



Introduction

This reference manual provides complete information for application developers on how to use the STM8S microcontroller memory and peripherals.

The STM8S is a family of microcontrollers with different memory sizes, packages and peripherals.

- The STM8S is designed for general purpose applications. For ordering information, pin description, mechanical and electrical device characteristics, please refer to the STM8S Performance line and Access line datasheets.
- For information on programming, erasing and protection of the internal Flash memory please refer to the STM8S Flash Programming Manual (PM0051) and the STM8 SWIM communication protocol and debug module User Manual (UM0470)
- For information on the STM8 core, please refer to the STM8 CPU Programming Manual (PM0051)

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1 Central processing unit (CPU)

1.1 Introduction

The CPU has an 8-bit architecture. Six internal registers allow efficient data manipulations. The CPU is able to execute 80 basic instructions. It features 20 addressing modes and can address 6 internal registers. For the complete description of the instruction set, refer to the STM8 microcontroller family programming manual (PM0044).

1.2 CPU registers

The 6 CPU registers are shown in the programming model in [Figure 1](#). Following an interrupt, the registers are pushed onto the stack in the order shown in [Figure 2](#). They are popped from stack in the reverse order. The interrupt routine must therefore handle it, if needed, through the POP and PUSH instructions.

1.2.1 Description of CPU registers

Accumulator (A)

The accumulator is an 8-bit general purpose register used to hold operands and the results of the arithmetic and logic calculations as well as data manipulations.

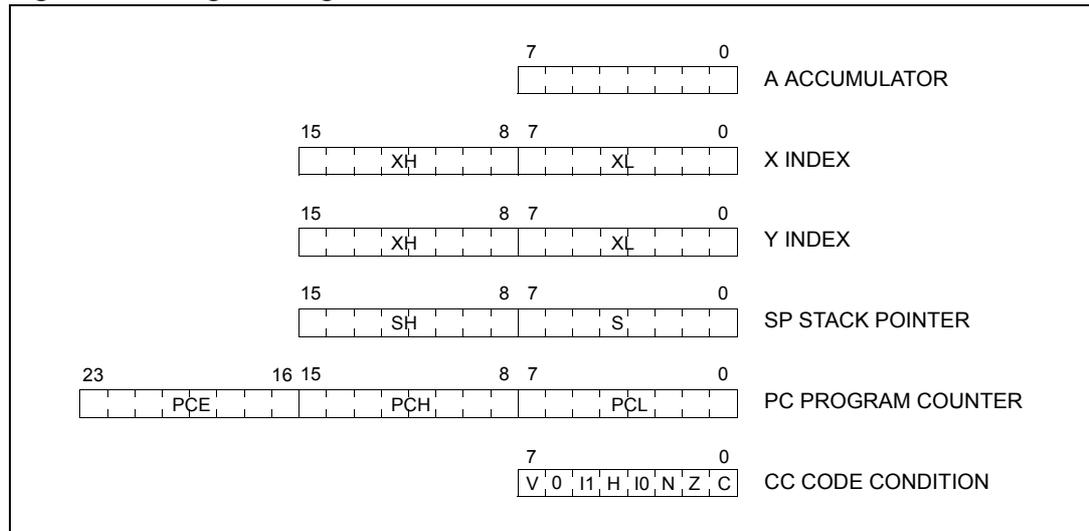
Index registers (X and Y)

These are 16-bit registers used to create effective addresses. They may also be used as temporary storage area for data manipulations and have an inherent use for some instructions (multiplication/division). In most of the cases, the cross assembler generates a PRECODE instruction (PRE) to indicate that the following instruction refers to the Y register.

Program counter (PC)

The program counter is a 24-bit register used to store the address of the next instruction to be executed by the CPU. It is automatically refreshed after each processed instruction. As a result, the STM8 core can access up to 16-Mbyte of memory.

Figure 1. Programming model



Stack pointer (SP)

The stack pointer is a 16-bit register. It contains the address of the next free location of the stack. Depending on the product, the most significant bits can be forced to a preset value.

The stack is used to save the CPU context on subroutine calls or interrupts. The user can also directly use it through the POP and PUSH instructions.

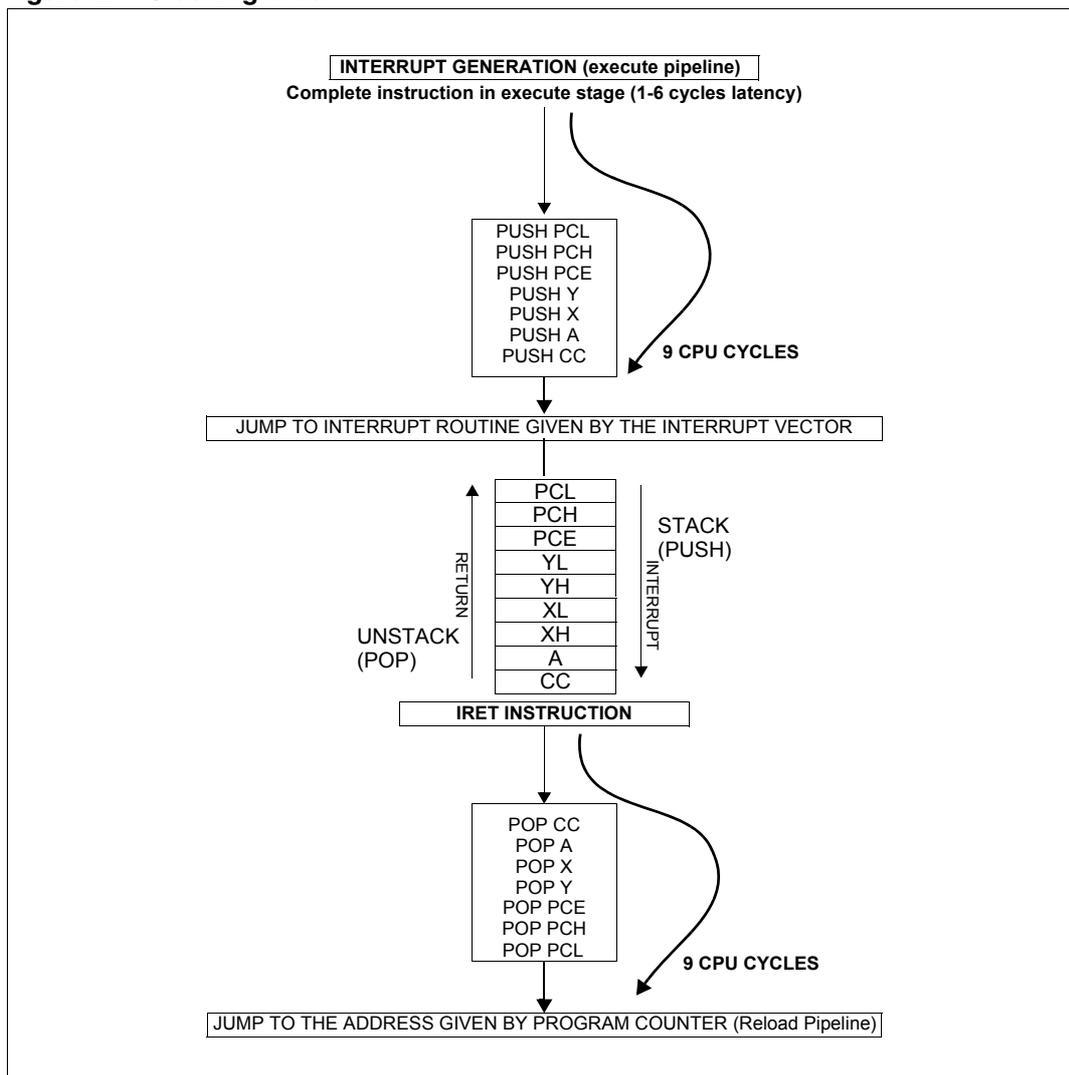
The stack pointer can be initialized by the startup function provided with the C compiler. For applications written in C language, the initialization is then performed according to the address specified in the linker file for C users. If you use your own linker file or startup file, make sure the stack pointer is initialized properly (with the address given in the datasheet). For applications written in assembler, you can use either the startup function provided by ST or write your own by initializing the stack pointer with the correct address.

The stack pointer is decremented after data has been pushed onto the stack and incremented after data is popped from the stack. It is up to the application to ensure that the lower limit is not exceeded.

A subroutine call occupies two or three locations. An interrupt occupies nine locations to store all the internal registers (except SP). For more details refer to [Figure 2](#).

Note: The WFI/HALT instructions save the context in advance. If an interrupt occurs while the CPU is in one of these modes, the latency is reduced.

Figure 2. Stacking order



Condition code register (CC)

The Condition Code register is an 8-bit register which indicates the result of the instruction just executed as well as the state of the processor. The 7th bit (MSB) of this register is reserved. These bits can be individually tested by a program and specified action taken as a result of their state. The following paragraphs describe each bit.

- **V: Overflow**

When set, V indicates that an overflow occurred during the last signed arithmetic operation, on the MSB result bit. See INC, INCW, DEC, DECW, NEG, NEGW, ADD, ADDW, ADC, SUB, SUBW, SBC, CP, CPW instructions.

- **I1: Interrupt mask level 1**

The I1 flag works in conjunction with the I0 flag to define the current interruptability level as shown in [Table 1](#). These flags can be set and cleared by software through the RIM, SIM, HALT, WFI, IRET, TRAP and POP instructions and are automatically set by hardware when entering an interrupt service routine.

Table 1. Interrupt levels

Interruptability	Priority	I1	I0
Interruptable Main	Lowest	1	0
Interruptable Level 1		0	1
Interruptable Level 2		0	0
Non Interruptable	Highest	1	1

- **H: Half carry bit**

The H bit is set to 1 when a carry occurs between the bits 3 and 4 of the ALU during an ADD or ADC instruction. The H bit is useful in BCD arithmetic subroutines.

- **I0: Interrupt mask level 0**

See Flag I1

- **N: Negative**

When set to 1, this bit indicates that the result of the last arithmetic, logical or data manipulation is negative (i.e. the most significant bit is a logic 1).

- **Z: Zero**

When set to 1, this bit indicates that the result of the last arithmetic, logical or data manipulation is zero.

- **C: Carry**

When set, C indicates that a carry or borrow out of the ALU occurred during the last arithmetic operation on the MSB operation result bit. This bit is also affected during bit test, branch, shift, rotate and load instructions. See ADD, ADC, SUB, SBC instructions.

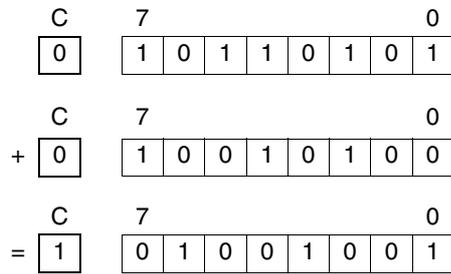
In division operation, C indicates if a trouble occurred during execution (quotient overflow or zero division). See DIV instruction.

In bit test operations, C is the copy of the tested bit. See BTJF, BTJT instructions.

In shift and rotate operations, the carry is updated. See RRC, RLC, SRL, SLL, SRA instructions.

This bit can be set, reset or complemented by software using SCF, RCF, CCF instructions.

Example: Addition
 $\$B5 + \$94 = "C" + \$49 = \149



1.2.2 STM8 CPU register map

The CPU registers are mapped in the STM8 address space as shown in [Table 2](#). These registers can only be accessed by the debug module but not by memory access instructions executed in the core.

Table 2. CPU register map

Address	Register name	7	6	5	4	3	2	1	0
00 7F00h	A	MSB	-	-	-	-	-	-	LSB
00 7F01h	PCE	MSB	-	-	-	-	-	-	LSB
00 7F02h	PCH	MSB	-	-	-	-	-	-	LSB
00 7F03h	PCL	MSB	-	-	-	-	-	-	LSB
00 7F04h	XH	MSB	-	-	-	-	-	-	LSB
00 7F05h	XL	MSB	-	-	-	-	-	-	LSB
00 7F06h	YH	MSB	-	-	-	-	-	-	LSB
00 7F07h	YL	MSB	-	-	-	-	-	-	LSB
00 7F08h	SPH	MSB	-	-	-	-	-	-	LSB
00 7F09h	SPL	MSB	-	-	-	-	-	-	LSB
00 7F0Ah	CC	V	0	I1	H	I0	N	Z	C

1.3 Global configuration register (CFG_GCR)

1.3.1 Activation level

The MCU activation level is configured by programming the AL bit in the CFG_GCR register. For information on the use of this bit refer to [Section 10.4: Activation level/low power mode control on page 93](#).

1.3.2 SWIM disable

By default, after an MCU reset, the SWIM pin is configured to allow communication with an external tool for debugging or Flash/EEPROM programming. This pin can be configured for

use as general purpose I/O by the application. This is done by setting the SWD bit in the CFG_GCR register.

1.3.3 Description of global configuration register (CFG_GCR)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved						AL	SWD
						rw	rw

Bits 7:2 Reserved, must be kept cleared.

Bit 1 **AL**: Activation level

This bit is set and cleared by software. It configures Main or Interrupt-only activation.

0: Main activation level. An IRET instruction will cause the context to be retrieved from the stack and the main program will continue after the WFI instruction.

1: Interrupt-only activation level. An IRET instruction will cause the CPU to go back to WFI/Halt mode without restoring the context.

Bit 0 **SWD**: SWIM disable

0: SWIM mode enabled

1: SWIM mode disabled

When SWIM mode is enabled, the SWIM pin cannot be used as general purpose I/O.

1.3.4 Global configuration register map and reset values

The CFG_GCR is mapped in the STM8 address space. Refer to the corresponding datasheet for the base address.

Table 3. CFG_GCR register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	CFG_GCR Reset value	-	-	-	-	-	-	AL 0	SWD 0

2 Boot ROM

The internal 2 Kbyte Boot ROM (available in some devices) contains the bootloader code. Its main task is to download the application program to the internal Flash/EEPROM through the SPI, CAN or UART interface and program the code, data, option bytes and interrupt vectors in the internal Flash/EEPROM.

The boot loader starts executing after reset. Refer to the STM8 Bootloader user manual (UM0560) for more details.

3 Memory and register map

For details on memory map, I/O port hardware register map and CPU/SWIM/debug module/interrupt controller registers, refer to the product datasheet.

3.1 Register description abbreviations

In the register descriptions of each chapter in this reference manual, the following abbreviations are used:

read/write (rw)	Software can read and write to these bits.
read-only (r)	Software can only read these bits.
write only (w)	Software can only write to this bit. Reading the bit returns a meaningless value.
read/write once (rwo)	Software can only write once to this bit and can also read it at any time. Only a reset can return the bit to its reset value.
read/clear (rc_w1)	Software can read as well as clear this bit by writing 1. Writing '0' has no effect on the bit value.
read/clear (rc_w0)	Software can read as well as clear this bit by writing 0. Writing '1' has no effect on the bit value.
read/set (rs)	Software can read as well as set this bit. Writing '0' has no effect on the bit value.

4 Flash program memory and data EEPROM (FLASH)

4.1 Introduction

The embedded Flash Program memory and data EEPROM memories are controlled by a common set of registers. Using these registers the application can program or erase memory contents, set write protection, or configure specific low power modes. The application can also program the device option bytes.

4.2 Glossary

- **Block**

A block is a set of bytes that can be programmed or erased in one single programming operation. Operations that are performed at block level are fast and standard programming and erasing. Refer to [Table 4](#) for the details on block size.
- **Page**

A page is a set of blocks. STM8L devices feature boot code, proprietary code, and data EEPROM areas which contents are protected by dedicated mechanisms. Their sizes are programmable through dedicated option bytes by increments of one page.

4.3 FLASH main features

- STM8S EEPROM is divided into two memory array:
 - Up to 128 Kbytes of Flash program memory. The density differs according to the devices. Refer to [Section 4.4: Memory organization](#) for details.
 - Up to 2 Kbytes of data EEPROM including option bytes. Data EEPROM density differs according to the devices. Refer to [Section 4.4: Memory organization](#) for details.
- Programming modes
 - Byte programming and automatic fast byte programming (without erase operation)
 - Word programming
 - Block programming and fast block programming mode (without erase operation)
 - Interrupt generation on end of program/erase operation and on illegal program operation
- Read-while-write capability (RWW). This feature is not available on all STM8 devices. Refer to the datasheets for details.
- In-application programming (IAP) and in-circuit programming (ICP) capabilities
- Protection features
 - Memory readout protection (ROP)
 - Program memory write protection with memory access security system (MASS keys)
 - Data memory write protection with memory access security system (MASS keys)
 - Programmable write protected user boot code area (UBC)
- Memory state configurable to operating or Power-down in Halt and Active-halt modes

4.4 Memory organization

STM8S EEPROM is organized in 32-bit words (4 bytes per word).

The memory organization differs according to the devices:

- Low density STM8S devices
 - 8 Kbytes of Flash Program Memory organized in 128 pages of 64 bytes each
 - 640 bytes of Data EEPROM organized in 10 pages of 64 bytes each. The data EEPROM includes one block of option bytes (64 bytes)
- Medium density STM8S devices
 - From 16 to 32 Kbytes of Flash Program memory organized in up to 64 pages of 512 bytes each.
 - 1 Kbytes of data EEPROM organized in 2 pages of 512 bytes each. The data EEPROM includes one block of option bytes (128 bytes)
- High density STM8S devices
 - From 32 to 128 Kbytes of Flash Program memory organized in up to 256 pages of 512 bytes each
 - From 1 to 2 Kbytes of data EEPROM organized in up to 4 pages of 512 bytes each. The data EEPROM includes one block of option bytes (128 bytes)

The page defines the granularity of the user boot code area as described in [Section 4.4.1: User boot area \(UBC\)](#).

[Figure 3](#), [Figure 4](#), and [Figure 5](#) show the Flash memory and data EEPROM organization for STM8S devices.

Figure 3. Flash memory and data EEPROM organization on low density STM8S

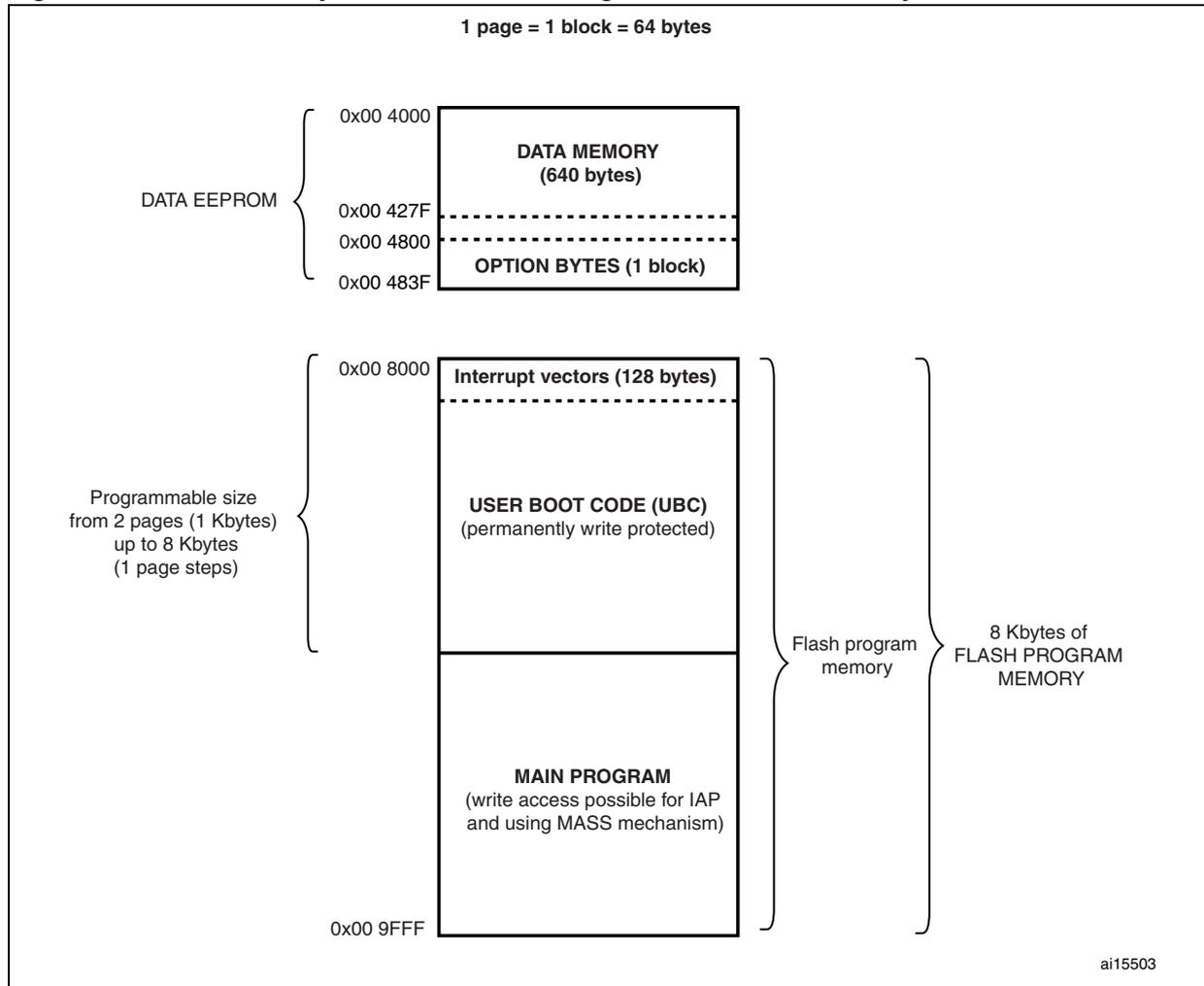


Figure 4. Flash memory and data EEPROM organization on medium density STM8S

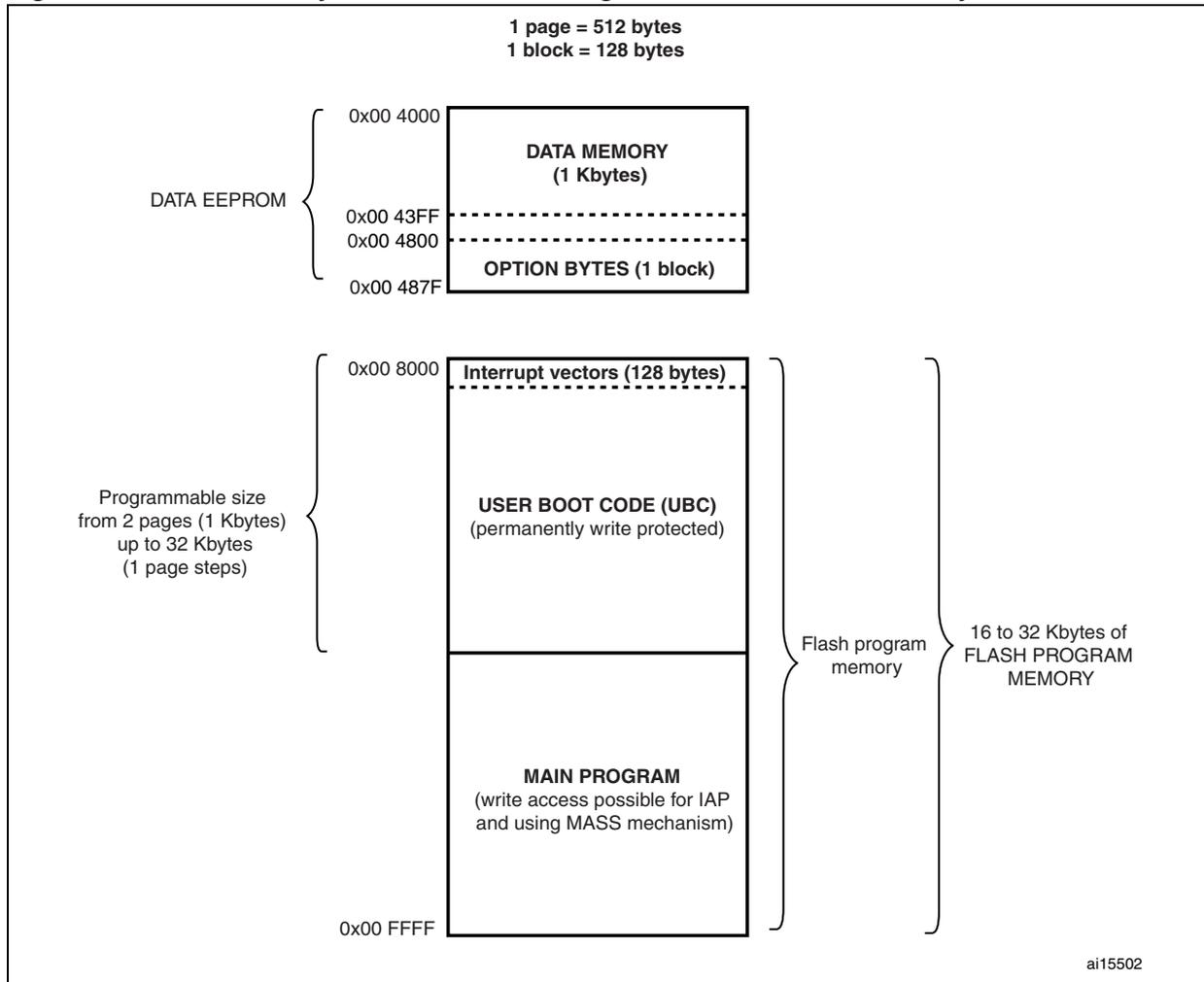
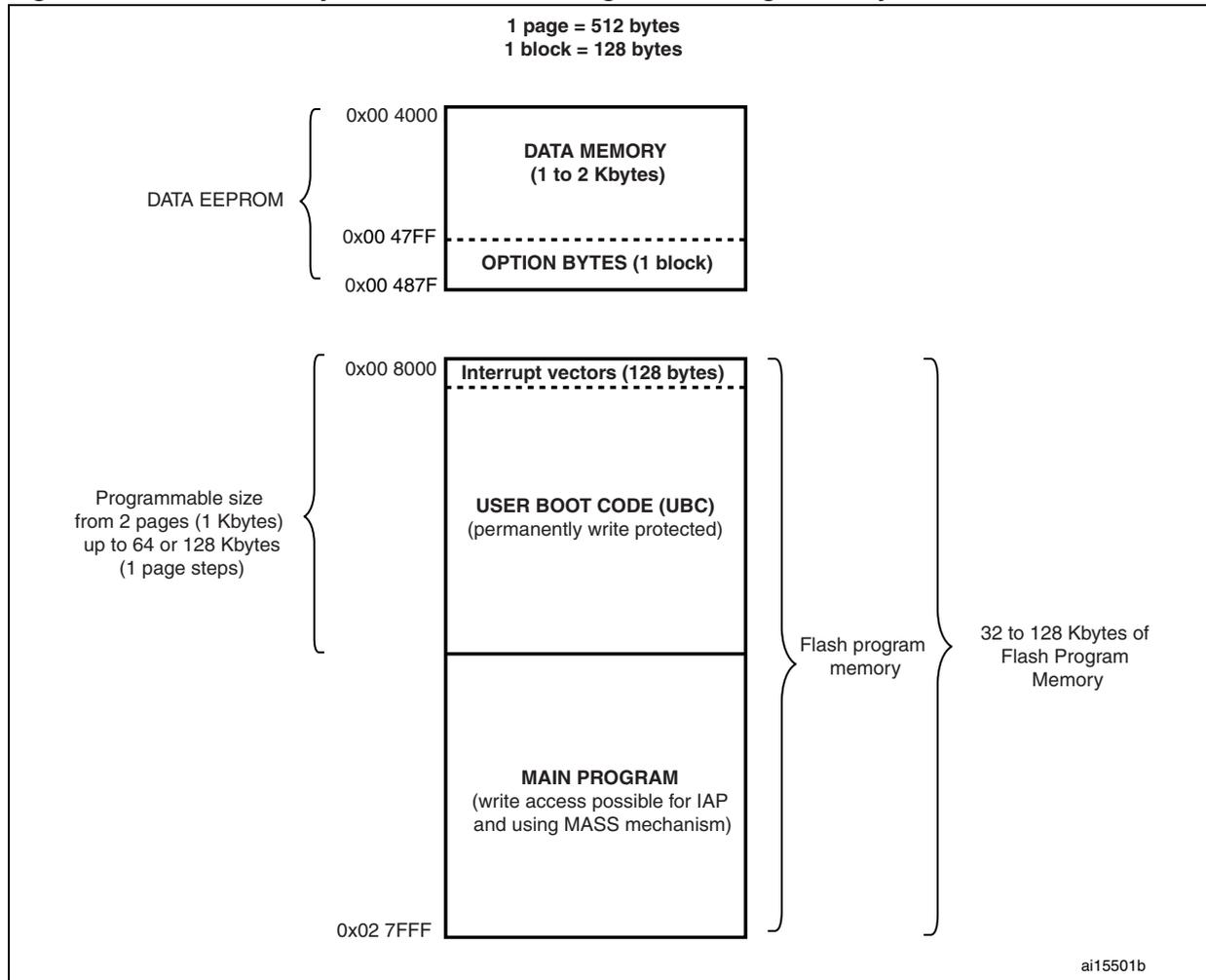


Figure 5. Flash memory and data EEPROM organization high density STM8S



4.4.1 User boot area (UBC)

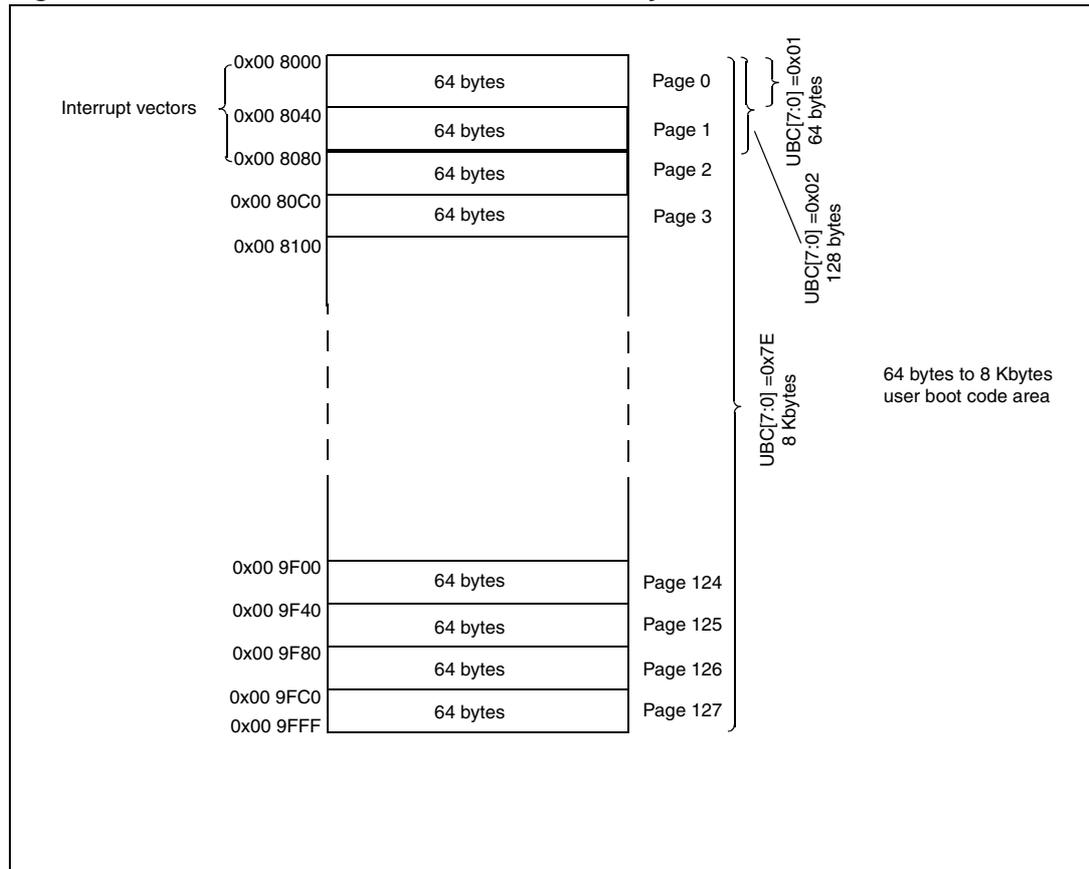
The user boot area (UBC) contains the reset and the interrupt vectors. It can be used to store the IAP and communication routines. The UBC area has a second level of protection to prevent unintentional erasing or modification during IAP programming. This means that it is always write protected and the write protection cannot be unlocked using the MASS keys.

The size of the UBC area can be configured in ICP mode (using the SWIM interface) through the UBC option byte. The UBC option byte specifies the number of pages allocated for the UBC area starting from address 0x00 8000.

The size of the UBC area can be obtained by reading the UBC option byte.

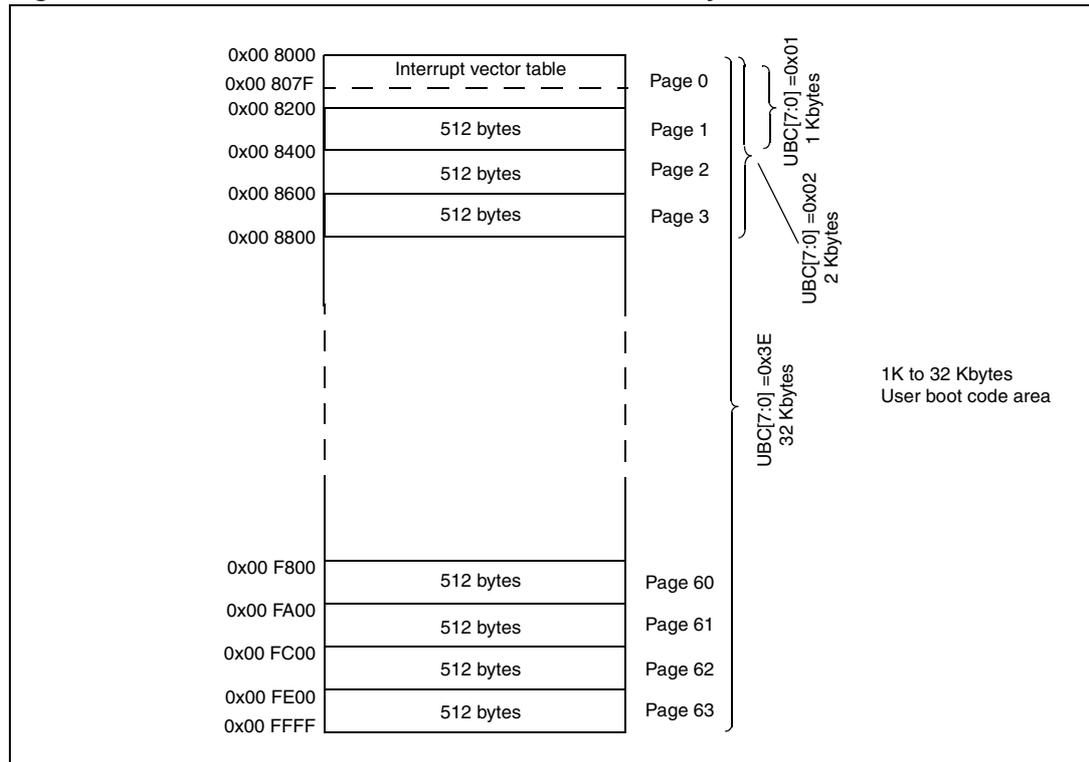
Refer to [Figure 6](#), [Figure 7](#) and [Figure 8](#) for a description of the UBC area memory mapping and to the option bytes section in the datasheet for more details on the UBC option byte.

Figure 6. UBC area size definition on low density STM8S devices



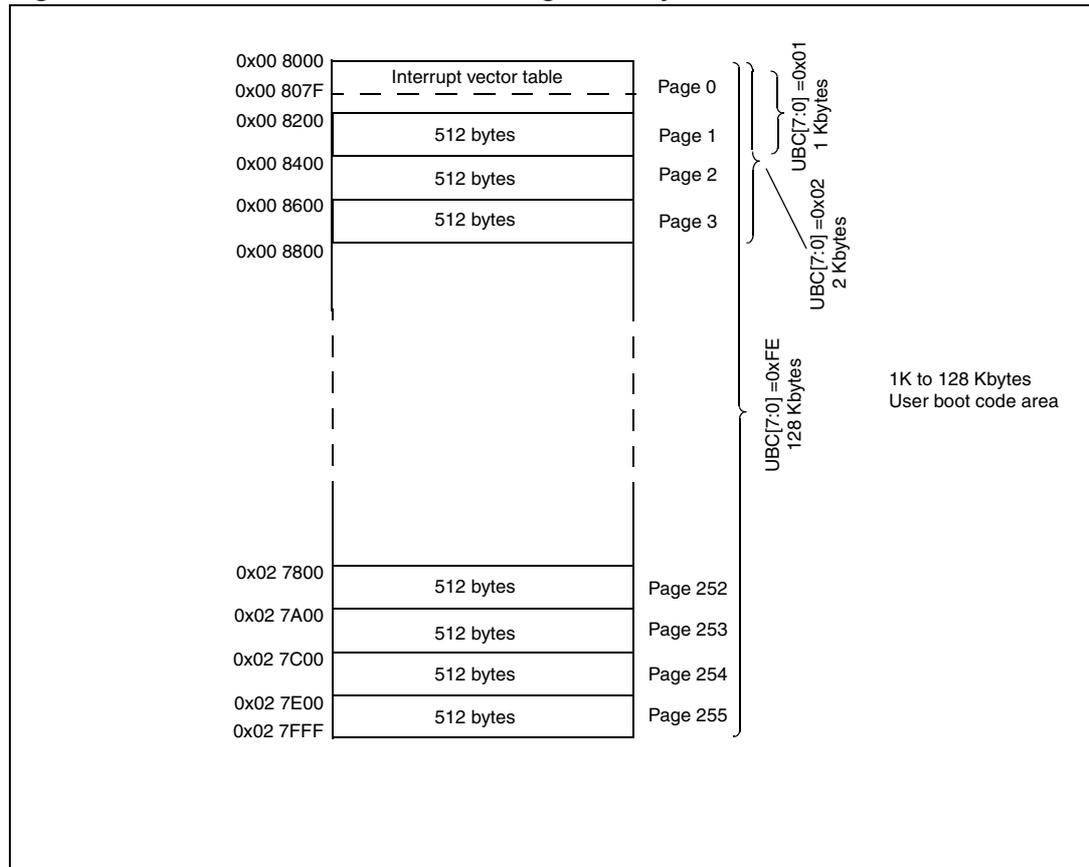
1. UBC[7:0] = 0x00 means no user boot code area is defined. Refer to the datasheet for the description of the UBC option byte.
2. The first 2 pages (128 bytes) contain the interrupt vectors.

Figure 7. UBC area size definition on medium density STM8S



1. UBC[7:0] = 0x00 means no user boot code area is defined. Refer to the datasheet for the description of the UBC option byte.
2. The first 2 pages (1 Kbytes) contain the interrupt vectors out of which only 128 bytes (32 IT vectors) are used.

Figure 8. UBC area size definition on high density STM8S



1. UBC[7:0] = 0x00 means no user boot code area is defined. Refer to the datasheet for the description of the UBC option byte.
2. The first 2 pages (1 Kbytes) contain the interrupt vectors out of which only 128 bytes (32 IT vectors) are used.

4.4.2 Data EEPROM (DATA)

The data EEPROM area can be used to store application data. By default, the DATA area is write protected to prevent unintentional modification when the main program is updated in IAP mode. The write protection can be unlocked only using specific a MASS key sequence (refer to [Enabling write access to the DATA area](#)).

Refer to [Section 4.4: Memory organization](#) for the size of the DATA area according to the STM8S devices.

4.4.3 Main program area

The main program is the part of the Flash program memory which is used to store the application code (see [Figure 3](#), [Figure 4](#) and [Figure 5](#)).

4.4.4 Option bytes

The option bytes are used to configure device hardware features and memory protection. They are located in a dedicated memory array of one block.

The option bytes can be modified both in ICP/SWIM and in IAP mode, with OPT bit of the FLASH_CR2 register set to '1' and the NOPT bit of the FLASH_NCR2 register set to '0' (see [Section 4.9.2: Flash control register 2 \(FLASH_CR2\)](#) and [Section 4.9.3: Flash complementary control register 2 \(FLASH_NCR2\)](#)).

Refer to the option bytes section in the datasheet for more information on option bytes, and to the STM8 SWIM protocol and debug module user manual (UM0470) for details on how to program them.

4.5 Memory protection

4.5.1 Readout protection

Readout protection is selected by programming the ROP option byte to 0xAA. When readout protection is enabled, reading or modifying the Flash program memory and DATA area in ICP mode (using the SWIM interface) is forbidden, whatever the write protection settings. Even if no protection can be considered as totally unbreakable, the readout feature provides a very high level of protection for a general purpose microcontroller.

The readout protection can be disabled on the program memory, UBC, DATA areas, by reprogramming the ROP option byte in ICP mode. In this case, the Flash program memory, the DATA area and the option bytes are automatically erased and the device can be reprogrammed.

Refer to [Table 5: Memory access versus programming method](#) for details on memory access when readout protection is enabled or disabled.

4.5.2 Memory access security system (MASS)

After reset, the main program and DATA areas are protected against unintentional write operations. They must be unlocked before attempting to modify their content. This unlock mechanism is managed by the memory access security system (MASS).

The UBC area specified in the UBC option byte is always write protected (see [Section 4.4.1: User boot area \(UBC\)](#)).

Once the memory has been modified, it is recommended to enable the write protection again to protect the memory content against corruption.

Enabling write access to the main program memory

After a device reset, it is possible to disable the main program memory write protection by writing consecutively two values called MASS keys to the FLASH_PUKR register (see [Section 4.9.6: Flash program memory unprotecting key register \(FLASH_PUKR\)](#)). These programmed keys are then compared to two hardware key values:

- First hardware key: 0b0101 0110 (0x56)
- Second hardware key: 0b1010 1110 (0xAE)

The following steps are required to disable write protection on the main program area:

1. Write the first 8-bit key into the FLASH_PUKR register. When this register is written for the first time after a reset, the data bus content is not latched into the register, but compared to the first hardware key value (0x56).
2. If the key available on the data bus is incorrect, then the FLASH_PUKR register remains locked until the next reset. Any new write commands sent to this address will be discarded.
3. If the first hardware key is correct, when the FLASH_PUKR register is written to for the second time, the data bus content is still not latched into the register, but compared to the second hardware key value (0xAE).
4. If the key available on the data bus is incorrect, then the write protection on program memory remains locked until the next reset. Any new write commands sent to this address will be discarded.
5. If the second hardware key is correct, the main program memory is write unprotected and the PUL bit of the FLASH_IAPSR is set (see [Section 4.9.8: Flash Status register \(FLASH_IAPSR\)](#) register).

Before starting programming, the application can verify that PUL bit is effectively set. The application can choose at any time to disable again write access to the Flash program memory by clearing the PUL bit.

Enabling write access to the DATA area

After a device reset, it is possible to disable the DATA area write protection by writing consecutively two values called MASS keys to the FLASH_DUKR register (see [Section 4.9.9: Flash register map and reset values](#)). These programmed keys are then compared to two hardware key values:

- First hardware key: 0b1010 1110 (0xAE)
- Second hardware key: 0b0101 0110 (0x56)

The following steps are required to disable write protection on the DATA area:

1. Write an first 8-bit key into the FLASH_DUKR register. When this register is written for the first time after a reset, the data bus content is not latched into the register, but compared to the first hardware key value (0xAE).
2. If the key available on the data bus is incorrect, the application can re-enter two MASS keys to try unprotecting the DATA area.
3. If the first hardware key is correct, the FLASH_DUKR register is programmed with the second key. The data bus content is still not latched into the register, but compared to the second hardware key value (0x56).
4. If the key available on the data bus is incorrect, then the data EEPROM area remains write protected until the next reset. Any new write command sent to this address is ignored.
5. If the second hardware key is correct, the DATA area is write unprotected and the DUL bit of the FLASH_IAPSR register is set (see [Section 4.9.8: Flash Status register \(FLASH_IAPSR\)](#)).

Before starting programming, the application can verify that the DATA area is not write protected by checking that the DUL bit is effectively set. The application can choose at any time to disable again write access to the DATA area by clearing the DUL bit.

4.5.3 Enabling write access to option bytes

The procedure for enabling write access to the option byte area is the same as that used for Data EEPROM. However, there is an additional OPT bit in *Flash control register 2 (FLASH_CR2)* to be set and the corresponding NOPT bit in the *Flash complementary control register 2 (FLASH_NCR2)* to be cleared in order to enable write access to the option bytes.

4.6 Memory programming

The main program memory, and the DATA area must be unlocked before attempting to perform any program operation. The unlock mechanism depends on the memory area to be programmed as described in [Section 4.5.2: Memory access security system \(MASS\)](#).

4.7 Read-while-write (RWW)

The RWW feature allows performing write operations on Data EEPROM while reading and executing the program memory. Execution time is therefore optimized. The opposite operation is not allowed: data memory cannot be read while writing to program memory.

This RWW feature is always enabled and can be used at any time.

Note: The RWW feature is not available on all devices. Refer to the datasheets for additional information.

4.7.1 Byte programming

The main program memory and the DATA area can be programmed at byte level. To program one byte, the application writes directly to the target address

- In main program memory
 - The application stops for the duration of the byte program operation.
- In DATA area
 - Devices with RWW capability: program execution does not stop, and the byte program operation is performed using the read-while-write (RWW) capability in IAP mode.
 - Devices without RWW capability: the application stops for the duration of the byte program operation.

To erase a byte, simply write 0x00 at the corresponding address.

The application can read the FLASH_IAPSR register to verify that the programming or erasing operation has been correctly executed:

- EOP flag is set after a successful programming operation
- WR_PG_DIS is set when the software has tried to write to a protected page. In this case, the write procedure is not performed.

As soon as one of these flags are set, a Flash interrupt is generated if it has been previously enabled by setting the IE bit of the FLASH_CR1 register.

Automatic fast byte programming

The programming duration can vary according to the initial content of the target address. If the word (4 bytes) containing the byte to be programmed is not empty, the whole word is automatically erased before the program operation. On the contrary if the word is empty, no erase operation is performed and the programming time is shorter (see t_{PROG} in Table “Flash program memory” in the datasheet).

however, the programming time can be fixed by setting the FIX bit of the FLASH_CR1 register to force the program operation to systematically erase the byte whatever its content (see [Section 4.9.1: Flash control register 1 \(FLASH_CR1\)](#)). The programming time is consequently fixed and equal to the sum of erase and write time (see t_{PROG} in Table “Flash program memory” in the datasheet).

Note: In order to write a byte fast (no erase), the whole word (4 bytes) into which it is written must previously be erased. It is consequently not possible to do two fast writes to the same word (without an erase before the second write): the first write will be fast but the second write to the other byte will require an erase.

4.7.2 Word programming

A word write operation allows to program an entire 4-byte word in one shot, thus minimizing the programming time.

Like byte programming, the word operation is available both for main program memory and data EEPROM. On some STM8S devices, the read-while-write (RWW) capability is also available when a word programming operation is performed on the data EEPROM. Refer to the datasheets for additional information.

To program a word, the WPRG/NWPRG bits in the FLASH_CR2 and FLASH_NCR2 registers must be previously set/cleared to enable word programming mode (see [Section 4.9.2: Flash control register 2 \(FLASH_CR2\)](#) and [Section 4.9.2: Flash control register 2 \(FLASH_CR2\)](#)). Then the 4 bytes of the word to be programmed must be loaded starting with the first address. The programming cycle starts automatically when the 4 bytes have been written.

Like for byte operation, the EOP and the WR_PG_DIS control flags of FLASH_IAPSR together with the Flash interrupt can be used to determine if the operation has been correctly completed.

4.7.3 Block programming

Block program operations are much faster than byte or word program operations. In a block program operation, a whole block is programmed or erased in a single programming cycle. Refer to [Table 4](#) for details on the block size according to the devices.

Block operations can be performed both to main program memory and DATA area:

- In main program memory
Block program operations to main program memory have to be executed totally from RAM.
- In DATA area
 - Devices with RWW capability: DATA block operations can be executed from main program memory. However the data loading phase (see below) has to be executed from RAM.
 - Devices without RWW capability: block program operations must be executed totally from RAM.

There are three possible block operation:

- Block programming also called standard block programming: the block is automatically erased before being programmed.
- Fast block programming: no previous erase operation is performed.
- Block erase

During block programming, interrupts are masked by hardware.

Standard block programming

A standard block program operation allows to write a whole block in one shot. The block is automatically erase before being programmed.

To program a whole block in standard mode, the PRG/NPRG bits in the FLASH_CR2 and FLASH_NCR2 registers must be previously set/cleared to enable standard block programming (see [Section 4.9.2: Flash control register 2 \(FLASH_CR2\)](#) and [Section 4.9.2: Flash control register 2 \(FLASH_CR2\)](#)). Then the block of data to be programmed must be loaded sequentially to the destination addresses in main program memory or DATA area. This causes all the bytes of data to be latched. To start programming the whole block, all the bytes of data must be written. All the bytes written in a programming sequence must be in the same block. This means that they must have the same high address: only the six least significant bits of the address can change. When the last byte of the target block is loaded, the programming starts automatically. It is preceded by an automatic erase operation of the whole block.

When programming a block in DATA area, the application can check the HVOFF bit in the [Flash Status register \(FLASH_IAPSR\)](#). As soon the HVOFF flag is reset the actual programming phase starts and the application can return to main program memory.

The EOP and the WR_PG_DIS control flags of the FLASH_IAPSR together with the Flash interrupt can be used to determine if the operation has been correctly completed.

Fast block programming

Fast block programming allows to program without first erasing the memory contents. Fast block programming is therefore twice as fast as standard programming.

This mode is intended only for programming parts that have already been erased. It is very useful for programming blank parts with the complete application code, as the time saving is significant.

Fast block programming is performed by using the same sequence as standard block programming. To enable fast block programming mode, the FPRG/NFPRG bits of the FLASH_CR2 and FLASH_NCR2 registers must be previously set/cleared.

The HVOFF flag can also be polled by the application, which can execute other instructions (RWW) during the actual programming phase of the DATA.

The EOP and the WR_PG_DIS bits of the FLASH_IAPSR register can be checked to determine if the fast block programming operation has been correctly completed.

Caution: The data programmed in the block are not guaranteed when the block is not blank before the fast block program operation.

Block erasing

A block erase allows to erase a whole block.

To erase a whole block, the ERASE/NERASE bits in the FLASH_CR2 and FLASH_NCR2 registers must be previously set/cleared to enable block erasing (see [Section 4.9.2: Flash control register 2 \(FLASH_CR2\)](#) and [Section 4.9.3: Flash complementary control register 2 \(FLASH_NCR2\)](#)). The block is then erased by writing '0x00 00 00 00' to any word inside the block. The word start address must end with '0', '4', '8', or 'C'.

The EOP and the WR_PG_DIS control flags of the FLASH_IAPSR together with the Flash interrupt can be used to determine if the operation has been correctly completed.

Table 4. Block size

STM8 microcontroller family	Block size
Low density STM8S	64 bytes
Medium density STM8S	128 bytes
High density STM8S	128 bytes

4.7.4 Option byte programming

Option byte programming is very similar to data EEPROM byte programming.

The application writes directly to the target address. The program does not stop and the write operation is performed using the RWW capability.

Refer to the datasheet for details of the option byte contents.

4.8 ICP and IAP

The in-circuit programming (ICP) method is used to update the entire content of the memory, using the SWIM interface to load the user application into the microcontroller. ICP offers quick and efficient design iterations and eliminates unnecessary package handling or socketing of devices. The SWIM interface (single wire interface module) uses the SWIM pin to connect to the programming tool.

In contrast to the ICP method, in-application programming (IAP) can use any communication interface supported by the microcontroller (I/Os, I²C, SPI, USART...) to download the data to be programmed in the memory. IAP allows reprogramming the Flash program memory content during application execution. Nevertheless, part of the application must have been previously programmed in Flash program memory using ICP.

Refer to the STM8 Flash programming manual (PM0051) and STM8 SWIM protocol and debug manual (UM0470) for more information on programming procedures.

Table 5. Memory access versus programming method⁽¹⁾

Mode	ROP	Memory Area	Access
User, IAP, and Bootloader (if available)	Readout protection enabled	User boot code area (UBC)	R/E
		Main program	R/W/E ⁽²⁾
		Data EEPROM area (DATA)	R/W/E ⁽³⁾
		Option bytes	R
	Readout protection disabled	User boot code area (UBC)	R/E ⁽⁴⁾
		Main program	R/W/E ⁽²⁾
		Data EEPROM area (DATA)	R/W/E ⁽³⁾
		Option bytes	R/W ⁽⁵⁾
ICP and SWIM	Readout protection enabled	User boot code area (UBC)	P
		Main program	P
		Data EEPROM area (DATA)	P
		Option bytes	R/W _{ROP} ⁽⁶⁾
	Readout protection disabled	User boot code area (UBC)	R/E ⁽⁴⁾
		Main program	R/W/E ⁽²⁾
		Data EEPROM area (DATA)	R/W/E ⁽³⁾
		Option bytes	R/W

1. R/W/E = Read; Write and Execute;
R/E = Read and Execute (write operation forbidden);
R = Read (write and execute operations forbidden);
P = the area cannot be accessed (read, execute and write operations forbidden);
P/W_{ROP} = Protected, write forbidden except for ROP option byte.
2. The Flash program memory is write protected (locked) until the correct MASS key is written in the FLASH_PUKR. It is possible to lock the memory again by resetting the PUL bit in the FLASH_IAPSR register. Unlocking can only be done once between two resets.
3. The data memory is write protected (locked) until the correct MASS key is written in the FLASH_DUKR. It is possible to lock the memory again by resetting the DUL bit in the IAPSR register.
4. To program the UBC area the application must first clear the UBC option byte.
5. The option bytes are write protected (locked) until the correct MASS key is written in the FLASH_DUKR (with OPT set to '1'). It is possible to lock the memory again by resetting the DUL bit in the FLASH_IAPSR register.
6. When ROP is removed, the whole memory is erased, including option bytes.

4.9 FLASH registers

4.9.1 Flash control register 1 (FLASH_CR1)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved				HALT	AHALT	IE	FIX
				rw	rw	rw	rw

Bits 7:4 Reserved, forced by hardware to 0.

Bit 3 **HALT**: Power-down in Halt mode

This bit is set and cleared by software.

0: Flash in power-down mode when MCU is in halt mode

1: Flash in operating mode when MCU is in halt mode

Bit 2 **AHALT**: Power-down in Active-halt mode

This bit is set and cleared by software.

0: Flash in operating mode when MCU is in Active-halt mode

1: Flash in power-down when MCU is in Active-halt mode

Bit 1 **IE**: Flash Interrupt enable

This bit is set and cleared by software.

0: Interrupt disabled

1: Interrupt enabled. An interrupt is generated if the EOP or WR_PG_DIS flag in the FLASH_IAPSR register is set.

Bit 0 **FIX**: Fixed Byte programming time

This bit is set and cleared by software.

0: Standard programming time of $(1/2 t_{prog})$ if the memory is already erased and t_{prog} otherwise.

1: Programming time fixed at t_{prog} .

4.9.2 Flash control register 2 (FLASH_CR2)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
OPT	WPRG	ERASE	FPRG	Reserved			PRG
rw	rw	rw	rw				ro

Bit 7 **OPT**: Write option bytes

This bit is set and cleared by software.

0: Write access to option bytes disabled

1: Write access to option bytes enabled

Bit 6 **WPRG**: Word programming

This bit is set by software and cleared by hardware when the operation is completed.

0: Word program operation disabled

1: Word program operation enabled

Bit 5 **ERASE**⁽¹⁾: Block erasing

This bit is set by software and cleared by hardware when the operation is completed.

0: Block erase operation disabled

1: Block erase operation enabled

Bit 4 **FPRG**⁽¹⁾: Fast block programming

This bit is set by software and cleared by hardware when the operation is completed (updated, please check).

0: Fast block program operation disabled

1: Fast block program operation enabled

Bit 3:1 Reserved

Bit 0 **PRG**: Standard block programming

This bit is set by software and cleared by hardware when the operation is completed.

0: Standard block programming operation disabled

1: Standard block programming operation enabled (automatically first erasing)

1. The ERASE and FPRG bits are locked when the memory is busy.

4.9.3 Flash complementary control register 2 (FLASH_NCR2)

Address offset: 0x02

Reset value: 0xFF

7	6	5	4	3	2	1	0
NOPT	NWPRG	NERASE	NFPRG	Reserved			NPRG
rw	rw	rw	rw	Res.			rw

Bit 7 **NOPT**: Write option bytes

This bit is set and cleared by software.

0: Write access to Option bytes enabled

1: Write access to Option bytes disabled

Bit 6 **NWPRG**: Word Programming

This bit is cleared by software and set by hardware when the operation is completed.

0: Word programming enabled

1: Word programming disabled

Bit 5 **NERASE**: Block erase

This bit is cleared by software and set by hardware when the operation is completed.

0: Block erase enabled

1: Block erase disabled

Bit 4 **NFPRG**: Fast block Programming

This bit is cleared by software and set by software reading the register.

0: Fast block programming enabled (no erase before programming, the programmed data values are not guaranteed when the block is not blank (fully erased) before the operation)

1: Fast block programming disabled

Bits 3:1 Reserved, forced by hardware to 1.

Bit 0 **NPRG**: Block programming

This bit is cleared by software and set by hardware when the operation is completed.

0: Block programming enabled

1: Block programming disabled

4.9.4 Flash protection register (FLASH_FPR)

Address offset: 0x03

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved		WPB5	WPB4	WPB3	WPB2	WPB1	WPB0
		ro	ro	ro	ro	ro	ro

Bit 7:6 Reserved - must be kept to '0'

Bit 5:0 **WPB[5:0]**: User boot code area protection bits

These bits show the size of the boot code area. They are loaded at startup with the content of the UBC option byte. Refer to the datasheet for the protected pages according to the bit values.

4.9.5 Flash protection register (FLASH_NFPR)

Address offset: 0x04

Reset value: 0xFF

7	6	5	4	3	2	1	0
Reserved		NWPB5	NWPB4	NWPB3	NWPB2	NWPB1	NWPB0
		ro	ro	ro	ro	ro	ro

Bit 7:6 Reserved - must be kept to '1'

Bit 5:0 **WPB[5:0]**: User boot code area protection bits

These bits show the size of the boot code area. They reflect the content of the NUBC option byte. Refer to the datasheet for the protected pages according to the bit values.

4.9.6 Flash program memory unprotecting key register (FLASH_PUKR)

Address offset: 0x08

Reset value: 0x00

7	6	5	4	3	2	1	0
MASS_PRG KEYS							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **PUK [7:0]**: Main program memory unlock keys

This byte is written by software (all modes). It returns 0x00 when read.

Refer to [Enabling write access to the main program memory on page 38](#) for the description of main program area write unprotection mechanism.

4.9.7 Data EEPROM unprotection key register (FLASH_DUKR)

Address offset: 0x0A

Reset value: 0x00

7	6	5	4	3	2	1	0
MASS_DATA KEYS							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **DUK[7:0]**: Data EEPROM write unlock keys

This byte is written by software (all modes). It returns 0x00 when read.

Refer to [Enabling write access to the DATA area on page 39](#) for the description of main program area write unprotection mechanism.

4.9.8 Flash Status register (FLASH_IAPSR)

Address offset: 0x05

Reset value: 0x40

7	6	5	4	3	2	1	0
Reserved	HVOFF	Reserved		DUL	EOP	PUL	WR_PG_DIS
	r			rc_w0	r	rc_w0	r

Bit 7 Reserved, forced by hardware to 0.

Bit 6 **HVOFF**: End of high voltage flag
 This bit is set and cleared by hardware.
 0: HV ON, start of actual programming
 1: HV OFF, end of high voltage

Bits 5:4 Reserved, forced by hardware to 0.

Bit 3 **DUL**: Data EEPROM area unlocked flag
 This bit is set by hardware and cleared by software by programming it to '0'.
 0: Data EEPROM area write protection enabled
 1: Data EEPROM area write protection can be disabled by MASS keys

Bit 2 **EOP**: End of programming (write or erase operation) flag
 This bit is set by hardware and cleared by software by reading the register.
 0: No EOP event occurred
 1: An EOP operation occurred. An interrupt is generated if the IE bit is set in the FLASH_CR1 register.

Bit 1 **PUL**: Flash Program memory unlocked flag
 This bit is set by hardware and cleared by software by programming it to '0'.
 0: Write protection of main Program area enabled
 1: Write protection of main Program area can be disabled by MASS keys.

Bit 0 **WR_PG_DIS**: Write attempted to protected page flag
 This bit is set by hardware and cleared by software by reading the register.
 0: No WR_PG_DIS event occurred
 1: A write attempt to a write protected page occurred. An interrupt is generated if the IE bit is set in the FLASH_CR1 register.

4.9.9 Flash register map and reset values

For details on the register boundary addresses, refer to in the general hardware register map in the datasheet.

Table 6. Flash register map and reset values

Address	Register name	7	6	5	4	3	2	1	0
0x00	FLASH_CR1 Reset Value	- 0	- 0	- 0	- 0	HALT 0	AHALT 0	IE 0	FIX 0
0x01	FLASH_CR2 Reset Value	OPT 0	WPRG 0	ERASE 0	FPRG 0	- 0	- 0	- 0	PRG 0
0x02	FLASH_NCR2 Reset Value	NOPT 1	NWPRG 1	NERASE 1	NFPRG 1	- 1	- 1	- 1	NPRG 1
0x03	FLASH_FPR Reset Value	- 0	- 0	WPB5 0	WPB4 0	WPB3 0	WPB2 0	WPB1 0	WPB0 0
0x04	FLASH_NFPR Reset Value	- 1	- 1	NWPB5 1	NWPB4 1	NWPB3 1	NWPB2 1	NWPB1 1	NWPB0 1
0x05	FLASH_IAPSR Reset Value	- 0	HVOFF 1	- 0	- 0	DUL 0	EOP 0	PUL 0	WR_PG_DIS 0
0x06-0x07	Reserved								
0x08	FLASH_PUKR Reset Value	PUK7 0	PUK6 0	PUK5 0	PUK4 0	PUK3 0	PUK2 0	PUK1 0	PUK0 0
0x09	Reserved								
0x0A	FLASH_DUKR Reset Value	DUK7 0	DUNP6 0	DUK5 0	DUK4 0	DUK3 0	DUK2 0	DUK1 0	DUK0 0

5 Single wire interface module (SWIM) and debug module (DM)

5.1 Introduction

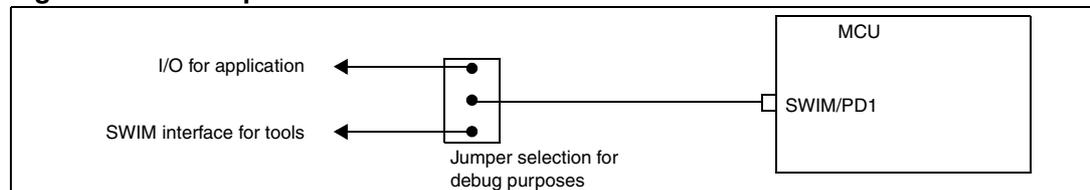
In-circuit debugging mode or in-circuit programming mode are managed through a single wire hardware interface featuring ultra fast memory programming. Coupled with an in-circuit debugging module, it also offers a non-intrusive emulation mode, making the in-circuit debugger extremely powerful, close in performance to a full-featured emulator.

5.2 Main features

- Based on an asynchronous, high sink (8 mA), open-drain, bidirectional communication.
- Allows reading or writing any part of memory space.
- Access to CPU registers (A, X, Y, CC, SP). They are memory mapped for read or write access.
- Non intrusive read/write on the fly to the RAM and peripheral registers.
- Device reset capability with status flag in the [Reset status register \(RST_SR\)](#).
- Clock speed selectable in the [SWIM clock control register \(CLK_SWIMCCR\)](#).

SWIM pin can be used as a standard I/O with some restrictions if you also want to use it for debug. The most secure way is to provide on the PCB a strap option.

Figure 9. SWIM pin connection



5.3 SWIM modes

After a power-on reset, the SWIM is reset and enters OFF mode.

1. **OFF:** Default state after power-on reset. The SWIM pin cannot be used by the application as an I/O.
2. **I/O:** This state is entered by software writing to the SWD bit in the [Global configuration register \(CFG_GCR\)](#). In this state, the SWIM pin can be used by the application as a standard I/O pin. In case of a reset, the SWIM goes back to OFF mode.
3. **SWIM:** This state is entered when a specific sequence is performed on the SWIM pin. In this state, the SWIM pin is used by the host tool to control the STM8 with 3 commands (SRST System Reset, ROTF Read On The Fly, WOTF Write On The Fly).

Note: Refer to the [STM8 SWIM communication Protocol and Debug Module User Manual](#) for a description of the SWIM and Debug module (DM) registers.

6 Power supply

The MCU has four distinct power supplies:

- V_{DD}/V_{SS} : Main power supply (3 V to 5.5 V)
- V_{DDIO}/V_{SSIO} : I/O power supply (3 V to 5.5 V)
- V_{DDA}/V_{SSA} : Power supply for the analog functions
- V_{REF+}/V_{REF-} : Reference supply for Analog Digital Converter

The V_{DD}/V_{SS} pins are used to supply the internal Main Voltage Regulator (MVR) and the internal Low Power Voltage Regulator (LPVR). The 2 regulator outputs are connected and provide the 1.8 V supply (V_{18}) to the MCU core (CPU, Flash and RAM)

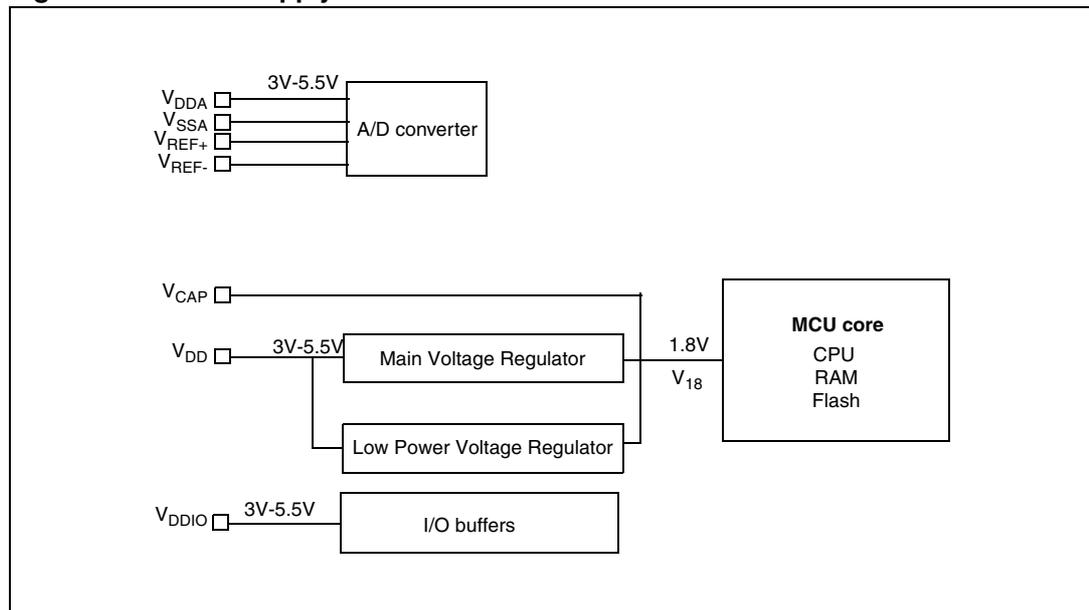
In low power modes the system automatically switches from the MVR to the LPVR in order to reduce current consumption.

To stabilize the MVR, a capacitor must be connected to the VCAP pin. The minimum recommended value is 470 nF with low Equivalent Series Resistance.

Depending on the package size, there are one or two pairs of dedicated pins for V_{DDIO}/V_{SSIO} to supply power to the I/Os.

V_{DDA}/V_{SSA} and V_{REF+}/V_{REF-} are connected to the Analog to Digital Converter (ADC).

Figure 10. Power supply overview



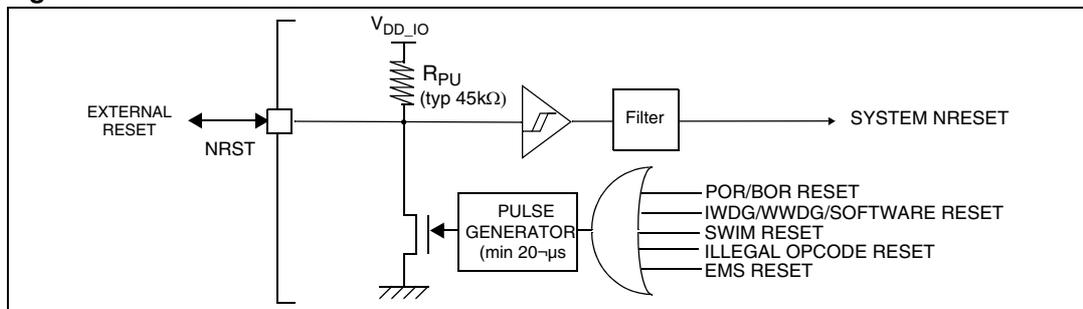
7 Reset (RST)

There are 9 reset sources:

- External reset through the NRST pin
- Power-on reset (POR)
- Brown-out Reset (BOR)
- Independent watchdog reset (IWDG)
- Window watchdog reset (WWDG)
- Software reset
- SWIM reset
- Illegal opcode reset
- EMS reset: generated if critical registers are corrupted or badly loaded

These sources act on the $\overline{\text{RESET}}$ pin and it is always kept low during the delay phase. The RESET service routine vector is fixed at address 6000h in the memory map.

Figure 11. Reset circuit



7.1 Reset circuit description

The NRST pin is both an input and an open-drain output with integrated R_{PU} weak pull-up resistor.

A minimum of 500 ns low pulse on the NRST pin generates an external reset. The reset detection is asynchronous and therefore the MCU can enter reset even in HALT mode.

The NRST pin also acts as an open-drain output for resetting external devices.

An internal temporization maintains a pulse of at least 20 μs whatever the internal reset source. An additional internal weak pull-up ensures a high level on the reset pin when the reset is not forced.

Refer to [Figure 11](#) and see Electrical parameters section of the datasheet for more details.

7.2 Internal reset sources

Each internal reset source is linked to a specific flag bit in the [Reset status register \(RST_SR\)](#) except POR/BOR which have no flag. These flags are set respectively at reset depending on the given reset source. So they are used to identify the last reset source. They are cleared by software writing the logic value "1".

7.2.1 Power-on reset (POR) and brown-out reset (BOR)

During power-on, the POR keeps the device under reset until the supply voltages (V_{DD} and V_{DDIO}) reach the voltage level at which the BOR starts to function. At this point, the BOR reset replaces the POR and the POR is automatically switched off. The BOR reset is maintained till the supply voltage reaches the operating voltage range.

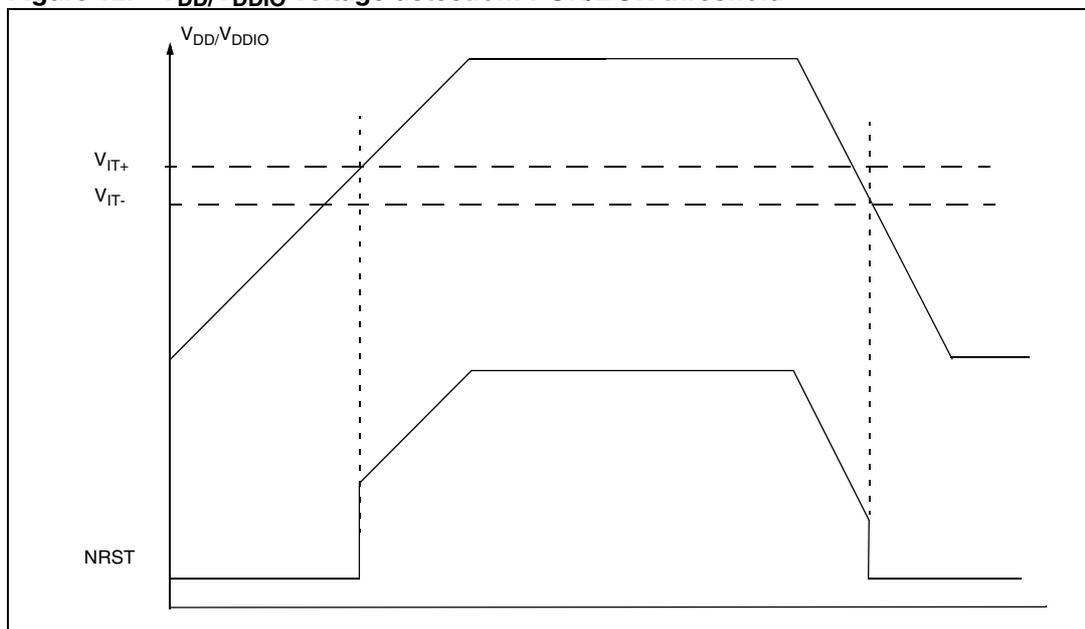
See Electrical parameters section of the datasheet for more details.

The BOR also generates a reset when the supply voltage drops below the V_{IT-} threshold. When this occurs, the POR is re-armed for the next power-on phase.

An hysteresis is implemented to ensure clean detection of voltage rise and fall.

The BOR always remains active even when the MCU is put into Low Power mode.

Figure 12. V_{DD}/V_{DDIO} voltage detection: POR/BOR threshold



7.2.2 Watchdog reset

Refer to [Section 15: Window watchdog \(WWDG\)](#) and [Section 14: Independent watchdog \(IWDG\)](#) for details.

7.2.3 Software reset

The application software can trigger reset by clearing bit T6 in the WWDG_CR register. Refer to [Section 15: Window watchdog \(WWDG\)](#).

7.2.4 SWIM reset

An external device connected to the SWIM interface can request the SWIM block to generate an MCU reset.

7.2.5 Illegal opcode reset

In order to provide enhanced robustness to the device against unexpected behavior, a system of illegal opcode detection is implemented. If a code to be executed does not correspond to any opcode or prebyte value, a reset is generated. This, combined with the Watchdog, allows recovery from an unexpected fault or interference.

Note: A valid prebyte associated with a valid opcode forming an unauthorized combination does not generate a reset.

7.2.6 EMS reset

To protect the application against spurious write access or system hang-up, possibly caused by electromagnetic disturbance, the most critical registers are implemented as two bit-fields that must contain complementary values. Mismatches are automatically detected by this mechanism, triggering an EMS reset and allowing the application to cleanly recover normal operations.

7.3 RST register description

7.3.1 Reset status register (RST_SR)

Address offset: 0x00

Reset value: undefined

7	6	5	4	3	2	1	0
Reserved			EMCF	SWIMF	ILLOPF	IWDGF	WWDGF
			rc_w1	rc_w1	rc_w1	rc_w1	rc_w1

Bits 7:5 Reserved, must be kept cleared.

Bit 4 **EMCF**: EMC reset flag

This bit is set by hardware and cleared by software writing "1".

0: No EMC reset occurred

1: An EMC reset occurred (possible cause: complementary register or option byte mismatch).

Bit 3 **SWIMF**: SWIM reset flag

This bit is set by hardware and cleared by software writing "1".

0: No SWIM reset occurred

1: A SWIM reset occurred

Bit 2 **ILLOPF**: Illegal opcode reset flag

This bit is set by hardware and cleared by software writing "1".

0: No ILLOP reset occurred

1: An ILLOP reset occurred

Bit 1 **IWDGF**: Independent Watchdog reset flag

This bit is set by hardware and cleared by software writing "1".

0: No IWDG reset occurred

1: An IWDG reset occurred

Bit 0 **WWDGF**: Window Watchdog reset flag

This bit is set by hardware and cleared by software writing "1".

0: No WWDG reset occurred

1: An WWDG reset occurred

7.4 RST register map

Refer to the corresponding datasheet for the base address.

Table 7. RST register map

Address offset	Register Name	7	6	5	4	3	2	1	0
0x00	RST_SR Reset value	- x	- x	- x	EMCF x	SWIMF x	ILLOPF x	IWDGF x	WWDGF x

8 Clock control (CLK)

The clock controller is designed to be powerful, very robust, and at the same time easy to use. Its purpose is to allow you to obtain the best performance in your application while at the same time get the full benefit of all the microcontroller's power saving capabilities.

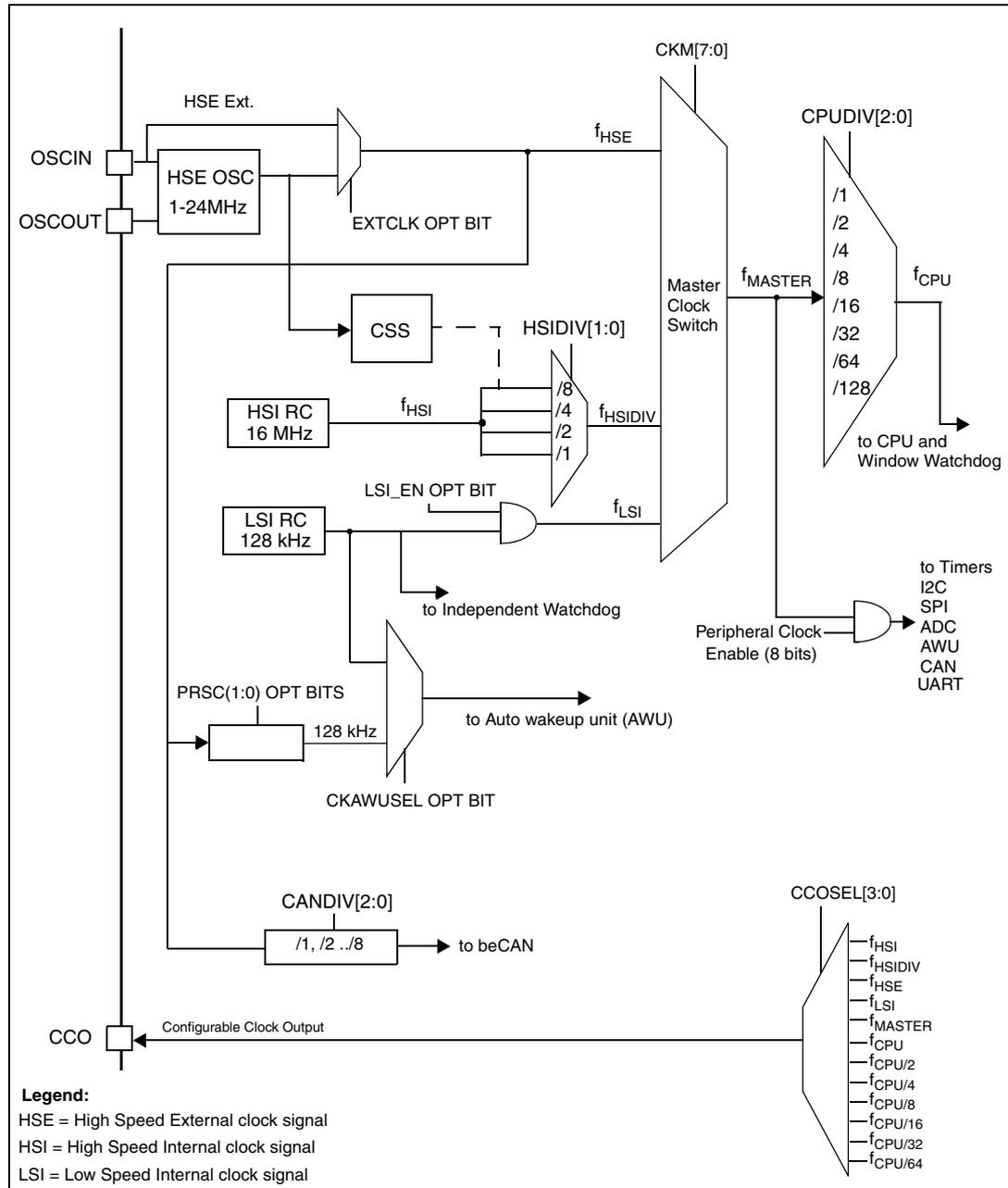
You can manage all the different clock sources independently and distribute them to the CPU and to the various peripherals. Prescalers are available for the master and CPU clocks.

