

18 Inter-integrated circuit (I2C) interface

18.1 I²C introduction

I²C (inter-integrated circuit) bus Interface serves as an interface between the microcontroller and the serial I²C bus. It provides multimaster capability, and controls all I²C bus-specific sequencing, protocol, arbitration and timing. It supports the standard mode (Sm, up to 100 kHz) and Fm mode (Fm, up to 400 kHz). The I2C bus frequency can be increased up to 1 MHz. For more details about the complete solution, please contact your local ST sales representative.

It may be used for a variety of purposes, including CRC generation and verification, SMBus (system management bus) and PMBus (power management bus).

18.2 I²C main features

- Parallel-bus/I²C protocol converter
- Multimaster capability: the same interface can act as Master or Slave
- I²C Master features:
 - Clock generation
 - Start and Stop generation
- I²C Slave features:
 - Programmable I²C Address detection
 - Dual Addressing Capability to acknowledge 2 slave addresses
 - Stop bit detection
- Generation and detection of 7-bit/10-bit addressing and General Call
- Supports different communication speeds:
 - Standard Speed (up to 100 kHz)
 - Fast Speed (up to 400 kHz)
 - The I2C bus frequency can be increased up to 1 MHz. For more details about the complete solution, please contact your local ST sales representative
- Analog noise filter
- Programmable digital noise filter
- Status flags:
 - Transmitter/Receiver mode flag
 - End-of-Byte transmission flag
 - I²C busy flag
- Error flags:
 - Arbitration lost condition for master mode
 - Acknowledgment failure after address/ data transmission
 - Detection of misplaced start or stop condition
 - Overrun/Underrun if clock stretching is disabled
- 2 Interrupt vectors:
 - 1 Interrupt for successful address/ data communication

- 1 Interrupt for error condition
- Optional clock stretching
- 1-byte buffer with DMA capability
- Configurable PEC (packet error checking) generation or verification:
 - PEC value can be transmitted as last byte in Tx mode
 - PEC error checking for last received byte
- SMBus 2.0 Compatibility:
 - 25 ms clock low timeout delay
 - 10 ms master cumulative clock low extend time
 - 25 ms slave cumulative clock low extend time
 - Hardware PEC generation/verification with ACK control
 - Address Resolution Protocol (ARP) supported
- PMBus Compatibility

Note: Some of the above features may not be available in certain products. The user should refer to the product data sheet, to identify the specific features supported by the I²C interface implementation.

18.3 I²C functional description

In addition to receiving and transmitting data, this interface converts it from serial to parallel format and vice versa. The interrupts are enabled or disabled by software. The interface is connected to the I²C bus by a data pin (SDA) and by a clock pin (SCL). It can be connected with a standard (up to 100 kHz) or fast (up to 400 kHz) I²C bus.

18.3.1 Mode selection

The interface can operate in one of the four following modes:

- Slave transmitter
- Slave receiver
- Master transmitter
- Master receiver

By default, it operates in slave mode. The interface automatically switches from slave to master, after it generates a START condition and from master to slave, if an arbitration loss or a Stop generation occurs, allowing multimaster capability.

Communication flow

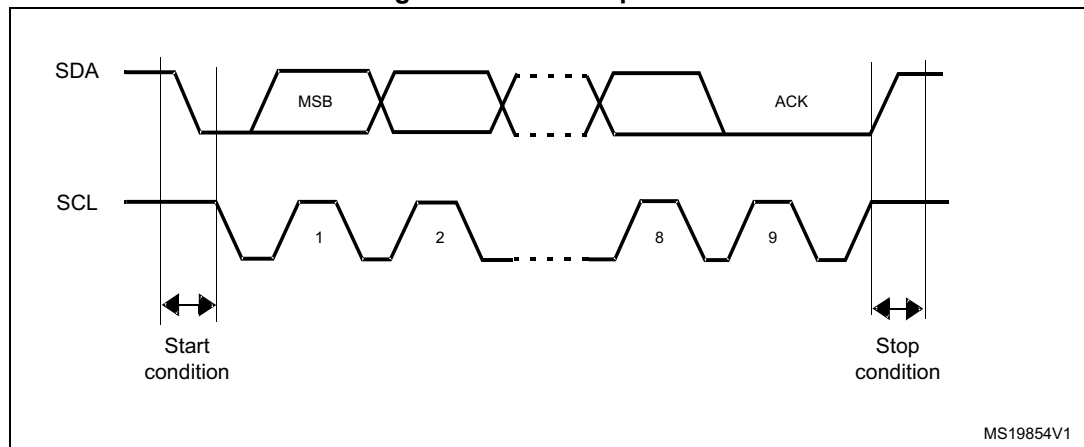
In Master mode, the I²C interface initiates a data transfer and generates the clock signal. A serial data transfer always begins with a start condition and ends with a stop condition. Both start and stop conditions are generated in master mode by software.

In Slave mode, the interface is capable of recognizing its own addresses (7 or 10-bit), and the General Call address. The General Call address detection may be enabled or disabled by software.

Data and addresses are transferred as 8-bit bytes, MSB first. The first byte(s) following the start condition contain the address (one in 7-bit mode, two in 10-bit mode). The address is always transmitted in Master mode.

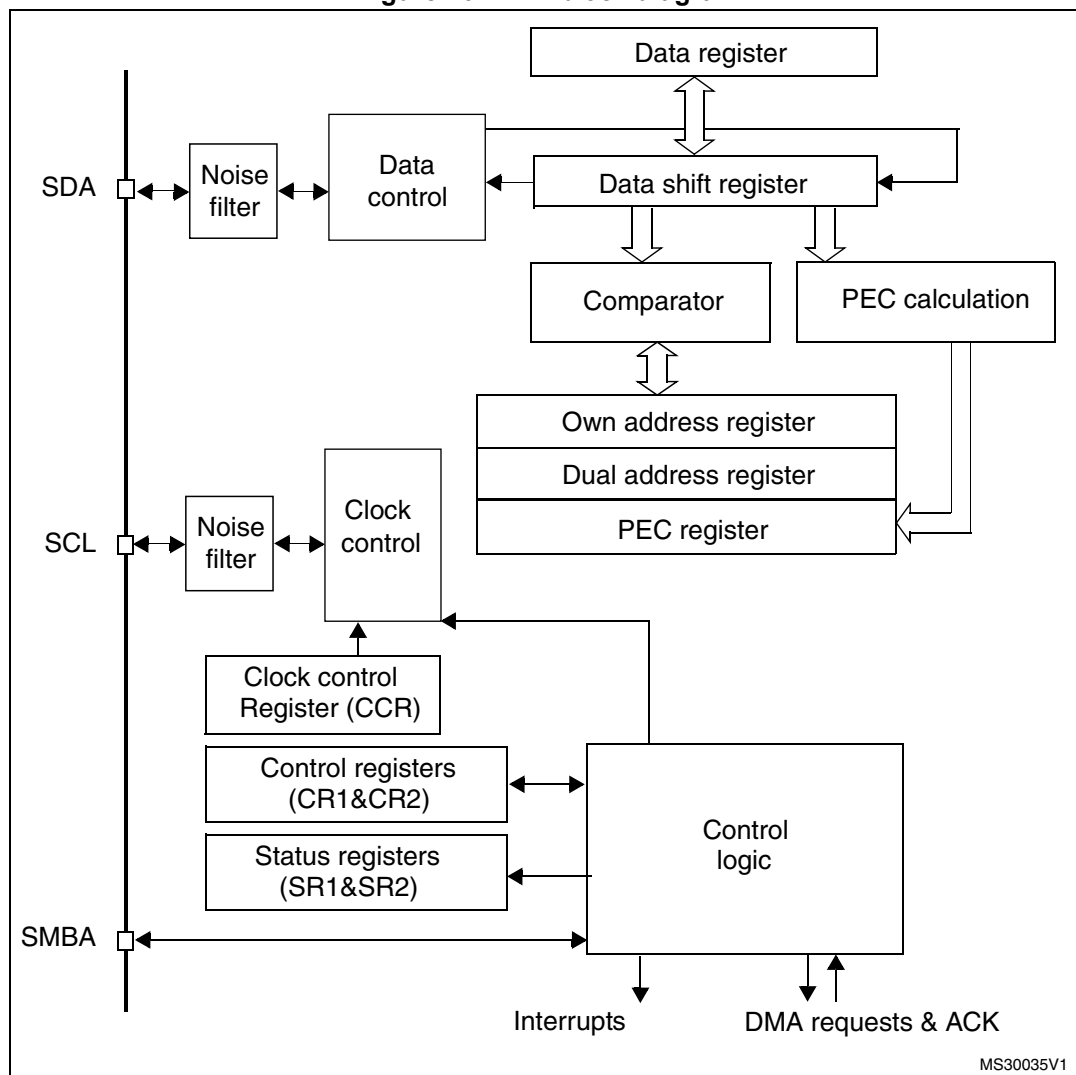
A 9th clock pulse follows the 8 clock cycles of a byte transfer, during which the receiver must send an acknowledge bit to the transmitter. Refer to [Figure 160](#).

Figure 160. I²C bus protocol



Acknowledge may be enabled or disabled by software. The I²C interface addresses (dual addressing 7-bit/ 10-bit and/or general call address) can be selected by software.

