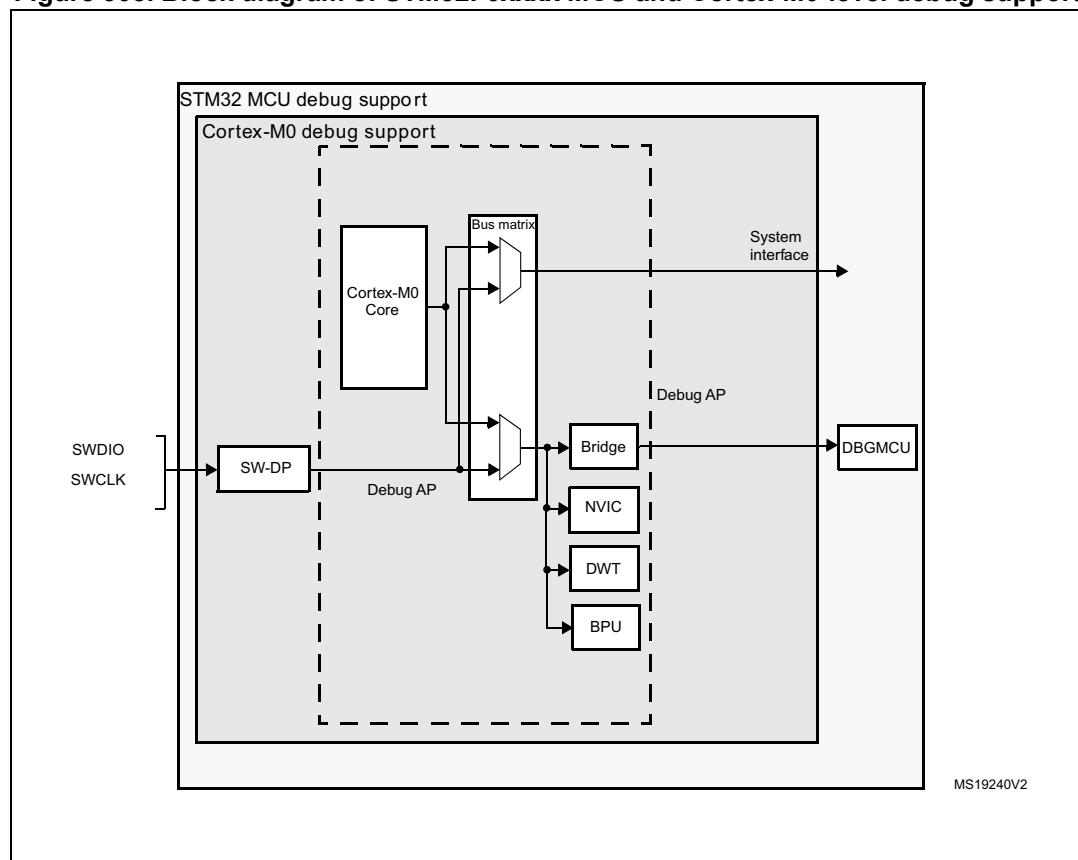
The STM32F0xxxx devices are built around a Cortex-M0 core which contains hardware extensions for advanced debugging features. The debug extensions allow the core to be stopped either on a given instruction fetch (breakpoint) or data access (watchpoint). When stopped, the core's internal state and the system's external state may be examined. Once examination is complete, the core and the system may be restored and program execution resumed.

The debug features are used by the debugger host when connecting to and debugging the STM32F0xxxx MCUs.

One interface for debug is available:

- Serial wire

**Figure 305. Block diagram of STM32F0xxxx MCU and Cortex-M0-level debug support**



1. The debug features embedded in the Cortex-M0 core are a subset of the ARM CoreSight Design Kit.

The ARM Cortex-M0 core provides integrated on-chip debug support. It is comprised of:

- SW-DP: Serial wire
- BPU: Break point unit
- DWT: Data watchpoint trigger

It also includes debug features dedicated to the STM32F0xxxx:

- Flexible debug pinout assignment
- MCU debug box (support for low-power modes, control over peripheral clocks, etc.)

**Note:** *For further information on debug functionality supported by the ARM Cortex-M0 core, refer to the Cortex-M0 Technical Reference Manual (see [Section 29.2: Reference ARM documentation](#)).*

## 29.2 Reference ARM documentation

- Cortex-M0 Technical Reference Manual (TRM)

It is available from:

[http://infocenter.arm.com/help/topic/com.arm.doc.ddi0432c/DDI0432C\\_cortex\\_m0\\_r0p0\\_trm.pdf](http://infocenter.arm.com/help/topic/com.arm.doc.ddi0432c/DDI0432C_cortex_m0_r0p0_trm.pdf)

- ARM Debug Interface V5
- ARM CoreSight Design Kit revision r1p1 Technical Reference Manual

## 29.3 Pinout and debug port pins

The STM32F0xxxx MCUs are available in various packages with different numbers of available pins.

### 29.3.1 SWD port pins

Two pins are used as outputs for the SW-DP as alternate functions of general purpose I/Os. These pins are available on all packages.

**Table 106. SW debug port pins**

SW-DP pin name	SW debug port		Pin assignment
	Type	Debug assignment	
SWDIO	IO	Serial Wire Data Input/Output	PA13
SWCLK	I	Serial Wire Clock	PA14

### 29.3.2 SW-DP pin assignment

After reset (SYSRESETn or PORESETn), the pins used for the SW-DP are assigned as dedicated pins which are immediately usable by the debugger host.

However, the MCU offers the possibility to disable the SWD port and can then release the associated pins for general-purpose I/O (GPIO) usage. For more details on how to disable SW-DP port pins, please refer to [Section 8.3.2: I/O pin alternate function multiplexer and mapping on page 127](#).