A safe and glitch-free switch mechanism allows you to switch the master clock on the fly from one clock source to another one.

EMS-hardened clock configuration registers

To protect the application against spurious write access or system hang-up, possibly caused by electromagnetic disturbance, the most critical CLK registers are implemented as two bit-fields that must contain complementary values. Mismatches are automatically detected by the CLK, triggering an EMS reset and allowing the application to cleanly recover normal operations. See [CLK register description](#) for more details.

Figure 13. Clock tree



8.1 Master clock sources

4 different clock sources can be used to drive the master clock:

- 1-24 MHz High Speed External crystal oscillator (HSE)
- Up to 24 MHz High Speed user-external clock (HSE user-ext)
- 16 MHz High Speed Internal RC oscillator (HSI)
- 128 kHz Low Speed Internal RC (LSI)

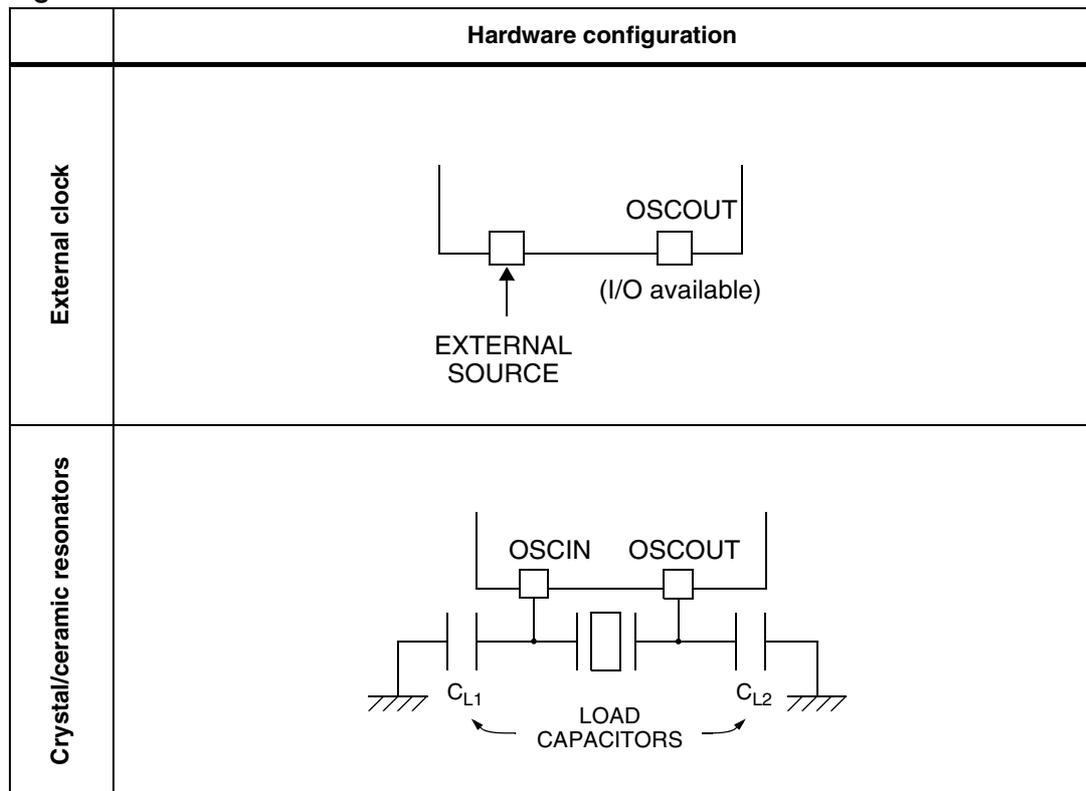
Each clock source can be switched on or off independently when it is not used, to optimize power consumption.

8.1.1 HSE

The High Speed External clock signal (HSE) can be generated from two possible clock sources:

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

Figure 14. HSE clock sources



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 start-up stabilization time. The loading capacitance values must be adjusted according to the selected oscillator.

External crystal/ceramic resonator (HSE crystal)

The 1 to 24 MHz external oscillator has the advantage of producing a very accurate rate on the main clock with 50% duty cycle.

The associated hardware configuration is shown in [Figure 14](#). Refer to the electrical characteristics section for more details.

At start up the clock signal produced by the oscillator is not stable, and by default a delay of 2048 osc cycles is inserted before the clock signal is released. You can program a shorter stabilization time in the HSECNT option byte, please refer to option bytes section in the datasheet.

The HSERDY flag in the [External clock register \(CLK_ECKR\)](#) indicates if the high-speed external oscillator is stable or not. At startup, the clock is not released until this bit is set by hardware.

The HSE Crystal can be switched on and off using the HSEEN bit in the [External clock register \(CLK_ECKR\)](#).

External source (HSE user-ext)

In this mode, an external clock source must be provided. It can have a frequency of up to 24MHz. You select this mode by programming the EXTCLK option bit. Refer to the option bytes section of the datasheet. The external clock signal (square, sinus or triangle) with ~50% duty cycle has to drive the OSCIN pin while the OSCOUT pin is available as standard I/O. See [Figure 13](#).

8.1.2 HSI

The HSI clock signal is generated from an internal 16 MHz RC oscillator together with a programmable divider (factor 1 to 8). This is programmed in the [Clock divider register \(CLK_CKDIVR\)](#).

Note: At startup the master clock source is automatically selected as HSI RC clock output divided by 8 ($f_{HSI}/8$).

The HSI RC oscillator has the advantage of providing a 16 MHz master clock source with 50% duty cycle at low cost (no external components). It also has a faster startup time than the HSE crystal oscillator however, even with calibration the frequency is less accurate than an external crystal oscillator or ceramic resonator.

The HSI RDY flag in the [Internal clock register \(CLK_I CKR\)](#) indicates if the HSI RC is stable or not. At startup, the HSI RC output clock is not released until this bit is set by hardware.

The HSI RC can be switched on and off using the HSIEN bit in the [Internal clock register \(CLK_I CKR\)](#).

Backup source

The HSI/8 signal can also be used as a backup source (Auxiliary clock) if the HSE crystal oscillator fails. Refer to [Section 8.6: Clock security system \(CSS\)](#).

Fast wakeup feature

If the FHWU bit in the [Internal clock register \(CLK_I CKR\)](#) is set, this automatically selects the HSI clock as master clock after MCU wakeup from Halt or Active Halt (see Low Power chapter).

Calibration

Each device is factory calibrated by ST.

After reset, the factory calibration value is automatically loaded in an internal calibration register.

If the application is subject to voltage or temperature variations this may affect the RC oscillator speed. You can trim the HSI frequency in the application using the [HSI clock calibration trimming register \(CLK_HSITRIMR\)](#). In this register there are 3 or 4 bits providing an additional trimming value that is added to the internal HSI calibration register value.

8.1.3 LSI

The 128 kHz LSI RC acts as a low power, low cost alternative master clock source as well as a low power clock source that can be kept running in Halt mode for the independent watchdog (IWDG) and Auto-Wakeup unit (AWU).

The LSI RC can be switched on and off using the LSIEN bit in the [Internal clock register \(CLK_ICKR\)](#).

The LSIRDY flag in the [Internal clock register \(CLK_ICKR\)](#) indicates if the low-speed internal oscillator is stable or not. At startup, the clock is not released until this bit is set by hardware.

Calibration

Like the HSI RC, the LSI RC device is factory calibrated by ST. However, it is not possible to perform further trimming.

Note: When using the Independent Watchdog with the LSI as clock source, in order to guarantee that the CPU will never run on the same clock in case of corruption, the LSI clock cannot be the master clock if LSI_EN option bit is reset. Refer to the option bytes section in the datasheet.

8.2 Master clock switching

The clock switching feature provides an easy to use, fast and secure way for the application to switch from one master clock source to another.

8.2.1 System startup

For fast system startup, after a reset the clock controller configures the master clock source as HSI RC clock output divided by 8 (HSI/8). This is to take advantage of the short stabilization time of the HSI oscillator. The /8 divider is to ensure safe start-up in case of poor V_{DD} conditions.

Once the master clock is released, the user program can switch the master clock to another clock source.

8.2.2 Master clock switching procedures

To switch clock sources, you can proceed in one of two ways:

- Automatic switching
- Manual switching

Automatic switching

The automatic switching enables the user to launch a clock switch with a minimum number of instructions. The software can continue doing other operations without taking care of the switch event exact time.

Refer to the flowchart in [Figure 15](#).

1. Enable the switching mechanism by setting the SWEN bit in the *Switch control register (CLK_SWCR)*.
2. Write the 8-bit value used to select the target clock source in the *Clock master switch register (CLK_SWR)*. The SWBSY bit in the CLK_SWCR register is set by hardware, and the target source oscillator starts. The old clock source continues to drive the CPU and peripherals.

As soon as the target clock source is ready (stabilized), the content of the CLK_SWR register is copied to the *Clock master status register (CLK_CMSR)*.

The SWBSY bit is cleared and the new clock source replaces the old one. The SWIF flag in the CLK_SWCR is set and an interrupt is generated if the SWIEN bit is set.

Manual switching

The manual switching is not as immediate as the automatic switching but it offers to the user a precise control of the switch event time.

Refer to the flowchart in *Figure 16*.

1. write the 8-bit value used to select the target clock source in the *Clock master switch register (CLK_SWR)*. Then the SWBSY bit is set by hardware, and the target source oscillator starts. The old clock source continues to drive the CPU and peripherals.
2. The software has to wait until the target clock source is ready (stabilized). This is indicated by the SWIF flag in the CLK_SWCR register and by an interrupt if the SWIEN bit is set.
3. The final software action is to set, at the chosen time, the SWEN bit in the CLK_SWCR register to execute the switch.

In both manual and automatic switching modes, the old master clock source will not be powered off automatically in case it is required by other blocks (the LSI RC may be used to drive the Independent Watchdog for example). The clock source can be powered off using the bits in the *Internal clock register (CLK_ICKR)* and *External clock register (CLK_ECKR)*.

If the clock switch does not work for any reason, software can reset the current switch operation by clearing the SWBSY flag. This will restore the CLK_SWR register to its previous content (old master clock).

Figure 15. Clock switching flowchart (automatic mode example)

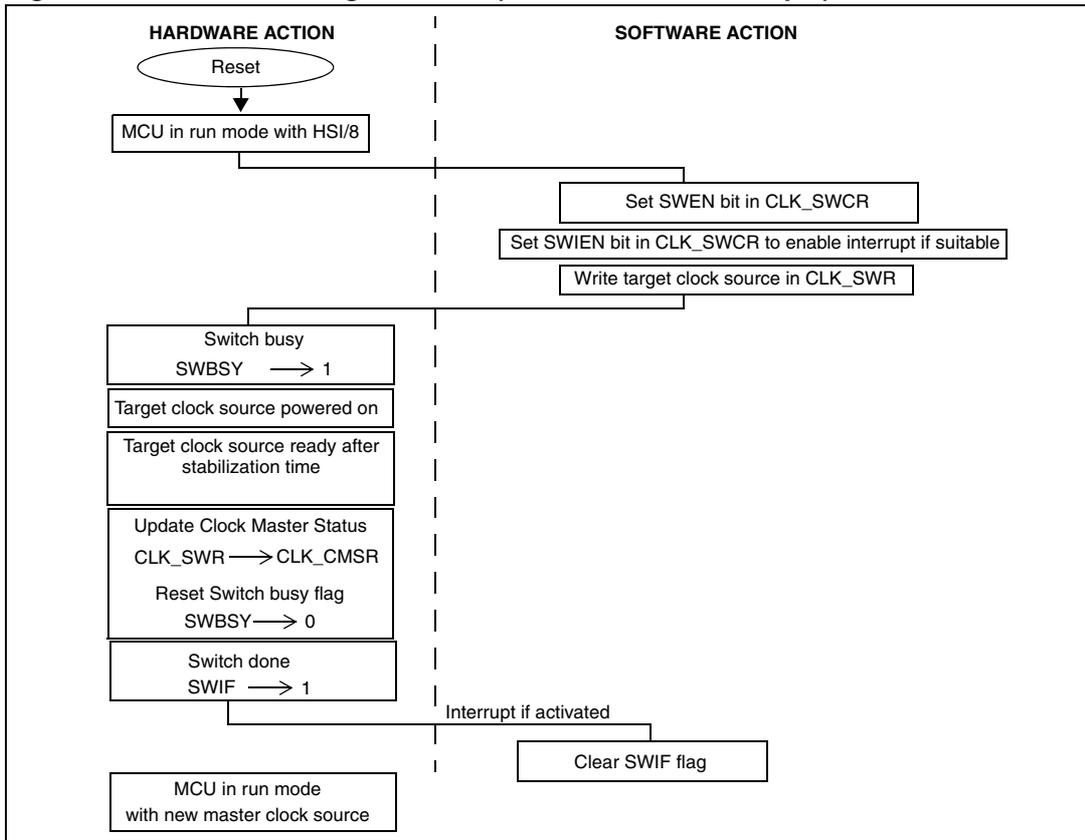
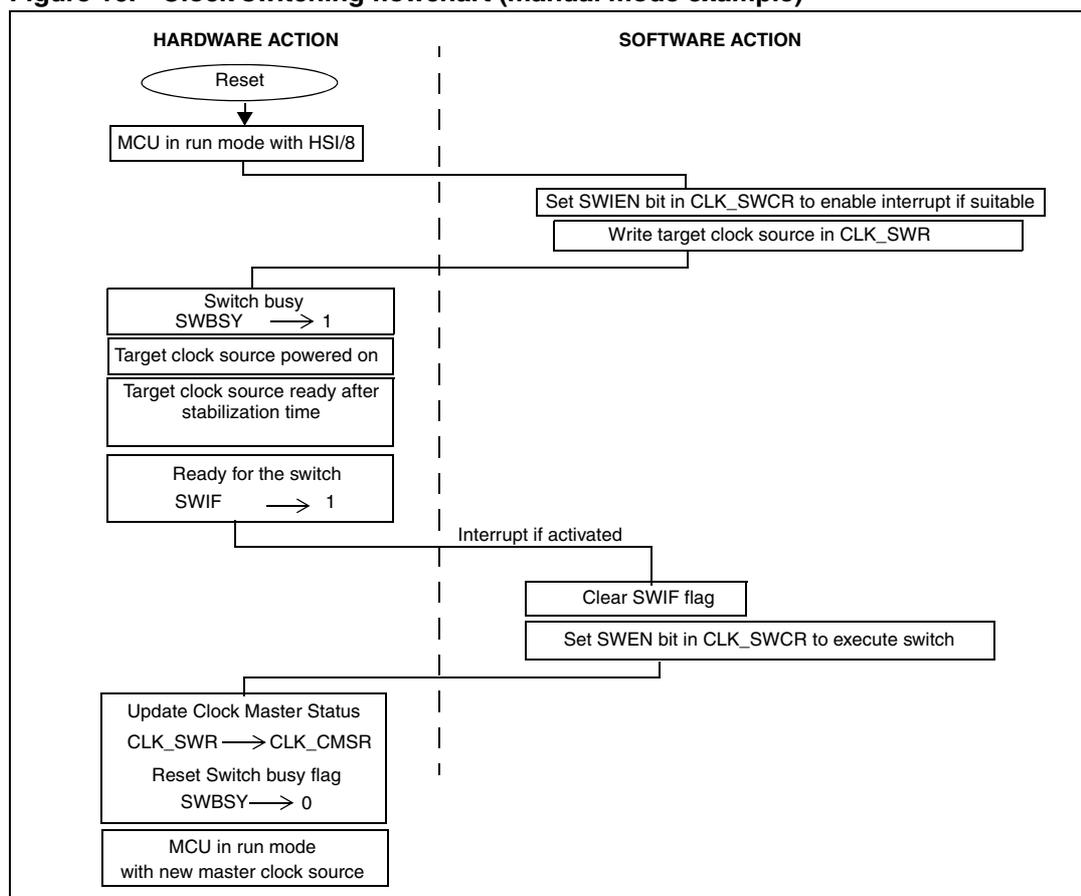


Figure 16. Clock switching flowchart (manual mode example)



8.3 Low speed clock selection

The Low speed clock source for the AWU or the Independent Watchdog can be LSI or HSE divided according to the CKAWUSEL option bit. Refer to option bytes section in the datasheet.

The division factor for HSE has to be programmed in the HSEPRSC[1:0] option bits Refer to in the option bytes section of the datasheet. The goal is to get 128 kHz at the output of the HSE prescaler.

8.4 CPU clock divider

The CPU clock (f_{CPU}) is derived from the master clock (f_{MASTER}), divided by a factor programmed in the CPUDIV[2:0] bits in the *Clock divider register (CLK_CKDIVR)*. Seven division factors (1 to 128 in steps of power of 2) can be selected. Refer to *Figure 13*.

The f_{CPU} signal is the clock for both the CPU and the Window Watchdog.

8.5 Peripheral clock gating (PCG)

Gating the clock to unused peripherals helps reduce power consumption. Peripheral clock Gating (PCG) mode allows you to selectively enable or disable the f_{MASTER} clock connection to the following peripherals at any time in run mode:

- ADC
- I2C
- AWU (register clock, not counter clock)
- SPI
- TIM[4:1]
- UART
- CAN (register clock, not CAN clock)

After a device reset, all peripheral clocks are enabled. You can disable the clock to any peripheral by clearing the corresponding PCKEN bit in the *Peripheral clock gating register 1 (CLK_PCKENR1)* and in the *Peripheral clock gating register 2 (CLK_PCKENR2)*. But you have to disable properly the peripheral using the appropriate bit, before stopping the corresponding clock.

To enable a peripheral, you must first enable the corresponding PCKEN bit in the CLK_PCKENR registers and then set the peripheral enable bit in the peripheral's control registers.

The AWU counter is driven by an internal or external clock (LSI or HSE) independent from f_{MASTER} , so that it continues to run even if the register clock to this peripheral is switched off.

8.6 Clock security system (CSS)

The Clock Security System (CSS) monitors HSE crystal clock source failures. When f_{MASTER} depends on HSE crystal, i.e. when HSE is selected, if the HSE clock fails due to a broken or disconnected resonator or any other reason, the clock controller activates a stall-safe recovery mechanism by automatically switching f_{MASTER} to the auxiliary clock source (HSI/8). Once selected the auxiliary clock source remains enabled until the MCU is reset.

You enable the clock security system by setting the CSSEN bit in the *Clock security system register (CLK_CSSR)*. For safety reason, once CSS is enabled it cannot be disabled until the next reset.

The following conditions must be met so that the CSS can detect HSE quartz crystal failures:

- HSE crystal on: (HSEEN=1 in the *External clock register (CLK_ECKR)*)
- HSE oscillator in quartz crystal configuration (EXTCLK option bit is set)
- CSS function enabled: (CSSEN=1 in the CLK_CSSR register)

If HSE is the current clock master when a failure is detected, the CSS performs the following actions:

- The CSSD bit is set in the CLK_CSSR register and an interrupt is generated if the CSSIEN bit is set.
- The *Clock master status register (CLK_CMSR)*, *Clock master switch register (CLK_SWR)* register and the HSIDIV[1:0] bits in the *Clock divider register (CLK_CKDIVR)* are set to their reset values (CKM[7:0]= SWI[7:0]=E1h). HSI/8 becomes the master clock.
- The HSIEN bit in the *Internal clock register (CLK_ICKR)* register is set (HSI on).
- The HSEEN bit in the *External clock register (CLK_ECKR)* is cleared (HSE off)
- The AUX bit is set to indicate that the HSI/8 auxiliary clock source is forced.

You can clear the CSSD bit by software but the AUX bit is cleared only by reset.

To select a faster clock speed, you can modify the HSIDIV[1:0] bits in the CLK_CKDIVR register after the CSSD bit in the CLK_CSSR register is cleared.

If HSE is not the current clock master when a failure is detected, the master clock is not switched to the auxiliary clock and none of the above actions are performed except:

- The HSEEN bit is cleared in the CLK_ECKR register, HSE is then switched OFF
- The CSSD bit is set in the CLK_CSSR register and interrupt is generated if CSSDIE is also set, it can be cleared by software.

If HSE is not the current clock master and the master clock switch to HSE is ongoing, the SWBSY bit in the CLK_SWCR register must be cleared by software before clearing the CSSD bit.

If HSE is selected by CCOSEL to be in output mode (see *Clock-out capability (CCO)*) when a failure is detected, the selection is automatically changed to force HSI (HSIDIV) instead of HSE.

8.7 Clock-out capability (CCO)

The configurable Clock Output (CCO) capability allows you to output a clock on the external CCO pin. You can select one of 6 clock signals as CCO clock:

- f_{HSE}
- f_{HSI}
- f_{HSIDIV}
- f_{LSI}
- f_{MASTER}
- f_{CPU} (with current prescaling selection)

Note: 50% duty cycle is not guaranteed on all possible prescaled values

The selection is controlled by the CCOSEL[3:0] bits in the [Configurable clock output register \(CLK_CCOR\)](#).

The user has to select first the desired clock for the dedicated I/O pin (see Pin Description chapter). This I/O must be set at 1 in the corresponding Px_CR1 register to be set as input with pull-up or push-pull output.

The sequence to really output the chosen clock starts with CCOEN=1 in [Configurable clock output register \(CLK_CCOR\)](#).

The CCOBSY is set to indicate that the Configurable Clock Output system is operating. As long as the CCOBSY bit is set, the CCOSEL bits are write protected.

The CCO automatically activates the target oscillator if needed. The CCORDY bit is set when the chosen clock is ready.

To disable the clock output the user has to clear the CCOEN bit. Both CCOBSY and CCORDY remain at 1 till the shut down is completed. The time between the clear of CCOEN and the reset of the two flags can be relatively long, for instance in case the selected clock output is very slow compared to f_{CPU} .

8.8 CLK interrupts

The following interrupts can be generated by the clock controller:

- Master clock source switch event
- Clock Security System event

Both interrupts are individually maskable.

Table 8. CLK interrupt requests

Interrupt event	Event flag	Enable control bit	Exit from Wait	Exit from Halt
CSS event	CSSD	CSSDIE	Yes	No
Master clock switch event	SWIF	SWIEN	Yes	No

8.9 CLK register description

8.9.1 Internal clock register (CLK_ICKR)

Address offset: 0x00

Reset value: 0x01

7	6	5	4	3	2	1	0
Reserved		REGAH	LSIRDY	LSIEN	FHW	HSIRDY	HSIEN
		rw	r	rw	rw	r	rw

Bits 7:6 Reserved, must be kept cleared.

Bit 5 **REGAH**: Regulator power off in Active Halt mode

This bit is set and cleared by software. When it is set, the main voltage regulator is powered off as soon as the MCU enters Active Halt mode, so the wakeup time is longer.

- 0: MVR regulator ON in active halt mode
- 1: MVR regulator OFF in active halt mode

Bit 4 **LSIRDY**: Low speed internal oscillator ready

This bit is set and cleared by hardware.

- 0: LSI clock not ready
- 1: LSI clock ready

Bit 3 **LSIEN**: Low speed internal RC oscillator enable

This bit is set and cleared by software. It is set by hardware whenever the LSI oscillator is required, for example:

- When switching to the LSI clock (see CLK_SWR register)
- When LSI is selected as the active CCO source (see CLK_CCOR register)
- When BEEP is enabled (BEEPEN bit set in the BEEP_CSR register)
- When LSI measurement is enabled (MSR bit set in the AWU_CSR register)

It cannot be cleared when LSI is selected as master clock source (CLK_CMSR register), as active CCO source or as clock source for the AWU peripheral or independent Watchdog.

- 0: Low-speed internal RC off
- 1: Low-speed internal RC on

Bit 2 **FHWU**: Fast wakeup from Halt/Active Halt modes

This bit is set and cleared by software.

- 0: Fast wakeup from Halt/Active Halt modes disabled
- 1: Fast wakeup from Halt/Active Halt modes enabled

Bit 1 **HSIRDY**: High speed internal oscillator ready

This bit is set and cleared by hardware.

- 0: HSI clock not ready
- 1: HSI clock ready

Bit 0 HSIEN: High speed internal RC oscillator enable

This bit is set and cleared by software. It is set by hardware whenever the HSI oscillator is required, for example:

- When activated as safe oscillator by the CSS
- When switching to HSI clock (see CLK_SWR register)
- When HSI is selected as the active CCO source (see CLK_CCOR register)

It cannot be cleared when HSI is selected as clock master (CLK_CMSR register), as active CCO source or if the safe oscillator (AUX) is enabled.

0: High-speed internal RC off

1: High-speed internal RC on

8.9.2 External clock register (CLK_ECKR)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved						HSERDY	HSEEN
						r	rw

Bits 7:2 Reserved, must be kept cleared.

Bit 1 **HSERDY**: High speed external crystal oscillator ready

This bit is set and cleared by hardware.

0: HSE clock not ready

1: HSE clock ready (HSE clock is stabilized and available)

Bit 0 **HSEEN**: High speed external crystal oscillator enable

This bit is set and cleared by software. It can be used to switch the external crystal oscillator on or off. It is set by hardware in the following cases:

- When switching to HSE clock (see CLK_SWR register)
- When HSE is selected as the active CCO source (see CLK_CCOR register)

It cannot be cleared when HSE is selected as clock master (indicated in CLK_CMSR register) or as the active CCO source.

0: HSE clock off

1: HSE clock on

8.9.3 Clock master status register (CLK_CMSR)

Address offset: 0x03

Reset value: 0xE1

7	6	5	4	3	2	1	0
CKM[7:0]							
r	r	r	r	r	r	r	r

Bits 7:0 **CKM[7:0]**: Clock master status bits

These bits are set and cleared by hardware. They indicate the currently selected master clock source. An invalid value occurring in this register will automatically generate an MCU reset.

0xE1: HSI selected as master clock source (reset value)

0xD2: LSI selected as master clock source (only if LSI_EN option bit is set)

0xB4: HSE selected as master clock source

8.9.4 Clock master switch register (CLK_SWR)

Address offset: 0x04

Reset value: 0xE1

7	6	5	4	3	2	1	0
SWI[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **SWI[7:0]**: Clock master selection bits

These bits are written by software to select the master clock source. Its contents are write protected while a clock switch is ongoing (while the SWBSY bit is set). They are set to the reset value (HSI) if the AUX bit is set in the CLK_CSSR register. If Fast Halt wakeup mode is selected (FHW bit = 1 in CLK_ICKR register) then these bits are set by hardware to E1h (HSI selected) when resuming from Halt/Active halt mode.

0xE1: HSI selected as master clock source (reset value)

0xD2: LSI selected as master clock source (only if LSI_EN option bit is set)

0xB4: HSE selected as master clock source

8.9.5 Switch control register (CLK_SWCR)

Address offset: 0x05

Reset value: undefined

7	6	5	4	3	2	1	0
Reserved				SWIF	SWIEN	SWEN	SWBSY
				rc_w0	rw	rw	rw

Bits 7:4 Reserved, must be kept cleared.

Bit 3 **SWIF**: Clock switch interrupt flag

This bit is set by hardware and cleared by software writing 0. Its meaning depends on the status of the SWEN bit. Refer to [Figure 15](#) and [Figure 16](#).

- **In manual switching mode (SWEN=0):**
 - 0: Target clock source not ready
 - 1: Target clock source ready
- **In automatic switching mode (SWEN=1):**
 - 0: No clock switch event occurred
 - 1: Clock switch event occurred

Bit 2 **SWIEN**: Clock switch interrupt enable

This bit is set and cleared by software.

- 0: Clock switch interrupt disabled
- 1: Clock switch interrupt enabled

Bit 1 **SWEN**: Switch start/stop

This bit is set and cleared by software. Writing a 1 to this bit enables switching the master clock to the source defined in the CLK_SWR register.

- 0: Disable clock switch execution
- 1: Enable clock switch execution

Bit 0 **SWBSY**: Switch busy

This bit is set and cleared by hardware. It can be cleared by software to reset the clock switch process.

- 0: No clock switch ongoing
- 1: Clock switch ongoing

8.9.6 Clock divider register (CLK_CKDIVR)

Address offset: 0x06

Reset value: 0x18

7	6	5	4	3	2	1	0
Reserved			HSIDIV[1:0]		CPUDIV[2:0]		
			rw	rw	rw	rw	rw

Bits 7:5 Reserved, must be kept cleared.

Bits 4:3 **HSIDIV[1:0]**: High speed internal clock prescaler

These bits are written by software to define the HSI prescaling factor.

- 00: $f_{HSI} = f_{HSI\ RC\ output}$
- 01: $f_{HSI} = f_{HSI\ RC\ output}/2$
- 10: $f_{HSI} = f_{HSI\ RC\ output}/4$
- 11: $f_{HSI} = f_{HSI\ RC\ output}/8$

Bits 2:0 **CPUDIV[2:0]**: CPU clock prescaler

These bits are written by software to define the CPU clock prescaling factor.

- 000: $f_{CPU} = f_{MASTER}$
- 001: $f_{CPU} = f_{MASTER}/2$
- 010: $f_{CPU} = f_{MASTER}/4$
- 011: $f_{CPU} = f_{MASTER}/8$
- 100: $f_{CPU} = f_{MASTER}/16$
- 101: $f_{CPU} = f_{MASTER}/32$
- 110: $f_{CPU} = f_{MASTER}/64$
- 111: $f_{CPU} = f_{MASTER}/128$

8.9.7 Peripheral clock gating register 1 (CLK_PCKENR1)

Address offset: 0x07

Reset value: 0xFF

7	6	5	4	3	2	1	0
PCKEN1[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **PCKEN1[7:0]**: Peripheral clock enable

These bits are written by software to enable or disable the f_{MASTER} clock to the corresponding peripheral. See [Table 9](#)

0: f_{MASTER} to peripheral disabled

1: f_{MASTER} to peripheral enabled

Table 9. Peripheral clock gating bits

Control bit	Peripheral
PCKEN17	TIM1
PCKEN16	TIM3
PCKEN15	TIM2
PCKEN14	TIM4
PCKEN13	UART2/3
PCKEN12	UART1
PCKEN11	SPI
PCKEN10	I ² C

8.9.8 Peripheral clock gating register 2 (CLK_PCKENR2)

Address offset: 0x0B

Reset value: 0xFF

7	6	5	4	3	2	1	0
PCKEN2[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **PCKEN2[7:0]**: Peripheral clock enable

These bits are written by software to enable or disable the f_{MASTER} clock to the corresponding peripheral. See [Table 9](#)

0: f_{MASTER} to peripheral disabled

1: f_{MASTER} to peripheral enabled

Table 10. Peripheral clock gating bits

Control bit	Peripheral
PCKEN27	CAN
PCKEN26	Reserved
PCKEN25	Reserved
PCKEN24	Reserved
PCKEN23	ADC
PCKEN22	AWU
PCKEN21	Reserved
PCKEN20	Reserved

8.9.9 Clock security system register (CLK_CSSR)

Address offset: 0x08

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved				CSSD	CSSDIE	AUX	CSSEN
				rc_w0	rw	r	rwo

Bits 7:4 Reserved, must be kept cleared.

Bit 3 **CSSD**: Clock security system detection

This bit is set by hardware and cleared by software writing 0.

0: CSS is OFF or no HSE crystal clock disturbance detected.

1: HSE crystal clock disturbance detected.

Bit 2 **CSSDIE**: Clock security system detection interrupt enable

This bit is set and cleared by software.

0: Clock security system interrupt disabled

1: Clock security system interrupt enabled

Bit 1 **AUX**: Auxiliary oscillator connected to master clock

This bit is set and cleared by hardware.

0: Auxiliary oscillator is OFF.

1: Auxiliary oscillator (HSI/8) is on and selected as current clock master source.

Bit 0 **CSSEN**: Clock security system enable

This bit can be read many times and be written once-only by software.

0: Clock security system off

1: Clock security system on

8.9.10 Configurable clock output register (CLK_CCOR)

Address offset: 0x09

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	CCOBSY	CCORDY	CCOSEL[3:0]				CCOEN
	r	r	rw	rw	rw	rw	rw

Bit 7 **Reserved**, must be kept cleared.

Bit 6 **CCOBSY**: Configurable clock output busy

This bit is set and cleared by hardware. It indicates that the selected CCO clock source is being switched-on and stabilized. While CCOBSY is set, the CCOSEL bits are write-protected. CCOBSY remains set until the CCO clock is enabled.

0: CCO clock not busy

1: CCO clock busy

Bit 5 **CCORDY**: Configurable clock output ready

This bit is set and cleared by hardware. It indicates that the CCO clock is being output.

0: CCO clock not available

1: CCO clock available

Bits 4:1 **CCOSEL[3:0]**: Configurable clock output selection.

These bits are written by software to select the source of the output clock available on the CLK_CCO pin. They are write-protected when CCOBSY is set.

0000: f_{HSIDIV}

0001: f_{LSI}

0010: f_{HSE}

0011: Reserved

0100: f_{CPU}

0101: $f_{CPU}/2$

0110: $f_{CPU}/4$

0111: $f_{CPU}/8$

1000: $f_{CPU}/16$

1001: $f_{CPU}/32$

1010: $f_{CPU}/64$

1011: f_{HSI}

1100: f_{MASTER}

1101: f_{CPU}

1110: f_{CPU}

1111: f_{CPU}

Bit 0 **CCOEN**: Configurable clock output enable

This bit is set and cleared by software.

0: CCO clock output disabled

1: CCO clock output enabled

8.9.11 CAN external clock control register (CLK_CANCCR)

Address offset: 0x0B

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved					CANDIV[2:0]		
					rw	rw	rw

Bits 7:0 **CANDIV[2:0]**: External CAN clock divider

These bits are written by software to define the divider for the external CAN clock. See [Section 23.9: Clock system on page 373](#) for more details.

000: External CAN clock = $f_{HSE}/1$ (reset value)

001: External CAN clock = $f_{HSE}/2$

...

111: External CAN clock = $f_{HSE}/8$

8.9.12 HSI clock calibration trimming register (CLK_HSITRIMR)

Address offset: 0x0C

Reset value: undefined

7	6	5	4	3	2	1	0
Reserved				HSITRIM[3:0]			
				rw	rw	rw	rw

Bits 7:3 Reserved, must be kept cleared.

Bits 2:0 **HSITRIM[3:0]** HSI trimming value

These bits are written by software to fine tune the HSI calibration.

Note: In high density devices only bits 2:0 are available.

In medium and low density devices bits 3:0 or 2:0 are available, depending on the option byte configuration (refer to datasheet).

8.9.13 SWIM clock control register (CLK_SWIMCCR)

Address offset: 0x0D

Reset value: undefined

7	6	5	4	3	2	1	0
Reserved							SWIMCLK
							rw

Bits 7:1 Reserved, must be kept cleared.

Bit 0 **SWIMCLK** SWIM clock divider

This bit is set and cleared by software.

0: SWIM clock divided by 2

1: SWIM clock not divided by 2

8.10 CLK register map

Table 11. CLK register map and reset values

Address Offset	Register Name	7	6	5	4	3	2	1	0
0x00	CLK_ICKR Reset value	- 0	- 0	REGAH 0	LSIRDY 0	LSIEN 0	FHWU 0	HSIRDY 0	HSIEN 1
0x01	CLK_ECKR Reset value	- 0	- 0	- 0	- 0	- 0	- 0	HSERDY 0	HSEEN 0
0x02	Reserved area (1 byte)								
0x03	CLK_CMSR Reset value	CKM7 1	CKM6 1	CKM5 1	CKM4 0	CKM3 0	CKM2 0	CKM1 0	CKM0 1
0x04	CLK_SWR Reset value	SWI7 1	SWI6 1	SWI5 1	SWI4 0	SWI3 0	SWI2 0	SWI1 0	SWI0 1
0x05	CLK_SWCR Reset value	- x	- x	- x	- x	SWIF 0	SWIEN 0	SWEN 0	SWBSY 0
0x06	CLK_CKDIVR Reset value	- 0	- 0	- 0	HSIDIV1 1	HSIDIV0 1	CPUDIV2 0	CPUDIV12 0	CPUDIV0 0
0x07	CLK_PCKENR1 Reset value	PCKEN17 1	PCKEN16 1	PCKEN15 1	PCKEN14 1	PCKEN13 1	PCKEN12 1	PCKEN11 1	PCKEN10 1
0x08	CLK_CSSR Reset value	- 0	- 0	- 0	- 0	CSSD 0	CSSDIE 0	AUX 0	CSSEN 0
0x09	CLK_GCOR Reset value	- 0	CCOBSY 0	CCORDY 0	CCOSEL3 0	CCOSEL2 0	CCOSEL1 0	CCOSEL0 0	CCOEN 0
0x0A	CLK_PCKENR2 Reset value	PCKEN27 1	PCKEN26 1	PCKEN25 1	PCKEN24 1	PCKEN23 1	PCKEN22 1	PCKEN21 1	PCKEN20 1
0x0B	CLK_CANCCR Reset value	- x	- x	- x	- x	- x	CANDIV2 0	CANDIV1 0	CANDIV0 0
0x0C	CLK_HSITRIMR Reset value	- x	- x	- x	- x	- x	HSITRIM2 0	HSITRIM1 0	HSITRIM0 0
0x0D	CLK_SWIMCCR Reset value	- x	- x	- x	- x	- x	- 0	- 0	SWIMCLK 0

9 Power management

By default, after a system or power reset, the microcontroller is in Run mode. In this mode the CPU is clocked by f_{CPU} and executes the program code, the system clocks are distributed to the active peripherals and the microcontroller is drawing full power.

While in Run mode, still keeping the CPU running and executing code, the application has several ways to reduce power consumption, such as:

- Slowing down the system clocks
- Gating the clocks to individual peripherals when they are unused
- Switching off any unused analog functions

However, when the CPU does not need to be kept running, three dedicated low power modes can be used:

- Wait
- Active Halt (configurable for slow or fast wakeup)
- Halt (configurable for slow or fast wakeup)

You can select one of these three modes and configure them to obtain the best compromise between lowest power consumption, fastest start-up time and available wakeup sources.

9.1 General considerations

Low power consumption features are generally very important for all types of application for energy saving. Ultra low power features are especially important for mobile applications to ensure long battery lifetimes. This is also crucial for environmental protection.

In a silicon chip there are two kind of consumption:

- **Static power consumption** which is due to analog polarization and leakages. This so small, it is only significant in Halt and Active Halt modes (refer to [Section 9.3: Low power modes](#)).
- **Dynamic power consumption** which comes from running the digital parts of the chip. It depends on V_{DD} , clock frequency and load capacitors.

In a microcontroller device the consumption depends on:

- V_{DD} supply voltage
- Analog performance
- MCU size or number of digital gates (leakages and load capacitors)
- Clock frequency
- Number of active peripherals
- Available low power modes and low power levels

Device processing performance is also very important, as this allows the application to minimize the time spent in Run mode and maximize the time in low power mode.

Using the MCU's flexible power management features, you can obtain a range of significant power savings while the system is running or able to resume operations quickly.

9.2 Clock management for low consumption

9.2.1 Slowing down the system clock

In Run mode, choosing the oscillator to be used as the system clock source is very important to ensure the best compromise between performance and consumption. The selection is done by programming the clock controller registers. Refer to the [Clock control \(CLK\)](#) section.

As a further measure, f_{CPU} can be reduced by writing to the CPUDIV[2:0] bits in the [Clock divider register \(CLK_CKDIVR\)](#). This reduces the speed of the CPU and consequently the power consumption of the MCU. The other peripherals (clocked by f_{MASTER}) are not affected by this setting.

To return to full speed at any time in Run mode, clear the CPUDIV[2:0] bits.

9.2.2 Peripheral clock gating

For additional power saving you can use Peripheral Clock Gating (PCG). This can be done at any time by selectively enabling or disabling the f_{MASTER} clock connection to individual peripherals. Refer to the [Clock control \(CLK\)](#) section.

These settings are effective in both Run and Wait modes.

9.3 Low power modes

The main characteristics of the four low power modes are summarized in [Table 12](#).

Table 12. Low power mode management

Mode (consumption level)	Main voltage regulator	Oscillators	CPU	Peripherals	Wakeup trigger event
Wait (-)	ON	ON	OFF	ON ⁽¹⁾	All internal interrupts (including AWU) or external interrupts, reset
Active Halt (--)	ON	OFF except LSI (or HSE)	OFF	Only AWU and IWDG if activated	AWU or external ⁽²⁾ interrupts, reset
Active Halt with MVR auto power off (---)	OFF (Low Power Regulator ON)	OFF except LSI only	OFF	Only AWU and IWDG if activated	AWU or external ⁽²⁾ interrupts, reset
Halt (----)	OFF (Low Power Regulator ON)	OFF	OFF	OFF	External ⁽²⁾ interrupts, reset

1. If the peripheral clock is not disabled by Peripheral Clock Gating function.
2. Including communication peripheral interrupts (see interrupt vector table).

9.3.1 Wait mode

Wait mode is entered from Run mode by executing a WFI (Wait For Interrupt) instruction: this stops the CPU but allows the other peripherals and interrupt controller to continue to run. Therefore the consumption decreases accordingly. Wait mode can be combined with PCG (peripheral clock gating), reduced CPU clock frequency and low mode clock source selection (LSI, HSI) to further reduce the power consumption of the device. Refer to the [Clock control \(CLK\)](#) description.

In Wait mode, all the registers and RAM contents are preserved, the previously defined clock configuration remains unchanged ([Clock master status register \(CLK_CMSR\)](#)).

When an internal or external interrupt request occurs, the CPU wakes-up from Wait mode and resumes processing.

9.3.2 Halt mode

In this mode the master clock is stopped. This means that the CPU and all the peripherals clocked by f_{MASTER} or by derived clocks are disabled. As a result, none of the peripherals are clocked and the digital part of the MCU consumes almost no power.

In Halt mode, all the registers and RAM contents are preserved, by default the clock configuration remains unchanged ([Clock master status register \(CLK_CMSR\)](#)).

The MCU enters Halt mode when a HALT instruction is executed. Wakeup from Halt mode is triggered by an external interrupt, sourced by a GPIO port configured as interrupt input or an Alternate Function pin capable of triggering a peripheral interrupt.

In this mode the MVR regulator is switched off to save power. Only the LPVR regulator (and brown-out reset) is active.

Fast clock wakeup

The HSI RC start-up time is much faster than the HSE crystal start-up time (refer to the Electrical Parameters in the datasheet). Therefore, to optimize the MCU wakeup time, it is recommended to select the HSI clock as the f_{MASTER} clock source before entering Halt mode.

This selection can be done without clock switching using the FHWU bit in the [Internal clock register \(CLK_I CKR\)](#). Refer to the [Clock control \(CLK\)](#) chapter.

9.3.3 Active Halt modes

Active Halt mode is similar to Halt mode except that it does not require an external interrupt for wakeup. It uses the AWU to generate a wakeup event internally after a programmable delay.

In Active Halt mode, the main oscillator, the CPU and almost all the peripherals are stopped. Only the LSI RC or HSE oscillators are running to drive the AWU counters and IWD counter if enabled.

To enter Active Halt mode, first enable the AWU as described in the AWU section. Then execute a HALT instruction.

Main voltage regulator (MVR) auto power-off

By default the main voltage regulator is kept on Active Halt mode. Keeping it active ensures fast wakeup from Active Halt mode. However, the current consumption of the MVR is non-negligible.

To further reduce current consumption, the MVR regulator can be powered off automatically when the MCU enters Active Halt mode. To configure this feature, set the REGAH bit in the [Internal clock register \(CLK_I CKR\)](#) register. In this mode:

- The MCU core is powered only by the LPVR regulator (same as in Halt mode).
- Only the LSI clock source can be used, as the HSE clock current consumption is too high for the LPVR.

The Main voltage regulator is powered on again at wakeup and it requires a longer wakeup time (Refer to the datasheet electrical characteristics section for wakeup timing and current consumption data).

Fast clock wakeup

As described for Halt mode, in order to get the shortest wakeup time, it is recommended to select HSI as the f_{MASTER} clock source. The FHWU bit is also available to save switching time.

A fast wakeup time is very important in Active Halt mode. It supplements the effect of CPU processing performance by helping to minimize the time MCU stays in Run mode between two periods in low power mode and thus reduces the overall average power consumption.

9.4 Additional analog power controls

9.4.1 Fast Flash wakeup from Halt mode

By default the Flash is in Power-down state when the microcontroller enters Halt mode. The current leakage is negligible, resulting in very low consumption in Halt mode. However the Flash wakeup time is relatively slow (several μs).

If you need the application to wakeup quickly from Halt mode, set the HALT bit in [Section 4.9.1: Flash control register 1 \(FLASH_CR1\)](#). This ensures that the Flash is in Standby mode when the microcontroller enters in Halt mode. Its wakeup time is reduced to a few ns. However, in this case the consumption is increased up to several μAs .

Refer to the Electrical characteristics section of the datasheet for more details.

9.4.2 Very low Flash consumption in Active Halt mode

By default, in Active-Halt mode, the Flash remains in operating mode to ensure the fastest wakeup time, however in this case the power consumption is not optimized.

To optimize the power consumption you can set the AHALT bit in Flash control register 1 (FLASH_CR1). This will switch the Flash to Power-down state when entering Active-Halt mode. The consumption decreases but the wakeup time increases up to a few μs .

10 Interrupt controller (ITC)

10.1 ITC introduction

- Management of hardware interrupts
 - External interrupt capability on all I/O pins with dedicated interrupt vector per port and dedicated flag per pin
 - Peripheral interrupt capability
- Management of software interrupt (TRAP)
- Nested or concurrent interrupt management with flexible interrupt priority and level management:
 - Up to 4 software programmable nesting levels
 - Up to 32 interrupt vectors fixed by hardware
 - 2 non maskable events: RESET, TRAP
 - 1 non-maskable top level hardware interrupt (TLI)

This interrupt management is based on:

- Bit I1 and I0 of the CPU Condition Code register (CCR)
- Software priority registers (ITC_SPRx)
- Reset vector address 0x00 8000 at the beginning of program memory. In devices with boot ROM, the Reset initialization routine is programmed in ROM by STMicroelectronics.
- Fixed interrupt vector addresses located at the high addresses of the memory map (0x00 8004 to 0x00 807Ch) sorted by hardware priority order.

10.2 Interrupt masking and processing flow

The interrupt masking is managed by bits I1 and I0 of the CCR register and by the ITC_SPRx registers which set the software priority level of each interrupt vector (see [Table 13](#)). The processing flow is shown in [Figure 17](#).

When an interrupt request has to be serviced:

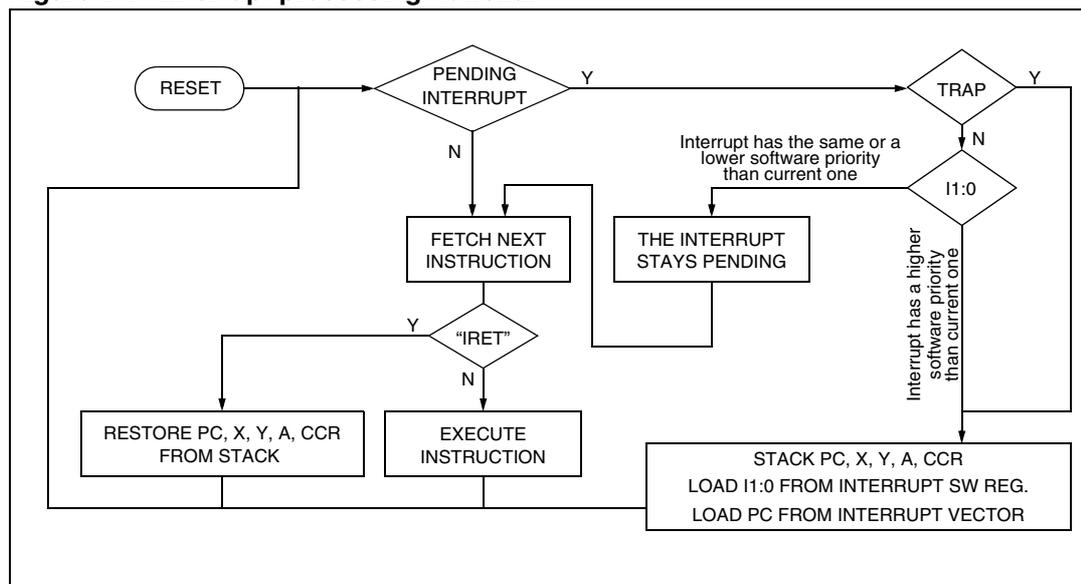
1. Normal processing is suspended at the end of the current instruction execution.
2. The PC, X, Y, A and CCR registers are saved onto the stack.
3. Bits I1 and I0 of CCR register are set according to the values in the ITC_SPRx registers corresponding to the serviced interrupt vector.
4. The PC is then loaded with the interrupt vector of the interrupt to service and the first instruction of the interrupt service routine is fetched (refer to [Table 16: Interrupt mapping](#) for details on vector addresses).

The interrupt service routine should end with the IRET instruction which causes the content of the saved registers to be recovered from the stack. As a consequence of the IRET instruction, bits I1 and I0 are restored from the stack and the program execution resumes.

Table 13. Software priority levels

Software priority	Level	I1	I0
Level 0 (main)	Low ↓ High	1	0
Level 1		0	1
Level 2		0	0
Level 3 (= software priority disabled)		1	1

Figure 17. Interrupt processing flowchart



10.2.1 Servicing pending interrupts

Several interrupts can be pending at the same time. The interrupt to be taken into account is determined by the following two-step process:

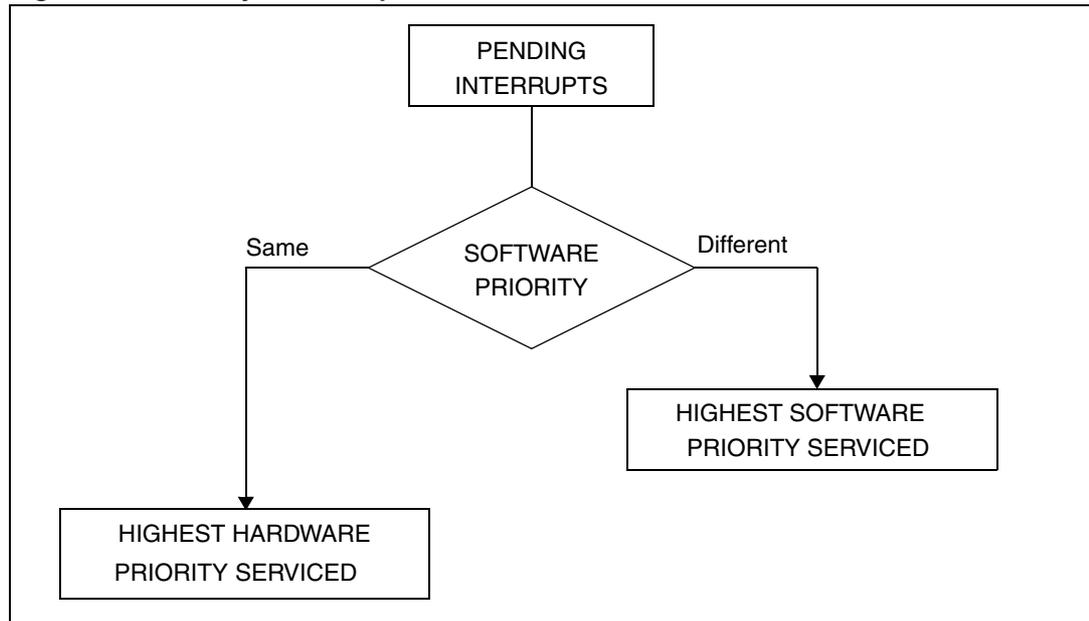
1. The highest software priority interrupt is serviced.
2. If several interrupts have the same software priority then the interrupt with the highest hardware priority is serviced first.

When an interrupt request is not serviced immediately, it is latched and then processed when its software priority combined with the hardware priority becomes the highest one.

- Note:*
- 1 The hardware priority is exclusive while the software one is not. This allows the previous process to succeed with only one interrupt.
 - 2 RESET, TLI and TRAP are considered as having the highest software priority in the decision process.
 - 3 A TLI interrupts all level-3 interrupts including TRAP and RESET.

See [Figure 18](#) for a description of pending interrupt servicing process.

Figure 18. Priority decision process



10.2.2 Interrupt sources

Two interrupt source types are managed by the STM8 interrupt controller:

- Non-maskable interrupts: RESET, TLI and TRAP
- Maskable interrupts: external interrupts or interrupts issued by internal peripherals

Non-maskable interrupt sources

Non-maskable interrupt sources are processed regardless of the state of bits I1 and I0 of the CCR register (see [Figure 17](#)). PC, X, Y, A and CCR registers are stacked only when a TRAP interrupt occurs. The corresponding vector is then loaded in the PC register and bits I1 and I0 of the CCR register are set to disable interrupts (level 3).

- TRAP (non-maskable software interrupt)

This software interrupt source is serviced when the TRAP instruction is executed. It is serviced as a TLI according to the flowchart shown in [Figure 17](#).
A TRAP interrupt does not allow the processor to exit from Halt mode.
- RESET

The RESET interrupt source has the highest STM8 software and hardware priorities. This means that all the interrupts are disabled at the beginning of the reset routine. They must be re-enabled by the RIM instruction (see [Table 15: Dedicated interrupt instruction set](#)).
A RESET interrupt allows the processor to exit from Halt mode.

See RESET chapter for more details on RESET interrupt management.
- TLI (top level hardware interrupt)

This hardware interrupt occurs when a specific edge is detected on the corresponding TLI input.

Caution: A TRAP instruction must not be used in a TLI service routine.

Maskable interrupt sources

Maskable interrupt vector sources are serviced if the corresponding interrupt is enabled and if its own interrupt software priority in ITC_SPRx registers is higher than the one currently being serviced (I1 and I0 in CCR register). If one of these two conditions is not met, the interrupt is latched and remains pending.

- **External interrupts**

External interrupts can be used to wake up the MCU from Halt mode. The device sensitivity to external interrupts can be selected by software through the External Interrupt Control registers (EXTI_CRx).

When several input pins connected to the same interrupt line are selected simultaneously, they are logically ORed.

When external level-triggered interrupts are latched, if the given level is still present at the end of the interrupt routine, the interrupt remains activated except if it has been inactivated in the routine.

- **Peripheral interrupts**

Most peripheral interrupts cause the MCU to wake up from Halt mode. See [Table 16: Interrupt mapping](#) for the list.

A peripheral interrupt occurs when a specific flag is set in the peripheral status register and the corresponding enable bit is set in the peripheral control register.

The standard sequence for clearing a peripheral interrupt performs an access to the status register followed by a read or write to an associated register. The clearing sequence resets the internal latch. A pending interrupt (that is an interrupt waiting to be serviced) is therefore lost when the clear sequence is executed.

10.3 Interrupts and low power modes

All interrupts allow the processor to exit from Wait mode.

Only external and other specific interrupts allow the processor to exit from Halt mode (see Wakeup from Halt and Wakeup from Active Halt columns in [Table 16: Interrupt mapping](#)).

When several pending interrupts are present while waking up from Halt mode, the first interrupt serviced can only be an interrupt with exit-from-Halt mode capability. It is selected through the decision process shown in [Figure 18](#). If the highest priority pending interrupt cannot wake up the device from Halt mode, it will be serviced next.

If any internal or external interrupt (from a timer for example) occurs while the HALT instruction is executing, the HALT instruction is completed but the interrupt invokes the wakeup process immediately after the HALT instruction has finished executing.

In this case the MCU is actually waking up from Halt mode to Run mode, with the corresponding delay of t_{WUH} as specified in the datasheet.

10.4 Activation level/low power mode control

The MCU activation level is configured by programming the AL bit in the CFG_GCR register (see [Section 1.3: Global configuration register \(CFG_GCR\) on page 26](#)).

This bit is used to control the low power modes of the MCU. In very low power applications, the MCU spends most of the time in WFI/Halt mode and is woken up (through interrupts) at specific moments in order to execute a specific task. Some of these recurring tasks are

short enough to be treated directly in an ISR (Interrupt Service Routine), rather than going back to the main program. To cover this case, you can set the AL bit before going to low power (by executing WFI/HALT instruction), then the interrupt routine returns directly to low power mode. The run time/ISR execution is reduced due to the fact that the register context is saved only on the first interrupt.

In a very simple application all the operations can be therefore executed in ISR only. In more complex ones, an interrupt routine may take the decision to relaunch the main program by simply resetting the AL bit.

For example, an application may need to be woken up by the Auto wakeup Unit (AWU) every 50 ms in order to check the status of some pins/sensors/push-buttons. Most of the time, as these pins are not active, the MCU can return to low-power without running the main program. If one of these pins is active, the ISR will decide to launch the main program and will do this by resetting the AL bit.

10.5 Concurrent and nested interrupt management

STM8 devices feature two interrupt management modes:

- Concurrent mode
- Nested mode

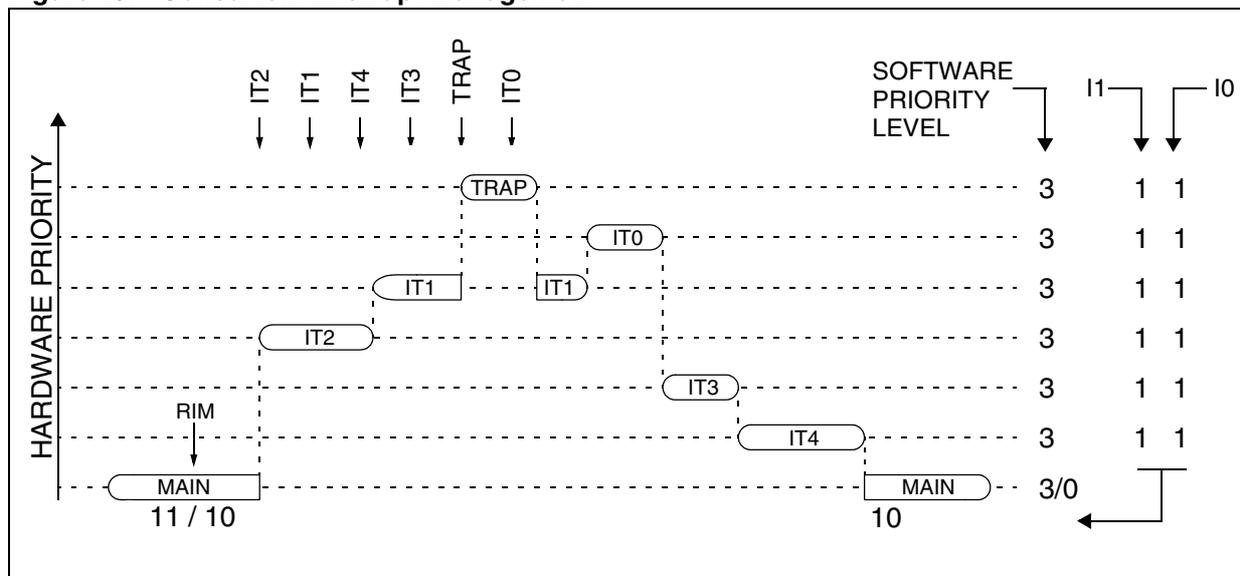
10.5.1 Concurrent interrupt management mode

In this mode, all interrupts are interrupt priority level 3 so that none of them can be interrupted, except by a TLI, RESET, or TRAP.

The hardware priority is given in the following order from the lowest to the highest priority, that is: MAIN, IT4, IT3, IT2, IT1, IT0, TRAP/TLI (same priority), and RESET.

Figure 19 shows an example of concurrent interrupt management mode.

Figure 19. Concurrent interrupt management



10.5.2 Nested interrupt management mode

In this mode, interrupts are allowed during interrupt routines. This mode is activated as soon as an interrupt priority level lower than level 3 is set.

The hardware priority is given in the following order from the lowest to the highest priority, that is: MAIN, IT4, IT3, IT2, IT1, IT0, and TRAP.

The software priority is configured for each interrupt vector by setting the corresponding I1_x and I0_x bits of the ITC_SPRx register. I1_x and I0_x bits have the same meaning as I1 and I0 bits of the CCR register (see [Table 14](#)).

Level 0 can not be programmed (I1_x=1, I0_x=0). In this case, the previously stored value is kept. For example: if previous value is CFh, and programmed value equals 64h, the result is 44h.

The RESET and TRAP vectors have no software priorities. When one is serviced, bits I1 and I0 of the CCR register are both set.

Caution: If bits I1_x and I0_x are modified while the interrupt x is executed, the device operates as follows: if the interrupt x is still pending (new interrupt or flag not cleared) and the new software priority is higher than the previous one, then the interrupt x is re-entered. Otherwise, the software priority remains unchanged till the next interrupt request (after the IRET of the interrupt x).

During the execution of an interrupt routine, the HALT, POPCC, RIM, SIM and WFI instructions change the current software priority till the next IRET instruction or one of the previously mentioned instructions is issued. See [Section 10.7](#) for the list of dedicated interrupt instructions.

[Figure 20](#) shows an example of nested interrupt management mode.

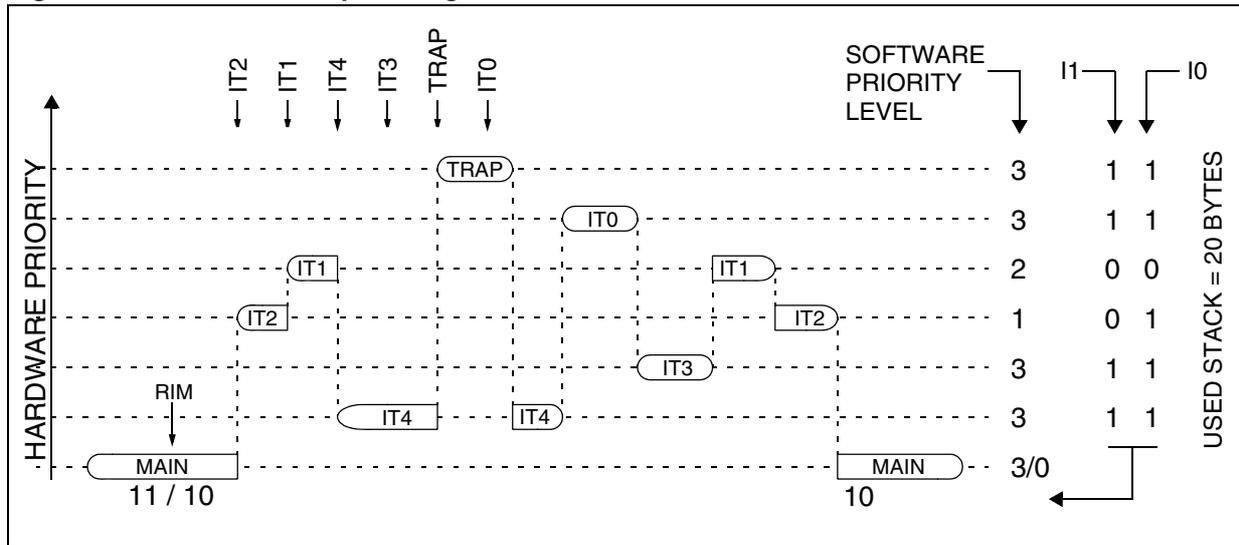
Warning: A stack overflow may occur without notifying the software of the failure.

Table 14. Vector address map versus software priority bits

Vector address	ITC_SPRx bits
0x00 8008h	I1_0 and I0_0 bits ⁽¹⁾
0x00 800Ch	I1_1 and I0_1 bits
...	...
0x00 807Ch	I1_29 and I0_29 bits

1. ITC_SPRx register bits corresponding to the TLI can be read and written. However they are not significant in the interrupt process management.

Figure 20. Nested interrupt management



10.6 External interrupts

Five interrupt vectors are dedicated to external Interrupt events:

- 5 lines on Port A: PA[6:2]
- 8 lines on Port B: PB[7:0]
- 8 lines on Port C: PC[7:0]
- 7 lines on Port D: PD[6:0]
- 8 lines on Port E: PE[7:0]

PD(7) is the Top Level Interrupt source (TLI).

To generate an interrupt, the corresponding GPIO port must be configured in input mode with interrupts enabled. Refer to the register description in the GPIO chapter for details.

The interrupt sensitivity must be configured in the external interrupt control register 1 (EXTI_CR1) and external interrupt control register 2 (EXTI_CR2) (see [Section 10.9.3](#) and [Section 10.9.4](#).)

10.7 Interrupt instructions

Table 15 shows the interrupt instructions.

Table 15. Dedicated interrupt instruction set

Instruction	New description	Function/example	I1	H	I0	N	Z	C
HALT	Entering Halt mode		1		0			
IRET	Interrupt routine return	Pop CCR, A, X, Y, PC	I1	H	I0	N	Z	C
JRM	Jump if I1:0=11 (level 3)	I1:0=11 ?						
JRNM	Jump if I1:0<>11	I1:0<>11 ?						
POP CC	Pop CCR from the Stack	Mem => CCR	I1	H	I0	N	Z	C
RIM	Enable interrupt (level 0 set)	Load I0 in I1:0 of CCR	1		0			
SIM	Disable interrupt (level 3 set)	Load I1 in I1:0 of CCR	1		1			
TRAP	Software trap	Software NMI	1		1			
WFI	Wait for interrupt		1		0			

10.8 Interrupt mapping

Table 16 shows the interrupt mapping.

Table 16. Interrupt mapping

IRQ No.	Source block	Description	Wakeup from Halt mode	Wakeup from Active Halt mode	Vector address
	RESET	Reset	Yes	Yes	0x00 8000
	TRAP	Software interrupt	-	-	0x00 8004
0	TLI	External Top level Interrupt	-	-	0x00 8008
1	AWU	Auto Wake up from Halt	-	Yes	0x00 800C
2	CLK	Clock controller	-	-	0x00 8010
3	EXTI0	Port A external interrupts	Yes	Yes	0x00 8014
4	EXTI1	Port B external interrupts	Yes	Yes	0x00 8018
5	EXTI2	Port C external interrupts	Yes	Yes	0x00 801C
6	EXTI3	Port D external interrupts	Yes	Yes	0x00 8020
7	EXTI4	Port E external interrupts	Yes	Yes	0x00 8024
8	CAN	CAN RX interrupt	Yes	Yes	0x00 8028
9	CAN	CAN TX/ER/SC interrupt	-	-	0x00 802C
10	SPI	End of Transfer	Yes	Yes	0x00 8030
11	TIM1	Update /Overflow/Underflow/Trigger/Break	-	-	0x00 8034
12	TIM1	Capture/Compare	-	-	0x00 8038
13	TIM2	Update /Overflow	-	-	0x00 803C

Table 16. Interrupt mapping (continued)

IRQ No.	Source block	Description	Wakeup from Halt mode	Wakeup from Active Halt mode	Vector address
14	TIM2	Capture/Compare	-	-	0x00 8040
15	TIM3	Update /Overflow	-	-	0x00 8044
16	TIM3	Capture/Compare	-	-	0x00 8048
17	UART1	Tx complete	-	-	0x00 804C
18	UART1	Receive Register DATA FULL	-	-	0x00 8050
19	I2C	I2C interrupt	Yes	Yes	0x00 8054
20	UART2/3	Tx complete	-	-	0x00 8058
21	UART2/3	Receive Register DATA FULL	-	-	0x00 805C
22	ADC	End of Conversion	-	-	0x00 8060
23	TIM4	Update/Overflow	-	-	0x00 8064
24	FLASH	EOP/WR_PG_DIS	-	-	0x00 8068
Reserved					0x00 806C to 0x00 807C

10.9 ITC registers

10.9.1 CPU Condition Code register interrupt bits (CCR)

Address: refer to the general hardware register map table in the datasheet

Reset value: 0x28

7	6	5	4	3	2	1	0
V	-	I1	H	I0	N	Z	C
r	r	rw	r	rw	r	r	r

Bits 5, 3⁽¹⁾ **I[1:0]**: Software Interrupt Priority bits⁽²⁾

These two bits indicate the software priority of the current interrupt request. When an interrupt request occurs, the software priority of the corresponding vector is loaded automatically from the software priority registers (ITC_SPRx).

The I[1:0] bits can be also set/cleared by software using the RIM, SIM, HALT, WFI, IRET or PUSH/POP instructions (see [Figure 20: Nested interrupt management](#)).

I1	I0	Priority	Level
1	0	Level 0 (main)	Low
0	1	Level 1	↓
0	0	Level 2	↓
1	1	Level 3 (= software priority disabled*)	High

1. Refer to the central processing section for details on the other CCR bits.
2. TLI, TRAP and RESET events can interrupt a level-3 program.

10.9.2 Software priority register x (ITC_SPRx)

Address offset: 0x00 to 0x07

Reset value: 0xFF

	7	6	5	4	3	2	1	0
ITC_SPR1	VECT3SPR[1:0]		VECT2SPR[1:0]		VECT1SPR[1:0]		VECT0SPR[1:0]	
ITC_SPR2	VECT7SPR[1:0]		VECT6SPR[1:0]		VECT5SPR[1:0]		VECT4SPR[1:0]	
ITC_SPR3	VECT11SPR[1:0]		VECT10SPR[1:0]		VECT9SPR[1:0]		VECT8SPR[1:0]	
ITC_SPR4	VECT15SPR[1:0]		VECT14SPR[1:0]		VECT13SPR[1:0]		VECT12SPR[1:0]	
ITC_SPR5	VECT19SPR[1:0]		VECT18SPR[1:0]		VECT17SPR[1:0]		VECT16SPR[1:0]	
ITC_SPR6	VECT23SPR[1:0]		VECT22SPR[1:0]		VECT21SPR[1:0]		VECT20SPR[1:0]	
ITC_SPR7	VECT27SPR[1:0]		VECT26SPR[1:0]		VECT25SPR[1:0]		VECT24SPR[1:0]	
ITC_SPR8	Reserved				VECT29SPR[1:0]		VECT28SPR[1:0]	
	rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **VECTxSPR[1:0]**: Vector x Software Priority bits

These eight read/write registers (ITC_SPR1 to ITC_SPR8) are written by software to define the software priority of each interrupt vector.

The list of vectors is given in [Table 14: Vector address map versus software priority bits](#).

Refer to [Section 10.9.1: CPU Condition Code register interrupt bits \(CCR\)](#) for the values to be programmed for each priority.

ITC_SPR1 bits 1:0 are forced to 1 by hardware (TLI)

ITC_SPR8 bits 7:4 are forced to 1 by hardware.

Note: It is forbidden to write 10b (priority level 0). If 10b is written, level 3 (value 11b) is forced by hardware.

10.9.3 External interrupt control register 1 (EXTI_CR1)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
PDIS[1:0]		PCIS[1:0]		PBIS[1:0]		PAIS[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:6 **PDIS[1:0]**: Port D external interrupt sensitivity bits

These bits can only be written when I1 and I0 in the CCR register are both set to 1 (level 3). They define the sensitivity of Port D external interrupts.

- 00: Falling edge and low level
- 01: Rising edge only
- 10: Falling edge only
- 11: Rising and falling edge

Bits 5:4 **PCIS[1:0]**: Port C external interrupt sensitivity bits

These bits can only be written when I1 and I0 in the CCR register are both set to 1 (level 3). They define the sensitivity of Port C external interrupts.

- 00: Falling edge and low level
- 01: Rising edge only
- 10: Falling edge only
- 11: Rising and falling edge

Bits 3:2 **PBIS[1:0]**: Port B external interrupt sensitivity bits

These bits can only be written when I1 and I0 in the CCR register are both set to 1 (level 3). They define the sensitivity of Port B external interrupts.

- 00: Falling edge and low level
- 01: Rising edge only
- 10: Falling edge only
- 11: Rising and falling edge

Bits 1:0 **PAIS[1:0]**: Port A external interrupt sensitivity bits

These bits can only be written when I1 and I0 in the CCR register are both set to 1 (level 3). They define the sensitivity of Port A external interrupts.

- 00: Falling edge and low level
- 01: Rising edge only
- 10: Falling edge only
- 11: Rising and falling edge

10.9.4 External interrupt control register 1 (EXTI_CR2)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved					TLIS	PEIS[1:0]	
					rw	rw	rw

Bits 7:4 Reserved, must be kept cleared.

Bit 2 **TLIS**: Top Level interrupt sensitivity

This bit is set and cleared by software. This bit can be written only when external interrupt is disabled on the corresponding GPIO port (PD7).

- 0: Falling edge
- 1: Rising edge

Bits 1:0 **PEIS[1:0]**: Port E external interrupt sensitivity bits

These bits can only be written when I1 and I0 in the CCR register are both set to 1 (level 3). They define the sensitivity of the Port E external interrupts.

- 00: Falling edge and low level
- 01: Rising edge only
- 10: Falling edge only
- 11: Rising and falling edge

10.9.5 ITC register map and reset values

Table 17. Interrupt register map

Address offset	Register name	7	6	5	4	3	2	1	0
ITC-SPR block⁽¹⁾									
0x00	ITC_SPR1 Reset value	VECT3SPR1 1	VECT3SPR0 1	VECT2SPR1 1	VECT2SPR0 1	VECT1SPR1 1	VECT1SPR0 1	Reserved 1	Reserved 1
0x01	ITC_SPR2 Reset value	VECT7SPR1 1	VECT7SPR0 1	VECT6SPR1 1	VECT6SPR0 1	VECT5SPR1 1	VECT5SPR0 1	VECT4SPR1 1	VECT4SPR0 1
0x02	ITC_SPR3 Reset value	VECT11SPR1 1	VECT11SPR0 1	VECT10SPR1 1	VECT10SPR0 1	VECT9SPR1 1	VECT9SPR0 1	VECT8SPR1 1	VECT8SPR0 1
0x03	ITC_SPR4 Reset value	VECT15SPR1 1	VECT15SPR0 1	VECT14SPR1 1	VECT14SPR0 1	VECT13SPR1 1	VECT13SPR0 1	VECT12SPR1 1	VECT12SPR0 1
0x04	ITC_SPR5 Reset value	VECT19SPR1 1	VECT19SPR0 1	VECT18SPR1 1	VECT18SPR0 1	VECT17SPR1 1	VECT17SPR0 1	VECT16SPR1 1	VECT16SPR0 1
0x05	ITC_SPR6 Reset value	VECT23SPR1 1	VECT23SPR0 1	VECT22SPR1 1	VECT22SPR0 1	VECT21SPR1 1	VECT21SPR0 1	VECT20SPR1 1	VECT20SPR0 1
0x06	ITC_SPR7 Reset value	VECT27SPR1 1	VECT27SPR0 1	VECT26SPR1 1	VECT26SPR0 1	VECT25SPR1 1	VECT25SPR0 1	VECT24SPR1 1	VECT24SPR0 1
0x07	ITC_SPR8 Reset value	-	-	-	-	-	-	VECT28SPR1 1	VECT28SPR0 1
ITC-EXTI block⁽²⁾									
0x00	EXTI_CR1	PDIS1 0	PDIS0 0	PCIS1 0	PCIS0 0	PBIS1 0	PBIS0 0	PAIS1 0	PAIS0 0
0x01	EXTI_CR2	- 0	- 0	0	0	- 0	TLIS 0	PEIS1 0	PEIS0 0

1. The address offsets are expressed for the ITC-SPR block base address (see CPU/SWIM/debug module/interrupt controller registers table in the datasheet).
2. The address offsets are expressed for the ITC-EXTI block base address (see General hardware register map table in the datasheet).

11 General purpose I/O ports (GPIO)

11.1 Introduction

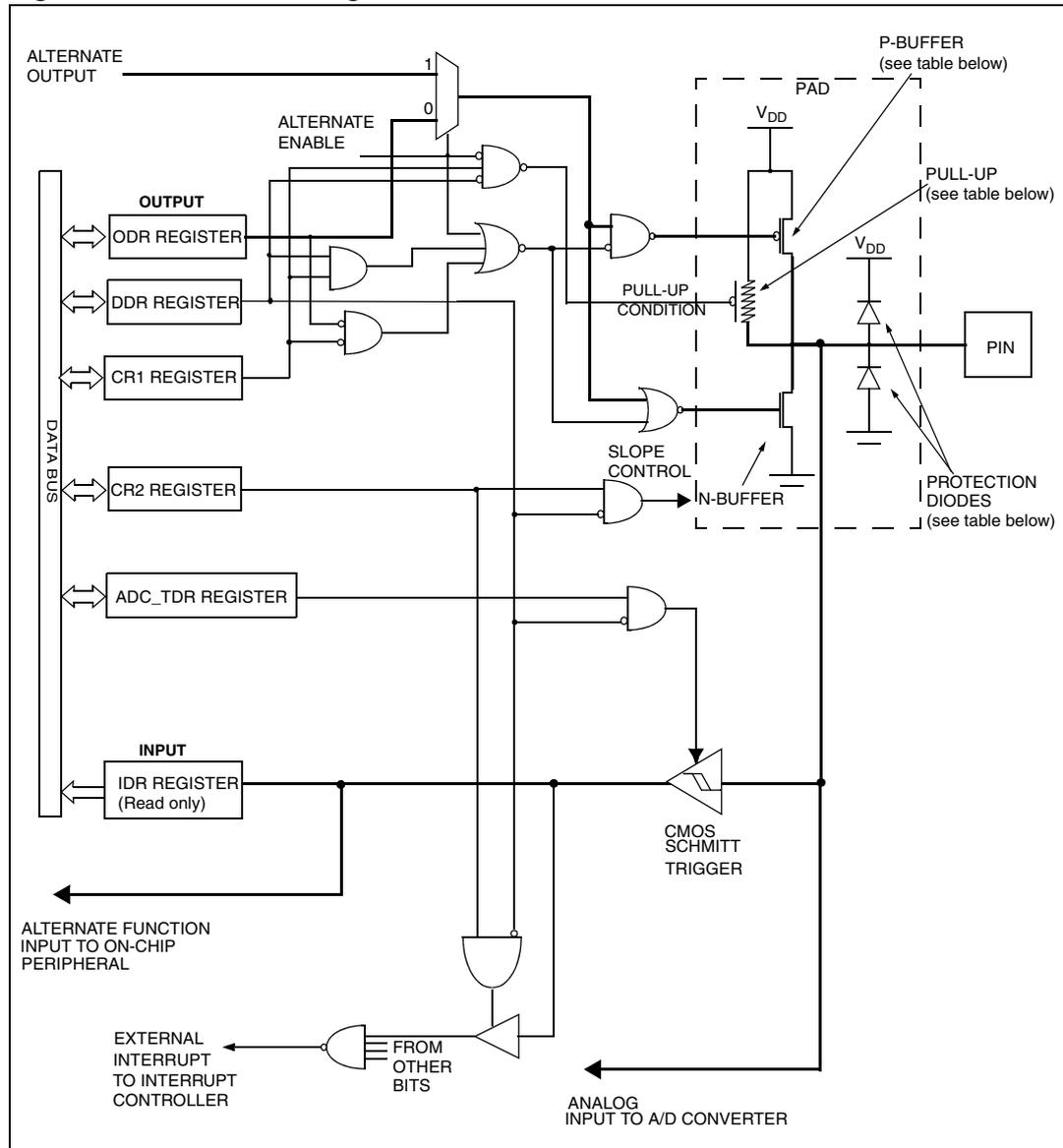
General purpose input/output ports are used for data transfers between the chip and the external world. An I/O port can contain up to eight pins. Each pin can be individually programmed as a digital input or digital output. In addition, some ports may have alternate functions like analog inputs, external interrupts, input/output for on-chip peripherals. Only one alternate function can be mapped to a pin at a time, the alternate function mapping is controlled by option byte. Refer to the datasheet for a description of the option bytes.