The block diagram of the I²C interface is shown in [Figure 161](#).

Figure 161. I²C block diagram

1. SMBA is an optional signal in SMBus mode. This signal is not applicable if SMBus is disabled.

18.3.2 I²C slave mode

By default the I²C interface operates in Slave mode. To switch from default Slave mode to Master mode a Start condition generation is needed.

The peripheral input clock must be programmed in the I2C_CR2 register in order to generate correct timings. The peripheral input clock frequency must be at least:

- 2 MHz in Sm mode
- 4 MHz in Fm mode

As soon as a start condition is detected, the address is received from the SDA line and sent to the shift register. Then it is compared with the address of the interface (OAR1) and with OAR2 (if ENDUAL=1) or the General Call address (if ENGCG = 1).

Note: In 10-bit addressing mode, the comparison includes the header sequence (11110xx0), where xx denotes the two most significant bits of the address.

Header or address not matched: the interface ignores it and waits for another Start condition.

Header matched (10-bit mode only): the interface generates an acknowledge pulse if the ACK bit is set and waits for the 8-bit slave address.

Address matched: the interface generates in sequence:

- An acknowledge pulse if the ACK bit is set
- The ADDR bit is set by hardware and an interrupt is generated if the ITEVFEN bit is set.
- If ENDUAL=1, the software has to read the DUALF bit to check which slave address has been acknowledged.

In 10-bit mode, after receiving the address sequence the slave is always in Receiver mode. It will enter Transmitter mode on receiving a repeated Start condition followed by the header sequence with matching address bits and the least significant bit set (11110xx1).

The TRA bit indicates whether the slave is in Receiver or Transmitter mode.

Slave transmitter

Following the address reception and after clearing ADDR, the slave sends bytes from the DR register to the SDA line via the internal shift register.

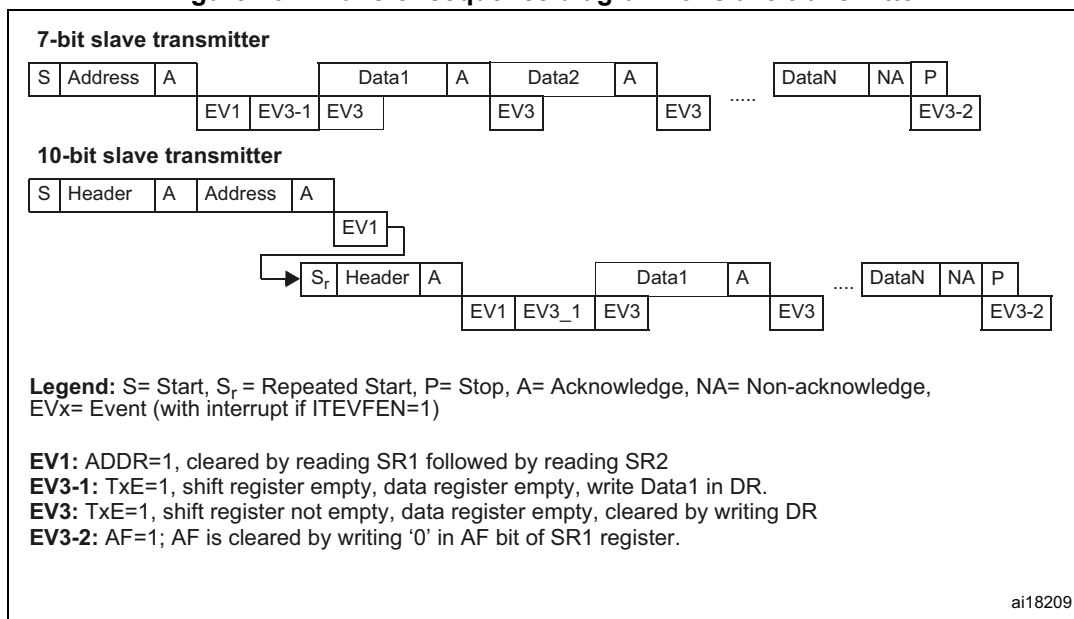
The slave stretches SCL low until ADDR is cleared and DR filled with the data to be sent (see [Figure 162](#) Transfer sequencing EV1 EV3).

When the acknowledge pulse is received:

- The TxE bit is set by hardware with an interrupt if the ITEVFEN and the ITBUFEN bits are set.

If TxE is set and some data were not written in the I2C_DR register before the end of the next data transmission, the BTF bit is set and the interface waits until BTF is cleared by a read to I2C_SR1 followed by a write to the I2C_DR register, stretching SCL low.

Figure 162. Transfer sequence diagram for slave transmitter



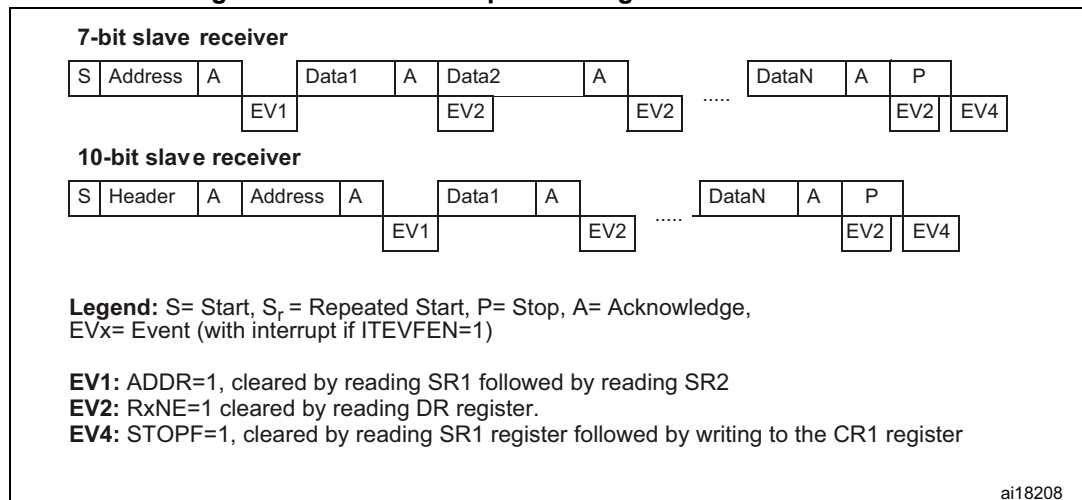
1. The EV1 and EV3_1 events stretch SCL low until the end of the corresponding software sequence.
2. The EV3 event stretches SCL low if the software sequence is not completed before the end of the next byte transmission.

Slave receiver

Following the address reception and after clearing ADDR, the slave receives bytes from the SDA line into the DR register via the internal shift register. After each byte the interface generates in sequence:

- An acknowledge pulse if the ACK bit is set
- The RxNE bit is set by hardware and an interrupt is generated if the ITEVFEN and ITBUFEN bit is set.

If RxNE is set and the data in the DR register is not read before the end of the next data reception, the BTF bit is set and the interface waits until BTF is cleared by a read from the I2C_DR register, stretching SCL low (see [Figure 163](#) Transfer sequencing).

Figure 163. Transfer sequence diagram for slave receiver

1. The EV1 event stretches SCL low until the end of the corresponding software sequence.
2. The EV2 event stretches SCL low if the software sequence is not completed before the end of the next byte reception.
3. After checking the SR1 register content, the user should perform the complete clearing sequence for each flag found set.
 Thus, for ADDR and STOPF flags, the following sequence is required inside the I2C interrupt routine:
 READ SR1
 if (ADDR == 1) {READ SR1; READ SR2}
 if (STOPF == 1) {READ SR1; WRITE CR1}
 The purpose is to make sure that both ADDR and STOPF flags are cleared if both are found set.

Closing slave communication

After the last data byte is transferred a Stop Condition is generated by the master. The interface detects this condition and sets:

- The STOPF bit and generates an interrupt if the ITEVFEN bit is set.

The STOPF bit is cleared by a read of the SR1 register followed by a write to the CR1 register (see EV4 in [Figure 163](#)).

18.3.3 I²C master mode

In Master mode, the I²C interface initiates a data transfer and generates the clock signal. A serial data transfer always begins with a Start condition and ends with a Stop condition. Master mode is selected as soon as the Start condition is generated on the bus with a START bit.

The following is the required sequence in master mode.

- Program the peripheral input clock in I2C_CR2 Register in order to generate correct timings
- Configure the clock control registers
- Configure the rise time register
- Program the I2C_CR1 register to enable the peripheral
- Set the START bit in the I2C_CR1 register to generate a Start condition

The peripheral input clock frequency must be at least:

- 2 MHz in Sm mode
- 4 MHz in Fm mode

SCL master clock generation

The CCR bits are used to generate the high and low level of the SCL clock, starting from the generation of the rising and falling edge (respectively). As a slave may stretch the SCL line, the peripheral checks the SCL input from the bus at the end of the time programmed in TRISE bits after rising edge generation.

- If the SCL line is low, it means that a slave is stretching the bus, and the high level counter stops until the SCL line is detected high. This allows to guarantee the minimum HIGH period of the SCL clock parameter.
- If the SCL line is high, the high level counter keeps on counting.