### 29.3.3 Internal pull-up & pull-down on SWD pins

Once the SW I/O is released by the user software, the GPIO controller takes control of these pins. The reset states of the GPIO control registers put the I/Os in the equivalent states:

- SWDIO: input pull-up
- SWCLK: input pull-down

*Having embedded pull-up and pull-down resistors removes the need to add external resistors.*

## 29.4 ID codes and locking mechanism

There are several ID codes inside the MCU. ST strongly recommends the tool manufacturers (Keil, IAR, Raisonance, ...) to lock their debugger using the MCU device ID located at address 0x40015800.

Only the DEV\_ID(15:0) should be used for identification by the debugger/programmer tools (the revision ID must not be taken into account).

### 29.4.1 MCU device ID code

The STM32F0 products integrate an MCU ID code. This ID identifies the ST MCU part number and the die revision.

This code is accessible by the software debug port (two pins) or by the user software.

#### **DBGMCU\_IDCODE**

Address: 0x40015800

Only 32-bit access supported. Read-only

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
REV_ID															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	DEV_ID											
				r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 **REV\_ID(15:0)** Revision identifier

This field indicates the revision of the device. It is read as 0x1000 for Revision 1.0 and 0x2000 for Revision 2.0.

Bits 15:12 Reserved: read 0b0110.

Bits 11:0 **DEV\_ID(11:0)**: Device identifier

This field indicates the device ID.

For STM32F0x1, the device ID is 0x440.

For STM32F0x0, the device ID is 0x444.

## 29.5 SWD port

### 29.5.1 SWD protocol introduction

This synchronous serial protocol uses two pins:

- SWCLK: clock from host to target
- SWDIO: bidirectional

The protocol allows two banks of registers (DPACC registers and APACC registers) to be read and written to.

Bits are transferred LSB-first on the wire.

For SWDIO bidirectional management, the line must be pulled-up on the board (100 kΩ recommended by ARM).

Each time the direction of SWDIO changes in the protocol, a turnaround time is inserted where the line is not driven by the host nor the target. By default, this turnaround time is one bit time, however this can be adjusted by configuring the SWCLK frequency.

## 29.5.2 SWD protocol sequence

Each sequence consist of three phases:

1. Packet request (8 bits) transmitted by the host
2. Acknowledge response (3 bits) transmitted by the target
3. Data transfer phase (33 bits) transmitted by the host or the target

**Table 107. Packet request (8-bits)**

Bit	Name	Description
0	Start	Must be “1”
1	APnDP	0: DP Access 1: AP Access
2	RnW	0: Write Request 1: Read Request
4:3	A[3:2]	Address field of the DP or AP registers (refer to <a href="#">Table 111 on page 739</a> )
5	Parity	Single bit parity of preceding bits
6	Stop	0
7	Park	Not driven by the host. Must be read as “1” by the target because of the pull-up

Refer to the Cortex-M0 *TRM* for a detailed description of DPACC and APACC registers.

The packet request is always followed by the turnaround time (default 1 bit) where neither the host nor target drive the line.

**Table 108. ACK response (3 bits)**

Bit	Name	Description
0..2	ACK	001: FAULT 010: WAIT 100: OK

The ACK Response must be followed by a turnaround time only if it is a READ transaction or if a WAIT or FAULT acknowledge has been received.

**Table 109. DATA transfer (33 bits)**

Bit	Name	Description
0..31	WDATA or RDATA	Write or Read data
32	Parity	Single parity of the 32 data bits

The DATA transfer must be followed by a turnaround time only if it is a READ transaction.

### 29.5.3 SW-DP state machine (reset, idle states, ID code)

The State Machine of the SW-DP has an internal ID code which identifies the SW-DP. It follows the JEP-106 standard. This ID code is the default ARM one and is set to **0x0BB11477** (corresponding to Cortex-M0).

**Note:** *Note that the SW-DP state machine is inactive until the target reads this ID code.*

- The SW-DP state machine is in RESET STATE either after power-on reset, or after the line is high for more than 50 cycles
- The SW-DP state machine is in IDLE STATE if the line is low for at least two cycles after RESET state.
- After RESET state, it is **mandatory** to first enter into an IDLE state AND to perform a READ access of the DP-SW ID CODE register. Otherwise, the target will issue a FAULT acknowledge response on another transactions.

Further details of the SW-DP state machine can be found in the *Cortex-M0 TRM* and the *CoreSight Design Kit r1p0 TRM*.

### 29.5.4 DP and AP read/write accesses

- Read accesses to the DP are not posted: the target response can be immediate (if ACK=OK) or can be delayed (if ACK=WAIT).
- Read accesses to the AP are posted. This means that the result of the access is returned on the next transfer. If the next access to be done is NOT an AP access, then the DP-RDBUFF register must be read to obtain the result.  
The READOK flag of the DP-CTRL/STAT register is updated on every AP read access or RDBUFF read request to know if the AP read access was successful.
- The SW-DP implements a write buffer (for both DP or AP writes), that enables it to accept a write operation even when other transactions are still outstanding. If the write buffer is full, the target acknowledge response is “WAIT”. With the exception of IDCODE read or CTRL/STAT read or ABORT write which are accepted even if the write buffer is full.
- Because of the asynchronous clock domains SWCLK and HCLK, two extra SWCLK cycles are needed after a write transaction (after the parity bit) to make the write effective internally. These cycles should be applied while driving the line low (IDLE state)  
This is particularly important when writing the CTRL/STAT for a power-up request. If the next transaction (requiring a power-up) occurs immediately, it will fail.