An Output Data register, Input pin register, Data Direction register, Option register, and Configuration register are associated with each port. A particular port will behave as an input or output depending on the status of the Data direction register of the port.

11.2 GPIO main features

- Port bits can be configured individually
- Selectable input modes: floating input or input with pull-up
- Selectable output modes: push-pull output or pseudo-open-drain.
- Separate registers for data input and output
- External interrupts can be enabled and disabled individually
- Output slope control for reduced EMC noise
- Alternate Function I/Os for on-chip peripherals
- Input Schmitt trigger can be disabled on analog inputs for reduced power consumption
- Read-Modify-Write possible on data output latch
- 5 V-tolerant inputs
- I/O state guaranteed in voltage range 1.6 V to $V_{DDIOmax}$

Figure 21. GPIO block diagram



11.3 Port configuration and usage

An Output Data Register (ODR), Pin Input Register (IDR), Data Direction Register (DDR) are always associated with each port.

The Control Register 1 (CR1) and Control Register 2 (CR2) allow input/output options. An I/O pin is programmed using the corresponding bits in the DDR, ODR, CR1 and CR2 registers.

Bit *n* in the registers corresponds to pin *n* of the Port.

The various configurations are summarized in [Table 18](#).

Table 18. I/O port configuration summary

Mode	DDR bit	CR1 bit	CR2 bit	Function	Pull-Up	P-Buffer	Diodes	
							to V _{DD}	to V _{SS}
Input	0	0	0	Floating without interrupt	Off	Off	On	On
	0	1	0	Pull-up without interrupt	On			
	0	0	1	Floating with interrupt	Off			
	0	1	1	Pull-up with interrupt	On			
Output	1	0	0	Open Drain Output	Off	Off	On	On
	1	1	0	Push Pull Output		On		
	1	x	1	Output speed limited to 10 MHz		Depends on CR1 bit		
	1	x	x	True Open Drain (on specific pins)	Not Implemented	Not Implemented (see note)		

Note: The diode to V_{DD} is not implemented in true open drain pads. A local protection between the pad and V_{OL} is implemented to protect the device against positive stress.

11.3.1 Input modes

Clearing the DDRx bit selects input mode. In this mode, reading a IDR bit returns the digital value of the corresponding I/O pin.

Refer to [Section 11.7: Input mode details on page 108](#) for information on analog input, external interrupts and Schmitt trigger enable/disable.

As shown in [Table 18](#), four different input modes can be theoretically be configured by software: floating without interrupt, floating with interrupt, pull-up without interrupt or pull-up with interrupt. However in practice, not all ports have external interrupt capability or pull-ups. You should refer to the datasheet pin-out description for details on the actual hardware capability of each port.

11.3.2 Output modes

Setting the DDRx bit selects output mode. In this mode, writing to the ODR bits applies a digital value to the I/O through the latch. Reading IDR bit returns the digital value from the corresponding I/O pin. Using the CR1, CR2 registers, different output modes can be configured by software: Push-Pull output, Open-drain output.

Refer to [Section 11.8: Output mode details on page 109](#) for more information.

11.4 Reset configuration

At reset, all ports are input floating.

11.5 Unused I/O pins

Unused I/O pins must be connected to fixed voltage levels. Either connect a pull-up or pull-down to the unused I/O pins.

11.6 Low power modes

Table 19. Effect of low power modes on GPIO ports

Mode	Description
WAIT	No effect on I/O ports. External interrupts cause the device to exit from WAIT mode.
HALT	No effect on I/O ports. External interrupts cause the device to wakeup from HALT mode.

Note: If PA1/PA2 pins are used to connect an external oscillator, to ensure a lowest power consumption in Halt mode, PA1 and PA2 must be configured as input pull-up.

11.7 Input mode details

11.7.1 Alternate function Input

Some I/Os can be used as alternate function input. For example as the port may be used as the input capture input to a timer. Alternate function inputs are not selected automatically, you select them by writing to a control bit in the registers of the corresponding peripheral. For Alternate Function input, you should select floating or pull-up input configuration in the DDR and CR1 registers.

11.7.2 Interrupt capability

You can configure an I/O as an input with interrupt by setting the CR2x bit while the I/O is in input mode. In this configuration, a signal edge or level input on the I/O generates an interrupt request.

Falling or rising edge sensitivity is programmed independently for each interrupt vector in the EXTI_CR[2:1] registers.

External interrupt capability is only available if the port is configured in input mode.

Interrupt masking

Interrupts can be enabled/disabled individually by programming the corresponding bit in the Configuration Register (Px_CR2). At reset the interrupts are disabled.

11.7.3 Analog channels

Analog channels of the I/O port can be selected by the ADC peripheral. As mentioned in the next section, the input Schmitt trigger should be disabled in the ADC_TDR register when using the analog channels.

Table 20. Recommended and non-recommended configurations for analog input

DDR	CR1	CR2	ADC_TDR	Configuration	Comments
0	0	0	1	Floating Input without interrupt, Schmitt trigger disabled	Recommended analog input configuration
0	1	x	x	Input with pull-up enabled	Not recommended for analog input, if analog voltage is present, these configurations cause excess current flow on the input pin.
1	0	x	x	Output	
1	1	x	x	Output	

11.7.4 Schmitt trigger

An internal input Schmitt trigger is included in some I/Os. The Schmitt trigger can be enabled/disabled using the ADC_TDR Schmitt Trigger Disable Register.

11.8 Output mode details

11.8.1 Alternate function output

Alternate function outputs provide a direct path from a peripheral to an output or to an I/O pad, taking precedence over the port bit in the Data Output Latch Register (Px_ODR) and forcing the Px_DDR corresponding bit to 1.

An alternate function output can be push-pull or pseudo-open drain depending on the peripheral and Control register 1 (Px_CR1) and slope can be controlled depending on the Control register 2 (Px_CR2) values.

Examples:

SPI output pins must be set-up as push-pull, fast slope for optimal operation. UART_Tx can be configured either in push-pull or open drain with an external pull-up in order to implement multi slave configuration.

11.8.2 Slope control

The output frequency can be controlled by software using the CR2 bit. Setting the CR bit selects 10 MHz output frequency. This feature can be applied in either Open Drain or Push-Pull output mode on I/O ports of output type O3 or O4. Refer to the pin description table for the specific output type information for each port.

11.9 GPIO registers

Note: The bit of each port register drives the corresponding pin of the port.

11.9.1 Port x output data register (Px_ODR)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0
rw							

Bits 7:0 **ODR[7:0]**: Output data register bits

Writing to the ODR register when in output mode applies a digital value to the I/O through the latch. Reading the ODR returns the previously latched value in the register.

In Input mode, writing in the ODR register, latches the value in the register but does not change the pin state. The ODR register is always cleared after reset. Bit read-modify-write instructions (BSET, BRST) can be used on the DR register to drive an individual pin without affecting the others.

11.9.2 Port x pin input register (Px_IDR)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0
r	r	r	r	r	r	r	r

Bits 7:0 **IDR[7:0]**: Pin input values

The Pin register can be used to read the pin value irrespective of whether port is in input or output mode. This register is Read-only.

0: Low logic level

1: High logic level

11.9.3 Port x data direction register (Px_DDR)

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
DDR7	DDR6	DDR5	DDR4	DDR3	DDR2	DDR1	DDR0
rw							

Bits 7:0 **DDR[7:0]**: Data direction bits

These bits are set and cleared by software to select input or output mode for a particular pin of a port.

0: Input mode

1: Output mode

11.9.4 Port x control register 1 (Px_CR1)

Address offset: 0x03

Reset value: 0x00

7	6	5	4	3	2	1	0
C17	C16	C15	C14	C13	C12	C11	C10
rw							

Bits 7:0 **C1[7:0]**: Control bits

These bits are set and cleared by software. They select different functions in input mode and output mode see [Table 18 on page 107](#).

- **In input mode (DDR=0):**

0: Floating input

1: Input with pull-up

- **In output mode (DDR=1):**

0: Pseudo Open Drain

1: Push-pull, slope control for the output depends on the corresponding CR2 bit

Note: This bit has no effect on true open drain ports (refer to pin marked "T" in datasheet pin description table).

11.9.5 Port x control register 2 (Px_CR2)

Address offset: 0x04

Reset value: 0x00

7	6	5	4	3	2	1	0
C27	C26	C25	C24	C23	C22	C21	C20
rw							

Bits 7:0 **C2[7:0]**: Control bits

These bits are set and cleared by software. They select different functions in input mode and output mode. In input mode, the CR2 bit enables the interrupt capability if available. If the I/O does not have interrupt capability, setting the CR2 bit has no effect.

In output mode, setting the bit increases the speed of the I/O. This applies to ports with O3 and O4 output types (see pin description table).

- **In input mode (DDR=0):**
 - 0: External interrupt disabled
 - 1: External interrupt enabled
- **In output mode (DDR=1) :**
 - 0: Output speed up to 2 MHz
 - 1: Output speed up to 10 MHz

11.9.6 GPIO register map and reset values

Each GPIO port has five registers mapped as shown in [Table 21](#). Refer to the register map in the corresponding datasheet for the base address for each port.

Note: At reset, all ports are input floating. Exceptions are indicated in the pin description table of the corresponding datasheet.

Table 21. GPIO register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	Px_ODR	ODR7 0	ODR6 0	ODR5 0	ODR4 0	ODR3 0	ODR2 0	ODR1 0	ODR0 0
0x01	Px_IDR	IDR7 0	IDR6 0	IDR5 0	IDR4 0	IDR3 0	IDR2 0	IDR1 0	IDR0 0
0x02	Px_DDR	DDR7 0	DDR6 0	DDR5 0	DDR4 0	DDR3 0	DDR2 0	DDR1 0	DDR0 0
0x03	Px_CR1	C17 0	C16 0	C15 0	C14 0	C13 0	C12 0	C11 0	C10 0
0x04	Px_CR2	C27 0	C26 0	C25 0	C24 0	C23 0	C22 0	C21 0	C20 0

12 Auto-wakeup (AWU)

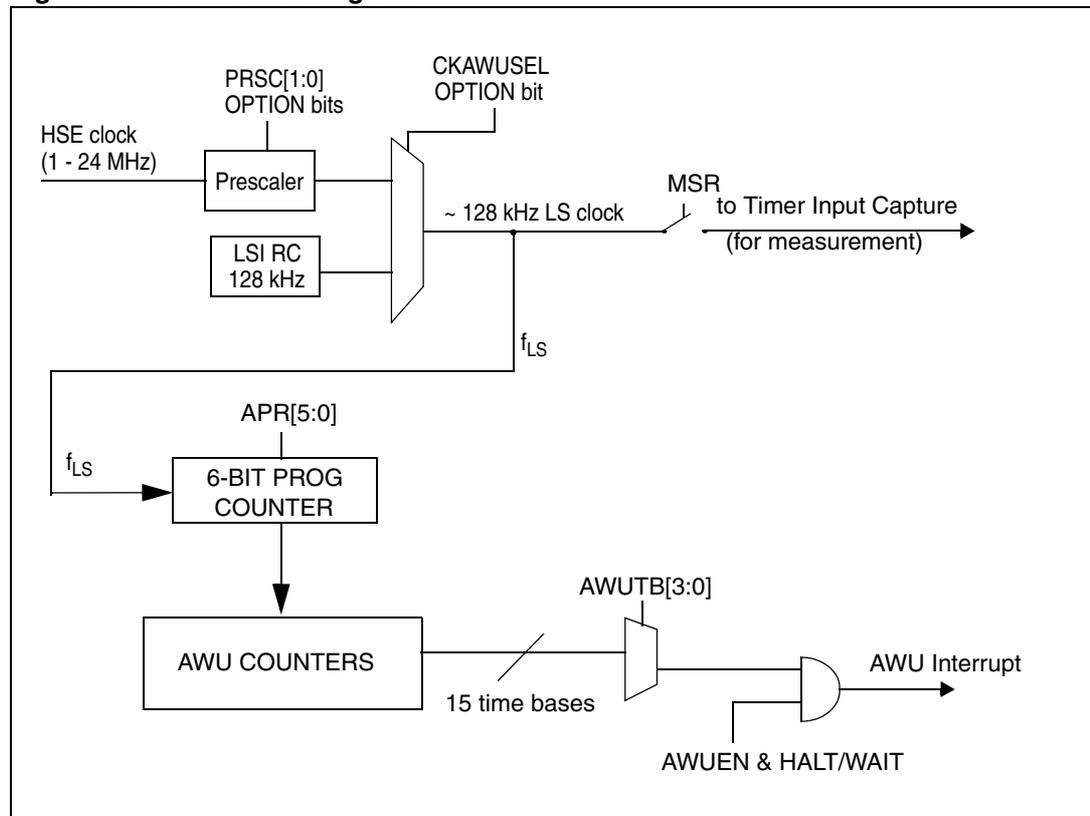
12.1 Introduction

The AWU is used to provide an internal wakeup time base that is used when the MCU goes into Active-halt power saving mode. This time base is clocked by the low speed internal (LSI) RC oscillator clock or the HSE crystal oscillator clock divided by a prescaler.

LSI clock measurement

To ensure the best possible accuracy when using the LSI clock, its frequency can be measured with TIM3 timer input capture 1.

Figure 22. AWU block diagram



Note: The LS clock source is selected by programming the CKAWUSEL option bit as explained in Clock Controller chapter.

12.2 AWU functional description

12.2.1 AWU operation

To use the AWU, perform the following steps in order:

1. Measure the LS clock frequency using the MSR bit in AWU_CSR register and TIM3 input capture 1.
2. Define the appropriate prescaler value by writing to the APR [5:0] bits in the [Asynchronous prescaler register \(AWU_APR\)](#).
3. Select the desired auto-wakeup delay by writing to the AWUTB[3:0] bits in the [Timebase selection register \(AWU_TBR\)](#).
4. Set the AWUEN bit in the [Control/status register \(AWU_CSR\)](#).
5. Execute the HALT instruction.

Note: The counters only start when the MCU enters Active-halt mode after a HALT instruction (Refer to the Active-halt mode section in the Power Management chapter). The AWU interrupt is then enabled at the same time.

The prescaler counter starts to count only if APR[5:0] value is different from its reset value, 0x3F.

Idle mode

If the AWU is not in use, then the AWUTB[3:0] bits the [Timebase selection register \(AWU_TBR\)](#) should be loaded with 0b0000 to reduce power consumption.

12.2.2 Time base selection

Please refer to the [Asynchronous prescaler register \(AWU_APR\)](#) and [Timebase selection register \(AWU_TBR\)](#) descriptions.

The AWU time intervals depend on the values of AWUTB[3:0] bits and on the values of APR [5:0] bits (APR_{DIV} values). 15 non-overlapped ranges of time intervals can be defined as follows:

Table 22. AWUTB[3:0] selection

AWUTB[3:0]	Time interval range	APR _{DIV} range
0b0001	$2/f_{LS} - 64/f_{LS}$	2 to 64
0b0010	$2 \times 32/f_{LS} - 2 \times 64/f_{LS}$	32 to 64
0b0011	$2 \times 2 \times 32/f_{LS} - 2^2 \times 64/f_{LS}$	32 to 64
0b0100	$2^2 \times 2 \times 32/f_{LS} - 2^3 \times 64/f_{LS}$	32 to 64
...		
0b1100	$2^{10} \times 2 \times 32/f_{LS} - 2^{11} \times 64/f_{LS}$	32 to 64
0b1101	$2^{11} \times 2 \times 32/f_{LS} - 2^{12} \times 64/f_{LS}$	32 to 64
0b1110	$2^{11} \times 130/f_{LS} - 2^{11} \times 320/f_{LS}$	26 to 64
0b1111	$2^{11} \times 330/f_{LS} - 2^{12} \times 960/f_{LS}$	11 to 64

In order to obtain the right values for AWUTB[3:0] and APR_{DIV}, you have first to search the interval range corresponding to the desired time interval. This gives the AWUTB[3:0] value. Then APR_{DIV} can be chosen to get a time interval value as close as possible to the desired one. This can be done using the formulas listed in the description of the [Timebase selection register \(AWU_TBR\)](#).

Note: If the target value is between $2^{12} \times 64/f_{LS}$ and $2^{11} \times 130/f_{LS}$ or between $2^{11} \times 320/f_{LS}$ and $2^{11} \times 330/f_{LS}$, the value closer to the target one must be chosen.

Table 23. Example where $f_{LS}=128$ kHz and target time is 78.5 ms

AWUTB[3:0]	Interval range	APR _{DIV} range
0001	0.015625 ms - 0.5 ms	2 to 64
0010	0.5 ms - 1.0 ms	32 to 64
...		
1000	32 ms - 64 ms	32 to 64
1001	64 ms - 128 ms	32 to 64
...		
1101	1.024 s - 2.048 s	32 to 64
1110	2.080 s - 5.120 s	26 to 64
1111	5.280 s - 30.720 s	11 to 64

The right TB[3:0] value is 1001. The "ideal APR_{DIV}" = $0.0785 \times f_{LS} / 2^8 = 39.25$. Therefore the value to be assigned to APR_{DIV} is 39, which gives a time interval of 78 ms.

12.2.3 LSI clock frequency measurement

The frequency dispersion of the Low Speed Internal RC (LSI) oscillator after RC factory trimming is 128 kHz +/- 12.5% on the whole temperature range. To obtain a precise AWU time interval or Beeper output, the exact LSI frequency has to be measured.

Use the following procedure:

1. Set the MSR bit in the *Control/status register (AWU_CSR)* to connect the LSI clock internally to ICAP1 of the TIM3 timer.
2. Measure the frequency of LSI clock using the Timer input capture interrupt.
3. Write the appropriate value in the APR [5:0] bits in the *Asynchronous prescaler register (AWU_APR)* to adjust the AWU time interval to the desired length. The AWUTB[3:0] bits can be modified to select different time intervals.

LSI clock frequency measurement can also be used to calibrate the Beeper frequency (see [Section 13.2.2](#))

12.3 AWU registers

12.3.1 Control/status register (AWU_CSR)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved		AWUF	AWUEN	Reserved			MSR
		r	rw				rw

Bits 7:6 Reserved, must be kept cleared.

Bit 5 **AWUF**: Auto-wakeup flag

This bit is set by hardware when the AWU module generates an interrupt and cleared by reading the AWU_CSR1 register. Writing to this bit does not change its value.

0: No AWU interrupt occurred

1: AWU interrupt occurred

Bit 4 **AWUEN**: Auto-wakeup enable

This bit is set and cleared by software. It enables the Auto-wakeup feature. If the microcontroller enters Active-halt or Wait mode, the AWU feature wakes up the microcontroller after a programmable time delay.

0: AWU (Auto-wakeup) disabled

1: AWU (Auto-wakeup) enabled

Bits 3:1 Reserved, must be kept cleared.

Bit 0 **MSR**: Measurement enable

This bit connects the f_{LS} clock to the TIM3 input capture. This allows the timer to be used to measure the LS frequency (f_{LS}).

0: Measurement disabled

1: Measurement enabled

12.3.2 Asynchronous prescaler register (AWU_APR)

Address offset: 0x01

Reset value: 0x3F

7	6	5	4	3	2	1	0
Reserved		APR[5:0]					
		rw	rw	rw	rw	rw	rw

Bits 7:6 Reserved, must be kept cleared.

Bits 5:0 **APR[5:0]**: Asynchronous Prescaler divider

These bits are written by software to select the prescaler divider (APR_{DIV}) feeding the counter clock.

0x00: $APR_{DIV} = 2$

0x01: $APR_{DIV} = 3$

...

0x06: $APR_{DIV} = 8$

...

0x0E: $APR_{DIV} = 16$

0x0F: $APR_{DIV} = 17$

....

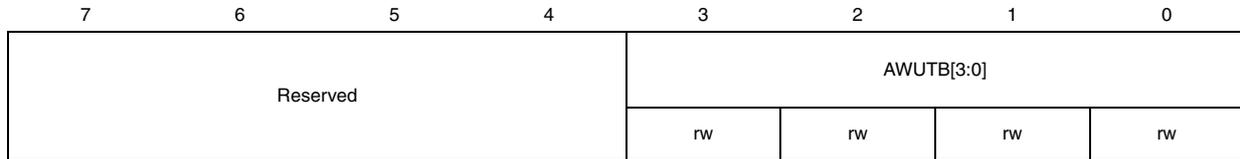
0x3E: $APR_{DIV} = 64$

Note: This register must not be kept at its reset value (0x3F)

12.3.3 Timebase selection register (AWU_TBR)

Address offset: 0x02

Reset value: 0x00



Bits 7:4 Reserved, must be kept cleared.

Bits 3:0 **AWUTB[3:0]**: Auto-wakeup timebase selection

These bits are written by software to define the time interval between AWU interrupts. AWU interrupts are enabled when AWUEN=1.

0000: No interrupt

- | | | |
|---|--|---|
| 0001 : APR_{DIV}/f_{LS} | 0010 : $2 \times APR_{DIV}/f_{LS}$ | 0011 : $2^2 APR_{DIV}/f_{LS}$ |
| 0100 : $2^3 APR_{DIV}/f_{LS}$ | 0101 : $2^4 APR_{DIV}/f_{LS}$ | 0110 : $2^5 APR_{DIV}/f_{LS}$ |
| 0111 : $2^6 APR_{DIV}/f_{LS}$ | 1000 : $2^7 APR_{DIV}/f_{LS}$ | 1001 : $2^8 APR_{DIV}/f_{LS}$ |
| 1010 : $2^9 APR_{DIV}/f_{LS}$ | 1011 : $2^{10} APR_{DIV}/f_{LS}$ | 1100 : $2^{11} APR_{DIV}/f_{LS}$ |
| 1101 : $2^{12} APR_{DIV}/f_{LS}$ | 1110 : $5 \times 2^{11} APR_{DIV}/f_{LS}$ | 1111 : $30 \times 2^{11} APR_{DIV}/f_{LS}$ |

12.3.4 AWU register map and reset values

Table 24. AWU register map

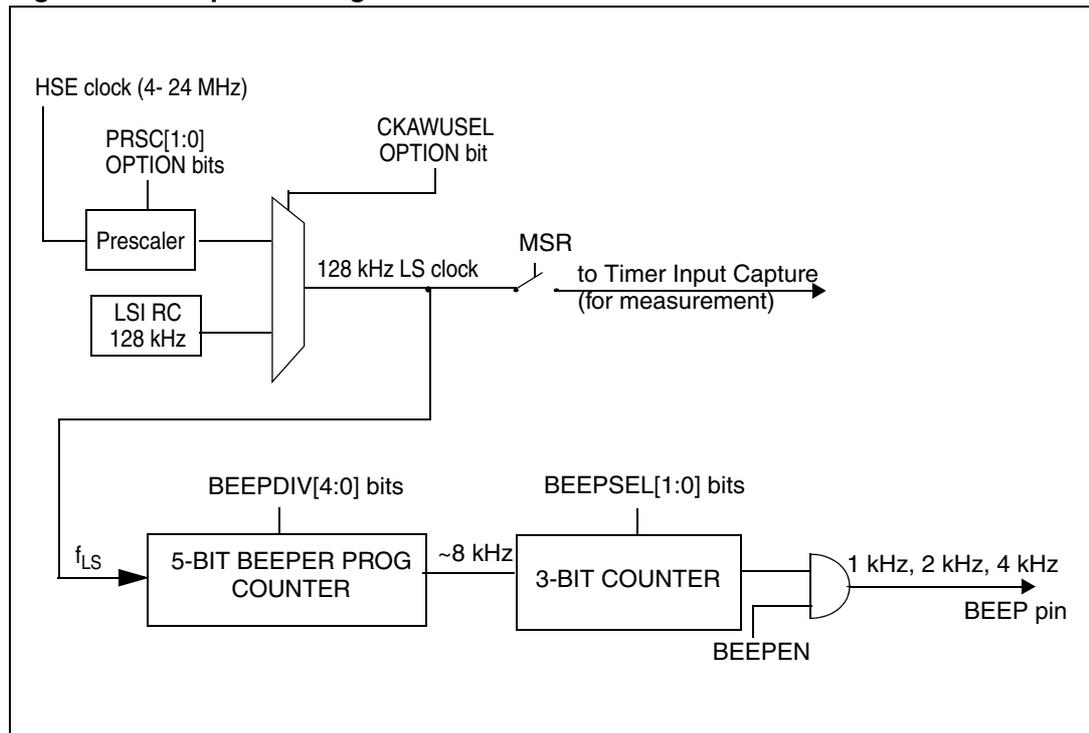
Address offset	Register name	7	6	5	4	3	2	1	0
0x00	AWU_CSR	- 0	- 0	AWUF 0	AWUEN 0	- 0	- 0	- 0	MSR 0
0x01	AWU_APR	- 0	- 0	APR5 1	APR4 1	APR3 1	APR2 1	APR1 1	APR0 1
0x02	AWU_TBR	-0	- 0	- 0	- 0	AWUTB3 0	AWUTB2 0	AWUTB1 0	AWUTB0 0

13 Beeper (BEEP)

13.1 Introduction

This function generates a beep signal in the range of 1, 2 or 4 kHz when the LS clock is operating at a frequency of 128 kHz.

Figure 23. Beeper block diagram



13.2 BEEP functional description

13.2.1 Beeper operation

To use the Beep function, perform the following steps in order:

1. Calibrate the LS clock frequency as described in [Section 13.2.2: Beeper calibration](#) to define BEEP_DIV[4:0] value.
2. Select 1 kHz, 2 kHz or 4 kHz output frequency by writing to the BEEPSEL[1:0] bits in the [Beep control/status register \(BEEP_CSR\)](#).
3. Set the BEEPEN bit in the [Beep control/status register \(BEEP_CSR\)](#) to enable the LS clock source.

Note: The prescaler counter starts to count only if BEEP_DIV[4:0] value is different from its reset value, 0x1F.

13.2.2 Beeper calibration

This procedure can be used to calibrate the LS 128 kHz clock in order to reach the standard frequency output, 1 kHz, 2 kHz or 4 kHz.

Use the following procedure:

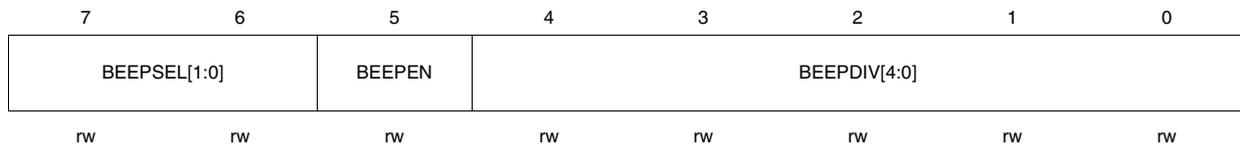
1. Measure the LSI clock frequency (refer to [Section 12.2.3: LSI clock frequency measurement](#) above)
2. Calculate the BEEP_DIV value as follows, where A and x are the integer and fractional part of $f_{LS}/8$ (in kHz):
BEEP_DIV = A-2 when x is less than or equal to $A/(1+2*A)$, else
BEEP_DIV = A-1
3. Write the resulting BEEP_DIV value in the BEEP_DIV[4:0] bits in the [Beep control/status register \(BEEP_CSR\)](#).

13.3 BEEP registers

13.3.1 Beep control/status register (BEEP_CSR)

Address offset: 0x00

Reset value: 0x1F



Bits 7:6 **BEEPSEL[1:0]**: Beep selection

These bits are set and cleared by software to select 1, 2 or 4 kHz beep output when calibration is done.

00: $f_{LS}/(8 \times BEEP_{DIV})$ kHz output

01: $f_{LS}/(4 \times BEEP_{DIV})$ kHz output

1x: $f_{LS}/(2 \times BEEP_{DIV})$ kHz output

Bit 5 **BEEPEN**: Beep enable

This bit is set and cleared by software to enable the beep feature.

0: Beep disabled

1: Beep enabled

Bits 4:0 **BEEPDIV[4:0]**: *Beep prescaler divider*

These bits are set and cleared by software to define the Beeper prescaler dividing factor $BEEP_{DIV}$.

0x00: $BEEP_{DIV} = 2$

0x01: $BEEP_{DIV} = 3$

...

0x0E: $BEEP_{DIV} = 16$

0x0F: $BEEP_{DIV} = 17$

....

0x1E: $BEEP_{DIV} = 32$

Note: This register must not be kept at its reset value (0x1F)

13.3.2 BEEP register map and reset values

Table 25. BEEP register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	BEEP_CSR	BEEPSEL2 0	BEEPSEL1 0	BEEPEN 0	BEEPDIV4 1	BEEPDIV3 1	BEEPDIV2 1	BEEPDIV1 1	BEEPDIV0 1

14 Independent watchdog (IWDG)

14.1 Introduction

The independent watchdog peripheral can be used to resolve processor malfunctions due to hardware or software failures. It is clocked by the 128 kHz LSI internal RC clock source, and thus stays active even if the main clock fails.

14.2 IWDG functional description

[Figure 24](#) shows the functional blocks of the independent Watchdog module.

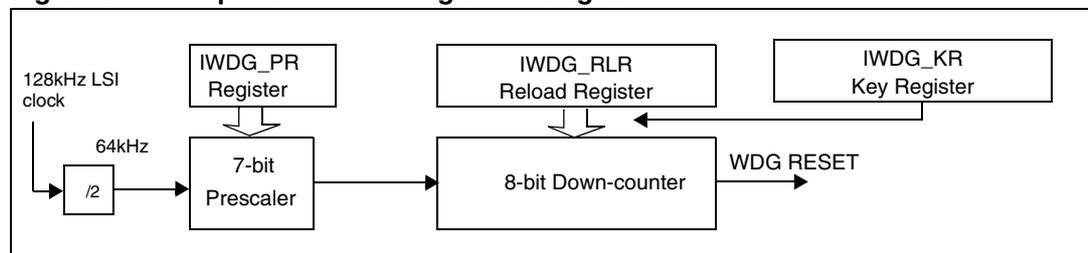
When the independent watchdog is started by writing the value 0xCC in the Key Register (IWDG_KR), the counter starts counting down from the reset value of 0xFF. When it reaches the end of count value (0x00) a reset signal is generated (WDG RESET).

The independent watchdog is configured through the IWDG_PR, and IWDG_RLR registers. The IWDG_PR register is used to select the prescaler divider feeding the counter clock. Whenever the KEY_REFRESH value (0xAA) is written in the IWDG_KR register, the IWDG is refreshed by reloading the IWDG_RLR value into the counter and the watchdog reset is prevented.

The IWDG_PR and IWDG_RLR registers are write protected. To modify them, first write the KEY_ACCESS code (0x55) in the IWDG_KR register. The sequence can be aborted by writing AAh in the IWDG_KR register to refresh it.

Refer to [Section 14.3: IWDG registers](#) for details on the IWDG registers.

Figure 24. Independent watchdog block diagram



Hardware watchdog feature

If the Hardware watchdog feature has been enabled through the IWDG_HW option byte, the watchdog is automatically enabled at power on, and generates a reset unless the Key register is written by the software before the counter reaches end of count. Refer to the Option Byte description in the datasheet.

Timeout period

The timeout period is a function of this value and the clock prescaler. Refer to [Table 26](#) for the values of the minimum timeout periods.

Table 26. Watchdog timeout period (with 64 kHz counter clock)

Prescaler divider	PR[2:0] bits	Min timeout RL[7:0]= 0x00	Max timeout RL[7:0]= 0xFF
/4	0	62.5 μ s	15.90 ms
/8	1	125 μ s	31.90 ms
/16	2	250 μ s	63.70 ms
/32	3	500 μ s	127 ms
/64	4	1.00 ms	255 ms
/128	5	2.00 ms	510 ms
/256	6	4.00 ms	1.02 s

14.3 IWDG registers

14.3.1 Key register (IWDG_KR)

Address offset: 0x00

Reset value: undefined

7	6	5	4	3	2	1	0
KEY[7:0]							
w	w	w	w	w	w	w	w

Bits 7:0 **KEY[7:0]**: Key value

The KEY_REFRESH value must be written by software at regular intervals, otherwise the watchdog generates an MCU reset when the counter reaches 0.

KEY_ENABLE value = 0xCC

Writing the KEY_ENABLE value starts the IWDG.

KEY_REFRESH value = 0xAA

Writing the KEY_REFRESH value refreshes the IWDG.

KEY_ACCESS value = 0x55

Writing the KEY_ACCESS value enables the access to the protected IWDG_PR and IWDG_RLR registers (see [Section 14.2](#))

14.3.2 Prescaler register (IWDG_PR)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved					PR[2:0]		
					rw	rw	rw

Bits 7:3 Reserved, must be kept cleared.

Bits 2:0 **PR[2:0]**: Prescaler divider

These bits are write access protected (see [Section 14.2](#)). They can be written by software to select the prescaler divider feeding the counter clock.

000: divider /4

001: divider /8

010: divider /16

011: divider /32

100: divider /64

101: divider /128

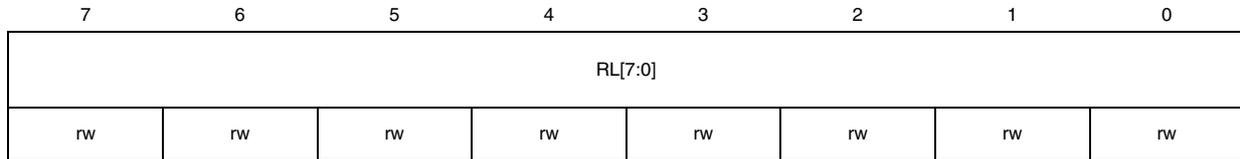
110: divider /256

111: Reserved

14.3.3 Reload register (IWDG_RLR)

Address offset: 0x02

Reset value: 0xFF



RL[7:0]: Watchdog counter reload value

Bits 7:0 These bits are write access protected (see [Section 14.2](#)). They are written by software to define the value to be loaded in the watchdog counter each time the value 0xAA is written in the IWDG_KR register. The watchdog counter counts down from this value. The timeout period is a function of this value and the clock prescaler. Refer to [Table 26](#).

14.3.4 IWDG register map and reset values

Table 27. IWDG register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	IWDG_KR Reset value	KEY7 x	KEY6 x	KEY5 x	KEY4 x	KEY3 x	KEY2 x	KEY1 x	KEY0 x
0x01	IWDG_PR Reset value	- 0	- 0	- 0	- 0	- 0	PR2 0	PR1 0	PR0 0
0x02	IWDG_RLR Reset value	RL7 1	RL6 1	RL5 1	RL4 1	RL3 1	RL2 1	RL1 1	RL0 1

15 Window watchdog (WWDG)

15.1 Introduction

The Window Watchdog is used to detect the occurrence of a software fault, usually generated by external interference or by unforeseen logical conditions, which causes the application program to abandon its normal sequence. The Watchdog circuit generates an MCU reset on expiry of a programmed time period, unless the program refreshes the contents of the downcounter before the T6 bit becomes cleared. An MCU reset is also generated if the 7-bit downcounter value (in the control register) is refreshed before the downcounter has reached the window register value. This implies that the counter must be refreshed in a limited window.

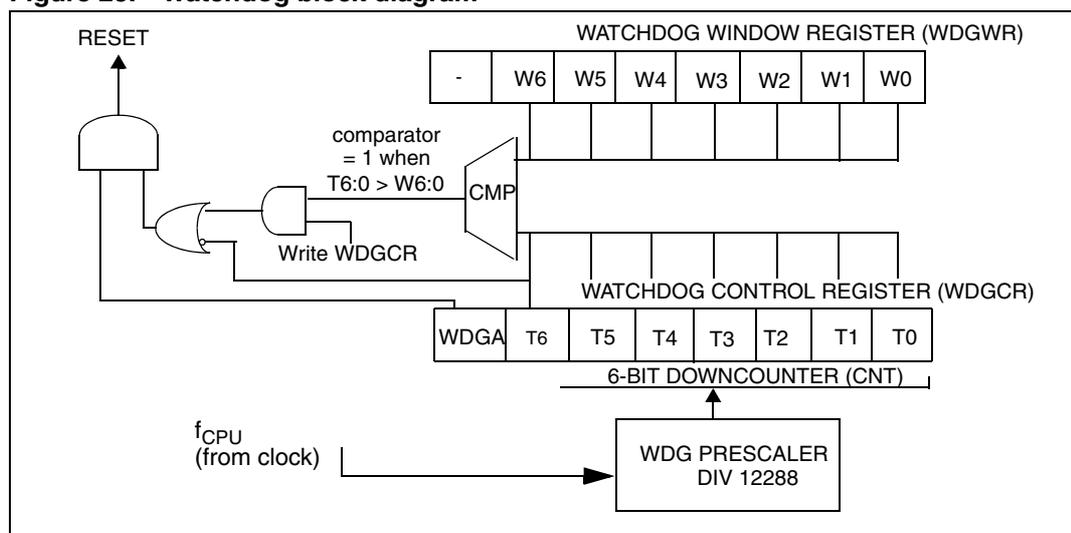
15.2 WWDG main features

- Programmable free-running downcounter
- Conditional reset
 - Reset (if watchdog activated) when the downcounter value becomes less than 0x40
 - Reset (if watchdog activated) if the downcounter is reloaded outside the window (see [Figure 27](#))
- Hardware/Software Watchdog activation (selectable by option byte)
- Optional reset on HALT instruction (configurable by option byte)

15.3 WWDG functional description

If the watchdog is activated (the WDGA bit is set) and when the 7-bit downcounter (T[6:0] bits) rolls over from 0x40 to 0x3F (T6 becomes cleared), it initiates a reset cycle pulling low the reset pin. If the software refreshes the counter while the counter is greater than the value stored in the window register, then a reset is generated.

Figure 25. Watchdog block diagram



The application program must write in the WDGCR register at regular intervals during normal operation to prevent an MCU reset. This operation must occur only when the counter value is lower than the window register value. The value to be stored in the WDGCR register must be between 0xFF and 0xC0 (see [Figure 26](#)):

- Enabling the watchdog:
When Software Watchdog is selected (by option byte), the watchdog is disabled after a reset. It is enabled by setting the WDGA bit in the WDGCR register, then it cannot be disabled again except by a reset.

When Hardware Watchdog is selected (by option byte), the watchdog is always active and the WDGA bit is not used.

- Controlling the downcounter:
This downcounter is free-running: It counts down even if the watchdog is disabled. When the watchdog is enabled, the T6 bit must be set to prevent generating an immediate reset.
The T[5:0] bits contain the number of increments which represents the time delay before the watchdog produces a reset (see [Figure 26: Approximate timeout duration](#)). The timing varies between a minimum and a maximum value due to the unknown status of the prescaler when writing to the WDGCR register (see [Figure 27](#)).

The window register (WDGWR) contains the high limit of the window: To prevent a reset, the downcounter must be reloaded when its value is lower than the window register value and greater than 0x3F. [Figure 27](#) describes the window watchdog process.

Note: The T6 bit can be used to generate a software reset (the WDGA bit is set and the T6 bit is cleared).

- Watchdog Reset on Halt option
If the watchdog is activated and the watchdog reset on halt option is selected, then the HALT instruction will generate a Reset.

15.4 Using Halt mode with the WWDG

If Halt mode with Watchdog is enabled by option byte (no watchdog reset on HALT instruction), it is recommended before executing the HALT instruction to refresh the WDG counter, to avoid an unexpected WDG reset immediately after waking up the microcontroller.

15.5 How to program the watchdog timeout

Figure 26 shows the linear relationship between the 6-bit value to be loaded in the Watchdog Counter (CNT) and the resulting timeout duration in milliseconds. This can be used for a quick calculation without taking the timing variations into account. If more precision is needed, use the formulae in Figure 27.

Warning: When writing to the WDGCR register, always write 1 in the T6 bit to avoid generating an immediate reset.

Figure 26. Approximate timeout duration

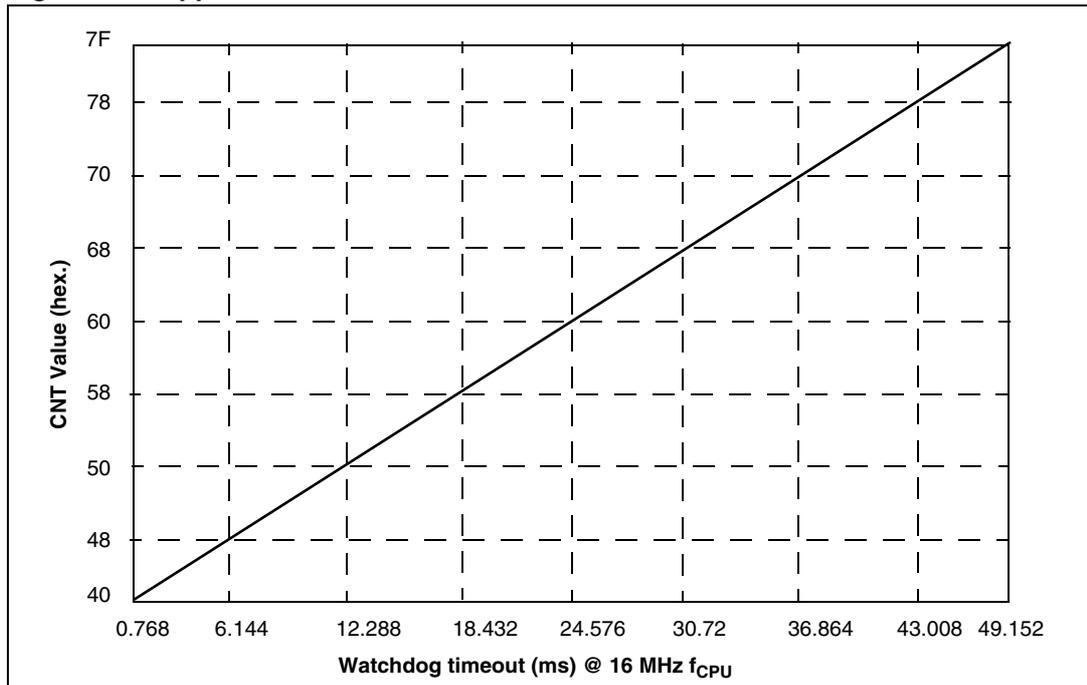
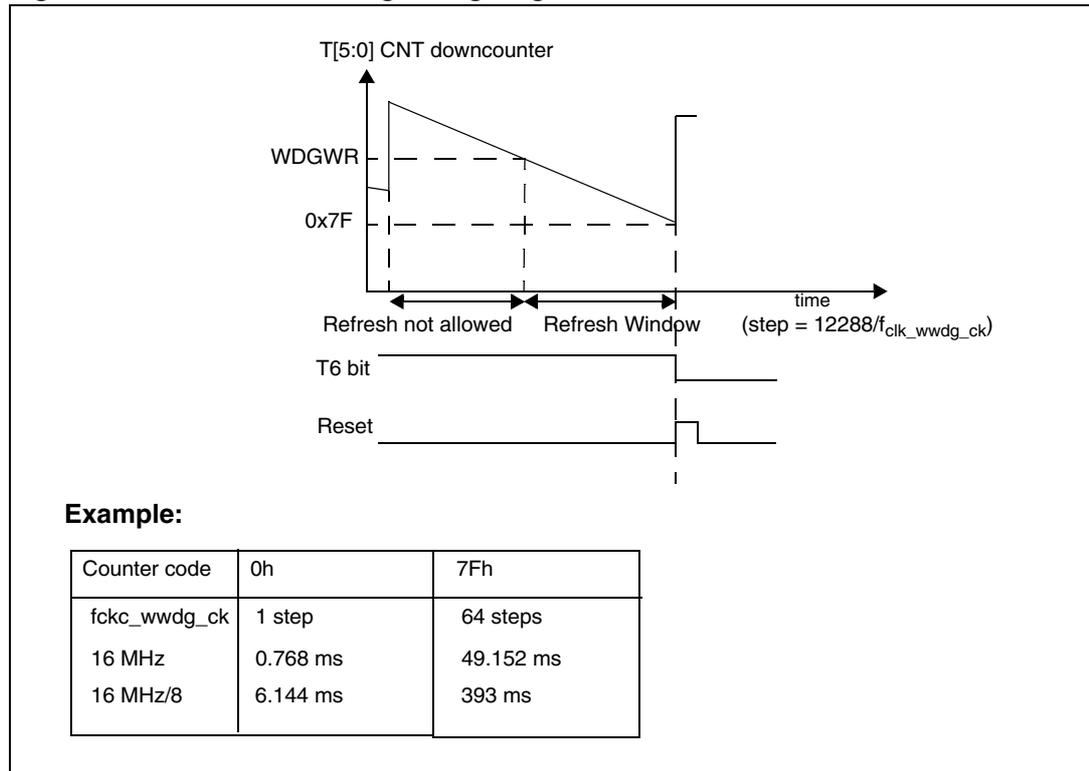


Figure 27. Window watchdog timing diagram



15.6 WWDG low power modes

Table 28. Effect of low power modes on WWDG

Mode	Description	
WAIT	No effect on Watchdog: The downcounter continues to decrement.	
HALT	WWDG_HALT in Option Byte	
	0	No Watchdog reset is generated. The MCU enters Halt mode. The Watchdog counter is decremented once and then stops counting and is no longer able to generate a watchdog reset until the MCU receives an external interrupt or a reset. If an interrupt is received (refer to interrupt table mapping to see interrupts which can occur in halt mode), the Watchdog restarts counting after the stabilization delay. If a reset is generated, the Watchdog is disabled (reset state) unless Hardware Watchdog is selected by option byte. For application recommendations see Section 15.8 below.
	1	A reset is generated instead of entering halt mode.
ACTIVE HALT	x	No reset is generated. The MCU enters Active Halt mode. The Watchdog counter is not decremented. It stops counting. When the MCU receives an oscillator interrupt or external interrupt, the Watchdog restarts counting immediately. When the MCU receives a reset the Watchdog restarts counting after the stabilization delay.

15.7 Hardware watchdog option

If Hardware Watchdog is selected by option byte, the watchdog is always active and the WDGA bit in the WDGCR is not used. Refer to the Option Byte description in the datasheet.

15.8 Using Halt mode with the WWDG (WWDGHALT option)

The following recommendation applies if Halt mode is used when the watchdog is enabled.

Before executing the HALT instruction, refresh the WDG counter, to avoid an unexpected WDG reset immediately after waking up the microcontroller.

15.9 WWDG interrupts

None.

15.10 WWDG registers

15.10.1 Control register (WWDG_CR)

Address offset: 0x00

Reset value: 0x7F

7	6	5	4	3	2	1	0
WDGA	T6	T5	T4	T3	T2	T1	T0
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **WDGA**: Activation bit ⁽¹⁾

This bit is set by software and only cleared by hardware after a reset. When WDGA = 1, the watchdog can generate a reset.

0: Watchdog disabled

1: Watchdog enabled

Bits 6:0 **T[6:0]**: 7-bit counter (MSB to LSB)

These bits contain the value of the watchdog counter. It is decremented every $12288 f_{ckc_wwdg_ck}$ cycles (approx.). A reset is produced when it rolls over from 0x40 to 0x3F (T6 becomes cleared).

1. This bit is not used if the hardware watchdog option is enabled by option byte.

15.10.2 Window register (WWDG_WR)

Address offset: 0x01

Reset value: 0x7F

7	6	5	4	3	2	1	0
Reserved	W6	W5	W4	W3	W2	W1	W0
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 Reserved

Bits 6:0 **W[6:0]**: 7-bit window value

These bits contain the window value to be compared to the downcounter.

15.11 Window watchdog register map and reset values

Table 29. WWDG register map and reset values

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	WWDG_CR Reset value	WDGA 0	T6 1	T5 1	T4 1	T3 1	T2 1	T1 1	T0 1
0x01	WWDG_WR Reset value	- 0	W6 1	W5 1	W4 1	W3 1	W2 1	W1 1	W0 1

16 Timer overview

There are three types of TIM timers: advanced control (TIM1), general purpose (TIM2/TIM3/TIM5), and basic timers (TIM4/TIM6). They have different features but are based on a common architecture. This makes it easier to design applications using the various timers (identical register mapping, common basic features).

In STM8S devices with TIM1, TIM5 and TIM6, the timers do not share any resources but they can be linked together and synchronized as described in [Synchronization from TIM5/TIM6 timers on page 157](#). In STM8S devices with TIM1, TIM2, TIM3 and TIM4, the timers are not linked together.

This section gives a comparison of the different timer features and glossary of internal timer signal names.

[Section 17: 16-bit advanced control timer \(TIM1\)](#) contains a full description of all the various timer modes. The other timer sections are more brief and give only specific details on each timer, its block diagram, and register description.

Table 30. Timer characteristics

Symbol	Parameter	Min	Typ	Max	Unit
$t_{w(ICAP)in}$	Input capture pulse time	2			t_{MASTER}
$t_{res(TIM)}$	Timer resolution time	1			t_{MASTER}
Res_{TIM}	Timer resolution with 16-bit counter		16		bit
	Timer resolution with 8-bit counter		8		bit
$t_{COUNTER}$	Counter clock period when internal clock is selected		1		t_{MASTER}
t_{MAX_COUNT}	Maximum possible count with 16-bit counter			65,536	t_{MASTER}
	Maximum possible count with 8-bit counter			256	t_{MASTER}

16.1 Timer feature comparison

Table 31. Timer feature comparison

Timer	Counter resolution	Counter type	Prescaler factor	Capture/compare channels	Complementary outputs	Repetition counter	External trigger input	External break input	Timer synchronization / chaining
TIM1 (advanced control timer)	16-bit	Up/down	Any integer from 1 to 65536	4	3	Yes	1	1	With TIM5/TIM6
TIM2 (general purpose timer)		Up	Any power of 2 from 1 to 32768	3	None	No	0	0	No
TIM3 (general purpose timer)				2					
TIM4 (basic timer)	8-bit		Any power of 2 from 1 to 128	0					
TIM5 (general purpose timer)	16-bit	Up	Any power of 2 from 1 to 32768	3	None	No	0	0	Yes
TIM6 (basic timer)	8-bit		Any power of 2 from 1 to 128	0					

16.2 Glossary of timer signal names

Table 32. Glossary of internal timer signals

Internal signal name	Description	Related figures
BI	Break interrupt	<i>Figure 28: TIM1 general block diagram on page 139</i>
CC <i>i</i> , CC1I, CC2I, CC3I, CC4I	Capture/compare interrupt	
CK_CNT	Counter clock	
CK_PSC	Prescaler clock	
CNT_EN	Counter enable	<i>Figure 32: Counter update when ARPE=0 (ARR not preloaded) with prescaler = 2 on page 143</i>
CNT_INIT	Counter initialize	
ETR	External trigger from TIMx_ETR pin	<i>Figure 42: TI2 external clock connection example on page 151</i>
ETRF	External trigger filtered	
ETRP	External trigger prescaled	
f _{MASTER}	Timer peripheral clock from clock controller (CLK)	<i>Figure 44: External trigger input block on page 152</i>
IC <i>i</i> , IC1, IC2	Input capture	<i>Figure 13: Clock tree on page 61</i>
IC/PS, IC1PS, IC2PS	Input capture prescaled	
MATCH1	Compare match	<i>Figure 61: Input stage of TIM 1 channel 1 on page 165</i>
OC <i>i</i> , OC1, OC2	Timer output channel	<i>Figure 51: Trigger/master mode selection blocks on page 157 and Section 17.7.2: Control register 2 (TIM1_CR2) on page 185</i>
OC/REF, OC1REF, OC2REF	Output compare reference signal	
TGI	Trigger interrupt	<i>Figure 65: Detailed output stage of channel with complementary output (channel 1) on page 169</i>
TI <i>i</i> , TI1, TI2	Timer input	<i>Figure 40: Clock/trigger controller block diagram on page 150</i>
TI/F, TI1F, TI2F	Timer input filtered	
TI1_ED	Timer input edge detector	
TI/FPx, TI1FP1, TI1FP2, TI2FP1, TI2FP2	Timer input filtered prescaled	
TRC	Trigger capture	
TRGI	Trigger input to clock/trigger/slave mode controller	<i>Figure 61: Input stage of TIM 1 channel 1 on page 165</i>
		<i>Figure 41: Control circuit in normal mode, f_{MASTER} divided by 1 on page 151</i>

Table 32. Glossary of internal timer signals (continued)

Internal signal name	Description	Related figures
UEV	Update event	<i>Figure 32: Counter update when ARPE=0 (ARR not preloaded) with prescaler = 2 on page 143</i>
UIF	Update interrupt	

17 16-bit advanced control timer (TIM1)

This section gives a description of the full set of timer features.

17.1 Introduction

TIM1 consists of a 16-bit up-down auto-reload counter driven by a programmable prescaler.

In this section, the index i , may be 1, 2, 3 or 4 referring to the four capture/compare channels.

The timer may be used for a variety of purposes, including:

- Time base generation
- Measuring the pulse lengths of input signals (input capture)
- Generating output waveforms (output compare, PWM and One Pulse Mode)
- Interruptcapability on various events (capture, compare, overflow, break, trigger)
- Synchronization with TIM5/TIM6 timers or external signals (external clock, reset, trigger and enable)

This timer is ideally suited for a wide range of control applications, including those requiring center-aligned PWM capability with complementary outputs and dead-time insertion.

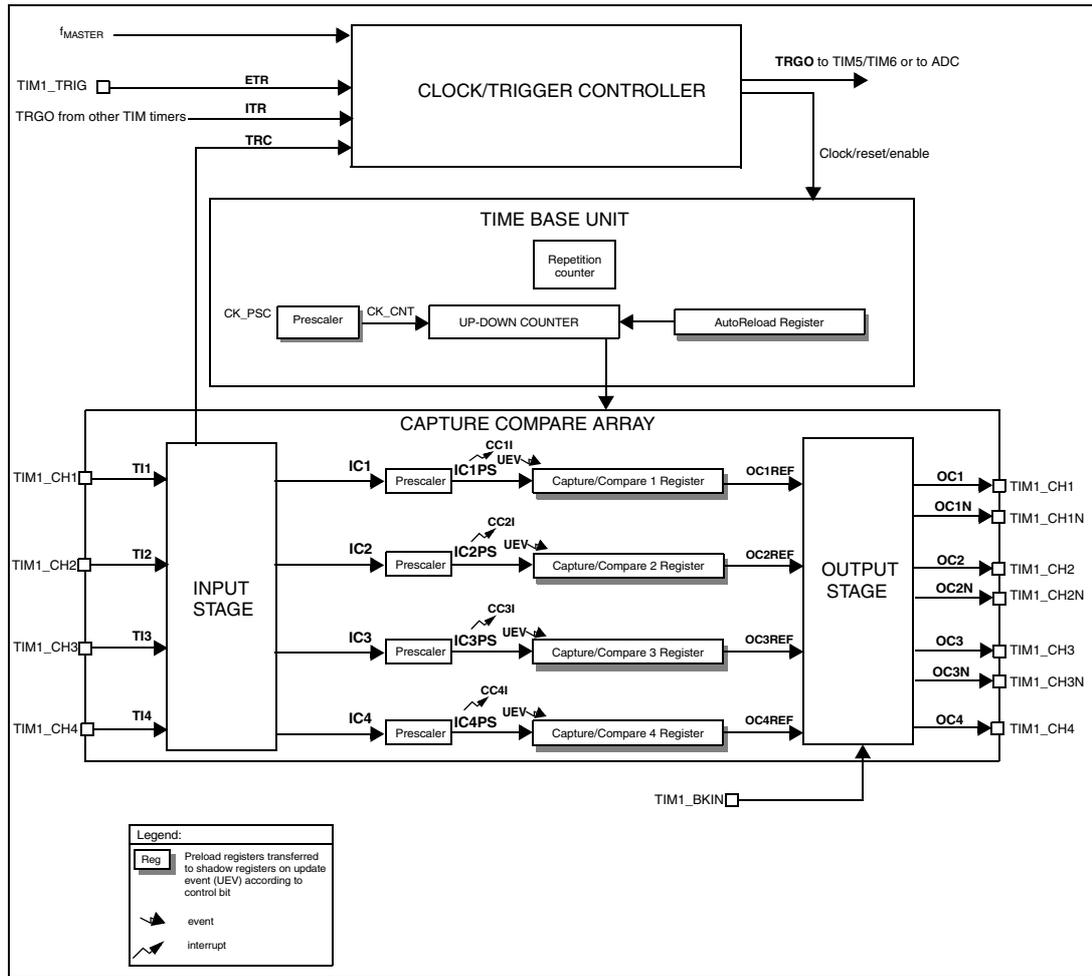
The timer clock can be sourced from internal clocks or from an external source selectable through a configuration register.

17.2 TIM1 main features

TIM1 features include:

- 16-bit up, down, up/down counter auto-reload counter.
- Repetition counter to update the timer registers only after a given number of cycles of the counter.
- 16-bit programmable prescaler allowing the counter clock frequency to be divided “on the fly” by any factor between 1 and 65536.
- Synchronization circuit to control the timer with external signals and to interconnect several timers (timer interconnection not implemented in some devices).
- 4 independent channels that can alternately be configured as:
 - Input capture
 - Output compare
 - PWM generation (edge and center-aligned mode)
 - 6-step PWM generation
 - One Pulse Mode output
 - Complementary Outputs on three channels with programmable dead-time insertion
- Break input to put the timer output signals in reset state or in a known state.
- Interrupt generation on the following events:
 - Update: counter overflow/underflow, counter initialization (by software or internal/external trigger)
 - Trigger event (counter start, stop, initialization or count by internal/external trigger)
 - Input capture
 - Output compare
 - Break input

Figure 28. TIM1 general block diagram

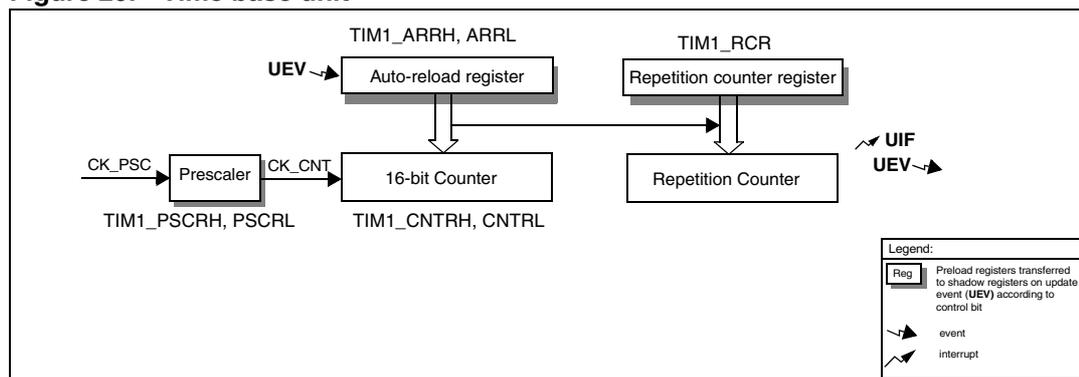


17.3 TIM1 time base unit

The timer has a *Time base unit* that includes:

- 16-bit up/down counter
- 16-bit auto-reload register
- Repetition counter
- Prescaler

Figure 29. Time base unit



The 16-bit counter, the prescaler, the auto-reload register and the repetition counter register can be written or read by software.

The auto-reload register is composed of a preload register plus a shadow register.

Writing to the auto-reload register can be done in two modes:

- **Auto-reload preload enabled** (ARPE bit set in the $TIM1_CR1$ register). In this mode, when data is written to the autoreload register, it is kept in the preload register and transferred into the shadow register at the next update event (UEV).
- **Auto-reload preload disabled** (ARPE bit cleared in the $TIM1_CR1$ register). In this mode, when data is written to the autoreload register it is transferred into the shadow register immediately.

An update event is generated:

- On a counter overflow or underflow.
- By software, setting the UG bit in the $TIM1_EGR$ register.
- By a trigger event from the clock/trigger controller.

With preload enabled ($ARPE=1$), when an update event occurs: the auto-reload shadow register is updated with the preload value ($TIM1_ARR$) and the buffer of the prescaler is reloaded with the preload value (content of the $TIM1_PSCR$ register).

The update event (UEV) can be disabled by setting the UDIS bit in the $TIM1_CR1$

The counter is clocked by the prescaler output CK_CNT , which is enabled only when the counter enable bit (CEN) in $TIM1_CR1$ register is set.

Note: The actual counter enable signal CNT_EN is set 1 clock cycle after CEN.

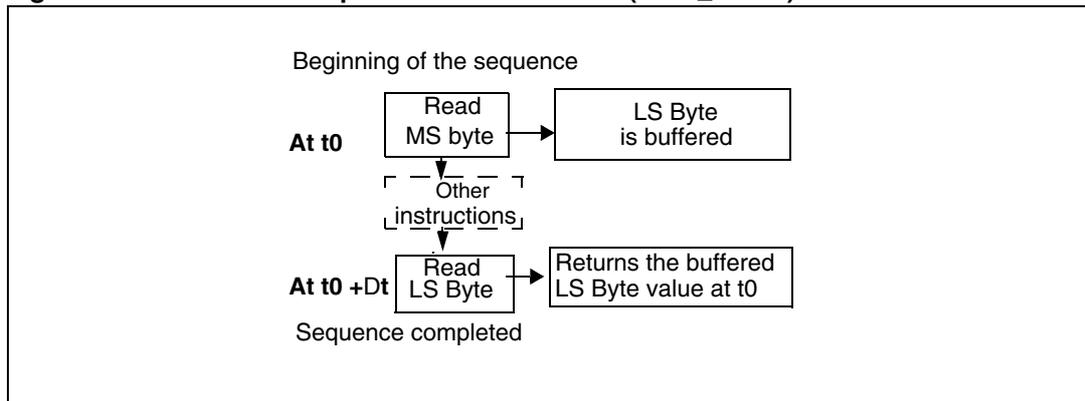
17.3.1 Reading and writing to the 16-bit counter

There is no buffering when writing the counter. Both TIM1_CNTRH and TIM1_CNTRL can be written at any time, so it is suggested not to write a new value into the counter while it is running to avoid loading a wrong intermediate content.

An 8-bit buffer is implemented for the read. The user must read the MS byte first, then the LS byte value is buffered automatically, as described in [Figure 30](#). This buffered value remains unchanged until the 16-bit read sequence is completed.

Note: Do not use the LDW instruction to read the 16-bit counter, because it reads the LS byte first, and would return a wrong result.

Figure 30. 16-bit read sequence for the counter (TIM1_CNTR)



17.3.2 Write sequence for 16-bit TIM1_ARR register

16-bit values are loaded in the TIM1_ARR register through preload registers. This must be performed by two write instructions, one for each byte. The MS byte must be written first.

The shadow register update is blocked as soon as the MS byte has been written, and stays blocked until the LS byte has been written. Do not use the LDW instruction, as this writes the LS byte first, and would produce wrong results in this case.

17.3.3 Prescaler

The prescaler implementation is as follows:

- The TIM1 prescaler is based on a 16-bit counter controlled through a 16-bit register (in TIM1_PSCR register). It can be changed on the fly as this control register is buffered. It can divide the counter clock frequency by any factor between 1 and 65536.

The counter clock frequency is calculated as follows:

$$f_{CK_CNT} = f_{CK_PSC} / (PSCR[15:0] + 1)$$

The prescaler value is loaded through a preload register. The shadow register, which contains the current value to be used is loaded as soon as the LS Byte has been written.

To update the 16-bit prescaler, load two bytes in separate write operations, MSB-first. Do not use the LDW instruction for this purpose, as it writes LSB-first.

The new prescaler value is taken into account in the following period (after the next counter update event).

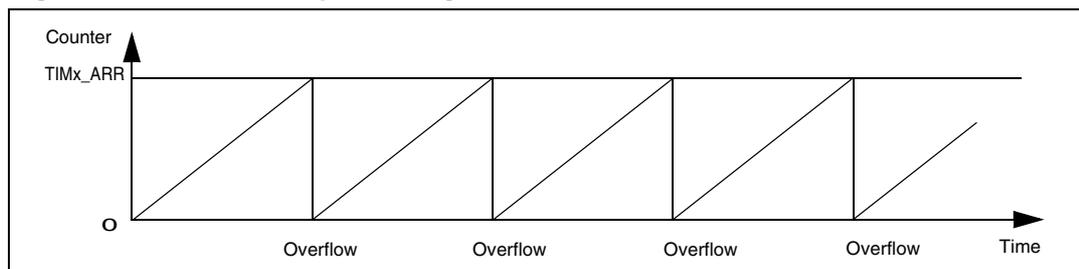
Read operations to the TIM1_PSCR registers access the preload registers, so no special care needs to be taken to read them.

17.3.4 Up-counting mode

In up-counting mode, the counter counts from 0 to a user-defined compare value (content of the TIM1_ARR register), then restarts from 0 and generates a counter overflow event, and an update event (UEV) if the UDIS bit is 0 in the TIM1_CR1 register.

Figure 31 shows an example of this counting mode.

Figure 31. Counter in up-counting mode



An update event can also be generated by setting the bit UG in the TIM1_EGR register (by software or by using the trigger controller).

The UEV event can be disabled by software by setting the UDIS bit in the TIM1_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event will occur until UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescaler division factor does not change). In addition, if the URS bit (update request selection) in TIM1_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIM1_SR1 register) is set (depending on the URS bit):

The auto-reload shadow register is updated with the preload value (TIM1_ARR),

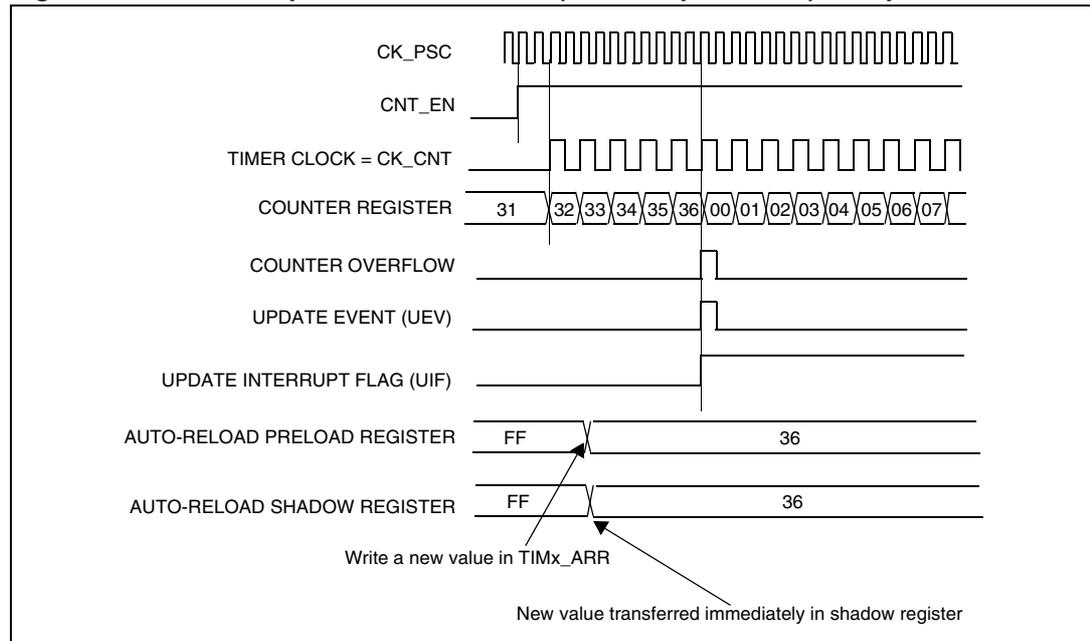
The buffer of the prescaler is reloaded with the preload value (content of the TIM1_PSCR register).

The following figures show two examples of the counter behavior for different clock frequencies when TIM1_ARR=36h.

In *Figure 32* the prescaler divider is set to 2, so the counter clock (CK_CNT) frequency is at half the frequency of the the prescaler clock source (CK_PSC).

In *Figure 32* the autoreload preload is disabled (ARPE=0), so the shadow register is changed immediately and counter overflow occurs when upcounting reaches 36h. This generates an update event.

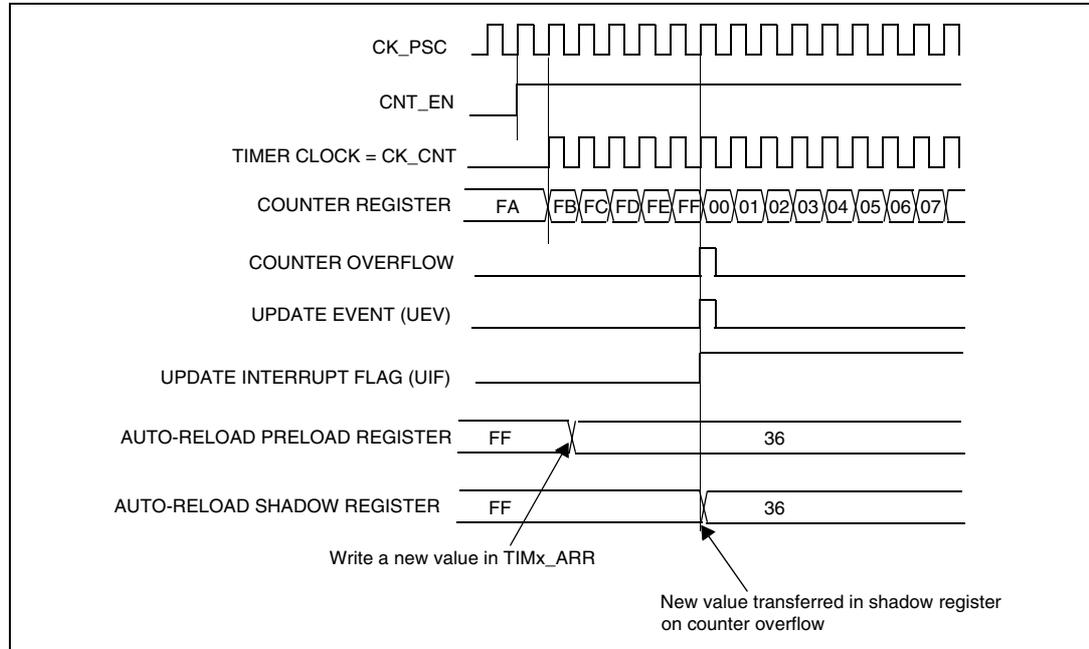
Figure 32. Counter update when ARPE=0 (ARR not preloaded) with prescaler = 2



In [Figure 33](#) the prescaler divider is set to 1, so CK_CNT has the same frequency as CK_PSC.

In [Figure 33](#) autoreload preload is enabled (ARPE=1), so the next counter overflow occurs at FFh. The new autoreload value register value of 36h is taken into account after the overflow which generates an update event.

Figure 33. Counter update event when ARPE=1 (TIM1_ARR preloaded)

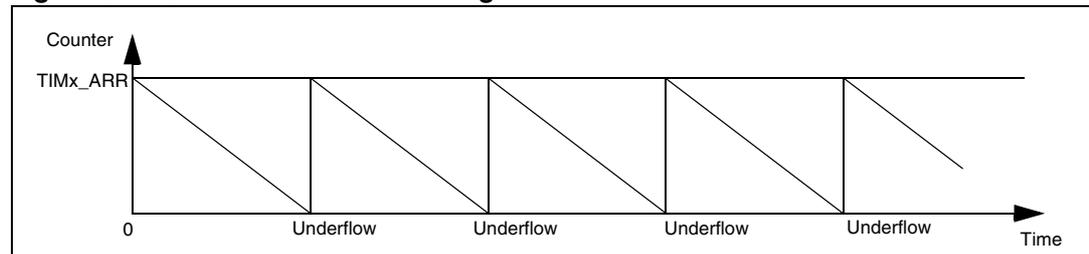


17.3.5 Down-counting mode

In down-counting mode, the counter counts from the auto-reload value (content of the TIM1_ARR register) down to 0, then restarts from the auto-reload value and generates a counter underflow and an update event (UEV) if the UDIS bit is 0 in the TIM1_CR1 register.

[Figure 34](#) shows an example of this counting mode.

Figure 34. Counter in down-counting mode



An update event can also be generated by setting the bit UG in the TIM1_EGR register (by software or by using the clock/trigger mode controller).

The UEV update event can be disabled by software by setting the UDIS bit in TIM1_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event will occur until UDIS bit has been written to 0.

However, the counter restarts from the current auto-reload value, whereas the counter of the prescaler restarts from 0 (but the prescale rate doesn't change).

In addition, if the URS bit (update request selection) in TIM1_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIM1_SR1 register) is set (depending on the URS bit):

The buffer of the prescaler is reloaded with the preload value (content of the TIM1_PSCR register),

The auto-reload shadow register is updated with the preload value (content of the TIM1_ARR register). Note that the auto-reload is updated before the counter is reloaded, so that the next period is the expected one.

The following figures show some examples of the counter behavior for different clock frequencies when TIM1_ARR=36h.

In downcounting mode, preload is normally not used so that the new value is taken into account in the next period (see [Figure 35](#)).

Figure 35. Counter update when ARPE=0 (ARR not preloaded) with prescaler = 2

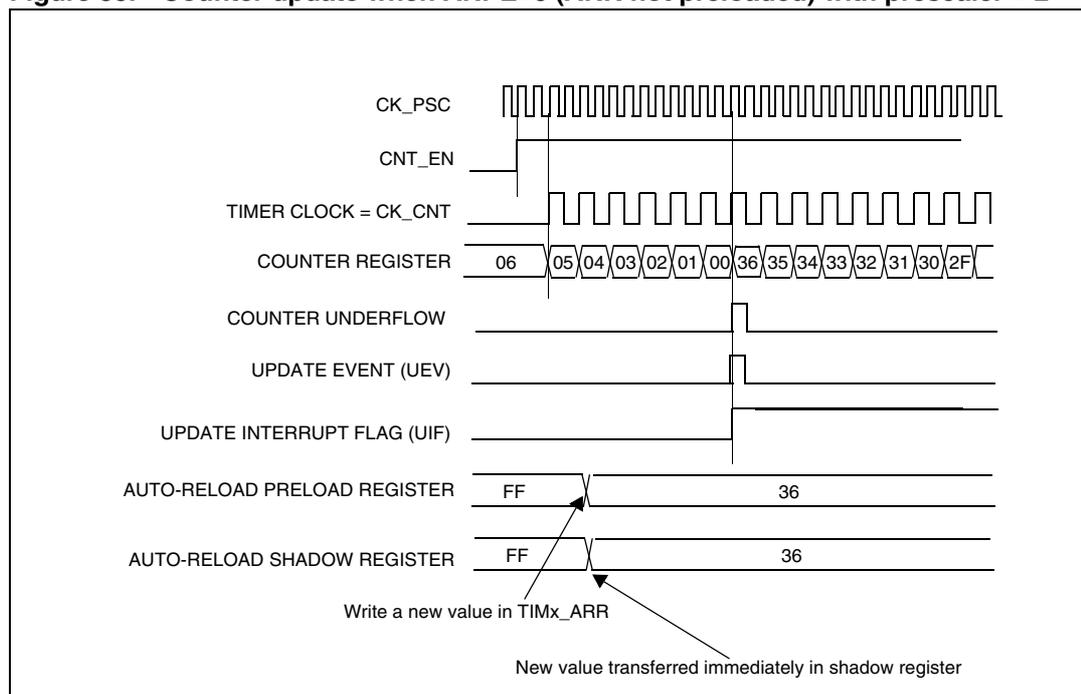
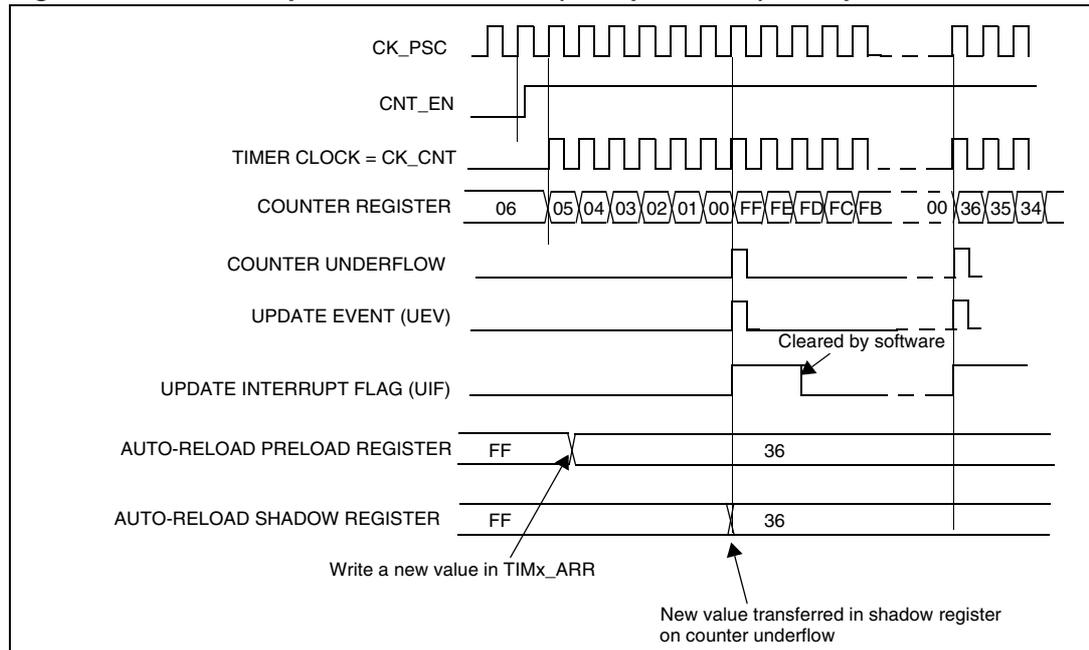


Figure 36. Counter update when ARPE=1 (ARR preloaded), with prescaler = 1



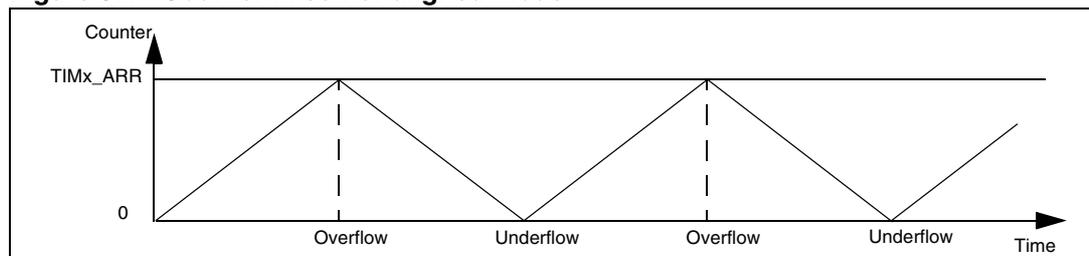
17.3.6 Center-aligned mode (up/down counting)

In center-aligned mode, the counter counts from 0 to the auto-reload value (content of the TIM1_ARR register) -1, generates a counter overflow event, then counts down to 0 and generates a counter underflow event. Then it restarts counting from 0.