Indeed, the feedback loop from the SCL rising edge generation by the peripheral to the SCL rising edge detection by the peripheral takes time even if no slave stretches the clock. This loopback duration is linked to the SCL rising time (impacting SCL VIH input detection), plus delay due to the noise filter present on the SCL input path, plus delay due to internal SCL input synchronization with APB clock. The maximum time used by the feedback loop is programmed in the TRISE bits, so that the SCL frequency remains stable whatever the SCL rising time.

Start condition

Setting the START bit causes the interface to generate a Start condition and to switch to Master mode (MSL bit set) when the BUSY bit is cleared.

Note: In master mode, setting the START bit causes the interface to generate a ReStart condition at the end of the current byte transfer.

Once the Start condition is sent:

- The SB bit is set by hardware and an interrupt is generated if the ITEVFEN bit is set.

Then the master waits for a read of the SR1 register followed by a write in the DR register with the Slave address (see [Figure 164](#) and [Figure 165](#) Transfer sequencing EV5).

Slave address transmission

Then the slave address is sent to the SDA line via the internal shift register.

- In 10-bit addressing mode, sending the header sequence causes the following event:
 - The ADD10 bit is set by hardware and an interrupt is generated if the ITEVFEN bit is set.

Then the master waits for a read of the SR1 register followed by a write in the DR register with the second address byte (see [Figure 164](#) and [Figure 165](#) Transfer sequencing).

- The ADDR bit is set by hardware and an interrupt is generated if the ITEVFEN bit is set.

Then the master waits for a read of the SR1 register followed by a read of the SR2 register (see [Figure 164](#) and [Figure 165](#) Transfer sequencing).

- In 7-bit addressing mode, one address byte is sent.

As soon as the address byte is sent,

- The ADDR bit is set by hardware and an interrupt is generated if the ITEVFEN bit is set.

Then the master waits for a read of the SR1 register followed by a read of the SR2 register (see [Figure 164](#) and [Figure 165](#) Transfer sequencing).

The master can decide to enter Transmitter or Receiver mode depending on the LSB of the slave address sent.

- In 7-bit addressing mode,
 - To enter Transmitter mode, a master sends the slave address with LSB reset.
 - To enter Receiver mode, a master sends the slave address with LSB set.
- In 10-bit addressing mode,
 - To enter Transmitter mode, a master sends the header (11110xx0) and then the slave address, (where xx denotes the two most significant bits of the address).
 - To enter Receiver mode, a master sends the header (11110xx0) and then the slave address. Then it should send a repeated Start condition followed by the header (11110xx1), (where xx denotes the two most significant bits of the address).

The TRA bit indicates whether the master is in Receiver or Transmitter mode.

Master transmitter

Following the address transmission and after clearing ADDR, the master sends bytes from the DR register to the SDA line via the internal shift register.

The master waits until the first data byte is written into I2C_DR (see [Figure 164](#) Transfer sequencing EV8_1).

When the acknowledge pulse is received, the TxE bit is set by hardware and an interrupt is generated if the ITEVFEN and ITBUFEN bits are set.

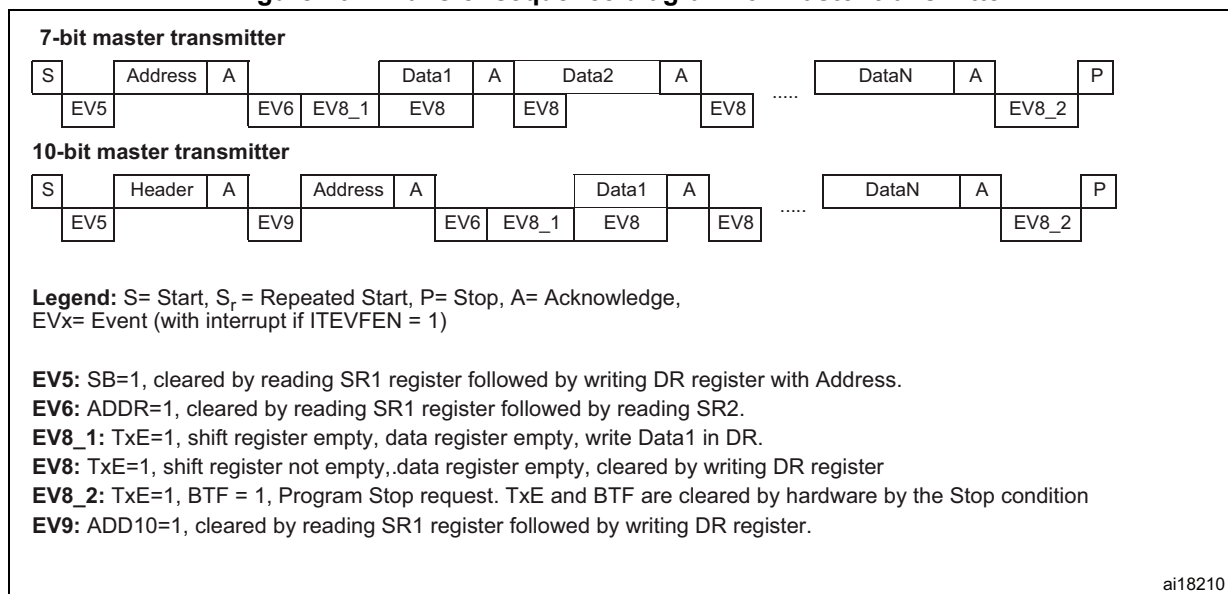
If TxE is set and a data byte was not written in the DR register before the end of the last data transmission, BTF is set and the interface waits until BTF is cleared by a write to I2C_DR, stretching SCL low.

Closing the communication

After the last byte is written to the DR register, the STOP bit is set by software to generate a Stop condition (see [Figure 164](#) Transfer sequencing EV8_2). The interface automatically goes back to slave mode (MSL bit cleared).

Note: Stop condition should be programmed during EV8_2 event, when either TxE or BTF is set.

Figure 164. Transfer sequence diagram for master transmitter



1. The EV5, EV6, EV9, EV8_1 and EV8_2 events stretch SCL low until the end of the corresponding software sequence.
2. The EV8 event stretches SCL low if the software sequence is not complete before the end of the next byte transmission.

Master receiver

Following the address transmission and after clearing ADDR, the I²C interface enters Master Receiver mode. In this mode the interface receives bytes from the SDA line into the DR register via the internal shift register. After each byte the interface generates in sequence:

1. An acknowledge pulse if the ACK bit is set
2. The RxNE bit is set and an interrupt is generated if the ITEVFEN and ITBUFEN bits are set (see [Figure 165](#) Transfer sequencing EV7).

If the RxNE bit is set and the data in the DR register is not read before the end of the last data reception, the BTF bit is set by hardware and the interface waits until BTF is cleared by a read in the DR register, stretching SCL low.

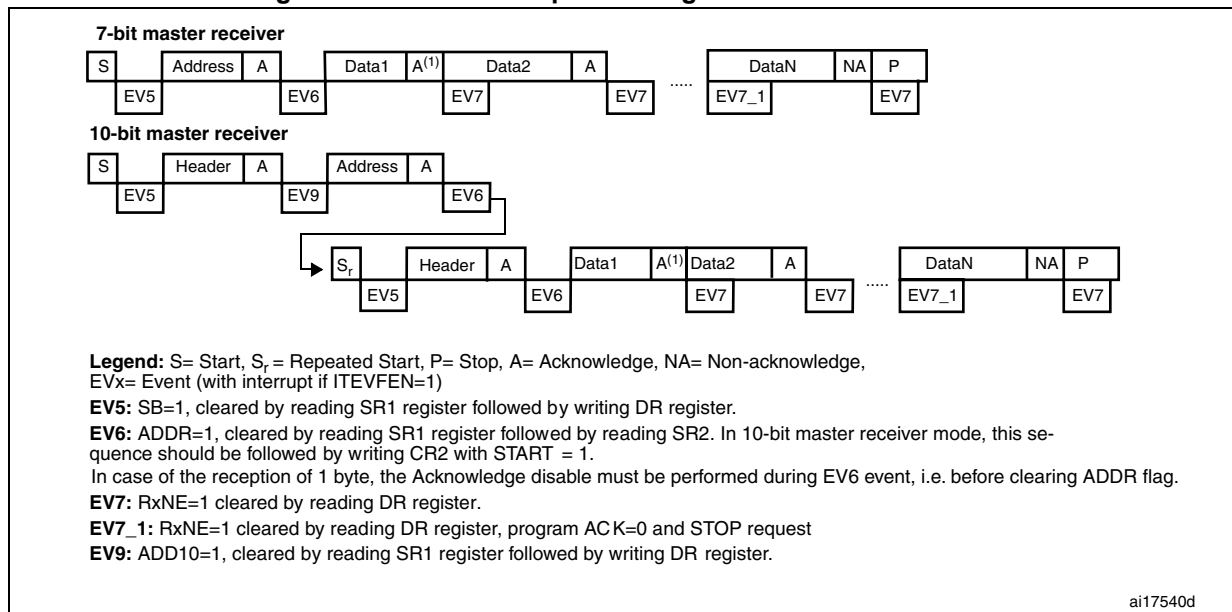
Closing the communication

The master sends a NACK for the last byte received from the slave. After receiving this NACK, the slave releases the control of the SCL and SDA lines. Then the master can send a Stop/Restart condition.