### 29.5.5 SW-DP registers

Access to these registers are initiated when APnDP=0

**Table 110. SW-DP registers**

A[3:2]	R/W	CTRLSEL bit of SELECT register	Register	Notes
00	Read		IDCODE	The manufacturer code is set to the default ARM code for Cortex-M0: <b>0x0BB11477</b> (identifies the SW-DP)
00	Write		ABORT	
01	Read/Write	0	DP-CTRL/STAT	Purpose is to: – request a system or debug power-up – configure the transfer operation for AP accesses – control the pushed compare and pushed verify operations. – read some status flags (overrun, power-up acknowledges)
01	Read/Write	1	WIRE CONTROL	Purpose is to configure the physical serial port protocol (like the duration of the turnaround time)
10	Read		READ RESEND	Enables recovery of the read data from a corrupted debugger transfer, without repeating the original AP transfer.
10	Write		SELECT	The purpose is to select the current access port and the active 4-words register window
11	Read/Write		READ BUFFER	This read buffer is useful because AP accesses are posted (the result of a read AP request is available on the next AP transaction). This read buffer captures data from the AP, presented as the result of a previous read, without initiating a new transaction

### 29.5.6 SW-AP registers

Access to these registers are initiated when APnDP=1

There are many AP Registers addressed as the combination of:

- The shifted value A[3:2]
- The current value of the DP SELECT register.

**Table 111. 32-bit debug port registers addressed through the shifted value A[3:2]**

Address	A[3:2] value	Description
0x0	00	Reserved, must be kept at reset value.
0x4	01	DP CTRL/STAT register. Used to: – Request a system or debug power-up – Configure the transfer operation for AP accesses – Control the pushed compare and pushed verify operations. – Read some status flags (overrun, power-up acknowledges)
0x8	10	DP SELECT register: Used to select the current access port and the active 4-words register window. – Bits 31:24: APSEL: select the current AP – Bits 23:8: reserved – Bits 7:4: APBANKSEL: select the active 4-words register window on the current AP – Bits 3:0: reserved
0xC	11	DP RDBUFF register: Used to allow the debugger to get the final result after a sequence of operations (without requesting new JTAG-DP operation)

### 29.6 Core debug

Core debug is accessed through the core debug registers. Debug access to these registers is by means of the debug access port. It consists of four registers:

**Table 112. Core debug registers**

Register	Description
DHCSR	<i>The 32-bit Debug Halting Control and Status Register</i> This provides status information about the state of the processor enable core debug halt and step the processor
DCRSR	<i>The 17-bit Debug Core Register Selector Register:</i> This selects the processor register to transfer data to or from.
DCRDR	<i>The 32-bit Debug Core Register Data Register:</i> This holds data for reading and writing registers to and from the processor selected by the DCRSR (Selector) register.
DEMCR	<i>The 32-bit Debug Exception and Monitor Control Register:</i> This provides Vector Catching and Debug Monitor Control.

These registers are not reset by a system reset. They are only reset by a power-on reset. Refer to the Cortex-M0 TRM for further details.

To Halt on reset, it is necessary to:

- enable the bit0 (VC\_CORRESET) of the Debug and Exception Monitor Control Register
- enable the bit0 (C\_DEBUGEN) of the Debug Halting Control and Status Register

## 29.7 BPU (Break Point Unit)

The Cortex-M0 BPU implementation provides four breakpoint registers. The BPU is a subset of the Flash Patch and Breakpoint (FPB) block available in ARMv7-M (Cortex-M3 & Cortex-M4).

### 29.7.1 BPU functionality

The processor breakpoints implement PC based breakpoint functionality.

Refer the ARMv6-M ARM and the ARM CoreSight Components Technical Reference Manual for more information about the BPU CoreSight identification registers, and their addresses and access types.

## 29.8 DWT (Data Watchpoint)

The Cortex-M0 DWT implementation provides two watchpoint register sets.

### 29.8.1 DWT functionality

The processor watchpoints implement both data address and PC based watchpoint functionality, a PC sampling register, and support comparator address masking, as described in the *ARMv6-M ARM*.

### 29.8.2 DWT Program Counter Sample Register

A processor that implements the data watchpoint unit also implements the ARMv6-M optional *DWT Program Counter Sample Register* (DWT\_PCSR). This register permits a debugger to periodically sample the PC without halting the processor. This provides coarse grained profiling. See the *ARMv6-M ARM* for more information.

The Cortex-M0 DWT\_PCSR records both instructions that pass their condition codes and those that fail.

## 29.9 MCU debug component (DBGMCU)

The MCU debug component helps the debugger provide support for:

- Low-power modes
- Clock control for timers, watchdog and I2C during a breakpoint

### 29.9.1 Debug support for low-power modes

To enter low-power mode, the instruction WFI or WFE must be executed.

The MCU implements several low-power modes which can either deactivate the CPU clock or reduce the power of the CPU.

The core does not allow FCLK or HCLK to be turned off during a debug session. As these are required for the debugger connection, during a debug, they must remain active. The MCU integrates special means to allow the user to debug software in low-power modes.

For this, the debugger host must first set some debug configuration registers to change the low-power mode behavior:

- In Sleep mode : FCLK and HCLK are still active. Consequently, this mode does not impose any restrictions on the standard debug features.
- In Stop/Standy mode, the DBG\_STOP bit must be previously set by the debugger.

This enables the internal RC oscillator clock to feed FCLK and HCLK in Stop mode.

### 29.9.2 Debug support for timers, watchdog and I<sup>2</sup>C

During a breakpoint, it is necessary to choose how the counter of timers and watchdog should behave:

- They can continue to count inside a breakpoint. This is usually required when a PWM is controlling a motor, for example.
- They can stop to count inside a breakpoint. This is required for watchdog purposes.

For the I<sup>2</sup>C, the user can choose to block the SMBUS timeout during a breakpoint.

### 29.9.3 Debug MCU configuration register (DBGMCU\_CR)

This register allows the configuration of the MCU under DEBUG. This concerns:

- Low-power mode support

This DBGMCU\_CR is mapped at address 0x4001 5804.

It is asynchronously reset by the PORRESET (and not the system reset). It can be written by the debugger under system reset.

If the debugger host does not support these features, it is still possible for the user software to write to these registers.

Address: 0x40015804

Only 32-bit access supported

POR Reset: 0x0000 0000 (not reset by system reset)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.														
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	DBG_STAND BY	DBG_STOP													
														rw	rw

Bits 31:3 Reserved, must be kept at reset value.

