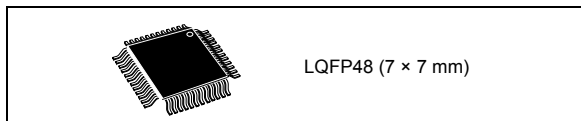


ARM[®] Cortex[®]-M4 32b MCU+FPU, 64KB Flash, 16KB SRAM,
2 ADCs, 3 DAC channels, 3 COMPs, Op-Amp, 1.8 V

Datasheet –production data

Features

- Core: ARM[®]-32-bit Cortex[®]-M4 CPU with FPU (72 MHz max), single-cycle multiplication and HW division, and DSP instruction
- Memories
 - Up to 64 KB of Flash memory
 - 12 KB of SRAM with HW parity check
 - Routine booster: 4 KB of SRAM on instruction and data bus with HW parity check (CCM)
- CRC calculation unit
- Reset and supply management
 - V_{DD} : 1.8 V +/-8%
 - V_{DDA} : voltage range: 1.65 to 3.6 V
 - Low-power modes: Sleep, Stop
 - V_{BAT} supply for RTC and backup registers
- Clock management
 - 4 to 32 MHz crystal oscillator
 - 32 kHz oscillator for RTC with calibration
 - Internal 8 MHz RC (up to 64 MHz with PLL option)
 - Internal 40 kHz oscillator
- Up to 36 fast I/O ports, all mappable on external interrupt vectors, several 5 V-tolerant
- Interconnect Matrix
- 7-channel DMA controller
- Up to two ADC 0.20 μ s (up to 14 channels) with selectable resolution of 12/10/8/6 bits, 0 to 3.6 V conversion range, single-ended/differential mode, separate analog supply from 1.8 to 3.6 V
- Temperature sensor
- Up to three 12-bit DAC channels with analog supply from 2.4 V to 3.6 V
- Three ultra-fast rail-to-rail analog comparators with analog supply from 1.8 V to 3.6 V
- One operational amplifiers that can be used in PGA mode, all terminals accessible with analog supply from 2.4 to 3.6 V
- Up to 17 capacitive sensing channels supporting touchkeys, linear and rotary touch sensors
- Up to 11 timers
 - One 32-bit timer and one 16-bit timer with up to 4 IC/OC/PWM or pulse counter and quadrature (incremental) encoder input
 - One 16-bit 6-channel advanced-control timer, with up to 6 PWM channels, deadtime generation and emergency stop
 - One 16-bit timer with 2 IC/OCs, 1 OCN/PWM, deadtime generation, emergency stop
 - Two 16-bit timers with IC/OC/OCN/PWM, deadtime generation and emergency stop
 - Two watchdog timers (independent, window)
 - SysTick timer: 24-bit downcounter
 - Up to two 16-bit basic timers to drive the DAC
- Calendar RTC with alarm, periodic wakeup from Stop
- Communication interfaces
 - CAN interface (2.0 B Active)
 - One I²C with 20 mA current sink to support Fast mode plus, SMBus/PMBus
 - Up to 3 USARTs, one with ISO/IEC 7816 interface, LIN, IrDA, modem control
 - One SPI
- Debug mode: serial wire debug (SWD), JTAG
- 96-bit unique ID
- All packages ECOPACK[®]2



Contents

1	Introduction	8
2	Description	9
3	Functional overview	12
3.1	ARM® Cortex®-M4 core with FPU with embedded Flash and SRAM	12
3.2	Memories	12
3.2.1	Embedded Flash memory	12
3.2.2	Embedded SRAM	12
3.2.3	Boot modes	13
3.3	Cyclic redundancy check calculation unit (CRC)	13
3.4	Power management	13
3.4.1	Power supply schemes	13
3.4.2	Power supply supervision	13
3.4.3	Low-power modes	14
3.5	Interconnect matrix	14
3.6	Clocks and startup	15
3.7	General-purpose inputs/outputs (GPIOs)	16
3.8	Direct memory access (DMA)	17
3.9	Interrupts and events	17
3.9.1	Nested vectored interrupt controller (NVIC)	17
3.9.2	Extended interrupt/event controller (EXTI)	17
3.10	Fast analog-to-digital converter (ADC)	18
3.10.1	Temperature sensor	18
3.10.2	Internal voltage reference (VREFINT)	18
3.10.3	V _{BAT} battery voltage monitoring	19
3.10.4	OPAMP2 reference voltage (VOPAMP2)	19
3.11	Digital-to-analog converter (DAC)	19
3.12	Operational amplifier (OPAMP)	19
3.13	Ultra-fast comparators (COMP)	20
3.14	Timers and watchdogs	20
3.14.1	Advanced timer (TIM1)	21

3.14.2	General-purpose timers (TIM2, TIM3, TIM15, TIM16, TIM17)	21
3.14.3	Basic timers (TIM6 and TIM7)	21
3.14.4	Independent watchdog	22
3.14.5	Window watchdog	22
3.14.6	SysTick timer	22
3.15	Real-time clock (RTC) and backup registers	22
3.16	Communication interfaces	23
3.16.1	Inter-integrated circuit interface (I ² C)	23
3.16.2	Universal synchronous/asynchronous receiver transmitters (USARTs) .	24
3.16.3	Serial peripheral interface (SPI)	25
3.16.4	Controller area network (CAN)	25
3.17	Infrared transmitter	25
3.18	Touch sensing controller (TSC)	26
3.19	Development support	27
3.19.1	Serial wire JTAG debug port (SWJ-DP)	27
4	Pinouts and pin description	28
5	Memory mapping	40
6	Electrical characteristics	43
6.1	Parameter conditions	43
6.1.1	Minimum and maximum values	43
6.1.2	Typical values	43
6.1.3	Typical curves	43
6.1.4	Loading capacitor	43
6.1.5	Pin input voltage	43
6.1.6	Power supply scheme	44
6.1.7	Current consumption measurement	45
6.2	Absolute maximum ratings	46
6.3	Operating conditions	48
6.3.1	General operating conditions	48
6.3.2	Operating conditions at power-up / power-down	49
6.3.3	Embedded reference voltage	50
6.3.4	Supply current characteristics	50
6.3.5	Wakeup time from low-power mode	63

6.3.6	External clock source characteristics	63
6.3.7	Internal clock source characteristics	68
6.3.8	PLL characteristics	69
6.3.9	Memory characteristics	70
6.3.10	EMC characteristics	71
6.3.11	Electrical sensitivity characteristics	72
6.3.12	I/O current injection characteristics	73
6.3.13	I/O port characteristics	74
6.3.14	NRST pin characteristics	78
6.3.15	NPOR pin characteristics	79
6.3.16	Timer characteristics	80
6.3.17	Communications interfaces	82
6.3.18	ADC characteristics	85
6.3.19	DAC electrical specifications	94
6.3.20	Comparator characteristics	96
6.3.21	Operational amplifier characteristics	97
6.3.22	Temperature sensor (TS) characteristics	100
7	Package characteristics	101
7.1	Package mechanical data	101
7.2	Thermal characteristics	105
7.2.1	Reference document	105
7.2.2	Selecting the product temperature range	106
8	Part numbering	107
9	Revision history	108

List of tables

Table 1.	STM32F328C8 family device features and peripherals count	10
Table 2.	V _{DDA} ranges for analog peripherals	13
Table 3.	STM32F328C8 Peripheral interconnect matrix.	14
Table 4.	Timer feature comparison.	20
Table 5.	Comparison of I2C analog and digital filters.	23
Table 6.	STM32F328C8 I ² C implementation	24
Table 7.	USART features	24
Table 8.	STM32F328C8 SPI implementation	25
Table 9.	Capacitive sensing GPIOs available on STM32F328C8 devices	26
Table 10.	No. of capacitive sensing channels available on STM32F328C8 devices	27
Table 11.	Legend/abbreviations used in the pinout table	29
Table 12.	STM32F328C8 pin definitions	29
Table 13.	Alternate functions	36
Table 14.	STM32F328C8 peripheral register boundary addresses	41
Table 15.	Voltage characteristics	46
Table 16.	Current characteristics	47
Table 17.	Thermal characteristics.	47
Table 18.	General operating conditions	48
Table 19.	Operating conditions at power-up / power-down	49
Table 20.	Embedded internal reference voltage.	50
Table 21.	Internal reference voltage calibration values	50
Table 22.	Typical and maximum current consumption from V _{DD} supply at V _{DD} = 1.8 V	52
Table 23.	Typical and maximum current consumption from the V _{DDA} supply	54
Table 24.	Typical and maximum V _{DD} consumption in Stop mode	54
Table 25.	Typical and maximum V _{DDA} consumption in Stop mode	54
Table 26.	Typical and maximum current consumption from V _{BAT} supply.	55
Table 27.	Typical current consumption in Run mode, code with data processing running from Flash	57
Table 28.	Typical current consumption in Sleep mode, code running from Flash or RAM	58
Table 29.	Switching output I/O current consumption	60
Table 30.	Peripheral current consumption	61
Table 31.	Low-power mode wakeup timings	63
Table 32.	High-speed external user clock characteristics.	63
Table 33.	Low-speed external user clock characteristics	64
Table 34.	HSE oscillator characteristics	65
Table 35.	LSE oscillator characteristics (f _{LSE} = 32.768 kHz)	67
Table 36.	HSI oscillator characteristics.	68
Table 37.	LSI oscillator characteristics	69
Table 38.	PLL characteristics	69
Table 39.	Flash memory characteristics	70
Table 40.	Flash memory endurance and data retention	70
Table 41.	EMS characteristics	71
Table 42.	EMI characteristics	72
Table 43.	ESD absolute maximum ratings	72
Table 44.	Electrical sensitivities	73
Table 45.	I/O current injection susceptibility	73
Table 46.	I/O static characteristics	74
Table 47.	Output voltage characteristics	76
Table 48.	I/O AC characteristics	77

Table 49.	NRST pin characteristics	78
Table 50.	NPOR pin characteristics	79
Table 51.	TIMx characteristics	80
Table 52.	IWDG min./max. timeout period at 40 kHz (LSI)	81
Table 53.	WWDG min./max. timeout value at 72 MHz (PCLK)	81
Table 54.	I2C analog filter characteristics	82
Table 55.	SPI characteristics	83
Table 56.	ADC characteristics	85
Table 57.	Maximum ADC RAIN	88
Table 58.	ADC accuracy - limited test conditions	89
Table 59.	ADC accuracy	91
Table 60.	ADC accuracy at 1MSPS	92
Table 61.	DAC characteristics	94
Table 62.	Comparator characteristics	96
Table 63.	Operational amplifier characteristics	97
Table 64.	Temperature sensor (TS) characteristics	100
Table 65.	Temperature sensor (TS) calibration values	100
Table 66.	LQFP48 – 7 x 7 mm, 48-pin low-profile quad flat package mechanical data	102
Table 67.	Package thermal characteristics	105
Table 68.	Ordering information scheme	107
Table 69.	Document revision history	108

List of figures

Figure 1.	STM32F328C8 block diagram	11
Figure 2.	Clock tree	16
Figure 3.	Infrared transmitter	26
Figure 4.	LQFP48 pinout	28
Figure 5.	STM32F328C8 memory map	40
Figure 6.	Pin loading conditions	43
Figure 7.	Pin input voltage	43
Figure 8.	Power supply scheme	44
Figure 9.	Current consumption measurement scheme	45
Figure 10.	Typical V_{BAT} current consumption (LSE and RTC ON/LSEDRV[1:0] = '00')	55
Figure 11.	High-speed external clock source AC timing diagram	64
Figure 12.	Low-speed external clock source AC timing diagram	64
Figure 13.	Typical application with an 8 MHz crystal	66
Figure 14.	Typical application with a 32.768 kHz crystal	68
Figure 15.	HSI oscillator accuracy characterization results for soldered parts	69
Figure 16.	TC and TTA I/O input characteristics - CMOS port	75
Figure 17.	TC and TTA I/O input characteristics - TTL port	76
Figure 18.	I/O AC characteristics definition	78
Figure 19.	Recommended NRST pin protection	79
Figure 20.	SPI timing diagram - slave mode and CPHA = 0	84
Figure 21.	SPI timing diagram - slave mode and CPHA = 1 ⁽¹⁾	84
Figure 22.	SPI timing diagram - master mode ⁽¹⁾	85
Figure 23.	ADC typical current consumption in single-ended and differential modes	87
Figure 24.	ADC accuracy characteristics	93
Figure 25.	Typical connection diagram using the ADC	93
Figure 26.	12-bit buffered /non-buffered DAC	95
Figure 27.	Maximum V_{REFINT} scaler startup time from power down	96
Figure 28.	OPAMP Voltage Noise versus Frequency	99
Figure 29.	LQFP48 – 7 x 7mm, 48-pin low-profile quad flat package outline	102
Figure 30.	LQFP48 recommended footprint	103
Figure 31.	LQFP48 marking example (package top view)	104

1 Introduction

This datasheet provides the ordering information and mechanical device characteristics of the STM32F328C8 microcontrollers.

This STM32F328C8 datasheet should be read in conjunction with the STM32F303xx, STM32F358xx and STM32F328xx advanced ARM-based 32-bit MCUs reference manual (RM00316) available from the STMicroelectronics website www.st.com.

For information on the Cortex[®]-M4 core with FPU, please refer to:

- ARM[®] Cortex[®]-M4 Processor Technical Reference Manual available from the www.arm.com website.
- STM32F3xxx and STM32F4xxx Cortex[®]-M4 programming manual (PM0214) available from the www.st.com website.



2 Description

The STM32F328C8 family is based on the high-performance ARM® 32-bit Cortex®-M4 RISC core operating at a frequency of up to 72 MHz, and embedding a floating point unit (FPU). The STM32F328C8 family incorporates high-speed embedded memories (up to 64 Kbytes of Flash memory, 12 Kbytes of SRAM), and an extensive range of enhanced I/Os and peripherals connected to two APB buses.

The STM32F328C8 devices offer up to two fast 12-bit ADCs (5 Msps), up to three ultra-fast comparators, an operational amplifier, three DAC channels, a low-power RTC, one general-purpose 32-bit timer, one timer dedicated to motor control, and four general-purpose 16-bit timers. They also feature standard and advanced communication interfaces: one I²C, one SPI, up to three USARTs and one CAN.

The STM32F328C8 family operates in the –40 to +85 °C and –40 to +105 °C temperature ranges from 1.8 V +/-8% power supply. A comprehensive set of power-saving mode allows the design of low-power applications.

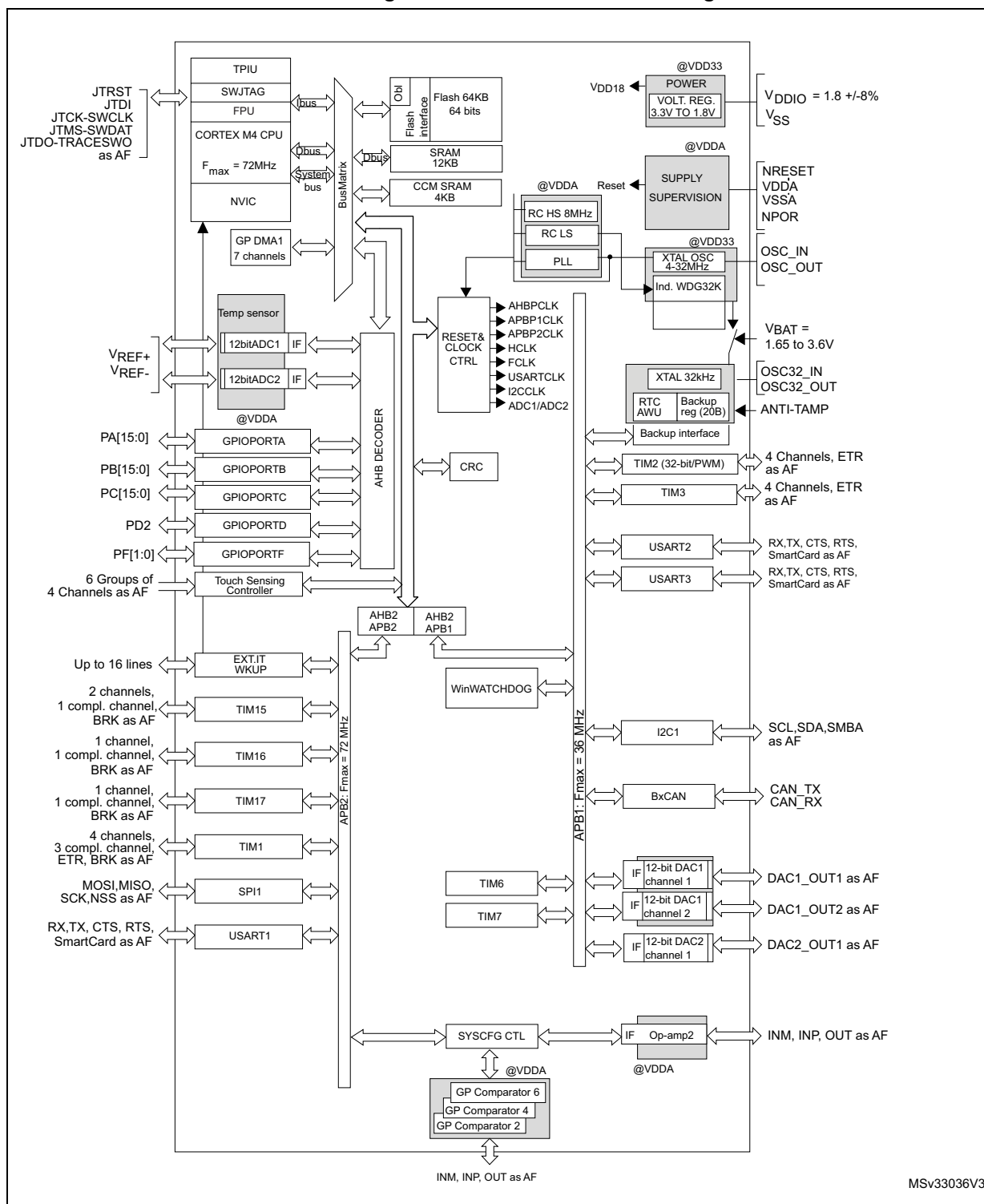
The STM32F328C8 family offers devices in 48-pin packages.

Table 1. STM32F328C8 family device features and peripherals count

Peripheral		STM32F328C8
Flash (Kbytes)		64
SRAM on data bus (Kbytes)		12
Core coupled memory SRAM on instruction bus (CCM SRAM) (Kbytes)		4
Timers	Advanced control	1 (16-bit)
	General purpose	4 (16-bit) 1 (32 bit)
	Basic	2 (16-bit)
	SysTick timer	1
	Watchdog timers (independent, window)	2
	PWM channels (all) ⁽¹⁾	22
	PWM channels (except complementary)	16
Comm. interfaces	SPI	1
	I ² C	1
	USART	3
	CAN	1
GPIOs	Normal I/Os (TC, TTa)	19
	5-Volt tolerant I/Os (FT,FTf)	17
Capacitive sensing channels		17
DMA channels		7
12-bit ADCs		2
Number of channels		14
12-bit DAC channels		3
Ultra-fast analog comparator		3
Operational amplifiers		1
CPU frequency		72 MHz
Operating voltage		$V_{DD} = 1.8\text{ V} \pm 8\%$, $V_{DDA} = 1.65\text{ V to }3.6\text{ V}$
Operating temperature		Ambient operating temperature: - 40 to 85 °C / - 40 to 105 °C Junction temperature: - 40 to 125 °C
Packages		LQFP48

1. This total considers also the PWMs generated on the complementary output channels.

Figure 1. STM32F328C8 block diagram



MSv33036V3

1. AF: alternate function on I/O pins.

3 Functional overview

3.1 ARM[®] Cortex[®]-M4 core with FPU with embedded Flash and SRAM

The ARM Cortex-M4 processor with FPU is the latest generation of ARM processors for embedded systems. It was developed to provide a low-cost platform that meets the needs of MCU implementation, with a reduced pin count and low-power consumption, while delivering outstanding computational performance and an advanced response to interrupts.

The ARM 32-bit Cortex-M4 RISC processor with FPU features exceptional code-efficiency, delivering the high-performance expected from an ARM core in the memory size usually associated with 8- and 16-bit devices.

The processor supports a set of DSP instructions which allow efficient signal processing and complex algorithm execution.

Its single precision FPU speeds up software development by using metalanguage development tools, while avoiding saturation.

With its embedded ARM core, the STM32F328C8 family is compatible with all ARM tools and software.

Figure 1 shows the general block diagrams of the STM32F328C8 family devices.

3.2 Memories

3.2.1 Embedded Flash memory

All STM32F328C8 devices feature up to 64 Kbytes of embedded Flash memory available for storing programs and data. The Flash memory access time is adjusted to the CPU clock frequency (0 wait state from 0 to 24 MHz, 1 wait state from 24 to 48 MHz and 2 wait states above).

3.2.2 Embedded SRAM

The STM32F328C8 devices feature 12 Kbytes of embedded SRAM with hardware parity check. The memory can be accessed in read/write at CPU clock speed with 0 wait states, allowing the CPU to achieve 90 Dhrystone Mips at 72 MHz when running code from CCM (core coupled memory) RAM.

The SRAM is organized as follows:

- 4 Kbytes of SRAM on instruction and data bus with parity check (core coupled memory or CCM) and used to execute critical routines or to access data
- 12 Kbytes of SRAM with parity check mapped on the data bus.

3.2.3 Boot modes

At startup, BOOT0 pin and BOOT1 option bit are used to select one of three boot options:

- Boot from user Flash
- Boot from system memory
- Boot from embedded SRAM

The boot loader is located in system memory. It is used to reprogram the Flash memory by using USART1 (PA9/PA10), USART2 (PA2/PA3), I2C1 (PB6/PB7).

3.3 Cyclic redundancy check calculation unit (CRC)

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code using a configurable generator polynomial value and size.

Among other applications, CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the EN/IEC 60335-1 standard, 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 linktime and stored at a given memory location.

3.4 Power management

3.4.1 Power supply schemes

- V_{SS} , $V_{DD} = 1.8\text{ V} \pm 8\%$: external power supply for I/Os and core. It is provided externally through VDD pins.
- V_{SSA} , $V_{DDA} = 1.65\text{ to }3.6\text{ V}$: external analog power supply for ADC, DACs, comparators operational amplifiers, reset blocks, RCs and PLL. The minimum voltage to be applied to V_{DDA} differs from one analog peripherals to another. See the table below, summarizing the V_{DDA} ranges for analog peripherals. The V_{DDA} voltage level must be always greater or equal to the V_{DD} voltage level and must be provided first.

Table 2. V_{DDA} ranges for analog peripherals

Analog peripheral	Min V_{DDA} supply	Max V_{DDA} supply
ADC/COMP	1.8 V	3.6 V
DAC/OPAMP	2.4 V	3.6 V

- $V_{BAT} = 1.65\text{ to }3.6\text{ V}$: power supply for RTC, external clock 32 kHz oscillator and backup registers (through power switch which is guaranteed in the full range of VDD) when VDD is not present.

3.4.2 Power supply supervision

The device power on reset is controlled through the external NPOR pin. The device remains in reset state when NPOR pin is held low. To guarantee a proper power-on reset, the NPOR

pin must be held low when VDDA is applied. Then, when VDD is stable, the reset state can be exited by:

- either putting the NPOR pin in high impedance. NPOR pin has an internal pull up
- or forcing the pin to high level by connecting it to VDDA.

3.4.3 Low-power modes

The STM32F328C8 supports three low-power modes to achieve the best compromise between low power consumption, short startup time and available wakeup sources:

- Sleep mode
In Sleep mode, only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.
- Stop mode
Stop mode achieves the lowest power consumption while retaining the content of SRAM and registers. All clocks in the 1.8 V domain are stopped, the PLL, the HSI RC and the HSE crystal oscillators are disabled. The voltage regulator can also be put either in normal or in low-power mode.
The device can be woken up from Stop mode by any of the EXTI line. The EXTI line source can be one of the 16 external lines, the PVD output, the RTC alarm, COMPx, I2C or USARTx.

Note: The RTC, the IWDG, and the corresponding clock sources are not stopped by entering Stop mode.

3.5 Interconnect matrix

Several peripherals have direct connections between them. This allows autonomous communication between peripherals, saving CPU resources thus power supply consumption. In addition, these hardware connections allow fast and predictable latency.

Table 3. STM32F328C8 Peripheral interconnect matrix

Interconnect source	Interconnect destination	Interconnect action
TIMx	TIMx	Timers synchronization or chaining
	ADCx DACx	Conversion triggers
	DMA	Memory to memory transfer trigger
	COMPx	Comparator output blanking
COMPx	TIMx	Timer input: ocrefclear input, input capture
ADCx	TIM1	Timer triggered by analog watchdog
GPIO RTCCLK HSE/32 MC0	TIM16	Clock source used as input channel for HSI and LSI calibration

Table 3. STM32F328C8 Peripheral interconnect matrix (continued)

Interconnect source	Interconnect destination	Interconnect action
CSS CPU (hard fault) RAM (parity error) COMPx PVD GPIO	TIM1 TIM15, 16, 17	Timer break
GPIO	TIMx	External trigger, timer break
	ADCx DACx	Conversion external trigger
DACx	COMPx	Comparator inverting input

Note: For more details about the interconnect actions, please refer to the corresponding sections in the RM0316 reference manual.

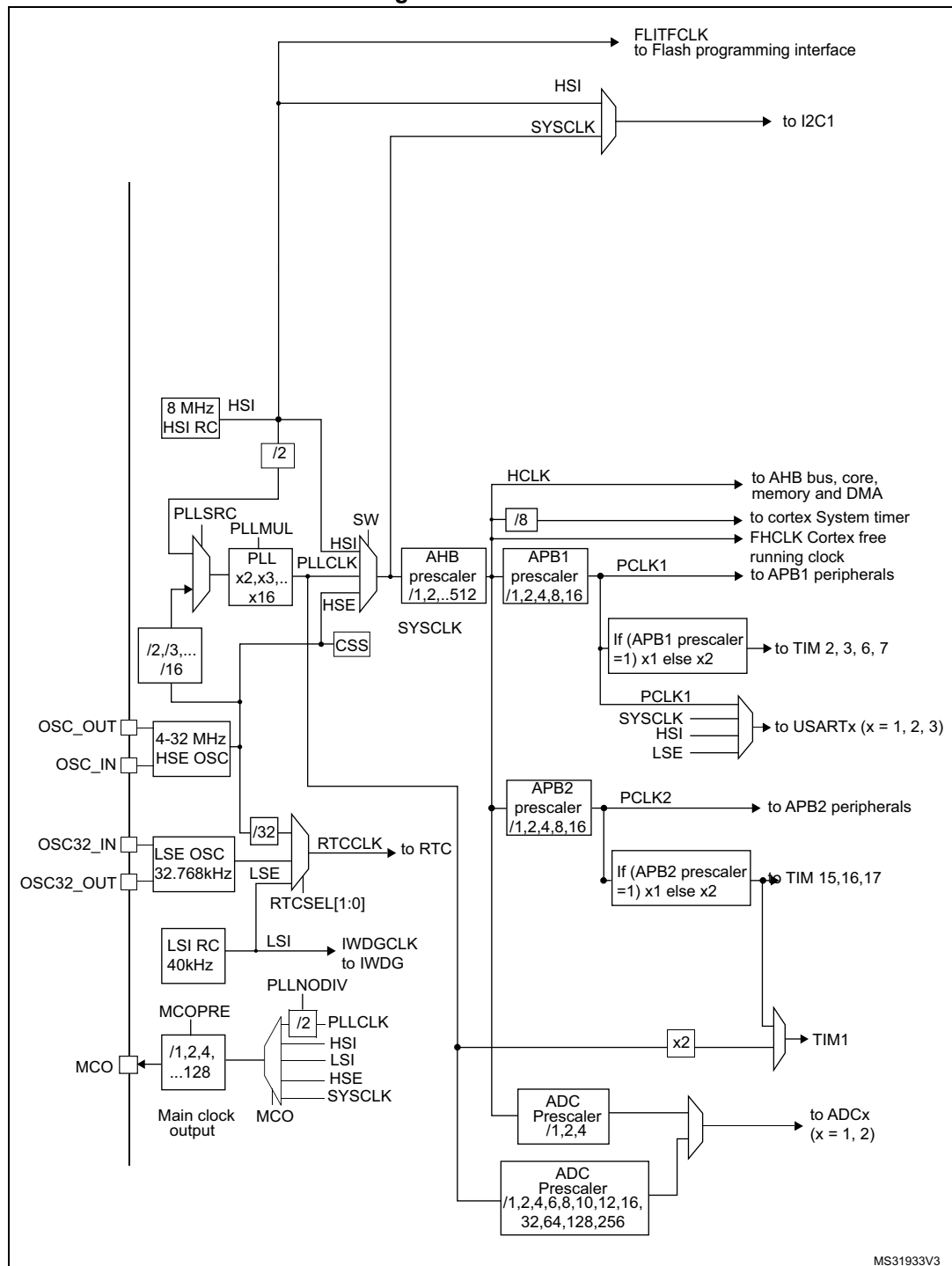
3.6 Clocks and startup

System clock selection is performed on startup, however the internal RC 8 MHz oscillator is selected as default CPU clock on reset. An external 4-32 MHz clock can be selected, in which case it is monitored for failure. If failure is detected, the system automatically switches back to the internal RC oscillator. A software interrupt is generated if enabled. Similarly, full interrupt management of the PLL clock entry is available when necessary (for example with failure of an indirectly used external oscillator).