1. To generate the nonacknowledge pulse after the last received data byte, the ACK bit must be cleared just after reading the second last data byte (after second last RxNE event).
2. In order to generate the Stop/Restart condition, software must set the STOP/START bit after reading the second last data byte (after the second last RxNE event).
3. In case a single byte has to be received, the Acknowledge disable is made during EV6 (before ADDR flag is cleared) and the STOP condition generation is made after EV6.

After the Stop condition generation, the interface goes automatically back to slave mode (MSL bit cleared).

Figure 165. Transfer sequence diagram for master receiver



1. If a single byte is received, it is NA.
2. The EV5, EV6 and EV9 events stretch SCL low until the end of the corresponding software sequence.
3. The EV7 event stretches SCL low if the software sequence is not completed before the end of the next byte reception.
4. The EV7_1 software sequence must be completed before the ACK pulse of the current byte transfer.

The procedures described below are recommended if the EV7-1 software sequence is not completed before the ACK pulse of the current byte transfer.

These procedures must be followed to make sure:

- The ACK bit is set low on time before the end of the last data reception
- The STOP bit is set high after the last data reception without reception of supplementary data.

For 2-byte reception:

- Wait until ADDR = 1 (SCL stretched low until the ADDR flag is cleared)
- Set ACK low, set POS high
- Clear ADDR flag
- Wait until BTF = 1 (Data 1 in DR, Data2 in shift register, SCL stretched low until a data 1 is read)
- Set STOP high
- Read data 1 and 2

For N > 2 -byte reception, from N-2 data reception

- Wait until BTF = 1 (data N-2 in DR, data N-1 in shift register, SCL stretched low until data N-2 is read)
- Set ACK low
- Read data N-2
- Wait until BTF = 1 (data N-1 in DR, data N in shift register, SCL stretched low until a data N-1 is read)
- Set STOP high
- Read data N-1 and N

18.3.4 Error conditions

The following are the error conditions which may cause communication to fail.

Bus error (BERR)

This error occurs when the I²C interface detects an external Stop or Start condition during an address or a data transfer. In this case:

- the BERR bit is set and an interrupt is generated if the ITERREN bit is set
- in Slave mode: data are discarded and the lines are released by hardware:
 - in case of a misplaced Start, the slave considers it is a restart and waits for an address, or a Stop condition
 - in case of a misplaced Stop, the slave behaves like for a Stop condition and the lines are released by hardware
- In Master mode: the lines are not released and the state of the current transmission is not affected. It is up to the software to abort or not the current transmission

Acknowledge failure (AF)

This error occurs when the interface detects a nonacknowledge bit. In this case:

- the AF bit is set and an interrupt is generated if the ITERREN bit is set
- a transmitter which receives a NACK must reset the communication:
 - If Slave: lines are released by hardware
 - If Master: a Stop or repeated Start condition must be generated by software

Arbitration lost (ARLO)

This error occurs when the I²C interface detects an arbitration lost condition. In this case

- the ARLO bit is set by hardware (and an interrupt is generated if the ITERREN bit is set)
- the I²C Interface goes automatically back to slave mode (the MSL bit is cleared). When the I²C loses the arbitration, it is not able to acknowledge its slave address in the same transfer, but it can acknowledge it after a repeated Start from the winning master.
- lines are released by hardware

Overrun/underrun error (OVR)

An overrun error can occur in slave mode when clock stretching is disabled and the I²C interface is receiving data. The interface has received a byte (RxNE=1) and the data in DR has not been read, before the next byte is received by the interface. In this case,

- The last received byte is lost.
- In case of Overrun error, software should clear the RxNE bit and the transmitter should re-transmit the last received byte.

Underrun error can occur in slave mode when clock stretching is disabled and the I²C interface is transmitting data. The interface has not updated the DR with the next byte (TxNE=1), before the clock comes for the next byte. In this case,

- The same byte in the DR register will be sent again
- The user should make sure that data received on the receiver side during an underrun error are discarded and that the next bytes are written within the clock low time specified in the I²C bus standard.

For the first byte to be transmitted, the DR must be written after ADDR is cleared and before the first SCL rising edge. If not possible, the receiver must discard the first data.

18.3.5 Programmable noise filter

In Fm mode, the I²C standard requires that spikes are suppressed to a length of 50 ns on SDA and SCL lines.

An analog noise filter is implemented in the SDA and SCL I/Os. This filter is enabled by default and can be disabled by setting the ANOFF bit in the I2C_FLTR register.

A digital noise filter can be enabled by configuring the DNF[3:0] bits to a non-zero value. This suppresses the spikes on SDA and SCL inputs with a length of up to $DNF[3:0] * T_{PCLK1}$.

Enabling the digital noise filter increases the SDA hold time by $(DNF[3:0] + 1) * T_{PCLK1}$.

To be compliant with the maximum hold time of the I²C-bus specification version 2.1 (Thd:dat), the DNF bits must be programmed using the constraints shown in [Table 69](#), and assuming that the analog filter is disabled.

Note: *DNF[3:0] must only be configured when the I²C is disabled (PE = 0). If the analog filter is also enabled, the digital filter is added to the analog filter.*

Table 69. Maximum DNF[3:0] value to be compliant with Thd:dat(max)

PCLK1 frequency	Maximum DNF value	
	Sm mode	Fm mode
$2 \leq F_{PCLK1} \leq 5$	2	0
$5 < F_{PCLK1} \leq 10$	12	0
$10 < F_{PCLK1} \leq 20$	15	1
$20 < F_{PCLK1} \leq 30$	15	7
$30 < F_{PCLK1} \leq 40$	15	13
$40 < F_{PCLK1} \leq 50$	15	15

Note: For each frequency range, the constraint is given based on the worst case which is the minimum frequency of the range. Greater DNF values can be used if the system can support maximum hold time violation.

18.3.6 SDA/SCL line control

- If clock stretching is enabled:
 - Transmitter mode: If TxNE=1 and BTF=1: the interface holds the clock line low before transmission to wait for the microcontroller to write the byte in the Data Register (both buffer and shift register are empty).
 - Receiver mode: If RxNE=1 and BTF=1: the interface holds the clock line low after reception to wait for the microcontroller to read the byte in the Data Register (both buffer and shift register are full).
- If clock stretching is disabled in Slave mode:
 - Overrun Error in case of RxNE=1 and no read of DR has been done before the next byte is received. The last received byte is lost.
 - Underrun Error in case TxNE=1 and no write into DR has been done before the next byte must be transmitted. The same byte will be sent again.
 - Write Collision not managed.

18.3.7 SMBus

Introduction

The System Management Bus (SMBus) is a two-wire interface through which various devices can communicate with each other and with the rest of the system. It is based on I²C principles of operation. SMBus provides a control bus for system and power management related tasks. A system may use SMBus to pass messages to and from devices instead of toggling individual control lines.

The System Management Bus Specification refers to three types of devices. A *slave* is a device that is receiving or responding to a command. A *master* is a device that issues commands, generates the clocks, and terminates the transfer. A *host* is a specialized master that provides the main interface to the system's CPU. A host must be a master-slave and must support the SMBus host notify protocol. Only one host is allowed in a system.

Similarities between SMBus and I²C

- 2-wire bus protocol (1 Clk, 1 Data) + SMBus Alert line optional
- Master-slave communication, Master provides clock
- Multi master capability
- SMBus data format similar to I²C 7-bit addressing format ([Figure 160](#)).

Differences between SMBus and I²C

The following table describes the differences between SMBus and I²C.

Table 70. SMBus vs. I²C

SMBus	I ² C
Max. speed 100 kHz	Max. speed 400 kHz
Min. clock speed 10 kHz	No minimum clock speed
35 ms clock low timeout	No timeout
Logic levels are fixed	Logic levels are V _{DD} dependent
Different address types (reserved, dynamic etc.)	7-bit, 10-bit and general call slave address types
Different bus protocols (quick command, process call etc.)	No bus protocols

SMBus application usage

With System Management Bus, a device can provide manufacturer information, tell the system what its model/part number is, save its state for a suspend event, report different types of errors, accept control parameters, and return its status. SMBus provides a control bus for system and power management related tasks.

Device identification

Any device that exists on the System Management Bus as a slave has a unique address called the Slave Address. For the list of reserved slave addresses, refer to the SMBus specification version. 2.0 (<http://smbus.org/>).

Bus protocols

The SMBus specification supports up to nine bus protocols. For more details of these protocols and SMBus address types, refer to SMBus specification version. 2.0. These protocols should be implemented by the user software.

Address resolution protocol (ARP)

SMBus slave address conflicts can be resolved by dynamically assigning a new unique address to each slave device. The Address Resolution Protocol (ARP) has the following attributes:

- Address assignment uses the standard SMBus physical layer arbitration mechanism
- Assigned addresses remain constant while device power is applied; address retention through device power loss is also allowed
- No additional SMBus packet overhead is incurred after address assignment. (i.e. subsequent accesses to assigned slave addresses have the same overhead as accesses to fixed address devices.)
- Any SMBus master can enumerate the bus

Unique device identifier (UDID)

In order to provide a mechanism to isolate each device for the purpose of address assignment, each device must implement a unique device identifier (UDID).