Bit 2 **DBG\_STANDBY**: Debug Standby mode

0: (FCLK=Off, HCLK=Off) The whole digital part is unpowered.

From software point of view, exiting from Standby is identical than fetching reset vector (except a few status bit indicated that the MCU is resuming from Standby)

1: (FCLK=On, HCLK=On) In this case, the digital part is not unpowered and FCLK and HCLK are provided by the internal RC oscillator which remains active. In addition, the MCU generate a system reset during Standby mode so that exiting from Standby is identical than fetching from reset

Bit 1 **DBG\_STOP**: Debug Stop mode

0: (FCLK=Off, HCLK=Off) In STOP mode, the clock controller disables all clocks (including HCLK and FCLK). When exiting from STOP mode, the clock configuration is identical to the one after RESET (CPU clocked by the 8 MHz internal RC oscillator (HSI)). Consequently, the software must reprogram the clock controller to enable the PLL, the Xtal, etc.

1: (FCLK=On, HCLK=On) In this case, when entering STOP mode, FCLK and HCLK are provided by the internal RC oscillator which remains active in STOP mode. When exiting STOP mode, the software must reprogram the clock controller to enable the PLL, the Xtal, etc. (in the same way it would do in case of **DBG\_STOP=0**)

### 29.9.4 Debug MCU APB1 freeze register (DBGMCU\_APB1\_FZ)

The DBGMCU\_APB1\_FZ register is used to configure the MCU under DEBUG. It concerns some APB peripherals:

- Timer clock counter freeze
- I2C SMBUS timeout freeze
- System window watchdog and independent watchdog counter freeze support

This DBGMCU\_APB1\_FZ is mapped at address 0x4001 5808.

The register is asynchronously reset by the POR (and not the system reset). It can be written by the debugger under system reset.

Address offset: 0x08

Only 32-bit access are supported.

Power on reset (POR): 0x0000 0000 (not reset by system reset)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_I2C1_SMBUS_TIMEOUT	Res.	Res.	Res.	Res.	Res.
										rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBG_IWDG_STOP	DBG_WWDG_STOP	DBG_RTC_STOP	Res.	DBG_TIM14_STOP	Res.	Res.	DBG_TIM6_STOP	Res.	Res.	DBG_TIM3_STOP	DBG_TIM2_STOP	rw
			rw	rw	rw		rw			rw			rw	rw	rw

Bits 31:22 Reserved, must be kept at reset value.

Bit 21 **DBG\_I2C1\_SMBUS\_TIMEOUT**: SMBUS timeout mode stopped when core is halted

- 0: Same behavior as in normal mode
- 1: The SMBUS timeout is frozen

Bits 20:13 Reserved, must be kept at reset value.

Bit 12 **DBG\_IWDG\_STOP**: Debug independent watchdog stopped when core is halted

- 0: The independent watchdog counter clock continues even if the core is halted
- 1: The independent watchdog counter clock is stopped when the core is halted

Bit 11 **DBG\_WWDG\_STOP**: Debug window watchdog stopped when core is halted

- 0: The window watchdog counter clock continues even if the core is halted
- 1: The window watchdog counter clock is stopped when the core is halted

- Bit 10 **DBG\_RTC\_STOP**: Debug RTC stopped when core is halted  
0: The clock of the RTC counter is fed even if the core is halted  
1: The clock of the RTC counter is stopped when the core is halted
- Bit 9 Reserved, must be kept at reset value.
- Bit 8 **DBG\_TIM14\_STOP**: TIM14 counter stopped when core is halted  
0: The counter clock of TIM14 is fed even if the core is halted  
1: The counter clock of TIM14 is stopped when the core is halted
- Bits 7:5 Reserved, must be kept at reset value.
- Bit 4 **DBG\_TIM6\_STOP**: TIM6 counter stopped when core is halted  
0: The counter clock of TIM6 is fed even if the core is halted  
1: The counter clock of TIM6 is stopped when the core is halted
- Bits 3:2 Reserved, must be kept at reset value.
- Bit 1 **DBG\_TIM3\_STOP**: TIM3 counter stopped when core is halted  
0: The counter clock of TIM3 is fed even if the core is halted  
1: The counter clock of TIM3 is stopped when the core is halted
- Bit 0 **DBG\_TIM2\_STOP**: TIM2 counter stopped when core is halted  
0: The counter clock of TIM2 is fed even if the core is halted  
1: The counter clock of TIM2 is stopped when the core is halted

### 29.9.5 Debug MCU APB2 freeze register (DBGMCU\_APB2\_FZ)

The DBGMCU\_APB2\_FZ register is used to configure the MCU under DEBUG. It concerns some APB peripherals:

- Timer clock counter freeze

This register is mapped at address 0x4001580C.

It is asynchronously reset by the POR (and not the system reset). It can be written by the debugger under system reset.

Address offset: 0x0C

Only 32-bit access is supported.

POR: 0x0000 0000 (not reset by system reset)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_TIM17_STOP	DBG_TIM16_STOP	DBG_TIM15_STOP
													rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	DBG_TIM1_STOP	Res.	Res.	Res.								
				rw											

Bits 31:19 Reserved, must be kept at reset value.

Bit 18 **DBG\_TIM17\_STOP**: TIM17 counter stopped when core is halted

- 0: The counter clock of TIM17 is fed even if the core is halted
- 1: The counter clock of TIM17 is stopped when the core is halted

Bit 17 **DBG\_TIM16\_STOP**: TIM16 counter stopped when core is halted

- 0: The counter clock of TIM16 is fed even if the core is halted
- 1: The counter clock of TIM16 is stopped when the core is halted

Bit 16 **DBG\_TIM15\_STOP**: TIM15 counter stopped when core is halted

- 0: The counter clock of TIM15 is fed even if the core is halted
- 1: The counter clock of TIM15 is stopped when the core is halted

Bits 15:12 Reserved, must be kept at reset value.