Several prescalers allow to configure the AHB frequency, the high speed APB (APB2) and the low speed APB (APB1) domains. The maximum frequency of the AHB and the high speed APB domains is 72 MHz, while the maximum allowed frequency of the low speed APB domain is 36 MHz.

TIM1 maximum frequency is 144 MHz.

Figure 2. Clock tree



3.7 General-purpose inputs/outputs (GPIOs)

Each of the GPIO pins can be configured by software as output (push-pull or open-drain), as input (with or without pull-up or pull-down) or as peripheral alternate function. Most of the

GPIO pins are shared with digital or analog alternate functions. All GPIOs are high current capable except for analog inputs.

The I/Os alternate function configuration can be locked if needed following a specific sequence in order to avoid spurious writing to the I/Os registers.

Fast I/O handling allows I/O toggling up to 36 MHz.

3.8 Direct memory access (DMA)

The flexible general-purpose DMA is able to manage memory-to-memory, peripheral-to-memory and memory-to-peripheral transfers. The DMA controller supports circular buffer management, avoiding the generation of interrupts when the controller reaches the end of the buffer.

Each of the 7 DMA channels is connected to dedicated hardware DMA requests, with software trigger support for each channel. Configuration is done by software and transfer sizes between source and destination are independent.

The DMA can be used with the main peripherals: SPI, I²C, USART, general-purpose timers, DAC and ADC.

3.9 Interrupts and events

3.9.1 Nested vectored interrupt controller (NVIC)

The STM32F328C8 devices embed a nested vectored interrupt controller (NVIC) able to handle up to 60 interrupt channels, that can be masked and 16 priority levels.

The NVIC benefits are the following:

- Closely coupled NVIC gives low latency interrupt processing
- Interrupt entry vector table address passed directly to the core
- Closely coupled NVIC core interface
- Allows early processing of interrupts
- Processing of late arriving higher priority interrupts
- Support for tail chaining
- Processor state automatically saved
- Interrupt entry restored on interrupt exit with no instruction overhead

The NVIC hardware block provides flexible interrupt management features with minimal interrupt latency.

3.9.2 Extended interrupt/event controller (EXTI)

The external interrupt/event controller consists of 27 edge detector lines used to generate interrupt/event requests and wake-up the system. Each line can be independently configured to select the trigger event (rising edge, falling edge, both) and can be masked independently. A pending register maintains the status of the interrupt requests. The EXTI can detect an external line with a pulse width shorter than the internal clock period. Up to 37 GPIOs can be connected to the 16 external interrupt lines.

3.10 Fast analog-to-digital converter (ADC)

Two 5 MSPS fast analog-to-digital converters, with selectable resolution between 12 and 6 bit, are embedded in the STM32F328C8 family devices. The ADCs have up to 14 external channels. Some of the external channels are shared between ADC1 and ADC2, performing conversions in single-shot or scan modes. The channels can be configured to be either single-ended input or differential input. In scan mode, automatic conversion is performed on a selected group of analog inputs.

The ADCs also have internal channels: temperature sensor connected to ADC1 channel 16, $V_{BAT}/2$ connected to ADC1 channel 17, voltage reference V_{REFINT} connected to both ADC1 and ADC2 channel 18 and VOPAMP2 connected to ADC2 channel 17.

Additional logic functions embedded in the ADC interface allow:

- Simultaneous sample and hold
- Interleaved sample and hold
- Single-shunt phase current reading techniques.

Three analog watchdogs are available per ADC. The ADC can be served by the DMA controller.

The analog watchdog feature allows very precise monitoring of the converted voltage of one, some or all selected channels. An interrupt is generated when the converted voltage is outside the programmed thresholds.

The events generated by the general-purpose timers (TIM2, TIM3, TIM6, TIM15) can be internally connected to the ADC start trigger and injection trigger, respectively, to allow the application to synchronize A/D conversion and timers.

3.10.1 Temperature sensor

The temperature sensor (TS) generates a voltage V_{SENSE} that varies linearly with temperature.

The temperature sensor is internally connected to the ADC1_IN16 input channel which is used to convert the sensor output voltage into a digital value.

The sensor provides good linearity but it has to be calibrated to obtain good overall accuracy of the temperature measurement. As the offset of the temperature sensor varies from chip to chip due to process variation, the uncalibrated internal temperature sensor is suitable for applications that detect temperature changes only.

To improve the accuracy of the temperature sensor measurement, each device is individually factory-calibrated by ST. The temperature sensor factory calibration data are stored by ST in the system memory area, accessible in read-only mode.

3.10.2 Internal voltage reference (VREFINT)

The internal voltage reference (VREFINT) provides a stable (bandgap) voltage output for the ADC and Comparators. VREFINT is internally connected to the ADC1_IN18 and ADC2_IN18 input channels. 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.

3.10.3 V_{BAT} battery voltage monitoring

This embedded hardware feature allows the application to measure the V_{BAT} battery voltage using the internal ADC channel ADC1_IN17. As the V_{BAT} voltage may be higher than V_{DDA} , and thus outside the ADC input range, the V_{BAT} pin is internally connected to a bridge divider by 2. As a consequence, the converted digital value is half the V_{BAT} voltage.

3.10.4 OPAMP2 reference voltage (VOPAMP2)

OPAMP2 reference voltage can be measured using ADC2 internal channel 17.

3.11 Digital-to-analog converter (DAC)

One 12-bit buffered DAC channel (DAC1_OUT1) and two 12-bit unbuffered DAC channels (DAC1_OUT2 and DAC2_OUT1) can be used to convert digital signals into analog voltage signal outputs. The chosen design structure is composed of integrated resistor strings and an amplifier in inverting configuration.

This digital interface supports the following features:

- Three DAC output channels
- 8-bit or 12-bit monotonic output
- Left or right data alignment in 12-bit mode
- Synchronized update capability
- Noise-wave generation (only on DAC1)
- Triangular-wave generation (only on DAC1)
- Dual DAC channel independent or simultaneous conversions
- DMA capability for each channel
- External triggers for conversion

3.12 Operational amplifier (OPAMP)

The STM32F328C8 embeds an operational amplifier (OPAMP2) with external or internal follower routing and PGA capability (or even amplifier and filter capability with external components). When an operational amplifier is selected, an external ADC channel is used to enable output measurement.

The operational amplifier features:

- 8 MHz GBP
- 0.5 mA output capability
- Rail-to-rail input/output
- In PGA mode, the gain can be programmed to 2, 4, 8 or 16.

3.13 Ultra-fast comparators (COMP)

The STM32F328C8 devices embed three ultra-fast rail-to-rail comparators (COMP2/4/6) which offer the features below:

- Programmable internal or external reference voltage
- Selectable output polarity.

The reference voltage can be one of the following:

- External I/O
- DAC output
- Internal reference voltage or submultiple (1/4, 1/2, 3/4). Refer to [Table 20: Embedded internal reference voltage](#) for values and parameters of the internal reference voltage.

All comparators can wake up from STOP mode, generate interrupts and breaks for the timers.

3.14 Timers and watchdogs

The STM32F328C8 includes advanced control timer, 5 general-purpose timers, basic timer, two watchdog timers and a SysTick timer. The table below compares the features of the advanced control, general purpose and basic timers.

Table 4. Timer feature comparison

Timer type	Timer	Counter resolution	Counter type	Prescaler factor	DMA request generation	Capture/compare Channels	Complementary outputs
Advanced control	TIM1 ⁽¹⁾	16-bit	Up, Down, Up/Down	Any integer between 1 and 65536	Yes	4	Yes
General-purpose	TIM2	32-bit	Up, Down, Up/Down	Any integer between 1 and 65536	Yes	4	No
General-purpose	TIM3	16-bit	Up, Down, Up/Down	Any integer between 1 and 65536	Yes	4	No
General-purpose	TIM15	16-bit	Up	Any integer between 1 and 65536	Yes	2	1
General-purpose	TIM16, TIM17	16-bit	Up	Any integer between 1 and 65536	Yes	1	1
Basic	TIM6, TIM7	16-bit	Up	Any integer between 1 and 65536	Yes	0	No

1. TIM1 can be clocked from the PLL running at 144 MHz when the system clock source is the PLL and AHB or APB2 subsystem clocks are not divided by more than 2 cumulatively.

3.14.1 Advanced timer (TIM1)

The advanced-control timer can be seen as a three-phase PWM multiplexed on 6 channels. They have complementary PWM outputs with programmable inserted dead-times. They can also be seen as complete general-purpose timers. The 4 independent channels can be used for:

- Input capture
- Output compare
- PWM generation (edge or center-aligned modes) with full modulation capability (0-100%)
- One-pulse mode output

In debug mode, the advanced-control timer counter can be frozen and the PWM outputs disabled to turn off any power switches driven by these outputs.

Many features are shared with those of the general-purpose TIM timers (described in [Section 3.14.2](#) using the same architecture, so the advanced-control timers can work together with the TIM timers via the Timer Link feature for synchronization or event chaining.

3.14.2 General-purpose timers (TIM2, TIM3, TIM15, TIM16, TIM17)

There are up to three general-purpose timers embedded in the STM32F328C8 (see [Table 4](#) for differences), that can be synchronized. Each general-purpose timer can be used to generate PWM outputs, or act as a simple time base.

- TIM2 and TIM3

They are full-featured general-purpose timers:

- TIM2 has a 32-bit auto-reload up/down counter and 32-bit prescaler
- TIM3 has a 16-bit auto-reload up/down counter and 16-bit prescaler.

These timers feature 4 independent channels for input capture/output compare, PWM or one-pulse mode output. They can work together, or with the other general-purpose timers via the Timer Link feature for synchronization or event chaining.

The counters can be frozen in debug mode.

All have independent DMA request generation and support quadrature encoders.

- TIM15, 16 and 17

These three timers general-purpose timers with mid-range features:

They have 16-bit auto-reload upcounters and 16-bit prescalers.

- TIM15 has 2 channels and 1 complementary channel
- TIM16 and TIM17 have 1 channel and 1 complementary channel

All channels can be used for input capture/output compare, PWM or one-pulse mode output.

The timers can work together via the Timer Link feature for synchronization or event chaining. The timers have independent DMA request generation.

The counters can be frozen in debug mode.

3.14.3 Basic timers (TIM6 and TIM7)

The basic timers are mainly used for DAC trigger generation. They can also be used as generic 16-bit timebases.

3.14.4 Independent watchdog

The independent watchdog is based on a 12-bit downcounter and 8-bit prescaler. It is clocked from an independent 40 kHz internal RC and as it operates independently from the main clock, it can operate in Stop mode. It can be used either as a watchdog to reset the device when a problem occurs, or as a free running timer for application timeout management. It is hardware or software configurable through the option bytes. The counter can be frozen in debug mode.

3.14.5 Window watchdog

The window watchdog is based on a 7-bit downcounter that can be set as free running. It can be used as a watchdog to reset the device when a problem occurs. It is clocked from the main clock. It has an early warning interrupt capability and the counter can be frozen in debug mode.

3.14.6 SysTick timer

This timer is dedicated to real-time operating systems, but could also be used as a standard down counter. It features:

- A 24-bit down counter
- Autoreload capability
- Maskable system interrupt generation when the counter reaches 0.
- Programmable clock source

3.15 Real-time clock (RTC) and backup registers

The RTC and the 5 backup registers are supplied through a switch that takes power from either the V_{DD} supply when present or the VBAT pin. The backup registers are five 32-bit registers used to store 20 bytes of user application data when V_{DD} power is not present.

They are not reset by a system or power reset.

The RTC is an independent BCD timer/counter. It supports the following features:

- Calendar with subsecond, seconds, minutes, hours (12 or 24 format), week day, date, month, year, in BCD (binary-coded decimal) format.
- Reference clock detection: a more precise second source clock (50 or 60 Hz) can be used to enhance the calendar precision.
- Automatic correction for 28, 29 (leap year), 30, and 31 days of the month.
- Two programmable alarms with wake up from Stop mode capability.
- On-the-fly correction from 1 to 32767 RTC clock pulses. This can be used to synchronize it with a master clock.
- Digital calibration circuit with 1 ppm resolution, to compensate for quartz crystal inaccuracy.
- Two anti-tamper detection pins with programmable filter. The MCU can be woken up from Stop mode on tamper event detection.
- Timestamp feature which can be used to save the calendar content. This function can be triggered by an event on the timestamp pin, or by a tamper event. The MCU can be woken up from Stop mode on timestamp event detection.
- 17-bit Auto-reload counter for periodic interrupt with wakeup from STOP capability.

The RTC clock sources can be:

- A 32.768 kHz external crystal
- A resonator or oscillator
- The internal low-power RC oscillator (typical frequency of 40 kHz)
- The high-speed external clock divided by 32.

3.16 Communication interfaces

3.16.1 Inter-integrated circuit interface (I²C)

The devices feature an I²C bus interface which can operate in multimaster and slave mode. It can support standard (up to 100 kHz), fast (up to 400 kHz) and fast mode + (up to 1 MHz) modes.

It supports 7-bit and 10-bit addressing modes, multiple 7-bit slave addresses (2 addresses, 1 with configurable mask). It also includes programmable analog and digital noise filters.

Table 5. Comparison of I2C analog and digital filters

	Analog filter	Digital filter
Pulse width of suppressed spikes	≥ 50 ns	Programmable length from 1 to 15 I2C peripheral clocks
Benefits	Available in Stop mode	1. Extra filtering capability vs. standard requirements. 2. Stable length
Drawbacks	Variations depending on temperature, voltage, process	Wakeup from Stop on address match is not available when digital filter is enabled.

In addition, it provides hardware support for SMBUS 2.0 and PMBUS 1.1: ARP capability, Host notify protocol, hardware CRC (PEC) generation/verification, timeouts verifications and ALERT protocol management. It also has a clock domain independent from the CPU clock, allowing the I2C1 to wake up the MCU from Stop mode on address match.

The I2C interface can be served by the DMA controller.

Refer to [Table 6](#) for the features available in I2C1.

Table 6. STM32F328C8 I²C implementation

I2C features ⁽¹⁾	I2C1
7-bit addressing mode	X
10-bit addressing mode	X
Standard mode (up to 100 kbit/s)	X
Fast mode (up to 400 kbit/s)	X
Fast Mode Plus with 20mA output drive I/Os (up to 1 Mbit/s)	X
Independent clock	X
SMBus	X
Wakeup from STOP	X

1. X = supported.

3.16.2 Universal synchronous/asynchronous receiver transmitters (USARTs)

The STM32F328C8 devices have three embedded universal synchronous receiver transmitters (USART1, USART2 and USART3).

The USART interfaces are able to communicate at speeds of up to 9 Mbits/s.

USART1 provides hardware management of the CTS and RTS signals. It supports IrDA SIR ENDEC, the multiprocessor communication mode, the single-wire half-duplex communication mode and has LIN Master/Slave capability.

All USART interfaces can be served by the DMA controller.

Refer to [Table 7](#) for the features available in the USART interfaces.

Table 7. USART features

USART modes/features ⁽¹⁾	USART1	USART2 USART3
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

Table 7. USART features (continued)

USART modes/features ⁽¹⁾	USART1	USART2 USART3
IrDA SIR ENDEC block	X	-
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.

3.16.3 Serial peripheral interface (SPI)

A SPI interface allows to communicate up to 18 Mbits/s in slave and master modes in full-duplex and simplex communication modes. The 3-bit prescaler gives 8 master mode frequencies and the frame size is configurable from 4 bits to 16 bits.

Refer to [Table 8](#) for the features available in SPI1.

Table 8. STM32F328C8 SPI implementation

SPI features ⁽¹⁾	SPI1
Hardware CRC calculation	X
Rx/Tx FIFO	X
NSS pulse mode	X
TI mode	X

1. X = supported.

3.16.4 Controller area network (CAN)

The CAN is compliant with specifications 2.0A and B (active) with a bit rate up to 1 Mbit/s. It can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers. It has three transmit mailboxes, two receive FIFOs with 3 stages and 14 scalable filter banks.

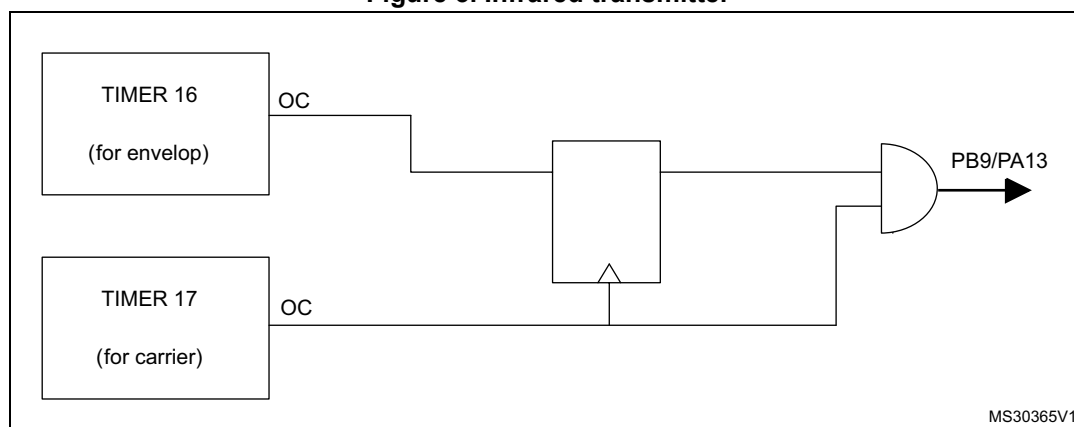
3.17 Infrared transmitter

The STM32F328C8 devices provide an infrared transmitter solution. The solution is based on internal connections between TIM16 and TIM17 as shown in the figure below.

TIM17 is used to provide the carrier frequency and TIM16 provides the main signal to be sent. The infrared output signal is available on PB9 or PA13.

To generate the infrared remote control signals, TIM16 channel 1 and TIM17 channel 1 must be properly configured to generate correct waveforms. All standard IR pulse modulation modes can be obtained by programming the two timers output compare channels.

Figure 3. Infrared transmitter



3.18 Touch sensing controller (TSC)

The STM32F328C8 devices provide a simple solution for adding capacitive sensing functionality to any application. These devices offer up to 17 capacitive sensing channels distributed over 6 analog I/Os group.

Capacitive sensing technology is able to detect the presence of a finger 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. It consists of charging the electrode capacitance and then transferring a part of the accumulated charges into a sampling capacitor until the voltage across this capacitor has reached a specific threshold. To limit the CPU bandwidth usage this acquisition is directly managed by the hardware touch sensing controller and only requires few external components to operate.

The touch sensing controller is fully supported by the STMTouch touch sensing firmware library which is free to use and allows touch sensing functionality to be implemented reliably in the end application.

Table 9. Capacitive sensing GPIOs available on STM32F328C8 devices

Group	Capacitive sensing group name	Pin name
1	TSC_G1_IO1	PA0
	TSC_G1_IO2	PA1
	TSC_G1_IO3	PA2
	TSC_G1_IO4	PA3
2	TSC_G2_IO1	PA4
	TSC_G2_IO2	PA5
	TSC_G2_IO3	PA6
	TSC_G2_IO4	PA7
3	TSC_G3_IO2	PB0
	TSC_G3_IO3	PB1

Table 9. Capacitive sensing GPIOs available on STM32F328C8 devices (continued)

Group	Capacitive sensing group name	Pin name
4	TSC_G4_IO1	PA9
	TSC_G4_IO2	PA10
	TSC_G4_IO3	PA13
	TSC_G4_IO4	PA14
5	TSC_G5_IO1	PB3
	TSC_G5_IO2	PB4
	TSC_G5_IO3	PB6
	TSC_G5_IO4	PB7
6	TSC_G6_IO1	PB11
	TSC_G6_IO2	PB12
	TSC_G6_IO3	PB13
	TSC_G6_IO4	PB14

Table 10. No. of capacitive sensing channels available on STM32F328C8 devices

Analog I/O group	Number of capacitive sensing channels
	STM32F328C8
G1	3
G2	3
G3	2
G4	3
G5	3
G6	3
Number of capacitive sensing channels	17

3.19 Development support

3.19.1 Serial wire JTAG debug port (SWJ-DP)

The ARM SWJ-DP Interface is embedded, and is a combined JTAG and serial wire debug port that enables either a serial wire debug or a JTAG probe to be connected to the target.

The JTAG TMS and TCK pins are shared respectively with SWDIO and SWCLK and a specific sequence on the TMS pin is used to switch between JTAG-DP and SW-DP.

4 Pinouts and pin description

Figure 4. LQFP48 pinout

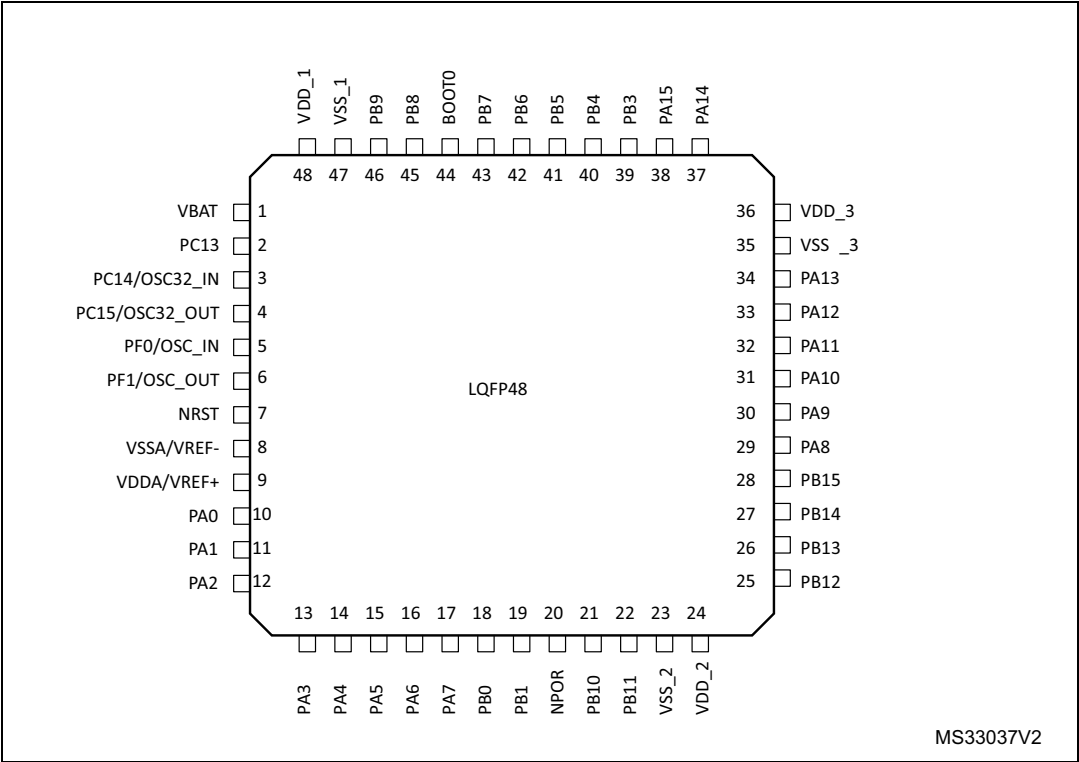


Table 11. Legend/abbreviations used in the pinout table

Name		Abbreviation	Definition
Pin name		Unless otherwise specified in brackets below the pin name, the pin function during and after reset is the same as the actual pin name	
Pin type		S	Supply pin
		I	Input only pin
		I/O	Input / output pin
I/O structure		FT	5 V tolerant I/O
		FTf	5 V tolerant I/O, FM+ capable
		TTa	3.3 V tolerant I/O directly connected to ADC
		TT	3.3 V tolerant I/O
		TC	Standard 3.3 V I/O
		B	Dedicated BOOT0 pin
		RST	Bi-directional reset pin with embedded weak pull-up resistor
		POR	External power-on reset pin with embedded weak pull-up resistor, powered from V _{DDA} .
Notes		Unless otherwise specified by a note, all I/Os are set as floating inputs during and after reset	
Pin functions	Alternate functions	Functions selected through GPIOx_AFR registers	
	Additional functions	Functions directly selected/enabled through peripheral registers	

Table 12. STM32F328C8 pin definitions

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
1	VBAT	S	-	Backup power supply	
2	PC13 ⁽¹⁾	I/O	TC	TIM1_CH1N	RTC_TAMP1/RT C_TS/ RTC_OUT/WKU P2
3	PC14 / OSC32_IN ⁽¹⁾	I/O	TC	-	OSC32_IN

Table 12. STM32F328C8 pin definitions (continued)

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
4	PC15 / OSC32_OUT ⁽¹⁾	I/O	TC	-	OSC32_OUT
5	PF0 / OSC_IN	I/O	FT	TIM1_CH3N	OSC_IN
6	PF1 / OSC_OUT	I/O	FT	-	OSC_OUT
7	NRST	I/O	RST	Device reset input / internal reset output (active low)	
8	VSSA/VREF-	S	-	Analog ground/Negative reference voltage	
9	VDDA/VREF+	S	-	Analog power supply/Positive reference voltage	
10	PA0	I/O	TTa	TIM2_CH1/ TIM2_ETR, TSC_G1_IO1, USART2_CTS, EVENTOUT	ADC1_IN1, RTC_TAMP2/WK UP1
11	PA1	I/O	TTa	TIM2_CH2, TSC_G1_IO2, USART2_RTS_D E, TIM15_CH1N, EVENTOUT	ADC1_IN2, RTC_REFIN
12	PA2	I/O	TTa	TIM2_CH3, TSC_G1_IO3, USART2_TX, COMP2_OUT, TIM15_CH1, EVENTOUT	ADC1_IN3, COMP2_INM
13	PA3	I/O	TTa	TIM2_CH4, TSC_G1_IO4, USART2_RX, TIM15_CH2, EVENTOUT	ADC1_IN4
14	PA4 ⁽²⁾	I/O	TTa	TIM3_CH2, TSC_G2_IO1, SPI1_NSS, USART2_CK, EVENTOUT	ADC2_IN1, DAC1_OUT1, COMP2_INM4, COMP4_INM4, COMP6_INM4

Table 12. STM32F328C8 pin definitions (continued)