In this mode, the DIR direction bit in the TIM1_CR1 register cannot be written. It is updated by hardware and gives the current direction of the counter.

The [Figure 37](#) shows an example of this counting mode.

Figure 37. Counter in center-aligned mode



If the timer has a repetition counter (in TIM1 for example), the update event (UEV) is generated after up and down-counting is repeated for the number of times programmed in the repetition counter register (TIM1_RCR). Else the update event is generated at each counter overflow and at each counter underflow.

Setting the bit UG in the TIM1_EGR register (by software or by using the clock/trigger mode controller) also generates an update event. In this case, the counter restarts counting from 0, as well as the counter of the prescaler.

The update event (UEV) can be disabled by software setting the UDIS bit in TIM1_CR1 register. This is to avoid updating the shadow registers while writing new values in the

preload registers. Then no update event will occur until UDIS bit has been written to 0. However, the counter continues counting up and down, based on the current auto-reload value. In timers with a repetition counter, the new update rate will be used because the repetition register is not double buffered. For this reason, you must take care when changing the update rate.

In addition, if the URS bit (update request selection) in TIM1_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt request will be sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

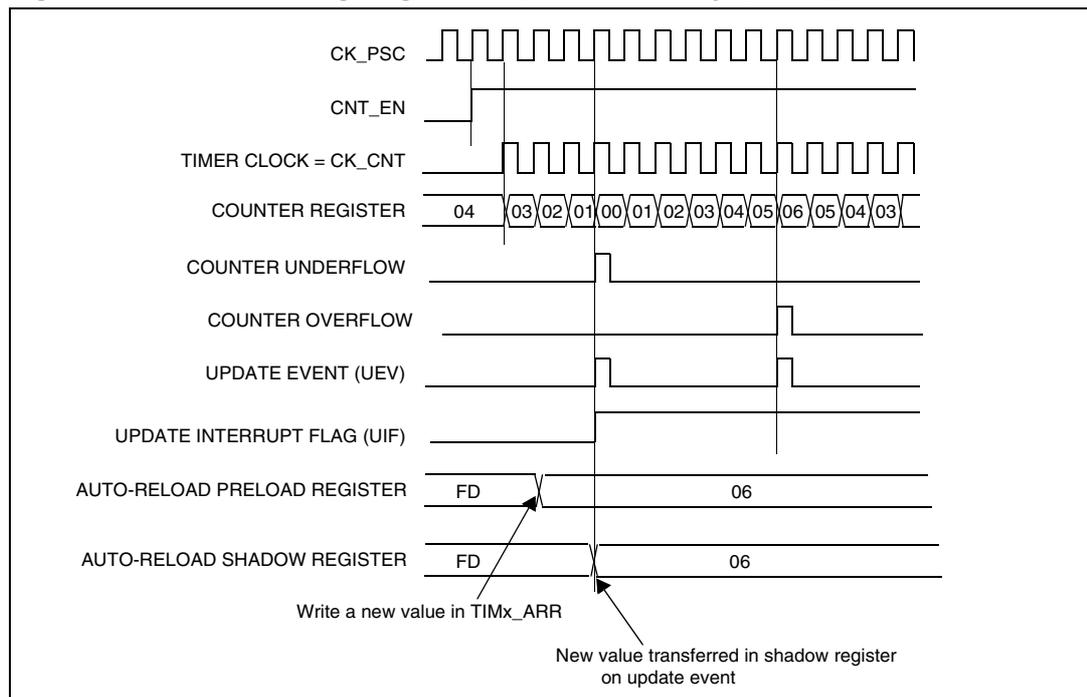
When an update event occurs, all the registers are updated and the update flag (UIF bit in TIM1_SR1 register) is set (depending on the URS bit).

The buffer of the prescaler is reloaded with the preload value (content of the TIM1_PSCR register).

The auto-reload shadow register is updated with the preload value (content of the TIM1_ARR register). Note that if the update source is a counter overflow, the auto-reload is updated before the counter is reloaded, so that the next period is the expected one (the counter is loaded with the new value).

Hereafter are some examples of the counter behavior for different clock frequencies.

Figure 38. Counter timing diagram, CK_PSC divided by 1, TIM1_ARR=06h, ARPE=1



Hints on using center-aligned mode:

- When starting in center-aligned mode, the current up-down configuration is used. It means that the counter will start counting up or down depending on the value written in

the DIR bit in the TIM1_CR1 register. Moreover, the DIR and CMS bits must not be changed at the same time by the software.

- Writing to the counter while running in center-aligned mode is not recommended as it can lead to unexpected results. In particular:
 - The direction is not updated if you write a value in the counter that is greater than the auto-reload value ($TIM1_CNT > TIM1_ARR$). For example, if the counter was counting up, it will continue to count up.
 - The direction is updated if you write 0 or write the TIM1_ARR value in the counter but no Update Event UEV is generated.
- The safest way to use center-aligned mode is to generate an update by software (setting the UG bit in the TIM1_EGR register) just before starting the counter and not to write the counter while it is running.

17.3.7 Repetition down-counter

Section 17.3: TIM1 time base unit describes how the update event (UEV) is generated with respect to the counter overflows/underflows. It is actually generated only when the repetition down-counter has reached zero. This can be useful while generating PWM signals.

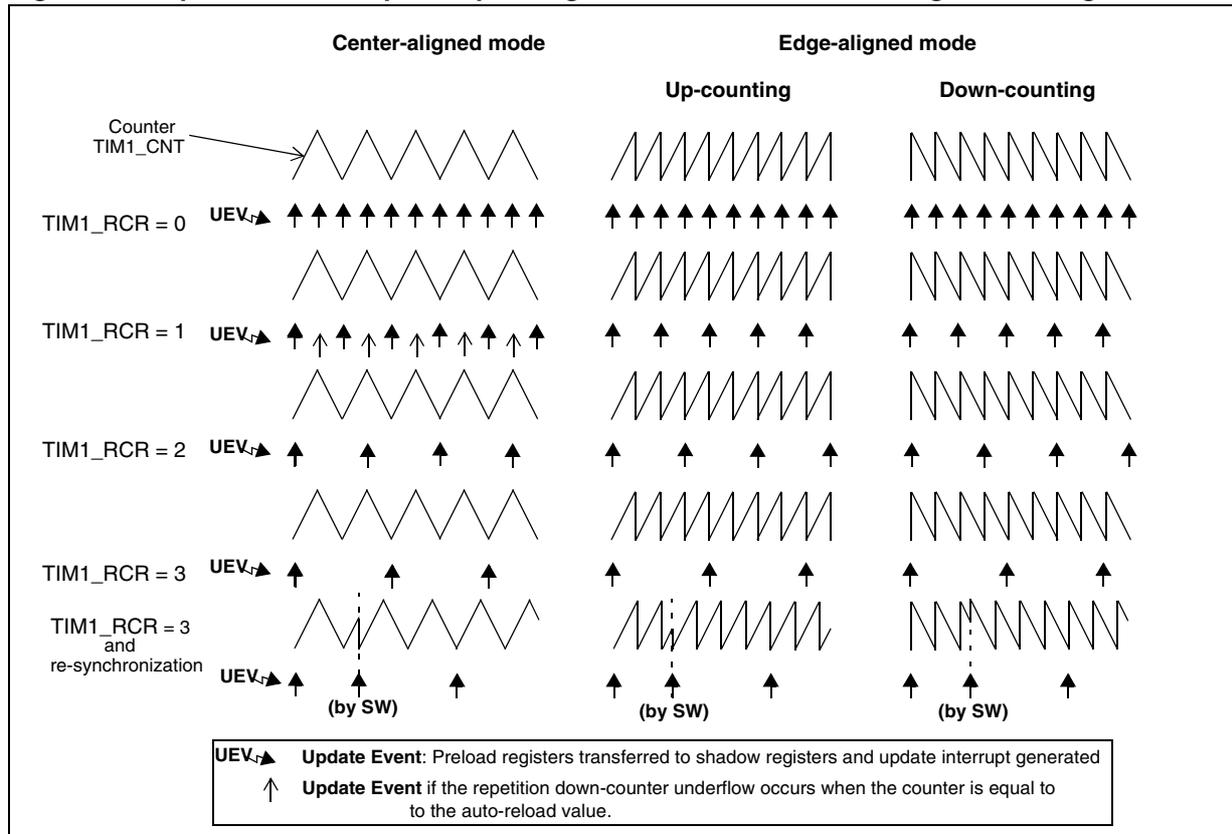
This means that data are transferred from the preload registers to the shadow registers (TIM1_ARR auto-reload register, TIM1_PSCSR prescaler register, but also TIM1_CCRx capture/compare registers in compare mode) every N counter overflows or underflows, where N is the value in the TIM1_RCR repetition counter register.

The repetition down-counter is decremented:

- At each counter overflow in up-counting mode,
- At each counter underflow in down-counting mode,
- At each counter overflow and at each counter underflow in center-aligned mode. Although this limits the maximum number of repetitions to 128 PWM cycles, it makes it possible to update the duty cycle twice per PWM period. When refreshing compare registers only once per PWM period in center-aligned mode, maximum resolution is $2 \times t_{CK_PSC}$, due to the symmetry of the pattern.

The repetition down-counter is an auto-reload type; the repetition rate will be maintained as defined by the TIM1_RCR register value (refer to [Figure 39](#)). When the update event is generated by software (by setting the UG bit in the TIM1_EGR register) or by hardware through the clock/trigger controller, it occurs immediately whatever is the value of the repetition down-counter and the repetition down-counter is reloaded with the content of the TIM1_RCR register.

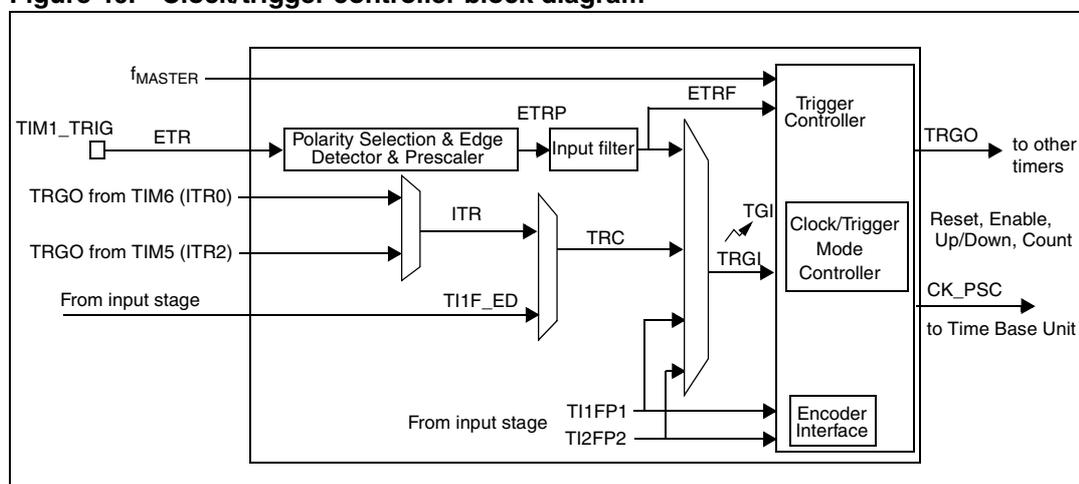
Figure 39. Update rate examples depending on mode and TIM1_RCR register settings



17.4 TIM1 clock/trigger controller

The clock/trigger controller allows you to configure the timer clock sources, input triggers and output triggers. The block diagram is shown in [Figure 40](#).

Figure 40. Clock/trigger controller block diagram



17.4.1 Prescaler clock (CK_PSC)

The Time base unit prescaler clock (CK_PSC) can be provided by the following clock sources:

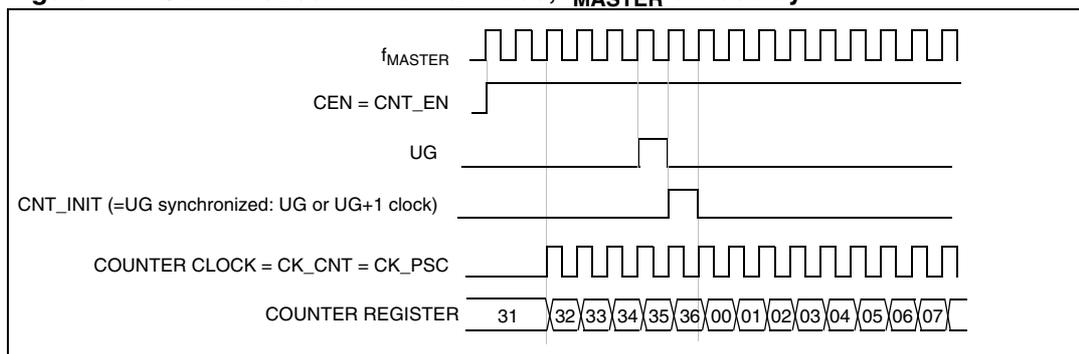
- Internal clock (f_{MASTER})
- External clock mode 1: external timer input (TIx)
- External clock mode 2: external trigger input ETR
- Internal trigger inputs (ITRx): using one timer as prescaler for another timer. Refer to [Using one timer as prescaler for another timer on page 158](#) for more details.

17.4.2 Internal clock source (f_{MASTER})

If both the clock/trigger mode controller and the external trigger input are disabled (SMS=0b000 in TIM1_SMCR and ECE=0 in the TIM1_ETR register), then the CEN, DIR and UG bits are actual control bits and can be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock.

The [Figure 41](#) shows the behavior of the control circuit and the up-counter in normal mode, without prescaler.

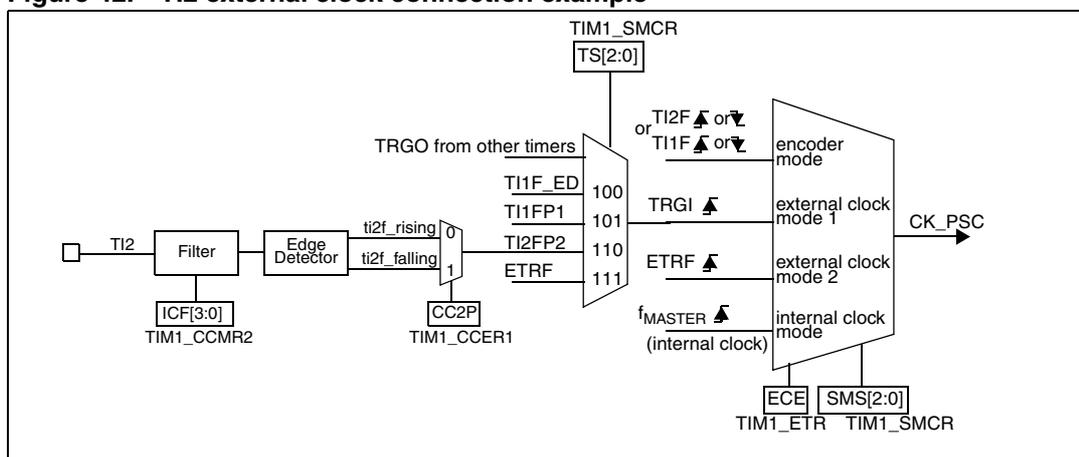
Figure 41. Control circuit in normal mode, f_{MASTER} divided by 1



17.4.3 External clock source mode 1

The counter can count at each rising or falling edge on a selected timer input. This mode is selected when SMS=0b111 in the TIM1_SMCR register.

Figure 42. TI2 external clock connection example



For example, to configure the up-counter to count in response to a rising edge on the TI2 input, use the following procedure:

1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S= '01' in the TIM1_CCMR2 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIM1_CCMR2 register (if no filter is needed, keep IC2F=0000).

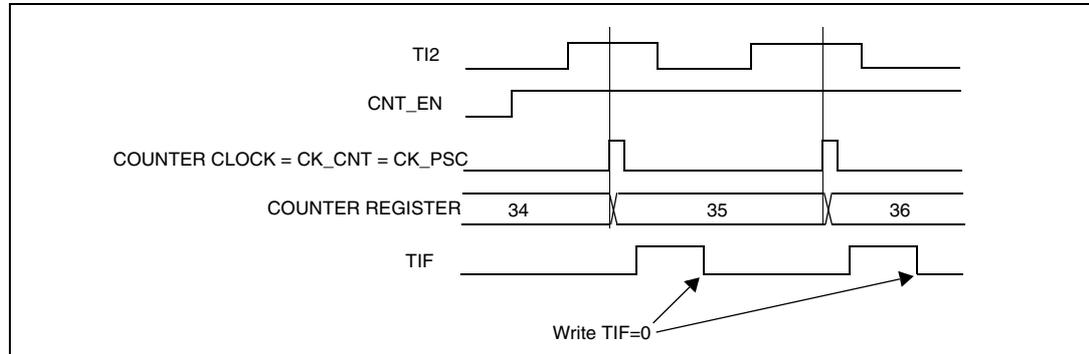
Note: The capture prescaler is not used for triggering, so you don't need to configure it. Also you don't need to configure the TI2S bits, they only select the input capture source.

3. Select rising edge polarity by writing CC2P=0 in the TIM1_CCER1 register.
4. Configure the timer in external clock mode 1 by writing SMS=0b111 in the TIM1_SMCR register.
5. Select TI2 as the input source by writing TS=110 in the TIM1_SMCR register.
6. Enable the counter by writing CEN=1 in the TIM1_CR1 register.

When a rising edge occurs on TI2, the counter counts once and the trigger flag is set (TIF bit in the TIM1_SR1 register) and an interrupt request can be sent if enabled (depending on the TIE bit in the TIM1_IER register).

The delay between the rising edge on TI2 and the actual reset of the counter is due to the resynchronization circuit on TI2 input.

Figure 43. Control circuit in external clock mode 1

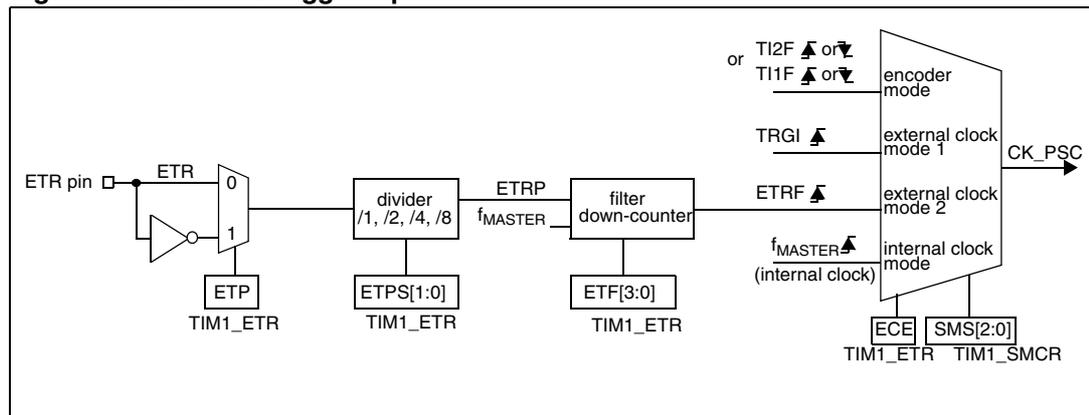


17.4.4 External clock source mode 2

The counter can count at each rising or falling edge on the external trigger input ETR. This mode is selected by writing ECE=1 in the TIM1_ETR register.

The [Figure 44](#) gives an overview of the external trigger input block.

Figure 44. External trigger input block

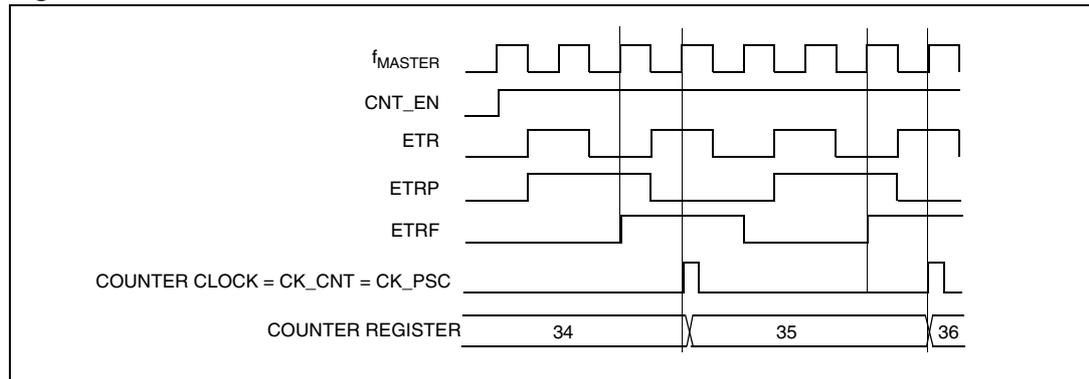


For example, to configure the up-counter to count each 2 rising edges on ETR, use the following procedure:

1. As no filter is needed in this example, write ETF[3:0]=0b0000 in the TIM1_ETR register.
2. Set the prescaler by writing ETPS[1:0]=0b01 in the TIM1_ETR register
3. Select rising edge detection on the ETR pin by writing ETP=0 in the TIM1_ETR register
4. Enable external clock mode 2 by writing ECE=1 in the TIM1_ETR register.
5. Enable the counter by writing CEN=1 in the TIM1_CR1 register.

The counter counts once each 2 ETR rising edges.

The delay between the rising edge on ETR and the actual reset of the counter is due to the resynchronization circuit on the ETRP signal.

Figure 45. Control circuit in external clock mode 2

17.4.5 Trigger synchronization

There are four trigger inputs (refer to [Table 32: Glossary of internal timer signals on page 135](#)):

- ETR
- TI1
- TI2
- TRGO from TIM5/TIM6

The TIM1 timer can be synchronized with an external trigger in three modes: trigger standard mode, trigger reset mode and trigger gated mode.

Trigger standard mode

The counter can start in response to an event on a selected input.

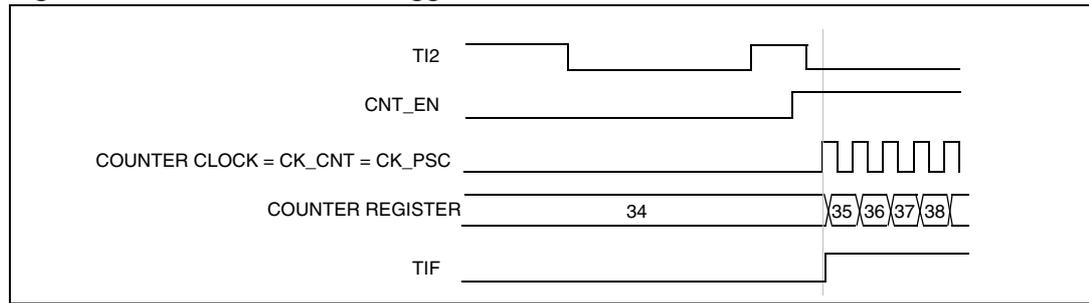
In the following example, the up-counter starts in response to a rising edge on TI2 input:

- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep $\text{IC2F}=0\text{b}0000$). The capture prescaler is not used for triggering, so you don't need to configure it. TI2S bits are selecting the input capture source only, and don't need to be configured too. Write $\text{CC2P}=0$ in TIM1_CCER1 register to select rising edge polarity.
- Configure the timer in trigger mode by writing $\text{SMS}=0\text{b}110$ in the TIM1_SMCR register. Select TI2 as the input source by writing $\text{TS}=0\text{b}110$ in the TIM1_SMCR register.

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual reset of the counter is due to the resynchronization circuit on TI2 input.

Figure 46. Control circuit in trigger mode



Trigger reset mode

The counter and its prescaler can be re-initialized in response to an event on a trigger input. Moreover, if the URS bit from the TIM1_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIM1_ARR, TIM1_CCRx) are updated.

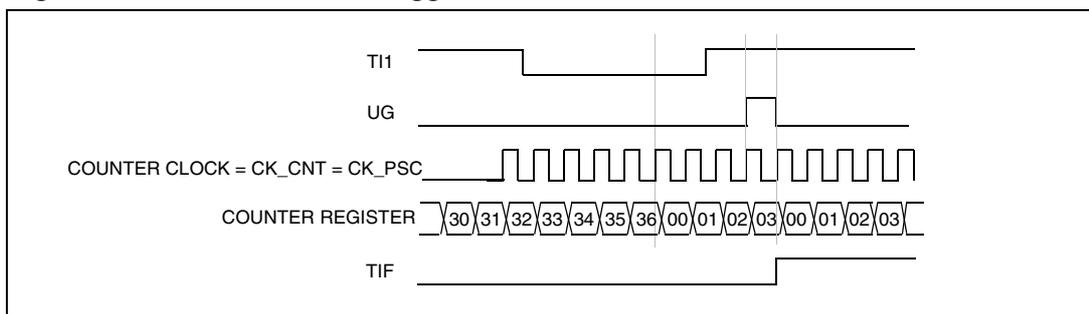
In the following example, the up-counter is cleared in response to a rising edge on TI1 input:

- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0b0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, and do not need to be configured either. Write CC1P=0 in TIM1_CCER1 register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIM1_SMCR register. Select TI1 as the input source by writing TS=0b101 in TIM1_SMCR register.
- Start the counter by writing CEN=1 in the TIM1_CR1 register.

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIM1_SR1 register) and an interrupt request can be sent if enabled (depending on the TIE in the TIM1_IER register).

The following figure shows this behaviour when the auto-reload register TIM1_ARR=36h. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

Figure 47. Control circuit in trigger reset mode



Trigger gated mode

The counter can be enabled depending on the level of a selected input.

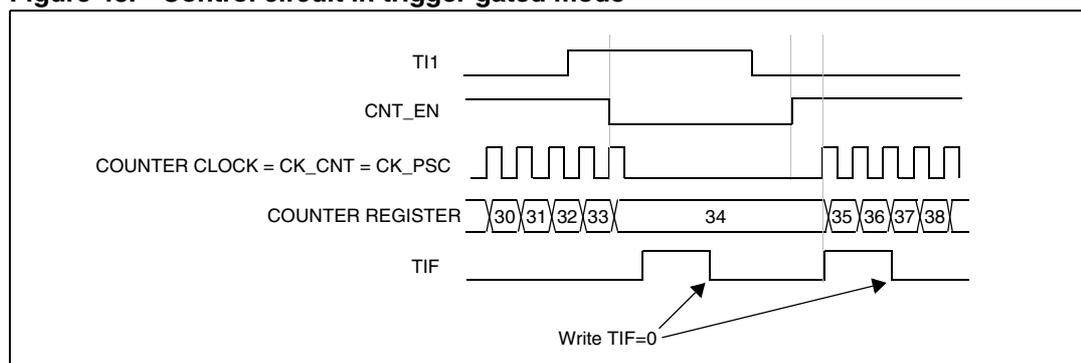
In the following example, the up-counter counts only when TI1 input is low:

1. Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep $IC1F=0b0000$). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, and do not need to be configured either. Write $CC1P=1$ in `TIM1_CCER1` register to validate the polarity (and detect low level only).
2. Configure the timer in trigger gated mode by writing $SMS=0b101$ in `TIM1_SMCR` register. Select TI1 as the input source by writing $TS=101$ in `TIM1_SMCR` register.
3. Enable the counter by writing $CEN=1$ in the `TIM1_CR1` register (in trigger gated mode, the counter doesn't start if $CEN=0$, whatever is the trigger input level).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

Figure 48. Control circuit in trigger gated mode



Combining trigger modes with external clock mode 2

The external clock mode 2 can be used in addition to another trigger mode. In this case, ETR is used as external clock input, and another input can be selected as trigger input (in trigger standard mode, trigger reset mode or trigger gated mode). Take care that you must not select ETR as TRGI (through the TS bits in `TIM1_SMCR` register).

In the following example, the up-counter counts at each rising edge on ETR as soon as a rising edge has occurred on TI1 (standard trigger mode with external ETR clock):

- Configure the external trigger input circuit by writing the `TIM1_ETR` register. In this example, we don't need any filter and write $ETF=0b0000$. Write $ETPS=00$ to disable the prescaler, $ETP=0$ to detect rising edges on ETR and $ECE=1$ to enable the external clock mode 2.
- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep $IC1F=0b0000$). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits

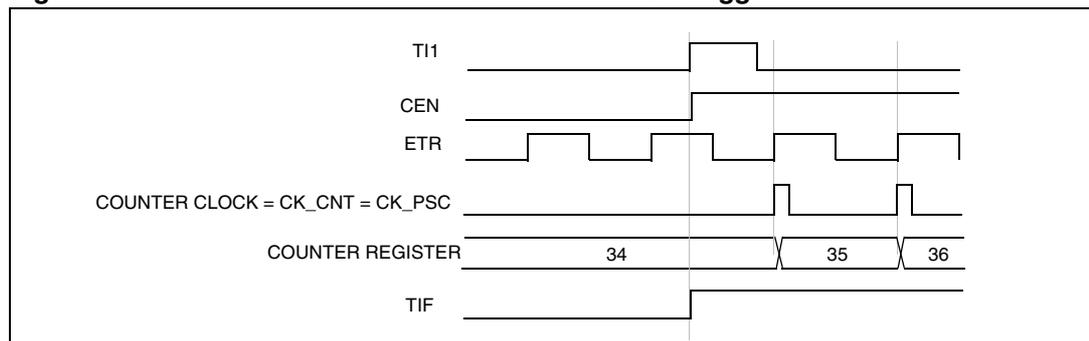
select the input capture source only, and do not need to be configured either. Write CC1P=0 in TIM1_CCER1 register to select rising edge polarity.

- Configure the timer in trigger mode by writing SMS=0b110 in TIM1_SMCR register. Select TI1 as the input source by writing TS=0b101 in TIM1SMCR register.

A rising edge on TI1 enables the counter and sets the TIF flag. Then the counter counts on ETR rising edges.

The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input. The delay between the rising edge on ETR and the actual reset of the counter is due to the resynchronization circuit on the ETRP signal.

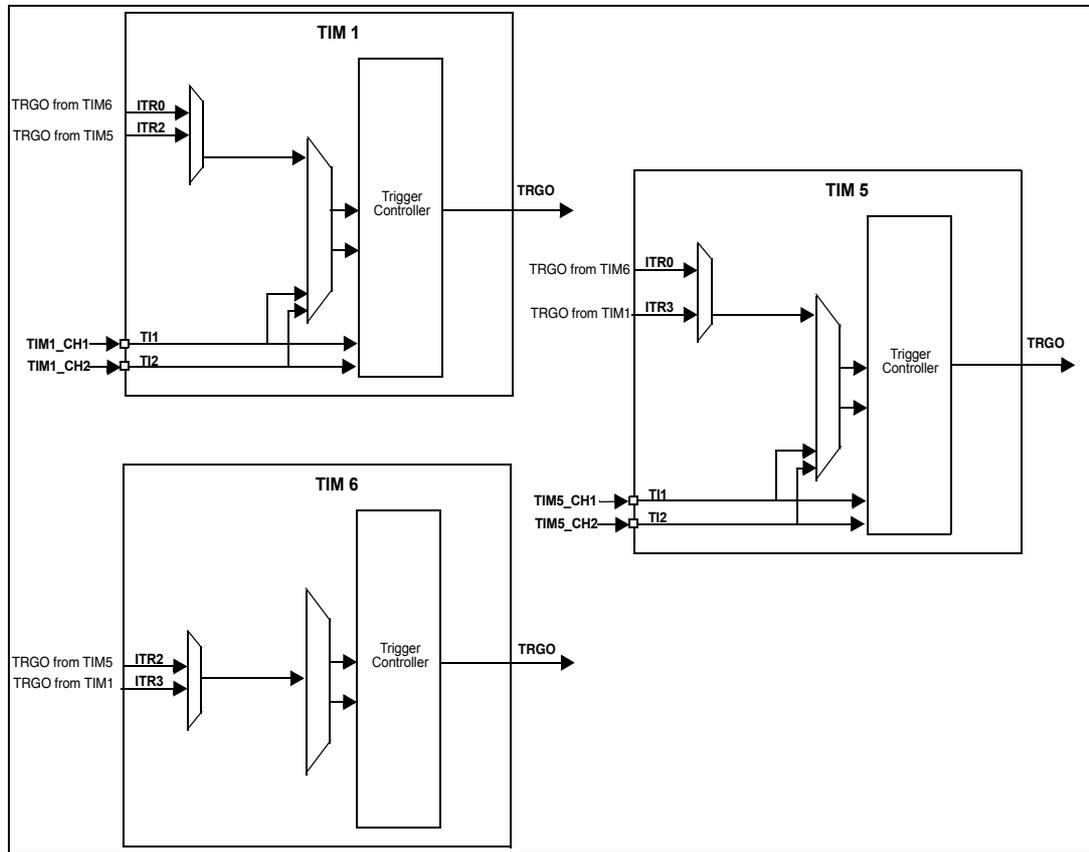
Figure 49. Control circuit in external clock mode 2 + trigger mode



17.4.6 Synchronization from TIM5/TIM6 timers

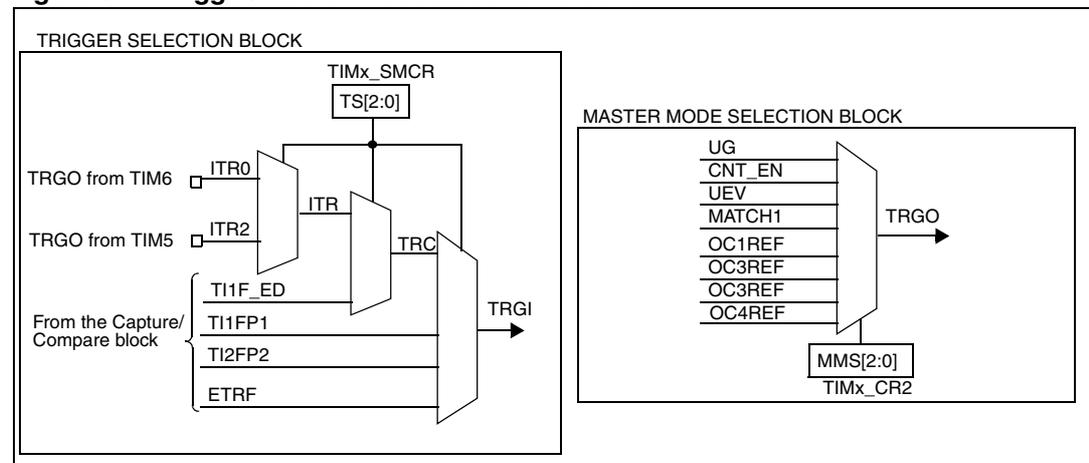
On some products, the timers are linked together internally for timer synchronization or chaining. When one timer is configured in master mode, it can output a trigger (TRGO) to reset, start, stop or clock the counter of any other Timer configured in slave mode.

Figure 50. Timer chaining system implementation example



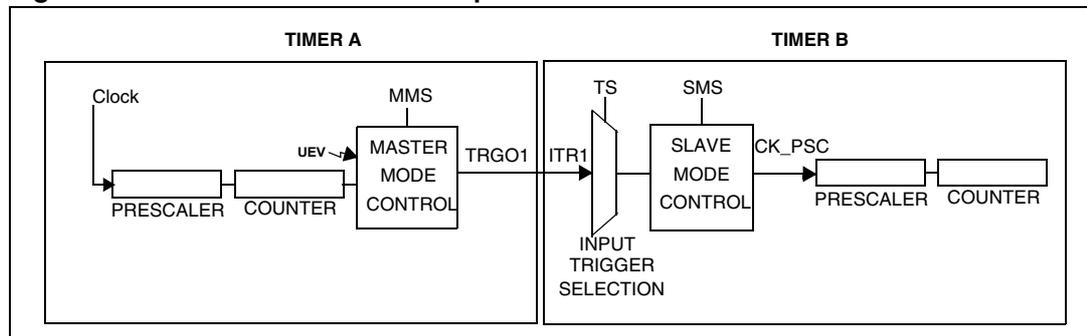
The following figure presents an overview of the trigger selection and the master mode selection blocks.

Figure 51. Trigger/master mode selection blocks



Using one timer as prescaler for another timer

Figure 52. Master/Slave timer example



For example, you can configure Timer A to act as a prescaler for Timer B. Refer to [Figure 52](#). To do this:

1. Configure Timer A in master mode so that it outputs a periodic trigger signal on each update event UEV. To configure that a rising edge is output on TRGO1 each time an update event is generated, write MMS=010 in the TIMx_CR2 register,.
2. Connect the TRGO1 output of Timer A to Timer B, Timer B must be configured in slave mode using ITR1 as internal trigger. Select this through the TS bits in the TIMx_SMCR register (writing TS=001).
3. Put the clock/trigger controller in external clock mode 1, by writing SMS=111 in the TIMx_SMCR register. This causes Timer B to be clocked by the rising edge of the periodic Timer A trigger signal (which corresponds to the Timer A counter overflow).
4. Finally enable both timers by setting their respective CEN bits (TIMx_CR1 register).

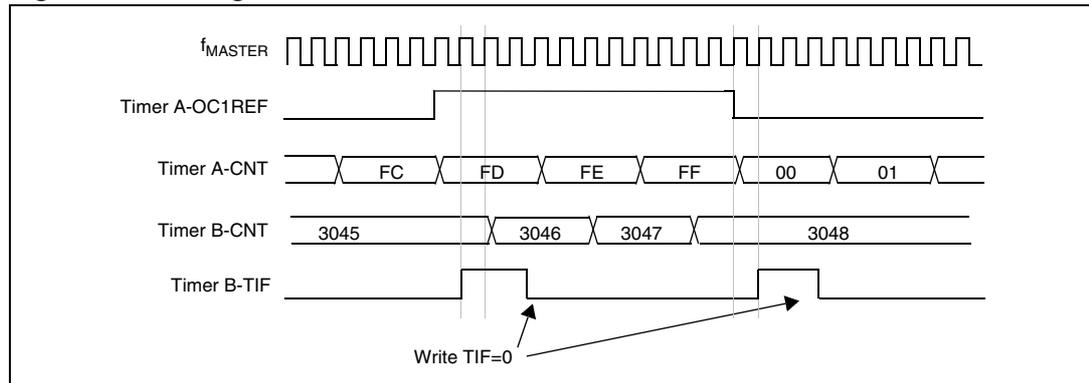
Note: If OCi is selected on Timer A as trigger output (MMS=1xx), its rising edge is used to clock the counter of Timer B.

Using one timer to enable another timer

In this example, we control the enable of Timer B with the output compare 1 of Timer A. Refer to [Figure 53](#) for connections. Timer B counts on the divided internal clock only when OC1REF of Timer A is high. Both counter clock frequencies are divided by 4 by the prescaler compared to f_{MASTER} ($f_{\text{CK_CNT}} = f_{\text{MASTER}}/4$).

1. Configure Timer A master mode to send its Output Compare 1 Reference (OC1REF) signal as trigger output (MMS=100 in the TIMx_CR2 register).
2. Configure the Timer A OC1REF waveform (TIMx_CCMR1 register).
3. Configure Timer B to get the input trigger from Timer A (TS=001 in the TIMx_SMCR register).
4. Configure Timer B in trigger gated mode (SMS=101 in TIMx_SMCR register).
5. Enable Timer B by writing '1' in the CEN bit (TIMx_CR1 register).
6. Start Timer A by writing '1' in the CEN bit (TIMx_CR1 register).

Note: The counter 2 clock is not synchronized with counter 1, this mode only affects the Timer B counter enable signal.

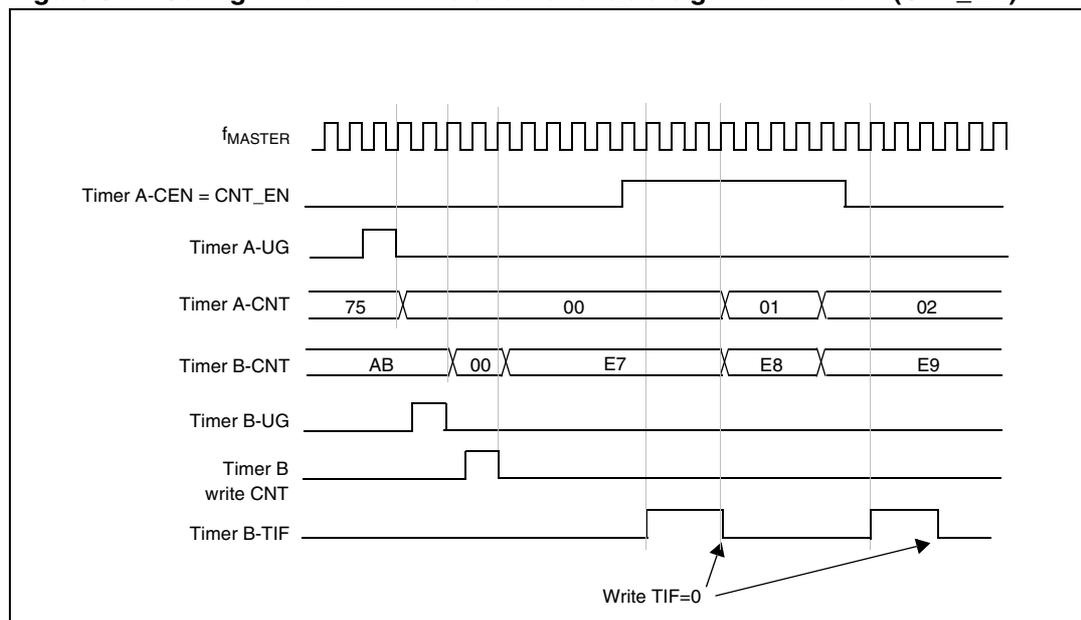
Figure 53. Gating Timer B with OC1REF of Timer A

In the example in [Figure 53](#), the Timer B counter and prescaler are not initialized before being started. So they start counting from their current value. It is possible to start from a given value by resetting both timers before starting Timer A. You can then write any value you want in the timer counters. The timers can easily be reset by software using the UG bit in the TIMx_EGR registers.

In the next example, we synchronize Timer A and Timer B. Timer A is the master and starts from 0. Timer B is the slave and starts from E7h. The prescaler ratio is the same for both timers. Timer B stops when Timer A is disabled by writing '0' to the CEN bit in the TIMx_CR1 register:

1. Configure Timer A master mode to send its Output Compare 1 Reference (OC1REF) signal as trigger output (MMS=100 in the TIMx_CR2 register).
2. Configure the Timer A OC1REF waveform (TIMx_CCMR1 register).
3. Configure Timer B to get the input trigger from Timer A (TS=001 in the TIMx_SMCR register).
4. Configure Timer B in trigger gated mode (SMS=101 in TIMx_SMCR register).
5. Reset Timer A by writing '1' in UG bit (TIMx_EGR register).
6. Reset Timer B by writing '1' in UG bit (TIMx_EGR register).
7. Initialize Timer B to 0xE7 by writing 'E7h' in the Timer B counter (TIMx_CNTRL).
8. Enable Timer B by writing '1' in the CEN bit (TIMx_CR1 register).
9. Start Timer A by writing '1' in the CEN bit (TIMx_CR1 register).
10. Stop Timer A by writing '0' in the CEN bit (TIMx_CR1 register).

Figure 54. Gating Timer B with the counter enable signal of Timer A (CNT_EN)

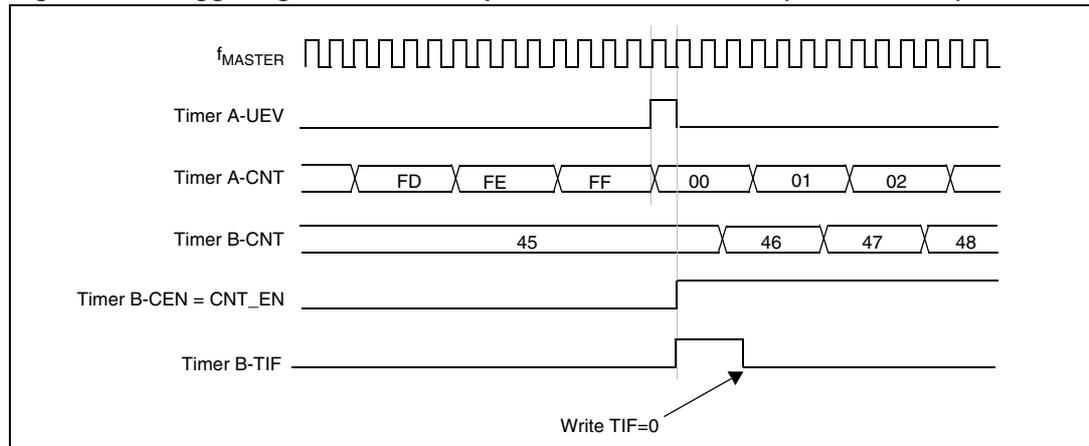


Using one timer to start another timer

In this example, we set the enable of Timer B with the update event of Timer A. Refer to [Figure 52](#) for connections. Timer B starts counting from its current value (which can be non-zero) on the divided internal clock as soon as the update event is generated by Timer A. When Timer B receives the trigger signal its CEN bit is automatically set and the counter counts until we write '0' to the CEN bit in the TIM1_CR1 register. Both counter clock frequencies are divided by 4 by the prescaler compared to f_{MASTER} (f_{CK_CNT} = f_{MASTER}/4).

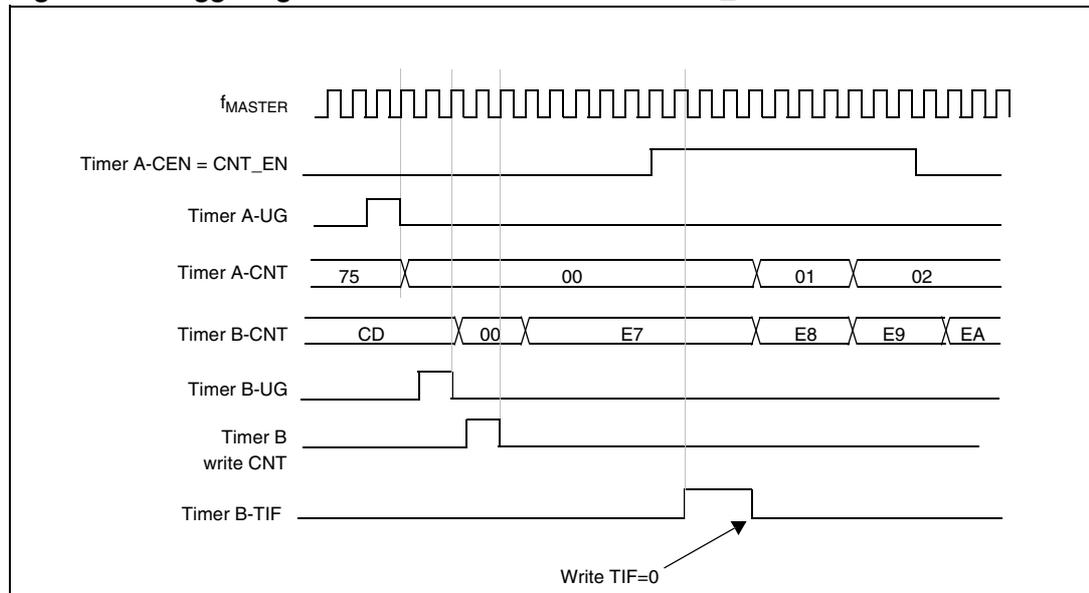
1. Configure Timer A master mode to send its Update Event (UEV) as trigger output (MMS=010 in the TIM1_CR2 register).
2. Configure the Timer A period (TIM1_ARR registers).
3. Configure Timer B to get the input trigger from Timer A (TS=001 in the TIM1_SMCR register).
4. Configure Timer B in trigger mode (SMS=110 in TIM1_SMCR register).
5. Start Timer A by writing '1' in the CEN bit (TIM1_CR1 register).

Figure 55. Triggering Timer B with update event of Timer A (TIMERA-UEV)



As in the previous example, you can initialize both counters before starting counting. [Figure 56](#) shows the behaviour with the same configuration as in the [Figure 54](#) but in trigger standard mode instead of trigger gated mode (SMS=110 in the TIM1_SMCR register).

Figure 56. Triggering Timer B with counter enable CNT_EN of Timer A



Starting 2 timers synchronously in response to an external trigger

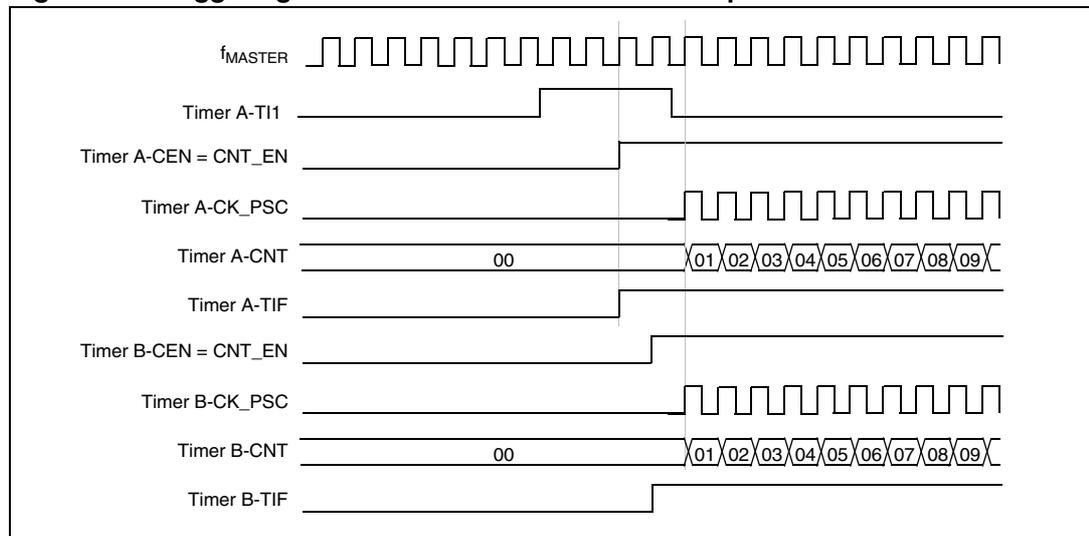
In this example, we set the enable of Timer A when its TI1 input rises, and the enable of Timer B with the enable of Timer A. Refer to [Figure 52](#) for connections. To ensure the counters alignment, Timer A must be configured in master/slave mode (slave with respect to TI1, master with respect to Timer B).

1. Configure Timer A master mode to send its Enable as trigger output (MMS=001 in the TIMx_CR2 register).
2. Configure Timer A slave mode to get the input trigger from TI1 (TS=100 in the TIMx_SMCR register).
3. Configure Timer A in trigger mode (SMS=110 in the TIMx_SMCR register).
4. Configure the Timer A in Master/Slave mode by writing MSM='1' (TIMx_SMCR register).
5. Configure Timer B to get the input trigger from Timer A (TS=001 in the TIMx_SMCR register).
6. Configure Timer B in trigger mode (SMS=110 in the TIMx_SMCR register).

When a rising edge occurs on TI1 (Timer A), both counters starts counting synchronously on the internal clock and both TIF flags are set.

Note: In this example both timers are initialized before starting (by setting their respective UG bits). Both counters starts from 0, but you can easily insert an offset between them by writing any of the counter registers (TIMx_CNT). You can see that the master/slave mode insert a delay between CNT_EN and CK_PSC on Timer A.

Figure 57. Triggering Timer A and B with Timer A TI1 input

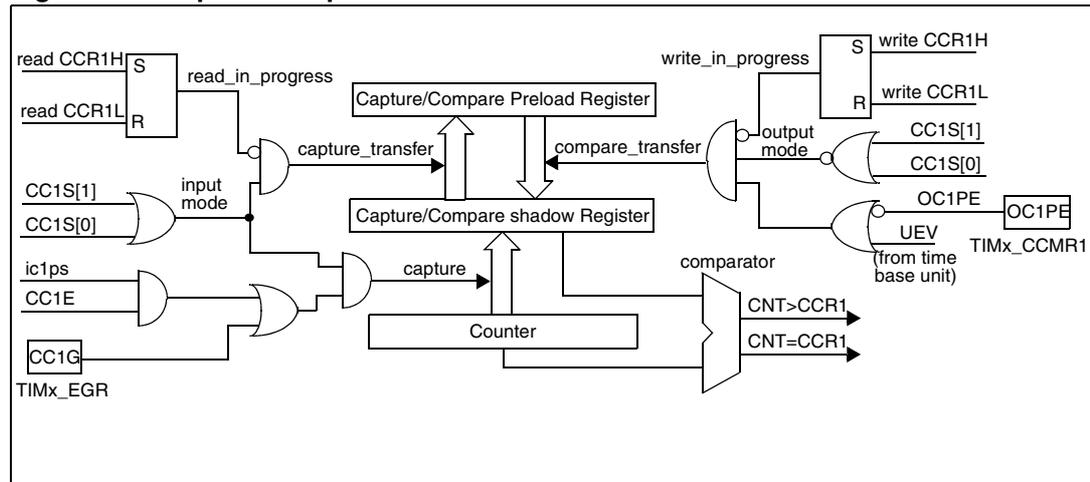


17.5 TIM1 capture/compare channels

The timer I/O pins (TIM1_CC*i*) can be configured either for input capture or output compare functions. The choice is made by configuring the CC*i*S channel selection bits in the capture/compare channel mode register (TIM1_CCMR*i*), where *i* is the channel number.

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), an input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

Figure 58. Capture/compare channel 1 main circuit



The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register. In capture mode, captures are actually done in the shadow register, which is copied into the preload register. In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

When the channel is configured in output mode (CC*i*S=0b00 in the TIM1_CCMR*i* register) where *i* is the channel number, the TIM1_CCR*i* register can be accessed without any restriction.

When the channel is configured in input mode, the sequence for reading the TIM1_CCR*i* register is the same as for the counter. See [Figure 59](#). When a capture occurs, the content of the counter is captured into the TIM1_CCR*i* shadow register. Then this value is loaded into the preload register, except during the read sequence, when the preload register is frozen.

Figure 59. 16-bit read sequence for the TIM1_CCR*i* register in capture mode

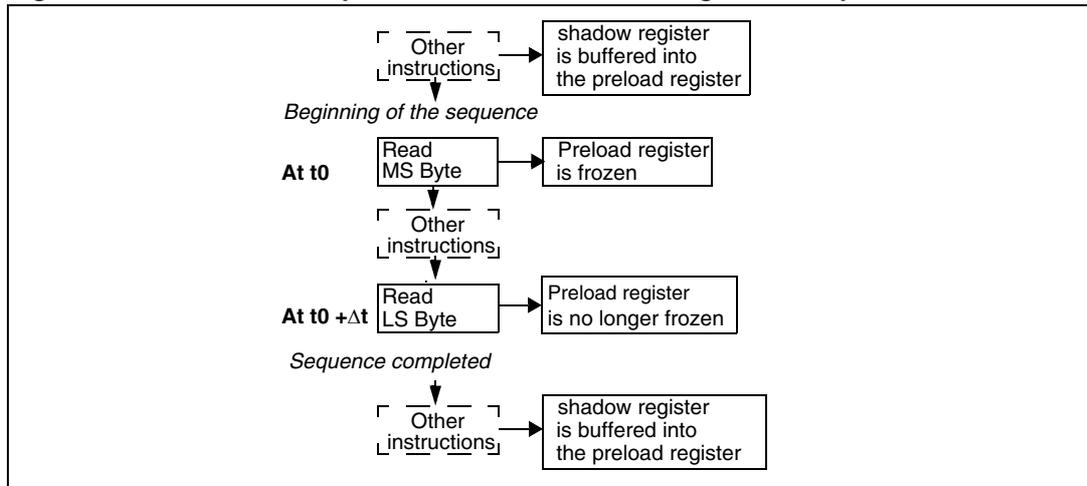


Figure 59 shows the sequence for reading the CCR*i* registers in the 16-bit timers. This buffered value remains unchanged until the 16-bit read sequence is completed.

After a complete reading sequence, if only the TIM1_CCR*L* register is read, it returns the LS Byte of the count value at the time of the read.

If the MS byte is read after the LS byte, it no longer corresponds to the same captured value as the LS byte.

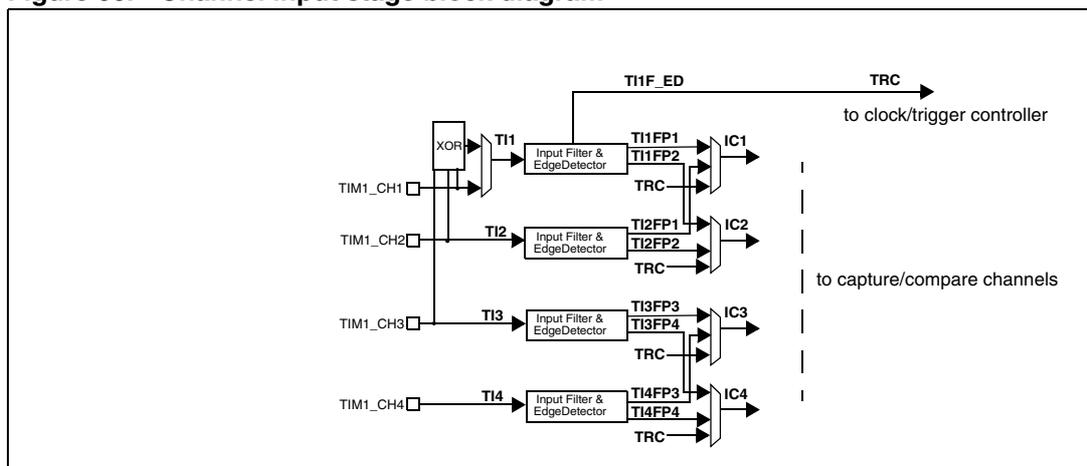
17.5.1 Write sequence for 16-bit TIM1_CCR*i* registers

16-bit values are loaded in the TIM1_CCR*i* registers through preload registers. This must be performed by two write instructions, one for each byte. The MS byte must be written first.

The shadow register update is blocked as soon as the MS byte has been written, and stays blocked until the LS byte has been written. Do not use the LDW instruction, as this writes the LS byte first, and would produce wrong results in this case.

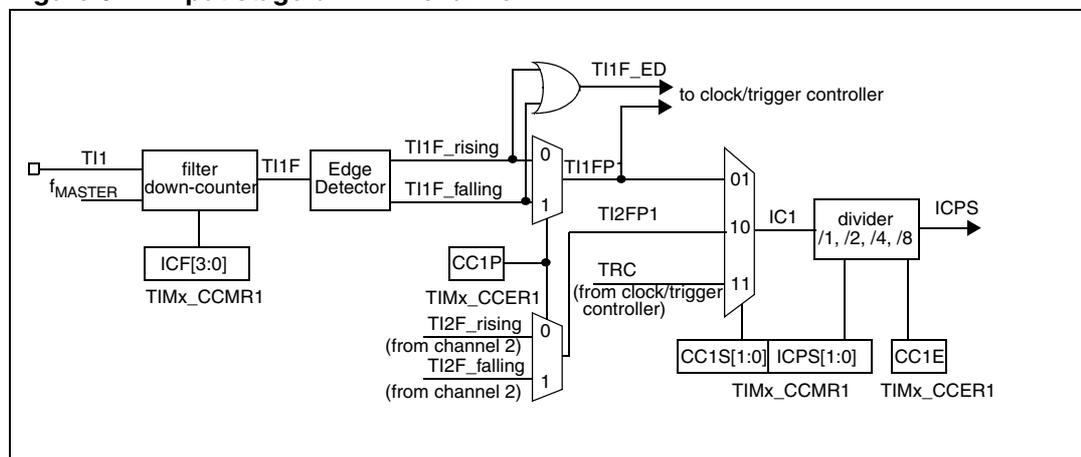
17.5.2 Input stage

Figure 60. Channel input stage block diagram



As shown in *Figure 61*, the input stage samples the corresponding Ti input to generate a filtered signal TiF . Then, an edge detector with polarity selection generates a signal ($TiFPx$) which can be used as trigger input by the clock/trigger controller or as the capture command. It is prescaled before the capture register (ICi/PS).

Figure 61. Input stage of TIM 1 channel 1



17.5.3 Input capture mode

In Input capture mode, the Capture/Compare Registers ($TIM1_CCRi$) are used to latch the value of the counter after a transition detected on the corresponding ICi signal. When a capture occurs, the corresponding $CCiF$ flag ($TIM1_SR1$ register) is set.

An interrupt can be sent if it is enabled by setting the $CCiE$ bit in the $TIM1_IER$ register. If a capture occurs while the $CCiF$ flag was already high, then the over-capture flag $CCiOF$ ($TIM1_SR2$ register) is set. $CCiF$ can be cleared by software by writing it to '0' or by reading the captured data stored in the $TIMx_CCRiL$ register. $CCiOF$ is cleared when you write it to '0'.

The following example shows how to capture the counter value in $TIM1_CCR1$ when $TI1$ input rises. To do this, use the following procedure:

1. Select the active input: For example, to link the $TIM1_CCR1$ register to the $TI1$ input, write the $CC1S$ bits to 0b01 in the $TIM1_CCMR1$ register. This configures the channel in input mode and the $TIM1_CCR1$ register becomes read-only.
2. Program the input filter duration that is needed for the type of the signal to be connected to the timer. This is done for each TIi input using the $ICiF$ bits in the $TIM1_CCMRi$ register. For example, if you know that when, the input signal toggles, it is unstable for up to $5 f_{MASTER}$ cycles, you must program the filter duration longer than 5 clock cycles. The filter bits allow you to select a duration of 8 cycles by writing the value 0b0011 in in these bits the $TIMx_CCMR1$ register. With this filter setting, a transition on

TI1 is valid only when 8 consecutive samples with the new level have been detected (sampled at f_{MASTER} frequency).

3. Select the edge of the active transition on the TI1 channel by writing CC1P bit to '0' in the TIM1_CCER1 register (rising edge in this case).
4. Program the input prescaler. In our example, we want the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to 0b00 in the TIM1_CCMR1 register).
5. Enable capture from the counter into the capture register by setting the CC1E bit in the TIM1_CCER1 register.
6. If needed, enable the related interrupt request by setting the CC1IE bit in the TIM1_IER register.

When an input capture occurs:

- The TIM1_CCR1 register gets the value of the counter on the active transition.
- The input capture flag (CC1IF) is set (interrupt flag). The overcapture flag CC1OF is also set if at least two consecutive captures occurred while the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.

To handle the overcapture event (CC1OF flag), it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

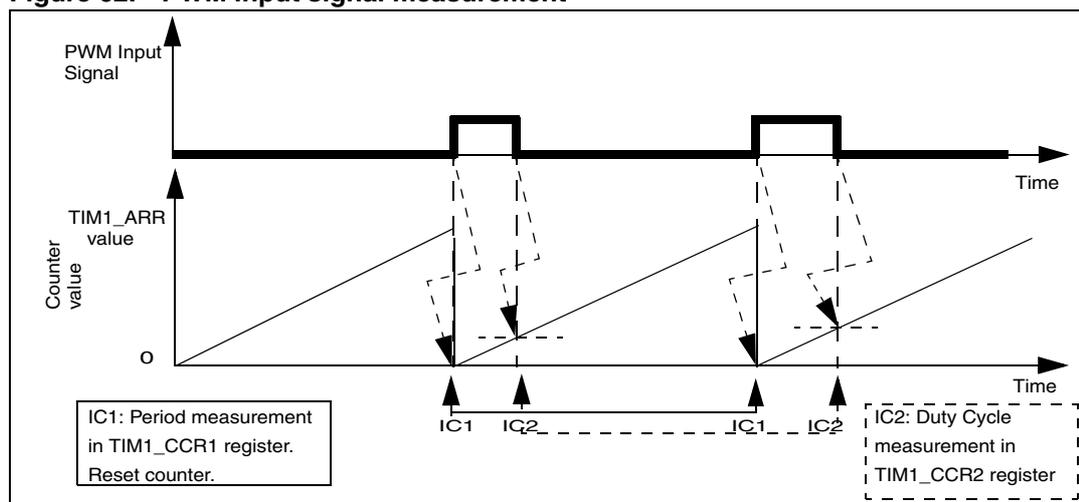
Note: IC interrupts can be generated by software by setting the corresponding CCiG bit in the TIM1_EGR register.

PWM input signal measurement

This mode is a particular case of input capture mode. The procedure is the same except:

- Two IC i are mapped on the same TI i input.
- These 2 IC i are active on edges with opposite polarity.
- One of the two TI/FP is selected as trigger input and the clock/trigger controller is configured in trigger reset mode.

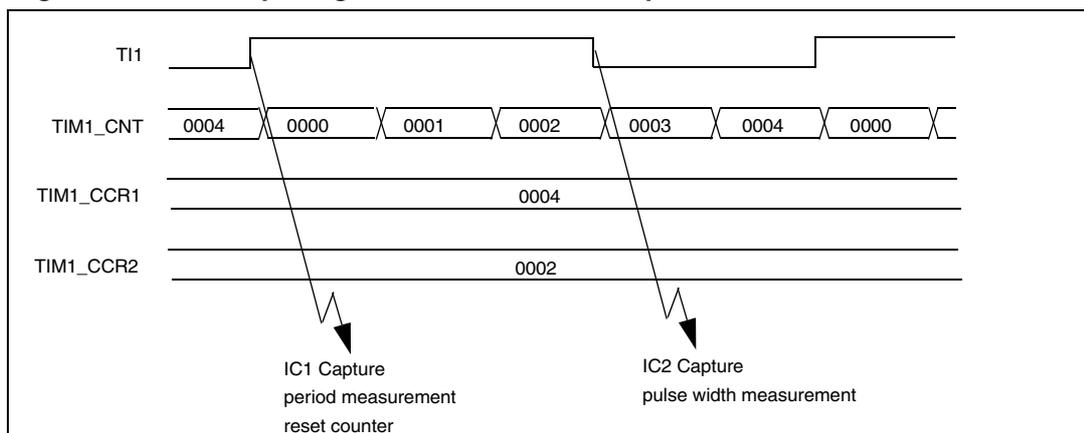
Figure 62. PWM input signal measurement



For example, you can measure the period (in the TIM1_CCR1 register) and the duty cycle (in the TIM1_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on f_{MASTER} frequency and prescaler value):

1. Select the active input capture or trigger input for TIM1_CCR1: write the CC1S bits to 0b01 in the TIM1_CCMR1 register (TI1FP1 selected).
2. Select the active polarity for TI1FP1 (used both for capture in TIMx_CCR1 and counter clear): write the CC1P bit to '0' (active on rising edge).
3. Select the active input for TIM1_CCR2: write the CC2S bits to 0b10 in the TIM1_CCMR2 register (TI1FP2 selected).
4. Select the active polarity for TI1FP2 (used for capture in TIM1_CCR2): write the CC2P bit to '1' (active on falling edge).
5. Select the valid trigger input: write the TS bits to 0b101 in the TIM1_SMCR register (TI1FP1 selected).
6. Configure the clock/trigger controller in reset mode: write the SMS bits to '100' in the TIM1_SMCR register.
7. Enable the captures: write the CC1E and CC2E bits to '1' in the TIM1_CCER1 register.

Figure 63. PWM input signal measurement example



17.5.4 Output stage

The output stage generates an intermediate waveform called OC/REF (active high) which is then used for reference. Break functions and polarity act at the end of the chain.

Figure 64. Channel output stage block diagram

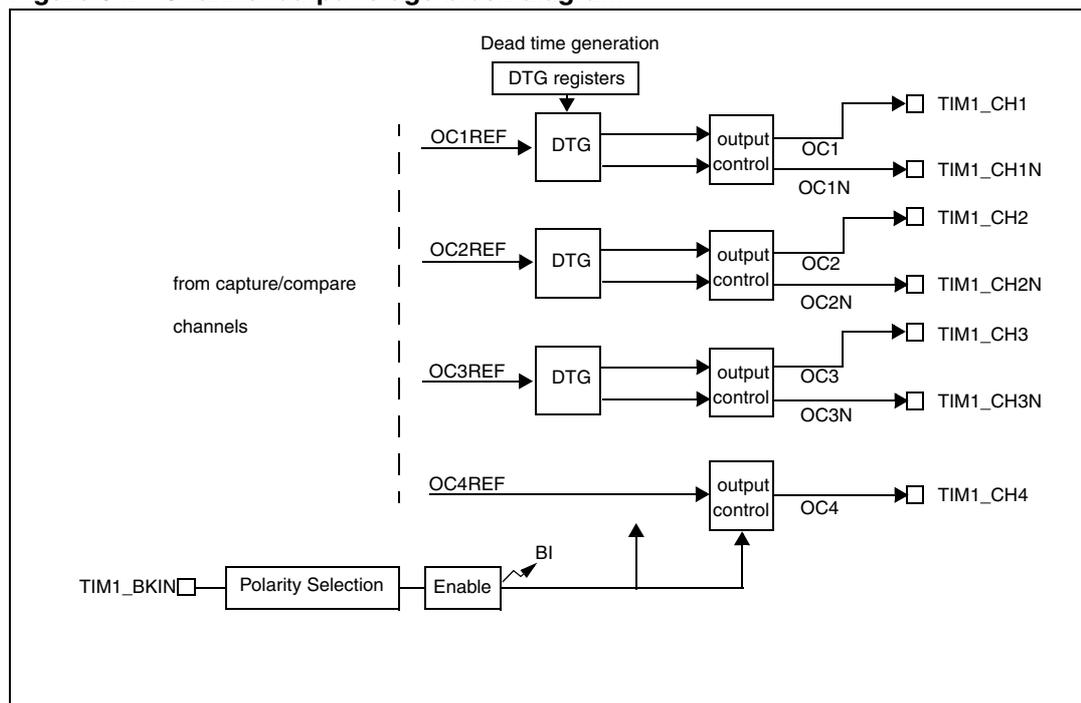
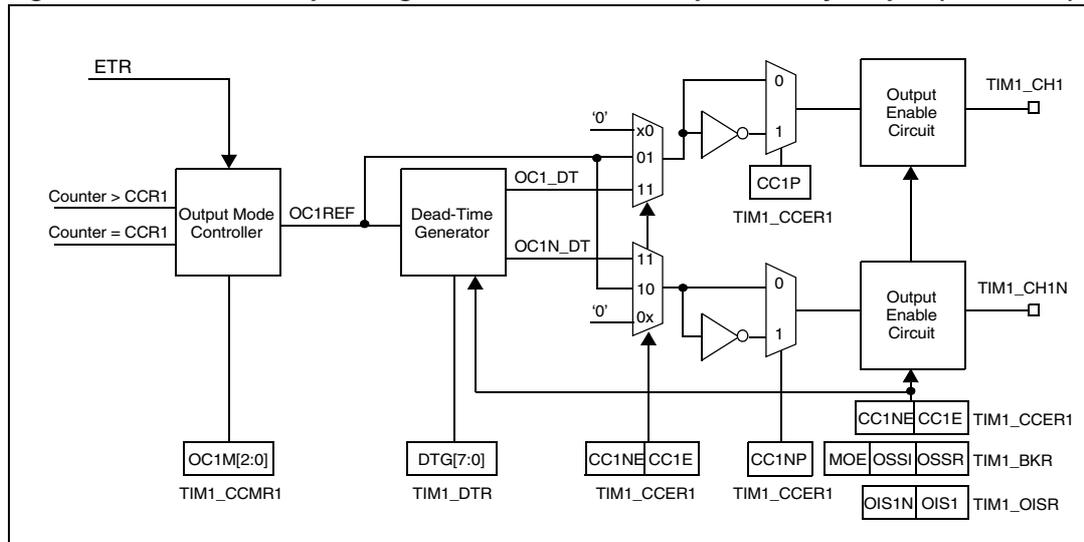


Figure 65. Detailed output stage of channel with complementary output (channel 1)



17.5.5 Forced output mode

In output mode (CC/S bits = 0b00 in the TIM1_CCMR*i* register) where *i* is the channel number, each output compare signal can be forced to high or low level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal to its active level, you just need to write '101' in the OC*M* bits in the corresponding TIM1_CCMR*i* register. Thus OC*REF* is forced high (OC*REF* is always active high) and the OC*i* output is forced to high or low level depending on the CC*P* polarity bit.

For example: CC*P*=0 (OC*i* active high) => OC*i* is forced to high level.

The OC*REF* signal can be forced low by writing the OC*M* bits to 0b100 in the TIM*x*_CCMR*x* register.

Anyway, the comparison between the TIM1_CCR*i* shadow register and the counter is still performed and allows the flag to be set. Interrupt requests can be sent accordingly. This is described in the Output Compare Mode section below.

17.5.6 Output compare mode

This function is used to control an output waveform or indicate when a period of time has elapsed.

When a match is found between the capture/compare register and the counter:

- Depending on the output compare mode, the corresponding OC*i* output pin:
 - keeps its level (OC*M*=0b000),
 - is set active (OC*M*=0b001),
 - is set inactive (OC*M*=0b010)
 - or toggles (OC*M*=0b011)
- Sets a flag in the interrupt status register (CC*I*F bit in the TIM1_SR1 register).
- Generates an interrupt if the corresponding interrupt mask is set (CC*I*E bit in the TIM1_IER register).

The output compare mode is defined by the $OC\overline{M}$ bits in the $TIM1_CCMRi$ register. The active or inactive level polarity is defined by the $CC\overline{P}$ bit in the $TIM1_CCERi$ register.

The $TIM1_CCRi$ registers can be programmed with or without preload registers using the $OC\overline{PE}$ bit in the $TIM1_CCMRi$ register.

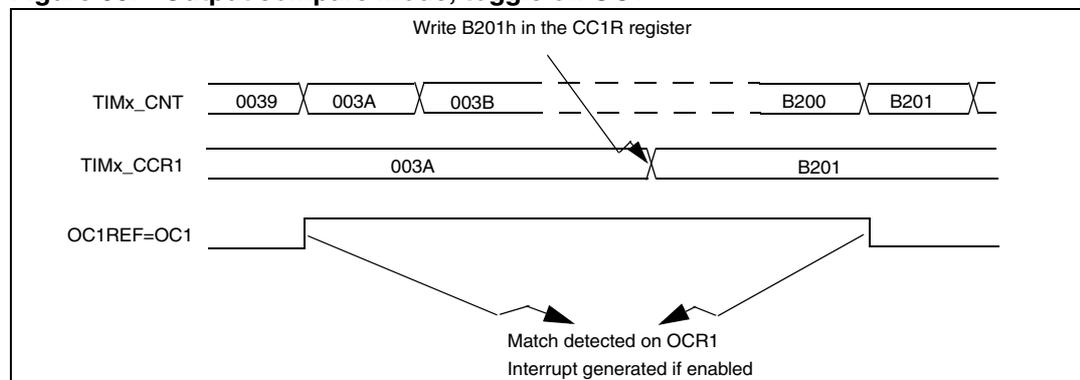
In output compare mode, the update event UEV has no effect on the $OC\overline{REF}$ and OCi output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse.

Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the $TIM1_ARR$ and $TIM1_CCRi$ registers.
3. Set the $CC\overline{IE}$ bit if an interrupt request is to be generated.
4. Select the output mode as follows:
 - Write $OC\overline{M} = 0b011$ to toggle OCi output pin when CNT matches $CCRi$
 - Write $OC\overline{PE} = 0$ to disable preload register
 - Write $CC\overline{P} = 0$ to select active high polarity
 - Write $CC\overline{E} = 1$ to enable the output
5. Enable the counter by setting the CEN bit in the $TIMx_CR1$ register.

The $TIM1_CCRi$ register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled ($OC\overline{PE}=0$, else $TIMx_CCRi$ shadow register will be updated only at the next update event UEV). An example is given in [Figure 66](#).

Figure 66. Output compare mode, toggle on OC1



17.5.7 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIM1_ARR register and a duty cycle determined by the value of the TIM1_CCR*i* register.

The PWM mode can be selected independently on each channel (one PWM per OC*i* output) by writing 0b110 (PWM mode 1) or 0b111 (PWM mode 2) in the OC*M* bits in the TIM1_CCMR*i* register. You must enable the corresponding preload register by setting the OC*i*PE bit in the TIM1_CCMR*i* register, and optionally enable the auto-reload preload register (in up-counting or center-aligned modes) by setting the ARPE bit in the TIM1_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIM1_EGR register.

OC*i* polarity is software programmable using the CC*P* bit in the TIM1_CCER*i* register. It can be programmed as active high or active low. OC*i* output is enabled by a combination of CC*E*, MOE, OIS*i*, OSSR and OSSI bits (TIM1_CCER*i* and TIM1_BKR registers). Refer to the TIM1_CCER*i* register description for more details.

In PWM mode (1 or 2), TIM1_CNT and TIM1_CCR*i* are always compared to determine whether $TIM1_CCR_i \leq TIM1_CNT$ or $TIM1_CNT \leq TIM1_CCR_i$ (depending on the direction of the counter).

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIM1_CR1 register.