For the details on 128-bit UDID and more information on ARP, refer to SMBus specification version 2.0.

SMBus alert mode

SMBus Alert is an optional signal with an interrupt line for devices that want to trade their ability to master for a pin. SMBA is a wired-AND signal just as the SCL and SDA signals are. SMBA is used in conjunction with the SMBus General Call Address. Messages invoked with the SMBus are two bytes long.

A slave-only device can signal the host through SMBA that it wants to talk by setting ALERT bit in I2C_CR1 register. The host processes the interrupt and simultaneously accesses all SMBA devices through the *Alert Response Address* (known as ARA having a value 0001 100X). Only the device(s) which pulled SMBA low will acknowledge the Alert Response Address. This status is identified using SMBALERT Status flag in I2C_SR1 register. The host performs a modified Receive Byte operation. The 7 bit device address provided by the slave transmit device is placed in the 7 most significant bits of the byte. The eighth bit can be a zero or one.

If more than one device pulls SMBA low, the highest priority (lowest address) device will win communication rights via standard arbitration during the slave address transfer. After acknowledging the slave address the device must disengage its SMBA pull-down. If the host still sees SMBA low when the message transfer is complete, it knows to read the ARA again.

A host which does not implement the SMBA signal may periodically access the ARA.

For more details on SMBus Alert mode, refer to SMBus specification version 2.0.

Timeout error

There are differences in the timing specifications between I²C and SMBus. SMBus defines a clock low timeout, TIMEOUT of 35 ms. Also SMBus specifies TLOW: SEXT as the cumulative clock low extend time for a slave device. SMBus specifies TLOW: MEXT as the cumulative clock low extend time for a master device. For more details on these timeouts, refer to SMBus specification version 2.0.

The status flag Timeout or Tlow Error in I2C_SR1 shows the status of this feature.

How to use the interface in SMBus mode

To switch from I²C mode to SMBus mode, the following sequence should be performed.

- Set the SMBus bit in the I2C_CR1 register
- Configure the SMBTYPE and ENARP bits in the I2C_CR1 register as required for the application

If you want to configure the device as a master, follow the Start condition generation procedure in [Section 18.3.3](#). Otherwise, follow the sequence in [Section 18.3.2](#).

The application has to control the various SMBus protocols by software.

- SMB Device Default Address acknowledged if ENARP=1 and SMBTYPE=0
- SMB Host Header acknowledged if ENARP=1 and SMBTYPE=1
- SMB Alert Response Address acknowledged if SMBALERT=1

18.3.8 DMA requests

DMA requests (when enabled) are generated only for data transfer. DMA requests are generated by Data Register becoming empty in transmission and Data Register becoming full in reception. The DMA must be initialized and enabled before the I2C data transfer. The DMAEN bit must be set in the I2C_CR2 register before the ADDR event. In master mode or in slave mode when clock stretching is enabled, the DMAEN bit can also be set during the ADDR event, before clearing the ADDR flag. The DMA request must be served before the end of the current byte transfer. When the number of data transfers which has been programmed for the corresponding DMA stream is reached, the DMA controller sends an End of Transfer EOT signal to the I²C interface and generates a Transfer Complete interrupt if enabled:

- Master transmitter: In the interrupt routine after the EOT interrupt, disable DMA requests then wait for a BTF event before programming the Stop condition.
- Master receiver
 - When the number of bytes to be received is equal to or greater than two, the DMA controller sends a hardware signal, EOT_1, corresponding to the last but one data byte (number_of_bytes – 1). If, in the I2C_CR2 register, the LAST bit is set, I²C automatically sends a NACK after the next byte following EOT_1. The user can generate a Stop condition in the DMA Transfer Complete interrupt routine if enabled.
 - When a single byte must be received: the NACK must be programmed during EV6 event, i.e. program ACK=0 when ADDR=1, before clearing ADDR flag. Then the user can program the STOP condition either after clearing ADDR flag, or in the DMA Transfer Complete interrupt routine.

Transmission using DMA

DMA mode can be enabled for transmission by setting the DMAEN bit in the I2C_CR2 register. Data will be loaded from a Memory area configured using the DMA peripheral (refer to the DMA specification) to the I2C_DR register whenever the TxE bit is set. To map a DMA stream x for I²C transmission (where x is the stream number), perform the following sequence:

1. Set the I2C_DR register address in the DMA_SxPAR register. The data will be moved to this address from the memory after each TxE event.
2. Set the memory address in the DMA_SxMA0R register (and in DMA_SxMA1R register in the case of a double buffer mode). The data will be loaded into I2C_DR from this memory after each TxE event.
3. Configure the total number of bytes to be transferred in the DMA_SxNDTR register. After each TxE event, this value will be decremented.
4. Configure the DMA stream priority using the PL[0:1] bits in the DMA_SxCR register.
5. Set the DIR bit in the DMA_SxCR register and configure interrupts after half transfer or full transfer depending on application requirements.
6. Activate the stream by setting the EN bit in the DMA_SxCR register.

When the number of data transfers which has been programmed in the DMA Controller registers is reached, the DMA controller sends an End of Transfer EOT/ EOT_1 signal to the I²C interface and the DMA generates an interrupt, if enabled, on the DMA stream interrupt vector.

Note: Do not enable the ITBUFEN bit in the I2C_CR2 register if DMA is used for transmission.

Reception using DMA

DMA mode can be enabled for reception by setting the DMAEN bit in the I2C_CR2 register. Data will be loaded from the I2C_DR register to a Memory area configured using the DMA peripheral (refer to the DMA specification) whenever a data byte is received. To map a DMA stream x for I²C reception (where x is the stream number), perform the following sequence:

1. Set the I2C_DR register address in DMA_SxPAR register. The data will be moved from this address to the memory after each RxNE event.
2. Set the memory address in the DMA_SxMA0R register (and in DMA_SxMA1R register in the case of a double buffer mode). The data will be loaded from the I2C_DR register to this memory area after each RxNE event.
3. Configure the total number of bytes to be transferred in the DMA_SxNDTR register. After each RxNE event, this value will be decremented.
4. Configure the stream priority using the PL[0:1] bits in the DMA_SxCR register
5. Reset the DIR bit and configure interrupts in the DMA_SxCR register after half transfer or full transfer depending on application requirements.
6. Activate the stream by setting the EN bit in the DMA_SxCR register.

When the number of data transfers which has been programmed in the DMA Controller registers is reached, the DMA controller sends an End of Transfer EOT/ EOT_1 signal to the I²C interface and DMA generates an interrupt, if enabled, on the DMA stream interrupt vector.

Note: Do not enable the ITBUFEN bit in the I2C_CR2 register if DMA is used for reception.

18.3.9 Packet error checking

A PEC calculator has been implemented to improve the reliability of communication. The PEC is calculated by using the $C(x) = x^8 + x^2 + x + 1$ CRC-8 polynomial serially on each bit.

- PEC calculation is enabled by setting the ENPEC bit in the I2C_CR1 register. PEC is a CRC-8 calculated on all message bytes including addresses and R/W bits.
 - In transmission: set the PEC transfer bit in the I2C_CR1 register after the TxE event corresponding to the last byte. The PEC will be transferred after the last transmitted byte.
 - In reception: set the PEC bit in the I2C_CR1 register after the RxNE event corresponding to the last byte so that the receiver sends a NACK if the next received byte is not equal to the internally calculated PEC. In case of Master-Receiver, a NACK must follow the PEC whatever the check result. The PEC must

be set before the ACK of the CRC reception in slave mode. It must be set when the ACK is set low in master mode.

- A PECERR error flag/interrupt is also available in the I2C_SR1 register.
- If DMA and PEC calculation are both enabled:-
 - In transmission: when the I²C interface receives an EOT signal from the DMA controller, it automatically sends a PEC after the last byte.
 - In reception: when the I²C interface receives an EOT_1 signal from the DMA controller, it will automatically consider the next byte as a PEC and will check it. A DMA request is generated after PEC reception.
- To allow intermediate PEC transfers, a control bit is available in the I2C_CR2 register (LAST bit) to determine if it is really the last DMA transfer or not. If it is the last DMA request for a master receiver, a NACK is automatically sent after the last received byte.
- PEC calculation is corrupted by an arbitration loss.

18.4 I²C interrupts

The table below gives the list of I²C interrupt requests.