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
15	PA5 ⁽²⁾	I/O	TTa	TIM2_CH1/ TIM2_ETR, TSC_G2_IO2, SPI1_SCK, EVENTOUT	ADC2_IN2, DAC1_OUT2, OPAMP2_VINM
16	PA6 ⁽²⁾	I/O	TTa	TIM16_CH1, TIM3_CH1, TSC_G2_IO3, SPI1_MISO, TIM1_BKIN, , EVENTOUT	ADC2_IN3, DAC2_OUT1, OPAMP2_VOUT
17	PA7	I/O	TTa	TIM17_CH1, TIM3_CH2, TSC_G2_IO4, SPI1_MOSI, TIM1_CH1N, EVENTOUT	ADC2_IN4, COMP2_INP, OPAMP2_VINP
18	PB0	I/O	TTa	TIM3_CH3, TSC_G3_IO2, TIM1_CH2N, EVENTOUT	ADC1_IN11, COMP4_INP, OPAMP2_VINP
19	PB1	I/O	TTa	TIM3_CH4, TSC_G3_IO3, TIM1_CH3N, COMP4_OUT, EVENTOUT	ADC1_IN12
20	NPOR	I	POR ⁽³⁾	Device power-on reset input	
21	PB10	I/O	TT	TIM2_CH3, TSC_SYNC, USART3_TX, EVENTOUT	-
22	PB11	I/O	TTa	TIM2_CH4, TSC_G6_IO1, USART3_RX, EVENTOUT	COMP6_INP
23	VSS	S	-	Digital ground	
24	VDD	S	-	Digital power supply	

Table 12. STM32F328C8 pin definitions (continued)

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
25	PB12	I/O	TTa	TSC_G6_IO2, TIM1_BKIN, USART3_CK, EVENTOUT	ADC2_IN13
26	PB13	I/O	TTa	TSC_G6_IO3, TIM1_CH1N, USART3_CTS, EVENTOUT	ADC1_IN13
27	PB14	I/O	TTa	TIM15_CH1, TSC_G6_IO4, TIM1_CH2N, USART3_RTS_D E, EVENTOUT	ADC2_IN14, OPAMP2_VINP
28	PB15	I/O	TTa	TIM15_CH2, TIM15_CH1N, TIM1_CH3N, EVENTOUT	ADC2_IN15, COMP6_INM, RTC_REFIN
29	PA8	I/O	FT	MCO, TIM1_CH1, USART1_CK, EVENTOUT	-
30	PA9	I/O	FT	TSC_G4_IO1, TIM1_CH2, USART1_TX, TIM15_BKIN, TIM2_CH3, EVENTOUT	-
31	PA10	I/O	FT	TIM17_BKIN, TSC_G4_IO2, TIM1_CH3, USART1_RX, COMP6_OUT, TIM2_CH4, EVENTOUT	-
32	PA11	I/O	FT	TIM1_CH1N, USART1_CTS, CAN_RX, TIM1_CH4, TIM1_BKIN2, EVENTOUT	-

Table 12. STM32F328C8 pin definitions (continued)

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
33	PA12	I/O	FT	TIM16_CH1, TIM1_CH2N, USART1_RTS_D E, COMP2_OUT, CAN_TX, TIM1_ETR, EVENTOUT	-
34	PA13	I/O	FT	JTMS/SWDAT, TIM16_CH1N, TSC_G4_IO3, IR_OUT, USART3_CTS, EVENTOUT	-
35	VSS	S	-	-	-
36	VDD	S	-	-	-
37	PA14	I/O	FTf	JTCK/SWCLK, TSC_G4_IO4, I2C1_SDA, TIM1_BKIN, USART2_TX, EVENTOUT	-
38	PA15	I/O	FTf	JTDI, TIM2_CH1/TIM2 _ETR, TSC_SYNC, I2C1_SCL, SPI1_NSS, USART2_RX, TIM1_BKIN, EVENTOUT	-
39	PB3	I/O	FT	JTDO/TRACE SWO, TIM2_CH2, TSC_G5_IO1, SPI1_SCK, USART2_TX, TIM3_ETR, EVENTOUT	-

Table 12. STM32F328C8 pin definitions (continued)

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
40	PB4	I/O	FT	NJTRST, TIM16_CH1, TIM3_CH1, TSC_G5_IO2, SPI1_MISO, USART2_RX, TIM17_BKIN, EVENTOUT	-
41	PB5	I/O	FT	TIM16_BKIN, TIM3_CH2, I2C1_SMBA, SPI1_MOSI, USART2_CK, TIM17_CH1, EVENTOUT	-
42	PB6	I/O	FTf	TIM16_CH1N, TSC_G5_IO3, I2C1_SCL, USART1_TX, EVENTOUT	-
43	PB7	I/O	FTf	TIM17_CH1N, TSC_G5_IO4, I2C1_SDA, USART1_RX, TIM3_CH4, EVENTOUT	-
44	BOOT0	I	B		-
45	PB8	I/O	FTf	TIM16_CH1, TSC_SYNC, I2C1_SCL, USART3_RX, CAN_RX, TIM1_BKIN, EVENTOUT	-
46	PB9	I/O	FTf	TIM17_CH1, I2C1_SDA, IR_OUT, USART3_TX, COMP2_OUT, CAN_TX, EVENTOUT	-

Table 12. STM32F328C8 pin definitions (continued)

Pin Number	Pin name (function after reset)	Pin type	I/O structure	Pin functions	
LQFP48				Alternate functions	Additional functions
47	VSS	S	-	-	-
48	VDD	S	-	-	-

- PC13, PC14 and PC15 are supplied through the power switch. Since the switch sinks only a limited amount of current (3 mA), the use of GPIO PC13 to PC15 in output mode is limited:
 - The speed should not exceed 2 MHz with a maximum load of 30 pF
 - These GPIOs must not be used as current sources (e.g. to drive an LED).
 After the first backup domain power-up, PC13, PC14 and PC15 operate as GPIOs. Their function then depends on the content of the Backup registers which is not reset by the main reset. For details on how to manage these GPIOs, refer to the Battery backup domain and BKP register description sections in the reference manual.
- These GPIOs offer a reduced touch sensing sensitivity. It is thus recommended to use them as sampling capacitor I/O.
- This pin is powered by VDDA.



Table 13. Alternate functions

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		SYS_AF	TIM2/ TIM15/ TIM16/ TIM17/ EVENT	TIM1/ TIM3/TI M15/TI M16	TSC	I2C1/ TIM1	SPI1/In frared	TIM1/ Infrared	USART1/ USART2/ USART3/ GPCOMP 6	GPCO MP2/ GPCO MP4/ GPCO MP6	CAN/ TIM1/TI M15	TIM2/ TIM3/TI M17	TIM1	TIM1	OpAmp 2		
Port A	PA0	-	TIM2_ CH1/ TIM2_ ETR	-	TSC_G 1_IO1	-	-	-	USART2_ CTS	-	-	-	-	-	-	-	EVEN TOUT
	PA1	-	TIM2_ CH2	-	TSC_G 1_IO2	-	-	-	USART2_ RTS_DE	-	TIM15_ CH1N	-	-	-	-	-	EVEN TOUT
	PA2	-	TIM2_ CH3	-	TSC_G 1_IO3	-	-	-	USART2_ TX	COMP2_ OUT	TIM15_ CH1	-	-	-	-	-	EVEN TOUT
	PA3	-	TIM2_ CH4	-	TSC_G 1_IO4	-	-	-	USART2_ RX	-	TIM15_ CH2	-	-	-	-	-	EVEN TOUT
	PA4	-	-	TIM3_ CH2	TSC_G 2_IO1	-	SPI1_N SS	-	USART2_ CK	-	-	-	-	-	-	-	EVEN TOUT
	PA5	-	TIM2_ CH1/ TIM2_ ETR	-	TSC_G 2_IO2	-	SPI1_S CK	-	-	-	-	-	-	-	-	-	EVEN TOUT
	PA6	-	TIM16_ CH1	TIM3_ CH1	TSC_G 2_IO3	-	SPI1_ MISO	TIM1_ BKIN	-	-	-	-	-	-	OPAMP 2_DIG	-	EVEN TOUT
	PA7	-	TIM17_ CH1	TIM3_ CH2	TSC_G 2_IO4	-	SPI1_ MOSI	TIM1_ CH1N	-	-	-	-	-	-	-	-	EVEN TOUT
	PA8	MCO	-	-	-	-	-	TIM1_ CH1	USART1_ CK	-	-	-	-	-	-	-	EVEN TOUT
	PA9	-	-	-	TSC_G 4_IO1	-	-	TIM1_ CH2	USART1_ TX	-	TIM15_ BKIN	TIM2_ CH3	-	-	-	-	EVEN TOUT

Table 13. Alternate functions (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		SYS_AF	TIM2/ TIM15/ TIM16/ TIM17/ EVENT	TIM1/ TIM3/TIM15/ TIM16	TSC	I2C1/ TIM1	SPI1/ Infrared	TIM1/ Infrared	USART1/ USART2/ USART3/ GPCOMP6	GPCOMP2/ GPCOMP4/ GPCOMP6	CAN/ TIM1/TIM15	TIM2/ TIM3/TIM17	TIM1	TIM1	OpAmp2		
Port A	PA10	-	TIM17_BKIN	-	TSC_G4_IO2	-	-	TIM1_CH3	USART1_RX	COMP6_OUT	-	TIM2_CH4	-	-	-	-	EVEN TOUT
	PA11	-	-	-	-	-	-	TIM1_CH1N	USART1_CTS	-	CAN_RX	-	TIM1_CH4	TIM1_BKIN2	-	-	EVEN TOUT
	PA12	-	TIM16_CH1	-	-	-	-	TIM1_CH2N	USART1_RTS_DE	COMP2_OUT	CAN_TX	-	TIM1_ETR	-	-	-	EVEN TOUT
	PA13	JTMS/ SWDAT	TIM16_CH1N	-	TSC_G4_IO3	-	IR_OUT	-	USART3_CTS	-	-	-	-	-	-	-	EVEN TOUT
	PA14	JTCK/ SWCLK	-	-	TSC_G4_IO4	I2C1_SDA	-	TIM1_BKIN	USART2_TX	-	-	-	-	-	-	-	EVEN TOUT
	PA15	JTDI	TIM2_CH1/ TIM2_ETR	-	TSC_SYNC	I2C1_SCL	SPI1_NSS	-	USART2_RX	-	TIM1_BKIN	-	-	-	-	-	EVEN TOUT
Port B	PB0	-	-	TIM3_CH3	TSC_G3_IO2	-	-	TIM1_CH2N	-	-	-	-	-	-	-	-	EVEN TOUT
	PB1	-	-	TIM3_CH4	TSC_G3_IO3	-	-	TIM1_CH3N	-	COMP4_OUT	-	-	-	-	-	-	EVEN TOUT
	PB3	JTDO/ TRACESWO	TIM2_CH2	-	TSC_G5_IO1	-	SPI1_SCK	-	USART2_TX	-	-	TIM3_ETR	-	-	-	-	EVEN TOUT
	PB4	NJTRST	TIM16_CH1	TIM3_CH1	TSC_G5_IO2	-	SPI1_MISO	-	USART2_RX	-	-	TIM17_BKIN	-	-	-	-	EVEN TOUT



Table 13. Alternate functions (continued)

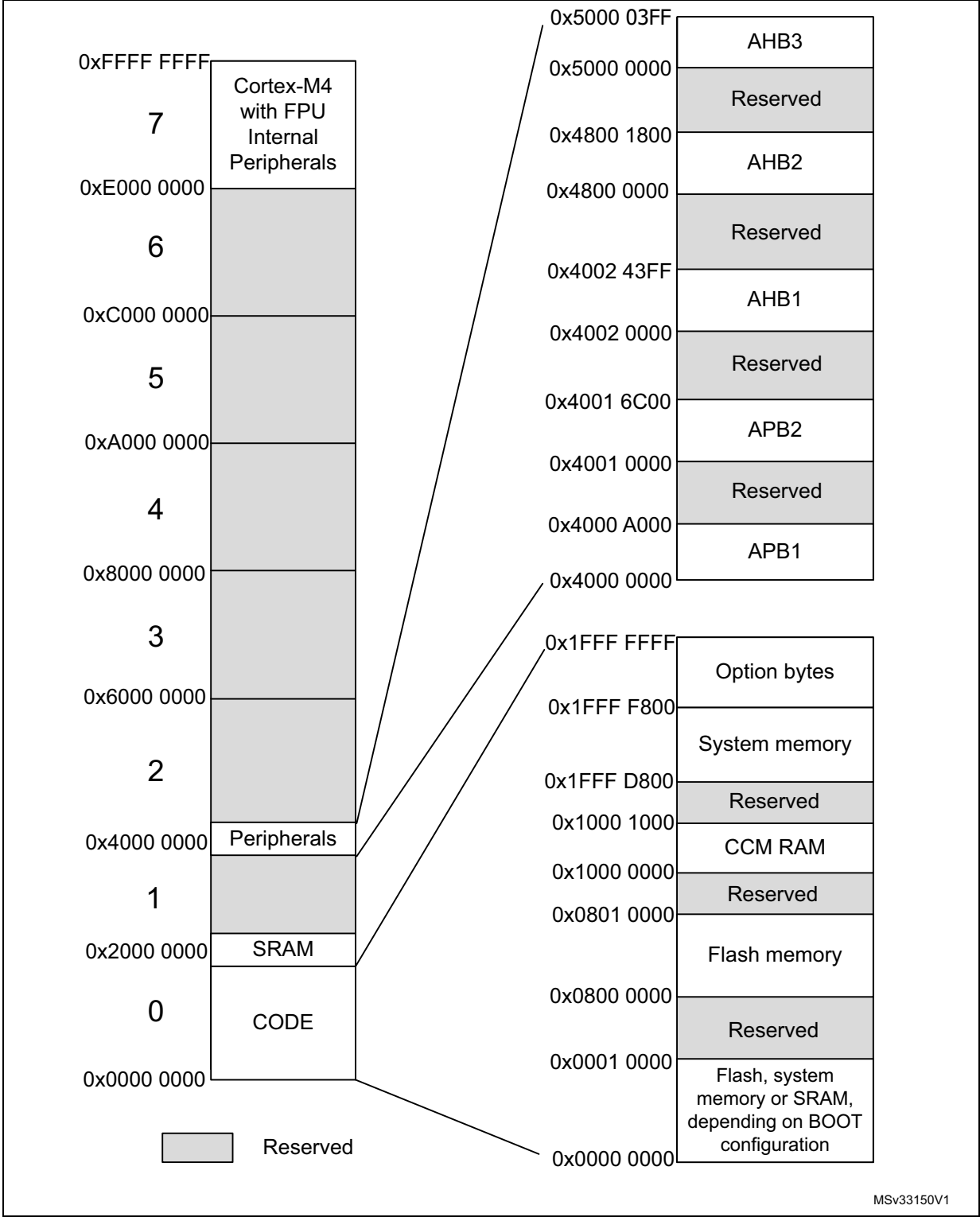
Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		SYS_AF	TIM2/ TIM15/ TIM16/ TIM17/ EVENT	TIM1/ TIM3/TIM15/ TIM16	TSC	I2C1/ TIM1	SPI1/Infrared	TIM1/ Infrared	USART1/ USART2/ USART3/ GPCOMP6	GPCOMP2/ GPCOMP4/ GPCOMP6	CAN/ TIM1/TIM15	TIM2/ TIM3/TIM17	TIM1	TIM1	OpAmp2		
Port B	PB5	-	TIM16_BKIN	TIM3_CH2		I2C1_SMB_A	SPI1_MOSI	-	USART2_CK	-	-	TIM17_CH1	-	-	-	-	EVEN TOUT
	PB6	-	TIM16_CH1N	-	TSC_G5_IO3	I2C1_SCL	-	-	USART1_TX	-	-	-	-	-	-	-	EVEN TOUT
	PB7	-	TIM17_CH1N	-	TSC_G5_IO4	I2C1_SDA	-	-	USART1_RX	-	-	TIM3_CH4	-	-	-	-	EVEN TOUT
	PB8	-	TIM16_CH1	-	TSC_SYNC	I2C1_SCL	-	-	USART3_RX	-	CAN_RX	-	-	TIM1_BKIN	-	-	EVEN TOUT
	PB9	-	TIM17_CH1	-		I2C1_SDA	-	IR_OUT	USART3_TX	COMP2_OUT	CAN_TX	-	-	-	-	-	EVEN TOUT
	PB10	-	TIM2_CH3	-	TSC_SYNC	-	-	-	USART3_TX	-	-	-	-	-	-	-	EVEN TOUT
	PB11	-	TIM2_CH4	-	TSC_G6_IO1	-	-	-	USART3_RX	-	-	-	-	-	-	-	EVEN TOUT
	PB12	-	-	-	TSC_G6_IO2	-	-	TIM1_BKIN	USART3_CK	-	-	-	-	-	-	-	EVEN TOUT
	PB13	-	-	-	TSC_G6_IO3	-	-	TIM1_CH1N	USART3_CTS	-	-	-	-	-	-	-	EVEN TOUT
	PB14	-	TIM15_CH1	-	TSC_G6_IO4	-	-	TIM1_CH2N	USART3_RTS_DE	-	-	-	-	-	-	-	EVEN TOUT
	PB15	-	TIM15_CH2	TIM15_CH1N	-	TIM1_CH3N	-	-	-	-	-	-	-	-	-	-	EVEN TOUT

Table 13. Alternate functions (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		SYS_AF	TIM2/ TIM15/ TIM16/ TIM17/ EVENT	TIM1/ TIM3/TIM15/ TIM16	TSC	I2C1/ TIM1	SPI1/Infrared	TIM1/ Infrared	USART1/ USART2/ USART3/ GPCOMP6	GPCOMP2/ GPCOMP4/ GPCOMP6	CAN/ TIM1/TIM15	TIM2/ TIM3/TIM17	TIM1	TIM1	OpAmp2		
Port C	PC13	-	-	-	-	TIM1_CH1N	-	-	-	-	-	-	-	-	-	-	-
	PC14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PC15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Port D	PD2	-	EVENT OUT	TIM3_ETR	-	-	-	-	-	-	-	-	-	-	-	-	-
Port F	PF0	-	-	-	-	-	-	TIM1_CH3N	-	-	-	-	-	-	-	-	-
	PF1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

5 Memory mapping

Figure 5. STM32F328C8 memory map



MSv33150V1



Table 14. STM32F328C8 peripheral register boundary addresses

Bus	Boundary address	Size (bytes)	Peripheral
AHB3	0x5000 0000 - 0x5000 03FF	1 K	ADC1 - ADC2
	0x4800 1800 - 0x4FFF FFFF	~132 M	Reserved
AHB2	0x4800 1400 - 0x4800 17FF	1 K	GPIOF
	0x4800 1000 - 0x4800 13FF	1 K	Reserved
AHB2	0x4800 0C00 - 0x4800 0FFF	1 K	GPIOD
	0x4800 0800 - 0x4800 0BFF	1 K	GPIOC
	0x4800 0400 - 0x4800 07FF	1 K	GPIOB
	0x4800 0000 - 0x4800 03FF	1 K	GPIOA
	0x4002 4400 - 0x47FF FFFF	~128 M	Reserved
AHB1	0x4002 4000 - 0x4002 43FF	1 K	TSC
	0x4002 3400 - 0x4002 3FFF	3 K	Reserved
	0x4002 3000 - 0x4002 33FF	1 K	CRC
	0x4002 2400 - 0x4002 2FFF	3 K	Reserved
	0x4002 2000 - 0x4002 23FF	1 K	Flash interface
	0x4002 1400 - 0x4002 1FFF	3 K	Reserved
	0x4002 1000 - 0x4002 13FF	1 K	RCC
	0x4002 0400 - 0x4002 0FFF	3 K	Reserved
	0x4002 0000 - 0x4002 03FF	1 K	DMA1
	0x4001 8000 - 0x4001 FFFF	32 K	Reserved
APB2	0x4001 4C00 - 0x4001 73FF	12 K	Reserved
	0x4001 4800 - 0x4001 4BFF	1 K	TIM17
	0x4001 4400 - 0x4001 47FF	1 K	TIM16
	0x4001 4000 - 0x4001 43FF	1 K	TIM15
	0x4001 3C00 - 0x4001 3FFF	1 K	Reserved
	0x4001 3800 - 0x4001 3BFF	1 K	USART1
	0x4001 3400 - 0x4001 37FF	1 K	Reserved
	0x4001 3000 - 0x4001 33FF	1 K	SPI1
	0x4001 2C00 - 0x4001 2FFF	1 K	TIM1
	0x4001 0800 - 0x4001 2BFF	9 K	Reserved
	0x4001 0400 - 0x4001 07FF	1 K	EXTI
	0x4001 0000 - 0x4001 03FF	1 K	SYSCFG + COMP + OPAMP
	0x4000 9C00 - 0x4000 FFFF	25 K	Reserved

Table 14. STM32F328C8 peripheral register boundary addresses (continued)

Bus	Boundary address	Size (bytes)	Peripheral
APB1	0x4000 9800 - 0x4000 9BFF	1 K	DAC2
	0x4000 7800 - 0x4000 97FF	8 K	Reserved
	0x4000 7400 - 0x4000 77FF	1 K	DAC1
	0x4000 7000 - 0x4000 73FF	1 K	PWR
	0x4000 6800 - 0x4000 6FFF	2 K	Reserved
	0x4000 6400 - 0x4000 67FF	1 K	bxCAN
	0x4000 5800 - 0x4000 63FF	3 K	Reserved
	0x4000 5400 - 0x4000 57FF	1 K	I2C1
	0x4000 4C00 - 0x4000 53FF	2 K	Reserved
	0x4000 4800 - 0x4000 4BFF	1 K	USART3
	0x4000 4400 - 0x4000 47FF	1 K	USART2
	0x4000 3400 - 0x4000 43FF	2 K	Reserved
	0x4000 3000 - 0x4000 33FF	1 K	IWDG
	0x4000 2C00 - 0x4000 2FFF	1 K	WWDG
	0x4000 2800 - 0x4000 2BFF	1 K	RTC
	0x4000 1800 - 0x4000 27FF	4 K	Reserved
	0x4000 1400 - 0x4000 17FF	1 K	TIM7
	0x4000 1000 - 0x4000 13FF	1 K	TIM6
	0x4000 0800 - 0x4000 0FFF	2 K	Reserved
	0x4000 0400 - 0x4000 07FF	1 K	TIM3
	0x4000 0000 - 0x4000 03FF	1 K	TIM2
	0x2000 3000 - 3FFF FFFF	~512 M	Reserved
	0x2000 0000 - 0x2000 2FFF	K	SRAM
	0x1FFF F800 - 0x1FFF FFFF	2 K	Option bytes
	0x1FFF D800 - 0x1FFF F7FF	8 K	System memory
	0x1000 2000 - 0x1FFF D7FF	~256 M	Reserved
	0x1000 0000 - 0x1000 0FFF	4 K	CCM RAM
	0x0804 0000 - 0x0FFF FFFF	~128 M	Reserved
	0x0800 0000 - 0x0800 FFFF	64 K	Main Flash memory
	0x0004 0000 - 0x07FF FFFF	~128 M	Reserved
	0x0000 000 - 0x0000 FFFF	64 K	Main Flash memory, system memory or SRAM depending on BOOT configuration

6 Electrical characteristics

6.1 Parameter conditions

Unless otherwise specified, all voltages are referenced to V_{SS} .

6.1.1 Minimum and maximum values

Unless otherwise specified, the minimum and maximum values are guaranteed in the worst conditions of ambient temperature, supply voltage and frequencies by tests in production on 100% of the devices with an ambient temperature at $T_A = 25\text{ }^{\circ}\text{C}$ and $T_A = T_{A\text{max}}$ (given by the selected temperature range).

Data based on characterization results, design simulation and/or technology characteristics are indicated in the table footnotes and are not tested in production. Based on characterization, the minimum and maximum values refer to sample tests and represent the mean value plus or minus three times the standard deviation (mean $\pm 3\sigma$).

6.1.2 Typical values

Unless otherwise specified, typical data are based on $T_A = 25\text{ }^{\circ}\text{C}$, $V_{DD} = 1.8\text{ V}$, $V_{DDA} = 3.3\text{ V}$. They are given only as design guidelines and are not tested.

Typical ADC accuracy values are determined by characterization of a batch of samples from a standard diffusion lot over the full temperature range, where 95% of the devices have an error less than or equal to the value indicated (mean $\pm 2\sigma$).

6.1.3 Typical curves

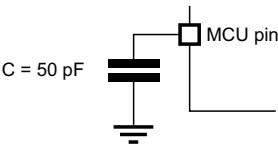
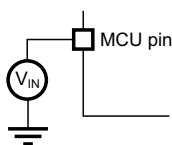
Unless otherwise specified, all typical curves are given only as design guidelines and are not tested.

6.1.4 Loading capacitor

The loading conditions used for pin parameter measurement are shown in [Figure 6](#).

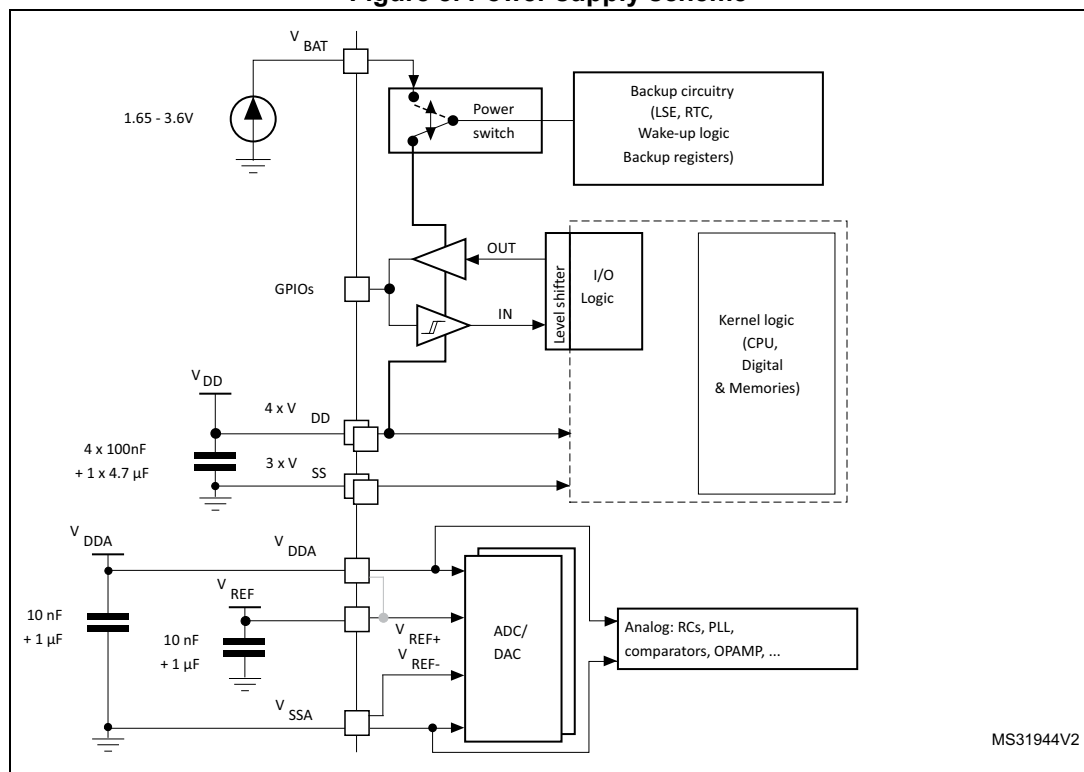
6.1.5 Pin input voltage

The input voltage measurement on a pin of the device is described in [Figure 7](#).