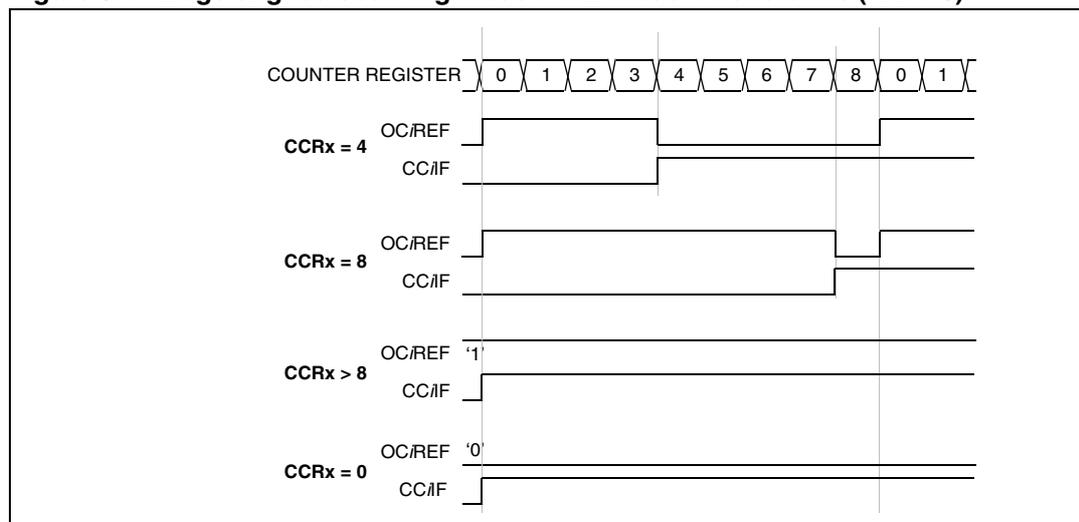
PWM edge-aligned mode

Up-counting configuration

Up-counting is active when the DIR bit in the TIM1_CR1 register is low.

In the following example, we consider the PWM mode 1. The reference PWM signal OC/REF is high as long as $TIM1_CNT < TIM1_CCR_i$ else it becomes low. If the compare value in TIM1_CCR*i* is greater than the auto-reload value (in TIM1_ARR) then OC/REF will be held at '1'. If the compare value is 0 then OC/REF will be held at '0'. [Figure 67](#) shows some edge-aligned PWM waveforms in an example where TIM1_ARR=8.

Figure 67. Edge-aligned counting mode PWM mode 1 waveforms (ARR=8)



Down-counting configuration

Down-counting is active when DIR bit in TIM1_CR1 register is high. Refer to [Down-counting mode on page 144](#)

In PWM mode 1, the reference signal OC/REF is low as long as TIM1_CNT > TIM1_CCR*i* else it becomes high. If the compare value in TIM1_CCR*i* is greater than the auto-reload value in TIM1_ARR, then OC/REF will be held at '1'. 0% PWM is not possible in this mode.

PWM center-aligned mode

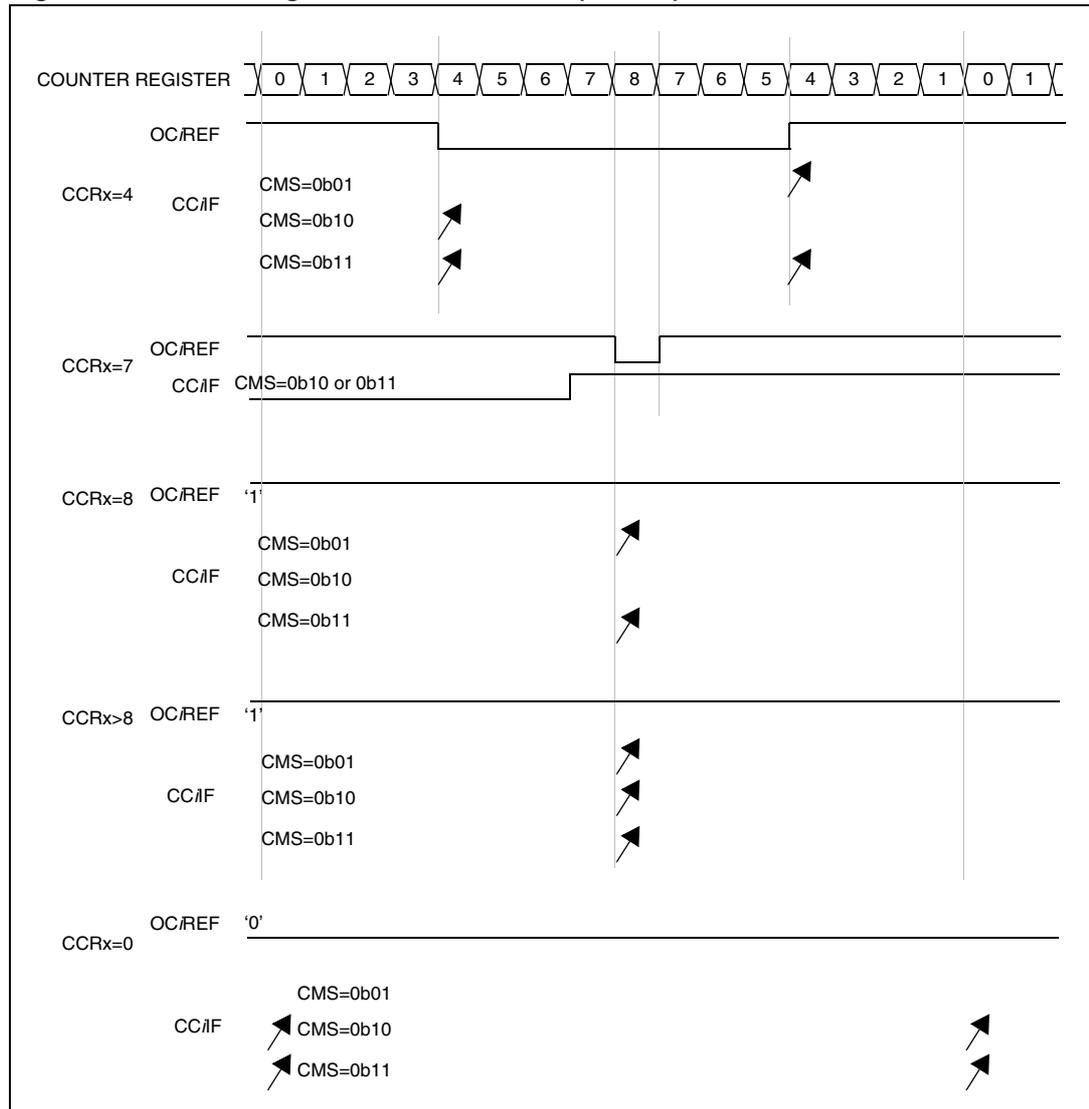
Center-aligned mode is active when the CMS bits in TIM1_CR1 register are different from '00' (all the remaining configurations having the same effect on the OC/REF/OC*i* signals).

The compare flag is set when the counter counts up, when it counts down or both when it counts up and down depending on the CMS bits configuration. The direction bit (DIR) in the TIM1_CR1 register is updated by hardware and is read-only in this mode. Refer to [Center-aligned mode \(up/down counting\) on page 146](#).

[Figure 68](#) shows some center-aligned PWM waveforms in an example where:

- The TIM1_ARR=8,
- PWM mode is PWM mode 1,
- the flag is set (arrow symbol in [Figure 68](#)) in three different cases:
 - only when the counter counts down (CMS=0b01)
 - only when the counter counts up (CMS=0b10) .
 - when the counter counts up and down (CMS=0b11) .

Figure 68. Center-aligned PWM waveforms (ARR=8)



One pulse mode

One Pulse Mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

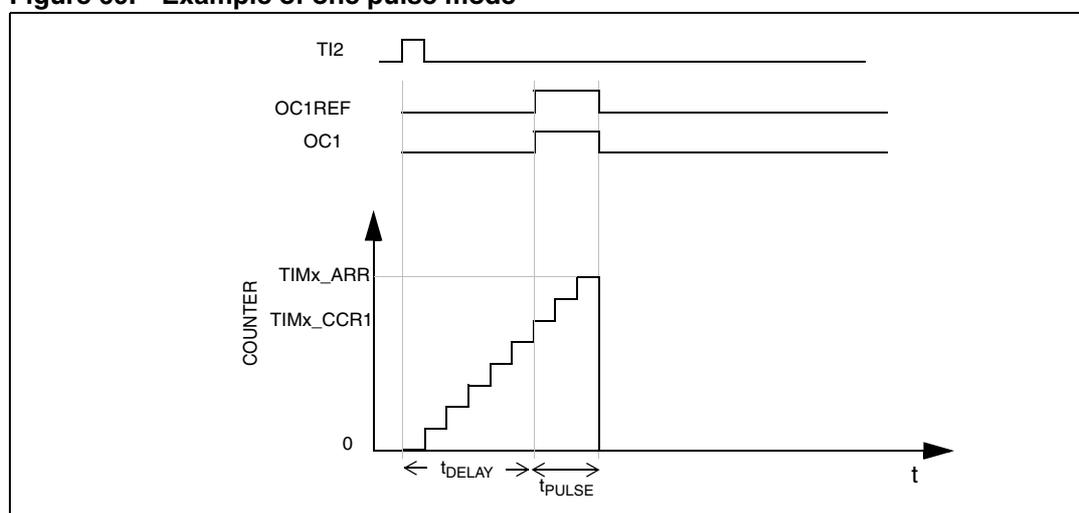
Starting the counter can be controlled through the clock/trigger controller. Generating the waveform can be done in output compare mode or PWM mode. You select One Pulse Mode by setting the OPM bit in the TIM1_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

In up-counting: $CNT < CCR_i \leq ARR$ (in particular, $0 < CCR_i$),

In down-counting: $CNT > CCR_i$.

Figure 69. Example of one pulse mode



For example you may want to generate a positive pulse on OC1 with a length of t_{PULSE} and after a delay of t_{DELAY} as soon as a positive edge is detected on the TI2 input pin.

Let's use IC2 as trigger 1:

- Map IC2 on TI2 by writing $CC2S=0b01$ in the TIM1_CCMR2 register.
- IC2 must detect a rising edge, write $CC2P='0'$ in the TIM1_CCER1 register.
- Configure IC2 as trigger for the clock/trigger controller (TRGI) by writing $TS=0b110$ in the TIM1_SMCR register.
- IC2 is used to start the counter by writing SMS to $0b110$ in the TIM1_SMCR register (trigger mode).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The t_{DELAY} is defined by the value written in the TIM1_CCR1 register.
- The t_{PULSE} is defined by the difference between the auto-reload value and the compare value (TIM1_ARR - TIM1_CCR1).
- Let's say you want to build a waveform with a transition from '0' to '1' when a compare match occurs and a transition from '1' to '0' when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC/M=0b111 in the TIM1_CCMR1 register. You can optionally enable the preload registers by writing OC1PE='1' in the TIM1_CCMR1 register and ARPE in the TIM1_CR1 register. In this case you have to write the compare value in the TIM1_CCR1 register, the auto-reload value in the TIM1_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0' in this example.

In our example, the DIR and CMS bits in the TIM1_CR1 register should be low.

You only want 1 pulse, so you write '1' in the OPM bit in the TIM1_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0).

Particular case: OC*i* fast enable:

In One Pulse Mode, the edge detection on TI*i* input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay $t_{\text{DELAY min}}$ we can get.

If you want to output a waveform with the minimum delay, you can set the OC/FE bit in the TIM1_CCMR*i* register. Then OC/REF (and OC*i*) will be forced in response to the stimulus, without taking in account the comparison. Its new level will be the same as if a compare match had occurred. OC/FE acts only if the channel is configured in PWM1 or PWM2 mode.

Complementary outputs and dead-time insertion

TIM1 can output two complementary signals per channel and manage the switching-off and the switching-on instants of the outputs. See [Figure 28: TIM1 general block diagram on page 139](#)

This time is generally known as dead-time. Dead-times must be adjusted depending on the characteristics of the devices connected to the outputs (ex: intrinsic delays of level-shifters, delays due to power switches).

The polarity of the outputs can be selected (main output OC*i* or complementary OC*i*N) independently for each output. This is done by writing to the CC*i*P and CC*i*NP bits in the TIM1_CCER*i* register.

The complementary signals OC*i* and OC*i*N are activated by a combination of several control bits: the CC*i*E and CC*i*NE bits in the TIM1_CCER*i* register and, if the break feature is implemented, the MOE, OIS*i*, OIS*i*N, OSS1 and OSSR bits in the TIM1_BKR register. Refer to [Table 34: Output control for complementary OC*i* and OC*i*N channels with break feature on page 204](#) for more details. In particular, the dead-time is activated when switching to the IDLE state (MOE falling down to 0).

Dead-time insertion is enabled by setting both CC*i*E and CC*i*NE bits, and the MOE bit if the break circuit is present. Each channel embeds an 8-bit dead-time generator. From a

reference waveform $OCi\ REF$, it generates 2 outputs OCi and $OCi\ N$. If OCi and $OCi\ N$ are active high:

- The OCi output signal is the same as the reference signal except for the rising edge, which is delayed relative to the reference rising edge.
- The $OCi\ N$ output signal is the opposite of the reference signal except for the rising edge, which is delayed relative to the reference falling edge.

If the delay is greater than the width of the active output (OCi or $OCi\ N$) then the corresponding pulse is not generated.

The following figures show the relationships between the output signals of the dead-time generator and the reference signal $OCi\ REF$. (we suppose $CCi\ P=0$, $CCi\ NP=0$, $MOE=1$, $CCi\ E=1$ and $CCi\ NE=1$ in these examples)

Figure 70. Complementary output with dead-time insertion

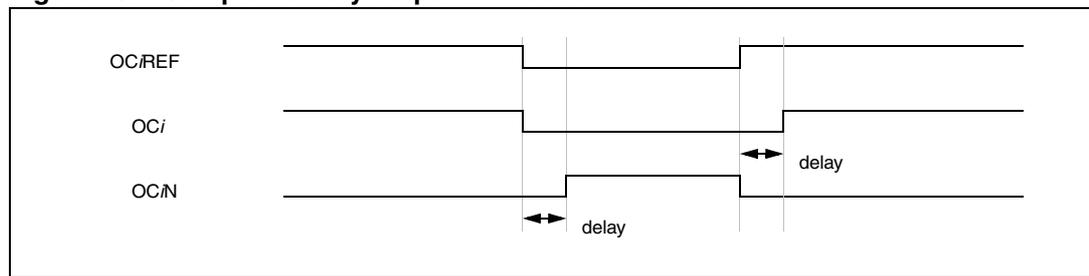


Figure 71. Dead-time waveforms with delay greater than the negative pulse

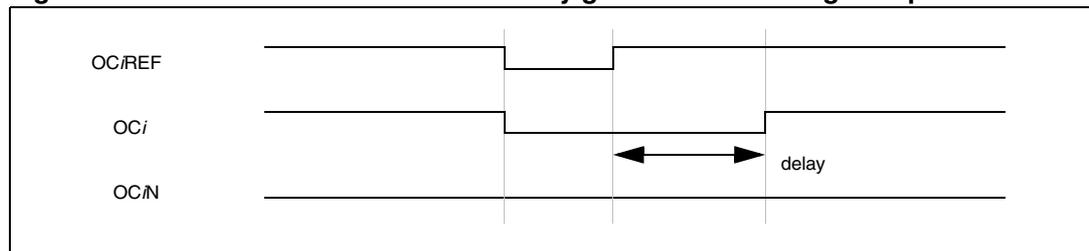
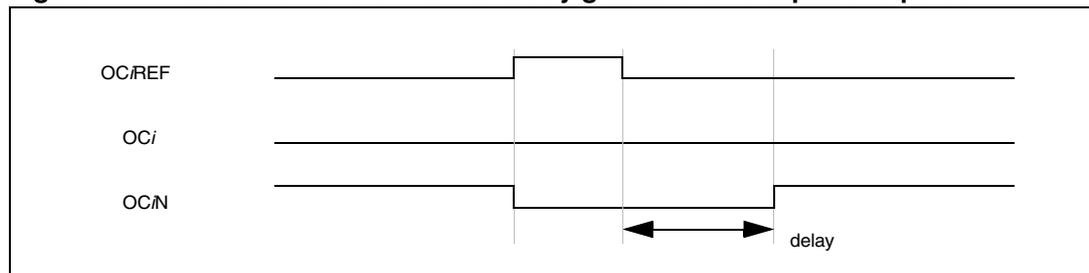


Figure 72. Dead-time waveforms with delay greater than the positive pulse



The dead-time delay is the same for each of the channels and is programmable with the DTG bits in the TIM1_DTR register. Refer to [Section 17.7.31: Dead-time register \(TIM1_DTR\) on page 214](#) for delay calculation.

Re-directing $OCi\ REF$ to OCi or $OCi\ N$

In output mode (forced, output compare or PWM), $OCi\ REF$ can be re-directed to the OCi output or to $OCi\ N$ output by configuring the $CCi\ E$ and $CCi\ NE$ bits in the corresponding TIM1_CCERi register. This means bypassing the dead-time generator

This allows you to send a specific waveform (such as PWM or static active level) on one output while the complementary remains at its inactive level. Other alternative possibilities are to have both outputs at inactive level or both outputs active and complementary with dead-time.

Note: When only OCiN is enabled (CCiE=0, CCiNE=1), it is not complemented and becomes active as soon as OCiREF is high. For example, if CCiNP=0 then OCiN=OCiREF. On the other hand, when both OCi and OCiN are enabled (CCiE=CCiNE=1) OCi becomes active when OCiREF is high whereas OCiN is complemented and becomes active when OCiREF is low.

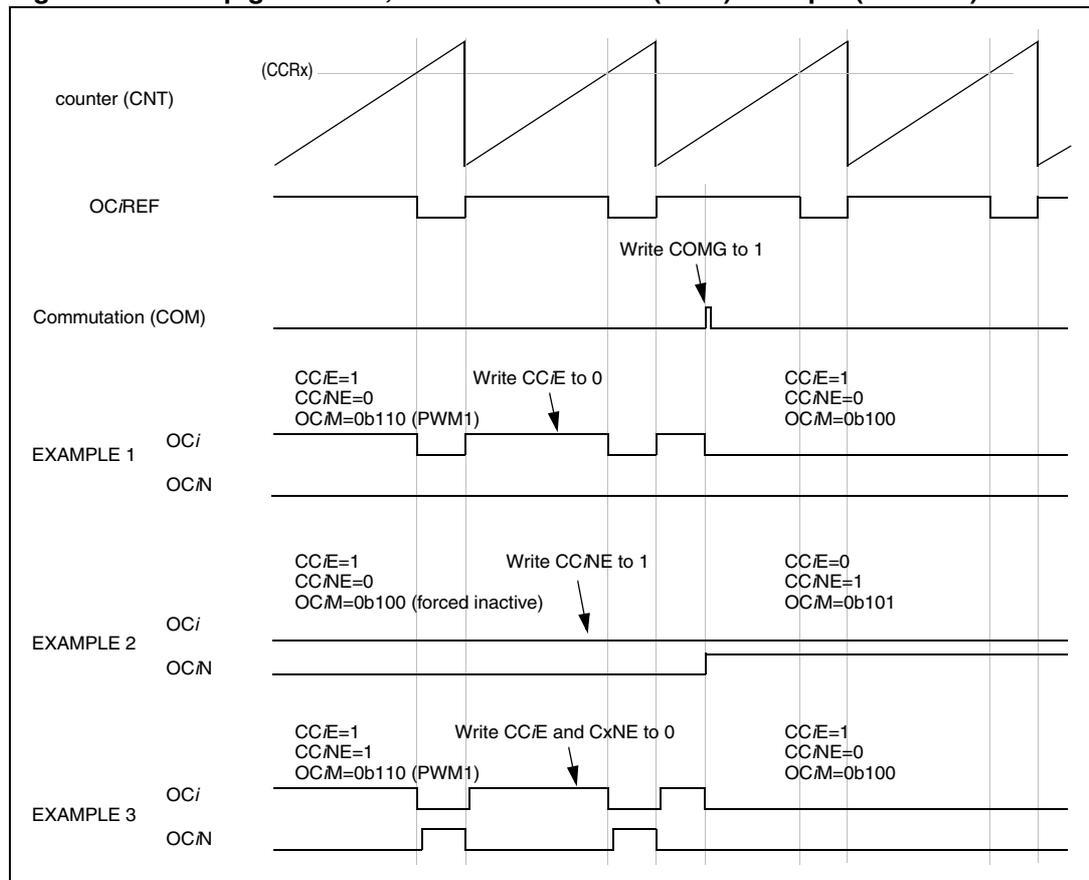
6-step PWM generation for motor control

When complementary outputs are implemented on a channel, preload bits are available on the OCiM, CCiE and CCiNE bits. The preload bits are transferred to the active bits at the Commutation event (COM). This allows you to program the configuration for the next step in advance and change the configuration of all the channels at the same time. The COM event can be generated by software by setting the COMG bit in the TIM1_EGR register or by hardware trigger (on the rising edge of TRGI).

A flag is set when the COM event occurs (COMIF bit in the TIM1_SR register), which can generate an interrupt (if the COMIE bit is set in the TIM1_IER register).

Figure 73 describes the behavior of the OCi and OCiN outputs when a COM event occurs, in three different examples of programmed configurations.

Figure 73. 6-step generation, commutation event (COM) example (OSSR=1)



17.5.8 Using the break function

The break function is often used in motor control. When using the break function, the output enable signals and inactive levels are modified according to additional control bits (MOE, OSSR and OSSI bits in the TIM1_BKR register).

When exiting from reset, the break circuit is disabled and the MOE bit is low. You can enable the break function by setting the BKE bit in the TIM1_BKR register. The break input polarity can be selected by configuring the BKP bit in the same register. BKE and BKP can be modified at the same time.

Because MOE falling edge can be asynchronous, a resynchronization circuit has been inserted between the actual signal (acting on the outputs) and the synchronous control bit (accessed in the TIM1_BKR register). It results in some delays between the asynchronous and the synchronous signals. In particular, if you write MOE to 1 whereas it was low, you must insert a delay (dummy instruction) before reading it correctly.

When a break occurs (selected level on the break input):

- The MOE bit is cleared asynchronously, putting the outputs in inactive state, idle state or in reset state (selected by the OSSI bit). This feature functions even if the MCU oscillator is off.
- Each output channel is driven with the level programmed in the OIS_i bit in the TIM1_OISR register as soon as MOE=0. If OSSI=0 then the timer releases the enable output else the enable output remains high.
- When complementary outputs are implemented:
 - The outputs are first put in reset state inactive state (depending on the polarity). This is done asynchronously so that it works even if no clock is provided to the timer.
 - If the timer clock is still present, then the dead-time generator is reactivated in order to drive the outputs with the level programmed in the OIS_i and OIS_iN bits after a dead-time. Even in this case, OC_i and OC_iN cannot be driven to their active level together. Note that because of the resynchronization on MOE, the dead-time duration is a bit longer than usual (around 2 ck_{tim} clock cycles).
- The break status flag (BIF bit in the TIM1_SR1 register) is set. An interrupt can be generated if the BIE bit in the TIM1_IER register is set.
- If the AOE bit in the TIM1_BKR register is set, the MOE bit is automatically set again at the next update event UEV. This can be used to perform a regulation, for instance. Else, MOE remains low until you write it to '1' again. In this case, it can be used for security and you can connect the break input to an alarm from power drivers, thermal sensors or any security components.

Note: The break inputs are acting on level. Thus, the MOE cannot be set while the break input is active (neither automatically nor by software). In the meantime, the status flag BIF cannot be cleared.

The break can be generated by the break input (BKIN) which has a programmable polarity and can be enabled or disabled by setting or resetting the BKE bit in TIM1_BKR register.

In addition to the break inputs and the output management, a write protection has been implemented inside the break circuit to safeguard the application. It allows you to freeze the configuration of several parameters (OC_i polarities and state when disabled, OCM configurations, break enable and polarity). You can choose from 3 levels of protection selected by the LOCK bits in the TIM1_BKR register. The LOCK bits can be written only once after an MCU reset.

Figure 74 shows an example of behavior of the outputs in response to a break.

Figure 74. Behavior of outputs in response to a break (channel without complementary output)

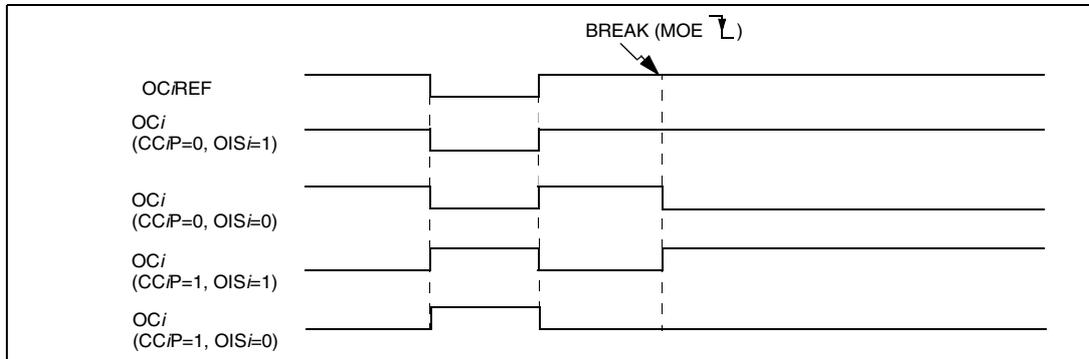
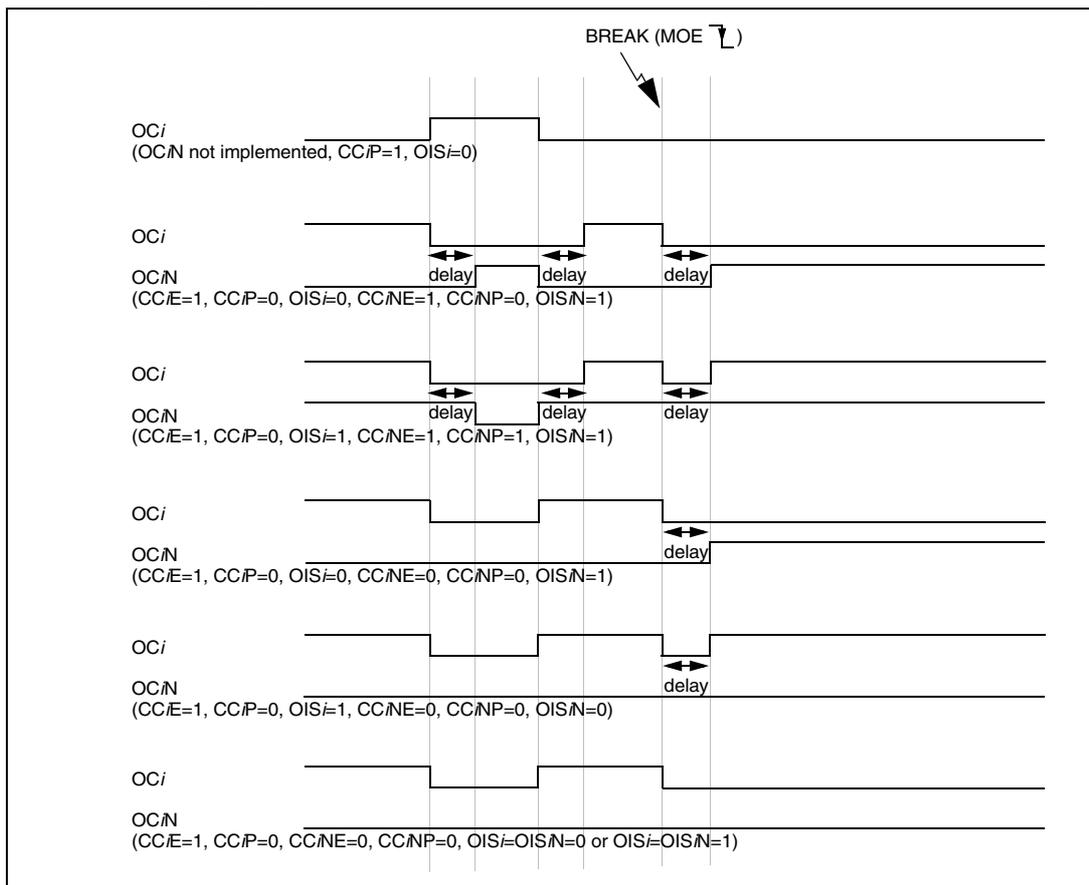


Figure 75 shows an example of behavior of the complementary outputs (TIM1 only) in response to a break.

Figure 75. Behavior of outputs in response to a break (TIM1 complementary outputs)



17.5.9 Clearing the OC/REF signal on an external event

The OC/REF signal of a given channel can be cleared when a high level is detected on ETRF (if OC/CE='1' in the TIM1_CCMR*i* register, one enable bit per channel). The OC/REF signal remains low until the next UEV update event occurs. This function can be used in output compare mode and PWM mode only, it does not work in forced mode.

It can be connected to the output of a comparator and be used for current handling, for instance.

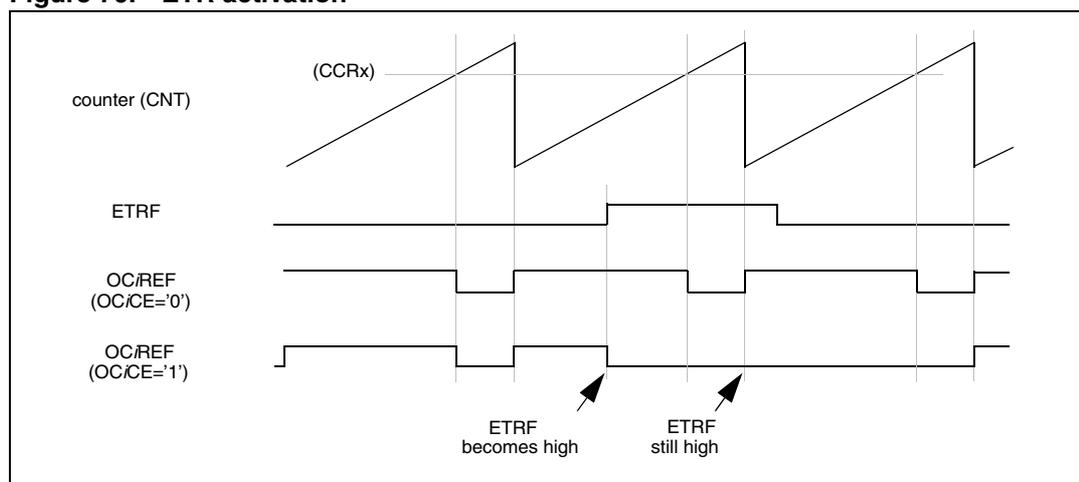
For example, the OC/REF signal can be connected to the output of a comparator to be used for current handling. In this case, the external trigger must be configured as follows:

1. The External Trigger Prescaler should be kept off: bits ETPS[1:0] in the TIM1_ETR register set to '00'.
2. The external clock mode 2 must be disabled: bit ECE in the TIM1_ETR register set to '0'.
3. The External Trigger Polarity (ETP) and the External Trigger Filter (ETF) can be configured as desired.

Refer to the external trigger input block diagram [Figure 44 on page 152](#)

[Figure 76](#) shows the behavior of the OC/REF signal when the ETRF input becomes high, for both values of the enable bit OC/CE. In this example, the timer is programmed in PWM mode.

Figure 76. ETR activation



17.5.10 Encoder interface mode

This mode is typically used for motor control. To select Encoder Interface mode write SMS=0b001 in the TIM1_SMCR register if the counter is counting on TI2 edges only, SMS=0b010 if it is counting on TI1 edges only and SMS=0b011 if it is counting on both TI1 and TI2 edges.

Select the TI1 and TI2 polarity by programming the CC1P and CC2P bits in the TIM1_CCER1 register. When needed, you can program the input filter as well.

The two inputs TI1 and TI2 are used to interface to an incremental encoder. Refer to [Table 33](#). The counter is clocked by each valid transition on TI1FP1 or TI2FP2 (TI1 and TI2 after input filter and polarity selection, TI1FP1=TI1 if not filtered and not inverted,

TI2FP2=TI2 if not filtered and not inverted) assuming that it is enabled (CEN bit in TIM1_CR1 register written to '1'). The sequence of transitions of the two inputs is evaluated and generates count pulses as well as the direction signal. Depending on the sequence the counter counts up or down, the DIR bit in the TIM1_CR1 register is modified by hardware accordingly. The DIR bit is calculated at each transition on any input (TI1 or TI2), whatever the counter is counting on TI1 only, TI2 only or both TI1 and TI2.

Encoder interface mode acts simply as an external clock with direction selection. This means that the counter just counts continuously between 0 and the auto-reload value in the TIM1_ARR register (0 to ARR or ARR down to 0 depending on the direction). So you must configure TIM1_ARR before starting. In the same way, the capture, compare, prescaler, trigger output features continue to work as normal. Encoder mode and External clock mode 2 are not compatible and must not be selected together.

In this mode, the counter is modified automatically following the speed and the direction of the incremental encoder and its content, therefore, always represents the encoder's position. The count direction correspond to the rotation direction of the connected sensor. The table summarizes the possible combinations, assuming TI1 and TI2 don't switch at the same time.

Table 33. Counting direction versus encoder signals

Active edge	Level on opposite signal (TI1FP1 for TI2, TI2FP2 for TI1)	TI1FP1 signal		TI2FP2 signal	
		Rising	Falling	Rising	Falling
Counting on TI1 only	High	Down	Up	No count	No count
	Low	Up	Down	No count	No count
Counting on TI2 only	High	No count	No count	Up	Down
	Low	No count	No count	Down	Up
Counting on TI1 and TI2	High	Down	Up	Up	Down
	Low	Up	Down	Down	Up

An external incremental encoder can be connected directly to the MCU without external interface logic. However, comparators will normally be used to convert the encoder's differential outputs to digital signals. This greatly increases noise immunity. The third encoder output which indicate the mechanical zero position, may be connected to an external interrupt input and trigger a counter reset.

The [Figure 77](#) gives an example of counter operation, showing count signal generation and direction control. It also shows how input jitter is compensated where both edges are

selected. This might occur if the sensor is positioned near to one of the switching points. For this example we assume that the configuration is the following:

- CC1S = 0b01 (TIM1_CCMR1 register, IC1 mapped on TI1).
- CC2S = 0b01 (TIM1_CCMR2 register, IC2 mapped on TI2).
- CC1P = 0 (TIM1_CCER1 register, IC1 non-inverted, IC1=TI1).
- CC2P = 0 (TIM1_CCER2 register, IC2 non-inverted, IC2=TI2).
- SMS = 0b011 (TIM1_SMCR register, both inputs are active on both rising and falling edges).
- CEN = 1 (TIM1_CR1 register, Counter is enabled).

Figure 77. Example of counter operation in encoder interface mode

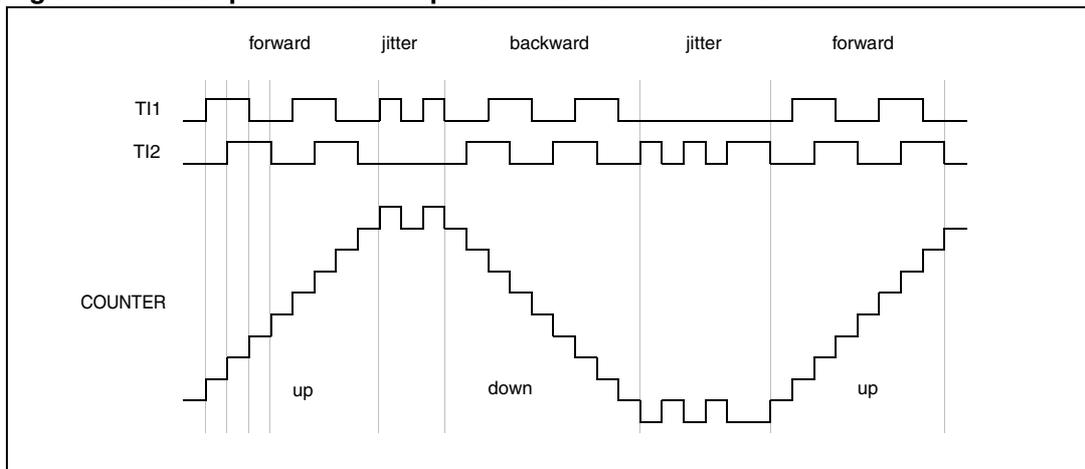
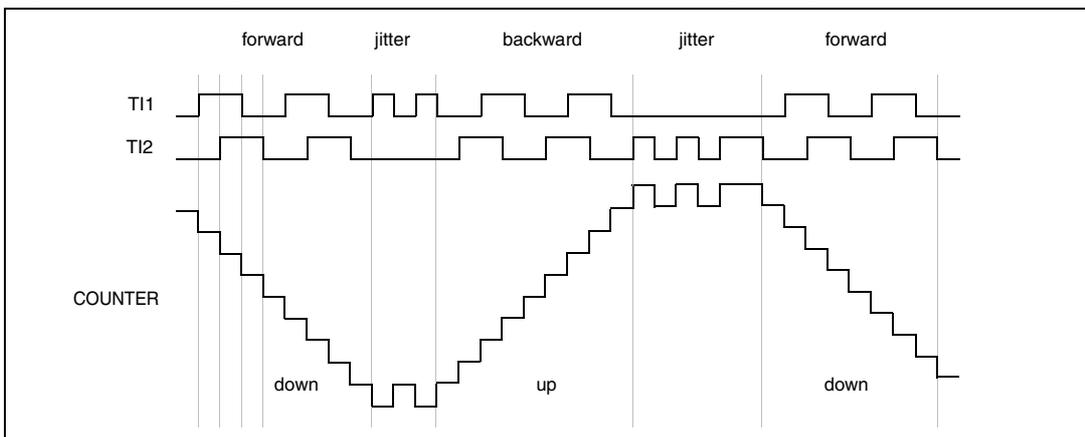


Figure 78 gives an example of counter behaviour when IC1 polarity is inverted (same configuration as above except CC1P='1').

Figure 78. Example of encoder interface mode with IC1 polarity inverted



The timer, when configured in Encoder Interface mode provides information on the sensor's current position. You can obtain dynamic information (speed, acceleration, deceleration) by measuring the period between two encoder events using a second timer configured in capture mode. The output of the encoder which indicates the mechanical zero can be used for this purpose. Depending on the time between two events, the counter can also be read at regular times. You can do this by latching the counter value into a third input capture

register if available (then the capture signal must be periodic and can be generated by another timer).

17.6 TIM1 interrupts

TIM1 has 8 interrupt request sources, mapped on 2 interrupt vectors:

- Break interrupt
- Trigger interrupt
- Commutation interrupt
- Capture/Compare 4 interrupt
- Capture/Compare 3 interrupt
- Capture/Compare 2 interrupt
- Capture/Compare 1 interrupt
- Update Interrupt (ex: overflow, underflow, counter initialization)

To use the interrupt features, for each interrupt channel used, set the desired “Interrupt Enable” bit: BIE, TIE, COMIE, CC1E, UIE bits in the TIM1_IER register to enable interrupt requests.

The different interrupt sources can be also generated by software using the corresponding bits in the TIM1_EGR register.

17.7 TIM1 registers

17.7.1 Control register 1 (TIM1_CR1)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
ARPE	CMS[1:0]		DIR	OPM	URS	UDIS	CEN
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIM1_ARR register is not buffered through a preload register. It can be written directly.
- 1: TIM1_ARR register is buffered through a preload register.

Bits 6:5 **CMS[1:0]**: Center-aligned mode selection

- 00: Edge-aligned mode. The counter counts up or down depending on the direction bit (DIR).
 - 01: Center-aligned mode 1. The counter counts up and down alternately. Output compare interrupt flags of channels configured in output (CCiS=00 in TIM1_CCMRx register) are set only when the counter is counting down.
 - 10: Center-aligned mode 2. The counter counts up and down alternately. Output compare interrupt flags of channels configured in output (CCiS=00 in TIM1_CCMRx register) are set only when the counter is counting up.
 - 11: Center-aligned mode 3. The counter counts up and down alternately. Output compare interrupt flags of channels configured in output (CCiS=00 in TIM1_CCMRx register) are set both when the counter is counting up and down.
- It is not allowed to switch from edge-aligned mode to center-aligned mode as long as the counter is enabled (CEN=1)
 - Encoder mode (SMS=001, 010 or 011 in TIM1_SMCR register) must be disabled in center-aligned mode.

Bit 4 **DIR**: Direction

- 0: Counter used as up-counter.
- 1: Counter used as down-counter.

Note: This bit is read-only when the timer is configured in Center-aligned mode or Encoder mode.

Bit 3 **OPM**: One pulse mode

- 0: Counter is not stopped at update event
- 1: Counter stops counting at the next update event (clearing the CEN bit).

Bit 2 **URS**: Update request source

- 0: When enabled by the UDIS bit, the UIF bit is set and an update interrupt request is sent when one of the following events occurs:
 - Registers are updated (counter overflow/underflow)
 - UG bit is set by software
 - Update event is generated through the clock/trigger controller
- 1: When enabled by the UDIS bit, the UIF bit is set and an update interrupt request is sent only when:
 - Registers are updated (counter overflow/underflow)

Bit 1 **UDIS**: Update disable.

0: An Update event is generated as soon as a counter overflow occurs or a software update is generated or an hardware reset is generated by the clock/trigger mode controller. Buffered registers are then loaded with their preload values

1: An Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). The counter and the prescaler are re initialized if the UG bit is set or if an hardware reset is received from the clock/trigger mode controller.

Bit 0 **CEN**: Counter enable

0: Counter disabled

1: Counter enabled

Note: External clock, trigger gated mode and encoder mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.

17.7.2 Control register 2 (TIM1_CR2)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
TI1S	MMS[2:0]			Reserved	COMS	Reserved	CCPC
rw	rw	rw	rw		rw		rw

Bit 7 **TI1S**: TI1 selection.

0: TI1 (input of the digital filter) is connected to CC1 input pin.

1: TI1 is connected to the 3 inputs CC1, CC2, CC3 (XOR combination)

Bits 6:4 **MMS[2:0]**: Master mode selection

These bits select the information to be sent in master mode to the ADC or to the other timers for synchronization (TRGO). The combination is as follows:

000: Reset - the UG bit from the TIM1_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (clock/trigger mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: Enable - the Counter Enable signal is used as trigger output (TRGO). It is used to start several timers or the ADC to control a window in which a slave timer or the ADC is enabled. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in trigger gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIM1_SMCR register).

010: Update - The update event is selected as trigger output (TRGO).

011: Compare Pulse (MATCH1) - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred (TRGO).

100: Compare - OC1REF signal is used as trigger output (TRGO).

101: Compare - OC2REF signal is used as trigger output (TRGO).

110: Compare - OC3REF signal is used as trigger output (TRGO).

111: Compare - OC4REF signal is used as trigger output (TRGO).

Bit 3 Reserved, must be kept cleared.

Bit 2 **COMS**: Capture/compare control update selection

0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting only the COMG bit.

1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI.

Note: This bit acts only on channels with complementary outputs.

Bit 1 Reserved, forced by hardware to 0.

Bit 0 **CCPC**: Capture/compare preloaded control

0: The CC/E, CC/NE, CC/P, CC/NP bits in the TIM1_CCERx register and the OC/M bit in the TIM1_CCMRx register are not preloaded

1: CC/E, CC/NE, CC/P, CC/NP and OC/M bits are preloaded, after having been written, they are updated only when COMG bit is set in the TIM1_EGR register.

Note: This bit acts only on channels with complementary outputs.

17.7.3 Slave mode control register (TIM1_SMCR)

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
MSM	TS[2:0]			Reserved	SMS[2:0]		
rw	rw	rw	rw		rw	rw	rw

Bit 7 **MSM**: Master/slave mode

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between TIM1 and another timer (through TRGO).

Bits 6:4 **TS[2:0]**: Trigger selection

This bit-field selects the trigger input (TRGI) to be used to synchronize the counter.

000: internal trigger ITR0 connected to TIM6 TRGO

001: reserved

010: internal trigger ITR2 connected to TIM5 TRGO

011: reserved

100: TI1 Edge Detector (TI1F_ED)

101: Filtered Timer Input 1 (TI1FP1)

110: Filtered Timer Input 2 (TI2FP2)

111: External Trigger input (ETRF)

Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.

Bit 3 Reserved, always read as 0.

Bits 2:0 **SMS[2:0]**: Clock/trigger/slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).
000: Clock/trigger controller disabled- if CEN = '1' then the prescaler is clocked directly by the internal clock.

001: Encoder mode 1 - Counter counts up or down on TI2FP2 edge depending on TI1FP1 level.

010: Encoder mode 2 - Counter counts up or down on TI1FP1 edge depending on TI2FP2 level.

011: Encoder mode 3 - Counter counts up or down on both TI1FP1 and TI2FP2 edges depending on the level of the other input.

100: Reset Mode - Rising edge of the selected trigger signal (TRGI) re-initializes the counter and generates an update of the registers.

101: Trigger gated Mode - The counter clock is enabled when the trigger signal (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger standard Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

Note: Trigger gated mode must not be used if TI1F_ED is selected as the trigger input (TS='100'). Indeed, TI1F_ED outputs 1 pulse for each transition on TI1F, whereas the trigger gated mode checks the level of the trigger signal.

17.7.4 External trigger register (TIM1_ETR)

Address offset: 0x03

Reset value: 0x00

7	6	5	4	3	2	1	0
ETP	ECE	ETPS[1:0]		ETF[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **ETP**: External Trigger Polarity.

This bit selects whether ETR or $\overline{\text{ETR}}$ is used for trigger operations

0: ETR is non-inverted, active at high level or rising edge.

1: ETR is inverted, active at low level or falling edge.

Bit 6 **ECE**: External Clock Enable.

This bit enables External clock mode 2.

0: External clock mode 2 disabled.

1: External clock mode 2 enabled. The counter is clocked by any active edge on the ETRF signal.

- Setting the ECE bit has the same effect as selecting the external clock mode 1 with TRGI connected to ETRF (SMS=111 and TS=111 in the TIM1_SMCR register).
- It is possible to use simultaneously the external clock mode 2 with the following modes: trigger standard mode, trigger reset mode and trigger gated mode. Nevertheless, TRGI must not be connected to ETRF in this case (TS bits must not be 111 in TIM1_SMCR register).
- If external clock mode 1 and external clock mode 2 are enabled at the same time, the external clock input will be ETRF.

Bits 5:4 **ETPS**: External trigger prescaler

External trigger signal ETRP frequency must be at most $1/4$ of f_{MASTER} frequency. A prescaler can be enabled to reduce ETRP frequency. It is useful when inputting fast external clocks.

00: Prescaler OFF

01: ETRP frequency divided by 2

10: ETRP frequency divided by 4

11: ETRP frequency divided by 8

Bits 3:0 **ETF**: External Trigger Filter.

This bit-field defines the frequency used to sample ETRP signal and the length of the digital filter applied to ETRP. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{MASTER} .

0001: $f_{\text{SAMPLING}}=f_{\text{MASTER}}$, N=2.

0010: $f_{\text{SAMPLING}}=f_{\text{MASTER}}$, N=4.

0011: $f_{\text{SAMPLING}}=f_{\text{MASTER}}$, N=8.

0100: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/2$, N=6.

0101: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/2$, N=8.

0110: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/4$, N=6.

0111: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/4$, N=8.

1000: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/8$, N=6.

1001: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/8$, N=8.

1010: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/16$, N=5.

1011: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/16$, N=6.

1100: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/16$, N=8.

1101: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/32$, N=5.

1110: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/32$, N=6.

1111: $f_{\text{SAMPLING}}=f_{\text{MASTER}}/32$, N=8.

17.7.5 Interrupt enable register (TIM1_IER)

Address offset: 0x04

Reset value: 0x00

7	6	5	4	3	2	1	0
BIE	TIE	COMIE	CC4IE	CC3IE	CC2IE	CC1IE	UIE
rw	rw	rw	rw	rw	rw	rw	rw

- Bit 7 **BIE**: Break interrupt enable
 0: Break interrupt disabled.
 1: Break interrupt enabled.
- Bit 6 **TIE**: Trigger interrupt enable
 0: Trigger Interrupt disabled.
 1: Trigger Interrupt enabled.
- Bit 5 **COMIE**: Commutation interrupt enable
 0: Commutation interrupt disabled.
 1: Commutation interrupt enabled.
- Bit 4 **CC4IE**: Capture/compare 4 interrupt enable
 0: CC4 interrupt disabled.
 1: CC4 interrupt enabled.
- Bit 3 **CC3IE**: Capture/compare 3 interrupt enable
 0: CC3 interrupt disabled.
 1: CC3 interrupt enabled.
- Bit 2 **CC2IE**: Capture/compare 2 interrupt enable
 0: CC2 interrupt disabled.
 1: CC2 interrupt enabled.
- Bit 1 **CC1IE**: Capture/compare 1 interrupt enable
 0: CC1 interrupt disabled.
 1: CC1 interrupt enabled.
- Bit 0 **UIE**: Update interrupt enable
 0: Update interrupt disabled.
 1: Update interrupt enabled.

17.7.6 Status register 1 (TIM1_SR1)

Address offset: 0x05

Reset Value: 0x00

7	6	5	4	3	2	1	0
BIF	TIF	COMIF	CC4IF	CC3IF	CC2IF	CC1IF	UIF
rc_w0							

Bit 7 **BIF**: Break Interrupt Flag.

This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.

0: No break event occurred.

1: An active level has been detected on the break input.

Bit 6 **TIF**: Trigger Interrupt Flag.

This flag is set by hardware on trigger event (active edge detected on TRGI signal, both edges in case trigger gated mode is selected). It is cleared by software.

0: No trigger event occurred.

1: Trigger interrupt pending.

Bit 5 **COMIF**: Commutation Interrupt Flag.

This flag is set by hardware on a Commutation event (COM) (when Capture/compare Control bits - CC/E, CC/NE, OC/M - have been updated). It is cleared by software.

0: No Commutation event (COM) occurred.

1: Commutation event (COM) interrupt pending.

Bit 4 **CC4IF**: Capture/Compare 4 Interrupt Flag.

Refer to CC1IF description

Bit 3 **CC3IF**: Capture/Compare 3 Interrupt Flag.

Refer to CC1IF description

Bit 2 **CC2IF**: Capture/Compare 2 Interrupt Flag.

Refer to CC1IF description

Bit 1 **CC1IF**: Capture/Compare 1 Interrupt Flag.

● **If channel CC1 is configured as output:**

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits from TIM1_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIM1_CNT has matched the content of the TIM1_CCR1 register.

Note: In center-aligned mode, the counter is considered to count up when its value is 0 and to count down when it is equal to the ARR value (it counts up from 0 to ARR-1 and from ARR down to 1). Thus, these 2 values are not flagged for all values of the CMS bits. However, CC1IF is set when CNT reaches the ARR value when the compare value is greater than the auto-reload value (CCR1>ARR).

● **If channel CC1 is configured as input:**

This bit is set by hardware on a capture. It is cleared by software or by reading the TIM1_CCR1L register.

0: No input capture occurred.

1: The counter value has been captured in the TIM1_CCR1 register (An edge has been detected on IC1 which matches the selected polarity).

Bit 0 **UIF**: Update Interrupt Flag.

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow or underflow if UDIS=0 in the TIM1_CR1 register.
- When CNT is re-initialized by software using the UG bit in TIM1_EGR register, if URS=0 and UDIS=0 in the TIM1_CR1 register.
- When CNT is re-initialized by a trigger event (refer to the TIM1_SMCR register description), if URS=0 and UDIS=0 in the TIM1_CR1 register.

17.7.7 Status register 2 (TIM1_SR2)

Address offset: 0x06

Reset Value: 0x00

	7	6	5	4	3	2	1	0
Reserved				CC4OF	CC3OF	CC2OF	CC1OF	Reserved
				rc_w0	rc_w0	rc_w0	rc_w0	
Reserved					CC3OF	CC2OF	CC1OF	Reserved
					rc_w0	rc_w0	rc_w0	

Bits 7:5 Reserved, must be kept cleared.

Bit 4 **CC4OF**: Capture/Compare 4 Overcapture Flag.

Refer to CC1OF description

Bit 3 **CC3OF**: Capture/Compare 3 Overcapture Flag.

Refer to CC1OF description

Bit 2 **CC2OF**: Capture/Compare 2 Overcapture Flag.

Refer to CC1OF description

Bit 1 **CC1OF**: Capture/compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected.

1: The counter value has been captured in TIM1_CCR1 register while CC1IF flag was already set

Bit 0 Reserved, must be kept cleared.

17.7.8 Event generation register (TIM1_EGR)

Address offset: 0x07

Reset value: 0x00

7	6	5	4	3	2	1	0
BG	TG	COMG	CC4G	CC3G	CC2G	CC1G	UG
w	w	w	w	w	w	w	w

Bit 7 **BG**: Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: A break event is generated. MOE bit is cleared and BIF flag is set. An interrupt is generated if enabled by the BIE bit.

Bit 6 **TG**: Trigger generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: The TIF flag is set in TIM1_SR1 register. An interrupt is generated if enabled by the TIE bit.

Bit 5 **COMG**: Capture/compare control update generation

This bit can be set by software, it is automatically cleared by hardware

0: No action

1: When the CCPC bit in the TIM1_CR2 register is set, it allows to update CC/E, CC/NE CC/P, CC/NP and OC/M bits

Note: This bit acts only on channels that have a complementary output.

Bit 4 **CC4G**: Capture/compare 4 generation

Refer to CC1G description

Bit 3 **CC3G**: Capture/compare 3 generation

Refer to CC1G description

Bit 2 **CC2G**: Capture/compare 2 generation

refer to CC1G description

Bit 1 **CC1G**: Capture/Compare 1 Generation.

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: A capture/compare event is generated on channel 1:

- **If the CC1 channel is configured in output mode:**
 - CC1IF flag is set, and the corresponding interrupt request is sent if enabled.
- **If the CC1 channel configured in input mode:**
 - The current value of the counter is captured in the TIM1_CCR1 register. The CC1IF flag is set, and the corresponding interrupt request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update Generation.

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Re-initializes the counter and generates an update of the registers. Note that the prescaler counter is also cleared. The counter is cleared if the center-aligned mode is selected or if DIR=0 (up-counting), else it takes the auto-reload value (TIM1_ARR) if DIR=1 (down-counting).

17.7.9 Capture/compare mode register 1 (TIM1_CCMR1)

Address offset: 0x08

Reset value: 0x00

The channel can be used in input (capture mode) or in output (compare mode). The direction of the channel is defined by configuring the CC1S bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So be aware that the same bit can have a different meaning for the input stage and for the output stage.

● **Channel configured in output**

7	6	5	4	3	2	1	0
OC1CE	OC1M[2:0]			OC1PE	OC1FE	CC1S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **OC1CE**: Output Compare 1 Clear Enable.

This bit is used to enable the clearing of the channel 1 output compare signal (OC1REF) by an external event on the TIM1_TRIG pin. See [Section 17.5.9 on page 180](#).

0: OC1REF is not affected by the ETRF input signal (derived from the TIM1_TRIG pin).

1: OC1REF is cleared as soon as a high level is detected on ETRF input signal (derived from the TIM1_TRIG pin).

Bits 6:4 **OC1M**: Output Compare 1 Mode.

These bits define the behavior of the output reference signal OC1REF from which OC1 is derived. OC1REF is active high whereas OC1 active level depends on the CC1P bit.

000: Frozen - The comparison between the output compare register TIM1_CCR1 and the counter TIM1_CNT has no effect on the outputs.

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIM1_CNT matches the capture/compare register 1 (TIM1_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIM1_CNT matches the capture/compare register 1 (TIM1_CCR1).

011: Toggle - OC1REF toggles when TIM1_CNT=TIM1_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In up-counting, channel 1 is active as long as TIM1_CNT<TIM1_CCR1 else inactive. In down-counting, channel 1 is inactive (OC1REF='0') as long as TIM1_CNT>TIM1_CCR1 else active (OC1REF='1').

111: PWM mode 2 - In up-counting, channel 1 is inactive as long as TIM1_CNT<TIM1_CCR1 else active. In down-counting, channel 1 is active as long as TIM1_CNT>TIM1_CCR1 else inactive.

- These bits can no longer be modified as long as LOCK level 3 has been programmed (LOCK bits in TIM1_BKR register) and CC1S='00' (the channel is configured in output).
- In PWM mode 1 or 2, the OCiREF level changes only when the result of the comparison changes or when the output compare mode switches from “frozen” mode to “PWM” mode. Refer to [PWM mode on page 171](#) for more details.
- On channels that have a complementary output, this bit field is preloaded. If the CCPC bit is set in the TIM1_CR2 register then the OCM active bits take the new value from the preload bits only when a commutation event (COM) is generated.

Bit 3 **OC1PE**: Output Compare 1 Preload Enable.

0: Preload register on TIM1_CCR1 disabled. TIM1_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIM1_CCR1 enabled. Read/Write operations access the preload register. TIM1_CCR1 preload value is loaded in the shadow register at each update event.

- These bits can no longer be modified as long as LOCK level 3 has been programmed (LOCK bits in TIM1_BKR register) and CC1S='00' (the channel is configured in output).
- For correct operation, preload registers must be enabled when the timer is in PWM mode. This is not mandatory in one pulse mode (OPM bit set in TIM1_CR1 register).

Bit 2 **OC1FE**: Output Compare 1 Fast Enable.

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently from the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OCFE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S[1:0]**: Capture/Compare 1 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1FP1.

10: CC1 channel is configured as input, IC1 is mapped on TI2FP1.

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode works only if an internal trigger input is selected through the TS bit (TIM1_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIM1_CCER1).

● Channel configured in input

7	6	5	4	3	2	1	0
IC1F[3:0]				IC1PSC[1:0]		CC1S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **IC1F[3:0]**: Input Capture 1 Filter.

This bit-field defines f_{SAMPLING} , the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

- 0000: No filter, $f_{\text{SAMPLING}} = f_{\text{MASTER}}$.
- 0001: $f_{\text{SAMPLING}} = f_{\text{MASTER}}$, N=2.
- 0010: $f_{\text{SAMPLING}} = f_{\text{MASTER}}$, N=4.
- 0011: $f_{\text{SAMPLING}} = f_{\text{MASTER}}$, N=8.
- 0100: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/2$, N=6.
- 0101: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/2$, N=8.
- 0110: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/4$, N=6.
- 0111: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/4$, N=8.
- 1000: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/8$, N=6.
- 1001: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/8$, N=8.
- 1010: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/16$, N=5.
- 1011: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/16$, N=6.
- 1100: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/16$, N=8.
- 1101: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/32$, N=5.
- 1110: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/32$, N=6.
- 1111: $f_{\text{SAMPLING}} = f_{\text{MASTER}}/32$, N=8.

Note: Even on channels that have a complementary output, this bit field is not preloaded and does not take into account the content of the CCPC bit (in the TIM1_CR2 register).

Bits 3:2 **IC1PSC[1:0]**: Input Capture 1 Prescaler.

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).
The prescaler is reset as soon as CC1E='0' (TIM1_CCER register).

- 00: no prescaler, capture is done each time an edge is detected on the capture input.
- 01: capture is done once every 2 events.
- 10: capture is done once every 4 events.
- 11: capture is done once every 8 events.

Bits 1:0 **CC1S[1:0]**: Capture/Compare 1 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

- 00: CC1 channel is configured as output.
- 01: CC1 channel is configured as input, IC1 is mapped on TI1FP1.
- 10: CC1 channel is configured as input, IC1 is mapped on TI2FP1.
- 11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode works only if an internal trigger input is selected through the TS bit (TIM1_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIM1_CCER1).

17.7.10 Capture/compare mode register 2 (TIM1_CCMR2)

Address offset: 0x09

Reset value: 0x00

● Channel configured in output

7	6	5	4	3	2	1	0
OC2CE	OC2M[2:0]			OC2PE	OC2FE	CC2S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **OC2CE**: Output Compare 2 Clear Enable.

Bits 6:4 **OC2M(2:0)**: Output Compare 2 Mode.

Bit 3 **OC2PE**: Output Compare 2 Preload Enable.

Bit 2 **OC2FE**: Output Compare 2 Fast Enable.

Bits 1:0 **CC2S[1:0]**: Capture/Compare 2 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2FP2.

10: CC2 channel is configured as input, IC2 is mapped on TI1FP2.

11: Reserved

Note: CC2S bits are writable only when the channel is OFF (CC2E and CC2NE= '0' in TIM1_CCER1 and updated).

● Channel configured in input

7	6	5	4	3	2	1	0
IC2F[3:0]				IC2PSC[1:0]		CC2S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **IC2F**: Input Capture 2 Filter.

Bits 3:2 **IC2PSC(1:0)**: Input Capture 2 Prescaler.

Bits 1:0 **CC2S[1:0]**: Capture/Compare 2 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2FP2.

10: CC2 channel is configured as input, IC2 is mapped on TI1FP2.

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode works only if an internal trigger input is selected through the TS bit (TIM1_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E and CC2NE= '0' in TIM1_CCER1 and updated).

17.7.11 Capture/compare mode register 3 (TIM1_CCMR3)

Address offset: 0x0A

Reset value: 0x00

Refer to the above CCMR1 register description.

- **Channel configured in output**

7	6	5	4	3	2	1	0
OC3CE	OC3M[2:0]			OC3PE	OC3FE	CC3S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **OC3CE**: Output Compare 3 clear enable

Bits 6:4 **OC3M[2:0]**: Output Compare 3 mode

Bit 3 **OC3PE**: Output Compare 3 preload enable

Bit 2 **OC3FE**: Output Compare 3 fast enable

Bits 1:0 **CC3S[1:0]**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output.

01: CC3 channel is configured as input, IC3 is mapped on TI3FP3.

10: CC3 channel is configured as input, IC3 is mapped on TI4FP3.

11: Reserved

Note: CC3S bits are writable only when the channel is OFF (CC3E and CC3NE= '0' in TIM1_CCER2 and updated).

● Channel configured in input

7	6	5	4	3	2	1	0
IC3F[3:0]				IC3PSC[1:0]		CC3S[1:0]	
	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **IC3F**: Input Capture 3 Filter.

Bits 3:2 **IC3PSC[1:0]**: Input Capture 3 Prescaler.

Bits 1:0 **CC3S[1:0]**: Capture/Compare 3 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output.

01: CC3 channel is configured as input, IC3 is mapped on TI3FP3.

10: CC3 channel is configured as input, IC3 is mapped on TI4FP3.

11: Reserved

Note: CC3S bits are writable only when the channel is OFF (CC3E and CC3NE= '0' in TIM1_CCER2 and updated).

17.7.12 Capture/compare mode register 4 (TIM1_CCMR4)

Address offset: 0x0B

Reset value: 0x00

Refer to the above CCMR1 register description.

- **Channel configured in output**

7	6	5	4	3	2	1	0
OC4CE	OC4M[2:0]			OC4PE	OC4FE	CC4S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **OC4CE**: Output Compare 4 Clear Enable.

Bits 6:4 **OC4M[2:0]**: Output Compare 4 Mode.

Bit 3 **OC4PE**: Output Compare 4 Preload Enable.

Bit 2 **OC4FE**: Output Compare 4 Fast Enable.

Bits 1:0 **CC4S[1:0]**: Capture/Compare 4 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output.

01: CC4 channel is configured as input, IC4 is mapped on TI3FP4.

10: CC4 channel is configured as input, IC4 is mapped on TI4FP4.

11: Reserved

Note: CC4S bits are writable only when the channel is OFF (CC4E and CC4NE= '0' in TIM1_CCER2 and updated).

● Channel configured in input

7	6	5	4	3	2	1	0
IC4F[3:0]				IC4PSC[1:0]		CC4S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **IC4F**: Input Capture 4 Filter.

Bits 3:2 **IC4PSC[1:0]**: Input Capture 4 Prescaler.

Bits 1:0 **CC4S[1:0]**: Capture/Compare 4 Selection.

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output.

01: CC4 channel is configured as input, IC4 is mapped on TI3FP4.

10: CC4 channel is configured as input, IC4 is mapped on TI1FP4.

11: Reserved

Note: CC4S bits are writable only when the channel is OFF (CC4E and CC4NE= '0' in TIM1_CCER2 and updated).

17.7.13 Capture/compare enable register 1 (TIM1_CCER1)

Address offset: 0x0C

Reset value: 0x00

7	6	5	4	3	2	1	0
CC2NP	CC2NE	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **CC2NP**: Capture/Compare 2 Complementary output polarity
Refer to CC1NP description

Bit 6 **CC2NE**: Capture/Compare 2 Complementary output enable
Refer to CC1NE description

Bit 5 **CC2P**: Capture/Compare 2 output polarity
Refer to CC1P description

Bit 4 **CC2E**: Capture/Compare 2 output enable
Refer to CC1E description

Bit 3 **CC1NP**: Capture/Compare 1 Complementary output polarity
0: OC1N active high.
1: OC1N active low.

- This bit is no longer writeable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIM1_BKR register) and CC1S="00" (the channel is configured in output).
- On channels that have a complementary output, this bit is preloaded. If the CCPC bit is set in the TIM1_CR2 register then the CC1NP active bit takes the new value from the preload bit only when a commutation event (COM) is generated.

Bit 2 **CC1NE**: Capture/Compare 1 Complementary output Enable.

0: Off - OC1N is not active. OC1N level is then function of MOE, OSSI, OSSR, OIS1, OIS1N and CC1E bits.

1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSSI, OSSR, OIS1, OIS1N and CC1E bits.

Note: On channels that have a complementary output, this bit is preloaded. If the CCPC bit is set in the TIM1_CR2 register then the CC1NE active bit takes the new value from the preload bit only when a commutation event (COM) is generated.

Bit 1 **CC1P**: Capture/Compare 1 output Polarity.

● **CC1 channel configured as output:**

0 : OC1 active high

1 : OC1 active low

● **CC1 channel configured as input for trigger function** (see [Figure 61](#)):

0 : Trigger on a high level or rising edge of TI1F

1 : Trigger on a low level or falling edge of TI1F

● **CC1 channel configured as input for capture function** (see [Figure 61](#)):

0 : Capture on a rising edge of TI1F or TI2F

1 : Capture on a falling edge of TI1F or TI2F

– This bit is no longer writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIM1_BKR register).

– On channels that have a complementary output, this bit is preloaded. If the CCPC bit is set in the TIM1_CR2 register then the CC1P active bit takes the new value from the preload bit only when a commutation event (COM) is generated.

Bit 0 **CC1E**: Capture/Compare 1 output Enable.

● **CC1 channel is configured as output:**

0: Off - OC1 is not active. OC1 level is then function of MOE, OSSI, OSSR, OIS1, OIS1N and CC1NE bits.

1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSSI, OSSR, OIS1, OIS1N and CC1NE bits.

● **CC1 channel is configured as input:**

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIM1_CCR1) or not.

0: Capture disabled.

1: Capture enabled.

Note: On channels that have a complementary output, this bit is preloaded. If the CCPC bit is set in the TIM1_CR2 register then the CC1E active bit takes the new value from the preload bit only when a commutation event (COM) is generated.

Table 34. Output control for complementary OC_i and OC_N channels with break feature

Control bits					Output states	
MOE bit	OSSI bit	OSSR bit	CC/E bit	CC/NE bit	OC _i output state	OC _N output state
1	X	0	0	0	Output Disabled (not driven by the timer)	Output Disabled (not driven by the timer)
		0	0	1	Output Disabled (not driven by the timer)	OCiREF + Polarity OCiN=OCiREF xor CCiNP
		0	1	0	OCiREF + Polarity OCi=OCiREF xor CCiP	Output Disabled (not driven by the timer)
		0	1	1	OCiREF + Polarity + dead-time	Complementary to OCiREF (not OCiREF) + Polarity + dead-time
		1	0	0	Output Disabled (not driven by the timer)	Output Disabled (not driven by the timer)
		1	0	1	Off-State (output enabled with inactive state) OCi=CCiP	OCiREF + Polarity OCiN=OCiREF xor CCiNP
		1	1	0	OCiREF + Polarity OCi=OCiREF xor CCiP	Off-State (output enabled with inactive state) OCiN=CCiNP
		1	1	1	OCiREF + Polarity + dead-time	Complementary to OCiREF (not OCiREF) + Polarity + dead-time
0	0	x	x	x	Output Disabled (not driven by the timer)	
	0					
	0					
	0					
	1				Off-State (output enabled with inactive state) Asynchronously: OCi=CCiP, OCiN=CCiNP Then if the clock is present: OCi=OISi and OCiN=OISiN after a dead-time, assuming that OISi and OISiN don't correspond to OCi and OCiN both to active state	
	1					
	1					
	1					

Note: The state of the external I/O pins connected to the OC_i channels depends on the OC_i channel state and the GPIO registers.

17.7.14 Capture/compare enable register 2 (TIM1_CCER2)

Address offset: 0x0D

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved		CC4P	CC4E	CC3NP	CC3NE	CC3P	CC3E
		rw	rw	rw	rw	rw	rw

Bits 7:6 Reserved

Bit 5 **CC4P**: Capture/Compare 4 output polarity.
Refer to CC1P description

Bit 4 **CC4E**: Capture/Compare 4 output enable.
Refer to CC1E description

Bit 3 **CC3NP**: Capture/Compare 3 Complementary output polarity.
Refer to CC1NP description

Bit 2 **CC3NE**: Capture/Compare 3 Complementary output Enable.
Refer to CC1NE description

Bit 1 **CC3P**: Capture/Compare 3 output polarity.
Refer to CC1P description

Bit 0 **CC3E**: Capture/Compare 3 output Enable.
Refer to CC1E description

17.7.15 Counter high (TIM1_CNTRH)

Address offset: 0x0E

Reset value: 0x00

7	6	5	4	3	2	1	0
CNT[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CNT[15:8]**: Counter value (MSB).

17.7.16 Counter low (TIM1_CNTRL)

Address offset: 0x0F

Reset value: 0x00

7	6	5	4	3	2	1	0
CNT[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CNT[7:0]**: Counter Value (LSB).

17.7.17 Prescaler high (TIM1_PSCRH)

Address offset: 0x10

Reset value: 0x00

7	6	5	4	3	2	1	0
PSC[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

PSC[15:8]: Prescaler value (MSB).

The prescaler value divides the CK_PSC clock frequency.

The counter clock frequency f_{CK_CNT} is equal to $f_{CK_PSC} / (PSCR[15:0]+1)$.

Bits 7:0 **PSCR** contain the value which will be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIM1_EGR register or through trigger controller when configured in trigger reset mode). This means that an update event must be generated in order that a new prescaler value can be taken into account.

17.7.18 Prescaler low (TIM1_PSCRL)

Address offset: 0x11

Reset value: 0x00

7	6	5	4	3	2	1	0
PSC[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **PSC[7:0]**: Prescaler value (LSB).

The prescaler value divides the CK_PSC clock frequency.

The counter clock frequency f_{CK_CNT} is equal to $f_{CK_PSC} / (PSCR[15:0]+1)$.

PSCR contain the value which will be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIM1_EGR register or through trigger controller when configured in trigger reset mode).

This means that an update event must be generated in order that a new prescaler value can be taken into account.

17.7.19 Auto-reload register high (TIM1_ARRH)

Address offset: 0x12

Reset value: 0xFF

7	6	5	4	3	2	1	0
ARR[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **ARR[15:8]**: Autoreload value (MSB).

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 17.3: TIM1 time base unit on page 140](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

17.7.20 Auto-reload register low (TIM1_ARRL)

Address offset: 0x13

Reset value: 0xFF

7	6	5	4	3	2	1	0
ARR[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **ARR[7:0]**: Autoreload value (LSB).

17.7.21 Repetition counter register (TIM1_RCR)

Address offset: 0x14

Reset value: 0xFF

7	6	5	4	3	2	1	0
REP[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **REP[7:0]**: Repetition counter value.

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to shadow registers) when preload registers are enabled, as well as the update interrupt generation rate if this interrupt is enabled.

Each time the REP_CNT related down-counter reaches zero, an update event is generated and it restarts counting from REP value. As REP_CNT is reloaded with REP value only at the repetition update event U_RC, any write to the TIM1_RCR register will not be taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to:

- the number of PWM periods in edge-aligned mode
- the number of half PWM periods in center-aligned mode.

17.7.22 Capture/compare register 1 high (TIM1_CCR1H)

Address offset: 0x15

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR1[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR1[15:8]**: Capture/compare 1 value (MSB).

- **If the CC1 channel is configured as output (CC1S bits in TIM1_CCMR1 register):**
 CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value). It is loaded permanently if the preload feature is not selected in the TIM1_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.
 The active capture/compare register contains the value to be compared to the counter TIM1_CNT and signalled on OC1 output.
- **If the CC1 channel is configured as input (CC1S bits in TIM1_CCMR1 register):**
 CCR1 is the counter value transferred by the last input capture 1 event (IC1). It is read-only in this case.

17.7.23 Capture/compare register 1 low (TIM1_CCR1L)

Address offset: 0x16

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR1[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR1[7:0]**: Capture/Compare 1 Value (LSB).

17.7.24 Capture/compare register 2 high (TIM1_CCR2H)

Address offset: 0x17

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR2[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR2[15:8]**: Capture/Compare 2 Value (MSB).

- **If the CC2 channel is configured as output (CC2S bits in TIM1_CCMR2 register):**
 CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value). It is loaded permanently if the preload feature is not selected in the TIM1_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.
 The active capture/compare register contains the value to be compared to the counter TIM1_CNT and signalled on OC2 output.
- **If the CC2 channel is configured as input (CC2S bits in TIM1_CCMR2 register):**
 CCR2 is the counter value transferred by the last input capture 2 event (IC2). It is read-only in this case.

17.7.25 Capture/compare register 2 low (TIM1_CCR2L)

Address offset: 0x18

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR2[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR2[7:0]**: Capture/Compare Value (LSB).

17.7.26 Capture/compare register 3 high (TIM1_CCR3H)

Address offset: 0x19

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR3[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR3[15:8]**: Capture/Compare Value (MSB).

- **If the CC3 channel is configured as output (CC3S bits in TIM1_CCMR3 register):**
 CCR3 is the value to be loaded in the actual capture/compare 3 register (preload value). It is loaded permanently if the preload feature is not selected in the TIM1_CCMR3 register (bit OC3PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.
 The active capture/compare register contains the value to be compared to the counter TIM1_CNT and signalled on OC3 output.
- **If the CC3 channel is configured as input (CC3S bits in TIM1_CCMR3 register):**
 CCR3 is the counter value transferred by the last input capture 3 event (IC3).

17.7.27 Capture/compare register 3 low (TIM1_CCR3L)

Address offset: 0x1A

Reset value: 0x00

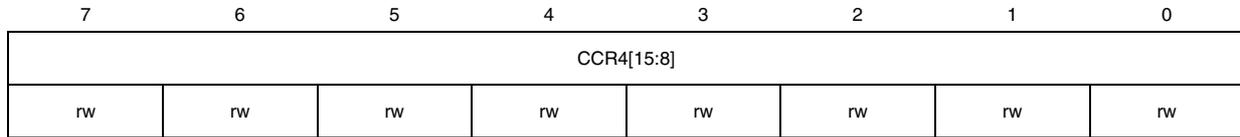
7	6	5	4	3	2	1	0
CCR3[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR3[7:0]**: Capture/Compare Value (LSB).

17.7.28 Capture/compare register 4 high (TIM1_CCR4H)

Address offset: 0x1B

Reset value: 0x00



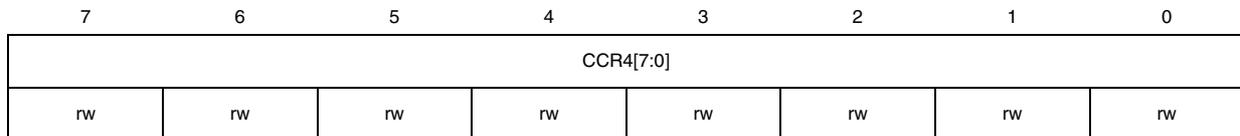
Bits 7:0 **CCR4[15:8]**: Capture/Compare Value (MSB).

- **If the CC4 channel is configured as output (CC4S bits in TIM1_CCMR4 register):**
 CCR4 is the value to be loaded in the actual capture/compare 3 register (preload value). It is loaded permanently if the preload feature is not selected in the TIM1_CCMR4 register (bit OC4PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.
 The active capture/compare register contains the value to be compared to the counter TIM1_CNT and signalled on OC4 output.
- **If the CC4 channel is configured as input (CC4S bits in TIM1_CCMR4 register):**
 CCR4 is the counter value transferred by the last input capture 4 event (IC4).

17.7.29 Capture/compare register 4 low (TIM1_CCR4L)

Address offset: 0x1C

Reset value: 0x00



Bits 7:0 **CCR4[7:0]**: Capture/Compare Value (LSB).

17.7.30 Break register (TIM1_BKR)

Address offset: 0x1D

Reset value: 0x00

7	6	5	4	3	2	1	0
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK	
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **MOE**: Main Output Enable.

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state.

1: OC and OCN outputs are enabled if their respective enable bits are set (CC/E in TIM1_CCERx registers).

See OC/OCN enable description for more details ([Section 17.7.13 on page 202](#)).

Bit 6 **AOE**: Automatic Output Enable.

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not be active)

Note: This bit can no longer be modified as long as LOCK level 1 has been programmed (LOCK bits in the TIM1_BKR register).

Bit 5 **BKP**: Break polarity.

0: Break input BKIN is active low

1: Break input BKIN is active high

Note: This bit can no longer be modified as long as LOCK level 1 has been programmed (LOCK bits in the TIM1_BKR register).

Bit 4 **BKE**: Break enable.

0: Break input (BKIN) disabled

1: Break input (BKIN) enabled

Note: This bit can no longer be modified as long as LOCK level 1 has been programmed (LOCK bits in the TIM1_BKR register).

Bit 3 **OSSR**: Off-State Selection for Run mode.

This bit is used when MOE=1 on channels with a complementary output which are configured as outputs.

See OC/OCN enable description for more details ([Section 17.7.13: Capture/compare enable register 1 \(TIM1_CCER1\) on page 202](#)).

0 : When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0).

1 : When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCiE=1 or CCiNE=1. Then, OC/OCN enable output signal=1

Note: This bit can no longer be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIM1_BKR register).

Bit 2 **OSSI**: Off-State Selection for Idle mode.

This bit is used when MOE=0 on channels configured as outputs.

See OC enable description for more details ([Section 17.7.13 on page 202](#)).

0: When inactive, OC*i* outputs are disabled (OC*i* enable output signal=0).

1: When inactive, OC*i* outputs are forced first with their idle level as soon as CC*i*E=1 (OC enable output signal=1)

Note: This bit can no longer be modified as soon as the LOCK level 2 has been programmed (LOCK bits in the TIM1_BKR register).

Bits 1:0 **LOCK[1:0]**: Lock configuration.

These bits offer a write protection against software errors.

00: LOCK OFF - No bits are write protected.

01: LOCK Level 1 = OIS*i* bit in TIM1_OISR register and BKE/BKP/AOE bits in TIM1_BKR register can no longer be written.

10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CC*i*P bits in TIM1_CCERx registers, as long as the related channel is configured in output through the CC*i*S bits) as well as the OSSR and OSSI bits can no longer be written.

11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OC*i*M and OC*i*PE bits in TIM1_CCMRx registers, as long as the related channel is configured in output through the CC*i*S bits) can no longer be written.