Bit 11 **DBG\_TIM1\_STOP**: TIM1 counter stopped when core is halted

- 0: The counter clock of TIM 1 is fed even if the core is halted
- 1: The counter clock of TIM 1 is stopped when the core is halted

Bits 0:10 Reserved, must be kept at reset value.

## 29.10 DBG register map

The following table summarizes the Debug registers.

**Table 113. DBG register map and reset values**

<b>Addr.</b>	<b>Register</b>	REV_ID																DEV_ID							
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13					
0x4001580C	DBGMCU_APB2_FZ	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.		
	Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value <sup>(1)</sup>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	DBGMCU_CR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	DBGMCU_IDCODE	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13					

1. The reset value is product dependent. For more information, refer to [Section 29.4.1: MCU device ID code](#).

## 30 Device electronic signature

The device electronic signature is stored in the System memory area of the Flash memory module, and can be read using the debug interface or by the CPU. It contains factory-programmed identification and calibration data that allow the user firmware or other external devices to automatically match to the characteristics of the STM32F0xxxx microcontroller.

### 30.1 Unique device ID register (96 bits)

The unique device identifier is ideally suited:

- for use as serial numbers (for example USB string serial numbers or other end applications)
- for use as part of the security keys in order to increase the security of code in Flash memory while using and combining this unique ID with software cryptographic primitives and protocols before programming the internal Flash memory
- to activate secure boot processes, etc.

The 96-bit unique device identifier provides a reference number which is unique for any device and in any context. These bits cannot be altered by the user.

Base address: 0x1FFF F7AC

Address offset: 0x00

Read only = 0xXXXX XXXX where X is factory-programmed

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
UID[31:16]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
UID[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:0 **UID[31:0]**: X and Y coordinates on the wafer expressed in BCD format

Address offset: 0x04

Read only = 0xXXXX XXXX where X is factory-programmed

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
UID[63:48]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
UID[47:32]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:8 **UID[63:40]**: LOT\_NUM[23:0]

Lot number (ASCII encoded)

Bits 7:0 **UID[39:32]**: WAF\_NUM[7:0]

Wafer number (8-bit unsigned number)

Address offset: 0x08

Read only = 0xXXXX XXXX where X is factory-programmed

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
UID[95:80]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
UID[79:64]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:0 **UID[95:64]**: LOT\_NUM[55:24]

Lot number (ASCII encoded)

## 30.2 Memory size data register

### 30.2.1 Flash size data register

Base address: 0x1FFF F7CC

Address offset: 0x00

Read only = 0xXXXX where X is factory-programmed

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FLASH_SIZE															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 15:0 **FLASH\_SIZE[15:0]**: Flash memory size

This bitfield indicates the size of the device Flash memory expressed in Kbytes.

As an example, 0x040 corresponds to 64 Kbytes.