Figure 6. Pin loading conditions	Figure 7. Pin input voltage
 <p>C = 50 pF</p> <p>MCU pin</p> <p>MS19210V1</p>	 <p>V_{IN}</p> <p>MCU pin</p> <p>MS19211V1</p>

6.1.6 Power supply scheme

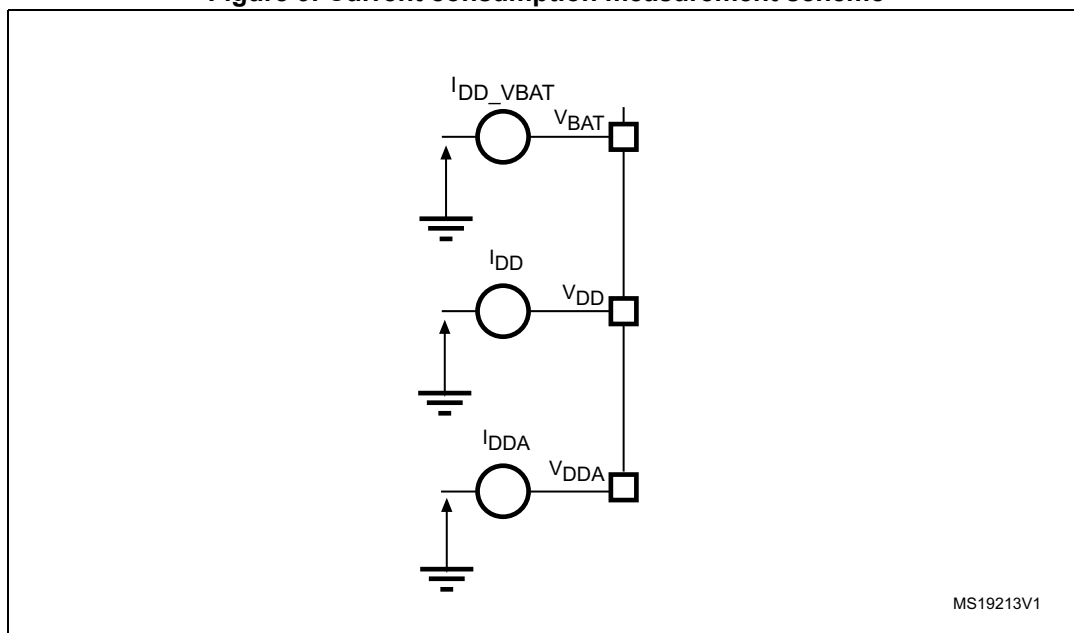
Figure 8. Power supply scheme



Caution: Each power supply pair (V_{DD}/V_{SS} , V_{DDA}/V_{SSA} etc..) must be decoupled with filtering ceramic capacitors as shown above. These capacitors must be placed as close as possible to, or below the appropriate pins on the underside of the PCB to ensure the good functionality of the device.

6.1.7 Current consumption measurement

Figure 9. Current consumption measurement scheme



6.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in [Table 15: Voltage characteristics](#), [Table 16: Current characteristics](#), and [Table 17: Thermal characteristics](#) may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 15. Voltage characteristics⁽¹⁾

Symbol	Ratings	Min.	Max.	Unit
$V_{DD}-V_{SS}$	External main supply voltage (including V_{DDA} , V_{BAT} and V_{DD})	-0.3	1.95	V
$V_{DDA}-V_{SS}$	External analog supply voltage	-0.3	4.0	
$V_{DD}-V_{DDA}$	Allowed voltage difference for $V_{DD} > V_{DDA}$	-	0.4	
$V_{IN}^{(2)}$	Input voltage on FT and FTf pins	$V_{SS} - 0.3$	$V_{DD} + 4.0$	
	Input voltage on TTa	$V_{SS} - 0.3$	4.0	
	Input voltage on POR pin	$V_{SS} - 0.3$	$V_{DDA} + 4.0$	
	Input voltage on any other pin	$V_{SS} - 0.3$	4.0	
	Input voltage on Boot0 pin	0	9	
$ \Delta V_{DDx} $	Variations between different V_{DD} power pins	-	50	mV
$ V_{SSx} - V_{SS} $	Variations between all the different ground pins	-	50	
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	see Section 6.3.11: Electrical sensitivity characteristics		-

1. All main power (V_{DD} , V_{DDA}) and ground (V_{SS} , V_{SSA}) pins must always be connected to the external power supply, in the permitted range. The following relationship must be respected between V_{DDA} and V_{DD} :
 V_{DDA} must power on before or at the same time as V_{DD} in the power up sequence.
 V_{DDA} must be greater than or equal to V_{DD} .
2. V_{IN} maximum must always be respected. Refer to [Table 16: Current characteristics](#) for the maximum allowed injected current values.

Table 16. Current characteristics

Symbol	Ratings	Max.	Unit
ΣI_{VDD}	Total current into sum of all VDD_x power lines (source) ⁽¹⁾	140	mA
ΣI_{VSS}	Total current out of sum of all VSS_x ground lines (sink) ⁽¹⁾	-140	
I_{VDD}	Maximum current into each VDD_x power line (source) ⁽¹⁾	100	
I_{VSS}	Maximum current out of each VSS_x ground line (sink) ⁽¹⁾	100	
$I_{IO(PIN)}$	Output current sunk by any I/O and control pin	25	
	Output current source by any I/O and control pin	-25	
$\Sigma I_{IO(PIN)}$	Total output current sunk by sum of all I/Os and control pins ⁽²⁾	80	
	Total output current sourced by sum of all I/Os and control pins ⁽²⁾	-80	
$I_{INJ(PIN)}$	Injected current on TT, FT, FTf and B pins ⁽³⁾	-5 / +0	
	Injected current on TC and RST pin ⁽⁴⁾	± 5	
	Injected current on TTa pins ⁽⁵⁾	± 5	
$\Sigma I_{INJ(PIN)}$	Total injected current (sum of all I/O and control pins) ⁽⁶⁾	± 25	

1. All main power (V_{DD} , V_{DDA}) and ground (V_{SS} and V_{SSA}) pins must always be connected to the external power supply, in the permitted range.
2. This current consumption must be correctly distributed over all I/Os and control pins. The total output current must not be sunk/sourced between two consecutive power supply pins referring to high pin count LQFP packages.
3. Positive injection is not possible on these I/Os and does not occur for input voltages lower than the specified maximum value.
4. A positive injection is induced by $V_{IN} > V_{DD}$ while a negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to [Table 15: Voltage characteristics](#) for the maximum allowed input voltage values.
5. A positive injection is induced by $V_{IN} > V_{DDA}$ while a negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer also to [Table 15: Voltage characteristics](#) for the maximum allowed input voltage values. Negative injection disturbs the analog performance of the device. See note 2. below [Table 56](#).
6. When several inputs are submitted to a current injection, the maximum $\Sigma I_{INJ(PIN)}$ is the absolute sum of the positive and negative injected currents (instantaneous values).

Table 17. Thermal characteristics

Symbol	Ratings	Value	Unit
T_{STG}	Storage temperature range	-65 to +150	°C
T_J	Maximum junction temperature	150	°C

6.3 Operating conditions

6.3.1 General operating conditions

Table 18. General operating conditions

Symbol	Parameter	Conditions	Min.	Max.	Unit
f_{HCLK}	Internal AHB clock frequency	-	0	72	MHz
f_{PCLK1}	Internal APB1 clock frequency	-	0	36	
f_{PCLK2}	Internal APB2 clock frequency	-	0	72	
V_{DD}	Standard operating voltage	-	1.65	1.95	V
V_{DDA}	Analog operating voltage (OPAMP and DAC not used)	Must have a potential equal to or higher than V_{DD}	1.65	3.6	
	Analog operating voltage (OPAMP and DAC used)		2.4	3.6	
V_{DDA}	Analog operating voltage (ADC used)		1.8 V	3.6 V	V
V_{BAT}	Backup operating voltage		1.65	3.6	V
V_{IN}	I/O input voltage	TC I/O	-0.3	$V_{DD}+0.3$	V
		TTa I/O	-0.3	$V_{DDA}+0.3$	
		FT, FTf and POR I/O pins	-0.3	5.2	
		BOOT0	0	5.5	
PD	Power dissipation at $T_A = 85\text{ °C}$ for suffix 6 or $T_A = 105\text{ °C}$ for suffix 7 ⁽¹⁾	LQFP48	-	364	mW
T_A	Ambient temperature for 6 suffix version	Maximum power dissipation	-40	85	°C
		Low power dissipation ⁽²⁾	-40	105	
	Ambient temperature for 7 suffix version	Maximum power dissipation	-40	105	°C
		Low power dissipation ⁽²⁾	-40	125	
T_J	Junction temperature range	6 suffix version	-40	105	°C
		7 suffix version	-40	125	

1. If T_A is lower, higher P_D values are allowed as long as T_J does not exceed T_{Jmax} (see [Section 7.2: Thermal characteristics](#)).
2. In low power dissipation state, T_A can be extended to this range as long as T_J does not exceed T_{Jmax} (see [Section 7.2: Thermal characteristics](#)).

6.3.2 Operating conditions at power-up / power-down

The parameters given in [Table 19](#) are derived from tests performed under the ambient temperature condition summarized in [Table 18](#).

Table 19. Operating conditions at power-up / power-down

Symbol	Parameter	Conditions	Min.	Max.	Unit
t_{VDD}	V_{DD} rise time rate	-	0	¥	$\mu\text{s/V}$
	V_{DD} fall time rate		20	¥	
t_{VDDA}	V_{DDA} rise time rate	-	0	¥	
	V_{DDA} fall time rate		20	¥	

6.3.3 Embedded reference voltage

The parameters given in [Table 20](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 18](#).

Table 20. Embedded internal reference voltage

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{REFINT}	Internal reference voltage	$-40\text{ }^{\circ}\text{C} < T_A < +105\text{ }^{\circ}\text{C}$	1.16	1.2	1.25	V
		$-40\text{ }^{\circ}\text{C} < T_A < +85\text{ }^{\circ}\text{C}$	1.16	1.2	1.24 ⁽¹⁾	V
$T_{S_vrefint}$	ADC sampling time when reading the internal reference voltage	-	2.2	-	-	μs
V_{RERINT}	Internal reference voltage spread over the temperature range	$V_{DD} = 31.8\text{ V} \pm 10\text{ mV}$	-	-	10 ⁽²⁾	mV
T_{Coff}	Temperature coefficient	-	-	-	100 ⁽²⁾	ppm/ $^{\circ}\text{C}$
T_{REFINT_RDY} ⁽³⁾	Internal reference voltage temporization	-	1.5	2.5	4.5	ms

1. Data based on characterization results, not tested in production.
2. Guaranteed by design, not tested in production.
3. Guaranteed by design, not tested in production. Latency between the time when pin NPOR is set to 1 by the application and the time when $V_{REFINTRDYF}$ is set to 1 by the hardware.

Table 21. Internal reference voltage calibration values

Calibration value name	Description	Memory address
V_{REFINT_CAL}	Raw data acquired at temperature of 30 $^{\circ}\text{C}$ $V_{DDA} = 3.3\text{ V}$	0x1FFF F7BA - 0x1FFF F7BB

6.3.4 Supply current characteristics

The current consumption is a function of several parameters and factors such as the operating voltage, ambient temperature, I/O pin loading, device software configuration, operating frequencies, I/O pin switching rate, program location in memory and executed binary code.

The current consumption is measured as described in [Figure 9: Current consumption measurement scheme](#).

All Run-mode current consumption measurements given in this section are performed with a reduced code that gives a consumption equivalent to CoreMark code.

Note: *The total current consumption is the sum of I_{DD} and I_{DDA} .*

Typical and maximum current consumption

The MCU is placed under the following conditions:

- All I/O pins are in input mode with a static value at V_{DD} or V_{SS} (no load)
- All peripherals are disabled except when explicitly mentioned
- The Flash memory access time is adjusted to the f_{HCLK} frequency (0 wait state from 0 to 24 MHz, 1 wait state from 24 to 48 MHz and 2 wait states from 48 to 72 MHz)
- Prefetch in ON (reminder: this bit must be set before clock setting and bus prescaling)
- When the peripherals are enabled $f_{PCLK2} = f_{HCLK}$ and $f_{PCLK1} = f_{HCLK}/2$
- When $f_{HCLK} > 8$ MHz, the PLL is ON and the PLL input is equal to HSI/2 (4 MHz) or HSE (8 MHz) in bypass mode.

The parameters given in to are derived from tests performed under ambient temperature and supply voltage conditions summarized in [Table 18](#).

Table 22. Typical and maximum current consumption from V_{DD} supply at $V_{DD} = 1.8\text{ V}$

Symbol	Parameter	Conditions	f _{HCLK}	All peripherals enabled				All peripherals disabled				Unit
				Typ.	Max. @ T _A ⁽¹⁾			Typ.	Max. @ T _A ⁽¹⁾			
					25 °C	85 °C	105 °C		25 °C	85 °C	105 °C	
I _{DD}	Supply current in Run mode, executing from Flash	External clock (HSE bypass)	72 MHz	46.4	49.4	50.4	52.1	26.1	27.4	27.9	28.2	mA
			64 MHz	40.4	42.8	43.9	46.4	23.4	24.6	25.0	25.3	
			48 MHz	31.0	32.7	33.7	35.1	17.9	18.7	19.2	19.5	
			32 MHz	21.2	22.3	23.0	24.3	12.3	12.9	13.2	13.4	
			24 MHz	16.1	16.9	17.6	17.9	9.4	9.9	10.1	10.4	
			8 MHz	5.5	6.1	6.3	7.1	3.26	3.51	3.76	3.93	
			1 MHz	1.03	1.25	1.52	1.62	0.71	0.89	1.00	1.14	
		Internal clock (HSI)	64 MHz	37.9	40.1	41.3	42.0	23.1	24.3	24.8	25.0	
			48 MHz	29.1	30.6	31.6	32.0	17.7	18.6	19.0	19.2	
			32 MHz	19.9	20.9	21.6	22.0	12.1	12.8	13.1	13.3	
			24 MHz	15.2	16.0	16.5	16.8	9.3	9.7	10.0	10.2	
			8 MHz	5.4	5.7	6.0	6.2	3.29	3.57	3.81	3.93	
	Supply current in Run mode, executing from RAM	External clock (HSE bypass)	72 MHz	46.3	49.2 ⁽²⁾	50.5	51.7 ⁽²⁾	27.3	28.8 ⁽²⁾	29.5	29.7 ⁽²⁾	
			64 MHz	40.1	44.0	45.1	45.7	24.2	25.6	26.2	26.5	
			48 MHz	30.9	33.3	34.4	34.8	17.9	19.4	19.9	20.2	
			32 MHz	21.2	22.6	23.3	23.6	12.4	13.1	13.4	13.7	
			24 MHz	16.1	17.0	17.7	18.0	9.4	9.9	10.2	10.4	
			8 MHz	5.4	6.0	6.1	6.3	3.11	3.35	3.57	3.74	
			1 MHz	0.69	0.85	1.09	1.31	0.40	0.57	0.80	0.96	
		Internal clock (HSI)	64 MHz	37.7	40.1	41.2	41.8	22.9	24.2	24.7	24.9	
			48 MHz	29.5	31.1	32.2	32.6	18.0	19.0	19.6	19.8	
			32 MHz	19.9	21.0	21.7	22.1	12.1	12.8	13.2	13.4	
			24 MHz	15.1	16.0	16.5	16.8	9.1	9.6	9.9	10.1	
			8 MHz	5.1	5.4	5.7	5.9	2.95	3.17	3.47	3.64	

Table 22. Typical and maximum current consumption from V_{DD} supply at $V_{DD} = 1.8$ V (continued)

Symbol	Parameter	Conditions	f _{HCLK}	All peripherals enabled				All peripherals disabled				Unit
				Typ.	Max. @ T _A ⁽¹⁾			Typ.	Max. @ T _A ⁽¹⁾			
					25 °C	85 °C	105 °C		25 °C	85 °C	105 °C	
I _{DD}	Supply current in Sleep mode, executing from Flash or RAM	External clock (HSE bypass)	72 MHz	29.2	30.8 ⁽²⁾	32.0	33.4 ⁽²⁾	6.3	6.6 ⁽²⁾	6.9	7.1 ⁽²⁾	mA
			64 MHz	26.1	27.5	28.5	29.7	5.6	5.9	6.2	6.4	
			48 MHz	19.8	20.8	21.6	22.0	4.22	4.48	4.76	4.98	
			32 MHz	13.3	14.0	14.6	15.0	2.84	3.06	3.33	3.56	
			24 MHz	10.1	10.6	11.1	11.4	2.18	2.37	2.62	2.83	
			8 MHz	3.31	3.83	3.88	4.04	0.61	0.79	1.03	1.25	
			1 MHz	0.43	0.62	0.89	1.03	0.10	0.28	0.50	0.69	
		Internal clock (HSI)	64 MHz	23.5	24.8	25.7	26.1	5.3	5.6	6.0	6.1	
			48 MHz	17.8	18.7	19.5	19.9	4.00	4.27	4.58	4.74	
			32 MHz	12.0	12.7	13.3	13.6	2.70	2.93	3.23	3.40	
			24 MHz	9.1	9.6	10.1	10.3	2.08	2.32	2.55	2.72	
			8 MHz	3.07	3.33	3.68	3.83	0.64	0.85	1.10	1.26	

1. Data based on characterization results, not tested in production unless otherwise specified.

2. Data based on characterization results and tested in production with code executing from RAM.

Table 23. Typical and maximum current consumption from the V_{DDA} supply

Symbol	Parameter	Conditions (1)	f _{HCLK}	V _{DDA} = 2.4 V				V _{DDA} = 3.6 V				Unit
				Typ.	Max. @ T _A ⁽²⁾			Typ.	Max. @ T _A ⁽²⁾			
					25 °C	85 °C	105 °C		25 °C	85 °C	105 °C	
I _{DDA}	Supply current in Run/Sleep mode, code executing from Flash or RAM	HSE bypass	72 MHz	224	252 ⁽³⁾	265	269 ⁽³⁾	245	272 ⁽³⁾	288	295 ⁽³⁾	μA
			64 MHz	196	225	237	241	214	243	257	263	
			48 MHz	147	174	183	186	159	186	196	201	
			32 MHz	100	126	133	135	109	133	142	145	
			24 MHz	79	102	107	108	85	108	113	116	
			8 MHz	3	5	5	6	4	6	6	7	
			1 MHz	3	5	5	6	3	5	6	6	
		HSI clock	64 MHz	259	288	304	309	285	315	332	338	
			48 MHz	208	239	251	254	230	258	271	277	
			32 MHz	162	190	198	202	179	206	216	219	
			24 MHz	140	168	175	178	155	181	188	191	
			8 MHz	62	85	88	89	71	94	96	98	

1. Current consumption from the V_{DDA} supply is independent of whether the peripherals are on or off. Furthermore when the PLL is off, I_{DDA} is independent from the frequency.

2. Data based on characterization results, not tested in production.

3. Data based characterization results and tested in production with code executing from RAM.

Table 24. Typical and maximum V_{DD} consumption in Stop mode

Symbol	Parameter	Conditions	Typ. @ V_{DD} ($V_{DD}=1.8 \text{ V}, V_{DDA}=3.3 \text{ V}$)	Max. ⁽¹⁾			Unit
			1.8 V	$T_A = 25 \text{ °C}$	$T_A = 85 \text{ °C}$	$T_A = 105 \text{ °C}$	
I_{DD}	Supply current in Stop mode	All oscillators OFF	5.67	16.7	150	345	μA

1. Data based on characterization results, not tested in production unless otherwise specified.

Table 25. Typical and maximum V_{DDA} consumption in Stop mode

Symbol	Parameter	Conditions	Typ. @ $V_{DDA} (V_{DD} = 1.8 \text{ V})$							Max. ⁽¹⁾			Unit
			1.8 V	2.0 V	2.4 V	2.7 V	3.0 V	3.3 V	3.6 V	$T_A = 25 \text{ °C}$	$T_A = 85 \text{ °C}$	$T_A = 105 \text{ °C}$	
I_{DDA}	Supply current in Stop mode	All oscillators OFF	0.70	0.71	0.72	0.75	0.80	0.87	0.94	1.6	2.2	2.8	μA

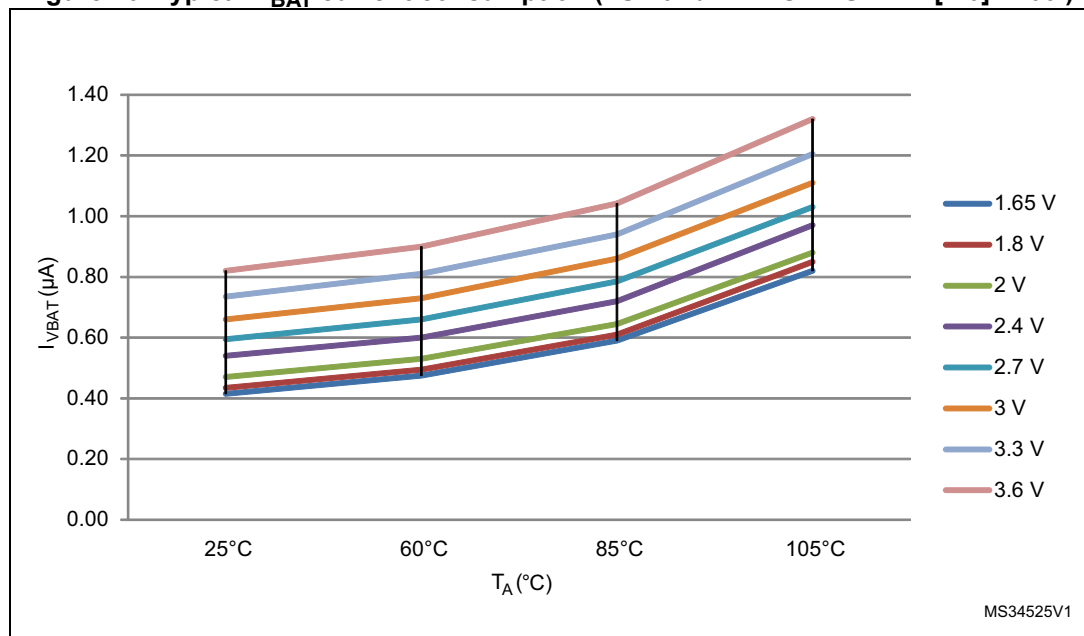
1. Data based on characterization results and tested in production.

Table 26. Typical and maximum current consumption from V_{BAT} supply

Symbol	Parameter	Conditions (1)	Typ.@ V_{BAT}								Max. @ $V_{BAT}=3.6V^{(2)}$			Unit
			1.65V	1.8V	2V	2.4V	2.7V	3V	3.3V	3.6V	$T_A=25^{\circ}C$	$T_A=85^{\circ}C$	$T_A=105^{\circ}C$	
I_{DD_VBAT}	Backup domain supply current	LSE & RTC ON; "Xtal mode" lower driving capability; LSEDRV[1:0] = '00'	0.42	0.44	0.47	0.54	0.60	0.66	0.74	0.82	-	-	-	μA
		LSE & RTC ON; "Xtal mode" higher driving capability; LSEDRV[1:0] = '11'	0.71	0.74	0.77	0.85	0.91	0.98	1.06	1.16	-	-	-	

1. Crystal used: Abracon ABS07-120-32.768 kHz-T with a CL of 6 pF for typical values.

2. Data based on characterization results, not tested in production.

Figure 10. Typical V_{BAT} current consumption (LSE and RTC ON/LSEDRV[1:0] = '00')

Typical current consumption

The MCU is placed under the following conditions:

- $V_{DD} = 1.8\text{ V}$, $V_{DDA} = 3.3\text{ V}$
- All I/O pins available on each package are in analog input configuration
- The Flash access time is adjusted to f_{HCLK} frequency (0 wait states from 0 to 24 MHz, 1 wait state from 24 to 48 MHz and 2 wait states from 48 MHz to 72 MHz), and Flash prefetch is ON
- When the peripherals are enabled, $f_{APB1} = f_{AHB}/2$, $f_{APB2} = f_{AHB}$
- PLL is used for frequencies greater than 8 MHz
- AHB prescaler of 2, 4, 8, 16 and 64 is used for the frequencies 4 MHz, 2 MHz, 1 MHz, 500 kHz and 125 kHz respectively.

Table 27. Typical current consumption in Run mode, code with data processing running from Flash

Symbol	Parameter	Conditions	f _{HCLK}	Typ		Unit
				Peripherals enabled	Peripherals disabled	
I _{DD}	Supply current in Run mode from V _{DD} supply	Running from HSE crystal clock 8 MHz, code executing from Flash	72 MHz	44.1	25.2	mA
			64 MHz	39.4	22.6	
			48 MHz	30.5	17.3	
			32 MHz	21.1	11.8	
			24 MHz	16.2	8.9	
			16 MHz	10.6	6.1	
			8 MHz	5.3	3.17	
			4 MHz	3.09	1.86	
			2 MHz	1.80	1.16	
			1 MHz	1.15	0.81	
			500 KHz	0.83	0.58	
			125 KHz	0.58	0.47	
I _{DDA} ^{(1) (2)}	Supply current in Run mode from V _{DDA} supply	Running from HSE crystal clock 8 MHz, code executing from Flash	72 MHz	234.9		μA
			64 MHz	206.7		
			48 MHz	154.2		
			32 MHz	106.3		
			24 MHz	83.4		
			16 MHz	60.4		
			8 MHz	0.87		
			4 MHz	0.87		
			2 MHz	0.87		
			1 MHz	0.87		
			500 KHz	0.87		
			125 KHz	0.87		

1. VDDA monitoring is OFF

2. When peripherals are enabled, the power consumption of the analog part of peripherals such as ADC, DAC, Comparators, OpAmp etc. is not included. Refer to the tables of characteristics in the subsequent sections.

Table 28. Typical current consumption in Sleep mode, code running from Flash or RAM

Symbol	Parameter	Conditions	f _{HCLK}	Typ		Unit
				Peripherals enabled	Peripherals disabled	
I _{DD}	Supply current in Run mode from V _{DD} supply	Running from HSE crystal clock 8 MHz, code executing from Flash	72 MHz	28.7	6.0	mA
			64 MHz	25.8	5.4	
			48 MHz	19.9	4.10	
			32 MHz	13.6	2.81	
			24 MHz	10.4	2.17	
			16 MHz	6.7	1.52	
			8 MHz	3.28	0.70	
			4 MHz	2.06	0.58	
			2 MHz	1.28	0.49	
			1 MHz	0.89	0.45	
			500 KHz	0.69	0.43	
			125 KHz	0.50	0.38	
I _{DDA} ⁽¹⁾	Supply current in Run mode from V _{DDA} supply	Running from HSE crystal clock 8 MHz, code executing from Flash	72 MHz	234.9		μA
			64 MHz	206.7		
			48 MHz	154.2		
			32 MHz	106.3		
			24 MHz	83.4		
			16 MHz	60.4		
			8 MHz	0.87		
			4 MHz	0.87		
			2 MHz	0.87		
			1 MHz	0.87		
			500 KHz	0.87		
			125 KHz	0.87		

1. When peripherals are enabled, the power consumption of the analog part of peripherals such as ADC, DAC, Comparators, OpAmp etc. is not included. Refer to the tables of characteristics in the subsequent sections.

I/O system current consumption

The current consumption of the I/O system has two components: static and dynamic.

I/O static current consumption

All the I/Os used as inputs with pull-up generate current consumption when the pin is externally held low. The value of this current consumption can be simply computed by using the pull-up/pull-down resistors values given in [Table 46: I/O static characteristics](#).

For the output pins, any external pull-down or external load must also be considered to estimate the current consumption.

Additional I/O current consumption is due to I/Os configured as inputs if an intermediate voltage level is externally applied. This current consumption is caused by the input Schmitt trigger circuits used to discriminate the input value. Unless this specific configuration is required by the application, this supply current consumption can be avoided by configuring these I/Os in analog mode. This is notably the case of ADC input pins which should be configured as analog inputs.

Caution: Any floating input pin can also settle to an intermediate voltage level or switch inadvertently, as a result of external electromagnetic noise. To avoid current consumption related to floating pins, they must either be configured in analog mode, or forced internally to a definite digital value. This can be done either by using pull-up/down resistors or by configuring the pins in output mode.

I/O dynamic current consumption

In addition to the internal peripheral current consumption (see [Table 30: Peripheral current consumption](#)), the I/Os used by an application also contribute to the current consumption. When an I/O pin switches, it uses the current from the MCU supply voltage to supply the I/O pin circuitry and to charge/discharge the capacitive load (internal or external) connected to the pin:

$$I_{SW} = V_{DD} \times f_{SW} \times C$$

where

I_{SW} is the current sunk by a switching I/O to charge/discharge the capacitive load

V_{DD} is the MCU supply voltage

f_{SW} is the I/O switching frequency

C is the total capacitance seen by the I/O pin: $C = C_{INT} + C_{EXT} + C_S$

The test pin is configured in push-pull output mode and is toggled by software at a fixed frequency.