Note: The LOCK bits can be written only once after the reset. Once the TIM1_BKR register has been written, their content is frozen until the next reset.

Note: As the bits AOE, BKP, BKE, OSSR and OSSI can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIM1_BKR register.

17.7.31 Dead-time register (TIM1_DTR)

Address offset: 0x1E

Reset value: 0x00

7	6	5	4	3	2	1	0
DTG[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **DTG[7:0]**: Dead-Time Generator set-up.

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT corresponds to this duration. t_{CK_PSC} is the TIM1 clock pulse.

$$DTG[7:5]=0xx \Rightarrow DT=DTG[7:0] \times t_{dtg} \text{ with } t_{dtg}=t_{CK_PSC}. \quad (f1)$$

$$DTG[7:5]=10x \Rightarrow DT=(64+DTG[5:0]) \times t_{dtg} \text{ with } t_{dtg}=2 \times t_{CK_PSC}. \quad (f2)$$

$$DTG[7:5]=110 \Rightarrow DT=(32+DTG[4:0]) \times t_{dtg} \text{ with } t_{dtg}=8 \times t_{CK_PSC}. \quad (f3)$$

$$DTG[7:5]=111 \Rightarrow DT=(32+DTG[4:0]) \times t_{dtg} \text{ with } t_{dtg}=16 \times t_{CK_PSC}. \quad (f4)$$

Example:

If $t_{CK_PSC}=125$ ns (8 MHz), dead-time possible values are:

DTG[7:0] = 0 to 7Fh from 0 to 15875 ns in 125 ns steps (refer to f1),

DTG[7:0] = 80h to BFh from 16 μ s to 31750 ns in 250 ns steps (refer to f2),

DTG[7:0] = C0h to DFh from 32 μ s to 63 μ s in 1 μ s steps (refer to f3),

DTG[7:0] = E0h to FFh from 64 μ s to 126 μ s in 2 μ s steps (refer to f4),

Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in the TIM1_BKR register).

17.7.32 Output idle state register (TIM1_OISR)

Address offset: 0x1F

Reset value: 0x00

	7	6	5	4	3	2	1	0
Reserved	OIS4	OIS3N	OIS3	OIS2N	OIS2	OIS1N	OIS1	
	rw	rw	rw	rw	rw	rw	rw	rw

Bit 6 **OIS4**: Output Idle state 4 (OC4 output).

Refer to OIS1 bit

Bit 5 **OIS3N**: Output Idle state 3 (OC3N output).

Refer to OIS1N bit

Bit 4 **OIS3**: Output Idle state 3 (OC3 output).

Refer to OIS1 bit

Bit 3 **OIS2N**: Output Idle state 2 (OC2N output).

Refer to OIS1N bit

Bit 2 **OIS2**: Output Idle state 2 (OC2 output).

Refer to OIS1 bit

Bit 1 **OIS1N**: Output Idle state 1 (OC1N output).

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

Note: This bit can no longer be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in the TIM1_BKR register).

Bit 0 **OIS1**: Output Idle state 1 (OC1 output).

0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0

1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

Note: This bit can no longer be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in the TIM1_BKR register).

17.7.33 TIM1 register map and reset values

Table 35. TIM1 register map

Address offset	Register Name	7	6	5	4	3	2	1	0
0x00	TIM1_CR1 Reset Value	ARPE 0	CMS1 0	CMS0 0	DIR 0	OPM 0	URS 0	UDIS 0	CEN 0
0x01	TIM1_CR2 Reset Value	TI1S 0	MMS2 0	MMS1 0	MMS0 0	- 0	COMS 0	- 0	CCPC 0
0x02	TIM1_SMCR Reset Value	MSM 0	TS2 0	TS1 0	TS0 0	- 0	SMS2 0	SMS1 0	SMS0 0

Table 35. TIM1 register map (continued)

Address offset	Register Name	7	6	5	4	3	2	1	0
0x03	TIM1_ETR Reset Value	ETP 0	ECE 0	ETPS1 0	ETPS0 0	EFT3 0	EFT2 0	EFT1 0	EFT0 0
0x04	TIM1_IER Reset Value	BIE 0	TIE 0	COMIE 0	CC4IE 0	CC3IE 0	CC2IE 0	CC1IE 0	UIE 0
0x05	TIM1_SR1 Reset Value	BIF 0	TIF 0	COMIF 0	CC4IF 0	CC3IF 0	CC2IF 0	CC1IF 0	UIF 0
0x06	TIM1_SR2 Reset Value	- 0	- 0	- 0	CC4OF 0	CC3OF 0	CC2OF 0	CC1OF 0	- 0
0x07	TIM1_EGR Reset Value	BG 0	TG 0	COMG 0	CC4G 0	CC3G 0	CC2G 0	CC1G 0	UG 0
0x08	TIM1_CCMR1 (output mode) Reset Value	OC1CE 0	OC1M2 0	OC1M1 0	OC1M0 0	OC1PE 0	OC1FE 0	CC1S1 0	CC1S0 0
	TIM1_CCMR1 (input mode) Reset value	IC1F3 0	IC1F2 0	IC1F1 0	IC1F0 0	IC1PSC1 0	IC1PSC0 0	CC1S1 0	CC1S0 0
0x09	TIM1_CCMR2 (output mode)	OC2CE 0	OC2M2 0	OC2M1 0	OC2M0 0	OC2PE 0	OC2FE 0	CC2S1 0	CC2S0 0
	TIM1_CCMR2 (input mode)	IC2F3 0	IC2F2 0	IC2F1 0	IC2F0 0	IC2PSC1 0	IC2PSC0 0	CC2S1 0	CC2S0 0
0x0A	TIM1_CCMR3 (output mode)	OC3CE 0	OC3M2 0	OC3M1 0	OC3M0 0	OC3PE 0	OC3FE 0	CC3S1 0	CC3S0 0
	TIM1_CCMR3 (input mode)	IC3F3 0	IC3F2 0	IC3F1 0	IC3F0 0	IC3PSC1 0	IC3PSC0 0	CC3S1 0	CC3S0 0
0x0Bh	TIM1_CCMR4 (output mode)	OC4CE 0	OC4M2 0	OC4M1 0	OC4M0 0	OC4PE 0	OC4FE 0	CC4S1 0	CC4S0 0
	TIM1_CCMR4 (input mode)	IC4F3 0	IC4F2 0	IC4F1 0	IC4F0 0	IC4PSC1 0	IC4PSC0 0	CC4S1 0	CC4S0 0
0x0Ch	TIM1_CCER1	CC2NP 0	CC2NE 0	CC2P 0	CC2E 0	CC1NP 0	CC1NE 0	CC1P 0	CC1E 0
0x0Dh	TIM1_CCER2	- 0	- 0	CC4P 0	CC4E 0	CC3NP 0	CC3NE 0	CC3P 0	CC3E 0
0x0Eh	TIM1_CNTRH	CNT15 0	CNT14 0	CNT13 0	CNT12 0	CNT11 0	CNT10 0	CNT9 0	CNT8 0
0x0Fh	TIM1_CNTRL	CNT7 0	CNT6 0	CNT5 0	CNT4 0	CNT3 0	CNT2 0	CNT1 0	CNT0 0
0x10h	TIM1_PSCRH	PSC15 0	PSC14 0	PSC13 0	PSC12 0	PSC11 0	PSC10 0	PSC9 0	PSC8 0
0x11h	TIM1_PSCRL	PSC7 0	PSC6 0	PSC5 0	PSC4 0	PSC3 0	PSC2 0	PSC1 0	PSC0 0
0x12h	TIM1_ARRH	ARR15 1	ARR14 1	ARR13 1	ARR12 1	ARR11 1	ARR10 1	ARR9 1	ARR8 1

Table 35. TIM1 register map (continued)

Address offset	Register Name	7	6	5	4	3	2	1	0
0x13h	TIM1_ARRL	ARR7 1	ARR6 1	ARR5 1	ARR4 1	ARR3 1	ARR2 1	ARR1 1	ARR0 1
0x14h	TIM1_RCR	REP7 0	REP6 0	REP5 0	REP4 0	REP3 0	REP2 0	REP1 0	REP0 0
0x15h	TIM1_CCR1H	CCR115 0	CCR114 0	CCR113 0	CCR112 0	CCR111 0	CCR110 0	CCR19 0	CCR18 0
0x16h	TIM1_CCR1L	CCR17 0	CCR16 0	CCR15 0	CCR14 0	CCR13 0	CCR12 0	CCR11 0	CCR10 0
0x17h	TIM1_CCR2H	CCR215 0	CCR214 0	CCR213 0	CCR212 0	CCR211 0	CCR210 0	CCR29 0	CCR28 0
0x18h	TIM1_CCR2L	CCR27 0	CCR26 0	CCR25 0	CCR24 0	CCR23 0	CCR22 0	CCR21 0	CCR20 0
0x19h	TIM1_CCR3H	CCR315 0	CCR314 0	CCR313 0	CCR312 0	CCR311 0	CCR310 0	CCR39 0	CCR38 0
0x1Ah	TIM1_CCR3L	CCR37 0	CCR36 0	CCR35 0	CCR34 0	CCR33 0	CCR32 0	CCR31 0	CCR30 0
0x1Bh	TIM1_CCR4H	CCR415 0	CCR414 0	CCR413 0	CCR412 0	CCR411 0	CCR410 0	CCR49 0	CCR48 0
0x1Ch	TIM1_CCR4L	CCR47 0	CCR46 0	CCR45 0	CCR44 0	CCR43 0	CCR42 0	CCR41 0	CCR40 0
0x1Dh	TIM1_BKR	MOE 0	AOE 0	BKP 0	BKE 0	OSSR 0	OSSI 0	LOCK 0	LOCK 0
0x1Eh	TIM1_DTR	DTG7 0	DTG6 0	DTG5 0	DTG4 0	DTG3 0	DTG2 0	DTG1 0	DTG0 0
0x1Fh	TIM1_OISR	- 0	OIS4 0	OIS3N 0	OIS3 0	OIS2N 0	OIS2 0	OIS1N 0	OIS1 0

18 16-bit general purpose timers (TIM2, TIM3, TIM5)

18.1 Introduction

This chapter describes TIM2 and TIM3 which are identical timers, with the exception that TIM2 has three channels and TIM3 has two channels. TIM5 is identical to TIM2 except that it has two additional registers to support timer synchronization and chaining.

Each timer consists of a 16-bit up-counting auto-reload counter driven by a programmable prescaler.

It may be used for a variety of purposes, including:

- Time base generation
- Measuring the pulse lengths of input signals (input capture)
- Generating output waveforms (output compare, PWM and One Pulse Mode)
- Interrupt capability on various events (capture, compare, overflow)
- Synchronization with other timers or external signals (external clock, reset, trigger and enable) (in devices with TIM5)

The timer clock can be sourced from internal clocks.

Only the main features of the general purpose timers are given in this chapter.

Refer to the corresponding paragraphs of [Section 17: 16-bit advanced control timer \(TIM1\) on page 137](#) for more details on each feature.

18.2 TIM2/TIM3 main features

TIM2/TIM3 features include:

- 16-bit up counting auto-reload counter.
- 4-bit programmable prescaler allowing the counter clock frequency to be divided “on the fly” by any power of 2 from 1 to 32768.
- 3 independent channels for:
 - Input capture
 - Output compare
 - PWM generation (edge-aligned Mode)
 - One Pulse Mode output
- Interrupt request generation on the following events:
 - Update: counter overflow, counter initialization (by software)
 - Input capture
 - Output compare

18.3 TIM5 main features

TIM5 features include:

- 16-bit up counting auto-reload counter.
- 4-bit programmable prescaler allowing the counter clock frequency to be divided “on the fly” by any power of 2 from 1 to 32768.
- 3 independent channels for:
 - Input capture
 - Output compare
 - PWM generation (edge-aligned Mode)
 - One Pulse Mode output
- Synchronization circuit to control the timer with external signals and to interconnect several timers
- Interrupt generation on the following events:
 - Update: counter overflow, counter initialization (by software)
 - Input capture
 - Output compare

18.4 TIM2/TIM3/TIM5 functional description

Figure 79. TIM2/TIM3 block diagram

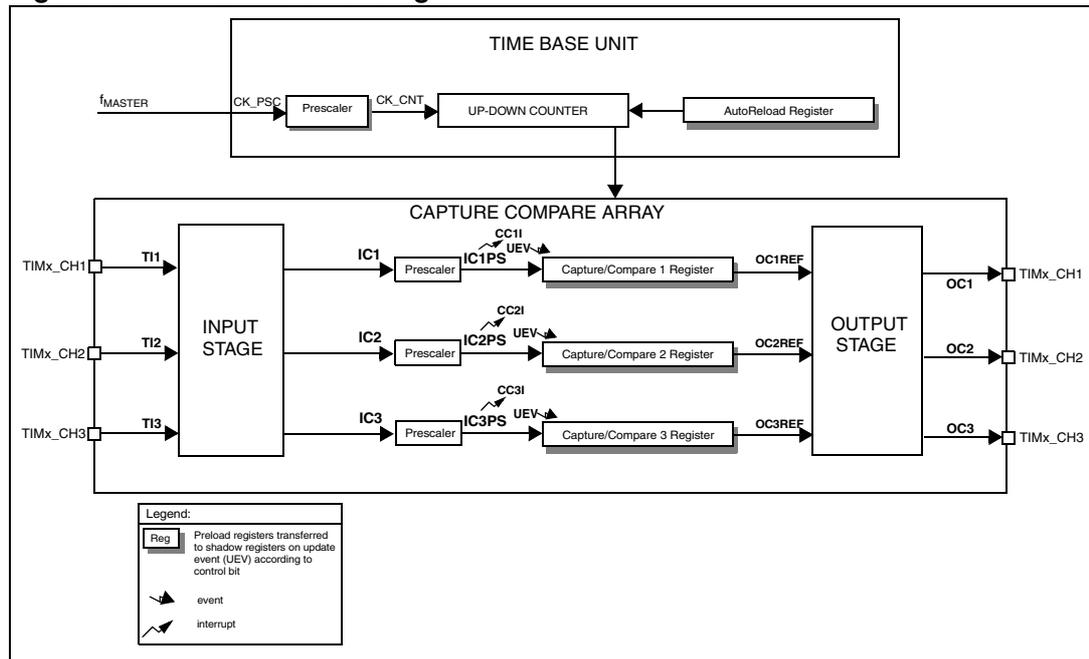
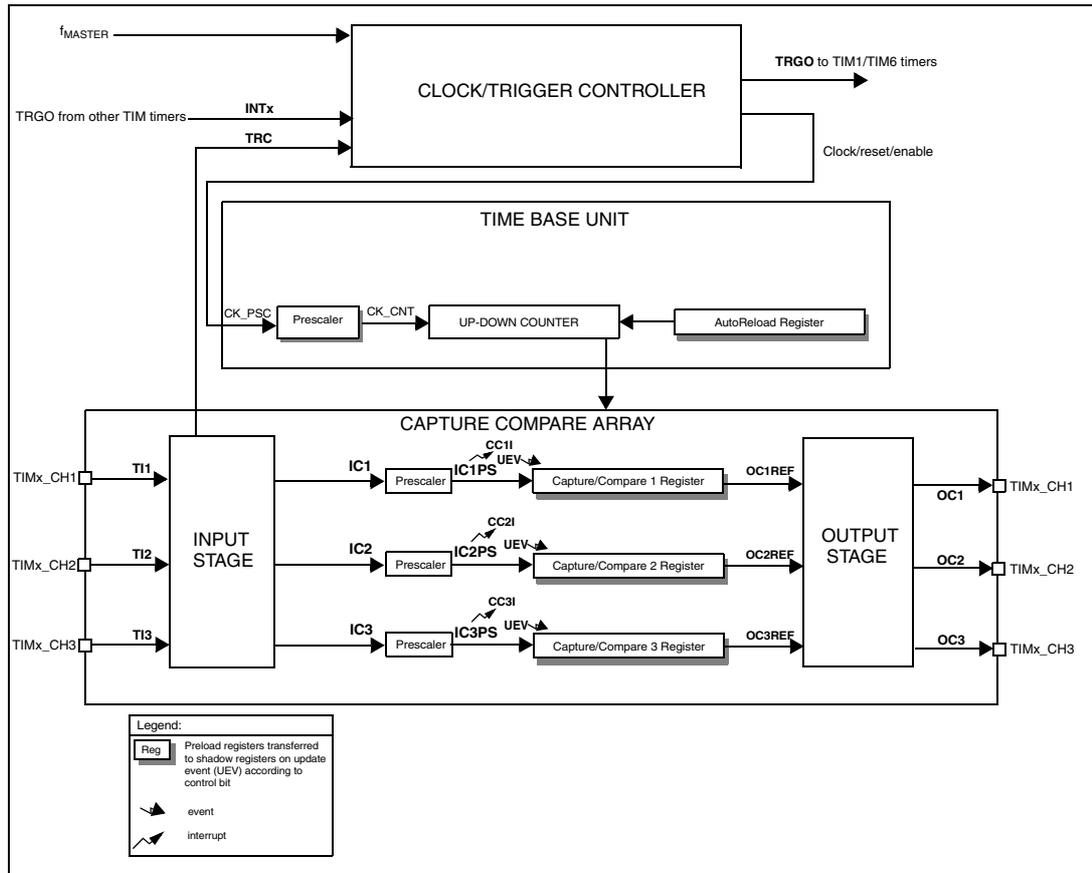


Figure 80. TIM5 block diagram



18.4.1 Time base unit

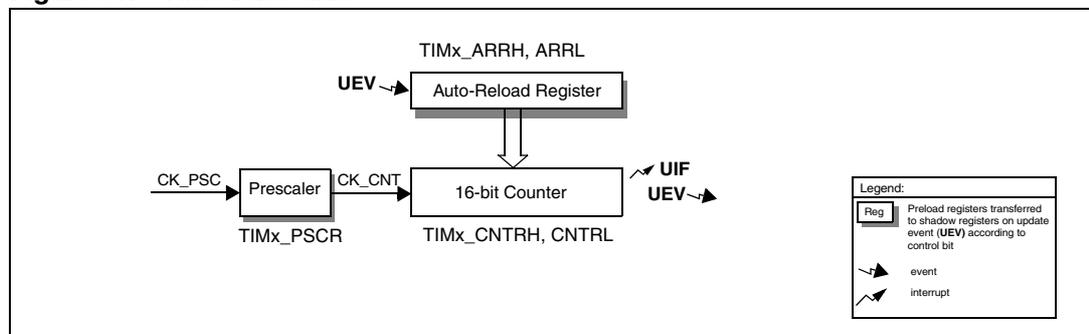
The timer has a *Time base unit* that includes:

- 16-bit up counter
- 16-bit auto-reload register
- 4-bit programmable prescaler

There is no repetition counter.

The clock source for is the internal clock (f_{MASTER}). It is connected directly to the CK_PSC clock that feeds the prescaler driving the counter clock CK_CNT.

Figure 81. Time base unit



For more details refer to [Section 17.3: TIM1 time base unit on page 140](#).

Prescaler

The prescaler implementation is as follows:

- The prescaler is based on a 16-bit counter controlled through a 4-bit register (in TIMx_PSCR register). It can be changed on the fly as this control register is buffered. It can divide the counter clock frequency by any power of 2 from 1 to 32768.

The counter clock frequency is calculated as follows:

$$f_{CK_CNT} = f_{CK_PSC} / 2^{(PSCR[3:0])}$$

The prescaler value is loaded through a preload register. The shadow register, which contains the current value to be used is loaded as soon as the LS Byte has been written.

The new prescaler value is taken into account in the following period (after the next counter update event).

Read operations to the TIMx_PSCR registers access the preload registers, so no special care needs to be taken to read them.

Counter operation

Refer to [Section 17.3.4: Up-counting mode on page 142](#).

18.4.2 Clock/trigger controller

A clock/trigger controller and the associated TIMx_CR2 and TIMx_SMCR registers are not implemented in TIM2/TIM3, only in TIM5. Refer to [Section 17.4: TIM1 clock/trigger controller on page 150](#)

18.4.3 Capture/compare channels

Input stage

Refer to [Section 17.5: TIM1 capture/compare channels on page 163](#).

There are two input channels, as shown in [Figure 82: Input stage block diagram](#).

Figure 82. Input stage block diagram

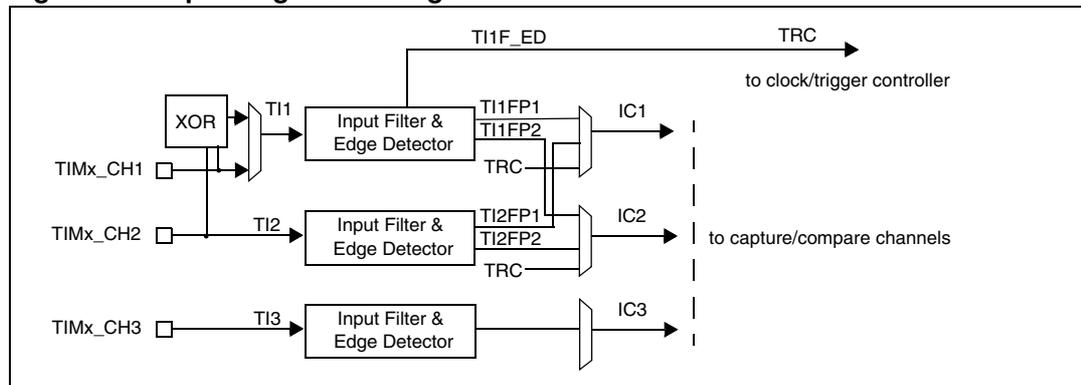
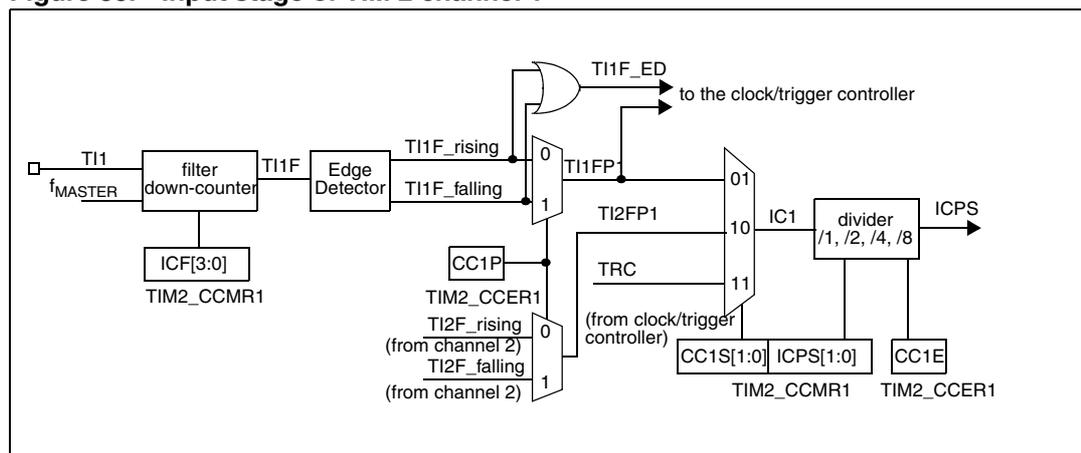


Figure 83. Input stage of TIM 2 channel 1

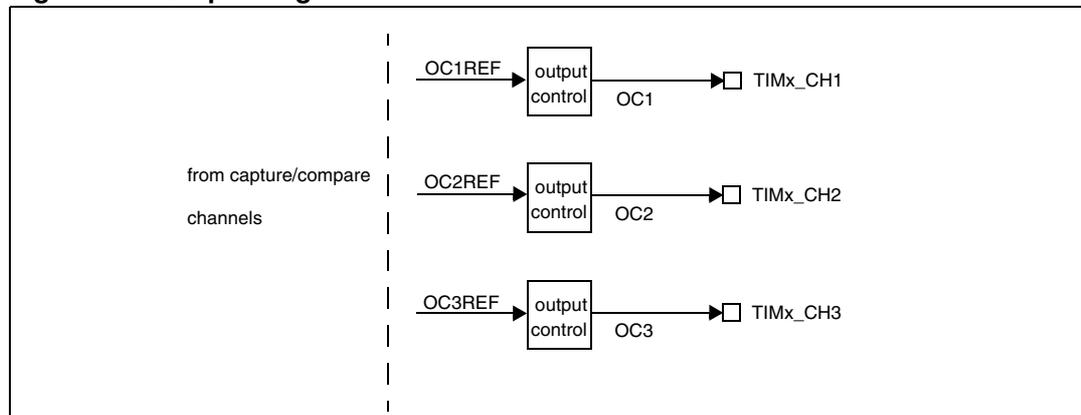


Output stage

Refer to [Section 17.5.4: Output stage on page 168](#), [Section 17.5.5: Forced output mode on page 169](#), [Section 17.5.7: PWM mode on page 171](#).

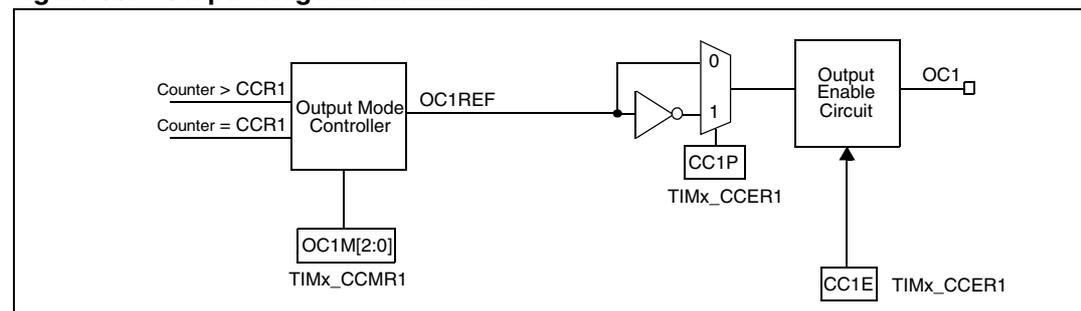
As shown in [Figure 84](#). TIMx outputs have no deadtime or complementary outputs.

Figure 84. Output stage



The output stage generates an intermediate waveform which is then used for reference: OCxREF (active high). Polarity acts at the end of the chain (see [Figure 85](#)).

Figure 85. Output stage of channel 1



18.5 TIM2/TIM3/TIM5 interrupts

The timers have 4 interrupt request sources:

- Capture/Compare 3 Interrupt
- Capture/Compare 2 Interrupt
- Capture/Compare 1 Interrupt
- Update Interrupt
- Trigger interrupt (TIM5 only)

To use the interrupt features, for each interrupt channel used, set the desired CC3IE and/or CC2IE and/or CC1IE bits in the TIMx_IER register to enable interrupt requests.

The different interrupt sources can be also generated by software using the corresponding bits in the TIMx_EGR register.

18.6 TIM2/TIM3/TIM5 registers

18.6.1 Control register 1 (TIMx_CR1)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
ARPE	Reserved			OPM	URS	UDIS	CEN
rw				rw	rw	rw	rw

Bit 7 **ARPE**: Auto-Reload Preload Enable

0: TIMx_ARR register is not buffered through a preload register. It can be written directly.

1: TIMx_ARR register is buffered through a preload register.

Bits 6:4 Reserved

Bit 3 **OPM**: One Pulse Mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the CEN bit)

Bit 2 **URS**: Update Request Source

0: When enabled, an update interrupt request is sent as soon as registers are updated (counter overflow)

1: When enabled, an update interrupt request is sent only when the counter reaches the overflow.

Bit 1 **UDIS**: Update Disable

0: An Update event is generated as soon as a counter overflow occurs or a software update is generated or an hardware reset is generated by the clock/trigger mode controller. Buffered registers are then loaded with their preload values

1: An Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). The counter and the prescaler are re-initialized if the UG bit is set .

Bit 0 **CEN**: Counter Enable.

0: Counter disabled

1: Counter enabled

18.6.2 Control register 2 (TIM5_CR2)

Address offset: 0x01

Reset value: 0x00

	7	6	5	4	3	2	1	0
	MMS[2:0]			Reserved				
Reserved	rw	rw	rw	Reserved				

Note: This register is only available in TIM5, see [Table 38 on page 243](#).

Bit 7 Reserved, must be kept cleared.

Bits 6:4 **MMS[2:0]**: Master mode selection.

These bits select the information to be sent in master mode to TIM1 and TIM2 for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIM3_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (clock/trigger mode controller configured in trigger reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter Enable signal is used as trigger output (TRGO). It is used to start several timers at the same time or to control a window in which a slave timer is enabled. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIM3_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO).

011: Reserved

100: Reserved

101: Reserved

111: Reserved

Bits 3:0 Reserved, must be kept cleared.

18.6.3 Slave mode control register (TIM5_SMCR)

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
MSM	TS[2:0]			Reserved	SMS[2:0]		
rw	rw	rw	rw		rw	rw	rw

Note: This register is only available in TIM5, see [Table 38 on page 243](#).

Bit 7 **MSM** Master/slave mode.

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between timers (through TRGO).

Bits 6:4 **TS[2:0]** Trigger Selection.

This bit-field selects the trigger input to be used to synchronize the counter.

000: internal trigger ITR0 connected to TIM6 TRGO

001: reserved

010: reserved

011: internal trigger ITR3 connected to TIM1 TRGO

100: reserved

101: reserved

110: reserved

111: reserved

Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.

Bit 3 Reserved, always read as 0.

Bits 2:0 **SMS[2:0]** Clock/trigger/slave mode selection.

When external signals are selected, the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Clock/trigger controller disabled - if CEN = '1' then the prescaler is clocked directly by the internal clock.

001: Reserved.

010: Reserved.

011: Reserved.

100: Trigger reset mode - Rising edge of the selected trigger signal (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger signal (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

18.6.4 Interrupt enable register (TIMx_IER)

Address offset: 0x01 (TIM2/3), 0x03 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	TIE	Reserved		CC2IE	CC2IE	CC1IE	UIE
	rw			rw	rw	rw	rw

Bits 7 Reserved

Bit 6 **TIE**: Trigger Interrupt Enable.

0: Trigger Interrupt disabled.

1: Trigger Interrupt enabled.

Note: In TIM2/TIM3 this bit is reserved.

Bits 5:4 Reserved, must be kept cleared.

Bit 3 **CC3IE**: Capture/Compare 3 Interrupt Enable

0: CC3 Interrupt disabled

1: CC3 Interrupt enabled

Bit 2 **CC2IE**: Capture/Compare 2 Interrupt Enable

0: CC2 Interrupt disabled

1: CC2 Interrupt enabled

Bit 1 **CC1IE**: Capture/Compare 1 Interrupt Enable

0: CC1 Interrupt disabled

1: CC1 Interrupt enabled

Bit 0 **UIE**: Update Interrupt Enable.

0: Update Interrupt disabled

1: Update Interrupt enabled

18.6.5 Status register 1 (TIMx_SR1)

Address offset: 0x02 (TIM2/3), 0x04 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	TIF	Reserved		CC3IF	CC2IF	CC1IF	UIF
	rc_w0			rc_w0	rc_w0	rc_w0	rc_w0

Bit 7 Reserved

Bit 6 **TIF**: Trigger Interrupt Flag.

This flag is set by hardware on trigger event (active edge detected on TRGI signal, both edges in case gated mode is selected). It is cleared by software.

0: No trigger event occurred.

1: Trigger interrupt pending.

Note: In TIM2/TIM3 this bit is reserved.

Bits 5:4 Reserved, must be kept cleared.

Bit 2 **CC2IF**: Capture/Compare 2 Interrupt Flag
Refer to CC1IF description

Bit 1 **CC1IF**: Capture/Compare 1 Interrupt Flag
If channel CC1 is configured as output:
This flag is set by hardware when the counter matches the compare value. It is cleared by software.
0: No match.
1: The content of the counter TIMx_CNT has matched the content of the TIMx_CCR1 register.
If channel CC1 is configured as input:
This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx_CCR1L register.
0: No input capture occurred.
1: The counter value has been captured in TIMx_CCR1 register (An edge has been detected on IC1 which matches the selected polarity).

Bit 0 **UIF**: Update Interrupt Flag
This bit is set by hardware on an update event. It is cleared by software.
0: No update occurred.
1: Update interrupt pending. This bit is set by hardware when the registers are updated:
–At overflow if UDIS=0 in the TIMx_CR1 register.
–When CNT is re-initialized by software using the UG bit in TIMx_EGR register, if URS=0 and UDIS=0 in the TIMx_CR1 register.

18.6.6 Status register 2 (TIMx_SR2)

Address offset: 0x03 (TIM2/3), 0x05 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved				CC3OF	CC2OF	CC1OF	Reserved
				rc_w0	rc_w0	rc_w0	

Bits 7:4 Reserved

Bit 3 **CC3OF**: Capture/Compare 3 Overcapture Flag
Refer to CC1OF description

Bit 2 **CC2OF**: Capture/Compare 2 Overcapture Flag
Refer to CC1OF description

Bit 1 **CC1OF**: Capture/Compare 1 Overcapture Flag
This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.
0: No overcapture has been detected.
1: The counter value has been captured in TIMx_CCR1 register while CC1IF flag was already set

Bit 0 Reserved, forced by hardware to 0.

18.6.7 Event generation register (TIMx_EGR)

Address offset: 0x04 (TIM2/3), 0x06 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	TG	Reserved		CC3G	CC2G	CC1G	UG
	w			w	w	w	w

Bit 7 Reserved.

Bit 6 **TG**: Trigger Generation.

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: The TIF flag is set in TIM1_SR1 register. An interrupt is generated if enabled by the TIE bit.

Note: In TIM2/TIM3 this bit is reserved.

Bits 5:4 Reserved.

Bit 3 **CC3G**: Capture/Compare 3 Generation

Refer to CC1G description

Bit 2 **CC2G**: Capture/Compare 2 Generation.

Refer to CC1G description

Bit 1 **CC1G**: Capture/Compare 1 Generation.

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

–If the CC1 channel is configured in output mode:

CC1IF flag is set, and the corresponding interrupt request is sent if enabled.

–If the CC1 channel configured in input mode:

The current value of the counter is captured in the TIMx_CCR1 register. The CC1IF flag is set, and the corresponding interrupt request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update Generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Re-initializes the counter and generates an update of the registers. Note that the prescaler counter is cleared too.

18.6.8 Capture/compare mode register 1 (TIMx_CCMR1)

The channel can be used in input (capture mode) or in output (compare mode). The direction of the channel is defined by configuring the CC1S bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So be aware that the same bit can have a different meaning for the input stage and for the output stage.

Address offset: 0x05 (TIM2/3), 0x07 (TIM5)

Reset value: 0x00

● Channel configured in output

7	6	5	4	3	2	1	0
Reserved	OC1M[2:0]			OC1PE	Reserved	CC1S[1:0]	
	rw	rw	rw	rw		rw	rw

Bit 7 Reserved

Bits 6:4 **OC1M[2:0]**: Output Compare 1 Mode

These bits defines the behavior of the output reference signal OC1REF from which OC1 is derived. OC1REF is active high whereas OC1 active level depends on the CC1P bit.

000 : Frozen - The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs.

001 : Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

010 : Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

011 : Toggle - OC1REF toggles when TIMx_CNT=TIMx_CCR1.

100 : Force inactive level - OC1REF is forced low.

101 : Force active level - OC1REF is forced high.

110 : PWM mode 1 - In up-counting, channel 1 is active as long as TIMx_CNT<TIMx_CCR1 else inactive. In down-counting, channel 1 is inactive (OC1REF='0') as long as TIMx_CNT>TIMx_CCR1 else active (OC1REF='1').

111 : PWM mode 2 - In up-counting, channel 1 is inactive as long as TIMx_CNT<TIMx_CCR1 else active.

Note: In PWM mode 1 or 2, the OC1REF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode. Refer to [Section 17.5.7 on page 171](#) for more details.

Bit 3 **OC1PE**: Output Compare 1 Preload Enable

0: Preload register on TIMx_CCR1 disabled. TIMx_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx_CCR1 enabled. Read/Write operations access the preload register. TIMx_CCR1 preload value is loaded in the shadow register at each update event.

Note: For correct operation, preload registers must be enabled when the timer is in PWM mode. This is not mandatory in one pulse mode (OPM bit set in TIMx_CR1 register).

Bit 2 Reserved.

Bits 1:0 **CC1S[1:0]**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1FP1.

10: CC1 channel is configured as input, IC1 is mapped on TI2FP1.

11: Reserved

Note: CC1S bits are writable only when the channel is OFF (CC1E= '0' in TIMx_CCER1 and updated).

● **Channel configured in input**

7	6	5	4	3	2	1	0
IC1F[3:0]				IC1PSC[1:0]		CC1S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **IC1F[3:0]**: Input Capture 1 Filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{MASTER} .

0001: $f_{SAMPLING} = f_{MASTER}$, N=2.

0010: $f_{SAMPLING} = f_{MASTER}$, N=4.

0011: $f_{SAMPLING} = f_{MASTER}$, N=8.

0100: $f_{SAMPLING} = f_{MASTER}/2$, N=6.

0101: $f_{SAMPLING} = f_{MASTER}/2$, N=8.

0110: $f_{SAMPLING} = f_{MASTER}/4$, N=6.

0111: $f_{SAMPLING} = f_{MASTER}/4$, N=8.

1000: $f_{SAMPLING} = f_{MASTER}/8$, N=6.

1001: $f_{SAMPLING} = f_{MASTER}/8$, N=8.

1010: $f_{SAMPLING} = f_{MASTER}/16$, N=5.

1011: $f_{SAMPLING} = f_{MASTER}/16$, N=6.

1100: $f_{SAMPLING} = f_{MASTER}/16$, N=8.

1101: $f_{SAMPLING} = f_{MASTER}/32$, N=5.

1110: $f_{SAMPLING} = f_{MASTER}/32$, N=6.

1111: $f_{SAMPLING} = f_{MASTER}/32$, N=8.

Bits 3:2 **IC1PSC[1:0]**: Input Capture 1 Prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).
 The prescaler is reset as soon as CC1E='0' (TIMx_CCER register).
 00: no prescaler, capture is done each time an edge is detected on the capture input.
 01: Capture is done once every 2 events.
 10: Capture is done once every 4 events.
 11: Capture is done once every 8 events.

Note: The internal event counter is not reset when IC1PSC is changed on the fly. In this case the old value is used until the next capture occurs. To force a new value to be taken in account immediately, you can clear the CC1E bit and set it again.

Bits 1:0 **CC1S[1:0]**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.
 00: CC1 channel is configured as output.
 01: CC1 channel is configured as input, IC1 is mapped on TI1FP1.
 10: CC1 channel is configured as input, IC1 is mapped on TI2FP1.
 11: Reserved

Note: CC1S bits are writable only when the channel is OFF (CC1E= '0' in TIMx_CCER1 and updated).

18.6.9 Capture/compare mode register 2 (TIMx_CCMR2)

Note: Refer to [Capture/compare mode register 1 \(TIM1_CCMR1\)](#) on page 195 for details on using these bits.

Address offset: 0x06 (TIM2/3), 0x08 (TIM5)

Reset value: 0x00

● **Channel configured in output**

7	6	5	4	3	2	1	0
Reserved	OC2M[2:0]			OC2PE	Reserved	CC2S[1:0]	
	rw	rw	rw	rw		rw	

Bit 7 Reserved

Bits 6:4 **OC2M[2:0]**: Output Compare 2 Mode

Bit 3 **OC2PE**: Output Compare 2 Preload Enable

Bit 2 Reserved.

Bits 1:0 **CC2S[1:0]**: Capture/Compare 2 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.
 00: CC2 channel is configured as output.
 01: CC2 channel is configured as input, IC2 is mapped on TI2FP2.
 10: CC2 channel is configured as input, IC2 is mapped on TI1FP2.
 11: Reserved

Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx_CCER1).

● **Channel configured in input**

7	6	5	4	3	2	1	0
IC2F[3:0]				IC2PSC[1:0]		CC2S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **IC2F[3:0]**: Input Capture 2 Filter

Bits 3:2 **IC2PCS[1:0]**: Input Capture 2 Prescaler

Bits 1:0 **CC2S[1:0]**: Capture/Compare 2 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2FP2.

10: CC2 channel is configured as input, IC2 is mapped on TI1FP2.

11: Reserved

Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx_CCER1).

18.6.10 Capture/compare mode register 3 (TIMx_CCMR3)

Refer to [Capture/compare mode register 1 \(TIM1_CCMR1\)](#) on page 195 for details on using these bits.

Address offset: 0x07 (TIM2), 0x09 (TIM5)

Reset value: 0x00

- **Channel configured in output**

7	6	5	4	3	2	1	0
Reserved	OC3M[2:0]			OC3PE	Reserved	CC3S[1:0]	
	rw	rw	rw	rw		rw	rw

Note: This register is not available in TIM3.

Bit 7 Reserved

Bits 6:4 **OC3M[2:0]**: Output Compare 3 Mode

Bit 3 **OC3PE**: Output Compare 3 Preload Enable

Bit 2 Reserved

Bits 1:0 **CC3S[1:0]**: Capture/Compare 3 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3FP3

10: Reserved

11: Reserved

Note: CC3S bits are writable only when the channel is OFF (CC3E = '0' in TIMx_CCER2).

- **Channel configured in input**

7	6	5	4	3	2	1	0
IC3F[3:0]				IC3PSC[1:0]		CC3S[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw

Note: This register is not available in TIM3.

Bits 7:4 **IC3F[3:0]** Input Capture 3 Filter

Bits 3:2 **IC3PSC[1:0]**: Input Capture 3 Prescaler

Bits 1:0 **CC3S[1:0]**: Capture/Compare 3 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3FP3

10: Reserved

11: Reserved

Note: CC3S bits are writable only when the channel is OFF (CC3E = '0' in TIMx_CCER2).

18.6.11 Capture/compare enable register 1 (TIMx_CCER1)

Address offset: 0x08 (TIM2), 0x07 (TIM3), 0x0A (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved		CC2P	CC2E	Reserved		CC1P	CC1E
		rw	rw			rw	rw

Bits 6:7 Reserved

Bit 5 **CC2P**: Capture/Compare 2 output Polarity
refer to CC1P description

Bit 4 **CC2E**: Capture/Compare 2 output Enable
refer to CC1E description

Bits 2:3 Reserved

Bit 1 **CC1P**: Capture/Compare 1 output Polarity

CC1 channel configured as output:

0 : OC1 active high

1 : OC1 active low

CC1 channel configured as input for capture function (see [Figure 61](#)):

0 : Capture is done on a rising edge of TI1F or TI2F

1 : Capture is done on a falling edge of TI1F or TI2F

Bit 0 **CC1E**: Capture/Compare 1 output Enable.

CC1 channel configured as output:

0 : Off - OC1 is not active.

1 : On - OC1 signal is output on the corresponding output pin.

CC1 channel configured as input:

In this case this bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx_CCR1) or not.

0 : Capture disabled.

1 : Capture enabled.

18.6.12 Capture/compare enable register 2 (TIMx_CCER2)

Address offset: 0x09 (TIM2), 0x0B (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved						CC3P	CC3E
						rw	rw

Note: This register is not available in TIM3.

Bits 7:2 Reserved

Bit 1 **CC3P**: Capture/Compare 3 output Polarity
Refer to CC1P description

Bit 0 **CC3E**: Capture/Compare 3 output Enable
Refer to CC1E description

18.6.13 Counter high (TIMx_CNTRH)

Address offset: 0x0A (TIM2), 0x08 (TIM3), 0x0C (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CNT[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CNT[15:8]**: Counter value (MSB)**18.6.14 Counter low (TIMx_CNTRL)**

Address offset: 0x0B (TIM2), 0x09 (TIM3), 0x0D (TIM5)

Reset value: 0x00

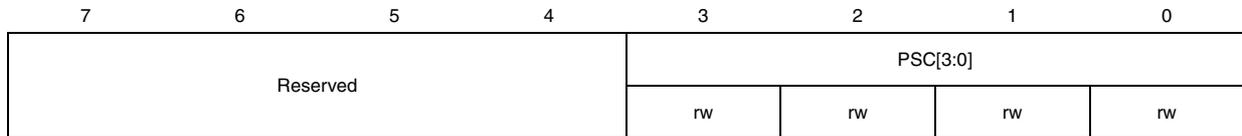
7	6	5	4	3	2	1	0
CNT[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CNT[7:0]**: Counter value (LSB)

18.6.15 Prescaler register (TIMx_PSCR)

Address offset: 0x0C (TIM2), 0x0A (TIM3), 0x0E (TIM5)

Reset value: 0x00



Bits 7:3 Reserved

Bits 2:0 **PSC[3:0]**: Prescaler value

The prescaler value divides the CK_PSC clock frequency.

The counter clock frequency f_{CK_CNT} is equal to $f_{CK_PSC} / 2^{(PSC[3:0])}$. PSC[7:4] are forced to 0 by hardware.

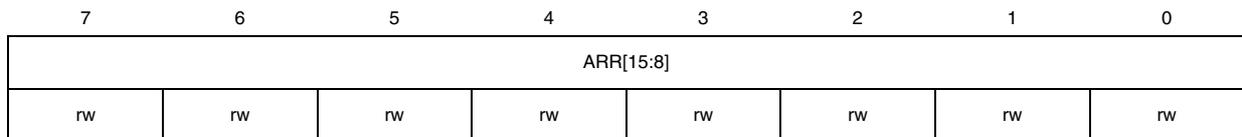
PSCR contains the value which will be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx_EGR register).

This means that an update event must be generated in order that a new prescaler value can be taken into account.

18.6.16 Auto-reload register high (TIMx_ARRH)

Address offset: 0x0D (TIM2), 0x0B (TIM3), 0x0F (TIM5)

Reset value: 0xFF



Bits 7:0 **ARR[15:8]**: Autoreload value (MSB)

ARR is the value to be loaded in the actual auto-reload register.

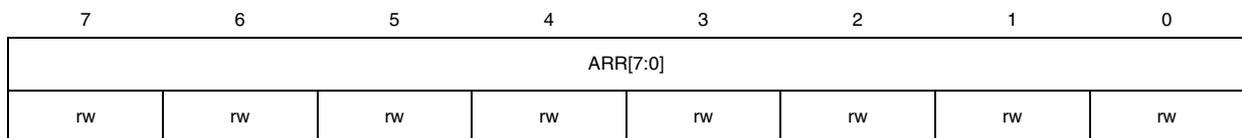
Refer to the [Section 17.3: TIM1 time base unit on page 140](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is 0.

18.6.17 Auto-reload register low (TIMx_ARRL)

Address offset: 0x0E (TIM2), 0x0C (TIM3), 0x10 (TIM5)

Reset value: 0xFF



Bits 7:0 **ARR[7:0]**: Autoreload value (LSB)

18.6.18 Capture/compare register 1 high (TIMx_CCR1H)

Address offset: 0x0F (TIM2), 0x0D (TIM3), 0x11 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR1[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR1[15:8]**: Capture/compare 1 value (MSB).**If the CC1 channel is configured as output (CC1S bits in TIMx_CCMR1 register):**

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC1 output.

If the CC1 channel is configured as input (CC1S bits in TIMx_CCMR1 register):

CCR1 is the counter value transferred by the last input capture 1 event (IC1). It is read-only in this case.

18.6.19 Capture/compare register 1 low (TIMx_CCR1L)

Address offset: 0x10 (TIM2), 0x0E (TIM3), 0x12 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR1[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR1[7:0]**: Capture/compare 1 value (LSB)

18.6.20 Capture/compare register 2 high (TIMx_CCR2H)

Address offset: 0x11 (TIM2), 0x0F (TIM3), 0x13 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR2[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR2[15:8]**: Capture/compare 2 value (MSB)

If the CC2 channel is configured as output (CC2S bits in TIMx_CCMR2 register):

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC2 output.

If the CC2 channel is configured as input (CC2S bits in TIMx_CCMR2 register):

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

18.6.21 Capture/compare register 2 low (TIMx_CCR2L)

Address offset: 0x12 (TIM2), 0x10 (TIM3), 0x14 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR2[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR2[7:0]**: Capture/compare value (LSB)

18.6.22 Capture/compare register 3 high (TIMx_CCR3H)

Address offset: 0x13 (TIM2), 0x15 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR3[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Note: This register is not available in TIM3.

Bits 7:0 **CCR3[15:8]**: Capture/Compare value (MSB)

If the CC3 channel is configured as output (CC3S bits in TIMx_CCMR3 register):

CCR3 is the value to be loaded in the actual capture/compare 3 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR3 register (bit OC3PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC3 output.

If the CC3 channel is configured as input (CC3S bits in TIMx_CCMR3 register):

CCR3 is the counter value transferred by the last input capture 3 event (IC3).

18.6.23 Capture/compare register 3 low (TIMx_CCR3L)

Address offset: 0x14 (TIM2), 0x16 (TIM5)

Reset value: 0x00

7	6	5	4	3	2	1	0
CCR3[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Note: This register is not available in TIM3.

Bits 7:0 **CCR3[7:0]**: Capture/compare value (LSB)

18.6.24 TIM2/TIM3/TIM5 register map and reset values

Table 36. TIM2 register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	TIM2_CR1 Reset Value	ARPE 0	- 0	- 0	- 0	OPM 0	URS 0	UDIS 0	CEN 0
0x01	TIM2_IER Reset Value	- 0	- 0	- 0	- 0	CC3IE 0	CC2IE 0	CC1IE 0	UIE 0
0x02	TIM2_SR1 Reset Value	- 0	- 0	- 0	- 0	CC3IF 0	CC2IF 0	CC1IF 0	UIF 0
0x03	TIM2_SR2 Reset Value	- 0	- 0	- 0	- 0	CC3OF 0	CC2OF 0	CC1OF 0	- 0
0x04	TIM2_EGR Reset Value	- 0	- 0	- 0	- 0	CC3G 0	CC2G 0	CC1G 0	UG 0
0x05	TIM2_CCMR1 (output mode) Reset Value	- 0	OC1M2 0	OC1M1 0	OC1M0 0	OC1PE 0	- 0	CC1S1 0	CC1S0 0
	TIM2_CCMR1 (input mode) Reset value	IC1F3 0	IC1F2 0	IC1F1 0	IC1F0 0	IC1PSC1 0	IC1PSC0 0	CC1S1 0	CC1S0 0
0x06	TIM2_CCMR2 (output mode) Reset Value	- 0	OC2M2 0	OC2M1 0	OC2M0 0	OC2PE 0	- 0	CC2S1 0	CC2S0 0
	TIM2_CCMR2 (input mode) Reset Value	IC2F3 0	IC2F2 0	IC2F1 0	IC2F0 0	IC2PSC1 0	IC2PSC0 0	CC2S1 0	CC2S0 0
0x07	TIM2_CCMR3 (output mode) Reset Value	- 0	OC3M2 0	OC3M1 0	OC3M0 0	OC3PE 0	- 0	CC3S1 0	CC3S0 0
	TIM2_CCMR3 (input mode) Reset Value	IC3F3 0	IC3F2 0	IC3F1 0	IC3F0 0	IC3PSC1 0	IC3PSC0 0	CC3S1 0	CC3S0 0
0x08	TIM2_CCER1 Reset Value	- 0	- 0	CC2P 0	CC2E 0	- 0	- 0	CC1P 0	CC1E 0
0x09	TIM2_CCER2 Reset Value	- 0	- 0	- 0	- 0	- 0	- 0	CC3P 0	CC3E 0
0x0A	TIM2_CNTRH Reset Value	CNT15 0	CNT14 0	CNT13 0	CNT12 0	CNT11 0	CNT10 0	CNT9 0	CNT8 0
0x0B	TIM2_CNTRL Reset Value	CNT7 0	CNT6 0	CNT5 0	CNT4 0	CNT3 0	CNT2 0	CNT1 0	CNT0 0
0x0C	TIM2_PSCR Reset Value	- 0	- 0	- 0	- 0	PSC3 0	PSC2 0	PSC1 0	PSC0 0
0x0D	TIM2_ARRH Reset Value	ARR15 1	ARR14 1	ARR13 1	ARR12 1	ARR11 1	ARR10 1	ARR9 1	ARR8 1

Table 36. TIM2 register map (continued)

Address offset	Register name	7	6	5	4	3	2	1	0
0x0E	TIM2_ARRL Reset Value	ARR7 1	ARR6 1	ARR5 1	ARR4 1	ARR3 1	ARR2 1	ARR1 1	ARR0 1
0x0F	TIM2_CCR1H Reset Value	CCR115 0	CCR114 0	CCR113 0	CCR112 0	CCR111 0	CCR110 0	CCR19 0	CCR18 0
0x10	TIM2_CCR1L Reset Value	CCR17 0	CCR16 0	CCR15 0	CCR14 0	CCR13 0	CCR12 0	CCR11 0	CCR10 0
0x11	TIM2_CCR2H Reset Value	CCR215 0	CCR214 0	CCR213 0	CCR212 0	CCR211 0	CCR210 0	CCR29 0	CCR28 0
0x12	TIM2_CCR2L Reset Value	CCR27 0	CCR26 0	CCR25 0	CCR24 0	CCR23 0	CCR22 0	CCR21 0	CCR20 0
0x13	TIM2_CCR3H Reset Value	CCR315 0	CCR314 0	CCR313 0	CCR312 0	CCR311 0	CCR310 0	CCR39 0	CCR38 0
0x14	TIM2_CCR3L Reset Value	CCR37 0	CCR36 0	CCR35 0	CCR34 0	CCR33 0	CCR32 0	CCR31 0	CCR30 0

Table 37. TIM3 register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	TIM3_CR1 Reset Value	ARPE 0	- 0	- 0	- 0	OPM 0	URS 0	UDIS 0	CEN 0
0x01	TIM3_IER Reset Value	- 0	0	- 0	- 0	- 0	CC2IE 0	CC1IE 0	UIE 0
0x02	TIM3_SR1 Reset Value	- 0	0	- 0	- 0	- 0	CC2IF 0	CC1IF 0	UIF 0
0x03	TIM3_SR2 Reset Value	- 0	- 0	- 0	- 0	- 0	CC2OF 0	CC1OF 0	- 0
0x04	TIM3_EGR Reset Value	- 0	0	- 0	- 0	- 0	CC2G 0	CC1G 0	UG 0
0x05	TIM3_CCMR1 (output mode) Reset Value	- 0	OC1M2 0	OC1M1 0	OC1M0 0	OC1PE 0	- 0	CC1S1 0	CC1S0 0
	TIM3_CCMR1 (input mode) Reset value	IC1F3 0	IC1F2 0	IC1F1 0	IC1F0 0	IC1PSC1 0	IC1PSC0 0	CC1S1 0	CC1S0 0
0x06	TIM3_CCMR2 (output mode) Reset Value	- 0	OC2M2 0	OC2M1 0	OC2M0 0	OC2PE 0	- 0	CC2S1 0	CC2S0 0
	TIM3_CCMR2 (input mode) Reset Value	IC2F3 0	IC2F2 0	IC2F1 0	IC2F0 0	IC2PSC1 0	IC2PSC0 0	CC2S1 0	CC2S0 0
0x07	TIM3_CCER1 Reset Value	- 0	- 0	CC2P 0	CC2E 0	- 0	- 0	CC1P 0	CC1E 0

Table 37. TIM3 register map (continued)

Address offset	Register name	7	6	5	4	3	2	1	0
0x08	TIM3_CNTRH Reset Value	CNT15 0	CNT14 0	CNT13 0	CNT12 0	CNT11 0	CNT10 0	CNT9 0	CNT8 0
0x09	TIM3_CNTRL Reset Value	CNT7 0	CNT6 0	CNT5 0	CNT4 0	CNT3 0	CNT2 0	CNT1 0	CNT0 0
0x0A	TIM3_PSCR Reset Value	- 0	- 0	- 0	- 0	PSC3 0	PSC2 0	PSC1 0	PSC0 0
0x0B	TIM3_ARRH Reset Value	ARR15 1	ARR14 1	ARR13 1	ARR12 1	ARR11 1	ARR10 1	ARR9 1	ARR8 1
0x0C	TIM3_ARRL Reset Value	ARR7 1	ARR6 1	ARR5 1	ARR4 1	ARR3 1	ARR2 1	ARR1 1	ARR0 1
0x0D	TIM3_CCR1H Reset Value	CCR115 0	CCR114 0	CCR113 0	CCR112 0	CCR111 0	CCR110 0	CCR19 0	CCR18 0
0x0E	TIM3_CCR1L Reset Value	CCR17 0	CCR16 0	CCR15 0	CCR14 0	CCR13 0	CCR12 0	CCR11 0	CCR10 0
0x0F	TIM3_CCR2H Reset Value	CCR215 0	CCR214 0	CCR213 0	CCR212 0	CCR211 0	CCR210 0	CCR29 0	CCR28 0
0x10h	TIM3_CCR2L Reset Value	CCR27 0	CCR26 0	CCR25 0	CCR24 0	CCR23 0	CCR22 0	CCR21 0	CCR20 0

Table 38. TIM5 register map

Address	Register name	7	6	5	4	3	2	1	0
0x00	TIM5_CR1 Reset Value	ARPE 0	- 0	- 0	- 0	OPM 0	URS 0	UDIS 0	CEN 0
0x01	TIM5_CR2 Reset Value	T1S 0	MMS2 0	MMS1 0	MMS0 0	- 0	COMS 0	- 0	CCPC 0
0x02	TIM5_SMCR Reset Value	MSM 0	TS2 0	TS1 0	TS0 0	- 0	SMS2 0	SMS1 0	SMS0 0
0x03	TIM5_IER Reset Value	- 0	TIE 0	- 0	- 0	CC3IE 0	CC2IE 0	CC1IE 0	UIE 0
0x04	TIM5_SR1 Reset Value	- 0	TIF 0	- 0	- 0	CC3IF 0	CC2IF 0	CC1IF 0	UIF 0
0x05	TIM5_SR2 Reset Value	- 0	- 0	- 0	- 0	CC3OF 0	CC2OF 0	CC1OF 0	- 0
0x06	TIM5_EGR Reset Value	- 0	TG 0	- 0	- 0	CC3G 0	CC2G 0	CC1G 0	UG 0
0x07	TIM5_CCMR1 (output mode) Reset Value	- 0	OC1M2 0	OC1M1 0	OC1M0 0	OC1PE 0	- 0	CC1S1 0	CC1S0 0
	TIM5_CCMR1 (input mode) Reset value	IC1F3 0	IC1F2 0	IC1F1 0	IC1F0 0	IC1PSC1 0	IC1PSC0 0	CC1S1 0	CC1S0 0

Table 38. TIM5 register map (continued)

Address	Register name	7	6	5	4	3	2	1	0
0x08	TIM5_CCMR2 (output mode) Reset Value	- 0	OC2M2 0	OC2M1 0	OC2M0 0	OC2PE 0	- 0	CC2S1 0	CC2S0 0
	TIM5_CCMR2 (input mode) Reset Value	IC2F3 0	IC2F2 0	IC2F1 0	IC2F0 0	IC2PSC1 0	IC2PSC0 0	CC2S1 0	CC2S0 0
0x09	TIM5_CCMR3 (output mode) Reset Value	- 0	OC3M2 0	OC3M1 0	OC3M0 0	OC3PE 0	- 0	CC3S1 0	CC3S0 0
	TIM5_CCMR3 (input mode) Reset Value	IC3F3 0	IC3F2 0	IC3F1 0	IC3F0 0	IC3PSC1 0	IC3PSC0 0	CC3S1 0	CC3S0 0
0x0A	TIM5_CCER1 Reset Value	- 0	- 0	CC2P 0	CC2E 0	- 0	- 0	CC1P 0	CC1E 0
0x0B	TIM5_CCER2 Reset Value	- 0	- 0	- 0	- 0	- 0	- 0	CC3P 0	CC3E 0
0x0C	TIM5_CNTRH Reset Value	CNT15 0	CNT14 0	CNT13 0	CNT12 0	CNT11 0	CNT10 0	CNT9 0	CNT8 0
0x0D	TIM5_CNTRL Reset Value	CNT7 0	CNT6 0	CNT5 0	CNT4 0	CNT3 0	CNT2 0	CNT1 0	CNT0 0
0x0E	TIM5_PSCR Reset Value	- 0	- 0	- 0	- 0	PSC3 0	PSC2 0	PSC1 0	PSC0 0
0x0F	TIM5_ARRH Reset Value	ARR15 1	ARR14 1	ARR13 1	ARR12 1	ARR11 1	ARR10 1	ARR9 1	ARR8 1
0x10	TIM5_ARRL Reset Value	ARR7 1	ARR6 1	ARR5 1	ARR4 1	ARR3 1	ARR2 1	ARR1 1	ARR0 1
0x11	TIM5_CCR1H Reset Value	CCR115 0	CCR114 0	CCR113 0	CCR112 0	CCR111 0	CCR110 0	CCR19 0	CCR18 0
0x12	TIM5_CCR1L Reset Value	CCR17 0	CCR16 0	CCR15 0	CCR14 0	CCR13 0	CCR12 0	CCR11 0	CCR10 0
0x13	TIM5_CCR2H Reset Value	CCR215 0	CCR214 0	CCR213 0	CCR212 0	CCR211 0	CCR210 0	CCR29 0	CCR28 0
0x14	TIM5_CCR2L Reset Value	CCR27 0	CCR26 0	CCR25 0	CCR24 0	CCR23 0	CCR22 0	CCR21 0	CCR20 0
0x15	TIM5_CCR3H Reset Value	CCR315 0	CCR314 0	CCR313 0	CCR312 0	CCR311 0	CCR310 0	CCR39 0	CCR38 0
0x16	TIM5_CCR3L Reset Value	CCR37 0	CCR36 0	CCR35 0	CCR34 0	CCR33 0	CCR32 0	CCR31 0	CCR30 0

19 8-bit basic timer (TIM4, TIM6)

19.1 Introduction

The timer consists of an 8-bit auto-reload up-counter driven by a programmable prescaler. It can be used for time base generation, with interrupt generation on timer overflow.

TIM6 is implemented with the clock/trigger controller for timer synchronization and chaining.

Refer to [Section 17.3 on page 140](#) for the general description of the timer features.

Figure 86. TIM4 block diagram

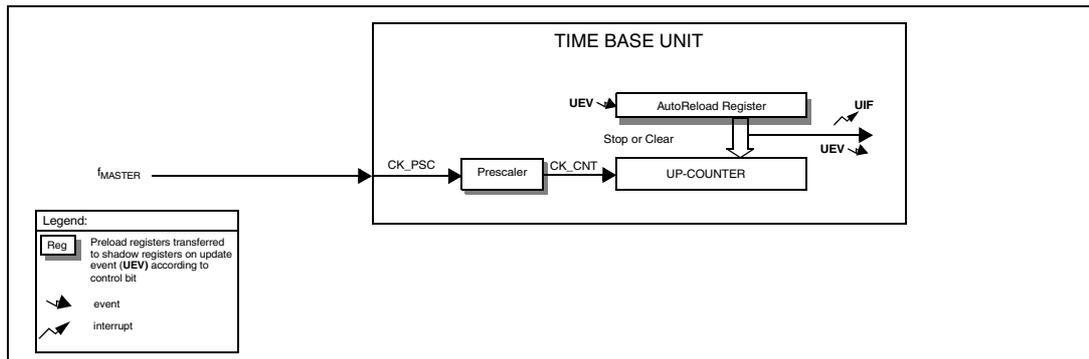
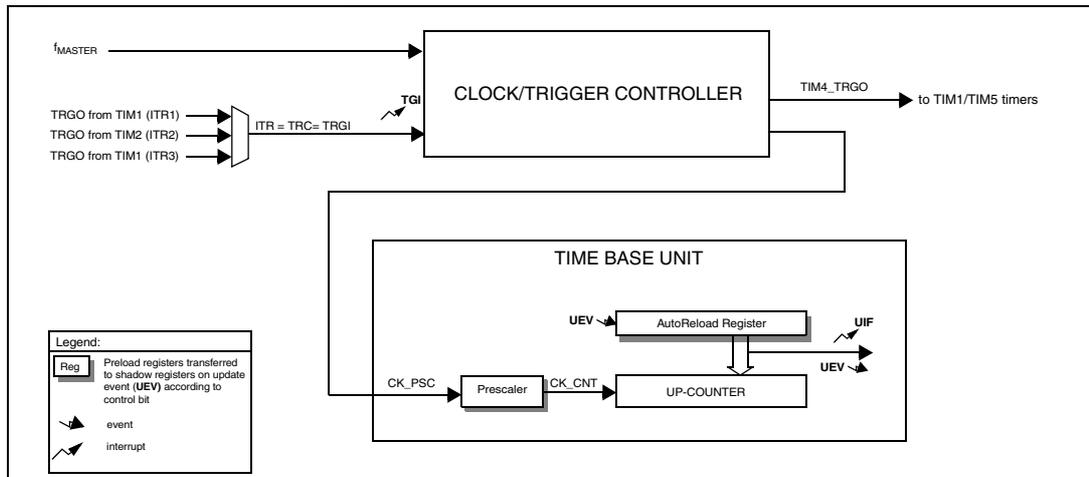


Figure 87. TIM6 block diagram



19.2 TIM4 main features

The main features include:

- 8-bit up counter auto-reload counter
- 3-bit programmable prescaler allowing dividing (also “on the fly”) the counter clock frequency by 1, 2, 4, 8, 16, 32, 64 and 128.
- Interrupt generation
 - On counter update: counter overflow
 -

19.3 TIM6 main features

The main features include:

- 8-bit up counter auto-reload counter
- 3-bit programmable prescaler allowing dividing (also “on the fly”) the counter clock frequency by 1, 2, 4, 8, 16, 32, 64 and 128.
- Synchronization circuit to control the timer with external signals and to interconnect several timers
- Interrupt generation
 - On counter update: counter overflow
 - On trigger input

19.4 TIM4/TIM6 interrupts

The timer has 2 interrupt request sources:

- Update Interrupt (overflow, counter initialization)
- Trigger input (TIM5 only)

19.5 TIM4/TIM6 clock selection

The clock source for the timer is the internal clock (f_{MASTER}). It is connected directly to the CK_PSC clock that feeds the prescaler driving the counter clock CK_CNT.

Prescaler

The prescaler implementation is as follows:

- The prescaler is based on a 7-bit counter controlled through a 3-bit register (in the TIMx_PSCR register). It can be changed on the fly as this control register is buffered. It can divide the counter clock frequency by any power of 2 from 1 to 128.

The counter clock frequency is calculated as follows:

$$f_{\text{CK_CNT}} = f_{\text{CK_PSC}} / 2^{(\text{PSCR}[2:0])}$$

The prescaler value is loaded through a preload register. The shadow register, which contains the current value to be used is loaded as soon as the LS Byte has been written.

Read operations to the TIMx_PSCR registers access the preload registers, so no special care needs to be taken to read them.

19.6 TIM4/TIM6 registers

19.6.1 Control register 1 (TIMx_CR1)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
ARPE	Reserved			OPM	URS	UDIS	CEN
rw				rw	rw	rw	rw

Bit 7 **ARPE**: Auto-Reload Preload Enable.

0: TIM4_ARR register is not buffered through a preload register. It can be written directly.

1: TIM4_ARR register is buffered through a preload register.

Bits 6:4 Reserved, must be kept cleared.

Bit 3 **OPM**: One Pulse Mode.

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the CEN bit).

Bit 2 **URS**: Update Request Source.

0: When enabled, an update interrupt request is sent as soon as registers are updated (counter overflow)

1: When enabled, an update interrupt request is sent only when the counter reaches the overflow/underflow.

Bit 1 **UDIS**: Update disable.

0: An Update event is generated as soon as a counter overflow occurs or a software update is generated. Buffered registers are then loaded with their preload values

1: An Update event is not generated, shadow registers keep their value (ARR, PSC). The counter and the prescaler are re-initialized if the UG bit is set .

Bit 0 **CEN**: Counter enable.

0: Counter disable.

1: Counter enable.

19.6.2 Control register 2 (TIM6_CR2)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	MMS[2:0]			Reserved			
	rw	rw	rw				

Note: This register is not available in TIM4.

Bit 7 Reserved, must be kept cleared.

Bits 6:4 **MMS[2:0]**: Master mode selection.

These bits select the information to be sent in master mode to for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIM6_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (clock/trigger mode controller configured in trigger reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter Enable signal is used as trigger output (TRGO). It is used to start several timers at the same time or to control a window in which a slave timer is enabled. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in the TIM4_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO).

011: Reserved

100: Reserved

101: Reserved

111: Reserved

Bits 3:0 Reserved, must be kept cleared.

19.6.3 Slave mode control register (TIM6_SMCR)

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
MSM	TS[2:0]			Reserved	SMS[2:0]		
rw	rw	rw	rw		rw	rw	rw

Note: This register is not available in TIM4.

Bit 7 **MSM**: Master/slave mode.

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between timers (through TRGO).

Bits 6:4 **TS[2:0]**: Trigger selection.

This bit-field selects the trigger input to be used to synchronize the counter.

000: reserved

001: reserved

010: internal trigger ITR2 connected to TIM5 TRGO

011: internal trigger ITR3 connected to TIM1 TRGO

100: reserved

101: reserved

110: reserved

111: reserved

Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.

Bit 3 Reserved, always read as 0.

Bits 2:0 **SMS[2:0]**: Clock/trigger/slave mode selection.

When external signals are selected, the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Clock/trigger controller disabled - if CEN = '1' then the prescaler is clocked directly by the internal clock.

001: Reserved.

010: Reserved.

011: Reserved.

100: Trigger reset mode - Rising edge of the selected trigger signal (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger signal (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

19.6.4 Interrupt enable register (TIMx_IER)

Address offset: 0x01(TIM4), 0x03 (TIM6)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	TIE	Reserved					UIE
	rw						rw

Bit 7 Reserved, must be kept cleared.

Bit 6 **TIE**: Trigger Interrupt Enable.

0: Trigger Interrupt disabled.

1: Trigger Interrupt enabled.

Note: In TIM4 this bit is reserved.

Bits 5:1 Reserved, must be kept cleared.

Bit 0 **UIE**: Update Interrupt Enable.

0: Update Interrupt disabled.

1: Update Interrupt enabled.

19.6.5 Status register 1 (TIMx_SR1)

0x02(TIM4), 0x04 (TIM6)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved							UIF
							rc_w0

Bit 7 Reserved, must be kept cleared.

Bit 6 **TIF**: Trigger Interrupt Flag.

This flag is set by hardware on trigger event (active edge detected on TRGI signal, both edges in case gated mode is selected). It is cleared by software.

0: No trigger event occurred.

1: Trigger interrupt pending.

Note: In TIM4 this bit is reserved.

Bits 5:1 Reserved, must be kept cleared.

Bit 0 **UIF**: Update Interrupt Flag.

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- at overflow if UDIS=0 in the TIM4_CR1 register.

- when CNT is re-initialized by software using the UG bit in the TIM4_EGR register, if URS=0 and UDIS=0 in the TIM4_CR1 register.

19.6.6 Event generation register (TIMx_EGR)

Address offset: 0x03(TIM4), 0x05 (TIM6)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	TG	Reserved					UG
	w						w

Bit 7 Reserved, must be kept cleared.

Bit 6 **TG**: Trigger Generation.

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: The TIF flag is set in TIM4_SR1 register. An interrupt is generated if enabled by the TIE bit.

Note: In TIM4 this bit is reserved.

Bits 5:1 Reserved, must be kept cleared.

Bit 0 **UG**: Update Generation.

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Re-initializes the counter and generates an update of the registers. Note that the prescaler counter is cleared too.

19.6.7 Counter (TIMx_CNTR)

Address offset: 0x04(TIM4), 0x06 (TIM6)

Reset value: 0x00

7	6	5	4	3	2	1	0
CNT[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CNT[7:0]**: Counter Value

19.6.8 Prescaler register (TIMx_PSCR)

Address offset: 0x05(TIM4), 0x07 (TIM6)

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved					PSC[2:0]		
					rw	rw	rw

Bits 7:3 Reserved, must be kept cleared

Bits 2:0 **PSC[2:0]**: Prescaler Value.

The prescaler value divides the CK_PSC clock frequency.

The counter clock frequency f_{CK_CNT} is equal to $f_{CK_PSC} / 2^{(PSC[2:0])}$.

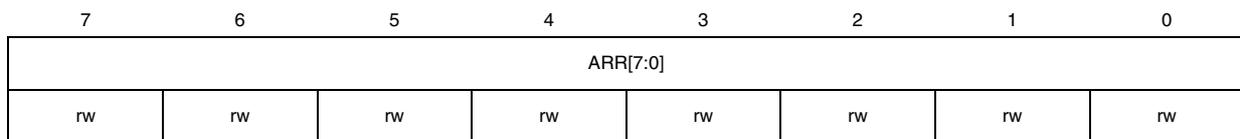
PSC contains the value which will be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIM4_EGR register).

This means that an update event must be generated in order that a new prescaler value can be taken into account.

19.6.9 Auto-reload register (TIMx_ARR)

Address offset: 0x06 (TIM4), 0x08 (TIM6)

Reset value: 0xFF



Bits 7:0 **ARR[7:0]**: Autoreload Value

19.6.10 TIM4/TIM6 register map and reset values

Table 39. TIM4 register map

Address	Register name	7	6	5	4	3	2	1	0
0x00	TIM4_CR1 Reset Value	ARPE 0	- 0	- 0	- 0	OPM 0	URS 0	UDIS 0	CEN 0
0x01	TIM4_IER Reset Value	- 0	UIE 0						
0x02	TIM4_SR1 Reset Value	- 0	UIF 0						
0x03	TIM4_EGR Reset Value	- 0	UG 0						
0x04	TIM4_CNTR Reset Value	CNT7 0	CNT6 0	CNT5 0	CNT4 0	CNT3 0	CNT2 0	CNT1 0	CNT0 0
0x05	TIM4_PSCR Reset Value	- 0	- 0	- 0	- 0	- 0	PSC2 0	PSC1 0	PSC0 0
0x06	TIM4_ARR Reset Value	ARR7 1	ARR6 1	ARR5 1	ARR4 1	ARR3 1	ARR2 1	ARR1 1	ARR0 1

Table 40. TIM6 register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	TIM6_CR1 Reset Value	ARPE 0	- 0	- 0	- 0	OPM 0	URS 0	UDIS 0	CEN 0
0x01	TIM6_CR2 Reset Value	- 0	MMS2 0	MMS1 0	MMS0 0	- 0	- 0	- 0	- 0
0x02	TIM6_SMCR Reset Value	MSM 0	TS2 0	TS1 0	TS0 0	- 0	SMS2 0	SMS1 0	SMS0 0
0x03	TIM6_IER Reset Value	- 0	TIE 0	- 0	- 0	- 0	- 0	- 0	UIE 0
0x04	TIM6_SR1 Reset Value	- 0	TIF 0	- 0	- 0	- 0	- 0	- 0	UIF 0
0x05	TIM6_EGR Reset Value	- 0	TG 0	- 0	- 0	- 0	- 0	- 0	UG 0
0x06	TIM6_CNTR	CNT7 0	CNT6 0	CNT5 0	CNT4 0	CNT3 0	CNT2 0	CNT1 0	CNT0 0
0x07	TIM6_PSCR	- 0	- 0	- 0	- 0	- 0	PSC2 0	PSC1 0	PSC0 0
0x08	TIM6_ARR	ARR7 1	ARR6 1	ARR5 1	ARR4 1	ARR3 1	ARR2 1	ARR1 1	ARR0 1

20 Serial peripheral interface (SPI)

20.1 Introduction

The Serial Peripheral Interface (SPI) allows half/ full duplex, synchronous, serial communication with external devices. The interface can be configured as the master and in this case it provides the communication clock (SCK) to the external slave device. The interface is also capable of operating in multi-master configuration.

It may be used for a variety of purposes, including simplex synchronous transfers on 2 lines with a possible bi-directional data line or reliable communication using CRC checking.

20.2 SPI main features

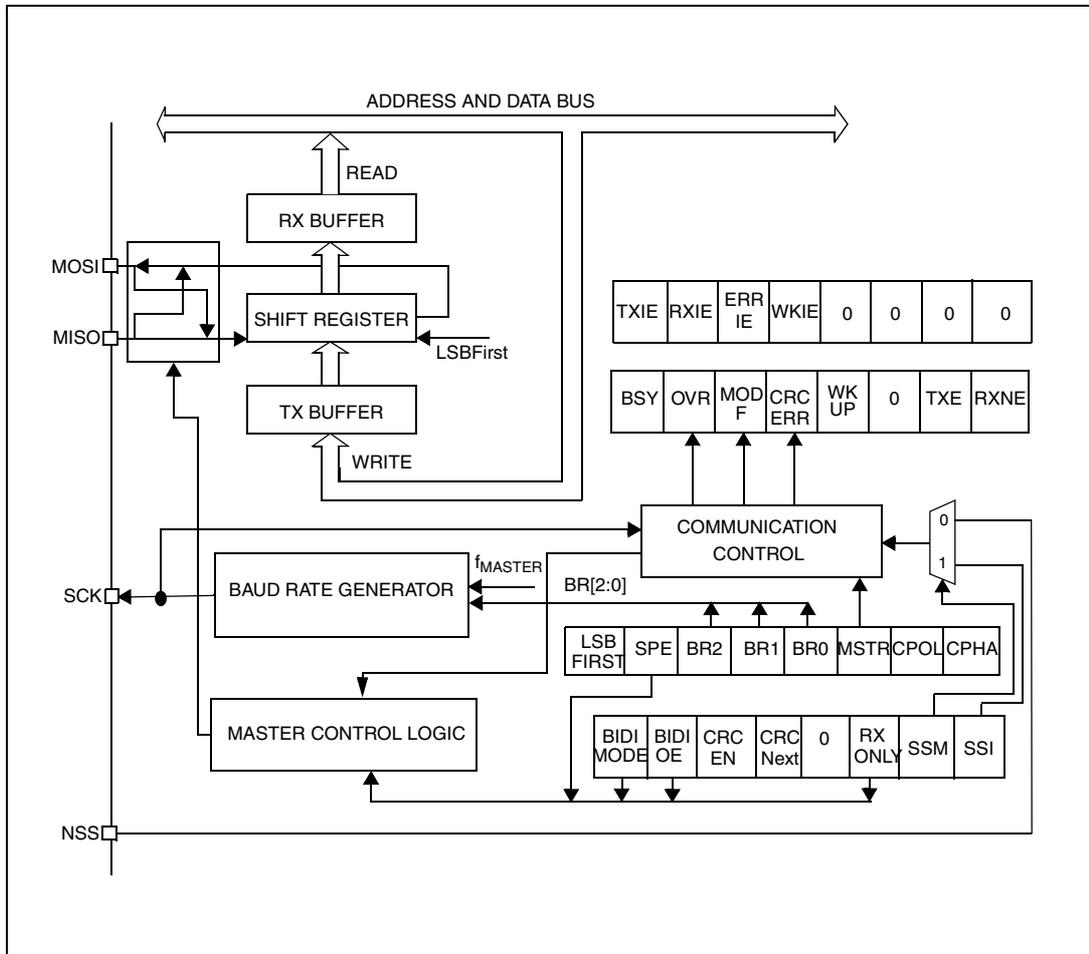
- Full duplex synchronous transfers (on 3 lines)
- Simplex synchronous transfers on 2 lines with or without a bi-directional data line
- Master or slave operation
- 8 Master mode frequencies ($f_{\text{MASTER}}/2$ max.)
- Slave mode frequency ($f_{\text{MASTER}}/2$ max.)
- Faster communication - Maximum SPI speed: 10 MHz
- NSS management by hardware or software for both master and slave
- Programmable clock polarity and phase
- Programmable data order with MSB-first or LSB-first shifting
- Dedicated transmission and reception flags with interrupt capability
- SPI bus busy status flag
- Master mode fault and overrun flags with interrupt capability
- Hardware CRC feature for reliable communication:
 - CRC value can be transmitted as last byte in Tx mode
 - CRC error checking for last received byte
- Wake-up capability:
The MCU wakes up from low power mode in full or half duplex transmit-only modes

20.3 SPI functional description

20.3.1 General description

The block diagram of the SPI is shown in [Figure 88](#).