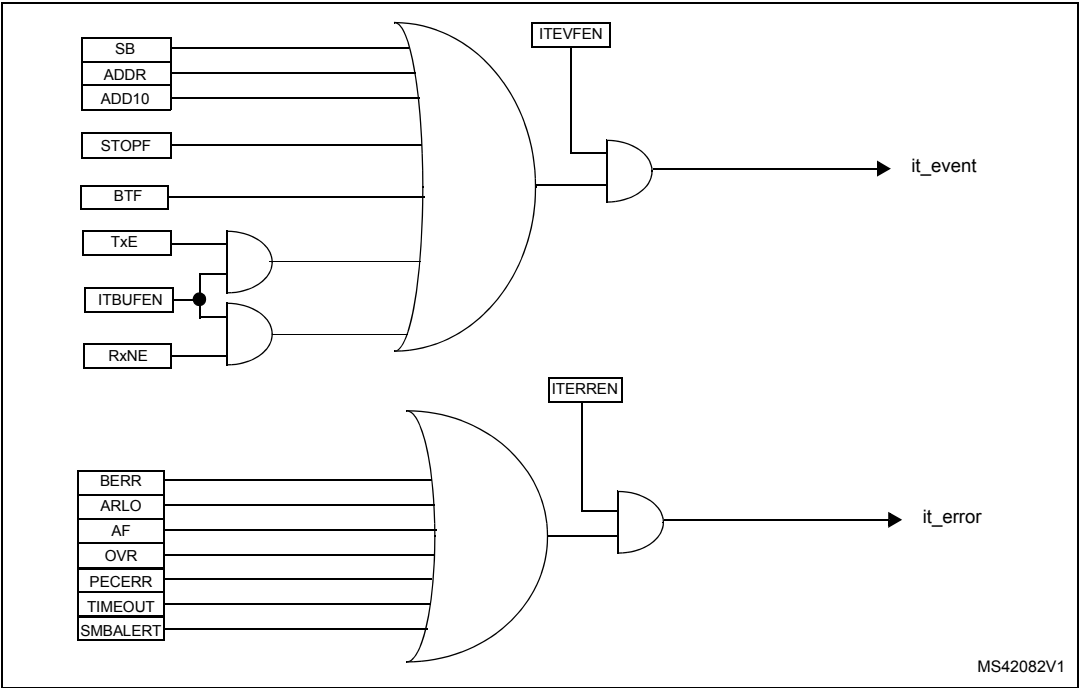
Table 71. I²C Interrupt requests

Interrupt event	Event flag	Enable control bit
Start bit sent (Master)	SB	ITEVFEN
Address sent (Master) or Address matched (Slave)	ADDR	
10-bit header sent (Master)	ADD10	
Stop received (Slave)	STOPF	
Data byte transfer finished	BTF	
Receive buffer not empty	RxNE	ITEVFEN and ITBUFEN
Transmit buffer empty	TxE	
Bus error	BERR	ITERREN
Arbitration loss (Master)	ARLO	
Acknowledge failure	AF	
Overrun/Underrun	OVR	
PEC error	PECERR	
Timeout/Tlow error	TIMEOUT	
SMBus Alert	SMBALERT	

Note: *SB, ADDR, ADD10, STOPF, BTF, RxNE and TxE are logically OR-ed on the same interrupt channel.*

BERR, ARLO, AF, OVR, PECERR, TIMEOUT and SMBALERT are logically OR-ed on the same interrupt channel.

Figure 166. I²C interrupt mapping diagram



18.5 I²C debug mode

When the microcontroller enters the debug mode (Cortex[®]-M4 with FPU core halted), the SMBUS timeout either continues to work normally or stops, depending on the DBG_I2Cx_SMBUS_TIMEOUT configuration bits in the DBG module. For more details, refer to [Section 23.16.2: Debug support for timers, watchdog and I2C](#).

18.6 I²C registers

Refer to [Section 2.2 on page 45](#) for a list of abbreviations used in register descriptions.

The peripheral registers have to be accessed by half-words (16 bits) or words (32 bits).

18.6.1 I²C Control register 1 (I2C_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SWRST	Res.	ALERT	PEC	POS	ACK	STOP	START	NO STRETCH	ENG	ENPEC	ENARP	SMB TYPE	Res.	SMBUS	PE
rw		rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw		rw	rw

Bit 15 **SWRST**: Software reset

When set, the I2C is under reset state. Before resetting this bit, make sure the I2C lines are released and the bus is free.

0: I²C Peripheral not under reset

1: I²C Peripheral under reset state

Note: This bit can be used to reinitialize the peripheral after an error or a locked state. As an example, if the BUSY bit is set and remains locked due to a glitch on the bus, the SWRST bit can be used to exit from this state.

Bit 14 Reserved, must be kept at reset value

Bit 13 **ALERT**: SMBus alert

This bit is set and cleared by software, and cleared by hardware when PE=0.

0: Releases SMBA pin high. Alert Response Address Header followed by NACK.

1: Drives SMBA pin low. Alert Response Address Header followed by ACK.

Bit 12 **PEC**: Packet error checking

This bit is set and cleared by software, and cleared by hardware when PEC is transferred or by a START or Stop condition or when PE=0.

0: No PEC transfer

1: PEC transfer (in Tx or Rx mode)

Note: PEC calculation is corrupted by an arbitration loss.

Bit 11 **POS**: Acknowledge/PEC Position (for data reception)

This bit is set and cleared by software and cleared by hardware when PE=0.

0: ACK bit controls the (N)ACK of the current byte being received in the shift register. The PEC bit indicates that current byte in shift register is a PEC.

1: ACK bit controls the (N)ACK of the next byte which will be received in the shift register. The PEC bit indicates that the next byte in the shift register is a PEC

Note: The POS bit must be used only in 2-byte reception configuration in master mode. It must be configured before data reception starts, as described in the 2-byte reception procedure recommended in [Section : Master receiver on page 482](#).

Bit 10 **ACK**: Acknowledge enable

This bit is set and cleared by software and cleared by hardware when PE=0.

0: No acknowledge returned

1: Acknowledge returned after a byte is received (matched address or data)

Bit 9 **STOP**: Stop generation

The bit is set and cleared by software, cleared by hardware when a Stop condition is detected, set by hardware when a timeout error is detected.

In Master Mode:

0: No Stop generation.

1: Stop generation after the current byte transfer or after the current Start condition is sent.

In Slave mode:

0: No Stop generation.

1: Release the SCL and SDA lines after the current byte transfer.

Bit 8 **START**: Start generation

This bit is set and cleared by software and cleared by hardware when start is sent or PE=0.

In Master Mode:

0: No Start generation

1: Repeated start generation

In Slave mode:

0: No Start generation

1: Start generation when the bus is free

Bit 7 **NOSTRETCH**: Clock stretching disable (Slave mode)

This bit is used to disable clock stretching in slave mode when ADDR or BTF flag is set, until it is reset by software.

0: Clock stretching enabled

1: Clock stretching disabled

Bit 6 **ENGCG**: General call enable

0: General call disabled. Address 00h is NACKed.

1: General call enabled. Address 00h is ACKed.

Bit 5 **ENPEC**: PEC enable

0: PEC calculation disabled

1: PEC calculation enabled

Bit 4 **ENARP**: ARP enable

0: ARP disable

1: ARP enable

SMBus Device default address recognized if SMBTYPE=0

SMBus Host address recognized if SMBTYPE=1

Bit 3 **SMBTYPE**: SMBus type

0: SMBus Device

1: SMBus Host

Bit 2 Reserved, must be kept at reset value

Bit 1 **SMBUS**: SMBus mode

0: I²C mode

1: SMBus mode

Bit 0 **PE**: Peripheral enable

0: Peripheral disable

1: Peripheral enable

Note: If this bit is reset while a communication is on going, the peripheral is disabled at the end of the current communication, when back to IDLE state.

All bit resets due to PE=0 occur at the end of the communication.

In master mode, this bit must not be reset before the end of the communication.

Note: When the STOP, START or PEC bit is set, the software must not perform any write access to I2C_CR1 before this bit is cleared by hardware. Otherwise there is a risk of setting a second STOP, START or PEC request.

18.6.2 I²C Control register 2 (I2C_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved			LAST	DMAEN	ITBUFEN	ITEVTEN	ITERREN	Reserved		FREQ[5:0]					
			rw	rw	rw	rw	rw			rw	rw	rw	rw	rw	rw

Bits 15:13 Reserved, must be kept at reset value

Bit 12 **LAST**: DMA last transfer

0: Next DMA EOT is not the last transfer

1: Next DMA EOT is the last transfer

Note: This bit is used in master receiver mode to permit the generation of a NACK on the last received data.

Bit 11 **DMAEN**: DMA requests enable

0: DMA requests disabled

1: DMA request enabled when TxNE=1 or RxNE =1

Bit 10 **ITBUFEN**: Buffer interrupt enable

0: TxNE = 1 or RxNE = 1 does not generate any interrupt.

1: TxNE = 1 or RxNE = 1 generates Event Interrupt (whatever the state of DMAEN)

Bit 9 **ITEVTEN**: Event interrupt enable

0: Event interrupt disabled

1: Event interrupt enabled

This interrupt is generated when:

- SB = 1 (Master)
- ADDR = 1 (Master/Slave)
- ADD10 = 1 (Master)
- STOPF = 1 (Slave)
- BTF = 1 with no TxE or RxNE event
- TxE event to 1 if ITBUFEN = 1
- RxNE event to 1 if ITBUFEN = 1

Bit 8 **ITERREN**: Error interrupt enable

0: Error interrupt disabled

1: Error interrupt enabled

This interrupt is generated when:

- BERR = 1
- ARLO = 1
- AF = 1
- OVR = 1
- PECERR = 1
- TIMEOUT = 1
- SMBALERT = 1

Bits 7:6 Reserved, must be kept at reset value

Bits 5:0 **FREQ[5:0]**: Peripheral clock frequency

The FREQ bits must be configured with the APB clock frequency value (I2C peripheral connected to APB). The FREQ field is used by the peripheral to generate data setup and hold times compliant with the I2C specifications. The minimum allowed frequency is 2 MHz, the maximum frequency is limited by the maximum APB1 frequency and cannot exceed 50 MHz (peripheral intrinsic maximum limit).