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## 31 Revision history

**Table 114. Document revision history**

Date	Revision	Changes
06-Apr-2012	1	<p>Initial release</p>
08-Aug-2012	2	<p><b>Documentation conventions:</b> Added 'Always read...' in <a href="#">Section 1.1: List of abbreviations for registers</a></p> <p><b>Memory map:</b> Added boot configuration link in <a href="#">Table 1: STM32F05xxx memory map and peripheral register boundary addresses</a> Added Footnote under <a href="#">Table 3: Boot modes</a> Remove 'DCode' after 'CPU' in <a href="#">Section : DMA bus</a> Replaced sentence and added Physical remap paragraph in <a href="#">Section 2.5: Boot configuration</a> Corrected Prefetch buffer and added paragraph in <a href="#">Section : The information block is divided into two parts:</a> Removed sentence 'It is set after the first...', removed note and added description of bit 5 in <a href="#">Section 3.5.1: Flash access control register (FLASH_ACR)</a></p> <p><b>CRC:</b> Replaced references to bits 4:3 and 2:1 in <a href="#">Section 5.4.3: Control register (CRC_CR)</a></p> <p><b>PWR:</b> Replaced 'POR', 'PDR' and 'PVD' by 'VPOR', 'VPDR' and 'VPVD' in <a href="#">Figure 7</a> and <a href="#">Figure 8</a> Modified "When VDDA is different from VDD..." paragraph in <a href="#">Section 6.1.1: Independent A/D and D/A converter supply and reference voltage</a> Moved arrow in <a href="#">Figure 7: Power on reset/power down reset waveform</a> Corrected WKUP1 in <a href="#">Section 6.4.2: Power control/status register (PWR_CSR)</a></p> <p><b>RCC:</b> Added Power reset in <a href="#">Section 7.1.2: System reset</a> Added paragraph 'For more details on how to measure..' in <a href="#">Section 7.2.2: HSI clock</a> Added 'LSE' and 'LSI' bullets in <a href="#">Section 7.2.11: Clock-out capability</a> Added 'I1', 'LSI' and 'LSE' in <a href="#">Figure 10: Clock tree</a> Added the sentence "... drive the HSI clock ..." to <a href="#">Section 7.2.2: HSI clock</a> Added "independent" to the title of <a href="#">Section 7.2.10: Independent watchdog clock</a> Replaced the first sentence after <a href="#">Figure 12: Frequency measurement with TIM14 in capture mode</a> Added the sentence "When the system is in stop mode..." in <a href="#">Section : The input capture channel of the Timer 14 can be a GPIO line or an internal clock of the MCU. This selection is performed through the TI1_RMP [1:0] bits in the TIM14_OR register. The possibilities available are the following ones.</a> Added <a href="#">Section 7.2.12: Internal/external clock measurement with TIM14</a> and <a href="#">Section 7.3: Low power modes</a> Modified description of Bit 19 and Bits 15:8 in <a href="#">Section 7.4.1: Clock control register (RCC_CR)</a></p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
08-Aug-2012	2 (Continued)	<p>Replaced text under 'PLLXTPRE' and modified description of bits 26:24 in <a href="#">Section 7.4.2: Clock configuration register (RCC_CFGR)</a></p> <p>Modified the formating in the register of <a href="#">Section 7.4.4</a> and <a href="#">Section 7.4.5: APB peripheral reset register 1 (RCC_APB1RSTR)</a></p> <p>Modified title of Bit 0 in the registers of <a href="#">Section 7.4.7: APB peripheral clock enable register 2 (RCC_APB2ENR)</a></p> <p>Replaced 'IWWDGRSTF' by 'IWDGRSTF and added PORV18RSTDF POR/PDR for bit 23 in <a href="#">Section 7.4.10: Control/status register (RCC_CSR)</a></p> <p>Modified <a href="#">Section 7.4.4: APB peripheral reset register 2 (RCC_APB2RSTR)</a> to <a href="#">Section 7.4.8: APB peripheral clock enable register 1 (RCC_APB1ENR)</a> title name.</p> <p><b>GPIO:</b> Replaced SWDAT in <a href="#">Section 8.3.1: General-purpose I/O (GPIO)</a> Added specific reset values in <a href="#">Section 8.4.3: GPIO port output speed register (GPIOx_OSPEEDR) (x = A..D, F)</a></p> <p><b>DMA:</b> Added 'I2C1', 'TIM15', 'TIM16 and 'TIM17' to <a href="#">Figure 19: DMA block diagram</a></p> <p><b>ADC:</b> Changed JIITOFF_D2 and JIITOFF_D4 to JIITOFF_DIV4 and JIITOFF_DIV2 in <a href="#">Section 12.12.5: ADC configuration register 2 (ADC_CFGR2)</a> and <a href="#">Section 12.12.11: ADC register map</a></p> <p><b>DAC:</b> Replaced 'SMPR' with 'SMP' in <a href="#">Section 12.12.11: ADC register map</a></p> <p><b>COMP:</b> Replaced note in <a href="#">Section 13.2: DAC main features</a></p> <p><b>Timers:</b> Added OCCS bit in <a href="#">Section 16.4.3: TIM2 and TIM3 slave mode control register (TIM2_SMCR and TIM3_SMCR)</a> and <a href="#">Section 15.4.3: TIM1 slave mode control register (TIM1_SMCR)</a> Mapped 'TI1_RMP' to bit 0 and 1 in <a href="#">Section 17.4.10: TIM14 capture/compare register 1 (TIM14_CCR1)</a></p> <p><b>Infrared</b> Infrared function output changed to IR_OUT</p> <p><b>IWDG:</b> Replaced 'IWWDG' occurrences by 'IWDG'</p> <p><b>RTC:</b> Removed V<sub>DD</sub> in <a href="#">Section 23.6.16: RTC backup registers (RTC_BKPxR)</a> Removed Tamper3 in RTC ISR and TAFCR registers</p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
08-Aug-2012	2 (Continued)	<p><b>I2C:</b> Modified <a href="#">Section 24.4.5: I2C initialization</a>, <a href="#">Section 24.4.6: Software reset</a> Removed ‘SWRST’ in <a href="#">Section 24.7.1: Control register 1 (I2Cx_CR1)</a> and <a href="#">Section 24.7.7: Interrupt and Status register (I2Cx_ISR)</a></p> <p><b>USART:</b> Removed “with a 12-bit mantissa and 4-bit fraction” in <a href="#">Section 25.5: USART functional description</a> Changed Equation in <a href="#">Section 25.5.5: Tolerance of the USART receiver to clock deviation</a> Changed reset values length in <a href="#">Section 25.7: USART registers</a> Corrected reset values for ‘DEP’, ‘TC’, ‘RDR’ and ‘TDR’ in <a href="#">Table 89: USART register map and reset values</a></p> <p><b>Debug:</b> Removed ‘Control of the trace..’ bullet in <a href="#">Section 29.9: MCU debug component (DBGMCU)</a> Replaced IDCODE values in <a href="#">Section 29.5.3: SW-DP state machine (reset, idle states, ID code)</a> and <a href="#">Section 29.5.5: SW-DP registers</a> Replaced “APB low” to APB1 in <a href="#">Section 29.9.2: Debug support for timers, watchdog and I2C</a> Corrected <a href="#">Figure 305: Block diagram of STM32F0xxxx MCU and Cortex-M0-level debug support</a> Modified the title of <a href="#">Section 29.3.1: SWD port pins</a> Modified <a href="#">Section 29.3.2: SW-DP pin assignment</a> and <a href="#">Section 29.3.3: Internal pull-up &amp; pull-down on SWD pins</a> Modified titles in <a href="#">Section 29.5: SWD port</a> and replaced ‘SWDAT’ Removed ‘DBG SLEEP’ in <a href="#">Section 29.9.3: Debug MCU configuration register (DBGMCU_CR)</a> Added ‘System’ to window watchdog in <a href="#">Section 29.9.4: Debug MCU APB1 freeze register (DBGMCU_APB1_FZ)</a> Marked bit 0, 5, 6 and 7 as reserved in <a href="#">Section 29.10: DBG register map</a></p> <p><b>Unique ID:</b> Removed Bold from ‘base address’ in <a href="#">Section 30.1: Unique device ID register (96 bits)</a></p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
10-May-2013	3	<p>Added part numbers STM32F06xxx throughout the document. Updated document title.</p> <p><b>Documentation conventions:</b> Added “(w_r0)” to <a href="#">Section 1.1: List of abbreviations for registers</a>. Added reference to PM0215 in <a href="#">Related documents</a>. Updated <a href="#">Glossary</a>.</p> <p><b>System and memory overview:</b> Modified Sections <a href="#">BusMatrix</a> and <a href="#">AHB2APB bridge</a>. Added <a href="#">Note:</a> in <a href="#">Section 2.3: Embedded SRAM</a>.</p> <p><b>Embedded Flash memory:</b> Updated <a href="#">Table 5: Access status versus protection level and execution modes</a>. Modified phrasing of <a href="#">Level 2: no debug</a> paragraph in <a href="#">Section 3.3.1: Read protection</a>. Added description of information block in <a href="#">Section 3.2.1: Flash memory organization</a>. Renamed “FKEYR” to “FKEY” and renamed “OPTKEYR” to “OPTKEY”. Renamed and modified <a href="#">Section 3.5.7: Flash Option byte register (FLASH_OBR)</a>. Modified information about reset value in <a href="#">Section 3.5.2: Flash key register (FLASH_KEYR)</a>, <a href="#">Section 3.5.3: Flash option key register (FLASH_OPTKEYR)</a>, <a href="#">Section 3.5.7: Flash Option byte register (FLASH_OBR)</a> and <a href="#">Section 3.5.8: Write protection register (FLASH_WRPR)</a>. Modified Section <a href="#">Unlocking the Flash memory</a>, item 5. in <a href="#">Main Flash memory programming</a>, procedure in sections <a href="#">Page Erase</a> and <a href="#">Mass Erase</a>. Added <a href="#">Note:</a> in <a href="#">Page Erase</a> and <a href="#">Mass Erase</a>. Updated <a href="#">Table 7: Flash interface - register map and reset values</a>.</p> <p><b>Option bytes:</b> Reworked <a href="#">Section 4: Option bytes</a>.</p> <p><b>PWR:</b> Modified introduction of <a href="#">Section 6.1: Power supplies</a>. Added bullet “In STM32F06x devices...” in <a href="#">Section 6.1.3: Voltage regulator</a>. Added section <a href="#">External NPOR signal</a>. Added <a href="#">Caution:</a> in <a href="#">Section 6.3: Low-power modes</a> and in <a href="#">Section 6.3.5: Standby mode</a>.</p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