Figure 88. SPI block diagram



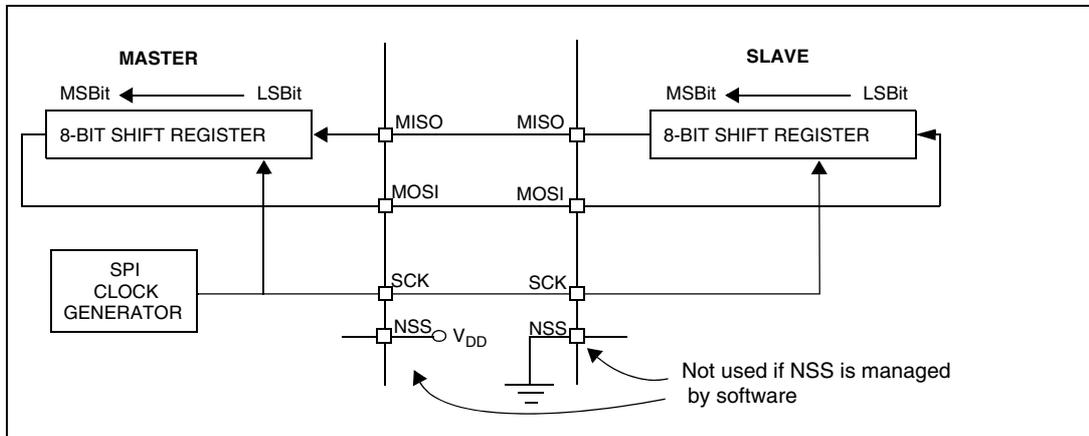
The SPI is connected to external devices through 4 pins:

- **MISO:** Master In / Slave Out data (port C7). This pin can be used to transmit data in slave mode and receive data in master mode.
- **MOSI:** Master Out / Slave In data (port C6). This pin can be used to transmit data in master mode and receive data in slave mode.
- **SCK:** Serial Clock output (port C5) for SPI masters and Serial Clock input for SPI slaves.
- **NSS:** Slave select (port E5). This is an optional pin to select master/ slave mode. This pin acts as a 'chip select' to let the SPI master communicate with slaves individually and to avoid contention on the data lines. Slave NSS inputs can be driven by standard I/O ports on the master Device.

A basic example of interconnections between a single master and a single slave is illustrated in [Figure 89](#).

Note: When using the SPI in high speed mode, the I/Os where SPI outputs are connected should be programmed as fast slope outputs in order to be able to reach the expected bus speed.

Figure 89. Single master/ single slave application



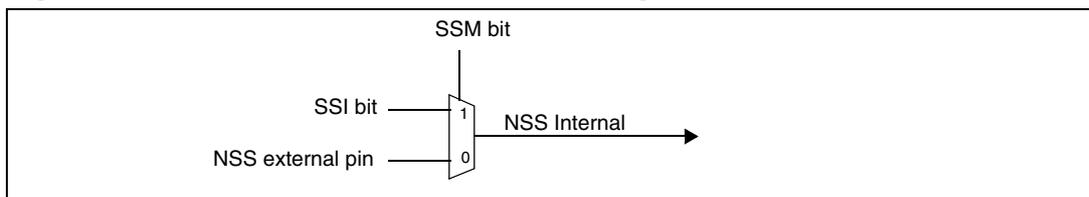
The MOSI pins are connected together and the MISO pins are connected together. In this way data is transferred serially between master and slave (most significant bit first).

The communication is always initiated by the master. When the master device transmits data to a slave device via MOSI pin, the slave device responds the MISO pin. This implies full duplex communication with both data out and data in synchronized with the same clock signal (which is provided by the master device via the SCK pin).

Slave select (NSS) pin management

As an alternative to using the NSS pin to control the Slave Select signal (NSS pin, port E5), the application can choose to manage the Slave Select signal by software. This is configured by the SSM bit in the SPI_CSR register (see [Figure 90](#)). In software management, the external NSS pin is free for other application uses and the internal NSS signal level is driven by writing to the SSI bit in the SPI_CSR register.

Figure 90. Hardware/software slave select management



Clock phase and clock polarity

Four possible timing relationships may be chosen by software, using the CPOL and CPHA bits. The CPOL (clock polarity) bit controls the steady state value of the clock when no data is being transferred. This bit affects both master and slave modes. If CPOL is reset, SCK pin has a low level idle state. If CPOL is set, SCK pin has a high level idle state.

Note: Make sure the SPI pin is configured at the idle state level of the SPI in order to avoid generating an edge on the SPI clock pin when enabling or disabling the SPI cell.

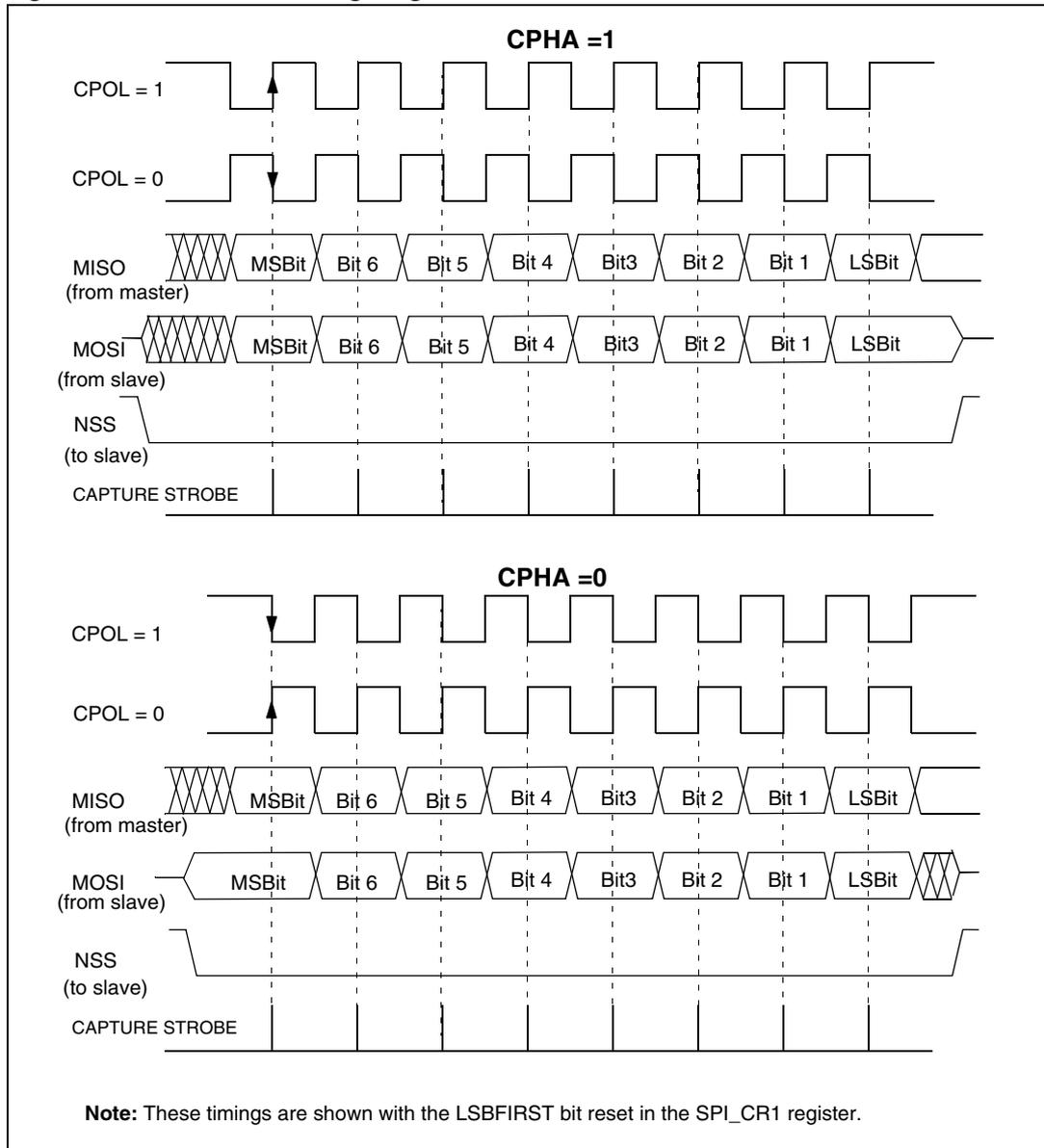
If CPHA (clock phase) bit is set, the second edge on the SCK pin (falling edge if the CPOL bit is reset, rising edge if the CPOL bit is set) is the MSBit capture strobe. Data is latched on the occurrence of the first clock transition. If CPHA bit is reset, the first edge on the SCK pin (falling edge if CPOL bit is set, rising edge if CPOL bit is reset) is the MSBit capture strobe. Data is latched on the occurrence of the second clock transition.

The combination of the CPOL clock polarity and CPHA (clock phase) bits selects the data capture clock edge.

Figure 91, shows an SPI transfer with the four combinations of the CPHA and CPOL bits. The diagram may be interpreted as a master or slave timing diagram where the SCK pin, the MISO pin, the MOSI pin are directly connected between the master and the slave device.

- Note:*
- 1 *Prior to changing the CPOL/CPHA bits the SPI must be disabled by resetting the SPE bit.*
 - 2 *Master and slave must be programmed with the same timing mode.*
 - 3 *The idle state of SCK must correspond to the polarity selected in the SPI_CR1 register (by pulling up SCK if CPOL=1 or pulling down SCK if CPOL=0).*

Figure 91. Data clock timing diagram



Frame format

Data can be shifted out either MSB-first or LSB-first depending on the value of the LSBFIRST bit in the SPI_CR1 Register.

20.3.2 SPI slave mode

In slave configuration, the serial clock is received on the SCK pin from the master device. The value set in the BR[2:0] bits in the SPI_CR1 register, does not affect the data transfer rate.

Procedure

1. Select the CPOL and CPHA bits to define one of the four relationships between the data transfer and the serial clock (see [Figure 91](#)). For correct data transfer, the CPOL and CPHA bits must be configured the same way in the slave device and the master device.
2. The frame format (MSB-first or LSB-first depending on the value of the LSBFIRST bit in the SPI_CR1 register) must be same as the master device.
3. In Hardware mode (refer to [Slave select \(NSS\) pin management on page 256](#)), the NSS pin must be connected to a low level signal during the complete byte transmit sequence. In Software mode, set the SSM bit and clear the SSI bit in the SPI_CR2 register.
4. Clear the MSTR bit and set the SPE bit to assign the pins to alternate function.

In this configuration the MOSI pin is a data input and the MISO pin is a data output.

Transmit sequence

The data byte is parallel loaded into the Tx buffer during a write cycle.

The transmit sequence begins when the slave device receives the clock signal and the most significant bit of the data on its MOSI pin. The remaining 7-bits are loaded into the shift-register. The TXE flag will be set on the transfer of data from the Tx Buffer to the shift register and an interrupt will be generated if TXIE bit in the SPI_ICR register is set.

When data transfer is complete:

- The Data in shift register is transferred to Rx Buffer and RXNE flag is set
- An Interrupt is generated if the RXIE bit is set.

After the last sampling clock edge the RXNE bit is set, a copy of the data byte received in the shift register is moved to the Rx buffer. When the SPI_DR register is read, the SPI peripheral returns this buffered value.

Clearing of the RXNE bit is performed by reading the SPI_DR register.

20.3.3 SPI master mode

In a master configuration, the serial clock is generated on the SCK pin.

Procedure

1. Select the BR[2:0] bits to define the serial clock baud rate (see SPI_CR1 register).
2. Select the CPOL and CPHA bits to define one of the four relationships between the data transfer and the serial clock (see [Figure 91](#)).
3. Configure the LSBFIRST bit in the SPI_CR1 register to define the Frame Format
4. In Hardware mode, connect the NSS pin to a high level signal during the complete byte transmit sequence. In software mode, set the SSM and SSI bits in the SPI_CR2 register.
5. The MSTR and SPE bits must be set (they remain set only if the NSS pin is connected to a high level signal).

In this configuration the MOSI pin is a data output and to the MISO pin is a data input.

Transmit sequence

The transmit sequence begins when a byte is written in the Tx Buffer.

The data byte is parallel loaded into the 8-bit shift register (from the internal bus) during first bit transmission and then shifted out serially to the MOSI pin MSB first or LSB first depending on the LSBFIRST bit in the SPI_CR1 register. The TXE flag will be set on the transfer of data from the Tx Buffer to the shift register and an interrupt will be generated if TXIE bit in the SPI_ICR register is set.

When data transfer is complete

- The data in shift register is transferred to RX Buffer and the RXNE flag is set
- An Interrupt is generated if the RXIE bit is set in the SPI_ICR register

At the last sampling clock edge the RXNE bit is set, a copy of the data byte received in the shift register is moved to the Rx buffer. When the SPI_DR register is read, the SPI peripheral returns this buffered value.

Clearing the RXNE bit is performed by reading the SPI_DR register.

A continuous transmit stream can be maintained if the next data to be transmitted is put in the Tx buffer once the transmission is started. Note that TXE flag should be '1' before an attempt to write the Tx buffer.

20.3.4 Simplex communication

The SPI is capable of operating in simplex mode in 2 configurations.

- 1 clock and 1 bi-directional data wire
- 1 clock and 1 data wire (Rx-only or full duplex)

1 Clock and 1 bi-directional data wire

This mode is enabled by setting the BDM bit in the SPI_CR2 register. In this mode SCK is used for the clock and MOSI in master or MISO in slave mode is used for data communication. The transfer direction (Input/Output) is selected by the BDOE bit in the SPI_CR2 register. When this bit is 1, the data line is output otherwise it is input.

1 Clock and 1 data wire (Rx-only or full duplex)

In order to free an I/O pin so it can be used for other purposes, you can disable the SPI output function by setting the RXONLY bit in the SPI_CR2 register. In this case, SPI will function in Receive-only mode. When the RXONLY bit is reset, the SPI will function in full duplex mode.

Receive-only mode

To start the communication in receive-only mode, you have to configure and enable the SPI.

- In master mode, the communication starts immediately and stops when the SPE bit is reset and the current reception terminates. There is no need to read the BUSY flag in this mode. It is always set, as communication is ongoing and bus is busy until the SPE bit is reset.
- In slave mode, the SPI will continue to receive as long as the NSS is pulled down (or the SSI bit is reset) and the SCK is running.

Note: The SPI can be used in Tx-only mode when the *RXONLY* bit in the *SPI_CR2* register is reset, the *RX* pin (*MISO* in master or *MOSI* in slave) can be used as *GPIO*. In this case, when the data register is read, it does not contain the received value.

20.3.5 Status flags

There are three status flags to allow the application to completely monitor the state of the SPI bus.

Busy flag

This flag indicates the state of the communication layer of the SPI. When it is set, it indicates that the SPI is busy communicating and/or there is a valid data byte in the Tx buffer waiting to be transmitted. The purpose of this flag is to indicate if there is any communication ongoing on the SPI bus or not. This flag will be set as soon as:

1. Data is written in the *SPI_DR* register in master mode
2. The *SCK* clock is present in slave mode

The *BUSY* flag will reset as soon as a byte is transmitted/ received. This flag is set and reset by hardware. You can monitor this flag to avoid write collision errors. Writing to this flag has no effect. This flag is has meaning only when the *SPE* bit is set.

Tx buffer empty flag (TXE)

This flag when set indicates that the Tx buffer is empty and the next data to be transmitted can be loaded into the buffer. The *TXE* flag is reset when the Tx buffer already has a data which is to be transmitted. This flag is reset when the SPI is disabled (*SPE* bit is reset).

Rx buffer not empty (RXNE)

This flag when set indicates that there is a valid received data in the Rx Buffer. This flag is reset when SPI Data register is read.

20.3.6 CRC calculation

A CRC calculator has been implemented for communication reliability. Separate CRC calculators are implemented for transmitted data and received data. The CRC is calculated using a programmable polynomial serially on each bit. The CRC is calculated on the sampling clock edge defined by the *CPHA* and *CPOL* bits in the *SPI_CR1* register.

CRC calculation is enabled by setting the *CRCEN* bit in the *SPI_CR1* register. This action resets the CRC registers (*SPI_RXCRCR* and *SPI_TXCRCR*). When the *CRCNEXT* bit in *SPI_CR2* is set, the *SPI_TXCRCR* value is transmitted at the end of the current byte transmission.

If a byte is present in the Tx buffer, the CRC value is transmitted only after the transmission of this byte. During the transmission of CRC, the CRC calculator is switched off and the register value remains unchanged.

The *CRCERR* flag in the *SPI_SR* register is set if the value received in the shift register during the *SPI_TXCRCR* value transmission does not match the *SPI_RXCRCR* value.

SPI communication using CRC is possible through the following procedure:

- Program the CPOL, CPHA, LSBfirst, BR, SSM, SSI and MSTR values.
- Program the polynomial in the SPI_CRCPR register
- Enable the CRC calculation by setting the CRCEN bit in the SPI_CR1 register. This also clears the SPI_RXCRCR and SPI_TXCRCR registers
- Enable the SPI by setting the SPE bit in SPI_CR1
- Start the communication and sustain the communication until all but one byte has been transmitted or received.
- On writing the last byte to the Txbuffer, set the CRCNext bit in the SPI_CR2 register to indicate that after transmission of the last byte, the CRC should be transmitted. The CRC calculation will be frozen during the CRC transmission.
- After transmitting the last byte, the SPI transmits the CRC. CRCNext bit is reset. The CRC is also received and compared against the SPI_RXCRCR value. If the value does not match, the CRCERR flag in SPI_SR is set and an interrupt can be generated when the ERRIE in the SPI_ICR register is set.

Note: With high bit rate frequencies, the user must take care when transmitting CRC. As the number of used CPU cycles has to be as low as possible in the CRC transfer phase, the calling of software functions in the CRC transmission sequence is forbidden to avoid errors in the last data and CRC reception.

20.3.7 Error flags

Master mode fault (MODF)

Master mode fault occurs when the master device has its NSS pin pulled low (in hardware mode) or SSI bit low (in software mode), this automatically sets the MODF bit. Master mode fault affects the SPI peripheral in the following ways:

- The MODF bit is set and an SPI interrupt is generated if the ERRIE bit is set.
- The SPE bit is reset. This blocks all output from the device and disables the SPI interface.
- The MSTR bit is reset, thus forcing the device into slave mode.

Use the following software sequence to clear the MODF bit:

1. Make a read or write access to the SPI_SR register while the MODF bit is set.
2. Then write to the SPI_CR1 register.

To avoid any multiple slave conflicts in a system comprising several MCUs, the NSS pin must be pulled high during the MODF bit clearing sequence. The SPE and MSTR bits can be restored to their original state during or after this clearing sequence.

As a security, hardware does not allow you to set the SPE and MSTR bits while the MODF bit is set.

In a slave device the MODF bit cannot be set. However, in a multi-master configuration, the device can be in slave mode with this MODF bit set. In this case, the MODF bit indicates that there might have been a multi-master conflict for system control. You can use an interrupt routine to recover cleanly from this state by performing a reset or returning to a default state.

Overrun condition

An overrun condition occurs, when the master device has sent data bytes and the slave device has not cleared the RXNE bit resulting from the previous data byte transmitted. When an overrun condition occurs:

- OVR bit is set and an interrupt is generated if the ERRIE bit is set.

In this case, the receiver buffer contents will not be updated with the newly received data from the master device. A read to the SPI_DR register returns this byte. All other subsequently transmitted bytes are lost.

Clearing the OVR bit is done by a read access to the SPI_SR register.

CRC error

This flag is used to verify the correctness of the value received when the CRCEN bit in the SPI_CR2 register is set. The CRCERR flag in the SPI_SR register is set if the value received in the shift register after the SPI_TXCRCR value transmission does not match the SPI_RXCRCR value. Refer to [Chapter 20.3.6: CRC calculation](#).

20.3.8 Disabling the SPI

When transfer is terminated, the application can stop the communication by disabling the SPI peripheral. This is done by resetting the SPE bit. Disabling the SPI peripheral while the last data transfer is still ongoing does not affect the data reliability if the device is *not* in Master transmit mode.

Note: In Master transmit mode (full duplex or simplex transmit-only), the application must make sure that no data transfer is ongoing by checking the BSY flag in the SPI_SR register before disabling the SPI master.

20.3.9 SPI low power modes

Table 41. SPI behavior in low power modes

Mode	Description
Wait	No effect on SPI. SPI interrupt events cause the device to exit from Wait mode.
Halt	SPI registers are frozen. In Halt mode, the SPI is inactive. If the SPI is in master mode, then communication resumes when the device is woken up by an interrupt with “wake-up from Halt mode” capability. If the SPI is in slave mode, then it can wake up the MCU from Halt mode after detecting the first sampling edge of data.

Using the SPI to wake up the device from Halt mode

- Full duplex and half duplex transmit-only modes

When the microcontroller is in Halt mode, the SPI is still capable of responding as a slave provided the NSS pin is tied low or the SSI bit is reset before entering Halt mode.

When the first sampling edge of data (as defined by the CPHA bit) is detected:

- The WKUP bit is set in the SPI_SR register
- An interrupt is generated if the WKIE bit in the SPI_ICR register is set.
- This interrupt wakes-up the device from Halt mode.
- Due to the time needed to restore the system clock, the SPI slave sends or receives a few data before being able to communicate correctly. It is then mandatory to use the following protocol:
 - a specific value is written into the SPI_DR before entering Halt mode. This value indicates to the external master that the SPI is in Halt mode
 - The external master sends the same byte continuously until it receives from the SPI slave device a new value other than the unique value indicating the SPI is in Halt mode. This new value indicates the SPI slave has woken-up and can correctly communicate.

- Half duplex receive-only mode

The wake-up functionality is not guaranteed in this half duplex receive-only mode since the time needed to restore the system clock can be greater than the data reception time. A loss of data in reception would then be induced.

20.3.10 SPI interrupts

Table 42. SPI interrupt requests

Interrupt event	Event flag	Enable control bit	Exit from Wait	Exit from Halt
Transmit buffer empty flag	TXE	TXIE	Yes	No
Receive buffer not empty flag	RXNE	RXIE	Yes	No
Wake-up event flag	WKUP	WKIE	Yes	Yes
Master mode fault event	MODF	ERRIE	Yes	No
Overrun error	OVR		Yes	No
CRC error flag	CRCERR		Yes	No

20.4 SPI registers

20.4.1 SPI control register 1 (SPI_CR1)

Address offset: 0x00

Reset Value: 0x00

7	6	5	4	3	2	1	0
LSBFIRST	SPE	BR [2:0]			MSTR	CPOL	CPHA
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **LSBFIRST**: Frame format ⁽¹⁾

- 0: MSB is transmitted first
- 1: LSB is transmitted first

Bit 6 **SPE**: SPI Enable ⁽¹⁾

- 0: Peripheral disabled
- 1: Peripheral enabled

Bits 5:3 **BR[2:0]**: Baud rate control

- 000: $f_{\text{MASTER}}/2$
- 001: $f_{\text{MASTER}}/4$
- 010: $f_{\text{MASTER}}/8$
- 011: $f_{\text{MASTER}}/16$
- 100: $f_{\text{MASTER}}/32$
- 101: $f_{\text{MASTER}}/64$
- 110: $f_{\text{MASTER}}/128$
- 111: $f_{\text{MASTER}}/256$

Note: These bits should not be changed when the communication is ongoing.

Bit 2 **MSTR**: Master selection ⁽¹⁾

- 0: Slave configuration
- 1: Master configuration

Bit 1 **CPOL**: Clock polarity ⁽¹⁾

- 0: SCK to 0 when idle
- 1: SCK to 1 when idle

Bit 0 **CPHA**: Clock phase ⁽¹⁾

- 0: The first clock transition is the first data capture edge
- 1: The second clock transition is the first data capture edge

1. This bit should not be changed when the communication is ongoing.

20.4.2 SPI control register 2 (SPI_CR2)

Address offset: 0x01

Reset Value: 0x00

7	6	5	4	3	2	1	0
BDM	BDOE	CRCEN	CRCNEXT	Reserved	RXOnly	SSM	SSI
rw	rw	rw	rw		rw	rw	rw

- Bit 7 **BDM**: Bi-directional data mode enable
 - 0: 2-line uni-directional data mode selected
 - 1: 1-line bi-directional data mode selected
- Bit 6 **BDOE**: Input/Output enable in bi-directional mode
 - This bit selects the direction of transfer in bi-directional mode when BDM is set to 1.
 - 0: Input enabled (receive-only mode)
 - 1: Output enabled (transmit-only mode)
 - In master mode, the MOSI pin is used and in slave mode, the MISO pin is used.
- Bit 5 **CRCEN**: Hardware CRC calculation enable
 - 0: CRC calculation disabled
 - 1: CRC calculation Enabled

Note: This bit should be written only when SPI is disabled (SPE = '0') for correct operation
- Bit 4 **CRCNEXT**: Transmit CRC next
 - 0: Next transmit value is from Tx buffer
 - 1: Next transmit value is from Tx CRC register
- Bit 3 Reserved, must be kept cleared.
- Bit 2 **RXONLY**: Receive only
 - 0: Full duplex (Transmit and receive)
 - 1: Output disabled (Receive only mode)
 - This bit combined with BDM bit selects the direction of transfer in 2 line uni-directional mode
 - This bit is also useful in a multi-slave system in which this particular slave is not accessed, the output from the accessed slave is not corrupted.
- Bit 1 **SSM**: Software slave management
 - 0: Software slave management disabled
 - 1: Software slave management enabled
 - When the SSM bit is set, the NSS pin input is replaced with the value coming from the SSI bit
- Bit 0 **SSI**: Internal slave select
 - This bit has effect only when SSM bit is set. The value of this bit is forced onto the NSS pin and the I/O value of the NSS pin is ignored.
 - 0: Slave mode
 - 1: Master mode

20.4.3 SPI interrupt control register (SPI_ICR)

Address offset: 0x02

Reset Value: 0x00

7	6	5	4	3	2	1	0
TXIE	RXIE	ERRIE	WKIE	Reserved			
rw	rw	rw	rw				

Bit 7 **TXIE**: Tx buffer empty interrupt enable

0: TXE interrupt masked

1: TXE interrupt not masked. This allows a interrupt request to be generated when the TXE flag is set.

Note: To function correctly, the TXIE bit should not be set at the same time.

Bit 6 **RXIE**: RX buffer not empty interrupt enable

0: RXNE interrupt masked

1: RXNE interrupt not masked. This allows a interrupt request to be generated when the RXNE flag is set.

Note: To function correctly, the RXIE bit should not be set at the same time.

Bit 5 **ERRIE**: Error interrupt enable

0: Error interrupt is masked

1: Error interrupt is enabled. This allows a interrupt request to be generated when an error condition occurs (CRCERR, OVR, MODF)

Bit 4 **WKIE**: Wakeup interrupt enable

0: wakeup interrupt masked

1: wakeup interrupt enabled. This allows a interrupt request to be generated when the WKUP flag is set.

Bits 3:0 Reserved, must be kept cleared.

20.4.4 SPI status register (SPI_SR)

Address offset: 0x03

Reset value: 0x02

7	6	5	4	3	2	1	0
BSY	OVR	MODF	CRCERR	WKUP	Reserved	TXE	RxNE
r	rc_w0	rc_w0	rc_w0	rc_w0	r	r	r

Bit 7 **BSY**: Busy flag

0: SPI not busy

1: SPI is busy in communication or Tx buffer is not empty

This flag is set and reset by hardware.

Note: In master receiver only mode (1-line bidirectional), checking the BSY Flag is forbidden.

Bit 6 **OVR**: Overrun flag

0: No Overrun occurred

1: Overrun occurred

This flag is set by hardware and reset by a software sequence.

Bit 5 **MODF**: Mode fault

0: No Mode fault occurred

1: Mode fault occurred

This flag is set by hardware and reset by a software sequence.

Bit 4 **CRCERR**: CRC error flag

0: CRC value received matches the SPI_RXCRCR value

1: CRC value received does not match the SPI_RXCRCR value

This flag is set by hardware and cleared by software writing 0.

Bit 3 **WKUP**: Wake-up Flag

0: No wake-up event occurred

1: wake-up event occurred

This flag is set on the first sampling edge on SCK when the STM8 is in Halt mode and the SPI is configured as slave.

This flag is reset by software writing 0.

Bit 2 Reserved, must be kept cleared.

Bit 1 **TXE**: Transmit buffer empty

0: Tx buffer not empty

1: Tx buffer empty

Bit 0 **RxNE**: Receive buffer not empty

0: Rx buffer empty

1: Rx buffer not empty

20.4.5 SPI data register (SPI_DR)

Address offset: 0x04

Reset value: 0x00

7	6	5	4	3	2	1	0
DR[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **DR[7:0]**: Data register

Byte received or to be transmitted.

The data register is split into 2 buffers - one for writing (Transmit buffer) and another one for reading (Receive buffer). A write to the data register will write into the Tx buffer and a read from the data register will return the value held in the Rx buffer.

20.4.6 SPI CRC polynomial register (SPI_CRCPR)

Address Offset: 0x05

Reset Value: 0x07

7	6	5	4	3	2	1	0
CRCPOLY[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CRCPOLY[7:0]**: CRC polynomial register

This register contains the polynomial for the CRC calculation.

The CRC polynomial (0x07) is the reset value of this register. You can configure an other polynomial as required for your application.

20.4.7 SPI Rx CRC register (SPI_RXCRCR)

Address offset: 0x06

Reset Value: 0x00

7	6	5	4	3	2	1	0
RxCRC[7:0]							
r	r	r	r	r	r	r	r

Bits 7:0 **RxCRC[7:0]**: Rx CRC Register

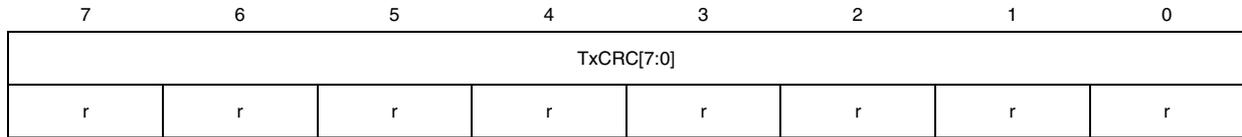
When CRC calculation is enabled, the RxCRC[7:0] bits contain the computed CRC value of the subsequently received bytes. This register is reset when the CRCEN bit in SPI_CR2 register is written to 1. The CRC is calculated serially using the polynomial programmed in the SPI_CRCPR register.

Note: A read to this register when the BSY Flag is set could return an incorrect value.

20.4.8 SPI Tx CRC register (SPI_TXCRCR)

Address offset: 0x07

Reset value: 0x00



Bits 7:0 **TxCRC[7:0]**: Tx CRC register

When CRC calculation is enabled, the TxCRC[7:0] bits contain the computed CRC value of the subsequently transmitted bytes. This register is reset when the CRCEN bit of SPI_CR2 is written to 1. The CRC is calculated serially using the polynomial programmed in the SPI_CRCPR register.

Note: A read to this register when the BSY flag is set could return a incorrect value

20.5 SPI register map and reset values

Table 43. SPI register map and reset values

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	SPI_CR1 Reset Value	LSBFirst 0	SPE 0	BR2 0	BR1 0	BR1 0	MSTR 0	CPOL 0	CPHA 0
0x01	SPI_CR2 Reset Value	BDM 0	BDOE 0	CRCEN 0	CRCNEXT 0	Reserved 0	RXONLY 0	SSM 0	SSI 0
0x02	SPI_ICR Reset Value	TXIE 0	RXIE 0	ERRIE 0	WKIE 0	Reserved 0	Reserved 0	Reserved 0	Reserved 0
0x03	SPI_SR Reset Value	BSY 0	OVR 0	MODF 0	CRCERR 0	WKUP 0	Reserved 0	TXE 1	RXNE 0
0x04	SPI_DR Reset Value	MSB 0	- 0	- 0	- 0	- 0	- 0	- 0	LSB 0
0x05	SPI_CRCPR Reset Value	MSB 0	- 0	- 0	- 0	- 0	- 1	- 1	LSB 1
0x06	SPI_RXCR Reset Value	MSB 0	- 0	- 0	- 0	- 0	- 0	- 0	LSB 0
0x07	SPI_TXCR Reset Value	MSB 0	- 0	- 0	- 0	- 0	- 0	- 0	LSB 0

21 Inter-integrated circuit (I²C) Interface

21.1 Introduction

I²C (Inter-Integrated Circuit) Bus Interface serves as an interface between the microcontroller and the serial I²C bus. It provides multi-master capability, and controls all I2C bus-specific sequencing, protocol, arbitration and timing. It supports standard and fast speed modes.

21.2 I²C main features

- Parallel-bus/I²C protocol converter
- Multi-master 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
 - 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)
- Status flags:
 - Transmitter/Receiver mode flag
 - End-of-Byte transmission flag
 - I²C busy flag
- Error flags:
 - Arbitration lost condition for master mode
 - Acknowledgement failure after address/ data transmission
 - Detection of misplaced start or stop condition
 - Overrun/Underrun if clock stretching is disabled
- 3 types of interrupts:
 - 1 Communication interrupt
 - 1 Error condition interrupt
 - 1 Wakeup from Halt interrupt
- Wakeup capability:
 - MCU wakes up from low power mode on address detection in slave mode.
- Optional clock stretching

21.3 I²C general 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.

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 Multi-Master capability.

Communication flow

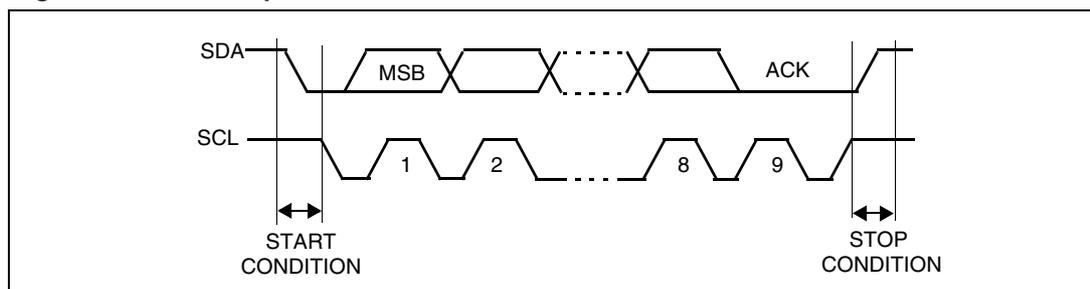
In Master mode, the I²C interface initiates a data transfer and generates the clock signal. A serial data transfer always begins with a start condition and ends with a stop condition. Both start and stop conditions are generated in master mode by software.

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 the following figure.

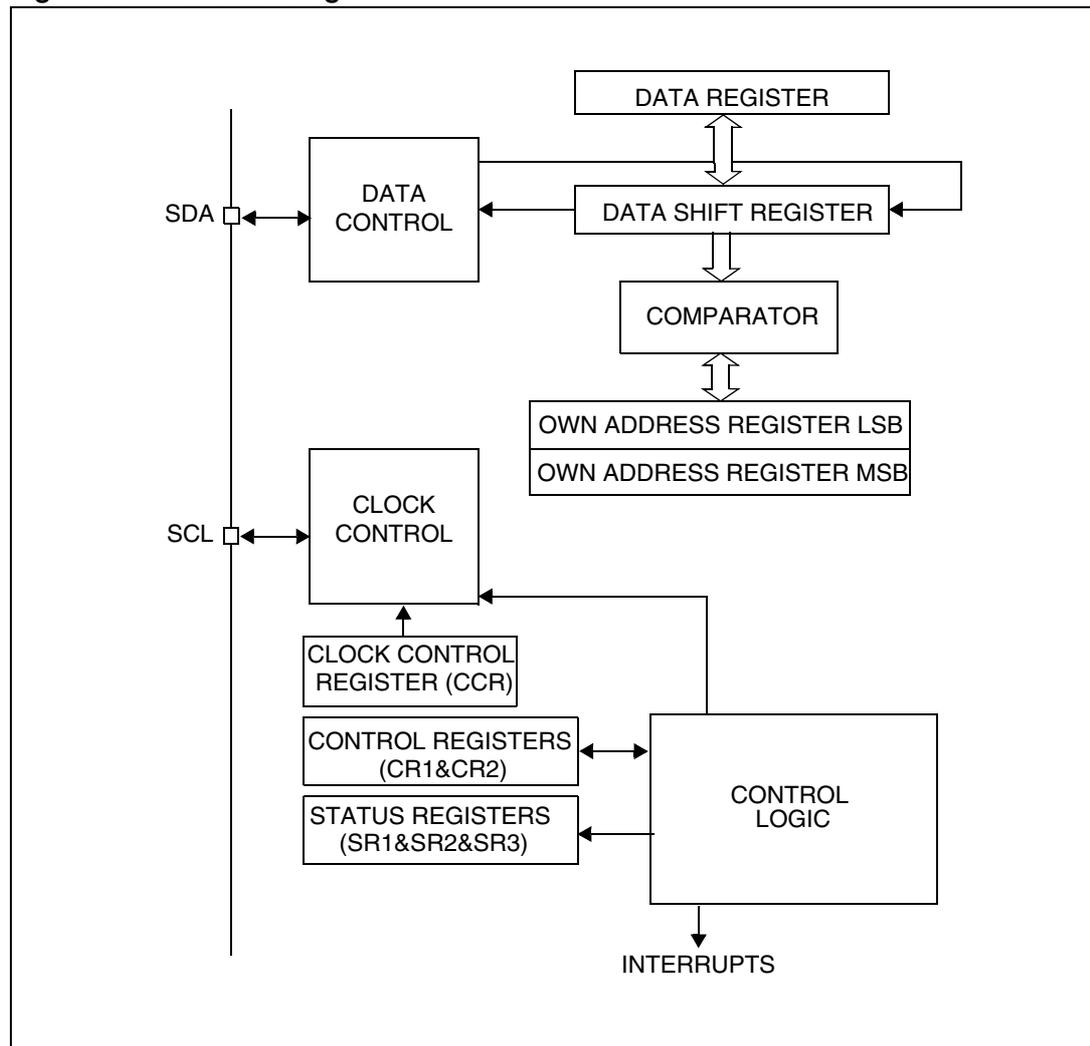
Figure 92. I²C bus protocol



Acknowledge may be enabled or disabled by software. The I²C interface addresses (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 93](#).

Figure 93. I²C block diagram



21.4 I²C functional description

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

21.4.1 I²C slave mode

The peripheral input clock must be programmed in the I2C_FREQR register in order to generate correct timings. The peripheral input clock frequency must be at least:

- 1 MHz in Standard mode
- 4 MHz in Fast 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 (OARLSB) and with OAR2 or the General Call address (if ENGC = 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 ITEVTEN bit is set.

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.

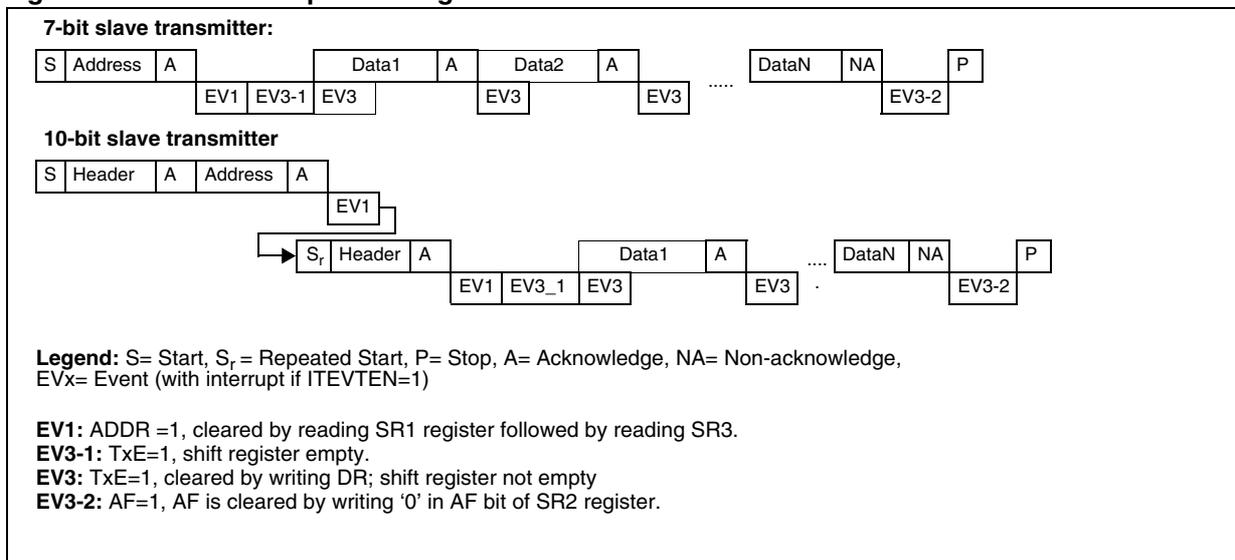
The slave stretches SCL low until ADDR is cleared and DR filled with the data to be sent (see [Figure 94](#) Transfer sequencing EV1 EV3).

When the acknowledge pulse is received:

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

If TxE is set and a data was not written in the DR register before the end of the next data transmission, the BTF bit is set and the interface waits for a write in the DR register, stretching SCL low.

Figure 94. Transfer sequence diagram for slave transmitter



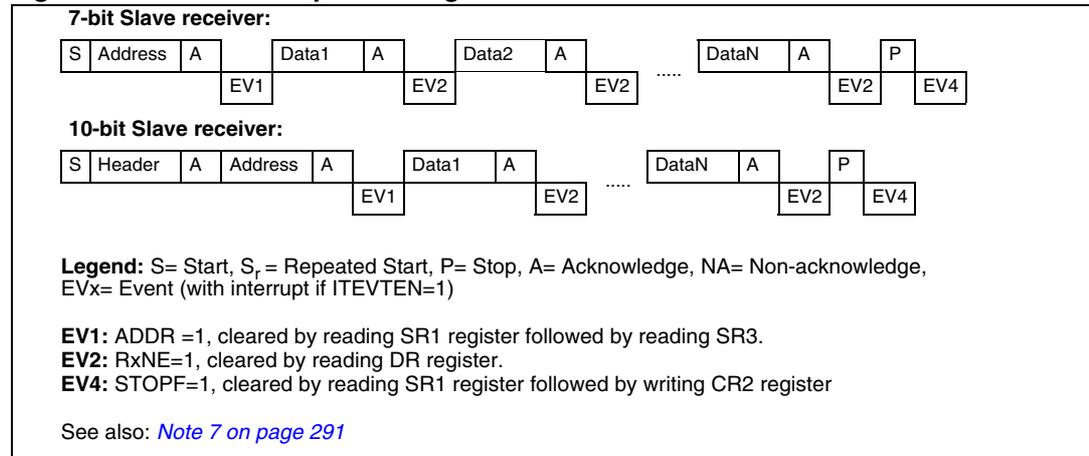
Slave receiver

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 ITEVTEN 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 for a read to the DR register, stretching SCL low (see [Figure 95](#) Transfer sequencing).

Figure 95. Transfer sequence diagram for slave receiver



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 ITEVTEN bit is set.

Then the interface waits for a read of the SR1 register followed by a write to the CR2 register (see [Figure 95](#) Transfer sequencing EV4).

21.4.2 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_FREQR 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_CR2 register to generate a Start condition

The peripheral input clock frequency must be at least:

- 1 MHz in Standard mode
- 4 MHz in Fast mode

Start condition

Setting the START bit while the BUSY bit is cleared causes the interface to generate a Start condition and switch to Master mode (M/SL bit set).

Once the Start condition is sent:

- The SB bit is set by hardware and an interrupt is generated if the ITEVTEN 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 96](#) & [Figure 97](#) 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 ITEVTEN 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 96](#) & [Figure 97](#) Transfer sequencing EV9).

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

Then the master waits for a read of the SR1 register followed by a read in the SR3 register (see [Figure 96](#) & [Figure 97](#) Transfer sequencing EV6).

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 and then the slave address with LSB reset.
 - To enter Receiver mode, a master sends the header and then the slave address with LSB reset. Then it should send 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 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 TxE is cleared, (see [Figure 96](#) Transfer sequencing EV8).

When the acknowledge pulse is received:

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

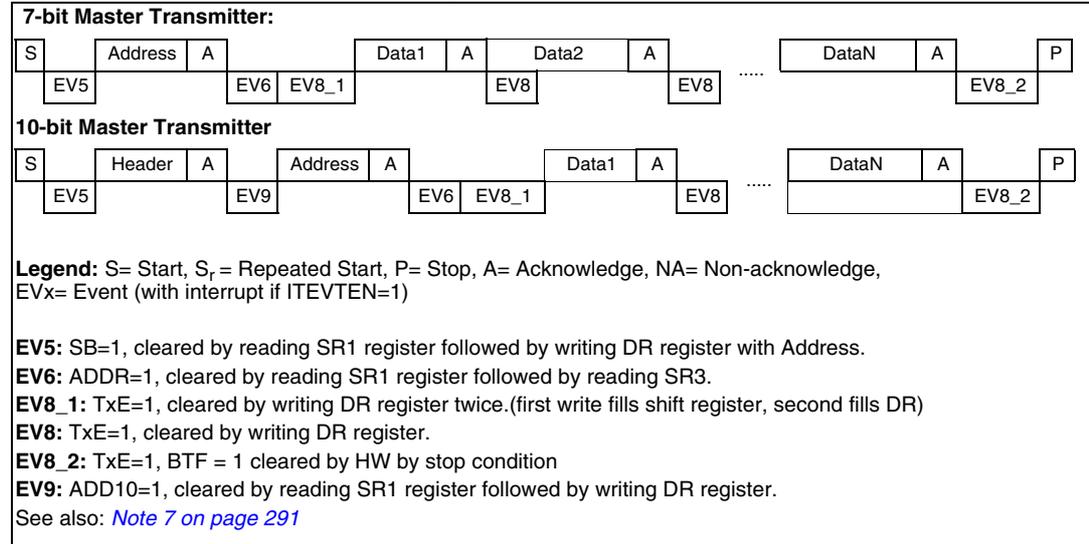
If TxE is set and a data byte was not written in the DR register before the end of the next data transmission, BTF is set and the interface waits until BTF is cleared.

Closing the communication

After writing the last byte to the DR register, the STOP bit is set by software to generate a Stop condition (see [Figure 96](#) Transfer sequencing EV8_2). The interface goes automatically back to slave mode (M/SL bit cleared).

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

Figure 96. Transfer sequence diagram for master transmitter



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:

- An acknowledge pulse if the ACK bit is set
- The RxNE bit is set and an interrupt is generated if the ITEVTEN and ITBUFEN bits are set (see [Figure 97](#) Transfer sequencing EV7).

If the RxNE bit is set and the data was not read in the DR register before the end of the next data reception, the BTF bit is set by hardware and the interface waits for a read in the DR register.

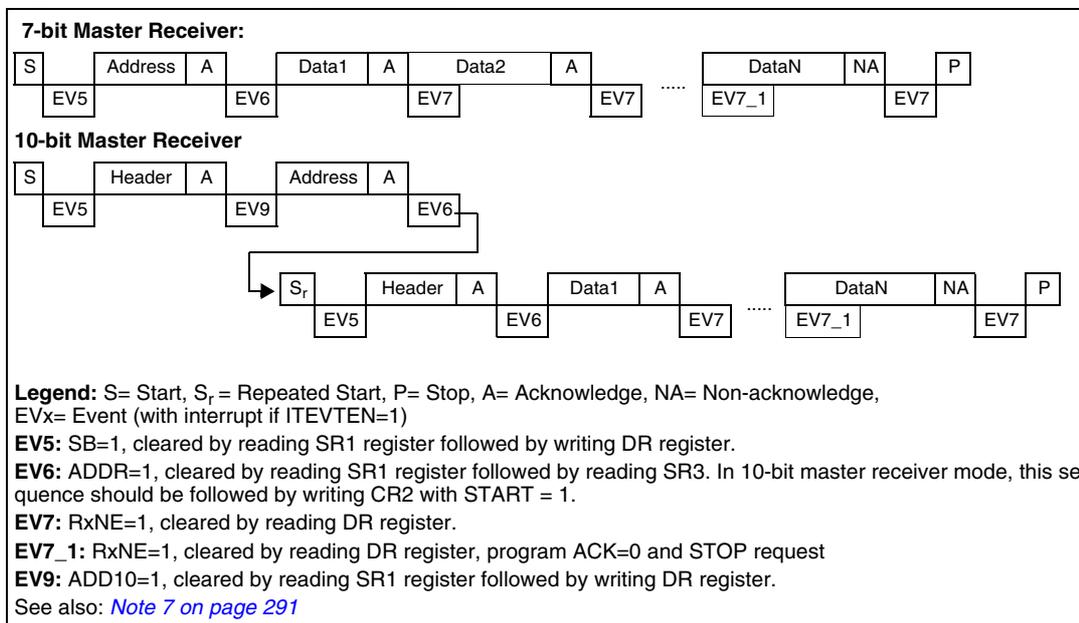
Closing the communication

The master send 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 master can send a Stop/Re-Start condition.

- In order to generate the non-acknowledge 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).
- In order to generate the Stop/Re-Start condition, software must set the STOP/ START bit just after reading the second last data byte (after the second last RxNE event).

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

Figure 97. Transfer sequence diagram for master receiver



21.4.3 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 a Stop or a Start condition during a byte transfer. In this case:

- The BERR bit is set and an interrupt is generated if the ITERREN bit is set
- In Slave mode: data is discarded and the lines are released by hardware:
 - In case of 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 acts in the same way as for a stop condition and the lines are released by hardware.
- In Master mode, a Stop condition must be generated by software.

Acknowledge failure (AF)

This error occurs when the interface detects a non-acknowledge 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 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 M/SL bit is cleared)
- 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 is discarded and that the next bytes are written within the clock low time specified in the I²C bus standard.

21.4.4 SDA/SCL line control

- If clock stretching is enabled:
 - Transmitter mode: If TxE=1 and BTF=1: the interface holds the clock line low before transmission to wait for the microcontroller to read SR1 and then 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 SR1 and then 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 TxE=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.

21.5 I²C low power modes

Table 44. I²C Interface behavior in low power modes

Mode	Description
WAIT	No effect on I ² C interface. I ² C interrupts cause the device to exit from Wait mode.
HALT	<p>In Slave mode : Communication is reset, except for configuration registers. Device is in slave mode. Wakeup from Halt interrupt is generated if ITEVTEN=1 and address matched (including allowed headers). The matched address is not acknowledged in Halt mode so the master has to send it again when the CPU is woken up to receive an acknowledge. If NOSTRETCH=0, SCLH will be stretched after acknowledge pulse in halt mode until WUFH is cleared by software; None of the flags are set by the address which wakes-up the CPU.</p> <p>In Master Mode : Communication is frozen until the CPU is woken up. Wakeup from Halt flag and interrupt are generated if ITEVTEN=1 and there is a HALT instruction.</p> <p><i>Note: it is forbidden to enter halt mode while a communication is on going.</i></p>

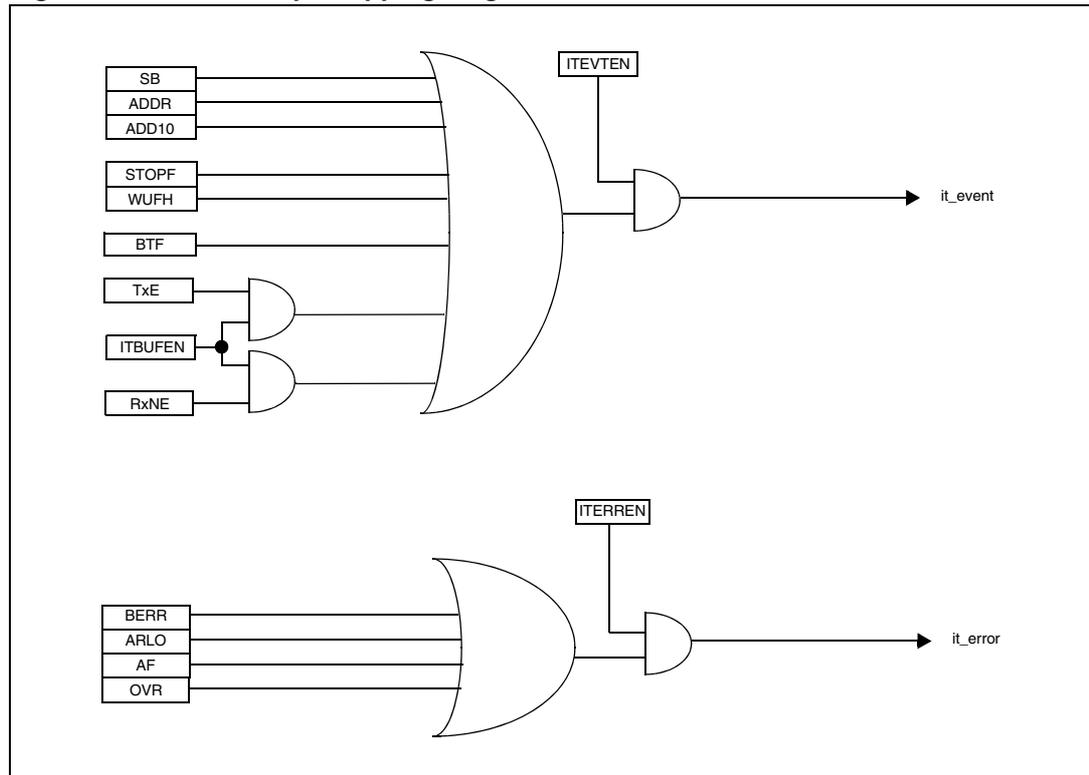
21.6 I²C interrupts

Table 45. I²C Interrupt requests

Interrupt event	Event flag	Enable control bit	Exit from Wait	Exit from Halt
Start bit sent (Master)	SB	ITEVTEN	Yes	No
Address sent (Master) or Address matched (Slave)	ADDR		Yes	No
10-bit header sent (Master)	ADD10		Yes	No
Stop received (Slave)	STOPF		Yes	No
Data Byte Transfer Finished	BTF		Yes	No
Wakeup from Halt	WUFH	ITEVTEN	Yes	Yes
Receive buffer not empty	RxNE	ITEVTEN and ITBUFEN	Yes	No
Transmit buffer empty	TxE		Yes	No
Bus error	BERR	ITERREN	Yes	No
Arbitration loss (Master)	ARLO		Yes	No
Acknowledge failure	AF		Yes	No
Overrun/Underrun	OVR		Yes	No

- Note:*
- 1 *SB, ADDR, ADD10, STOPF, BTF, RxNE and TxE are ORed on the same interrupt channel.*
 - 2 *BERR, ARLO, AF, OVR, are ORed on the same interrupt channel.*
 - 3 *WUFH uses another interrupt channel*
 - 4 *The 3 previous channels can be ORed on the same one.*

Figure 98. I²C interrupt mapping diagram



21.7 I2C registers

21.7.1 Control register 1 (I2C_CR1)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
NOSTRETCH	ENGC	Reserved					PE
rw	rw						rw

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 **ENGC**: General Call Enable

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

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

Bits 5:1 Reserved, read as 0.

Bit 0 **PE**: Peripheral Enable

0: Peripheral disable

1: Peripheral enable: the corresponding I/Os are selected as alternate functions.

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.

21.7.2 Control register 2 (I2C_CR2)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
SWRST	reserved			POS	ACK	STOP	START
rw				rw	rw	rw	rw

Bit 7 **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 state
- 1: I2C Peripheral under reset state

Note: This bit can be used in case the BUSY bit is set to '1' when no stop condition has been detected on the bus.

Bits 6:4 Reserved, read as '0'

Bit 3 **POS**: Acknowledge 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.
- 1: ACK bit controls the (N)ACK of the next byte which will be received in the shift register.

Note: This bit must be configured before data reception starts.

Bit 2 **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 1 **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.

Note: The BTF bit in the I2C_SR1 register must be cleared when the Stop request occurs.

- **In Slave mode:**

- 0: No Stop generation.
- 1: Release the SCL and SDA lines after the current byte transfer.

Bit 0 **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

21.7.3 Frequency register (I2C_FREQR)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
reserved		FREQ[5:0]					
r	r	rw	rw	rw	rw	rw	rw

Bits 7:6 Reserved, read as '0'.

Bits 5:0 **FREQ[5:0]** Peripheral Clock Frequency. ⁽¹⁾

Input clock frequency must be programmed to generate correct timings:

The allowed range is between 1 MHz and 50 MHz

000000: not allowed

000001: 1 MHz

000010: 2 MHz

...

110010: 50 MHz

Higher values: not allowed.

- The minimum peripheral clock frequencies for respecting the I²C bus timings are:
1 MHz for standard mode and 4 MHz for fast mode

21.7.4 Own address register LSB (I2C_OARL)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
ADD[7:1]							ADD0
rw	rw	rw	rw	rw	rw	rw	rw

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

21.7.5 Own address register MSB (I2C_OARH)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
ADDMODE	ADDCONF	reserved			ADD[9:8]		reserved
rw	rw	r	r	r	rw	rw	r

Bit 7 **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 6 **ADDCONF** Address mode configuration
 This bit must set by software (must always be written as '1').

Bits 5:3 Reserved, read as '0'.

Bit 2:1 **ADD[9:8]** Interface address
 10-bit addressing mode: bits9:8 of address.

Bit 0 Reserved, read as '0'.

21.7.6 Data register (I2C_DR)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
DR[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **DR[7:0]** Data Register ⁽¹⁾⁽²⁾⁽³⁾

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 (TxE=1)
- Receiver mode: Received byte is copied into DR (RxNE=1).

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

21.7.7 Status register 1 (I2C_SR1)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
TxE	RxNE	Reserved	STOPF	ADD10	BTF	ADDR	SB
r	r	r	r	r	r	r	r

Bit 7 **TxE**: Data Register Empty (transmitters) ⁽¹⁾

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.

Bit 6 **RxNE**: Data Register not Empty (receivers) ^{(2) (3)}

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.

Bit 5 Reserved, read as '0'.

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

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 CR2 register, or by hardware when PE=0

Bit 3 **ADD10**: 10-bit header sent (Master mode) ⁽⁵⁾

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.

Bit 2 **BTF**: Byte Transfer Finished ⁽⁶⁾⁽⁷⁾

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 reading SR1 followed 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.

Bit 1 **ADDR**: Address sent (master mode)/matched (slave mode) ⁽⁷⁾

This bit is cleared by software reading SR1 register followed reading SR3, 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 is recognized. (when enabled depending on configuration).

- **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) ⁽⁷⁾

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

1. The interrupt will be generated when DR is copied into shift register after an ACK pulse. If a NACK is received, copy is not done and TxE is not set.
2. The interrupt will be generated when Shift register is copied into DR after an ACK pulse.
3. RxNE is not set in case of ARLO event.
4. The STOPF bit is not set after a NACK reception
5. The ADD10 bit is not set after a NACK reception
6. The BTF bit is not set after a NACK reception, or in case of an ARLO event.
7. If $f_{\text{MASTER}} < 2 \text{ MHz}$, it is highly recommended to use interrupts to manage the communication. Otherwise, if polling is used to manage the SB, ADDR or BTF flags, 5 CPU cycles must be inserted between detecting that the flag has been set and the second action which clears it (a write to I2C_DR for SB, a write or a read to I2C_DR for BTF, a read from I2C_SR3 for ADDR) these 5 CPU cycles can be inserted by executing 5 NOPs, for example.

21.7.8 Status register 2 (I2C_SR2)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
Reserved		WUFH	Reserved	OVR	AF	ARLO	BERR
		rc_w0		rc_w0	rc_w0	rc_w0	rc_w0

Bits 7:6 Reserved, always read as 0.

Bit 5 **WUFH**: Wakeup from Halt

0: no wakeup from HALT mode

1: 7-bit address or header match in HALT mode (slave mode) or Halt entered when in master mode.

Note: This bit is set asynchronously in slave mode (during HALT mode). It is set only if ITEVTEN = 1.

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

Bit 4 Reserved, always read as 0.

Bit 3 **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 the SCL rising edge, the sent data is unspecified and a hold timing error occurs.

Bit 2 **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 1 **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 (M/SL=0).

Bit 0 **BERR**: Bus Error

0: No misplaced Start or Stop condition

1: Misplaced Start or Stop condition

- Set by hardware when the interface detects a misplaced Start or Stop condition
- Cleared by software writing 0, or by hardware when PE=0.

21.7.9 Status register 3 (I2C_SR3)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
Reserved			GENCALL	Reserved	TRA	BUSY	MSL
r	r	r	r	r	r	r	r

Bits 7:5 Reserved, read as '0'.

Bit 4 **GENCALL**: General Call Header (Slave mode)

0: No General Call

1: General Call header received when ENGC=1

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

Bit 3 Reserved, read as '0'.

Bit 2 **TRA**: Transmitter/Receiver

0: Data bytes received

1: Data bytes transmitted

This bit is set depending on R/W bit of 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.

21.7.10 Interrupt register (I2C_ITR)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
reserved					ITBUFEN	ITEVTEN	ITERREN
r	r	r	rw	rw	rw	rw	rw

Bits 7:3 Reserved, read as '0'.

Bit 2 **ITBUFEN**: Buffer Interrupt Enable

- 0: TxE = 1 or RxNE = 1 does not generate any interrupt.
- 1: TxE = 1 or RxNE = 1 generates Event Interrupt

Bit 1 **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
- WUFH = 1 (asynchronous interrupt to wakeup from halt)

Bit 0 **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

21.7.11 Clock control register low (I2C_CCRL)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
CCR[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **CCR[7:0]** Clock Control Register (Master mode)

Controls the SCLH clock in master mode.

- **Standard Mode:**

$$t_{high} = CCR * t_{CK}$$

$$t_{low} = CCR * t_{CK}$$

- **Fast Mode:**

If DUTY = 0:

$$t_{high} = CCR * t_{CK}$$

$$t_{low} = 2 * CCR * t_{CK}$$

If DUTY = 1: (to reach 400 kHz)

$$t_{high} = 9 * CCR * t_{CK}$$

$$t_{low} = 16 * CCR * t_{CK}$$

Notes:

- $t_{CK} = 1 / f_{CK}$. f_{CK} is the input clock to the peripheral configured using clock control register.
- The minimum allowed value is 04h, except in FAST DUTY mode where the minimum allowed value is 0x01.
- t_{high} includes the SCLH rising edge
- t_{low} includes the SCLH falling edge
- I²C communication speed, $f_{SCL} = 1 / (T_{high} + T_{low})$
- These timings are without filters.

21.7.12 Clock control register high (I2C_CCRH)

Reset Value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
F/S	DUTY	reserved		CCR[11:8]			
rw	rw	r		rw			

Bit 7 **F/S**: I2C master mode selection

- 0: Standard mode I2C
- 1: Fast mode I2C

Bit 6 **DUTY**: Fast Mode Duty Cycle

- 0: Fast mode $t_{low}/t_{high} = 2$
- 1: Fast mode $t_{low}/t_{high} = 16/9$ (see CCR)

Bits 5:4 Reserved, must be kept cleared.

Bits 3:0 **CCR[11:8]**: Clock Control Register in Fast/Standard mode (Master mode)

Controls the SCLH clock in master mode.

- **Standard Mode:**

$$t_{high} = CCR * t_{CK}$$

$$t_{low} = CCR * t_{CK}$$

- **Fast Mode:**

If DUTY = 0:

$$t_{high} = CCR * t_{CK}$$

$$t_{low} = 2 * CCR * t_{CK}$$

If DUTY = 1: (to reach 400 kHz)

$$t_{high} = 9 * CCR * t_{CK}$$

$$t_{low} = 16 * CCR * t_{CK}$$

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

If FREQR = 08, $t_{CK} = 125$ ns so CCR must be programmed with 28h

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

- Note:*
- 1 t_{high} includes the SCLH rising edge
 - 2 t_{low} includes the SCLH falling edge
 - 3 These timings are without filters.

- Note:*
- 1 The CCR registers must be configured only when the I²C is disabled (PE=0).
 - 2 $f_{CK} = \text{multiple of } 10 \text{ MHz}$ is required to generate Fast clock at 400 kHz
 - 3 $f_{CK} \geq 1 \text{ MHz}$ is required to generate Standard clock at 100 kHz

21.7.13 TRISE register (I2C_TRISER)

Address offset: 0x0D

Reset value: 0x02

7	6	5	4	3	2	1	0
Reserved		TRISE[5:0]					
r	r	rw	rw	rw	rw	rw	rw

Bits 7:6 Reserved, read as '0'.

Bits 5:0 **TRISE[5:0]** Maximum Rise Time in Fast/Standard mode (Master mode)

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

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

If the value in the I2C_FREQR register = 08h, then t_{CK} = 125ns 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).

21.7.14 I²C register map and reset values

Table 46. I2C register map

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	I2C_CR1 Reset Value	NO STRETCH 0	ENGC 0	- 0	- 0	- 0	- 0	- 0	PE 0
0x01	I2C_CR2 Reset Value	SWRST 0	- 0	- 0	- 0	POS 0	ACK 0	STOP 0	START 0
0x02	I2C_FREQR Reset Value	- 0	- 0	FREQ5 0	FREQ4 0	FREQ3 0	FREQ2 0	FREQ1 0	FREQ0 0
0x03	I2C_OARL Reset Value	ADD7 0	ADD6 0	ADD5 0	ADD4 0	ADD3 0	ADD2 0	ADD1 0	ADD0 0
0x04	I2C_OARH Reset Value	ADDMODE 0	ADDCONF 0	- 0	- 0	- 0	ADD9 0	ADD8 0	- 0
0x05	Reserved								
0x06	I2C_DR Reset Value	DR7 0	DR6 0	DR5 0	DR4 0	DR3 0	DR2 0	DR1 0	DR0 0
0x07	I2C_SR1 Reset Value	TxE 0	RxNE 0	- 0	STOPF 0	ADD10 0	BTF 0	ADDR 0	SB 0
0x08	I2C_SR2 Reset Value	- 0	- 0	WUFH 0	- 0	OVR 0	AF 0	ARLO 0	BERR 0
0x09	I2C_SR3 Reset Value	- 0	- 0	- 0	GENCALL 0	- 0	TRA 0	BUSY 0	MSL 0
0x0A	I2C_ITR Reset Value	- 0	- 0	- 0	- 0	- 0	ITBUFEN 0	ITEVTEN 0	ITERREN 0
0x0B	I2C_CCRL Reset Value	CCR7 0	CCR6 0	CCR5 0	CCR4 0	CCR3 0	CCR2 0	CCR1 0	CCR0 0
0x0C	I2C_CCRH Reset Value	FS 0	DUTY 0	- 0	- 0	CCR11 0	CCR10 0	CCR9 0	CCR8 0
0x0D	I2C_TRISE Reset Value	- 0	- 0	TRISE5 0	TRISE4 0	TRISE3 0	TRISE2 0	TRISE1 1	TRISE0 0

22 Universal asynchronous receiver transmitter (UART)

22.1 Introduction

The UARTs in the STM8S microcontroller family (UART1, UART2 or UART3) offer a flexible means of full-duplex data exchange with external equipment requiring an industry standard NRZ asynchronous serial data format (UART mode). The STM8 UARTs offer a very wide range of baud rates and can also be used for multi-processor communication. They also support LIN (Local Interconnection Network) protocol version 1.3, 2.0 and 2.1 and J2602 in master mode.

UART1 and UART2 have extended features (see [Table 47](#)):

- LIN slave mode is supported in UART2 and UART3.
- Synchronous one-way communication, Smartcard Protocol and IrDA (Infrared Data Association) SIR ENDEC specifications are supported in UART1 and UART2.
- Half-duplex single wire communication is supported in UART1.

Refer to the datasheet for information on the availability of the UART configurations (UART1, UART2 or UART3) in each microcontroller type.

Table 47. UART configurations⁽¹⁾

Feature	UART1	UART2	UART3
Asynchronous mode	X	X	X
Multiprocessor Communication	X	X	X
Synchronous communication	X	X	NA
Smartcard mode	X	X	NA
IrDA mode	X	X	NA
Half-Duplex (Single-Wire mode)	X	NA	NA
LIN master mode	X	X	X
LIN slave mode	NA	X	X

1. X = supported; NA = not applicable.

22.2 UART main features

- Full duplex, asynchronous communications
- NRZ standard format (Mark/Space)
- High-precision baud rate generator system
 - Common programmable transmit and receive baud rates up to $f_{\text{MASTER}}/16$
- Programmable data word length (8 or 9 bits)
- Configurable stop bits - support for 1 or 2 stop bits
- LIN Master mode:
 - LIN break and delimiter generation
 - LIN break and delimiter detection with separate flag and interrupt source for readback checking
- Transmitter clock output for synchronous communication (UART1, UART2)
- IrDA SIR Encoder Decoder (UART1, UART2)
 - Support for 3/16 bit duration for normal mode
- Smartcard Emulation Capability (UART1, UART2)
 - The Smartcard interface supports the asynchronous protocol for Smartcards as defined in ISO 7816-3 standards
 - 1.5 Stop Bits for Smartcard operation
- Single wire Half Duplex Communication (UART1)
- Separate enable bits for Transmitter and Receiver
- Transfer detection flags:
 - Receive buffer full
 - Transmit buffer empty
 - End of Transmission flags
- Parity control:
 - Transmits parity bit
 - Checks parity of received data byte
- 4 error detection flags:
 - Overrun error
 - Noise error
 - Frame error
 - Parity error
- 6 interrupt sources with flags:
 - Transmit data register empty
 - Transmission complete
 - Receive data register full
 - Idle line received
 - Parity error
 - LIN break and delimiter detection (UART2, UART3)

- 2 interrupt vectors:
 - Transmitter interrupt
 - Receiver interrupt
- Reduced power consumption mode
- Multi-Processor communication - enter into mute mode if address match does not occur
- Wakeup from mute mode (by idle line detection or address mark detection)
- 2 receiver wakeup modes:
 - Address bit (MSB)
 - Idle line

22.3 UART functional description

The interface is externally connected to another device by two or three pins (see [Figure 99: UART1 block diagram](#), [Figure 100: UART2 block diagram](#) and [Figure 101: UART3 block diagram](#)). Any UART bidirectional communication requires a minimum of two pins: UART Receive data input (UART_RX) and UART transmit data output (UART_TX):

UART_RX is the serial data input. Over-sampling techniques are used for data recovery by discriminating between valid incoming data and noise.

UART_TX is the serial data output. When the transmitter is disabled, the output pin returns to its I/O port configuration. When the transmitter is enabled and nothing is to be transmitted, the pin is at high level.

Through these pins, serial data is transmitted and received in normal UART mode as frames comprising:

- An Idle Line prior to transmission or reception
- A start bit
- A data word (8 or 9 bits) least significant bit first
- 1, 1.5 and 2 Stop bits indicating that the frame is complete
- A status register (UART_SR)
- Data Register (UART_DR)
- 16-bit baud rate prescaler (UART_BRR)
- Guard time Register for use in Smartcard mode

Refer to the register description for the definitions of each bit.

The following pin is required to interface in synchronous mode:

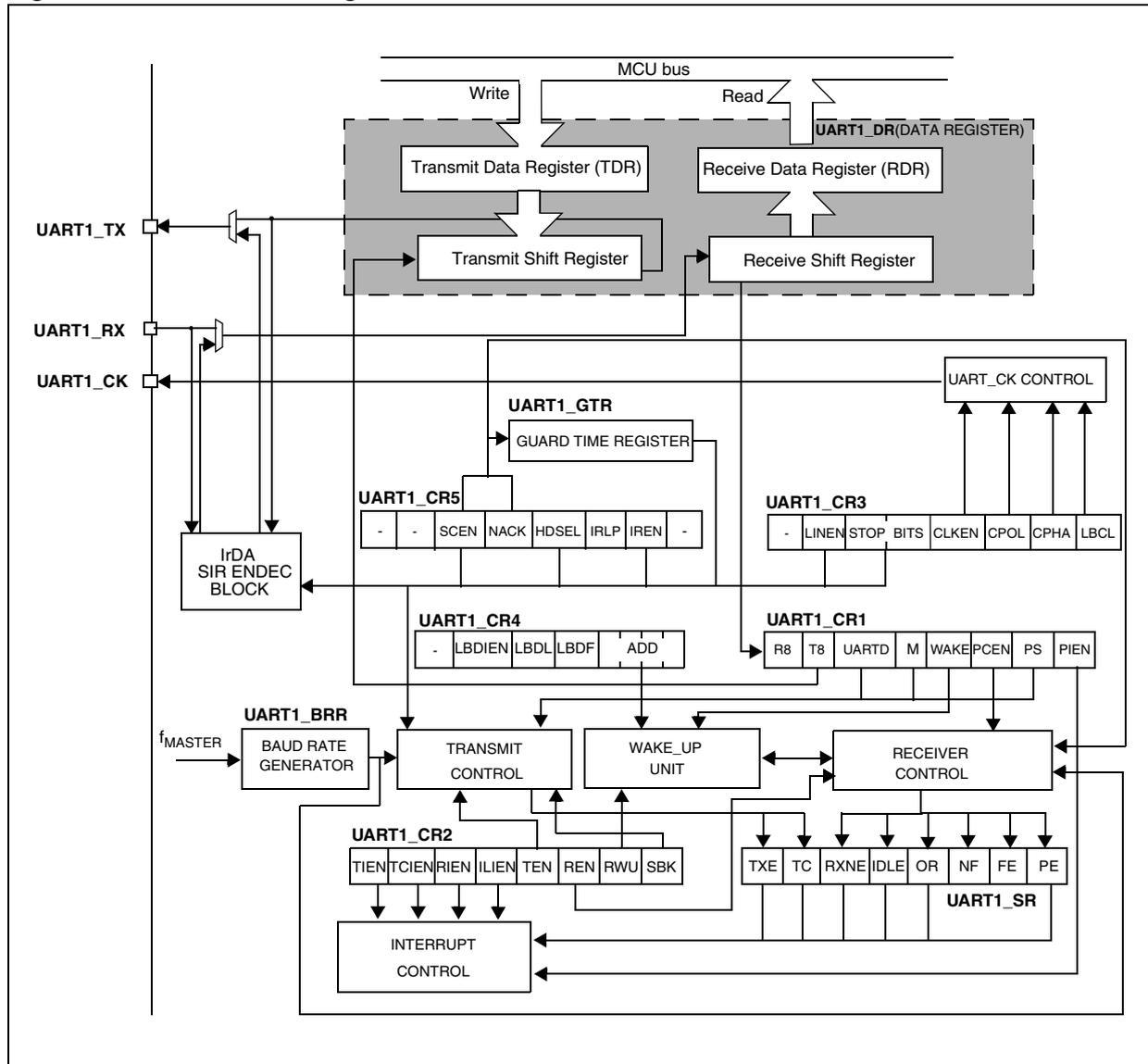
UART_CK: Transmitter clock output. This pin outputs the transmitter data clock for synchronous transmission (no clock pulses on start bit and stop bit, and a software option to send a clock pulse on the last data bit). This can be used to control peripherals that have shift registers (e.g. LCD drivers). The clock phase and polarity are software programmable.

The UART_RX and UART_TX pins are used in IrDA mode as follows:

UART_RX = IrDA_RDI: Receive Data Input in IrDA mode

UART_TX = IrDA_TDO: Transmit Data Output in IrDA mode

Figure 99. UART1 block diagram



22.3.1 UART character description

Word length may be selected as being either 8 or 9 bits by programming the M bit in the UART_CR1 register (see [Figure 102](#)).

The UART_TX pin is in low state during the start bit. It is in high state during the stop bit.

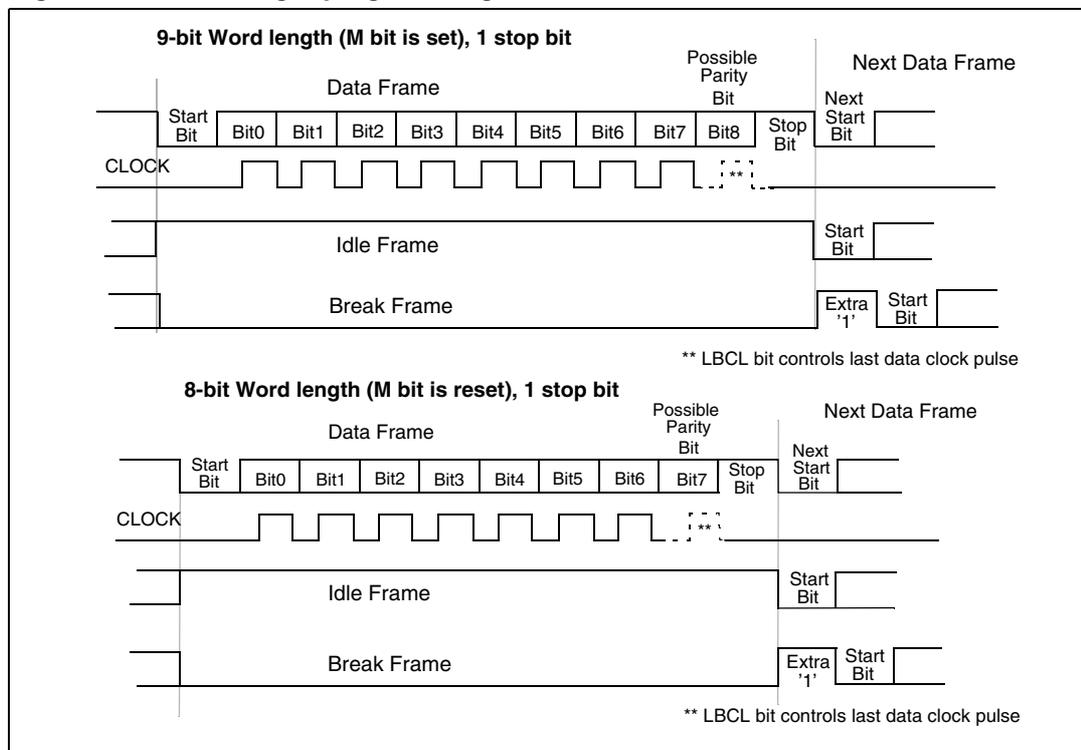
An **Idle character** is interpreted as an entire frame of “1”s (the number of “1” ‘s includes the start bit, the number of data bits and the number of stop bits).