Table 29. Switching output I/O current consumption

Symbol	Parameter	Conditions ⁽¹⁾	I/O toggling frequency (f _{SW})	Typ	Unit
I _{SW}	I/O current consumption	$V_{DD} = 1.8\text{ V}$ $C_{ext} = 0\text{ pF}$ $C = C_{INT} + C_{EXT} + C_S$	2 MHz	0.10	mA
			4 MHz	0.17	
			8 MHz	0.40	
			18 MHz	0.78	
			36 MHz	1.51	
			48 MHz	2.06	
		$V_{DD} = 1.8\text{ V}$ $C_{ext} = 10\text{ pF}$ $C = C_{INT} + C_{EXT} + C_S$	2 MHz	0.14	
			4 MHz	0.25	
			8 MHz	0.57	
			18 MHz	1.16	
			36 MHz	2.45	
			48 MHz	3.03	
		$V_{DD} = 1.8\text{ V}$ $C_{ext} = 22\text{ pF}$ $C = C_{INT} + C_{EXT} + C_S$	2 MHz	0.19	
			4 MHz	0.36	
			8 MHz	0.75	
			18 MHz	1.59	
			36 MHz	3.25	
		$V_{DD} = 1.8\text{ V}$ $C_{ext} = 33\text{ pF}$ $C = C_{INT} + C_{EXT} + C_S$	2 MHz	0.23	
			4 MHz	0.45	
			8 MHz	0.94	
			18 MHz	1.97	
			36 MHz	3.62	
		$V_{DD} = 1.8\text{ V}$ $C_{ext} = 47\text{ pF}$ $C = C_{INT} + C_{EXT} + C_S$	2 MHz	0.28	
			4 MHz	0.55	
			8 MHz	1.15	
			18 MHz	2.42	

1. CS = 5 pF (estimated value).

On-chip peripheral current consumption

The MCU is placed under the following conditions:

- all I/O pins are in analog input configuration
- all peripherals are disabled unless otherwise mentioned
- the given value is calculated by measuring the current consumption
 - with all peripherals clocked off
 - with only one peripheral clocked on
- ambient operating temperature at 25°C and $V_{DD} = 1.8\text{ V}$, $V_{DDA} = 3.3\text{ V}$.

Table 30. Peripheral current consumption

Peripheral	Typical consumption ⁽¹⁾	Unit
	I_{DD}	
BusMatrix ⁽²⁾	11.1	μA/MHz
DMA1	8.0	
CRC	2.1	
GPIOA	8.7	
GPIOB	8.4	
GPIOC	8.4	
GIOD	2.6	
GPIOF	1.7	
TSC	4.7	
ADC1&2	17.4	
APB2-Bridge ⁽³⁾	3.3	
SYSCFG	4.2	
TIM1	8.2	
USART1	20.3	
TIM15	13.8	
TIM16	9.7	
TIM17	10.3	
APB1-Bridge ⁽³⁾	5.3	
TIM2	43.4	
TIM3	34.0	
TIM6	9.7	
TIM7	10.3	
WWDG	6.9	
USART2	18.8	
USART3	19.1	
I2C1	13.3	

Table 30. Peripheral current consumption (continued)

Peripheral	Typical consumption ⁽¹⁾	Unit
	I _{DD}	
CAN	31.3	
PWR	4.7	
DAC	15.4	
DAC2	8.6	
SPI1	8.2	

1. The power consumption of the analog part (I_{DDA}) of peripherals such as ADC, DAC, Comparators, OpAmp etc. is not included. Refer to the tables of characteristics in the subsequent sections.
2. BusMatrix is automatically active when at least one master is ON (CPU or DMA1).
3. The APBx bridge is automatically active when at least one peripheral is ON on the same bus.

6.3.5 Wakeup time from low-power mode

The wakeup times given in are measured starting from the wakeup event trigger up to the first instruction executed by the CPU:

- For Stop or Sleep mode: the wakeup event is WFE.
- WKUP1 (PA0) pin is used to wakeup from Stop and Sleep modes.

All timings are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 18](#).

Table 31. Low-power mode wakeup timings

Symbol	Parameter	Typ. @ $V_{DD} = 1.8\text{ V}$, $V_{DDA} = 3.3\text{ V}$	Max	Unit
t_{WUSTOP}	Wakeup from Stop mode	4.5	4.5	μs
t_{WUPOR}	Wakeup from power off mode	74.4	103	
$t_{WUSLEEP}$	Wakeup from Sleep mode	6	-	CPU clock cycles

6.3.6 External clock source characteristics

High-speed external user clock generated from an external source

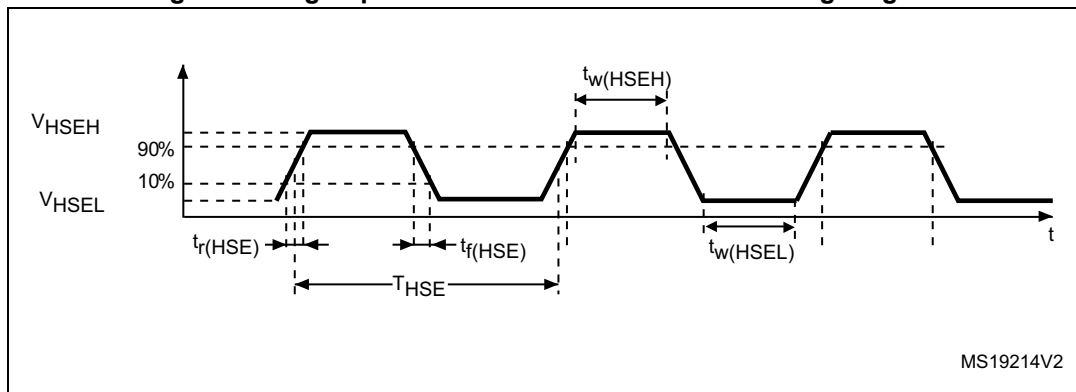
In bypass mode the HSE oscillator is switched off and the input pin is a standard GPIO. The external clock signal has to respect the I/O characteristics in [Section 6.3.13](#). However, the recommended clock input waveform is shown in [Figure 11](#).

Table 32. High-speed external user clock characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
f_{HSE_ext}	User external clock source frequency ⁽¹⁾	-	1	8	32	MHz
V_{HSEH}	OSC_IN input pin high level voltage		$0.7V_{DD}$	-	V_{DD}	V
V_{HSEL}	OSC_IN input pin low level voltage		V_{SS}	-	$0.3V_{DD}$	
$t_{w(HSEH)}$ $t_{w(HSEL)}$	OSC_IN high or low time ⁽¹⁾		15	-	-	ns
$t_{r(HSE)}$ $t_{f(HSE)}$	OSC_IN rise or fall time ⁽¹⁾		-	-	20	

1. Guaranteed by design, not tested in production.

Figure 11. High-speed external clock source AC timing diagram



Low-speed external user clock generated from an external source

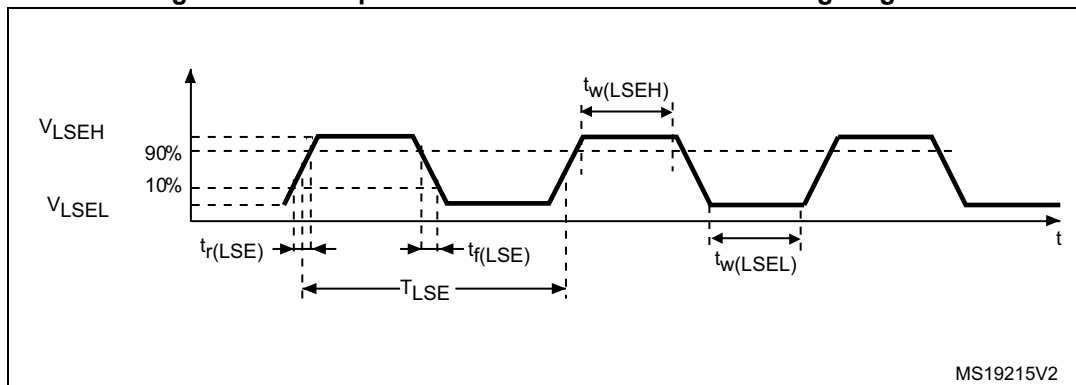
In bypass mode the LSE oscillator is switched off and the input pin is a standard GPIO. The external clock signal has to respect the I/O characteristics in [Section 6.3.13](#). However, the recommended clock input waveform is shown in [Figure 12](#)

Table 33. Low-speed external user clock characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
f_{LSE_ext}	User External clock source frequency ⁽¹⁾	-	-	32.768	1000	kHz
V_{LSEH}	OSC32_IN input pin high level voltage		$0.7V_{DD}$	-	V_{DD}	V
V_{LSEL}	OSC32_IN input pin low level voltage		V_{SS}	-	$0.3V_{DD}$	
$t_{w(LSEH)}$ $t_{w(LSEL)}$	OSC32_IN high or low time ⁽¹⁾		450	-	-	ns
$t_{r(LSE)}$ $t_{f(LSE)}$	OSC32_IN rise or fall time ⁽¹⁾		-	-	50	

1. Guaranteed by design, not tested in production.

Figure 12. Low-speed external clock source AC timing diagram



High-speed external clock generated from a crystal/ceramic resonator

The high-speed external (HSE) clock can be supplied with a 4 to 32 MHz crystal/ceramic resonator oscillator. All the information given in this paragraph are based on design simulation results obtained with typical external components specified in [Table 34](#). In the application, 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. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

Table 34. HSE oscillator characteristics

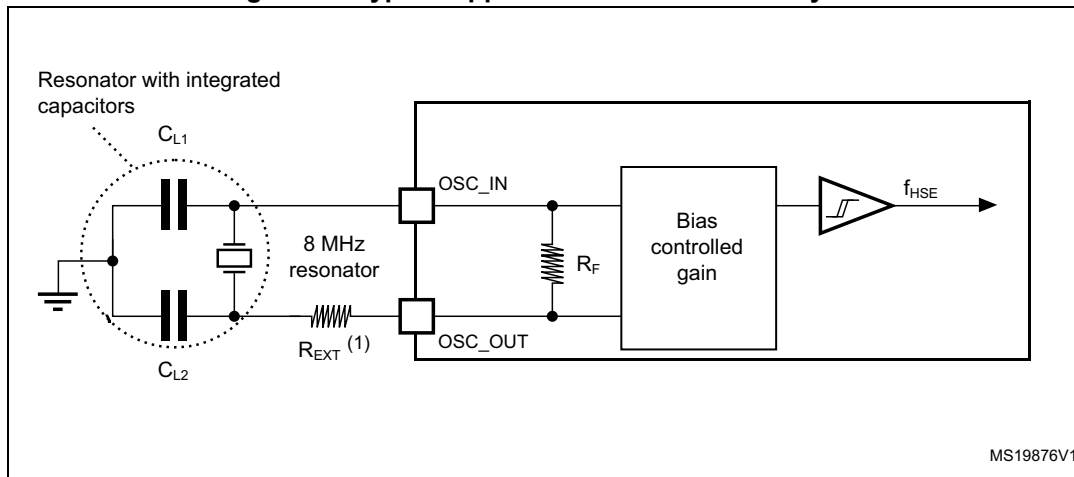
Symbol	Parameter	Conditions ⁽¹⁾	Min. ⁽²⁾	Typ.	Max. ⁽²⁾	Unit
f_{OSC_IN}	Oscillator frequency		4	8	32	MHz
R_F	Feedback resistor		-	200	-	k Ω
I_{DD}	HSE current consumption	During startup ⁽³⁾	-	-	8.5	mA
		$V_{DD}=1.8\text{ V}$, $R_m=30\Omega$, $CL=10\text{ pF}@8\text{ MHz}$	-	0.4	-	
		$V_{DD}=1.8\text{ V}$, $R_m=45\Omega$, $CL=10\text{ pF}@8\text{ MHz}$	-	0.5	-	
		$V_{DD}=1.8\text{ V}$, $R_m=30\Omega$, $CL=5\text{ pF}@32\text{ MHz}$	-	0.8	-	
		$V_{DD}=1.8\text{ V}$, $R_m=30\Omega$, $CL=10\text{ pF}@32\text{ MHz}$	-	1	-	
		$V_{DD}=1.8\text{ V}$, $R_m=30\Omega$, $CL=20\text{ pF}@32\text{ MHz}$	-	1.5	-	
g_m	Oscillator transconductance	Startup	10	-	-	mA/V
$t_{SU(HSE)}^{(4)}$	Startup time	V_{DD} is stabilized	-	2	-	ms

1. Resonator characteristics given by the crystal/ceramic resonator manufacturer.
2. Guaranteed by design, not tested in production.
3. This consumption level occurs during the first 2/3 of the $t_{SU(HSE)}$ startup time.
4. $t_{SU(HSE)}$ is the startup time measured from the moment it is enabled (by software) to a stabilized 8 MHz oscillation is reached. This value is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer.

For C_{L1} and C_{L2} , it is recommended to use high-quality external ceramic capacitors in the 5 pF to 25 pF range (typ.), designed for high-frequency applications, and selected to match the requirements of the crystal or resonator (see [Figure 13](#)). C_{L1} and C_{L2} are usually the same size. The crystal manufacturer typically specifies a load capacitance which is the series combination of C_{L1} and C_{L2} . PCB and MCU pin capacitance must be included (10 pF can be used as a rough estimate of the combined pin and board capacitance) when sizing C_{L1} and C_{L2} .

Note: For information on selecting the crystal, refer to the application note AN2867 “Oscillator design guide for ST microcontrollers” available from the ST website www.st.com.

Figure 13. Typical application with an 8 MHz crystal



1. R_{EXT} value depends on the crystal characteristics.

Low-speed external clock generated from a crystal/ceramic resonator

The low-speed external (LSE) clock can be supplied with a 32.768 kHz crystal/ceramic resonator oscillator. All the information given in this paragraph are based on design simulation results obtained with typical external components specified in [Table 35](#). In the application, 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. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

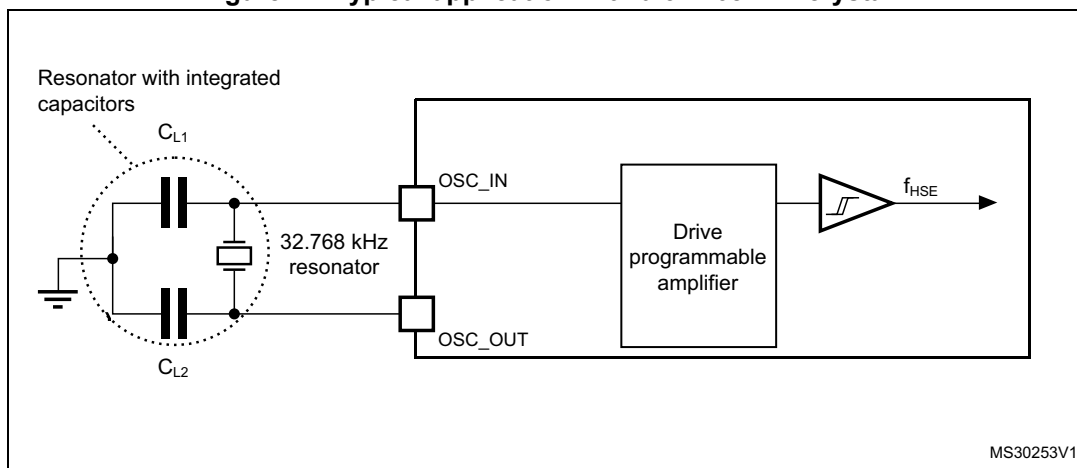
Table 35. LSE oscillator characteristics ($f_{LSE} = 32.768 \text{ kHz}$)

Symbol	Parameter	Conditions ⁽¹⁾	Min. (2)	Typ.	Max. (2)	Unit
I_{DD}	LSE current consumption	LSEDRV[1:0]=00 lower driving capability	-	0.5	0.9	μA
		LSEDRV[1:0]=01 medium low driving capability	-	-	1	
		LSEDRV[1:0]=10 medium high driving capability	-	-	1.3	
		LSEDRV[1:0]=11 higher driving capability	-	-	1.6	
g_m	Oscillator transconductance	LSEDRV[1:0]=00 lower driving capability	5	-	-	$\mu\text{A/V}$
		LSEDRV[1:0]=01 medium low driving capability	8	-	-	
		LSEDRV[1:0]=10 medium high driving capability	15	-	-	
		LSEDRV[1:0]=11 higher driving capability	25	-	-	
$t_{SU(LSE)}^{(3)}$	Startup time	V_{DD} is stabilized	-	2	-	s

1. Refer to the note and caution paragraphs below the table, and to the application note AN2867 "Oscillator design guide for ST microcontrollers".
2. Guaranteed by design, not tested in production.
3. $t_{SU(LSE)}$ is the startup time measured from the moment it is enabled (by software) to a stabilized 32.768 kHz oscillation is reached. This value is measured for a standard crystal and it can vary significantly with the crystal manufacturer.

Note: For information on selecting the crystal, refer to the application note AN2867 "Oscillator design guide for ST microcontrollers" available from the ST website www.st.com.

Figure 14. Typical application with a 32.768 kHz crystal



MS30253V1

Note: An external resistor is not required between OSC32_IN and OSC32_OUT and it is forbidden to add one.

6.3.7 Internal clock source characteristics

The parameters given in [Table 36](#) are derived from tests performed under ambient temperature and supply voltage conditions summarized in [Table 18](#).

High-speed internal (HSI) RC oscillator

Table 36. HSI oscillator characteristics⁽¹⁾

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
f_{HSI}	Frequency	-	-	8	-	MHz
TRIM	HSI user trimming step	-	-	-	1 ⁽²⁾	%
DuCy _(HSI)	Duty cycle	-	45 ⁽²⁾	-	55 ⁽²⁾	%
ACC _{HSI}	Accuracy of the HSI oscillator (factory calibrated)	$T_A = -40$ to $105\text{ }^{\circ}\text{C}$	-2.8 ⁽³⁾	-	3.8 ⁽³⁾	%
		$T_A = -10$ to $85\text{ }^{\circ}\text{C}$	-1.9 ⁽³⁾	-	2.3 ⁽³⁾	
		$T_A = 0$ to $85\text{ }^{\circ}\text{C}$	-1.9 ⁽³⁾	-	2 ⁽³⁾	
		$T_A = 0$ to $70\text{ }^{\circ}\text{C}$	-1.3 ⁽³⁾	-	2 ⁽³⁾	
		$T_A = 0$ to $55\text{ }^{\circ}\text{C}$	-1 ⁽³⁾	-	2 ⁽³⁾	
		$T_A = 25\text{ }^{\circ}\text{C}$ ⁽⁴⁾	-1	-	1	
$t_{\text{su(HSI)}}$	HSI oscillator startup time	-	1 ⁽²⁾	-	2 ⁽²⁾	μs
$I_{\text{DDA(HSI)}}$	HSI oscillator power consumption	-	-	80	100 ⁽²⁾	μA

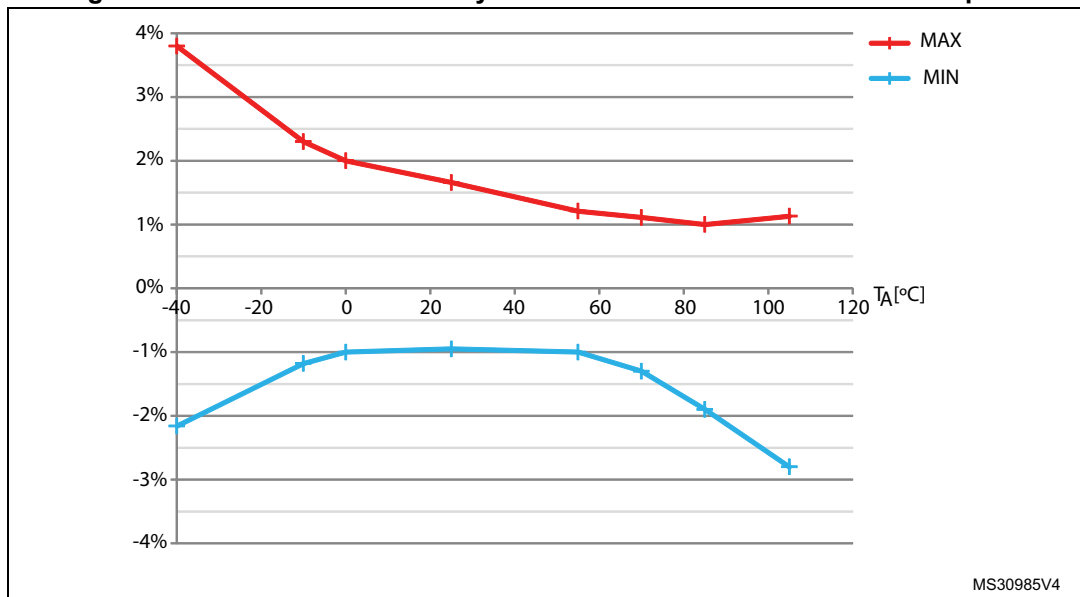
1. $V_{\text{DDA}} = 3.3\text{ V}$, $T_A = -40$ to $105\text{ }^{\circ}\text{C}$ unless otherwise specified.

2. Guaranteed by design, not tested in production.

3. Data based on characterization results, not tested in production.

4. Factory calibrated, parts not soldered

Figure 15. HSI oscillator accuracy characterization results for soldered parts



MS30985V4

Low-speed internal (LSI) RC oscillator

Table 37. LSI oscillator characteristics⁽¹⁾

Symbol	Parameter	Min.	Typ.	Max.	Unit
f_{LSI}	Frequency	30	40	50	kHz
$t_{su(LSI)}^{(2)}$	LSI oscillator startup time	-	-	85	μ s
$I_{DD(LSI)}^{(2)}$	LSI oscillator power consumption	-	0.75	1.2	μ A

1. $V_{DDA} = 3.3$ V, $T_A = -40$ to 105 °C unless otherwise specified.

2. Guaranteed by design, not tested in production.

6.3.8 PLL characteristics

The parameters given in [Table 38](#) are derived from tests performed under ambient temperature and supply voltage conditions summarized in [Table 18](#).

Table 38. PLL characteristics

Symbol	Parameter	Value			Unit
		Min.	Typ.	Max.	
f_{PLL_IN}	PLL input clock ⁽¹⁾	1 ⁽²⁾	-	24 ⁽²⁾	MHz
	PLL input clock duty cycle	40 ⁽²⁾	-	60 ⁽²⁾	%
f_{PLL_OUT}	PLL multiplier output clock	16 ⁽²⁾	-	72	MHz
t_{LOCK}	PLL lock time	-	-	200 ⁽²⁾	μ s
Jitter	Cycle-to-cycle jitter	-	-	300 ⁽²⁾	ps

1. Take care of using the appropriate multiplier factors so as to have PLL input clock values compatible with the range defined by f_{PLL_OUT} .

2. Guaranteed by design, not tested in production.

6.3.9 Memory characteristics

Flash memory

The characteristics are given at $T_A = -40$ to $+105\text{ }^{\circ}\text{C}$ unless otherwise specified.

Table 39. Flash memory characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max. ⁽¹⁾	Unit
t_{prog}	16-bit programming time	$T_A = -40$ to $+105\text{ }^{\circ}\text{C}$	40	53.5	60	μs
t_{ERASE}	Page (2 KB) erase time	$T_A = -40$ to $+105\text{ }^{\circ}\text{C}$	20	-	40	ms
t_{ME}	Mass erase time	$T_A = -40$ to $+105\text{ }^{\circ}\text{C}$	20	-	40	ms
I_{DD}	Supply current	Write mode	-	-	10	mA
		Erase mode	-	-	12	mA

1. Guaranteed by design, not tested in production.

Table 40. Flash memory endurance and data retention

Symbol	Parameter	Conditions	Value	Unit
			Min. ⁽¹⁾	
N_{END}	Endurance	$T_A = -40$ to $+85\text{ }^{\circ}\text{C}$ (6 suffix versions) $T_A = -40$ to $+105\text{ }^{\circ}\text{C}$ (7 suffix versions)	10	kcycles
t_{RET}	Data retention	1 kcycle ⁽²⁾ at $T_A = 85\text{ }^{\circ}\text{C}$	30	Years
		1 kcycle ⁽²⁾ at $T_A = 105\text{ }^{\circ}\text{C}$	10	
		10 kcycles ⁽²⁾ at $T_A = 55\text{ }^{\circ}\text{C}$	20	

1. Data based on characterization results, not tested in production.

2. Cycling performed over the whole temperature range.

6.3.10 EMC characteristics

Susceptibility tests are performed on a sample basis during device characterization.

Functional EMS (electromagnetic susceptibility)

While a simple application is executed on the device (toggling 2 LEDs through I/O ports), the device is stressed by two electromagnetic events until a failure occurs. The failure is indicated by the LEDs:

- **Electrostatic discharge (ESD)** (positive and negative) is applied to all device pins until a functional disturbance occurs. This test is compliant with the IEC 61000-4-2 standard.
- **FTB**: A Burst of Fast Transient voltage (positive and negative) is applied to V_{DD} and V_{SS} through a 100 pF capacitor, until a functional disturbance occurs. This test is compliant with the IEC 61000-4-4 standard.

A device reset allows normal operations to be resumed.

The test results are given in [Table 41](#). They are based on the EMS levels and classes defined in application note AN1709.

Table 41. EMS characteristics

Symbol	Parameter	Conditions	Level/Class
V_{FESD}	Voltage limits to be applied on any I/O pin to induce a functional disturbance	$V_{DD} = 1.8\text{ V}$, LQFP64, $T_A = +25^\circ\text{C}$, $f_{HCLK} = 72\text{ MHz}$ conforms to IEC 61000-4-2	2B
V_{EFTB}	Fast transient voltage burst limits to be applied through 100 pF on V_{DD} and V_{SS} pins to induce a functional disturbance	$V_{DD} = 1.8\text{ V}$, LQFP64, $T_A = +25^\circ\text{C}$, $f_{HCLK} = 72\text{ MHz}$ conforms to IEC 61000-4-4	4A

Designing hardened software to avoid noise problems

EMC characterization and optimization are performed at component level with a typical application environment and simplified MCU software. It should be noted that good EMC performance is highly dependent on the user application and the software in particular.

Therefore it is recommended that the user applies EMC software optimization and prequalification tests in relation with the EMC level requested for his application.

Software recommendations

The software flowchart must include the management of runaway conditions such as:

- Corrupted program counter
- Unexpected reset
- Critical Data corruption (control registers...)

Prequalification trials

Most of the common failures (unexpected reset and program counter corruption) can be reproduced by manually forcing a low state on the NRST pin or the Oscillator pins for 1 second.

To complete these trials, ESD stress can be applied directly on the device, over the range of specification values. When unexpected behavior is detected, the software can be hardened to prevent unrecoverable errors occurring (see application note AN1015).

Electromagnetic Interference (EMI)

The electromagnetic field emitted by the device are monitored while a simple application is executed (toggling 2 LEDs through the I/O ports). This emission test is compliant with IEC 61967-2 standard which specifies the test board and the pin loading.

Table 42. EMI characteristics

Symbol	Parameter	Conditions	Monitored frequency band	Max vs. [f _{HSE} /f _{HCLK}]	Unit
				8/72 MHz	
S _{EMI}	Peak level	V _{DD} = 1.8 V, T _A = 25 °C, LQFP64 package compliant with IEC 61967-2	0.1 to 30 MHz	7	dBμV
			30 to 130 MHz	10	
			130 MHz to 1GHz	26	
			SAE EMI Level	4	-

6.3.11 Electrical sensitivity characteristics

Based on three different tests (ESD, LU) using specific measurement methods, the device is stressed in order to determine its performance in terms of electrical sensitivity.

Electrostatic discharge (ESD)

Electrostatic discharges (a positive then a negative pulse separated by 1 second) are applied to the pins of each sample according to each pin combination. The sample size depends on the number of supply pins in the device (3 parts × (n+1) supply pins). This test conforms to the JESD22-A114/C101 standard.