0b000000: Not allowed

0b000001: Not allowed

0b000010: 2 MHz

...

0b110010: 50 MHz

Higher than 0b100100: Not allowed

18.6.3 I²C Own address register 1 (I2C_OAR1)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADD MODE	Reserved					ADD[9:8]		ADD[7:1]							ADD0
rw						rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 **ADDMODE** Addressing mode (slave mode)

0: 7-bit slave address (10-bit address not acknowledged)

1: 10-bit slave address (7-bit address not acknowledged)

Bit 14 Should always be kept at 1 by software.

Bits 13:10 Reserved, must be kept at reset value

Bits 9:8 **ADD[9:8]**: Interface address

7-bit addressing mode: don't care

10-bit addressing mode: bits9:8 of address

Bits 7:1 **ADD[7:1]**: Interface address

bits 7:1 of address

Bit 0 **ADD0**: Interface address

7-bit addressing mode: don't care

10-bit addressing mode: bit 0 of address

18.6.4 I²C Own address register 2 (I2C_OAR2)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved								ADD2[7:1]							ENDUAL
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved, must be kept at reset value

Bits 7:1 **ADD2[7:1]**: Interface address

bits 7:1 of address in dual addressing mode

Bit 0 **ENDUAL**: Dual addressing mode enable

0: Only OAR1 is recognized in 7-bit addressing mode

1: Both OAR1 and OAR2 are recognized in 7-bit addressing mode

18.6.5 I²C Data register (I2C_DR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved								DR[7:0]							
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved, must be kept at reset value

Bits 7:0 **DR[7:0]** 8-bit data register

Byte received or to be transmitted to the bus.

- Transmitter mode: Byte transmission starts automatically when a byte is written in the DR register. A continuous transmit stream can be maintained if the next data to be transmitted is put in DR once the transmission is started (TxNE=1)
- Receiver mode: Received byte is copied into DR (RxNE=1). A continuous transmit stream can be maintained if DR is read before the next data byte is received (RxNE=1).

*Note: In slave mode, the address is not copied into DR.**Write collision is not managed (DR can be written if TxNE=0).**If an ARLO event occurs on ACK pulse, the received byte is not copied into DR and so cannot be read.*

18.6.6 I²C Status register 1 (I2C_SR1)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SMB ALERT	TIME OUT	Res.	PEC ERR	OVR	AF	ARLO	BERR	TxE	RxNE	Res.	STOPF	ADD10	BTF	ADDR	SB
rc_w0	rc_w0		rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	r	r		r	r	r	r	r

Bit 15 **SMBALERT**: SMBus alert

In SMBus host mode:

0: no SMBALERT

1: SMBALERT event occurred on pin

In SMBus slave mode:

0: no SMBALERT response address header

1: SMBALERT response address header to SMBALERT LOW received

- Cleared by software writing 0, or by hardware when PE=0.

Bit 14 **TIMEOUT**: Timeout or Tlow error

0: No timeout error

1: SCL remained LOW for 25 ms (Timeout)

or

Master cumulative clock low extend time more than 10 ms (Tlow:mext)

or

Slave cumulative clock low extend time more than 25 ms (Tlow:sext)

– When set in slave mode: slave resets the communication and lines are released by hardware

– When set in master mode: Stop condition sent by hardware

– Cleared by software writing 0, or by hardware when PE=0.

Note: This functionality is available only in SMBus mode.

Bit 13 Reserved, must be kept at reset value

Bit 12 **PECERR**: PEC Error in reception

0: no PEC error: receiver returns ACK after PEC reception (if ACK=1)

1: PEC error: receiver returns NACK after PEC reception (whatever ACK)

– Cleared by software writing 0, or by hardware when PE=0.

Note: When the received CRC is wrong, PECERR is not set in slave mode if the PEC control bit is not set before the end of the CRC reception. Nevertheless, reading the PEC value determines whether the received CRC is right or wrong.

Bit 11 **OVR**: Overrun/Underrun

0: No overrun/underrun

1: Overrun or underrun

– Set by hardware in slave mode when NOSTRETCH=1 and:

– In reception when a new byte is received (including ACK pulse) and the DR register has not been read yet. New received byte is lost.

– In transmission when a new byte should be sent and the DR register has not been written yet. The same byte is sent twice.

– Cleared by software writing 0, or by hardware when PE=0.

Note: If the DR write occurs very close to SCL rising edge, the sent data is unspecified and a hold timing error occurs

Bit 10 **AF**: Acknowledge failure

0: No acknowledge failure

1: Acknowledge failure

– Set by hardware when no acknowledge is returned.

– Cleared by software writing 0, or by hardware when PE=0.

Bit 9 **ARLO**: Arbitration lost (master mode)

0: No Arbitration Lost detected

1: Arbitration Lost detected

Set by hardware when the interface loses the arbitration of the bus to another master

– Cleared by software writing 0, or by hardware when PE=0.

After an ARLO event the interface switches back automatically to Slave mode (MSL=0).

Note: In SMBUS, the arbitration on the data in slave mode occurs only during the data phase, or the acknowledge transmission (not on the address acknowledge).

Bit 8 **BERR**: Bus error

- 0: No misplaced Start or Stop condition
- 1: Misplaced Start or Stop condition

- Set by hardware when the interface detects an SDA rising or falling edge while SCL is high, occurring in a non-valid position during a byte transfer.
- Cleared by software writing 0, or by hardware when PE=0.

Bit 7 **TxE**: Data register empty (transmitters)

- 0: Data register not empty
- 1: Data register empty

- Set when DR is empty in transmission. TxE is not set during address phase.
- Cleared by software writing to the DR register or by hardware after a start or a stop condition or when PE=0.

TxE is not set if either a NACK is received, or if next byte to be transmitted is PEC (PEC=1)

Note: TxE is not cleared by writing the first data being transmitted, or by writing data when BTF is set, as in both cases the data register is still empty.

Bit 6 **RxNE**: Data register not empty (receivers)

- 0: Data register empty
- 1: Data register not empty

- Set when data register is not empty in receiver mode. RxNE is not set during address phase.
- Cleared by software reading or writing the DR register or by hardware when PE=0.

RxNE is not set in case of ARLO event.

Note: RxNE is not cleared by reading data when BTF is set, as the data register is still full.

Bit 5 Reserved, must be kept at reset value

Bit 4 **STOPF**: Stop detection (slave mode)

- 0: No Stop condition detected
- 1: Stop condition detected

- Set by hardware when a Stop condition is detected on the bus by the slave after an acknowledge (if ACK=1).
- Cleared by software reading the SR1 register followed by a write in the CR1 register, or by hardware when PE=0

Note: The STOPF bit is not set after a NACK reception.

It is recommended to perform the complete clearing sequence (READ SR1 then WRITE CR1) after the STOPF is set. Refer to [Figure 163](#).

Bit 3 **ADD10**: 10-bit header sent (Master mode)

- 0: No ADD10 event occurred.
- 1: Master has sent first address byte (header).

- Set by hardware when the master has sent the first byte in 10-bit address mode.
- Cleared by software reading the SR1 register followed by a write in the DR register of the second address byte, or by hardware when PE=0.

Note: ADD10 bit is not set after a NACK reception

Bit 2 BTF: Byte transfer finished

0: Data byte transfer not done
1: Data byte transfer succeeded

- Set by hardware when NOSTRETCH=0 and:
- In reception when a new byte is received (including ACK pulse) and DR has not been read yet (RxNE=1).
- In transmission when a new byte should be sent and DR has not been written yet (TxE=1).
- Cleared by software by either a read or write in the DR register or by hardware after a start or a stop condition in transmission or when PE=0.

Note: The BTF bit is not set after a NACK reception

The BTF bit is not set if next byte to be transmitted is the PEC (TRA=1 in I2C_SR2 register and PEC=1 in I2C_CR1 register)

Bit 1 ADDR: Address sent (master mode)/matched (slave mode)

This bit is cleared by software reading SR1 register followed reading SR2, or by hardware when PE=0.

Address matched (Slave)

0: Address mismatched or not received.
1: Received address matched.

- Set by hardware as soon as the received slave address matched with the OAR registers content or a general call or a SMBus Device Default Address or SMBus Host or SMBus Alert is recognized. (when enabled depending on configuration).

Note: In slave mode, it is recommended to perform the complete clearing sequence (READ SR1 then READ SR2) after ADDR is set. Refer to [Figure 163](#).

Address sent (Master)

0: No end of address transmission
1: End of address transmission

- For 10-bit addressing, the bit is set after the ACK of the 2nd byte.
- For 7-bit addressing, the bit is set after the ACK of the byte.

Note: ADDR is not set after a NACK reception

Bit 0 SB: Start bit (Master mode)

0: No Start condition
1: Start condition generated.