10-May-2013	3 (Continued)	<p><b>RCC:</b>  Inverted order of sections <a href="#">Section 7.1.1: Power reset</a> and <a href="#">Section 7.1.2: System reset</a>.  Added <a href="#">Caution:</a> in <a href="#">External crystal/ceramic resonator (HSE crystal)</a> and <a href="#">Caution:</a> in <a href="#">Section 7.2.4: LSE clock</a>  Added bullet “The timer clock frequencies are automatically fixed by hardware...” in <a href="#">Section 7.2: Clocks</a>.  Updated <a href="#">Section 7.1.1: Power reset</a>, <a href="#">Section 7.1.2: System reset</a>, <a href="#">Section 7.1.3: Backup domain reset</a>, <a href="#">Calibration of the HSI14</a>, <a href="#">Section 7.2.11: Clock-out capability</a>, <a href="#">Section 7.2.12: Internal/external clock measurement with TIM14</a>, <a href="#">Section 7.4.2: Clock configuration register (RCC_CFGR)</a>, <a href="#">Section 7.4.4: APB peripheral reset register 2 (RCC_APB2RSTR)</a>, <a href="#">Section 7.4.12: Clock configuration register 2 (RCC_CFGR2)</a>, <a href="#">Section 7.4.13: Clock configuration register 3 (RCC_CFGR3)</a>.  Modified <a href="#">Figure 9: Simplified diagram of the reset circuit</a> and <a href="#">Figure 10: Clock tree</a>.  Replaced FORCE_OBL with OBL_LAUNCH in <a href="#">Option byte loader reset</a>.  Deleted <a href="#">Section 7.2.13: Clock-independent system clock sources for TIM14</a>.  Added USART3EN, UART4EN and UART5EN in <a href="#">Table 18: RCC register map and reset values</a>.  Modified reset values of RCC_CSR register in <a href="#">Table 18: RCC register map and reset values</a>.  Modified reset value and description of Bit 23 in <a href="#">Section 7.4.10: Control/status register (RCC_CSR)</a>.  Specified Bit 8 as obsolete in <a href="#">Section 7.4.13: Clock configuration register 3 (RCC_CFGR3)</a>.</p> <p><b>GPIO:</b>  Updated <a href="#">Section 8.1: GPIO introduction</a>.  Removed “Analog” arrows in <a href="#">Figure 14: Basic structure of a five-volt tolerant I/O port bit</a>.  Renamed <a href="#">Section 8.4.11: GPIO port bit reset register (GPIOx_BRR) (x=A..D, F)</a>.</p> <p><b>SYSCFG:</b>  Modified values of register bits 23, 22 and 20.</p> <p><b>Interrupts and events:</b>  Added Priority numbers and modified description of EXTI4_15 in <a href="#">Table 26: Vector table</a>.</p> <p><b>ADC:</b>  Rephrased part of <a href="#">Section 12.4.1: Calibration (ADCAL)</a>.  Replaced AUTDLY with WAIT in sections <a href="#">Section 12.5.5: Example timing diagrams (single/continuous modes hardware/software triggers)</a> and <a href="#">Section 12.12.4: ADC configuration register 1 (ADC_CFGR1)</a>.  Updated <a href="#">Figure 23: ADC block diagram</a>.  Replaced "0x44...0x2FC" with "0x44...0x304" in <a href="#">Table 37: ADC register map and reset values</a>.</p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
10-May-2013	3 (Continued)	<p><b>DAC:</b> Corrected name of <a href="#">Table 40: ADC3 &amp; ADC4 - External trigger for regular channels</a>. Replaced every occurrence of “DAC1” with “DAC”.</p> <p><b>COMP:</b> Replaced “COMP1SW1 : Comparator enable” with “COMP1SW1 : Comparator 1 non inverting input DAC switch” in <a href="#">Section 14.4.1: COMP control and status register (COMP_CSR)</a>.</p> <p><b>TIM2 and TIM3:</b> Corrected <a href="#">Figure 104: Advanced-control timer block diagram</a>.</p> <p><b>TIM14:</b> Updated <a href="#">Figure 155: TIM16 and TIM17 block diagram</a>.</p> <p><b>TIM15/16/17:</b> Updated <a href="#">Section 18.1: TIM15/16/17 introduction</a>, <a href="#">Section 18.3: TIM16 and TIM17 main features</a> and <a href="#">Section 18.4.4: Clock sources</a>. Removed Note in <a href="#">Section 18.6.1: TIM16 and TIM17 control register 1 (TIM16_CR1 and TIM17_CR1)</a>. Marked as “reserved”: Bits 14 and 6 in <a href="#">Section 18.6.3: TIM16 and TIM17 DMA/interrupt enable register (TIM16_DIER and TIM17_DIER)</a>, bits 6 and 0 in <a href="#">Section 18.6.4: TIM16 and TIM17 status register (TIM16_SR and TIM17_SR)</a>, and bit 6 in <a href="#">Section 18.6.5: TIM16 and TIM17 event generation register (TIM16_EGR and TIM17_EGR)</a>. Updated <a href="#">Table 56: TIM16 and TIM17 register map and reset values</a>.</p> <p><b>RTC:</b> Replaced “power-on reset” with “backup domain reset” throughout <a href="#">Section 23: Real-time clock (RTC)</a>. Removed “the backup registers are reset when a tamper detection event occurs” in <a href="#">Section 23.2: RTC main features</a>. Updated <a href="#">RTC backup registers</a>. Updated RTC_ISR register reset values in <a href="#">Section 23.3.8: Resetting the RTC</a> and <a href="#">Section 23.6.4: RTC initialization and status register (RTC_ISR)</a>.</p> <p><b>I2C:</b> Updated case of digital filter enabled and <a href="#">Table 67: Comparison of analog vs. digital filters</a>. Added note for WUPEN in <a href="#">Section 24.7.1: Control register 1 (I2Cx_CR1)</a>. Corrected <a href="#">Figure 217: Transfer sequence flowchart for I2C master transmitter for N&gt;255 bytes</a>. Removed maximum values of parameter “Data hold time” and added row “Data valid time” in <a href="#">Table 68: I2C-SMBUS specification data setup and hold times</a>. Updated sub-sections <a href="#">I2C timings</a> and <a href="#">Slave clock stretching (NOSTRETCH = 0)</a>.</p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
10-May-2013	3 (Continued)	<p><b>I2C (continued):</b> Updated <a href="#">Figure 198: I2C1 block diagram</a> and <a href="#">Figure 201: Setup and hold timings</a>. Reclassified section “I2C register map” from <a href="#">2.8</a> to <a href="#">24.7.12</a>. Added <a href="#">Caution: “If wakeup from Stop is disabled...”</a> in <a href="#">Section 24.4.15: Wakeup from STOP on address match</a>. Added <a href="#">Section 24.5: I2C low power modes</a>. Moved <a href="#">Section 24.7: I2C debug mode</a> to <a href="#">24.4.18</a> and renamed it <a href="#">Debug mode</a>. Updated <a href="#">Table 71: Examples of timings settings for fI2CCLK = 8 MHz</a>.</p> <p><b>USART:</b> Removed note on bit 19 (RWU) in <a href="#">Section 25.7.8: Interrupt &amp; status register (USART_ISR)</a>.</p> <p><b>SPI/I2S:</b> Reorganized SPI initialization and sequence handling sections. Corrected and updated SPI disabling and DMA handling procedures. Updated description of NSSP and TI modes. Corrected DMA CRC management. Removed CRC interrupt capability. Changed RXONLY and BIDIMODE bit description. Modified sections : <a href="#">Simplex communications on page 642</a> and : <a href="#">Data frame format on page 647</a>, <a href="#">26.3.7: Procedure for enabling SPI on page 649</a>, <a href="#">Figure 260: Hardware/software slave select management</a>, <a href="#">Figure 261: Data clock timing diagram</a>, <a href="#">Figure 262: Data alignment when data length is not equal to 8-bit or 16-bit</a>, <a href="#">Figure 269: TI mode transfer</a>. Modified reset value of SPIx_I2SPR in <a href="#">Section 26.7.9: SPIx_I2S prescaler register (SPIx_I2SPR)</a>. Added <a href="#">Figure 264: Master full duplex communication</a>, <a href="#">Figure 265: Slave full duplex communication</a>, <a href="#">Figure 266: Master full duplex communication with CRC</a>, <a href="#">Figure 267: Master full duplex communication in packed mode</a>.</p> <p><b>TSC:</b> Replaced “Power-on reset value” with “Reset value” in <a href="#">Section 27.6.2: TSC interrupt enable register (TSC_IER)</a>.</p> <p><b>Debug:</b> Renamed <a href="#">Section 29.3.2: SW-DP pin assignment</a>. Changed description of Bits 11:0 in <a href="#">Section 29.4.1: MCU device ID code</a>. Modified notes regarding IDCODE register in <a href="#">Table 110: SW-DP registers</a>.</p>