Table 43. ESD absolute maximum ratings

Symbol	Ratings	Conditions	Class	Maximum value ⁽¹⁾	Unit
V _{ESD(HBM)}	Electrostatic discharge voltage (human body model)	T _A = +25 °C, conforming to JESD22-A114	2	2000	V
V _{ESD(CDM)}	Electrostatic discharge voltage (charge device model)	T _A = +25 °C, conforming to JESD22-C101	II	250	

1. Data based on characterization results, not tested in production.

Static latch-up

Two complementary static tests are required on six parts to assess the latch-up performance:

- A supply overvoltage is applied to each power supply pin
- A current injection is applied to each input, output and configurable I/O pin

These tests are compliant with EIA/JESD 78A IC latch-up standard.

Table 44. Electrical sensitivities

Symbol	Parameter	Conditions	Class
LU	Static latch-up class	$T_A = +105\text{ }^{\circ}\text{C}$ conforming to JESD78A	II level A

6.3.12 I/O current injection characteristics

As a general rule, current injection to the I/O pins, due to external voltage below V_{SS} or above V_{DD} (for standard, 3 V-capable I/O pins) should be avoided during normal product operation. However, in order to give an indication of the robustness of the microcontroller in cases when abnormal injection accidentally happens, susceptibility tests are performed on a sample basis during device characterization.

Functional susceptibility to I/O current injection

While a simple application is executed on the device, the device is stressed by injecting current into the I/O pins programmed in floating input mode. While current is injected into the I/O pin, one at a time, the device is checked for functional failures.

The failure is indicated by an out of range parameter: ADC error above a certain limit (higher than 5 LSB TUE), out of conventional limits of induced leakage current on adjacent pins (out of $-5\text{ }\mu\text{A}/+0\text{ }\mu\text{A}$ range), or other functional failure (for example reset occurrence or oscillator frequency deviation). The test results are given in [Table 45: I/O current injection susceptibility](#).

Table 45. I/O current injection susceptibility

Symbol	Description	Functional susceptibility		Unit
		Negative injection	Positive injection	
I_{INJ}	Injected current on BOOT0	-0	NA	mA
	Injected current on PB11, other TT, FT, FTf and NPOR pins	-5	NA	
	Injected current on PC0, PC1, PC2, PC3 (TTa pins) and PF1 pin (FT pin).	0	+5	

Table 45. I/O current injection susceptibility (continued)

Symbol	Description	Functional susceptibility		Unit
		Negative injection	Positive injection	
I_{INJ}	Injected current on PA0, PA1, PA2, PA3, PA4, PA5, PA6, PA7, PB0, PB1, PB12, PB13, PB14, PB15 with induced leakage current on other pins from this group less than -100 μ A or more than +900 μ A	-5	+5	mA
	Injected current on all other TC, TTa and RESET pins	- 5	+5	

Note: *It is recommended to add a Schottky diode (pin to ground) to analog pins which may potentially inject negative currents.*

6.3.13 I/O port characteristics

General input/output characteristics

Unless otherwise specified, the parameters given in [Table 46](#) are derived from tests performed under the conditions summarized in [Table 18](#). All I/Os are CMOS and TTL compliant.

Table 46. I/O static characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{IL}	Low level input voltage	TT, TC and TTa I/O	-	-	$0.3 V_{DD} + 0.07^{(1)}$	V
		FT and FTf I/O	-	-	$0.475 V_{DD} - 0.2^{(1)}$	
		BOOT0	-	-	$0.3 V_{DD} - 0.3^{(1)}$	
		All I/Os except BOOT0	-	-	$0.3 V_{DD}^{(2)}$	
V_{IH}	High level input voltage	TTa and TT I/O	$0.445 V_{DD} + 0.398^{(1)}$	-	-	
		FT and FTf I/O	$0.5 V_{DD} + 0.2^{(1)}$	-	-	
		BOOT0	$0.2 V_{DD} + 0.95^{(1)}$	-	-	
		All I/Os except BOOT0	$0.7 V_{DD}^{(2)}$	-	-	
V_{hys}	Schmitt trigger hysteresis	TT, TC and TTa I/O	-	200 ⁽¹⁾	-	mV
		FT and FTf I/O	-	100 ⁽¹⁾	-	
		BOOT0	-	300 ⁽¹⁾	-	

Table 46. I/O static characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{lkg}	Input leakage current ⁽³⁾	TC, FT, TT, FTf and TTa I/O in digital mode $V_{SS} \leq V_{IN} \leq V_{DD}$	-	-	± 0.1	μA
		TTa I/O in digital mode $V_{DD} \leq V_{IN} \leq V_{DDA}$	-	-	1	
		TTa I/O in analog mode $V_{SS} \leq V_{IN} \leq V_{DDA}$	-	-	0.2	
		FT and FTf I/O ⁽⁴⁾ $V_{DD} \leq V_{IN} \leq 5 V$	-	-	10	
		POR $V_{DDA} \leq V_{IN} \leq 5 V$	-	-	10	
R_{PU}	Weak pull-up equivalent resistor ⁽⁵⁾	$V_{IN} = V_{SS}$	25	40	55	$k\Omega$
R_{PD}	Weak pull-down equivalent resistor ⁽⁵⁾	$V_{IN} = V_{DD}$	25	40	55	$k\Omega$
C_{IO}	I/O pin capacitance	-	-	5	-	pF

1. Data based on design simulation.

2. Tested in production.

3. Leakage could be higher than the maximum value. if negative current is injected on adjacent pins. Refer to [Table 45: I/O current injection susceptibility](#).

4. To sustain a voltage higher than $V_{DD} + 0.3 V$, the internal pull-up/pull-down resistors must be disabled.

5. Pull-up and pull-down resistors are designed with a true resistance in series with a switchable PMOS/NMOS. This PMOS/NMOS contribution to the series resistance is minimum (~10% order).

All I/Os are CMOS and TTL compliant (no software configuration required). Their characteristics cover more than the strict CMOS-technology or TTL parameters. The coverage of these requirements is shown in [Figure 16](#) and [Figure 17](#) for standard I/Os.

Figure 16. TC and TTa I/O input characteristics - CMOS port

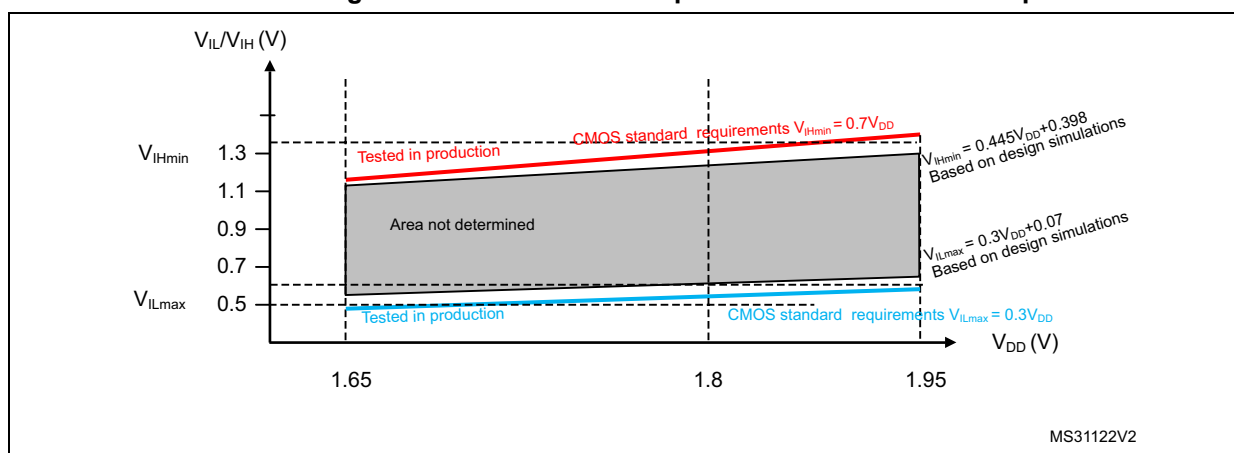
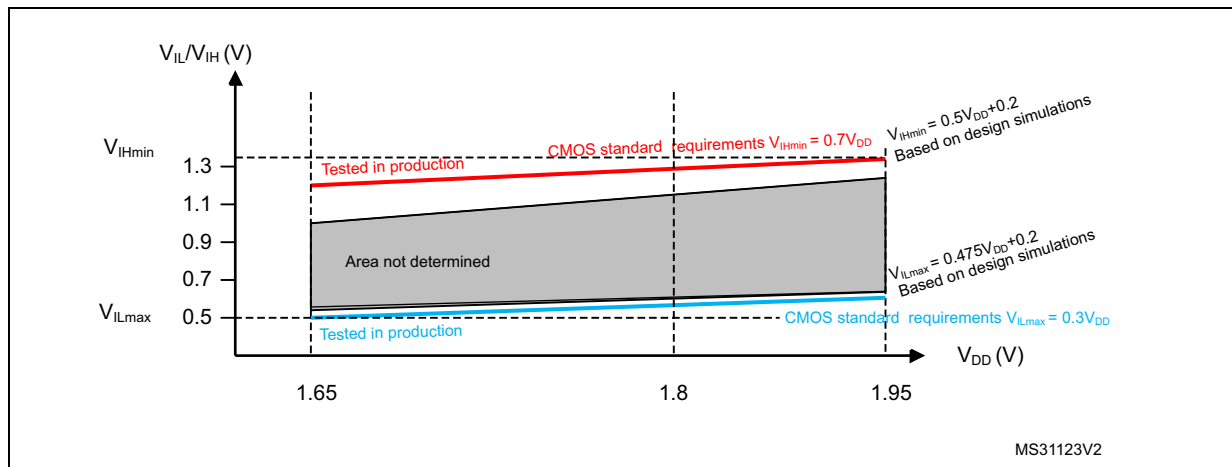


Figure 17. TC and TTa I/O input characteristics - TTL port



Output driving current

The GPIOs (general purpose input/outputs) can sink or source up to ± 8 mA, and sink or source up to ± 20 mA (with a relaxed V_{OL}/V_{OH}).

In the user application, the number of I/O pins which can drive current must be limited to respect the absolute maximum rating specified in [Section 6.2](#):

- The sum of the currents sourced by all the I/Os on V_{DD} , plus the maximum Run consumption of the MCU sourced on V_{DD} , cannot exceed the absolute maximum rating ΣI_{VDD} (see [Table 16](#)).
- The sum of the currents sunk by all the I/Os on V_{SS} plus the maximum Run consumption of the MCU sunk on V_{SS} cannot exceed the absolute maximum rating ΣI_{VSS} (see [Table 16](#)).

Output voltage levels

Unless otherwise specified, the parameters given in [Table 43: ESD absolute maximum ratings](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 18](#). All I/Os (FT, TTa and TC unless otherwise specified) are CMOS and TTL compliant.

Table 47. Output voltage characteristics

Symbol	Parameter	Conditions	Min.	Max.	Unit
$V_{OL}^{(1)}$	Output low level voltage for an I/O pin	$I_{IO} = +4$ mA $1.65\text{ V} < V_{DD} < 1.95\text{ V}$	-	0.4	V
$V_{OH}^{(2)}$	Output high level voltage for an I/O pin	$I_{IO} = -4$ mA $1.65\text{ V} < V_{DD} < 1.95\text{ V}$	$V_{DD} - 0.4$	-	
$V_{OLFM+}^{(1)(3)}$	Output low level voltage for an FTf I/O pin in FM+ mode	$I_{IO} = +10$ mA $V_{DD} = 1.65\text{ V to } 1.95\text{ V}$	-	0.4	

1. The I_{IO} current sunk by the device must always respect the absolute maximum rating specified in [Table 16](#) and the sum of I_{IO} (I/O ports and control pins) must not exceed $\Sigma I_{IO(PIN)}$.
2. The I_{IO} current sourced by the device must always respect the absolute maximum rating specified in [Table 16](#) and the sum of I_{IO} (I/O ports and control pins) must not exceed $\Sigma I_{IO(PIN)}$.
3. Guaranteed by Design, not tested in production.

Input/output AC characteristics

The definition and values of input/output AC characteristics are given in [Figure 18](#) and [Table 58](#), respectively.

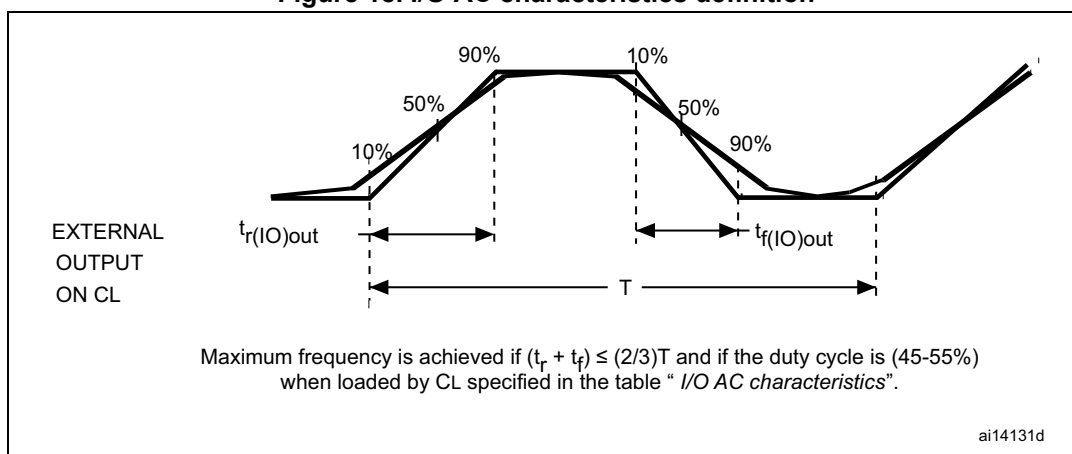
Unless otherwise specified, the parameters given are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 18](#).

Table 48. I/O AC characteristics⁽¹⁾

OSPEEDRx[1:0] value ⁽¹⁾	Symbol	Parameter	Conditions	Min	Max	Unit
x0	$f_{\max(\text{IO})\text{out}}$	Maximum frequency ⁽²⁾	$C_L = 50 \text{ pF}$, $V_{DD} = 1.65 \text{ V to } 1.95 \text{ V}$	-	1	MHz
	$t_{f(\text{IO})\text{out}}$	Output high to low level fall time		-	125 ⁽³⁾	ns
	$t_{r(\text{IO})\text{out}}$	Output low to high level rise time		-	125 ⁽²⁾	
01	$f_{\max(\text{IO})\text{out}}$	Maximum frequency ⁽²⁾		-	4 ⁽³⁾	MHz
	$t_{f(\text{IO})\text{out}}$	Output high to low level fall time		-	62.5 ⁽³⁾	ns
	$t_{r(\text{IO})\text{out}}$	Output low to high level rise time		-	62.5 ⁽³⁾	
11	$f_{\max(\text{IO})\text{out}}$	Maximum frequency ⁽³⁾		-	10 ⁽³⁾	MHz
	$t_{f(\text{IO})\text{out}}$	Output high to low level fall time		-	25 ⁽²⁾	ns
	$t_{r(\text{IO})\text{out}}$	Output low to high level rise time		-	25 ⁽³⁾	
FM+ configuration ⁽⁴⁾	$f_{\max(\text{IO})\text{out}}$	Maximum frequency ⁽²⁾		-	0.5 ⁽⁴⁾⁽³⁾	MHz
	$t_{f(\text{IO})\text{out}}$	Output high to low level fall time		-	16 ⁽⁴⁾⁽³⁾	ns
	$t_{r(\text{IO})\text{out}}$	Output low to high level rise time		-	44 ⁽⁴⁾⁽³⁾	
-	$t_{\text{EXTI}pw}$	Pulse width of external signals detected by the EXTI controller	-	10	-	ns

1. The I/O speed is configured using the OSPEEDRx[1:0] bits. Refer to the RM0364 reference manual for a description of GPIO Port configuration register.
2. The maximum frequency is defined in [Figure 18](#).
3. Guaranteed by design, not tested in production.
4. The I/O speed configuration is bypassed in FM+ I/O mode. Refer to the STM32F30x and STM32F301xx reference manual RM0364 for a description of FM+ I/O mode configuration.

Figure 18. I/O AC characteristics definition



6.3.14 NRST pin characteristics

The NRST pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, R_{PU} (see [Table 46](#)).

Unless otherwise specified, the parameters given in [Table 49](#) are derived from tests performed under ambient temperature and V_{DD} supply voltage conditions summarized in [Table 18](#).

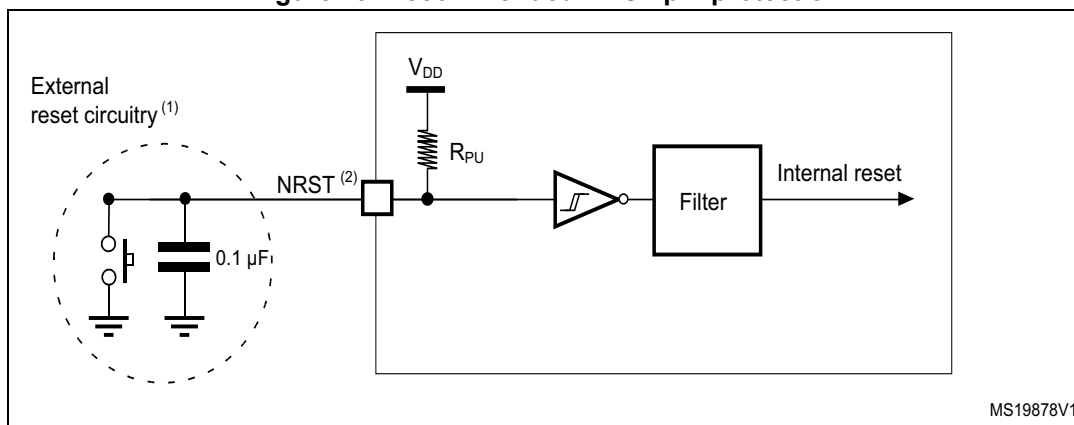
Table 49. NRST pin characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{IL(NRST)}^{(1)}$	NRST Input low level voltage	-	-	-	$0.3V_{DD} + 0.07^{(1)}$	V
$V_{IH(NRST)}^{(1)}$	NRST Input high level voltage	-	$0.445V_{DD} + 0.398^{(1)}$	-	-	
$V_{hys(NRST)}$	NRST Schmitt trigger voltage hysteresis	-	-	200	-	mV
R_{PU}	Weak pull-up equivalent resistor ⁽²⁾	$V_{IN} = V_{SS}$	25	40	55	k Ω
$V_{F(NRST)}^{(1)}$	NRST Input filtered pulse	-	-	-	100 ⁽¹⁾	ns
$V_{NF(NRST)}^{(1)}$	NRST Input not filtered pulse	-	700 ⁽¹⁾	-	-	ns

1. Guaranteed by design, not tested in production.

2. The pull-up is designed with a true resistance in series with a switchable PMOS. This PMOS contribution to the series resistance must be minimum (~10% order).

Figure 19. Recommended NRST pin protection



1. The reset network protects the device against parasitic resets.
2. The user must ensure that the level on the NRST pin can go below the $V_{IL(NRST)}$ max level specified in [Table 49](#). Otherwise the reset will not be taken into account by the device.

6.3.15 NPOR pin characteristics

The NPOR pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, R_{PU} (see [Table 53](#)) connected to V_{DDA} supply. Unless otherwise specified, the parameters given in [Table 53](#) are derived from tests performed under ambient temperature and V_{DDA} supply voltage conditions summarized in [Table 18](#).

Table 50. NPOR pin characteristics

Symbol ⁽¹⁾	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{IL(NPOR)}$	NPOR Input low level voltage	-	-	-	$0.475 V_{DDA} - 0.2$	V
$V_{IH(NPOR)}$	NPOR Input high level voltage	-	$0.5 V_{DDA} + 0.2$	-	-	
$V_{hys(NPOR)}$	NPOR Schmitt trigger voltage hysteresis	-	-	100	-	mV
R_{PU}	Weak pull-up equivalent resistor ⁽²⁾	$V_{IN} = V_{SS}$	25	40	55	k Ω

1. Guaranteed by design, not tested in production.
2. The pull-up is designed with a true resistance in series with a switchable PMOS. This PMOS contribution to the series resistance must be minimum (~10% order).

6.3.16 Timer characteristics

The parameters given in [Table 51](#) are guaranteed by design.

Refer to [Section 6.3.13: I/O port characteristics](#) for details on the input/output alternate function characteristics (output compare, input capture, external clock, PWM output).

Table 51. TIMx⁽¹⁾⁽²⁾ characteristics

Symbol	Parameter	Conditions	Min.	Max.	Unit
$t_{\text{res(TIM)}}$	Timer resolution time	-	1	-	t_{TIMxCLK} K
		$f_{\text{TIMxCLK}} = 72 \text{ MHz}$	13.9	-	ns
		$f_{\text{TIM1CLK}} = 144 \text{ MHz}$	6.95	-	ns
f_{EXT}	Timer external clock frequency on CH1 to CH4	-	0	$f_{\text{TIMxCLK}}/2$	MHz
		$f_{\text{TIMxCLK}} = 72 \text{ MHz}$	0	36	MHz
Res_{TIM}	Timer resolution	TIMx (except TIM2)	-	16	bit
		TIM2	-	32	
t_{COUNTER}	16-bit counter clock period	-	1	65536	t_{TIMxCLK} K
		$f_{\text{TIMxCLK}} = 72 \text{ MHz}$	0.0139	910	μs
		$f_{\text{TIM1CLK}} = 144 \text{ MHz}$	0.0069	455	μs
$t_{\text{MAX_COUNT}}$	Maximum possible count with 32-bit counter	-	-	65536×65536	t_{TIMxCLK} K
		$f_{\text{TIMxCLK}} = 72 \text{ MHz}$	-	59.65	s
		$f_{\text{TIM1CLK}} = 144 \text{ MHz}$	-	29.825	s

1. TIMx is used as a general term to refer to the TIM1, TIM2, TIM3, TIM15, TIM16 and TIM17 timers.

2. Guaranteed by design, not tested in production.

Table 52. IWDG min./max. timeout period at 40 kHz (LSI) ⁽¹⁾

Prescaler divider	PR[2:0] bits	Min. timeout (ms) RL[11:0]= 0x000	Max. timeout (ms) RL[11:0]= 0xFFFF
/4	0	0.1	409.6
/8	1	0.2	819.2
/16	2	0.4	1638.4
/32	3	0.8	3276.8
/64	4	1.6	6553.6
/128	5	3.2	13107.2
/256	7	6.4	26214.4

1. These timings are given for a 40 kHz clock but the microcontroller's internal RC frequency can vary from 30 to 60 kHz. Moreover, given an exact RC oscillator frequency, the exact timings still depend on the phasing of the APB interface clock versus the LSI clock so that there is always a full RC period of uncertainty.

Table 53. WWDG min./max. timeout value at 72 MHz (PCLK) ⁽¹⁾

Prescaler	WDGTB	Min. timeout value	Max. timeout value
1	0	0.05687	3.6409
2	1	0.1137	7.2817
4	2	0.2275	14.564
8	3	0.4551	29.127

1. Guaranteed by design, not tested in production.

6.3.17 Communications interfaces

I²C interface characteristics

The I2C interface meets the timings requirements of the I²C-bus specification and user manual rev. 03 for:

- Standard-mode (Sm): with a bit rate up to 100 kbit/s
- Fast-mode (Fm): with a bit rate up to 400 kbit/s
- Fast-mode Plus (Fm+): with a bit rate up to 1 Mbit/s.

The I2C timings requirements are guaranteed by design when the I2C peripheral is properly configured (refer to Reference manual).

The SDA and SCL I/O requirements are met with the following restrictions: the SDA and SCL I/O pins are not "true" open-drain. When configured as open-drain, the PMOS connected between the I/O pin and VDD is disabled, but is still present. Only FTf I/O pins support Fm+ low level output current maximum requirement. Refer to [Section 6.3.13: I/O port characteristics](#) for the I2C I/O characteristics.

All I2C SDA and SCL I/Os embed an analog filter. Refer to the table below for the analog filter characteristics:

Table 54. I2C analog filter characteristics⁽¹⁾

Symbol	Parameter	Min.	Max.	Unit
t_{AF}	Maximum pulse width of spikes that are suppressed by the analog filter.	50 ⁽²⁾	260 ⁽³⁾	ns

1. Guaranteed by design, not tested in production.
2. Spikes with width below $t_{AF}(\text{min.})$ are filtered.
3. Spikes with width above $t_{AF}(\text{max.})$ are not filtered.

SPI characteristics

Unless otherwise specified, the parameters given in [Table 49](#) for SPI are derived from tests performed under ambient temperature, f_{PCLKx} frequency and V_{DD} supply voltage conditions summarized in [Table 18: General operating conditions](#).

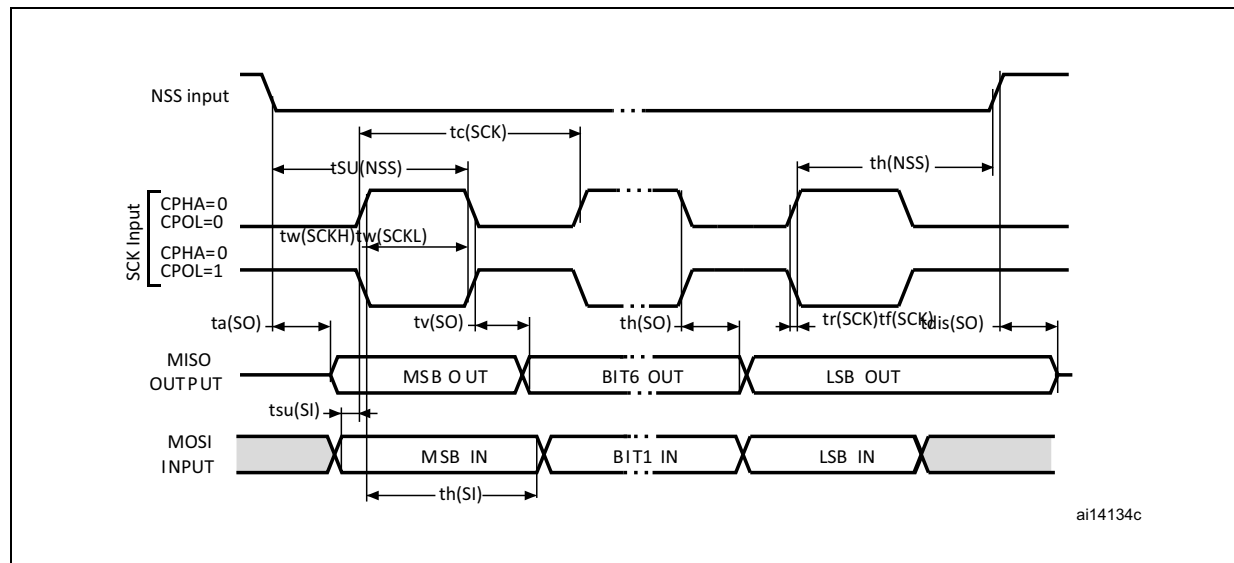
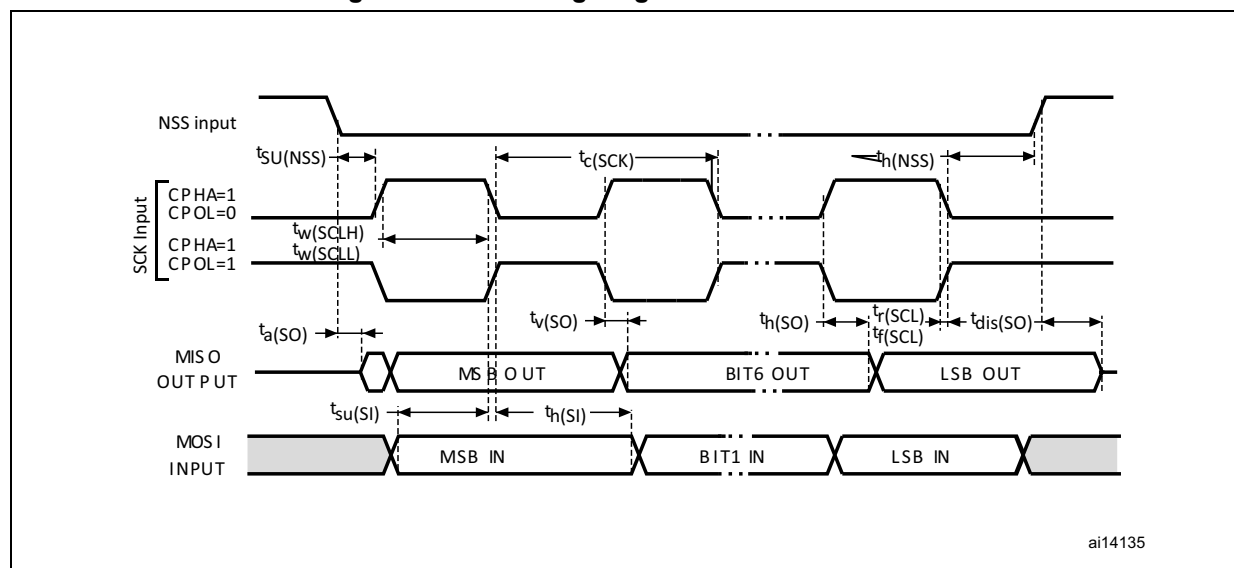
Refer to [Section 6.3.13: I/O port characteristics](#) for more details on the input/output alternate function characteristics (NSS, SCK, MOSI, MISO for SPI).