- Set when a Start condition generated.
- Cleared by software by reading the SR1 register followed by writing the DR register, or by hardware when PE=0

18.6.7 I²C Status register 2 (I2C_SR2)

Address offset: 0x18

Reset value: 0x0000

Note: Reading I2C_SR2 after reading I2C_SR1 clears the ADDR flag, even if the ADDR flag was set after reading I2C_SR1. Consequently, I2C_SR2 must be read only when ADDR is found set in I2C_SR1 or when the STOPF bit is cleared.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PEC[7:0]								DUALF	SMB HOST	SMBDE FAULT	GEN CALL	Res.	TRA	BUSY	MSL
r	r	r	r	r	r	r	r	r	r	r	r		r	r	r

Bits 15:8 **PEC[7:0]** Packet error checking register

This register contains the internal PEC when ENPEC=1.

Bit 7 **DUALF**: Dual flag (Slave mode)

0: Received address matched with OAR1

1: Received address matched with OAR2

– Cleared by hardware after a Stop condition or repeated Start condition, or when PE=0.

Bit 6 **SMBHOST**: SMBus host header (Slave mode)

0: No SMBus Host address

1: SMBus Host address received when SMBTYPE=1 and ENARP=1.

– Cleared by hardware after a Stop condition or repeated Start condition, or when PE=0.

Bit 5 **SMBDEFAULT**: SMBus device default address (Slave mode)

0: No SMBus Device Default address

1: SMBus Device Default address received when ENARP=1

– Cleared by hardware after a Stop condition or repeated Start condition, or when PE=0.

Bit 4 **GENCALL**: General call address (Slave mode)

0: No General Call

1: General Call Address received when ENGC=1

– Cleared by hardware after a Stop condition or repeated Start condition, or when PE=0.

Bit 3 Reserved, must be kept at reset value

Bit 2 **TRA**: Transmitter/receiver

0: Data bytes received

1: Data bytes transmitted

This bit is set depending on the R/W bit of the address byte, at the end of total address phase.

It is also cleared by hardware after detection of Stop condition (STOPF=1), repeated Start condition, loss of bus arbitration (ARLO=1), or when PE=0.

Bit 1 **BUSY**: Bus busy

0: No communication on the bus

1: Communication ongoing on the bus

– Set by hardware on detection of SDA or SCL low

– cleared by hardware on detection of a Stop condition.

It indicates a communication in progress on the bus. This information is still updated when the interface is disabled (PE=0).

Bit 0 **MSL**: Master/slave

0: Slave Mode

1: Master Mode

– Set by hardware as soon as the interface is in Master mode (SB=1).

– Cleared by hardware after detecting a Stop condition on the bus or a loss of arbitration (ARLO=1), or by hardware when PE=0.

Note: Reading I2C_SR2 after reading I2C_SR1 clears the ADDR flag, even if the ADDR flag was set after reading I2C_SR1. Consequently, I2C_SR2 must be read only when ADDR is found set in I2C_SR1 or when the STOPF bit is cleared.

18.6.8 I²C Clock control register (I2C_CCR)

Address offset: 0x1C

Reset value: 0x0000

Note: f_{PCLK1} must be at least 2 MHz to achieve Sm mode I²C frequencies. It must be at least 4 MHz to achieve Fm mode I²C frequencies. It must be a multiple of 10MHz to reach the 400 kHz maximum I²C Fm mode clock.

The CCR register must be configured only when the I2C is disabled (PE = 0).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
F/S	DUTY	Reserved		CCR[11:0]											
r/w	r/w			r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Bit 15 **F/S**: I2C master mode selection

0: Sm mode I2C

1: Fm mode I2C

Bit 14 **DUTY**: Fm mode duty cycle

0: Fm mode $t_{low}/t_{high} = 2$

1: Fm mode $t_{low}/t_{high} = 16/9$ (see CCR)

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

Bits 11:0 **CCR[11:0]**: Clock control register in Fm/Sm mode (Master mode)

Controls the SCL clock in master mode.

Sm mode or SMBus:

$$T_{high} = CCR * T_{PCLK1}$$

$$T_{low} = CCR * T_{PCLK1}$$

Fm mode:

If DUTY = 0:

$$T_{high} = CCR * T_{PCLK1}$$

$$T_{low} = 2 * CCR * T_{PCLK1}$$

If DUTY = 1: (to reach 400 kHz)

$$T_{high} = 9 * CCR * T_{PCLK1}$$

$$T_{low} = 16 * CCR * T_{PCLK1}$$

For instance: in Sm mode, to generate a 100 kHz SCL frequency:

If FREQR = 08, $T_{PCLK1} = 125$ ns so CCR must be programmed with 0x28

(0x28 \Leftrightarrow 40d x 125 ns = 5000 ns.)

Note: The minimum allowed value is 0x04, except in FAST DUTY mode where the minimum allowed value is 0x01

$t_{high} = t_{r(SCL)} + t_{w(SCLH)}$. See device datasheet for the definitions of parameters.

$t_{low} = t_{f(SCL)} + t_{w(SCLL)}$. See device datasheet for the definitions of parameters.

I2C communication speed, $f_{SCL} \sim 1/(t_{high} + t_{low})$. The real frequency may differ due to the analog noise filter input delay.

The CCR register must be configured only when the I²C is disabled (PE = 0).

18.6.9 I²C TRISE register (I2C_TRISE)

Address offset: 0x20

Reset value: 0x0002

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved										TRISE[5:0]					
										rw	rw	rw	rw	rw	rw

Bits 15:6 Reserved, must be kept at reset value

Bits 5:0 **TRISE[5:0]**: Maximum rise time in Fm/Sm mode (Master mode)

These bits should provide the maximum duration of the SCL feedback loop in master mode. The purpose is to keep a stable SCL frequency whatever the SCL rising edge duration.

These bits must be programmed with the maximum SCL rise time given in the I²C bus specification, incremented by 1.

For instance: in Sm mode, the maximum allowed SCL rise time is 1000 ns.

If, in the I2C_CR2 register, the value of **FREQ[5:0]** bits is equal to 0x08 and $T_{PCLK1} = 125$ ns therefore the **TRISE[5:0]** bits must be programmed with 09h.

(1000 ns / 125 ns = 8 + 1)

The filter value can also be added to **TRISE[5:0]**.

If the result is not an integer, **TRISE[5:0]** must be programmed with the integer part, in order to respect the t_{HIGH} parameter.

Note: TRISE[5:0] must be configured only when the I2C is disabled (PE = 0).

18.6.10 I²C FLTR register (I2C_FLTR)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved										ANOFF		DNF[3:0]			
										rw	rw	rw	rw	rw	rw

Bits 15:5 Reserved, must be kept at reset value

Bit 4 **ANOFF**: Analog noise filter OFF

0: Analog noise filter enable

1: Analog noise filter disable

Note: ANOFF must be configured only when the I2C is disabled (PE = 0).

Bits 3:0 **DNF[3:0]**: Digital noise filter

These bits are used to configure the digital noise filter on SDA and SCL inputs. The digital filter will suppress the spikes with a length of up to **DNF[3:0] * TPCLK1**.

0000: Digital noise filter disable

0001: Digital noise filter enabled and filtering capability up to 1* TPCLK1.

...

1111: Digital noise filter enabled and filtering capability up to 15* TPCLK1.

Note: DNF[3:0] must be configured only when the I2C is disabled (PE = 0). If the analog filter is also enabled, the digital filter is added to the analog filter.

18.6.11 I²C register map

The table below provides the I²C register map and reset values.

Table 72. I²C register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	I2C_CR1	Reserved																SWRST	Reserved	ALERT	PEC	POS	ACK	STOP	START	NOSTRETCH	ENG	ENPEC	ENARP	SMBTYPE	Reserved	SMBUS	PE
	Reset value																	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x04	I2C_CR2	Reserved																		LAST	DMAEN	ITBUFEN	ITEVTEN	ITERREN	Reserved	FREQ[5:0]							
	Reset value																			0	0	0	0	0		0	0	0	0	0	0	0	
0x08	I2C_OAR1	Reserved														ADDMODE	Reserved				ADD[9:8]		ADD[7:1]					ADD0					
	Reset value															0					0	0						0					
0x0C	I2C_OAR2	Reserved																						ADD2[7:1]					ENDUAL				
	Reset value																							0	0	0	0	0	0	0	0	0	0
0x10	I2C_DR	Reserved																						DR[7:0]									
	Reset value																							0	0	0	0	0	0	0	0	0	0
0x14	I2C_SR1	Reserved														SMBALERT	TIMEOUT	Reserved	PECERR	OVR	AF	ARLO	BERR	TxE	RxNE	Reserved	STOPF	ADD10	BTF	ADDR	SB		
	Reset value															0	0		0	0	0	0	0	0	0	0	0	0	0	0			
0x18	I2C_SR2	Reserved														PEC[7:0]							DUALF	SMBHOST	SMBDEFAULT	GENCALL	Reserved	TRA	BUSY	MSL			
	Reset value															0	0	0	0	0	0	0	0	0	0	0	0	0	0				
0x1C	I2C_CCR	Reserved														F/S	DUTY	Reserved	CCR[11:0]														
	Reset value															0	0		0	0	0	0	0	0	0	0	0	0	0	0	0		
0x20	I2C_TRISE	Reserved																						TRISE[5:0]									
	Reset value																							0	0	0	0	0	1	0			
0x24	I2C_FLTR	Reserved																										ANOFF	DNF[3:0]				
	Reset value																											0	0	0	0	0	0

Refer to [Section 3.3: Memory map](#) for the register boundary addresses table.