**Table 114. Document revision history (continued)**

Date	Revision	Changes
21-May-2013	4	<p><b>ADC:</b></p> <p>Added note in <a href="#">Section 12.5.2: Programmable resolution (RES) - fast conversion mode</a>: RES[1:0] can be changed only when ADEN=0.</p> <p>Added bit CKMODE.</p> <p>Rewrote <a href="#">Section 12.4.2: ADC on-off control (ADEN, ADDIS, ADRDY)</a> and <a href="#">Section 12.4.3: ADC clock (CKMODE)</a>.</p> <p>Added <a href="#">Figure 26: ADC clock scheme</a>.</p> <p>Fixed issues concerning CKMODE &amp; JITOOF bits. Now bits JITOOF_DIV4/DIV2 bits are replaced with bits CKMODE[1:0] at the same position and with same decoding as v1.</p> <p>Changed note on ADRDY in <a href="#">Section 12.4.2: ADC on-off control (ADEN, ADDIS, ADRDY)</a>.</p> <p>Extended <a href="#">Section 12.12.8: ADC channel selection register (ADC_CHSEL)</a> (added channel 18).</p> <p>Removed reference to TSVREFE bit in <a href="#">Section 12.9: Temperature sensor and internal reference voltage</a> and added reference to TSEN/VREFEN instead.</p>

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