Table 55. SPI characteristics⁽¹⁾

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCK} $1/t_{c(SCK)}$	SPI clock frequency	Master mode	-	-	18	MHz
		Slave mode			12.5	
Duty(SCK)	Duty cycle of SPI clock frequency	Slave mode	30	50	70	%
$t_{su(NSS)}$	NSS setup time	Slave mode, SPI presc = 2	$4 \cdot T_{pclk}$	-	-	ns
$t_{h(NSS)}$	NSS hold time	Slave mode, SPI presc = 2	$2 \cdot T_{pclk}$	-	-	
$t_{w(SCKH)}$ $t_{w(SCKL)}$	SCK high and low time	Master mode	$T_{pclk}-2$	T_{pclk}	$T_{pclk}+2$	
$t_{su(MI)}$	Data input setup time	Master mode	0	-	-	
$t_{su(SI)}$		Slave mode	3	-	-	
$t_{h(MI)}$	Data input hold time	Master mode	5	-	-	
$t_{h(SI)}$		Slave mode	1	-	-	
$t_a(SO)$	Data output access time	Slave mode	10	-	40	
$t_{dis(SO)}$	Data output disable time	Slave mode	10	-	17	
$t_v(SO)$	Data output valid time	Slave mode	-	22	39	
$t_v(MO)$		Master mode	-	1.5	5	
$t_h(SO)$	Data output hold time	Slave mode	11	-	-	
$t_h(MO)$		Master mode	0	-	-	

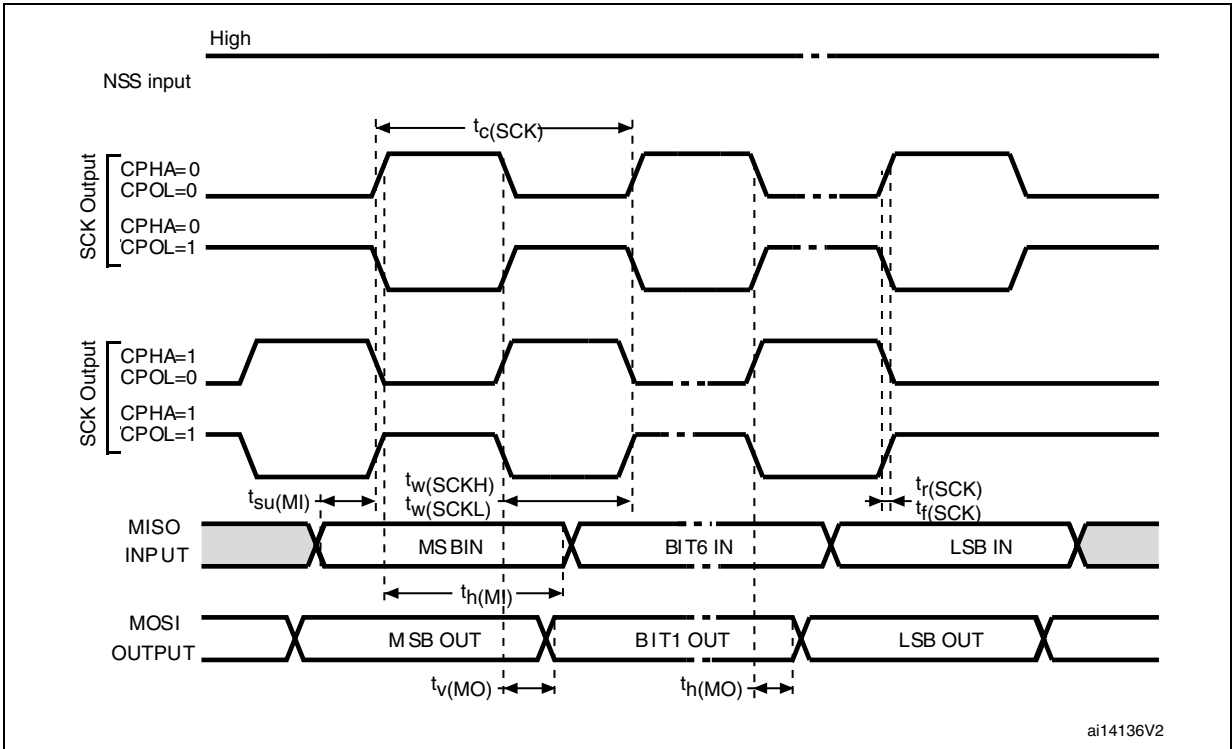
1. Data based on characterization results, not tested in production.

Figure 20. SPI timing diagram - slave mode and CPHA = 0

Figure 21. SPI timing diagram - slave mode and CPHA = 1⁽¹⁾

1. Measurement points are done at 0.5V_{DD} and with external C_L = 30 pF.

Figure 22. SPI timing diagram - master mode⁽¹⁾



1. Measurement points are done at 0.5V_{DD} and with external C_L = 30 pF.
1. Measurement points are done at 0.5V_{DD} and with external CL=30 pF.
2. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.
1. Measurement points are done at 0.5V_{DD} and with external CL=30 pF.
2. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

CAN (controller area network) interface

Refer to [Section 6.3.13: I/O port characteristics](#) for more details on the input/output alternate function characteristics (CAN_TX and CAN_RX).

6.3.18 ADC characteristics

Unless otherwise specified, the parameters given in [Table 56](#) to [Table 59](#) are guaranteed by design, with conditions summarized in [Table 18](#).

Table 56. ADC characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V _{DDA}	Analog supply voltage for ADC	-	1.8	-	3.6	V

Table 56. ADC characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{DDA}	ADC current consumption (Figure 23)	Single ended mode, 5 MSPS,	-	1011.3	1172.0	μA
		Single ended mode, 1 MSPS	-	214.7	322.3	
		Single ended mode, 200 KSPS	-	54.7	81.1	
		Differential mode, 5 MSPS,	-	1061.5	1243.6	
		Differential mode, 1 MSPS	-	246.6	337.6	
		Differential mode, 200 KSPS	-	56.4	83.0	
f_{ADC}	ADC clock frequency	-	0.14	-	72	MHz
$f_S^{(1)}$	Sampling rate	Resolution = 12 bits, Fast Channel	0.01	-	5.14	MSPS
		Resolution = 10 bits, Fast Channel	0.012	-	6	
		Resolution = 8 bits, Fast Channel	0.014	-	7.2	
		Resolution = 6 bits, Fast Channel	0.0175	-	9	
$f_{TRIG}^{(1)}$	External trigger frequency	$f_{ADC} = 72$ MHz Resolution = 12 bits	-	-	5.14	MHz
		Resolution = 12 bits	-	-	14	$1/f_{ADC}$
V_{AIN}	Conversion voltage range ⁽²⁾	-	0	-	V_{DDA}	V
$R_{AIN}^{(1)}$	External input impedance	-	-	-	100	$k\Omega$
$C_{ADC}^{(1)}$	Internal sample and hold capacitor	-	-	5	-	pF
$t_{CAL}^{(1)}$	Calibration time	$f_{ADC} = 72$ MHz	1.56			μs
		-	112			$1/f_{ADC}$
$t_{latr}^{(1)}$	Trigger conversion latency Regular and injected channels without conversion abort	CKMODE = 00	1.5	2	2.5	$1/f_{ADC}$
		CKMODE = 01	-	-	2	$1/f_{ADC}$
		CKMODE = 10	-	-	2.25	$1/f_{ADC}$
		CKMODE = 11	-	-	2.125	$1/f_{ADC}$
$t_{latrinj}^{(1)}$	Trigger conversion latency Injected channels aborting a regular conversion	CKMODE = 00	2.5	3	3.5	$1/f_{ADC}$
		CKMODE = 01	-	-	3	$1/f_{ADC}$
		CKMODE = 10	-	-	3.25	$1/f_{ADC}$
		CKMODE = 11	-	-	3.125	$1/f_{ADC}$

Table 56. ADC characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$t_S^{(1)}$	Sampling time	$f_{ADC} = 72 \text{ MHz}$	0.021	-	8.35	μs
		-	1.5	-	601.5	$1/f_{ADC}$
$T_{ADCVREG_STUP}^{(1)}$	ADC Voltage Regulator Start-up time	-	-	-	10	μs
$t_{CONV}^{(1)}$	Total conversion time (including sampling time)	$f_{ADC} = 72 \text{ MHz}$ Resolution = 12 bits	0.19	-	8.52	μs
		Resolution = 12 bits	14 to 614 (t_S for sampling + 12.5 for successive approximation)			$1/f_{ADC}$

1. Data guaranteed by design, not tested in production.

2. V_{REF+} can be internally connected to V_{DDA} and V_{REF-} can be internally connected to V_{SSA} , depending on the package. Refer to [Table 12: STM32F328C8 pin definitions](#) for further details.

[Figure 23](#) illustrates the ADC current consumption as per the clock frequency in single-ended and differential modes.

Figure 23. ADC typical current consumption in single-ended and differential modes

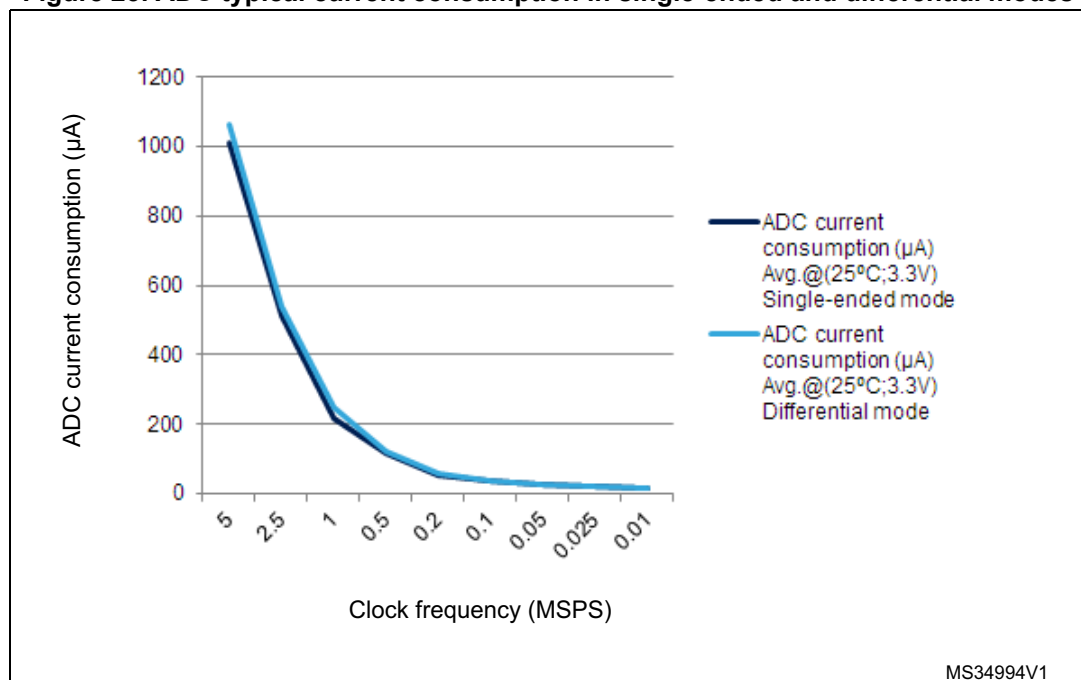


Table 57. Maximum ADC $R_{AIN}^{(1)}$

Resolution	Sampling cycle @ 72 MHz	Sampling time [ns] @ 72 MHz	R_{AIN} max. (k Ω)		
			Fast channels ⁽²⁾	Slow channels	Other channels ⁽³⁾
12 bits	1.5	20.83	0.018	NA	NA
	2.5	34.72	0.150	NA	0.022
	4.5	62.50	0.470	0.220	0.180
	7.5	104.17	0.820	0.560	0.470
	19.5	270.83	2.70	1.80	1.50
	61.5	854.17	8.20	6.80	4.70
	181.5	2520.83	22.0	18.0	15.0
	601.5	8354.17	82.0	68.0	47.0
10 bits	1.5	20.83	0.082	NA	NA
	2.5	34.72	0.270	0.082	0.100
	4.5	62.50	0.560	0.390	0.330
	7.5	104.17	1.20	0.82	0.68
	19.5	270.83	3.30	2.70	2.20
	61.5	854.17	10.0	8.2	6.8
	181.5	2520.83	33.0	27.0	22.0
	601.5	8354.17	100.0	82.0	68.0
8 bits	1.5	20.83	0.150	NA	0.039
	2.5	34.72	0.390	0.180	0.180
	4.5	62.50	0.820	0.560	0.470
	7.5	104.17	1.50	1.20	1.00
	19.5	270.83	3.90	3.30	2.70
	61.5	854.17	12.00	12.00	8.20
	181.5	2520.83	39.00	33.00	27.00
	601.5	8354.17	100.00	100.00	82.00
6 bits	1.5	20.83	0.270	0.100	0.150
	2.5	34.72	0.560	0.390	0.330
	4.5	62.50	1.200	0.820	0.820
	7.5	104.17	2.20	1.80	1.50
	19.5	270.83	5.60	4.70	3.90
	61.5	854.17	18.0	15.0	12.0
	181.5	2520.83	56.0	47.0	39.0
	601.5	8354.17	100.00	100.0	100.0

1. Data based on characterization results, not tested in production.

2. All fast channels, expect channel on PA6.
3. Channels available on PA6.

Table 58. ADC accuracy - limited test conditions⁽¹⁾⁽²⁾

Symbol	Parameter	Conditions			Min (3)	Typ	Max (3)	Unit
ET	Total unadjusted error	ADC clock freq. ≤ 72 MHz Sampling freq. ≤ 5 Msps V _{DDA} = 3.3 V 25°C	Single ended	Fast channel 5.1 Ms	-	±4	±4.5	LSB
				Slow channel 4.8 Ms	-	±5.5	±6	
Differential	Fast channel 5.1 Ms		-	±3.5	±4			
	Slow channel 4.8 Ms		-	±3.5	±4			
EO	Offset error		Single ended	Fast channel 5.1 Ms	-	±2	±2	
				Slow channel 4.8 Ms	-	±1.5	±2	
			Differential	Fast channel 5.1 Ms	-	±1.5	±2	
				Slow channel 4.8 Ms	-	±1.5	±2	
EG	Gain error		Single ended	Fast channel 5.1 Ms	-	±3	±4	
				Slow channel 4.8 Ms	-	±5	±5.5	
			Differential	Fast channel 5.1 Ms	-	±3	±3	
				Slow channel 4.8 Ms	-	±3	±3.5	
ED	Differential linearity error	Single ended	Fast channel 5.1 Ms	-	±1	±1		
			Slow channel 4.8 Ms	-	±1	±1		
		Differential	Fast channel 5.1 Ms	-	±1	±1		
			Slow channel 4.8 Ms	-	±1	±1		
EL	Integral linearity error	Single ended	Fast channel 5.1 Ms	-	±1.5	±2		
			Slow channel 4.8 Ms	-	±2	±3		
		Differential	Fast channel 5.1 Ms	-	±1.5	±1.5		
			Slow channel 4.8 Ms	-	±1.5	±2		
ENOB ⁽⁴⁾	Effective number of bits	Single ended	Fast channel 5.1 Ms	10.8	10.8	-	bit	
			Slow channel 4.8 Ms	10.8	10.8	-		
		Differential	Fast channel 5.1 Ms	11.2	11.3	-		
			Slow channel 4.8 Ms	11.2	11.3	-		
SINAD ⁽⁴⁾	Signal-to-noise and distortion ratio	Single ended	Fast channel 5.1 Ms	66	67	-	dB	
			Slow channel 4.8 Ms	66	67	-		
		Differential	Fast channel 5.1 Ms	69	70	-		
			Slow channel 4.8 Ms	69	70	-		

Table 58. ADC accuracy - limited test conditions⁽¹⁾⁽²⁾ (continued)

Symbol	Parameter	Conditions			Min (3)	Typ	Max (3)	Unit
SNR ⁽⁴⁾	Signal-to-noise ratio	ADC clock freq. ≤ 72 MHz Sampling freq ≤ 5 Msps V _{DDA} = 3.3 V 25°C	Single ended	Fast channel 5.1 Ms	66	67	-	dB
				Slow channel 4.8 Ms	66	67	-	
			Differential	Fast channel 5.1 Ms	69	70	-	
				Slow channel 4.8 Ms	69	70	-	
THD ⁽⁴⁾	Total harmonic distortion		Single ended	Fast channel 5.1 Ms	-	-80	-80	
				Slow channel 4.8 Ms	-	-78	-77	
			Differential	Fast channel 5.1 Ms	-	-83	-82	
				Slow channel 4.8 Ms	-	-81	-80	

1. ADC DC accuracy values are measured after internal calibration.
2. ADC accuracy vs. negative Injection Current: Injecting negative current on any analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to analog pins which may potentially inject negative current. Any positive injection current within the limits specified for $I_{INJ(PIN)}$ and $\Sigma I_{INJ(PIN)}$ in [Section 6.3.13](#) does not affect the ADC accuracy.
3. Data based on characterization results, not tested in production.
4. Value measured with a -0.5 dB full scale 50 kHz sine wave input signal.

Table 59. ADC accuracy ⁽¹⁾⁽²⁾⁽³⁾

Symbol	Parameter	Conditions			Min ⁽⁴⁾	Max ⁽⁴⁾	Unit
ET	Total unadjusted error	ADC clock freq. ≤ 72 MHz, Sampling freq. ≤ 5 Msps 1.8 V ≤ V _{DDA} ≤ 3.6 V	Single ended	Fast channel 5.1 Ms	-	±6.5	LSB
				Slow channel 4.8 Ms	-	±6.5	
			Differential	Fast channel 5.1 Ms	-	±4	
				Slow channel 4.8 Ms	-	±4.5	
EO	Offset error		Single ended	Fast channel 5.1 Ms	-	±3	
				Slow channel 4.8 Ms	-	±3	
			Differential	Fast channel 5.1 Ms	-	±2.5	
				Slow channel 4.8 Ms	-	±2.5	
EG	Gain error		Single ended	Fast channel 5.1 Ms	-	±6	
				Slow channel 4.8 Ms	-	±6	
			Differential	Fast channel 5.1 Ms	-	±3.5	
				Slow channel 4.8 Ms	-	±4	
ED	Differential linearity error	Single ended	Fast channel 5.1 Ms	-	±1.5		
			Slow channel 4.8 Ms	-	±1.5		
		Differential	Fast channel 5.1 Ms	-	±1.5		
			Slow channel 4.8 Ms	-	±1.5		
EL	Integral linearity error	Single ended	Fast channel 5.1 Ms	-	±3		
			Slow channel 4.8 Ms	-	±3.5		
		Differential	Fast channel 5.1 Ms	-	±2		
			Slow channel 4.8 Ms	-	±2.5		
ENOB ⁽⁵⁾	Effective number of bits	Single ended	Fast channel 5.1 Ms	10.4	-	bits	
			Slow channel 4.8 Ms	10.4	-		
		Differential	Fast channel 5.1 Ms	10.8	-		
			Slow channel 4.8 Ms	10.8	-		
SINAD ⁽⁵⁾	Signal-to-noise and distortion ratio	Single ended	Fast channel 5.1 Ms	64	-	dB	
			Slow channel 4.8 Ms	63	-		
		Differential	Fast channel 5.1 Ms	67	-		
			Slow channel 4.8 Ms	67	-		

Table 59. ADC accuracy ⁽¹⁾⁽²⁾⁽³⁾ (continued)

Symbol	Parameter	Conditions			Min ⁽⁴⁾	Max ⁽⁴⁾	Unit
SNR ⁽⁵⁾	Signal-to-noise ratio	ADC clock freq. ≤ 72 MHz, Sampling freq ≤ 5 Msps, 1.8 V ≤ V _{DDA} ≤ 3.6 V	Single ended	Fast channel 5.1 Ms	64	-	dB
				Slow channel 4.8 Ms	64	-	
			Differential	Fast channel 5.1 Ms	67	-	
				Slow channel 4.8 Ms	67	-	
THD ⁽⁵⁾	Total harmonic distortion		Single ended	Fast channel 5.1 Ms	-	-75	
				Slow channel 4.8 Ms	-	-75	
			Differential	Fast channel 5.1 Ms	-	-79	
				Slow channel 4.8 Ms	-	-78	

1. ADC DC accuracy values are measured after internal calibration.
2. ADC accuracy vs. negative Injection Current: Injecting negative current on any analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to analog pins which may potentially inject negative current. Any positive injection current within the limits specified for $I_{INJ(PIN)}$ and $\Sigma I_{INJ(PIN)}$ in [Section 6.3.13](#) does not affect the ADC accuracy.
3. Better performance may be achieved in restricted V_{DDA} , frequency and temperature ranges.
4. Data based on characterization results, not tested in production.
5. Value measured with a -0.5 dB full scale 50 kHz sine wave input signal.

Table 60. ADC accuracy ⁽¹⁾⁽²⁾ at 1MSPS

Symbol	Parameter	Test conditions		Typ	Max ⁽³⁾	Unit
ET	Total unadjusted error	ADC Freq ≤ 72 MHz Sampling Freq ≤ 1MSPS 2.4 V ≤ V _{DDA} = V _{REF+} ≤ 3.6 V Single-ended mode	Fast channel	±2.5	±5	LSB
			Slow channel	±3.5	±5	
EO	Offset error		Fast channel	±1	±2.5	
			Slow channel	±1.5	±2.5	
EG	Gain error		Fast channel	±2	±3	
			Slow channel	±3	±4	
ED	Differential linearity error		Fast channel	±0.7	± 2	
			Slow channel	±0.7	±2	
EL	Integral linearity error		Fast channel	±1	±3	
			Slow channel	±1.2	±3	

1. ADC DC accuracy values are measured after internal calibration.
2. ADC accuracy vs. negative Injection Current: Injecting negative current on any analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to analog pins which may potentially inject negative current.. Any positive injection current within the limits specified for $I_{INJ(PIN)}$ and $\Sigma I_{INJ(PIN)}$ in [Section 6.3.13: I/O port characteristics](#) does not affect the ADC accuracy.
3. Data based on characterization results, not tested in production.

Figure 24. ADC accuracy characteristics

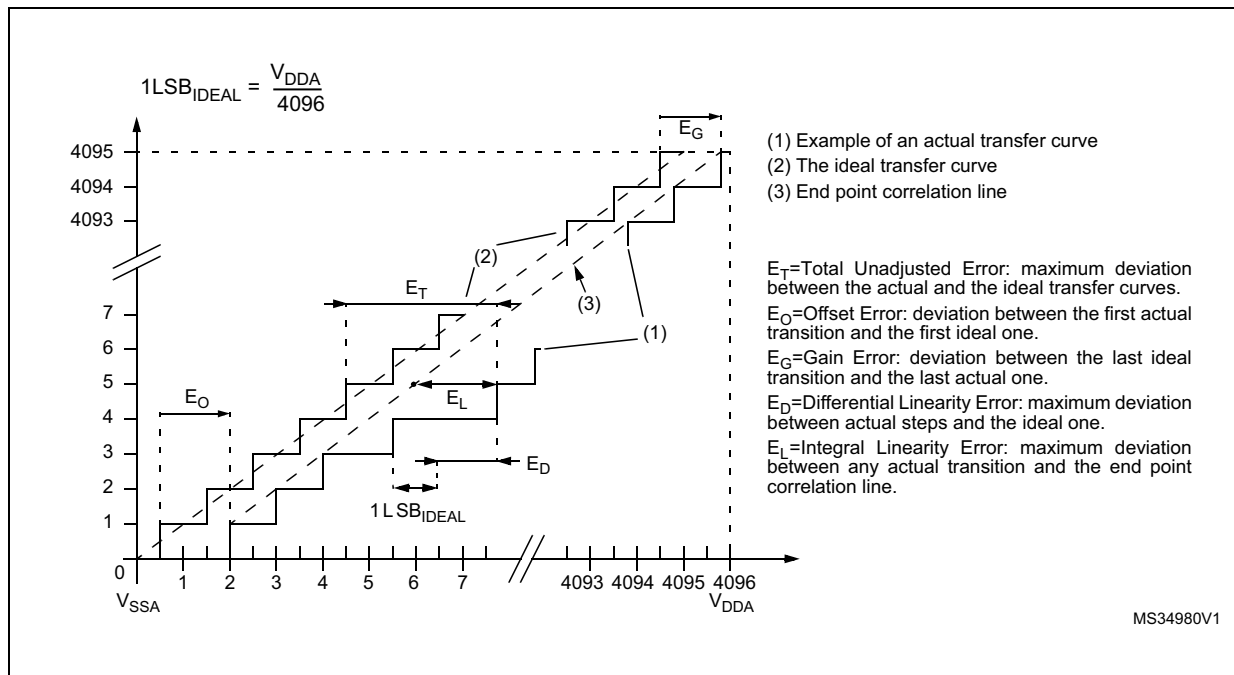
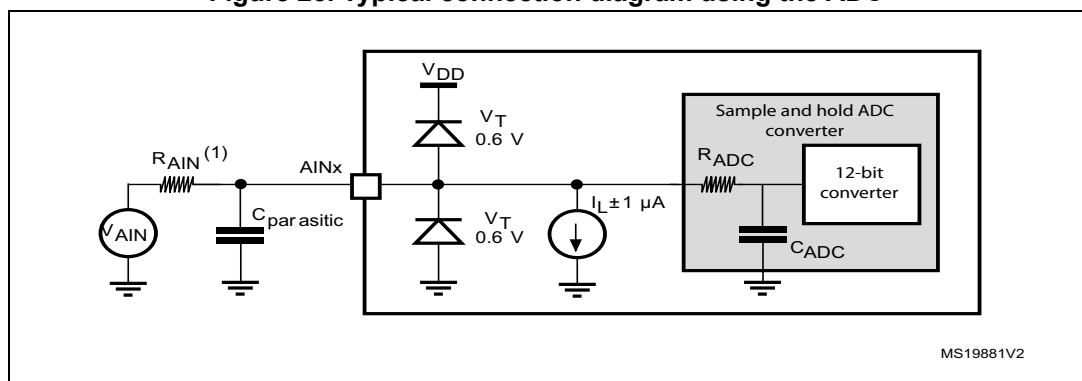


Figure 25. Typical connection diagram using the ADC



1. Refer to [Table 56](#) for the values of R_{AIN} .
2. $C_{parasitic}$ represents the capacitance of the PCB (dependent on soldering and PCB layout quality) plus the pad capacitance (roughly 7 pF). A high $C_{parasitic}$ value will downgrade conversion accuracy. To remedy this, f_{ADC} should be reduced.

General PCB design guidelines

Power supply decoupling should be performed as shown in [Figure 8: Power supply scheme](#). The 10 nF capacitor should be ceramic (good quality) and it should be placed as close as possible to the chip.

6.3.19 DAC electrical specifications

Table 61. DAC characteristics

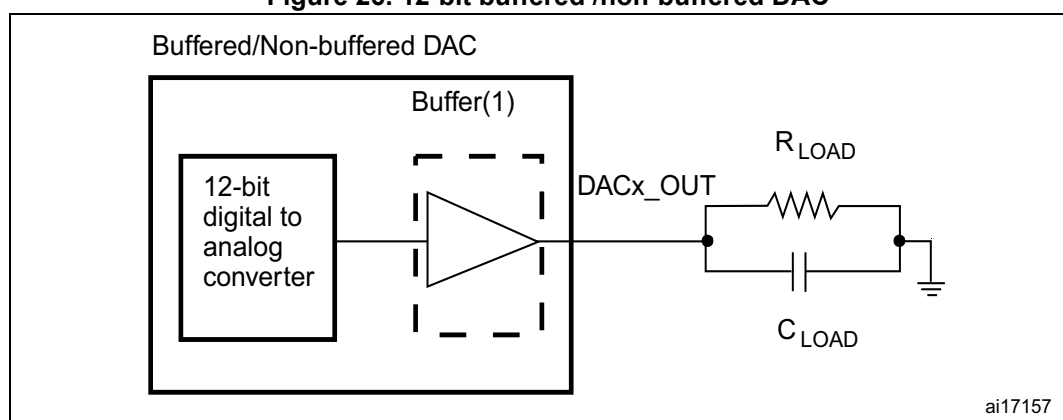
Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DDA}	Analog supply voltage	DAC output buffer ON	2.4	-	3.6	V
$R_{LOAD}^{(1)}$	Resistive load	DAC output buffer ON	5	-	-	k Ω
$R_O^{(1)}$	Output impedance	DAC output buffer OFF	-	-	15	k Ω
$C_{LOAD}^{(1)}$	Capacitive load	DAC output buffer ON	-	-	50	pF
$V_{DAC_OUT}^{(1)}$	Voltage on DAC_OUT output	Corresponds to 12-bit input code (0x0E0) to (0xF1C) at $V_{DDA} = 3.6$ V and (0x155) and (0xEAB) at $V_{DDA} = 2.4$ V	0.2	-	$V_{DDA} - 0.2$	V
		DAC output buffer OFF	-	0.5	-	mV
			-	-	$V_{DDA} - 1LSB$	V
$I_{DDA}^{(3)}$	DAC DC current consumption in quiescent mode ⁽²⁾	With no load, middle code (0x800) on the input	-	-	380	μ A
		With no load, worst code (0xF1C) on the input.	-	-	480	μ A
DNL ⁽³⁾	Differential non linearity Difference between two consecutive code-1LSB)	Given for a 10-bit input code DAC1 channel 1	-	-	± 0.5	LSB
		Given for a 12-bit input code DAC1 channel 1	-	-	± 2	LSB
		Given for a 10-bit input code DAC1 channel 2 & DAC2 channel 1	-	-	-0.75/+0.25	LSB
		Given for a 12-bit input code DAC1 channel 2 & DAC2 channel 1	-	-	-3/+1	LSB
INL ⁽³⁾	Integral non linearity (difference between measured value at Code i and the value at Code i on a line drawn between Code 0 and last Code 4095)	Given for a 10-bit input code	-	-	± 1	LSB
		Given for a 12-bit input code	-	-	± 4	LSB
Offset ⁽³⁾	Offset error (difference between measured value at Code (0x800) and the ideal value = $V_{DDA}/2$)	-	-	-	± 10	mV
		Given for a 10-bit input code at $V_{DDA} = 3.6$ V	-	-	± 3	LSB
		Given for a 12-bit input code	-	-	± 12	LSB
Gain error ⁽³⁾	Gain error	Given for a 12-bit input code	-	-	± 0.5	%

Table 61. DAC characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$t_{\text{SETTLING}}^{(3)}$	Settling time (full scale: for a 12-bit input code transition between the lowest and the highest input codes when DAC_OUT reaches final value $\pm 1\text{LSB}$)	$C_{\text{LOAD}} \leq 50 \text{ pF}$, $R_{\text{LOAD}} \geq 5 \text{ k}\Omega$	-	3	4	μs
Update rate ⁽³⁾	Max frequency for a correct DAC_OUT change when small variation in the input code (from code i to i+1LSB)	$C_{\text{LOAD}} \leq 50 \text{ pF}$, $R_{\text{LOAD}} \geq 5 \text{ k}\Omega$	-	-	1	MS/s
$t_{\text{WAKEUP}}^{(3)}$	Wakeup time from off state (Setting the ENx bit in the DAC Control register)	$C_{\text{LOAD}} \leq 50 \text{ pF}$, $R_{\text{LOAD}} \geq 5 \text{ k}\Omega$	-	6.5	10	μs
PSRR+ ⁽¹⁾	Power supply rejection ratio (to V_{DDA}) (static DC measurement)	No R_{LOAD} , $C_{\text{LOAD}} = 50 \text{ pF}$	-	-67	-40	dB

1. Guaranteed by design, not tested in production.
2. Quiescent mode refers to the state of the DAC a keeping steady value on the output, so no dynamic consumption is involved.
3. Data based on characterization results, not tested in production.

Figure 26. 12-bit buffered /non-buffered DAC



1. The DAC integrates an output buffer that can be used to reduce the output impedance and to drive external loads directly without the use of an external operational amplifier. The buffer can be bypassed by configuring the BOFFx bit in the DAC_CR register.

6.3.20 Comparator characteristics

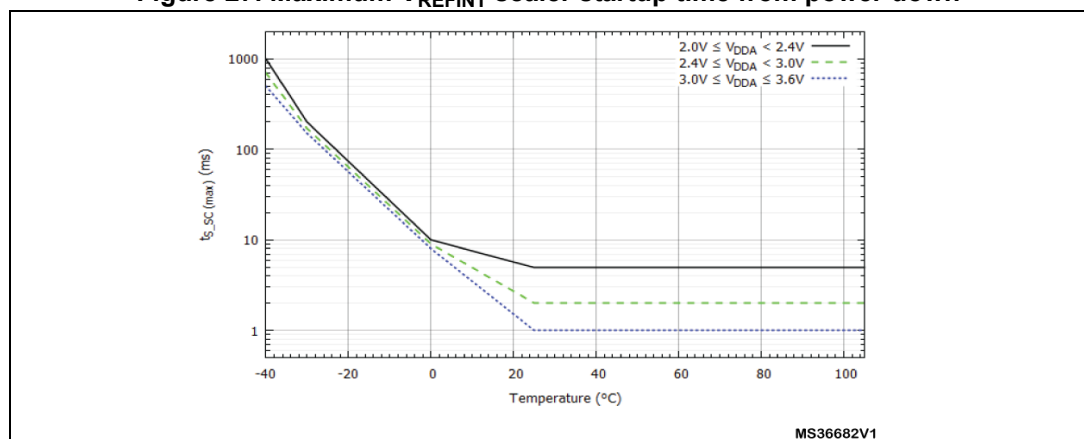
Table 62. Comparator characteristics⁽¹⁾

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{DDA}	Analog supply voltage	V_{REFINT} scaler not in use	1.8	-	3.6	V
		V_{REFINT} scaler in use	2	-	3.6	
V_{IN}	Comparator input voltage range	-	0	-	V_{DDA}	
V_{BG}	Scaler input voltage	-	-	V_{REFINT}	-	
V_{SC}	Scaler offset voltage	-	-	± 5	± 10	mV
t_{S_SC}	V_{REFINT} scaler startup time from power down	First V_{REFINT} scaler activation after device power on	-	-	1 ⁽²⁾	s
		Next activations	-	-	0.2	ms
t_{START}	Comparator startup time	$V_{DDA} \geq 2.7$ V	-	-	4	μ s
		$V_{DDA} < 2.7$ V	-	-	10	
t_D	Propagation delay for 200 mV step with 100 mV overdrive	$V_{DDA} \geq 2.7$ V	-	25	28	ns
		$V_{DDA} < 2.7$ V	-	28	30	
	Propagation delay for full range step with 100 mV overdrive	$V_{DDA} \geq 2.7$ V	-	32	35	
		$V_{DDA} < 2.7$ V	-	35	40	
V_{OFFSET}	Comparator offset error	$V_{DDA} \geq 2.7$ V	-	± 5	± 10	mV
		$V_{DDA} < 2.7$ V	-	-	± 25	
TV_{OFFSET}	Total offset variation	Full temperature range	-	-	3	mV
$I_{DD(COMP)}$	COMP current consumption	-	-	400	600	μ A

1. Guaranteed by design, not tested in production.

2. For more details and conditions see [Figure 27: Maximum \$V_{REFINT}\$ scaler startup time from power down](#).

Figure 27. Maximum V_{REFINT} scaler startup time from power down



6.3.21 Operational amplifier characteristics

Table 63. Operational amplifier characteristics⁽¹⁾

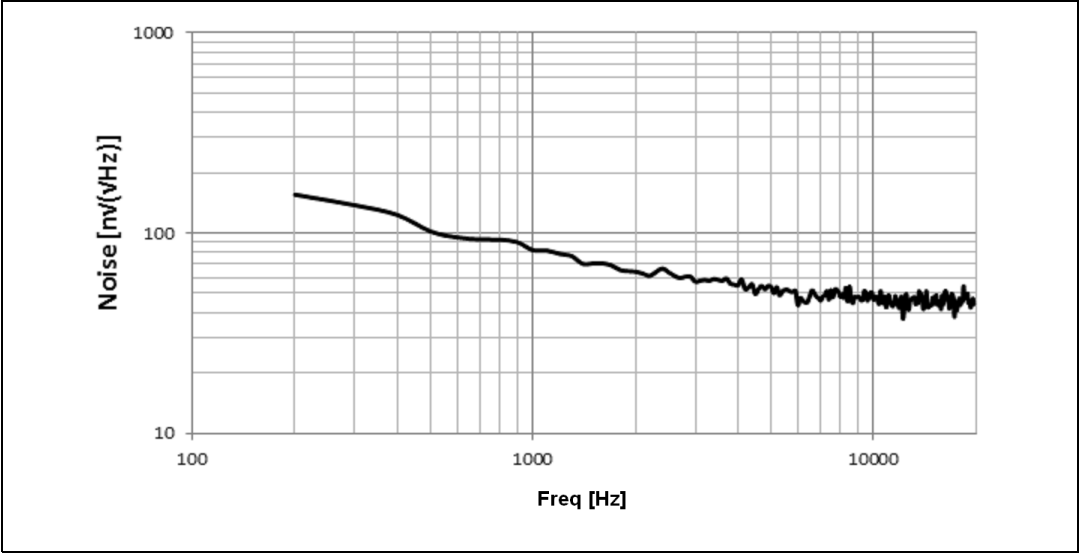
Symbol	Parameter		Condition	Min.	Typ.	Max.	Unit
V _{DDA}	Analog supply voltage		-	2.4	-	3.6	V
CMIR	Common mode input range		-	0	-	V _{DDA}	V
V _I OFFSET	Input offset voltage	Maximum calibration range	25°C, No Load on output.	-	-	4	mV
			All voltage/Temp.	-	-	6	
		After offset calibration	25°C, No Load on output.	-	-	1.6	
			All voltage/Temp.	-	-	3	
ΔV _I OFFSET	Input offset voltage drift		-	-	5	-	μV/°C
I _{LOAD}	Drive current		-	-	-	500	μA
IDDOPAMP	Consumption		No load, quiescent mode	-	690	1450	μA
CMRR	Common mode rejection ratio		-	-	90	-	dB
PSRR	Power supply rejection ratio		DC	73	117	-	dB
GBW	Bandwidth		-	-	8.2	-	MHz
SR	Slew rate		-	-	4.7	-	V/μs
R _{LOAD}	Resistive load		-	4	-	-	kΩ
C _{LOAD}	Capacitive load		-	-	-	50	pF
VOH _{SAT}	High saturation voltage		R _{load} = min, Input at V _{DDA} .	-	-	100	mV
			R _{load} = 20K, Input at V _{DDA} .	-	-	20	
VOL _{SAT}	Low saturation voltage		R _{load} = min, input at 0 V	-	-	100	
			R _{load} = 20K, input at 0 V.	-	-	20	
φm	Phase margin		-	-	62	-	°
t _{OFFTRIM}	Offset trim time: during calibration, minimum time needed between two steps to have 1 mV accuracy		-	-	-	2	ms
t _{WAKEUP}	Wake up time from OFF state.		C _{LOAD} ≤50 pf, R _{LOAD} ≥ 4 kΩ, Follower configuration	-	2.8	5	μs
t _{S_OPAM_VOUT}	ADC sampling time when reading the OPAMP output			400	-	-	ns

Table 63. Operational amplifier characteristics⁽¹⁾ (continued)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
PGA gain	Non inverting gain value	-	-	2	-	-
			-	4	-	-
			-	8	-	-
			-	16	-	-
R_{network}	R2/R1 internal resistance values in PGA mode ⁽²⁾	Gain=2	-	5.4/5.4	-	k Ω
		Gain=4	-	16.2/5.4	-	
		Gain=8	-	37.8/5.4	-	
		Gain=16	-	40.5/2.7	-	
PGA gain error	PGA gain error	-	-1%	-	1%	
I_{bias}	OPAMP input bias current	-	-	-	$\pm 0.2^{(3)}$	μA
PGA BW	PGA bandwidth for different non inverting gain	PGA Gain = 2, $C_{\text{load}} = 50\text{pF}$, $R_{\text{load}} = 4\text{K}\Omega$	-	4	-	MHz
		PGA Gain = 4, $C_{\text{load}} = 50\text{pF}$, $R_{\text{load}} = 4\text{K}\Omega$	-	2	-	
		PGA Gain = 8, $C_{\text{load}} = 50\text{pF}$, $R_{\text{load}} = 4\text{K}\Omega$	-	1	-	
		PGA Gain = 16, $C_{\text{load}} = 50\text{pF}$, $R_{\text{load}} = 4\text{K}\Omega$	-	0.5	-	
e_n	Voltage noise density	@ 1KHz, Output loaded with 4 K Ω	-	109	-	$\frac{nV}{\sqrt{Hz}}$
		@ 10KHz, Output loaded with 4 K Ω	-	43	-	

1. Guaranteed by design, not tested in production.
2. R2 is the internal resistance between OPAMP output and OPAMP inverting input.
R1 is the internal resistance between OPAMP inverting input and ground.
The PGA gain = $1 + R2/R1$
3. Mostly TTa I/O leakage, when used in analog mode.

Figure 28. OPAMP Voltage Noise versus Frequency



6.3.22 Temperature sensor (TS) characteristics

Table 64. Temperature sensor (TS) characteristics

Symbol	Parameter	Min.	Typ.	Max.	Unit
$T_L^{(1)}$	V_{SENSE} linearity with temperature	-	± 1	± 2	°C
Avg_Slope ⁽¹⁾	Average slope	4.0	4.3	4.6	mV/°C
V_{25}	Voltage at 25 °C	1.34	1.43	1.52	V
$t_{START}^{(1)}$	Startup time	4	-	10	μs
$T_{S_temp}^{(1)(2)}$	ADC sampling time when reading the temperature	2.2	-	-	μs

1. Guaranteed by design, not tested in production.

2. Shortest sampling time can be determined in the application by multiple iterations.

Table 65. Temperature sensor (TS) calibration values

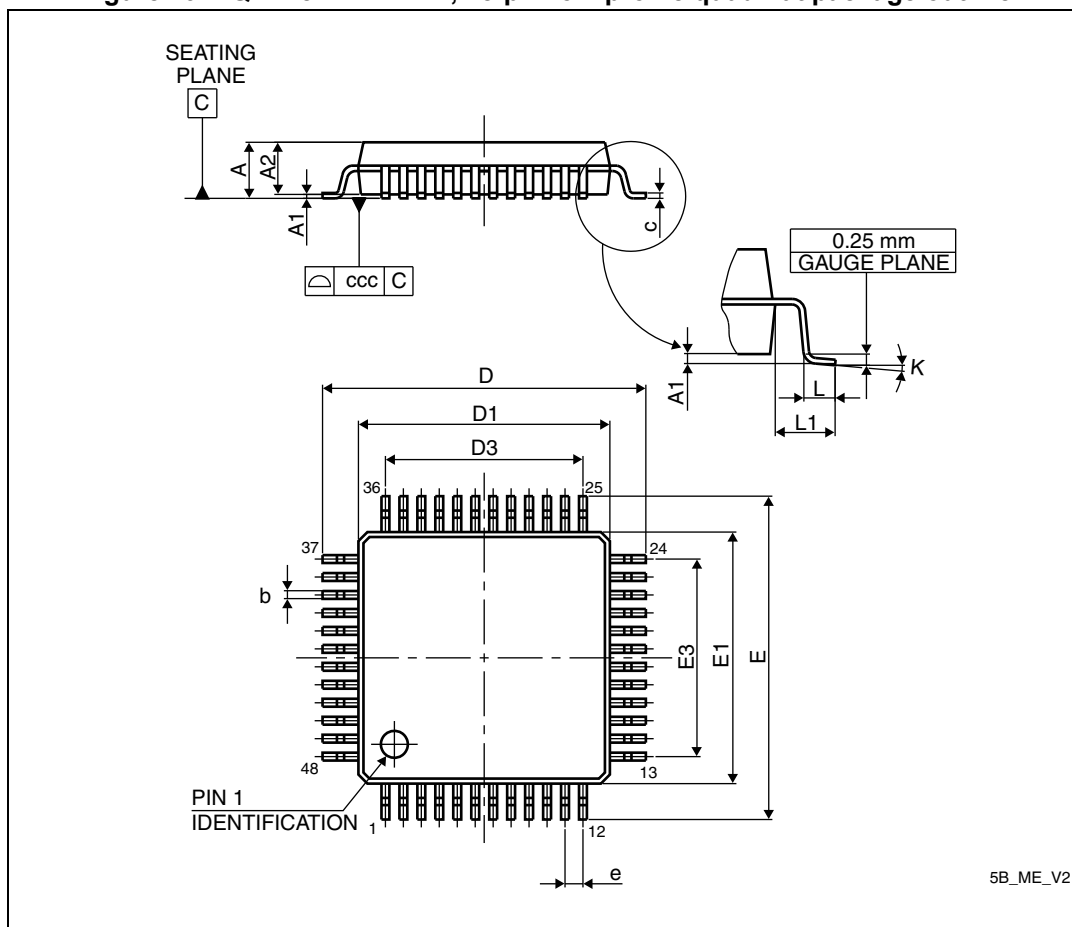
Calibration value name	Description	Memory address
TS_CAL1	TS ADC raw data acquired at temperature of 30 °C, $V_{DDA} = 3.3$ V	0x1FFF F7B8 - 0x1FFF F7B9
TS_CAL2	TS ADC raw data acquired at temperature of 110 °C $V_{DDA} = 3.3$ V	0x1FFF F7C2 - 0x1FFF F7C3

7 Package characteristics

7.1 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK[®] packages, depending on their level of environmental compliance. ECOPACK[®] specifications, grade definitions and product status are available at: www.st.com. ECOPACK[®] is an ST trademark.

Figure 29. LQFP48 – 7 x 7mm, 48-pin low-profile quad flat package outline



1. Drawing is not to scale.

Table 66. LQFP48 – 7 x 7 mm, 48-pin low-profile quad flat package mechanical data

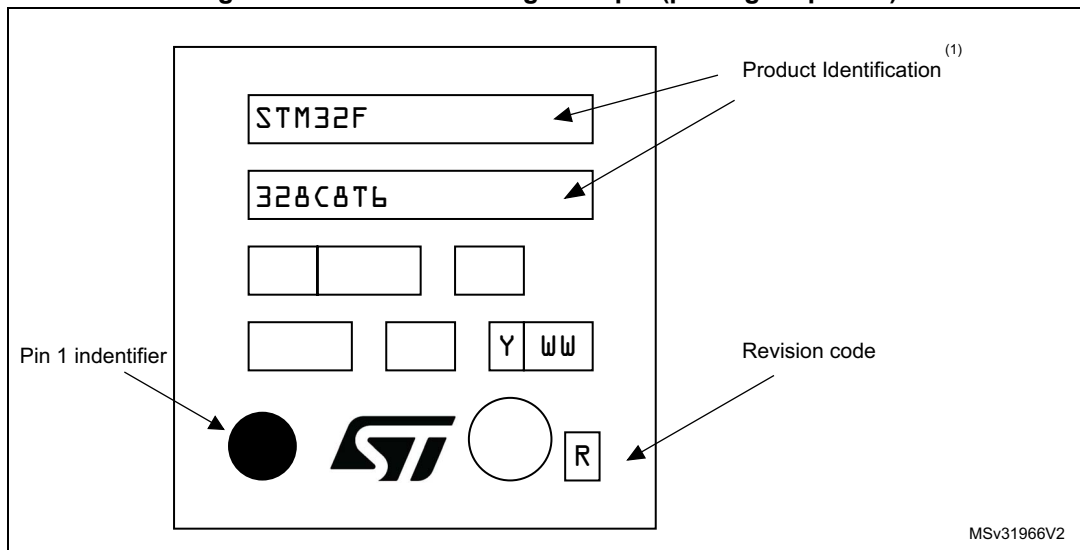
Symbol	millimeters			inches ⁽¹⁾		
	Min	Typ	Max	Min	Typ	Max
A	-	-	1.600	-	-	0.0630
A1	0.050	-	0.150	0.0020	-	0.0059
A2	1.350	1.400	1.450	0.0531	0.0551	0.0571
b	0.170	0.220	0.270	0.0067	0.0087	0.0106
c	0.090	-	0.200	0.0035	-	0.0079
D	8.800	9.000	9.200	0.3465	0.3543	0.3622
D1	6.800	7.000	7.200	0.2677	0.2756	0.2835
D3	-	5.500	-	-	0.2165	-
E	8.800	9.000	9.200	0.3465	0.3543	0.3622
E1	6.800	7.000	7.200	0.2677	0.2756	0.2835
E3	-	5.500	-	-	0.2165	-

Symbol	millimeters			inches ⁽¹⁾		
	Min	Typ	Max	Min	Typ	Max
e	-	0.500	-	-	0.0197	-
L	0.450	0.600	0.750	0.0177	0.0236	0.0295
L1	-	1.000	-		0.0394	-
k	0°	3.5°	7°	0°	3.5°	7°
ccc	-	-	0.080	-	-	0.0031

Figure 10: Plan view of the recommended layout. The diagram shows a rectangular layout with dimensions 9.70 by 9.70. It features four groups of rectangular elements arranged in a cross pattern. The top group has 36 elements, the bottom group has 12 elements, the left group has 48 elements, and the right group has 24 elements. Various spacing dimensions are indicated: 0.50, 1.20, 0.30, 0.20, 5.80, 7.30, and 9.70.

Marking of engineering samples

Figure 31. LQFP48 marking example (package top view)



1. Parts marked as "ES", "E" or accompanied by an Engineering Sample notification letter, are not yet qualified and therefore not yet ready to be used in production and any consequences deriving from such usage will not be at ST charge. In no event, ST will be liable for any customer usage of these engineering samples in production. ST Quality has to be contacted prior to any decision to use these Engineering samples to run qualification activity.

7.2 Thermal characteristics

The maximum chip-junction temperature, $T_J \text{ max}$, in degrees Celsius, may be calculated using the following equation:

$$T_J \text{ max} = T_A \text{ max} + (P_D \text{ max} \times \Theta_{JA})$$

Where:

- $T_A \text{ max}$ is the maximum ambient temperature in °C,
- Θ_{JA} is the package junction-to-ambient thermal resistance, in °C/W,
- $P_D \text{ max}$ is the sum of $P_{INT} \text{ max}$ and $P_{I/O} \text{ max}$ ($P_D \text{ max} = P_{INT} \text{ max} + P_{I/O} \text{ max}$),
- $P_{INT} \text{ max}$ is the product of I_{DD} and V_{DD} , expressed in Watts. This is the maximum chip internal power.

$P_{I/O} \text{ max}$ represents the maximum power dissipation on output pins where:

$$P_{I/O} \text{ max} = \Sigma (V_{OL} \times I_{OL}) + \Sigma ((V_{DD} - V_{OH}) \times I_{OH}),$$

taking into account the actual V_{OL} / I_{OL} and V_{OH} / I_{OH} of the I/Os at low and high level in the application.

Table 67. Package thermal characteristics

Symbol	Parameter	Value	Unit
Θ_{JA}	Thermal resistance junction-ambient LQFP48 - 7 × 7 mm / 0.5 mm pitch	55°C/W	°C/W

7.2.1 Reference document

JESD51-2 Integrated Circuits Thermal Test Method Environment Conditions - Natural Convection (Still Air). Available from www.jedec.org.

7.2.2 Selecting the product temperature range

When ordering the microcontroller, the temperature range is specified in the ordering information scheme shown in [Table 68: Ordering information scheme](#).

Each temperature range suffix corresponds to a specific guaranteed ambient temperature at maximum dissipation and, to a specific maximum junction temperature.

As applications do not commonly use the STM32F328C8 at maximum dissipation, it is useful to calculate the exact power consumption and junction temperature to determine which temperature range will be best suited to the application.

The following examples show how to calculate the temperature range needed for a given application.

Example: high-performance application

Assuming the following application conditions:

Maximum ambient temperature $T_{Amax} = 82\text{ °C}$ (measured according to JESD51-2),
 $I_{DDmax} = 50\text{ mA}$, $V_{DD} = 3.5\text{ V}$, maximum 20 I/Os used at the same time in output at low level with $I_{OL} = 8\text{ mA}$, $V_{OL} = 0.4\text{ V}$ and maximum 2 I/Os used at the same time in output mode at low level with $I_{OL} = 20\text{ mA}$, $V_{OL} = 1.3\text{ V}$

$$P_{INTmax} = 50\text{ mA} \times 3.5\text{ V} = 175\text{ mW}$$

$$P_{IOmax} = 20 \times 8\text{ mA} \times 0.4\text{ V} + 2 \times 20\text{ mA} \times 1.3\text{ V} = 61.6\text{ mW}$$

$$\text{This gives: } P_{INTmax} = 175\text{ mW and } P_{IOmax} = 61.6\text{ mW}$$

$$P_{Dmax} = 175 + 61.6 = 236.6\text{ mW}$$

$$\text{Thus: } P_{Dmax} = 236.6\text{ mW}$$

Using the values obtained in [Table 67](#) T_{Jmax} is calculated as follows:

– For LQFP48, 55 °C/W

$$T_{Jmax} = 82\text{ °C} + (55\text{ °C/W} \times 236.6\text{ mW}) = 82\text{ °C} + 13.01\text{ °C} = 95.01\text{ °C}$$

This is within the range of the suffix 6 version parts ($-40 < T_J < 105\text{ °C}$).

In this case, parts must be ordered at least with the temperature range suffix 6 (see [Table 68: Ordering information scheme](#)).

8 Part numbering

Table 68. Ordering information scheme

Example:	STM32	F	328	C	8	T	6	xxx
Device family								
STM32 = ARM®-based 32-bit microcontroller								
Product type								
F = general-purpose								
Device subfamily								
328 = STM32F328xx								
Pin count								
C = 48								
Flash memory size								
8 = 64 Kbytes of Flash memory								
Package								
T = LQFP								
Temperature range								
6 = Industrial temperature range, –40 to 85 °C								
7 = Industrial temperature range, –40 to 105 °C								
Options								
xxx = programmed parts								
TR = tape and reel								

9 Revision history

Table 69. Document revision history

Date	Revision	Changes
28-May-2014	1	Initial release
08-Dec-2014	2	Updated: Table 12: STM32F328C8 pin definitions Table 51: TIMx characteristics Table 36: HSI oscillator characteristics Table 30: Peripheral current consumption Table 43: ESD absolute maximum ratings Table 44: Electrical sensitivities Table 45: I/O current injection susceptibility
30-Jan-2014	3	Updated: Figure 1: STM32F328C8 block diagram Table 34: HSE oscillator characteristics Table 39: Flash memory characteristics Added Figure 11: High-speed external clock source AC timing diagram

IMPORTANT NOTICE – PLEASE READ CAREFULLY

STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST's terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers' products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2015 STMicroelectronics – All rights reserved