A **Break character** is interpreted on receiving “0”s for a frame period. At the end of the break frame the transmitter inserts either 1 or 2 stop bits (logic “1” bit) to acknowledge the start bit.

Transmission and reception are driven by a common baud rate generator, the clock for each is generated when the enable bit is set respectively for the transmitter and receiver.

The details of each block is given below.

Figure 102. Word length programming



22.3.2 Transmitter

The transmitter can send data words of either 8 or 9 bits depending on the M bit status. When the M bit is set, word length is 9 bits and the 9th bit (the MSB) has to be stored in the T8 bit in the UART_CR1 register.

When the transmit enable bit (TEN) is set, the data in the transmit shift register is output on the UART_TX pin and the corresponding clock pulses are output on the UART_CK pin.

Character transmission

During an UART transmission, data shifts out least significant bit first on the UART_TX pin. In this mode, the UART_DR register consists of a buffer (TDR) between the internal bus and the transmit shift register (see [Figure 99](#)).

Every character is preceded by a start bit which is a logic level low for one bit period. The character is terminated by a configurable number of stop bits.

The following stop bits are supported by UART.

- Note:*
- 1 *The TEN bit should not be reset during transmission of data. Resetting the TEN bit during the transmission will corrupt the data on the UART_TX pin as the baud rate counters will get frozen. The current data being transmitted will be lost.*
 - 2 *An idle frame will be sent after the TEN bit is enabled.*

Configurable stop bits

The number of stop bits to be transmitted with every character can be programmed in Control register 3, bits 5,4.

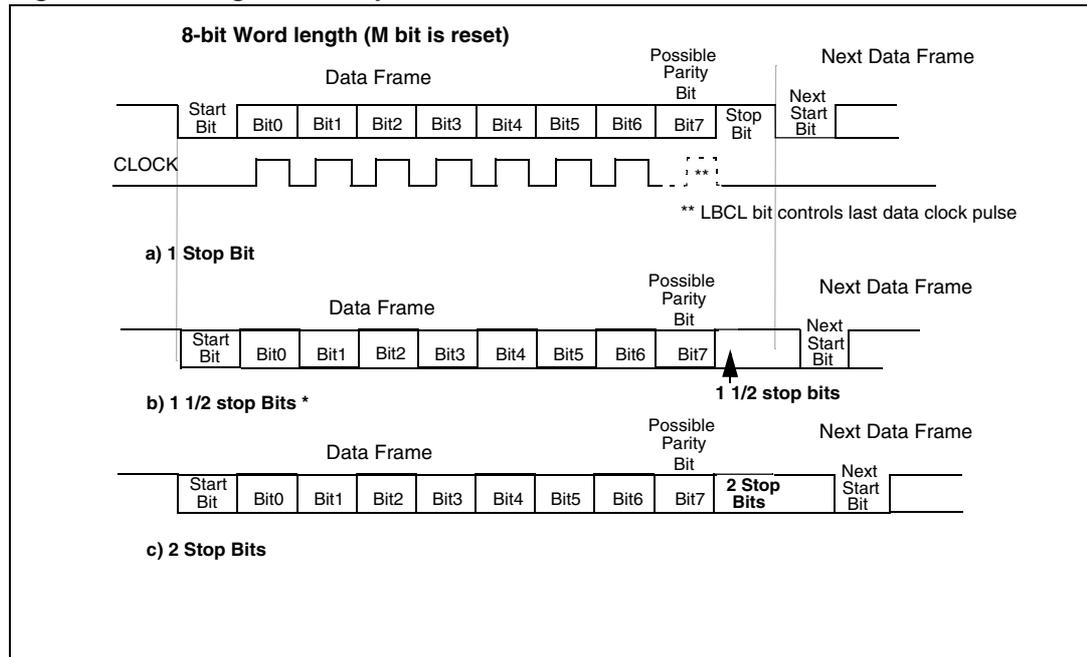
- 1 stop bit: This is the default value of number of stop bits.
- 2 Stop bits: This is supported by normal mode UART.
- 1.5 Stop bits: To be used in Smartcard mode only.

An idle frame transmission will include the stop bits.

A break transmission consists of 10 low bits followed by the configured number of stop bits (when $m = 0$) and 11 low bits followed by the configured number of stop bits (when $m = 1$). It is not possible to transmit long breaks (break of length greater than 10/11 low bits).

- Note:* *In LIN mode (see [Section 22.3.7 on page 315](#)), a standard 13-bit break is always generated.*

Figure 103. Configurable stop bits

**Procedure:**

1. Program the M bit in UART_CR1 to define the word length.
2. Program the number of stop bits in UART_CR3.
3. Select the desired baud rate by programming the baud rate registers in the following order:
 - a) UART_BRR2
 - b) UART_BRR1
4. Set the TEN bit in UART_CR2 to enable transmitter mode.
5. Write the data to send in the UART_DR register (this clears the TXE bit). Repeat this for each data to be transmitted in case of single buffer.

Single byte communication

Clearing the TXE bit is always performed by a write to the data register.

The TXE bit is set by hardware and it indicates:

- The data has been moved from TDR to the shift register and the data transmission has started.
- The TDR register is empty.
- The next data can be written in the UART_DR register without overwriting the previous data.

This flag generates an interrupt if the TIEN bit is set.

When a transmission is taking place, a write instruction to the UART_DR register stores the data in the TDR register. The data is copied in the shift register at the end of the current transmission.

When no transmission is taking place, a write instruction to the UART_DR register places the data directly in the shift register, the data transmission starts, and the TXE bit is immediately set.

When a frame transmission is complete (after the stop bit) the TC bit is set and an interrupt is generated if the TCIEN is set. Clearing the TC bit is performed by the following software sequence:

1. A read to the UART_SR register
2. A write to the UART_DR register

Break character

Setting the SBK bit transmits a break character. The break frame length depends on the M bit (see [Figure 102](#)).

If the SBK bit is set to '1' a break character is sent on the UART_TX line after completing the current character transmission. This bit is reset by hardware when the break character is completed (during the stop bit of the break character). The UART inserts a logic 1 bit at the end of the last break frame to guarantee the recognition of the start bit of the next frame.

Note: The break character is sent without taking into account the number of stop bits. If the UART is programmed with 2 stop bits, the TX line is pulled low until the end of the first stop bit only. Then 2 logic 1 bits are inserted before the next character.

Note: If the software resets the SBK bit before the start of break transmission, the break character is not transmitted. For two consecutive breaks, the SBK bit should be set after the stop bit of the previous break.

Idle character

Setting the TEN bit drives the UART to send an idle frame before the first data frame.

22.3.3 Receiver

The UART can receive data words of either 8 or 9 bits. When the M bit is set, word length is 9 bits and the MSB is stored in the R8 bit in the UART_CR1 register.

Character reception

During an UART reception, data shifts in least significant bit first through the UART_RX pin. In this mode, the UART_DR register consists of a buffer (RDR) between the internal bus and the received shift register (see [Figure 2](#)).

Procedure:

1. Program the M bit in UART_CR1 to define the word length.
2. Program the number of stop bits in UART_CR3.
3. Select the desired baud rate by programming the baud rate registers in the following order:
 - a) UART_BRR2
 - b) UART_BRR1
4. Set the REN bit UART_CR2. This enables the receiver which begins searching for a start bit.

When a character is received

- The RXNE bit is set. It indicates that the content of the shift register is transferred to the RDR.
- An interrupt is generated if the RIEN bit is set.
- The error flags can be set if a frame error, noise or an overrun error has been detected during reception.
- Clearing the RXNE bit is performed by a software read to the UART_DR register. The RXNE flag can also be cleared by writing a zero to it. The RXNE bit must be cleared before the end of the reception of the next character to avoid an overrun error.

Note: The REN bit should not be reset while receiving data. If the REN bit is disabled during reception, the reception of the current byte will be aborted.

Break character

When a break character is received, the UART handles it as a framing error.

Idle character

When an idle frame is detected, there is the same procedure as a data received character plus an interrupt if the ILIEN bit is set.

Overrun error

An overrun error occurs when a character is received when RXNE has not been reset. Data can not be transferred from the shift register to the RDR register until the RXNE bit is cleared.

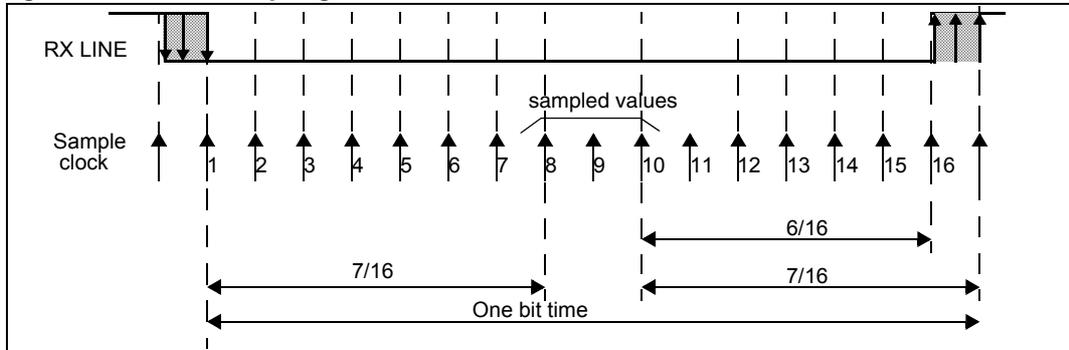
When an overrun error occurs:

- The OR bit is set.
- The RDR content will not be lost. The previous data is available when a read to UART_DR is performed.
- The shift register will be overwritten. The second data received during overrun is lost.
- An interrupt is generated if the RIEN bit is set.
- The OR bit is reset by a read to the UART_SR register followed by a UART_DR register read operation.

Noise error

Over-sampling techniques are used for data recovery by discriminating between valid incoming data and noise.

Figure 104. Data sampling for noise detection



Note: The sample clock frequency is 16x baud rate.

Table 48. Noise detection from sampled data

Sampled value	NF status	Received bit value	Data validity
000	0	0	Valid
001	1	0	Not Valid
010	1	0	Not Valid
011	1	1	Not Valid
100	1	0	Not Valid
101	1	1	Not Valid
110	1	1	Not Valid
111	0	1	Valid

When noise is detected in a frame:

- The NF is set at the rising edge of the RXNE bit.
- The invalid data is transferred from the Shift register to the UART_DR register.

This bit rises at the same time as the RXNE bit which generates an interrupt. The NF bit is reset by a UART_SR register read operation followed by a UART_DR register read operation.

Framing error

A framing error is detected when:

The stop bit is not recognized on reception at the expected time, following either a de-synchronization or excessive noise.

When the framing error is detected:

- The FE bit is set by hardware
- The invalid data is transferred from the Shift register to the UART_DR register.
- No interrupt is generated in case of single byte communication. However, this bit rises at the same time as the RXNE bit which itself generates an interrupt.

The FE bit is reset by a UART_SR register read operation followed by a UART_DR register read operation.

Configurable stop bits during reception:

The number of stop bits to be received can be configured through the control bits of Control Register 3 - it can be either 1 or 2 in normal mode, 1 in IrDA mode and 1.5 in Smartcard mode.

1. *1 Stop Bit*: Sampling for 1 stop Bit is done on the 8th, 9th and 10th samples.
2. *1.5 stop Bits (Smartcard mode only)*: Sampling for 1.5 stop bits is done on the 16th, 17th and 18th samples. An NACK signal received from the Smartcard forces the data signal low during the sampling, flagged as a framing error. Then, the FE flag is set with the RXNE at the end of the 1.5 stop bit.
3. *2 Stop Bits*: Sampling for 2 stop bits is done on the 8th, 9th and 10th samples of the first stop bit. If a framing error is detected during the first stop bit the framing error flag will be set. The second stop bit is not checked for framing error. The RXNE flag will be set at the end of the first stop bit.

22.3.4 High precision baud rate generator

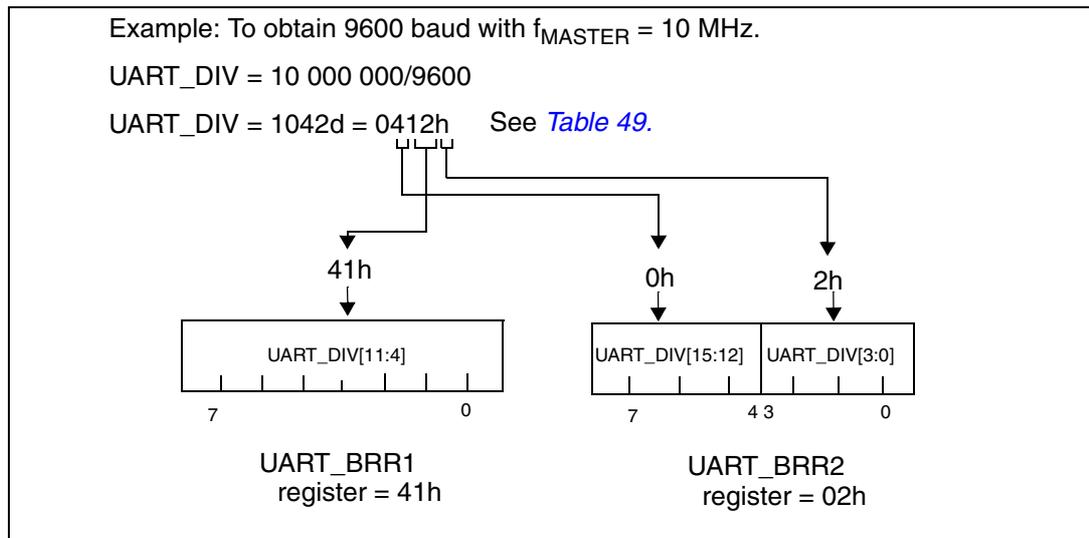
The receiver and transmitter (Rx and Tx) are both set to the same baud rate programmed by a 16-bit divider UART_DIV according to the following formula:

$$\text{Tx/ Rx baud rate} = \frac{f_{\text{MASTER}}}{\text{UART_DIV}}$$

The UART_DIV baud rate divider is an unsigned integer, coded in the BRR1 and BRR2 registers as shown in [Figure 105](#).

Refer to [Table 49](#). for typical baud rate programming examples.

Figure 105. How to code UART_DIV in the BRR registers



Note: The Baud Counters will be updated with the new value of the Baud Registers after a write to BRR1. Hence the Baud Register value should not be changed during a transaction. The BRR2 should be programmed before BRR1.

Note: UART_DIV must be greater than or equal to 16d.

Table 49. Baud rate programming and error calculation

Baud rate in kbps	f _{MASTER} = 10 MHz					f _{MASTER} = 24 MHz				
	Actual	% Error (1)	UART_DIV	BRR1	BRR2	Actual	% Error(1)	UART_DIV	BRR1	BRR2
2.4	2.399	-0.04%	1047h	04h	17h	2.4	0.0%	2710h	71h	20h
9.6	9.596	-0.04%	0412h	41h	02h	9.6	0.0%	09C4h	9Ch	04h
19.2	19.193	-0.03%	0209h	20h	09h	19.2	0.0%	04E2	4Eh	02h
57.6	57.471	-0.22%	00AEh	0Ah	0Eh	57.554	-0.08%	01A1h	1Ah	01h
115.2	114.942	-0.22%	0057h	05h	07h	115.385	0.16%	00D0h	0Dh	00h
230.4	232.558	-0.94%	002Bh	02h	0Bh	230.769	0.16%	0068h	06h	08h
460.8	454.545	-1.36%	0016h	01h	06h	461.538	0.16%	0034h	03h	04h
921.6	NA	NA	NA			923.077	0.16%	001Ah	01h	0Ah

1. Error % = (Calculated - Desired) Baud Rate / Desired Baud Rate

Note: The lower the f_{MASTER} frequency, the lower will be the accuracy for a particular baud rate. The upper limit of the achievable baud rate can be fixed with this data.

22.3.5 Parity control

Parity control (generation of parity bit in transmission and parity checking in reception) can be enabled by setting the PCEN bit in the UART_CR1 register. Depending on the frame length defined by the M bit, the possible UART frame formats are as listed in [Table 50](#).

Table 50. Frame formats

M bit	PCEN bit	UART frame
0	0	SB 8 bit data STB
0	1	SB 7-bit data PB STB
1	0	SB 9-bit data STB
1	1	SB 8-bit data PB STB

Legends: SB: Start Bit, STB: Stop Bit, PB: Parity Bit

Note: In case of wakeup by an address mark, the MSB bit of the data is taken into account and not the parity bit

Even parity: the parity bit is calculated to obtain an even number of “1s” inside the frame made of the 7 or 8 LSB bits (depending on whether M is equal to 0 or 1) and the parity bit.

Ex: data=00110101; 4 bits set => parity bit will be 0 if even parity is selected (PS bit in UART_CR1 = 0).

Odd parity: the parity bit is calculated to obtain an odd number of “1s” inside the frame made of the 7 or 8 LSB bits (depending on whether M is equal to 0 or 1) and the parity bit.

Example: data=00110101; 4 bits set => parity bit will be 1 if odd parity is selected (PS bit in UART_CR1 = 1).

Transmission: If the PCEN bit is set in UART_CR1 then the MSB bit of the data written in the data register is not transmitted but is changed by the parity bit to give an even number of '1's if even parity is selected (PS=0) or an odd number of '1's if odd parity is selected (PS=1).

Reception: If the parity check fails, the PE flag is set in the UART_SR register and an interrupt is generated if the PIEN bit is set in the UART_CR1 register.

22.3.6 Multi-processor communication

It is possible to perform multi-processor communication with the UART (several UARTs connected in a network). For example, one of the UARTs can be the master, its TX output is connected to the RX input of the other UART. The others are slaves, their respective TX outputs are logically ANDed together and connected to the RX input of the master.

In multi-processor configurations it is often desirable that only the intended message recipient should actively receive the full message contents, thus reducing redundant UART service overhead for all non addressed receivers.

The non addressed devices may be placed in mute mode by means of the muting function. In mute mode:

- None of the reception status bits can be set.
- All the receive interrupts are inhibited.
- The RWU bit in UART_CR1 register is set to 1. RWU can be controlled automatically by hardware or written by the software under certain conditions.

The UART can enter or exit from mute mode using one of two methods, depending on the WAKE bit in the UART_CR1 register:

- Idle Line detection if the WAKE bit is reset,
- Address Mark detection if the WAKE bit is set.

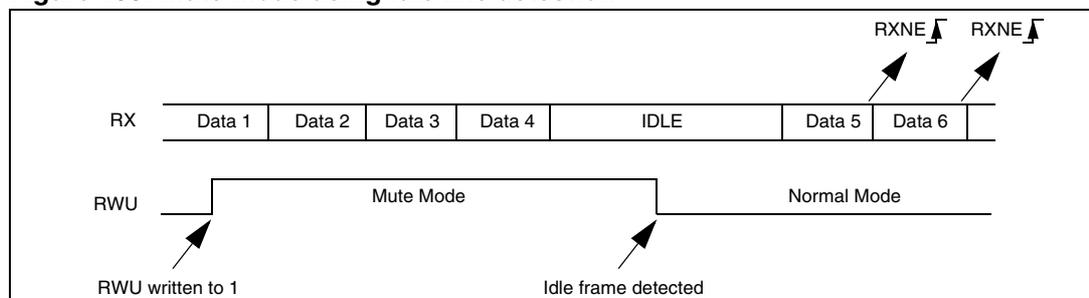
Idle line detection (WAKE=0)

The UART enters mute mode when the RWU bit is written to 1.

It wakes up when an Idle frame is detected. Then the RWU bit is cleared by hardware but the IDLE bit is not set in the UART_SR register. RWU can also be written to 0 by software.

An example of mute mode behavior using idle line detection is given in [Figure 106](#).

Figure 106. Mute mode using Idle line detection



Address mark detection (WAKE=1)

In this mode, bytes are recognized as addresses if their MSB is a '1' else they are considered as data. In an address byte, the address of the targeted receiver is put on the 4 LSB. This 4-bit word is compared by the receiver with its own address which is programmed in the ADD bits in the UART_CR4 register.

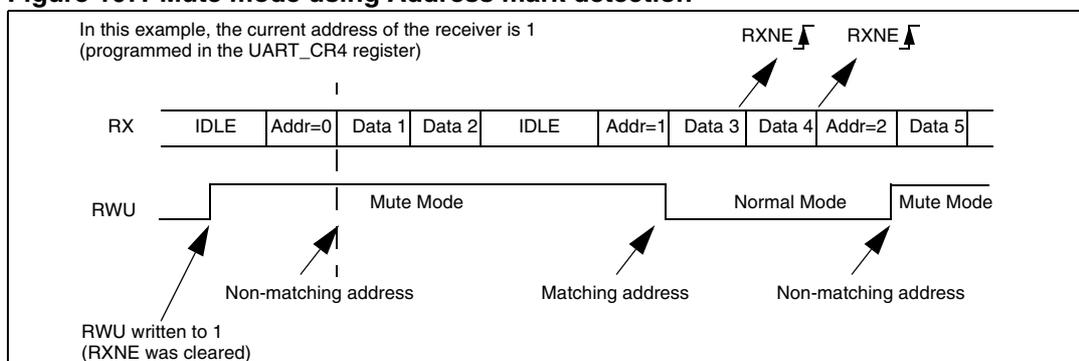
The UART enters mute mode when an address character is received which does not match its programmed address. The RXNE flag is not set for this address byte and no interrupt request is issued as the UART would have entered mute mode.

It exits from mute mode when an address character is received which matches the programmed address. Then the RWU bit is cleared and subsequent bytes are received normally. The RXNE bit is set for the address character since the RWU bit has been cleared.

The RWU bit can be written to 0 or 1 when the receiver buffer contains no data (RXNE=0 in the UART_SR register). Otherwise the write attempt is ignored.

An example of mute mode behavior using address mark detection is given in [Figure 107](#).

Figure 107. Mute mode using Address mark detection



Note: If parity control is enabled, the parity bit remains in the MSB and the address bit is put in the "MSB - 1" bit.

For example, with 7-bit data, address mode and parity control:

SB | 7-bit data | ADD | PB | STB

where:

SB = Start Bit

STB = Stop Bit

ADD = Address bit

PB = Parity Bit

22.3.7 LIN (local interconnection network) mode

The UART supports LIN break and delimiter generation in LIN master mode.

Refer to [Section 22.4.1: Master mode on page 323](#) for details. LIN slave mode is supported by the UART2 and 3 only, not by UART1.

LIN mode is selected by setting the LINEN bit in the UART_CR3 register. In LIN mode, the following bits must be kept cleared:

- CLKEN, STOP[1:0] in the UART_CR3 register
- SCEN, HDSEL and IREN in the UART_CR5 register

22.3.8 UART synchronous communication

The UART transmitter allows the user to control bidirectional synchronous serial communications in master mode.

In synchronous mode, the following bits must be kept cleared:

- LINEN bit in the UART_CR3 register
- SCEN, HDSEL and IREN bits in the UART_CR5 register

Note: This feature is only available in UART1 and UART2.

The UART_CK pin is the output of the UART transmitter clock. No clock pulses are sent to the UART_CK pin during start bit and stop bit. Depending on the state of the LBCL bit in the UART_CR3 register clock pulses will or will not be generated during the last valid data bit (address mark). The CPOL bit in the UART_CR3 register allows the user to select the clock polarity, and the CPHA bit in the UART_CR3 register allows the user to select the phase of the external clock (see [Figure 108](#), [Figure 109](#) & [Figure 110](#)).

During idle and break frames, the external CK clock is not activated.

In synchronous mode, the UART receiver works differently compared to asynchronous mode. If RE=1, the data is sampled on SCLK (rising or falling edge, depending on CPOL and CPHA), without any oversampling. A setup and a hold time (even if the hold time is not relevant due to the SPI protocol) must be respected (which depends on the baud rate: 1/16 bit time for an integer baud rate).

- Note:*
- 1 The UART_CK pin works in conjunction with the TX pin. When the UART transmitter is disabled (TEN and REN= 0), the UART_CK and UART_TX pins go into high impedance state.
 - 2 The LBCL, CPOL and CPHA bits in UART_CR3 have to be selected when both the transmitter and the receiver are disabled (TEN=REN=0) to ensure that the clock pulses function correctly. These bits should not be changed while the transmitter or the receiver is enabled.
 - 3 It is recommended to set TE and RE are set in the same instruction in order to minimize the setup and the hold time of the receiver.
 - 4 The UART supports master mode only: it cannot receive or send data related to an input clock (SCLK is always an output).
 - 5 The data given in this section apply only when the UART_DIV[3:0] bits in the UART_BRR2 register are kept at 0. Else the setup and hold times are not 1/16 of a bit time but 4/16 of a bit time.

This option allows to serially control peripherals which consist of shift registers, without losing any functions of the asynchronous communication which can still talk to other asynchronous transmitters and receivers.

Figure 108. UART example of synchronous transmission

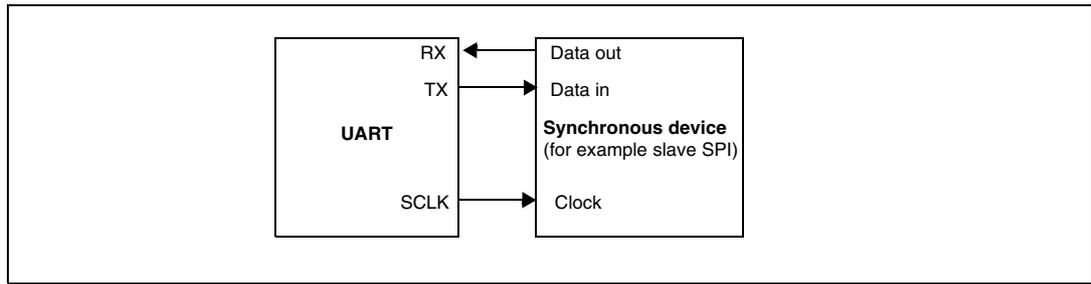


Figure 109. UART data clock timing diagram (M=0)

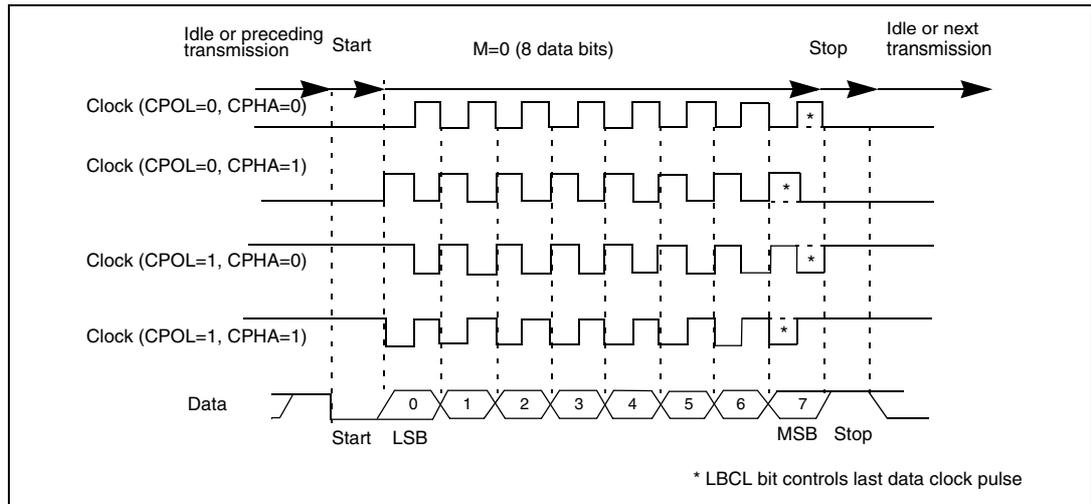


Figure 110. UART data clock timing diagram (M=1)

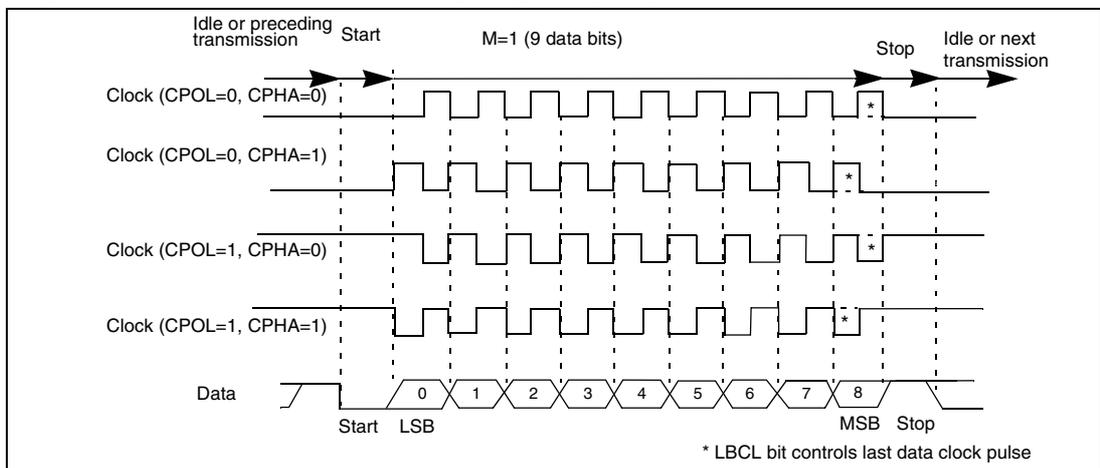
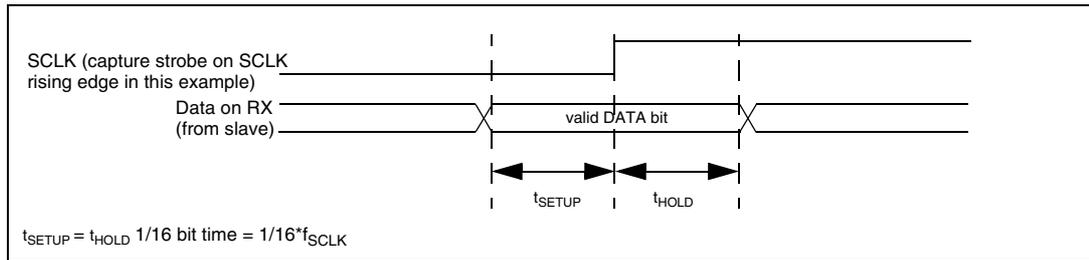


Figure 111. RX data setup/hold time



Note: The function of `UART_CK` is different in Smartcard mode. Refer to [Section 22.3.10: Smartcard](#) for more details.

22.3.9 Single wire half duplex communication

The UART can be configured to follow a single wire half duplex protocol. Single-wire half-duplex mode is selected by setting the `HDSEL` bit in the `UART_CR5` register. In this mode, the following bits must be kept cleared:

- `LINEN` and `CLKEN` bits in the `UART_CR3` register
- `SCEN` and `IREN` bits in the `UART_CR5` register

Note: This feature is only available in `UART1`.

As soon as `HDSEL` is set:

- `UART_RX` is no longer used
- `UART_TX` is always released when no data is transmitted. Thus, it acts as a standard I/O in idle or in reception. This means that the I/O must be configured so that `UART_TX` is configured as floating input (or output high open-drain) when not driven by the UART.

Apart from this, the communications are similar to what is done in normal UART mode. The conflicts on the line must be managed by the software (by the use of a centralized arbiter, for instance). In particular, the transmission is never blocked by hardware and continue to occur as soon as a data is written in the data register while the `TEN` bit is set.

22.3.10 Smartcard

Smartcard mode is selected by setting the `SCEN` bit in the `UART_CR5` register. In smartcard mode, the following bits must be kept cleared:

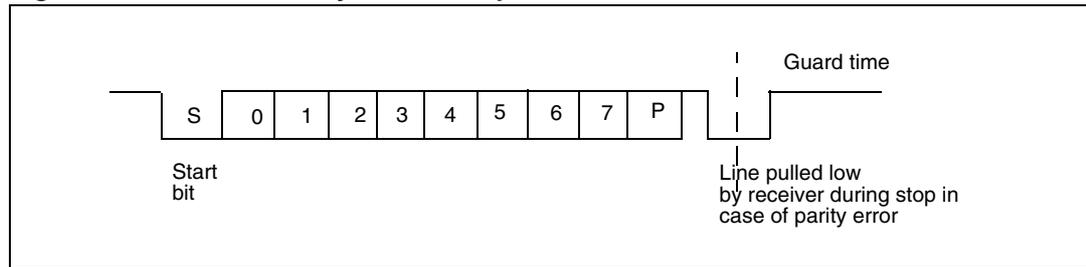
- `LINEN` bit in the `UART_CR3` register,
- `HDSEL` and `IREN` bits in the `UART_CR5` register.

Moreover, the `CKEN` bit may be set in order to provide a clock to the smartcard.

Note: This feature is only available in `UART1` and `UART2`.

The Smartcard interface is designed to support asynchronous protocol Smartcards as defined in the ISO7816-3 standard. The UART should be configured as eight bits plus parity and 1.5 stop bits. With Smartcard mode enabled (which can be done by setting the `SCEN` bit in the `UART_CR5`) the UART can communication with an asynchronous Smartcard.

Figure 112. ISO 7816-3 asynchronous protocol



When connected to a smartcard, the UART_TX output drives a bidirectional line that is also driven by the smartcard.

Smartcard is a single wire half duplex communication protocol.

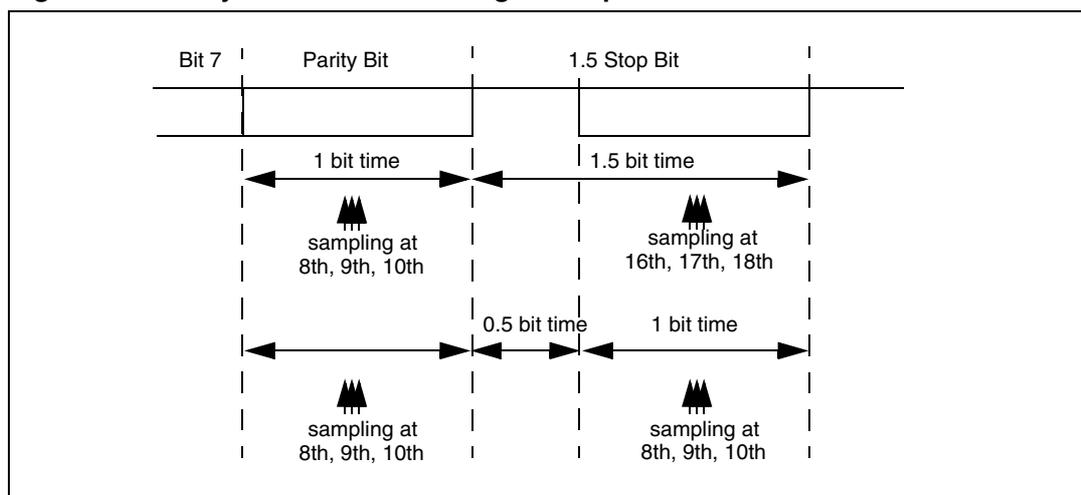
- Transmission of data from the transmit shift register is guaranteed to be delayed by a minimum of 1/2 baud clock. In normal operation a full transmit shift register will start shifting on the next baud clock edge. In Smartcard mode this transmission is further delayed by a guaranteed 1/2 baud clock.
- If a parity error is detected during reception of a frame programmed with a 1.5 stop bit period, the transmit line is pulled low for a baud clock period after 1/2 baud clock period. This is to indicate to the Smartcard that the data transmitted to the UART has not been correctly received. This NACK signal (pulling transmit line low for 1 baud clock) will cause a framing error on the transmitter side (configured with 1.5 stop bits). The application can handle re-sending of data according to the protocol. A parity error is 'NACK'ed by the receiver if the NACK control bit is set, otherwise a NACK is not transmitted.
- The TE bit must be set to enable:
 - Data transmission
 - Transmission of acknowledgements in case of parity error.
 Software must manage the timing of data transmission to avoid conflicts on the data line when it writes new data in the data register.
- The RE bit must be set to enable:
 - Data reception (sent by the Smartcard as well as by the UART),
 - Detection of acknowledgements in case of parity error.
- The assertion of the TC flag can be delayed by programming the Guard Time register. In normal operation, TC is asserted when the transmit shift register is empty and no further transmit requests are outstanding. In Smartcard mode an empty transmit shift register triggers the guard time counter to count up to the programmed value in the Guard Time register. TC is forced low during this time. When the guard time counter reaches the programmed value TC is asserted high.
- The de-assertion of TC flag is unaffected by Smartcard mode.
- If a framing error is detected on the transmitter end (due to a NACK from the receiver), the NACK will not be detected as a start bit by the receive block of the transmitter. According to the ISO protocol, the duration of the received NACK can be 1 or 2 baud clock periods.
- On the receiver side, if a parity error is detected and a NACK is transmitted the receiver will not detect the NACK as a start bit.
- The output enable signal for the Smartcard I/O enables driving into a bidirectional line which is also driven by the Smartcard. This signal is active while transmitting the start

and data bits and transmitting NACK. While transmitting the stop bits this signal is disabled, so that the UART weakly drives a '1' on the bidirectional line.

- Note: 1 A break character is not significant in Smartcard mode. A 00h data with a framing error will be treated as data and not as a break.
- 2 No IDLE frame is transmitted when toggling the TEN bit. The IDLE frame (as defined for the other configurations) is not defined by the ISO protocol.

Figure 113 details how the NACK signal is sampled by the UART. In this example the UART is transmitting a data and is configured with 1.5 stop bits. The receiver part of the UART is enabled in order to check the integrity of the data and the NACK signal.

Figure 113. Parity error detection using 1.5 stop bits



The UART can provide a clock to the smartcard through the UART_CK output. In smartcard mode, UART_CK is not associated to the communication but is simply derived from the internal peripheral input clock through a 5-bit prescaler. The division ratio is configured in the prescaler register UART_PSCR. UART_CK frequency can be programmed from $f_{MASTER}/2$ to $f_{MASTER}/62$, where f_{MASTER} is the peripheral input clock.

22.3.11 IrDA SIR ENDEC block

IrDA mode is selected by setting the IREN bit in the UART_CR5 register. The STOP bits in the UART_CR3 register must be configured to "1 stop bit". In IrDA mode, the following bits must be kept cleared:

- LINEN, STOP and CKEN bits in the UART_CR3 register,
- SCEN and HDSEL bits in the UART_CR5 register.

Note: This feature is only available in UART1 and UART2.

The IrDA SIR physical layer specifies use of a Return to Zero, Inverted (RZI) modulation scheme that represents logic 0 as an infrared light pulse (see Figure 114).

The SIR Transmit encoder modulates the Non Return to Zero (NRZ) transmit bit stream output from the UART. The output pulse stream is transmitted to an external output driver and infrared LED. The UART supports only bit rates up to 115.2 kbps for the SIR ENDEC. In normal mode the transmitted pulse width is specified as 3/16 of a bit period.

The SIR receive decoder demodulates the return-to-zero bit stream from the infrared detector and outputs the received NRZ serial bit stream to UART. The decoder input is normally HIGH (marking state) in the idle state. The transmit encoder output has the opposite polarity to the decoder input. A start bit is detected when the decoder input is low.

- IrDA is a half duplex communication protocol. If the Transmitter is busy (i.e. the UART is sending data to the IrDA encoder), any data on the IrDA receive line will be ignored by the IrDA decoder and if the Receiver is busy (UART is receiving decoded data from the UART), data on the TX from the UART to IrDA will not be encoded by IrDA. While receiving data, transmission should be avoided as the data to be transmitted could be corrupted.
- A '0' is transmitted as a high pulse and a '1' is transmitted as a '0'. The width of the pulse is specified as 3/16th of the selected bit period in normal mode (see [Figure 115](#)).
- The SIR decoder converts the IrDA compliant receive signal into a bit stream for the UART.
- The SIR receive logic interprets a high state as a logic one and low pulses as logic zeros.
- The transmit encoder output has the opposite polarity to the decoder input. The SIR output is in low state when idle.
- The IrDA specification requires the acceptance of pulses greater than 1.41 us. The acceptable pulse width is programmable. Glitch detection logic on the receiver end filters out pulses of width less than 2 PSC periods (PSC is the prescaler value programmed in UART_PSCR). Pulses of width less than 1 PSC period are always rejected, but those of width greater than one and less than two periods may be accepted or rejected, those greater than 2 periods will be accepted as a pulse. The IrDA encoder/decoder doesn't work when PSC=0.
- The receiver can communicate with a low-power transmitter.
- In IrDA mode, the STOP bits in the UART_CR2 register must be configured to "1 stop bit".

IrDA low-power mode

The IrDA can be used either in normal mode or in Low Power mode. The Low Power mode is selected by setting the IRLP bit in UART_CR5 register.

Transmitter:

In low-power mode the pulse width is not maintained at 3/16 of the bit period. Instead, the width of the pulse is 3 times the low-power baud rate which can be a minimum of 1.42 MHz. Generally this value is 1.8432 MHz (1.42 MHz < PSC < 2.12 MHz). A low-power mode programmable divisor divides the system clock to achieve this value.

Receiver:

Receiving in low-power mode is similar to receiving in normal mode. For glitch detection the UART should discard pulses of duration shorter than 1/PSC. A valid low is accepted only if its duration is greater than 2 periods of the IrDA low-power Baud clock (PSC value in UART_PSCR).

- Note:*
- 1 A pulse of width less than two and greater than one PSC period(s) may or may not be rejected.
 - 2 The receiver set up time should be managed by software. The IrDA physical layer specification specifies a minimum of 10 ms delay between transmission and reception (IrDA is a half duplex protocol).

Figure 114. IrDA SIR ENDEC- block diagram

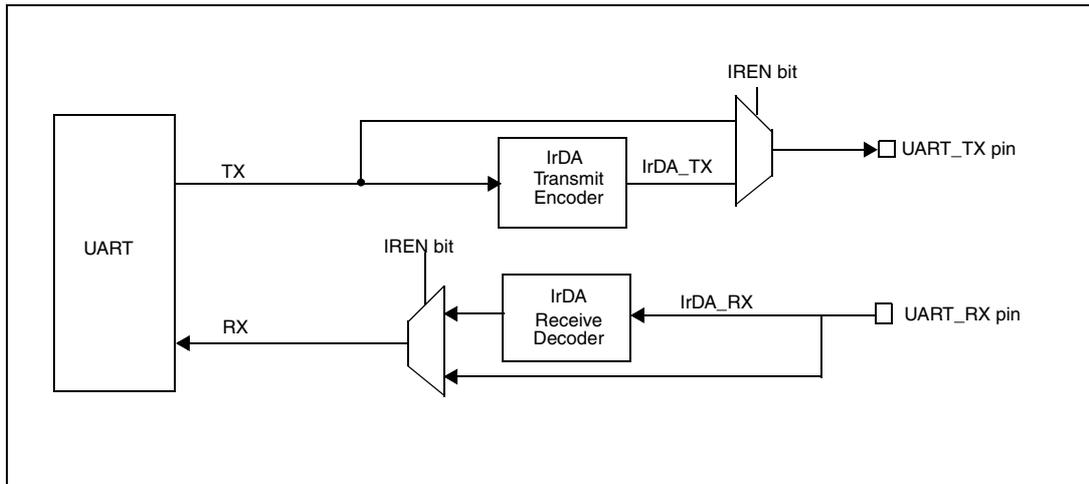
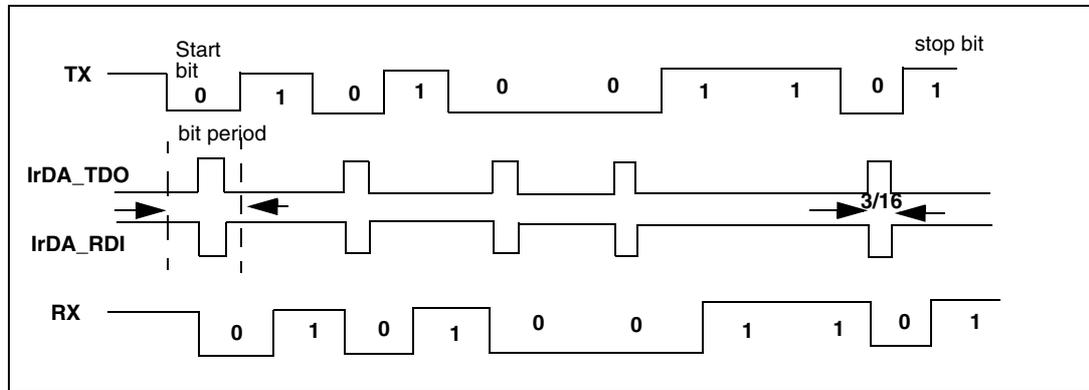


Figure 115. IrDA data modulation (3/16) - normal mode



22.4 LIN mode functional description

In LIN mode, 8-bit data format with 1 stop bit is required in accordance with the LIN standard.

To configure these settings, clear the M bit in UART_CR1 register and clear the STOP[1:0] bits in the UART_CR3 register.

22.4.1 Master mode

UART initialization

Procedure:

1. Select the desired baudrate by programming the UART_BRR2 and UART_BRR1 registers.
2. Enable LIN mode by setting the LINEN bit in the UART_CR3 register.
3. Enable the transmitter and receiver by setting the TEN and REN bits in the UART_CR2 register.

LIN header transmission

According to the LIN protocol, any communication on the LIN bus is triggered by the Master sending a Header, followed by the response. The Header is transmitted by the Master Task (master node) while the data are transmitted by the Slave task of a node (master node or one of the slave nodes).

Procedure without error monitoring:

1. Request Break + Delimiter transmission (13 dominant bits and 1 recessive bit) by setting the SBK bit in the UART_CR2 register.
2. Request Synch Field transmission by writing 0x55 in the UART_DR register.
3. Wait for the TC flag in the UART_SR register.
4. Request Identifier Field transmission by writing the protected identifier value in the UART_DR register.
5. Wait for the TC flag in the UART_SR register.

Procedure with error monitoring:

1. Request Break + Delimiter transmission (13 dominant bits and 1 recessive bit) by setting the SBK bit in the UART_CR2 register;
2. Wait for the LBDF flag in the UART_CR4 register.
3. Request Synch Field transmission by writing 0x55 into UART_DR register.
4. Wait for the RXNE flag in the UART_SR register and read back the UART_DR register.
5. Request Identifier Field transmission by writing the protected identifier value in the UART_DR register.
6. Wait for the RXNE flag in the UART_SR register and read back the UART_DR register.

The LBDF flag is set only if a valid Break + Delimiter has been received back on the UART_RX pin.

LIN break and delimiter detection

When the LIN mode is enabled, the break detection circuit is activated. The detection is totally independent from the normal UART receiver. A break can be detected whenever it occurs, during idle state or during a frame.

When the receiver is enabled (REN=1 in UART_CR2), the circuit looks at the UART_RX input for a start signal. The method for detecting start bits is the same when searching break characters or data. After a start bit has been detected, the circuit samples the next bits exactly like for the data (on the 8th, 9th and 10th samples). If 10 bits (when the LBDL = 0 in UART_CR4) or 11 bits (when LBDL=1 in UART_CR4) are detected as '0', and are followed by a delimiter character, the LBDF flag is set in UART_CR4. If the LBDIEN bit=1, an interrupt is generated.

If a '1' is sampled before the 10 or 11 have occurred, the break detection circuit cancels the current detection and searches for a start bit again. If LIN mode is disabled (LINEN=0), the receiver continues working as a normal UART, without taking into account the break detection.

If LIN mode is enabled (LINEN=1), as soon as a framing error occurs (i.e. stop bit detected at '0', which will be the case for any break frame), the receiver stops until the break detection circuit receives either a '1', if the break word was not complete, or a delimiter character if a break has been detected.

The behavior of the break detector state machine and the break flag is shown in [Figure 116: Break detection in LIN mode \(11-bit break length - LBDL bit is set\) on page 325](#).

The LBDF flag is used in master mode, in slave mode the LHDF flag is used instead.

Examples of break frames are given on [Figure 117: Break detection in LIN mode vs Framing error detection on page 325](#).

Figure 116. Break detection in LIN mode (11-bit break length - LBDL bit is set)

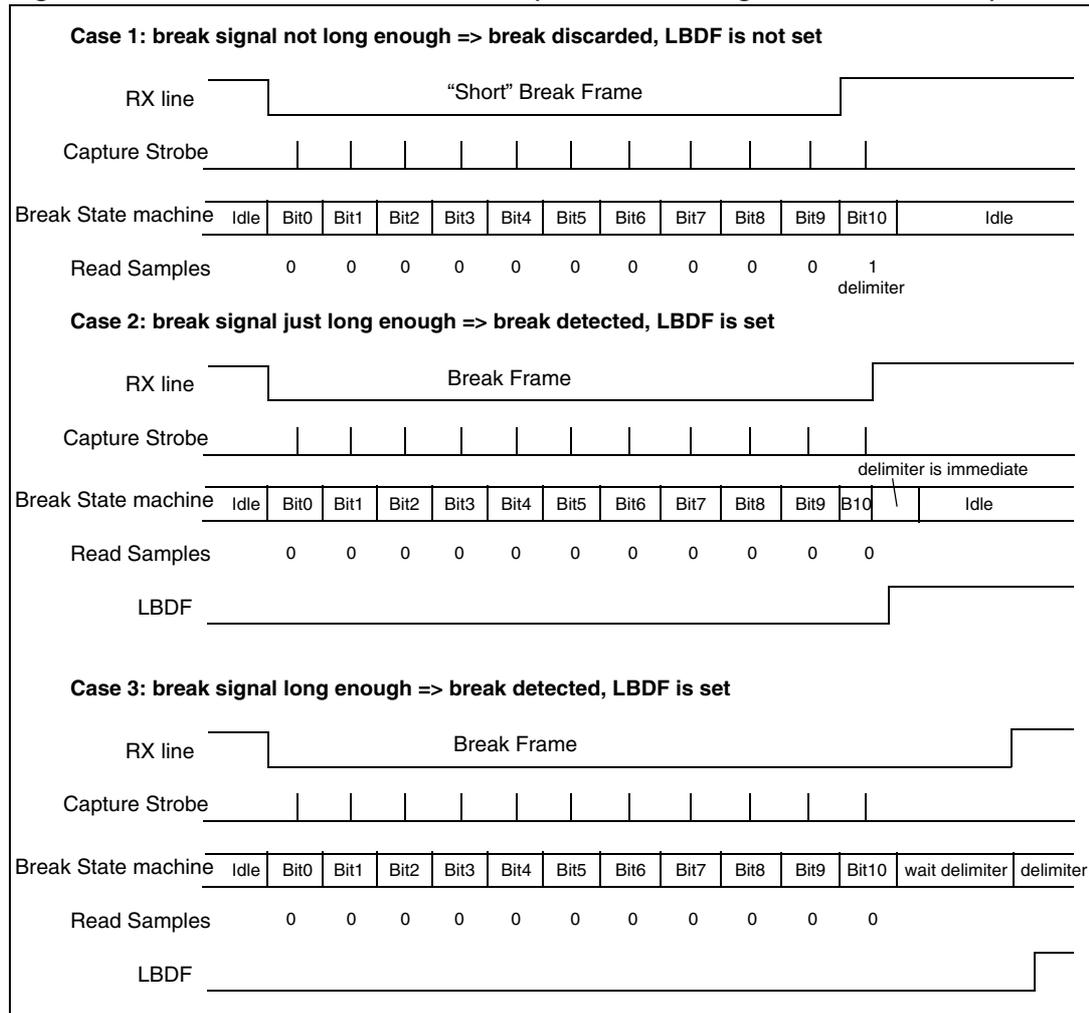
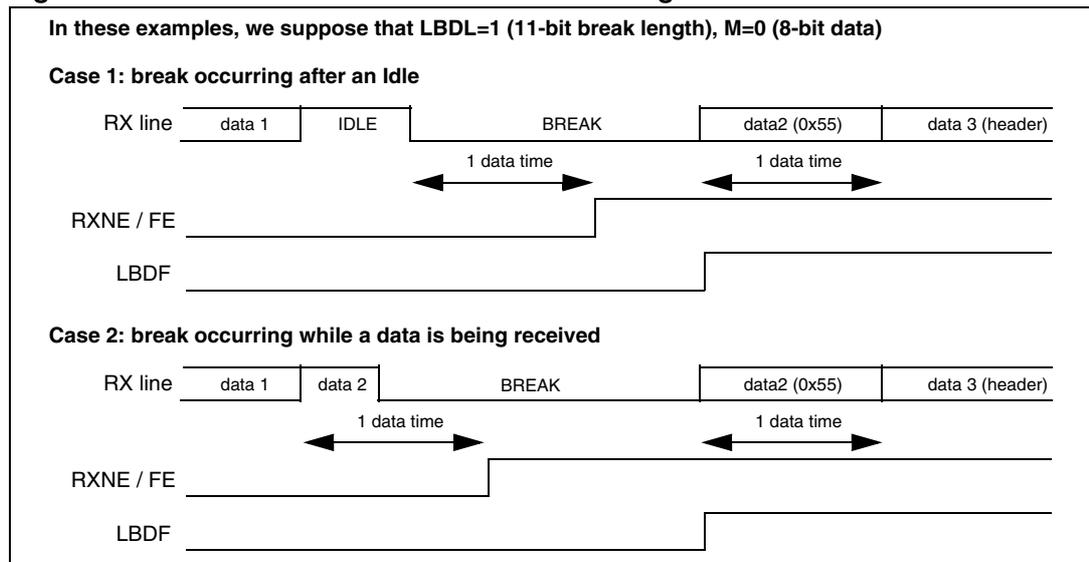


Figure 117. Break detection in LIN mode vs Framing error detection



Response transmission (master is the publisher of the response)

The response is composed of bytes with a standard UART format: 8-bit data, 1 stop bit, no parity.

In order to send n data bytes, the application must repeat the following sequence n times:

1. Write data in UART_DR register
2. Wait for RXNE flag in UART_SR register
3. Check for readback value by reading the UART_DR register

Response reception (master is the subscriber of the response)

In order to receive n data bytes, the application must repeat following sequence n times:

1. Wait for the RXNE flag in the UART_SR register
2. Read the UART_DR register

Discard Response (slave to slave communication)

In case of slave to slave communication and if the master does not need to check errors in the response, the application can ignore the RXNE flag till the next frame slot. The RXNE and OR flags should be cleared before starting the next Break transmission.

Note: Receiving back a Break will also set the RXNE and FE flags before setting the LBDF flag. Therefore, if the RX interrupt is used, it's better to disable it (by clearing the RIEN bit in the UART_CR2 register) before sending the Break, to avoid an additional interrupt. In case of slave to slave communication, RIEN bit can be cleared once the header has been transmitted.

22.4.2 Slave mode with automatic resynchronization disabled

Note: This feature is only available in UART2 and UART3.

UART initialization

Procedure:

1. Select the desired baudrate by programming UART_BRR2 and UART_BRR1 registers,
2. Enable transmitter and receiver by setting TEN and REN bits in UART_CR2 register,
3. Enable LSLV bit in UART_CR6 register,
4. Enable LIN mode by setting LINEN bit in UART_CR3 register,

LIN Header reception

According to the LIN protocol, a slave node must wait for a valid header, coming from the master node. Then application has to take following action, depending on the header Identifier value:

- Receive the response
- Transmit the response
- Ignore the response and wait for next header

When a LIN Header is received:

- The LHDF flag in the UART_CR6 register indicates that a LIN Header has been detected.
- An interrupt is generated if the LHDIEN bit in the UART_CR6 register is set.
- The LIN Identifier is available in the UART_DR register.

Note: It is recommended to put UART in mute mode by setting RWU bit. This mode allows detection of headers only and prevents the reception of any other characters.

Setting the PCEN bit in the UART_CR2 register while LIN is in slave mode enables the Identifier parity check. The PE flag in the UART_CR6 register is set together with the LHDF flag in the UART_CR6 register if the Identifier parity is not correct.

Response transmission (slave is the publisher of the response)

In order to send n data bytes, the application must repeat following sequence n times:

1. Write data in the UART_DR register
2. Wait for the RXNE flag in the UART_SR register
3. Check for readback value by reading the UART_DR register

Once response transmission is completed, software can set the RWU bit.

Response reception (slave is the subscriber of the response)

In order to receive n data bytes, the application must repeat following sequence n times:

1. Wait for the RXNE flag in the UART_SR register
2. Read the UART_DR register

Once response reception is completed, software can set the RWU bit.

Discard Response

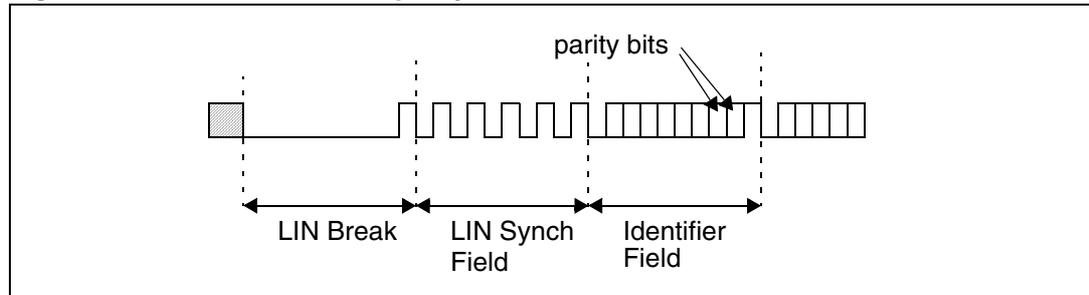
Software can set the RWU bit immediately.

LIN Slave parity

In LIN Slave mode (LINEN and LSLV bits are set) LIN parity checking can be enabled by setting the PCEN bit. An interrupt is generated if an ID parity error occurs (PE bit rises) and the PIEN bit is set.

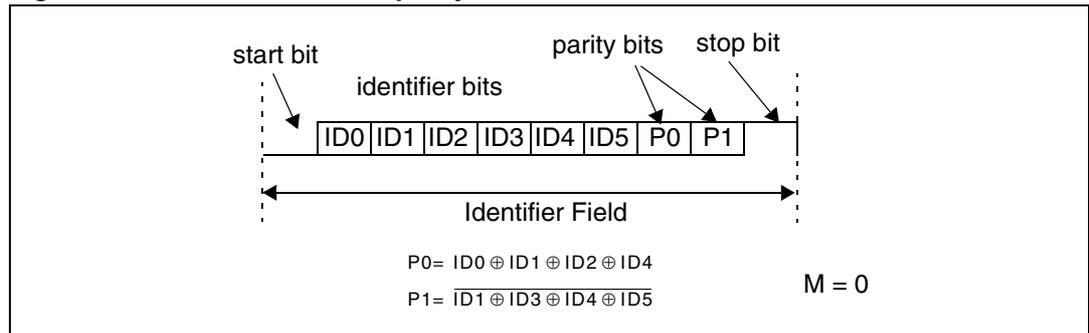
In this case, the parity bits of the LIN Identifier Field are checked. The identifier character is recognized as the third received character after a break character (included):

Figure 118. LIN identifier field parity bits



The bits involved are the two MSB positions (7th and 8th bits) of the identifier character. The check is performed as specified by the LIN specification:

Figure 119. LIN identifier field parity check



LIN header error detection

The LIN Header Error Flag indicates that an invalid LIN Header has been detected.

When a LIN Header Error occurs:

- The LHE flag is set
- An interrupt is generated if the RIEN bit in the UART_CR2 register is set.

The LHE bit is reset by an access to the UART_SR register followed by a read of the UART_DR register.

LHE is set if one of the following conditions occurs:

- Break Delimiter is too short
- Synch Field is different from 55h
- Framing error in Synch Field or Identifier Field
- A LIN header reception time-out

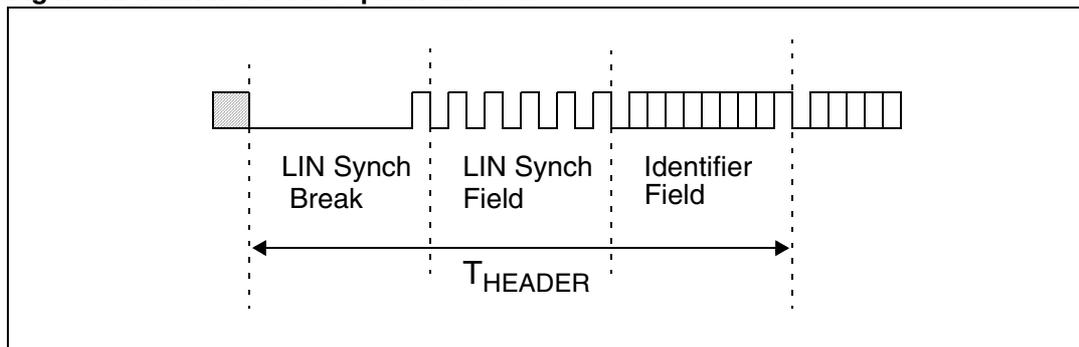
Note: If a LIN header error occurs, the LSF bit in the UART_CR6 register must be cleared by software

LIN header time-out error

The UART automatically monitors the THEADER_MAX condition given by the LIN protocol.

If the entire Header (up to and including the STOP bit of the LIN Identifier Field) is not received within the maximum time limit of 57 bit times then a LIN Header Error is signaled and the LHE bit is set in the UART_SR register.

Figure 120. LIN header reception time-out



The time-out counter is enabled at each break detection. It is stopped in the following conditions:

- A LIN Identifier Field has been received
- An LHE error occurred (other than a time-out error).
- A software reset of LSF bit (transition from high to low) occurred during the analysis of the LIN Synch Field

If LHE bit is set due to this error during the LIN Synch Field (if LASE bit = 1) then the UART goes into a blocked state (the LSF bit is set).

If LHE bit is set due to this error during Fields other than LIN Synch Field or if LASE bit is reset then the current received Header is discarded and the UART searches for a new Break Field.

Note on LIN Header time-out limit

According to the LIN specification, the maximum length of a LIN Header which does not cause a time-out is equal to:

$$1.4 * (34 + 1) = 49 \text{ TBIT_MASTER.}$$

TBIT_MASTER refers to the master baud rate.

When checking this time-out, the slave node is desynchronized for the reception of the LIN Break and Synch fields. Consequently, a margin must be allowed, taking into account the worst case: This occurs when the LIN identifier lasts exactly 10 TBIT_MASTER periods. In this case, the LIN Break and Synch fields last 49 - 10 = 39 TBIT_MASTER periods.

Assuming the slave measures these first 39 bits with a desynchronized clock of 15.5%. This leads to a maximum allowed Header Length of:

$$\begin{aligned} &39 \times (1/0.845) \text{ TBIT_MASTER} + 10 \text{ TBIT_MASTER} \\ &= 56.15 \text{ TBIT_SLAVE} \end{aligned}$$

A margin is provided so that the time-out occurs when the header length is greater than 57 TBIT_SLAVE periods. If it is less than or equal to 57 TBIT_SLAVE periods, then no time-out occurs.

Mute mode and errors

In mute mode, if an LHE error occurs during the analysis of the LIN Synch Field or if a LIN Header Time-out occurs then the LHE bit is set but it does not wake up from mute mode. In this case, the current header analysis is discarded. If needed, the software has to reset the LSF bit. Then the UART searches for a new LIN header.

In mute mode, if a framing error occurs on a data (which is not a break), it is discarded and the FE bit is not set.

Any LIN header which respects the following conditions causes a wake-up from mute mode:

- A valid LIN Break and Delimiter
- A valid LIN Synch Field (without deviation error)
- A LIN Identifier Field without framing error. Note that a LIN parity error on the LIN Identifier Field does not prevent wake-up from mute mode.
- No LIN Header Time-out should occur during Header reception.

22.4.3 Slave mode with automatic resynchronization enabled

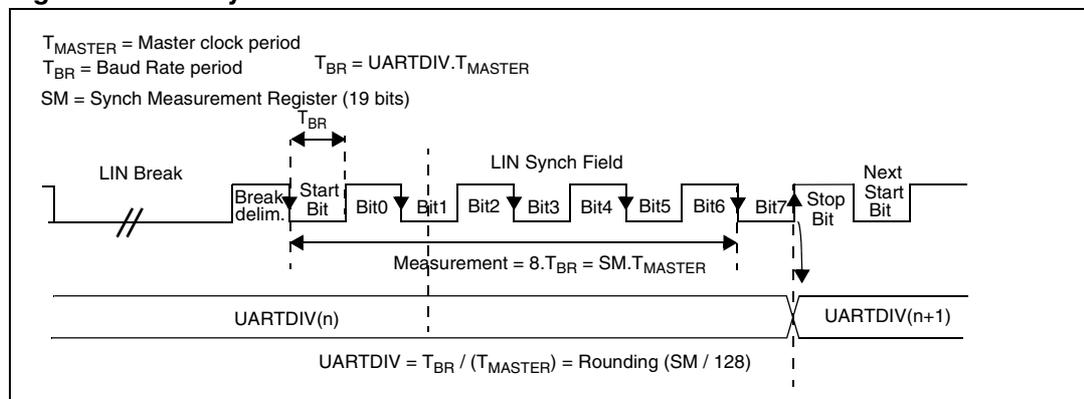
This mode is similar to slave mode as described in [Section 22.4.2: Slave mode with automatic resynchronization disabled](#), with the addition of automatic resynchronization enabled by the LASE bit. In this mode UART adjusts the baudrate generator after each Synch Field reception.

Note: This feature is only available in UART2 and UART3.

Automatic resynchronization

When automatic resynchronization is enabled, after each LIN Break, the time duration between 5 falling edges on RDI is sampled on f_MASTER and the result of this measurement is stored in an internal 19-bit register called SM (not user accessible) (See [Figure 121](#)). Then the UARTDIV value (and its associated BRR1 and BRR2 registers) are automatically updated at the end of the fifth falling edge. During LIN Synch field measurement, the UART state machine is stopped and no data is transferred to the data register.

Figure 121. LIN synch field measurement



UARTDIV is an unsigned integer, coded in the BRR1 and BRR2 registers as shown in [Figure 105](#).

If LASE bit = 1 then UARTDIV is automatically updated at the end of each LIN Synch Field.

Three registers are used internally to manage the auto-update of the LIN divider (UARTDIV):

- UARTDIV_NOM (nominal value written by software at UART_BRR1 and UART_BRR2 addresses)
- UARTDIV_MEAS (results of the Field Synch measurement)
- UARTDIV (used to generate the local baud rate)

The control and interactions of these registers are explained in [Figure 122](#) and [Figure 123](#). They depend on the LDUM bit setting (LIN Divider Update Method)

As explained in [Figure 122](#) and [Figure 123](#), UARTDIV can be updated by two concurrent actions: a transfer from UARTDIV_MEAS at the end of the LIN Sync Field and a transfer from UARTDIV_NOM due to a software write to BRR1. If both operations occur at the same time, the transfer from UARTDIV_NOM has priority.

Figure 122. UARTDIV read / write operations when LDUM = 0

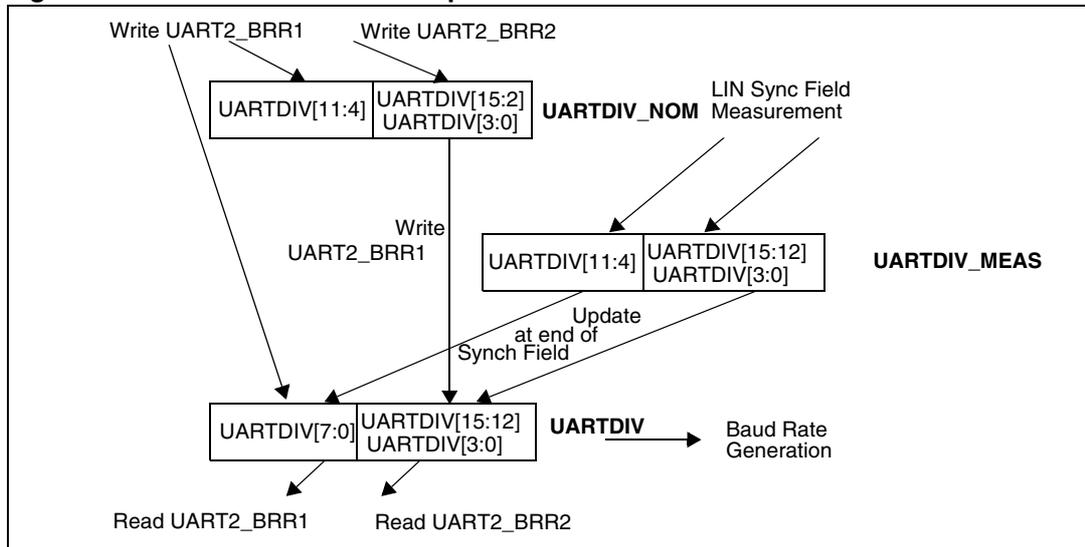
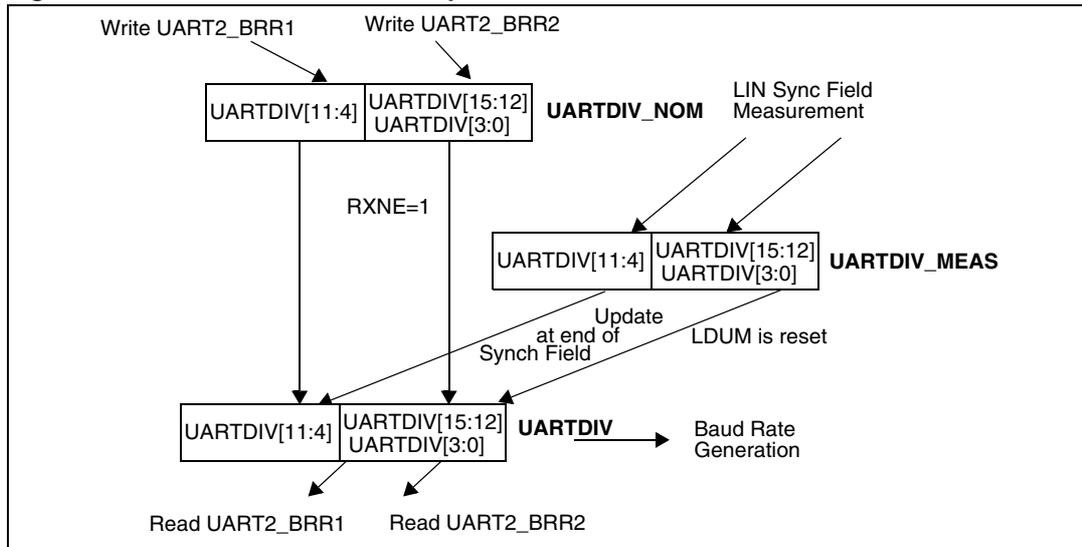


Figure 123. UARTDIV read / write operations when LDUM = 1



Deviation error on the synch field

The deviation error is checked by comparing the current baud rate (relative to the slave oscillator) with the received LIN Synch Field (relative to the master oscillator). Two checks are performed in parallel.

The first check is based on a measurement between the first falling edge and the last falling edge of the Synch Field.

- If $D1 > 14.84\%$ LHE is set
- If $D1 < 14.06\%$ LHE is not set
- If $14.06\% < D1 < 14.84\%$ LHE can be either set or reset depending on the dephasing between the signal on UART_RX pin and the f_{MASTER} clock

The second check is based on a measurement of time between each falling edge of the Synch Field

- If $D2 > 18.75\%$ LHE is set
- If $D2 < 15.62\%$ LHE is not set
- If $15.62\% < D2 < 18.75\%$ LHE can be either set or reset depending on dephasing between the signal on UART_RX pin and the f_{MASTER} clock

Note that the UART does not need to check if the next edge occurs slower than expected. This is covered by the check for deviation error on the full synch byte.

Note: Deviation checking is based on the current baudrate and not on the nominal one. Therefore, in order to guarantee correct deviation checking, the baudrate generator must reload the nominal value before each new Break reception. This nominal value is programmed by the

application during initialization. To do this software must set the LDUM bit before checksum reception.

If LDUM bit is set, the next character reception will automatically reload the baudrate generator with nominal value.

You can also reload the nominal value by writing to BRR2 and BRR1. This second method is typically used when an error occurs during response transmission or reception.

If for any reason, the LDUM bit is set when UART is receiving a new Break and a Synch Field, this bit will be ignored and cleared. UART will adjust the baudrate generator with a value calculated from the synch field.

LIN header error detection

LHE is set if one of the following conditions occurs:

- Break Delimiter is too short
- Deviation error on the Synch Field is outside the LIN specification which allows up to +/-14% of period deviation between the slave and master oscillators.
- Framing error in Synch Field or Identifier Field
- A LIN header reception time-out
- An overflow during the Synch Field Measurement, which leads to an overflow of the divider registers

LIN header time-out error

The description in the section [LIN header time-out error on page 329](#) applies also when automatic resynchronization is enabled.

UART clock tolerance when synchronized

When synchronization has been performed, following reception of a LIN Break, the UART has the same clock deviation tolerance as in UART mode, which is explained below:

During reception, each bit is oversampled 16 times. The mean of the 8th, 9th and 10th samples is considered as the bit value.

Consequently, the clock frequency should not vary more than 6/16 (37.5%) within one bit.

The sampling clock is resynchronized at each start bit, so that when receiving 10 bits (one start bit, 1 data byte, 1 stop bit), the clock deviation should not exceed 3.75%.

UART clock tolerance when unsynchronized

When LIN slaves are unsynchronized (meaning no characters have been transmitted for a relatively long time), the maximum tolerated deviation of the UART clock is +/-14%.

If the deviation is within this range then the LIN Break is detected properly when a new reception occurs.

This is made possible by the fact that masters send 13 low bits for the LIN Break, which can be interpreted as 11 low bits ($13 \text{ bits} \cdot -14\% = 11.18$) by a "fast" slave and then considered as a LIN Break. According to the LIN specification, a LIN Break is valid when its duration is greater than $t_{\text{SBRKTS}} = 10$. This means that the LIN Break must last at least 11 low bits.

If the period desynchronization of the slave is +14% (slave too slow), the character "00h" which represents a sequence of 9 low bits must not be interpreted as a break character ($9 \text{ bits} + 14\% = 10.26$). Consequently, a valid LIN break must last at least 11 low bits.

Clock deviation causes

The causes which contribute to the total deviation are:

- DTRA: Deviation due to transmitter error. Note: the transmitter can be either a master or a slave (in case of a slave listening to the response of another slave).
- DMEAS: Error due to the LIN Synch measurement performed by the receiver.
- DQUANT: Error due to the baud rate quantization of the receiver.
- DREC: Deviation of the local oscillator of the receiver: This deviation can occur during the reception of one complete LIN message assuming that the deviation has been compensated at the beginning of the message.
- DTCL: Deviation due to the transmission line (generally due to the transceivers)
- All the deviations of the system should be added and compared to the UART clock tolerance:
 - $DTRA + DMEAS + DQUANT + DREC + DTCL < 3.75\%$

Error due to LIN synch measurement

The LIN Synch Field is measured over eight bit times.

This measurement is performed using a counter clocked by the CPU clock. The edge detections are performed using the CPU clock cycle.

This leads to a precision of 2 CPU clock cycles for the measurement which lasts $8 \times \text{UARTDIV}$ clock cycles.

Consequently, this error (DMEAS) is equal to:

$$2 / (8 \times \text{UARTDIVMIN})$$

UARTDIVMIN corresponds to the minimum LIN prescaler content, leading to the maximum baud rate, taking into account the maximum deviation of +/-14%.

Error due to baud rate quantization

The baud rate can be adjusted in steps of $1 / (\text{UARTDIV})$. The worst case occurs when the "real" baud rate is in the middle of the step.

This leads to a quantization error (DQUANT) equal to $1 / (2 \times \text{UARTDIVMIN})$.

Impact of clock deviation on maximum baud rate

The choice of the nominal baud rate (UARTDIVNOM) will influence both the quantization error (DQUANT) and the measurement error (DMEAS). The worst case occurs for UARTDIVMIN.

Consequently, at a given CPU frequency, the maximum possible nominal baud rate (LPRMIN) should be chosen with respect to the maximum tolerated deviation given by the equation:

$$DTRA + 1 / (2 \times \text{UARTDIVMIN}) + DREC + DTCL < 3.75\%$$

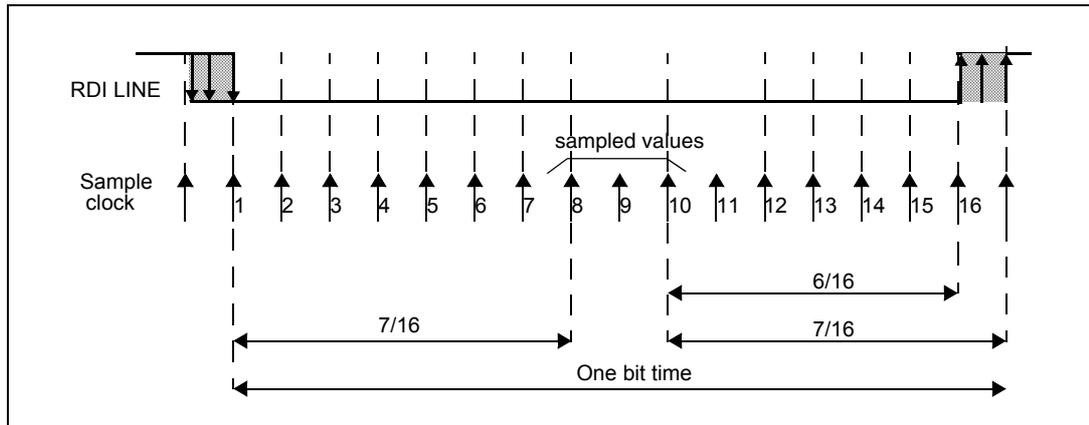
Example:

A nominal baud rate of 20 Kbits/s at $T_{CPU} = 125 \text{ ns}$ (8 MHz) leads to $\text{UARTDIVNOM} = 25d$.

$$\text{UARTDIVMIN} = 25 - 0.15 \times 25 = 21.25$$

$$DQUANT = 1 / (2 \times \text{UARTDIVMIN}) = 0.0015\%$$

Figure 124. Bit sampling in reception mode



22.4.4 LIN mode selection

Table 51. LIN mode selection

LINE	LSLV	LASE	Meaning
0	0	0	LIN mode disabled
1	1	0	LIN Master Mode
		1	LIN Slave Mode with Automatic resynchronization disabled
		1	LIN Slave Mode with Automatic resynchronization enabled

22.5 UART low power modes

Table 52. UART interface behavior in low power modes

Mode	Description
WAIT	No effect on UART. UART interrupts cause the device to exit from Wait mode.
HALT	UART registers are frozen. In Halt mode, the UART stops transmitting/receiving until Halt mode is exited.

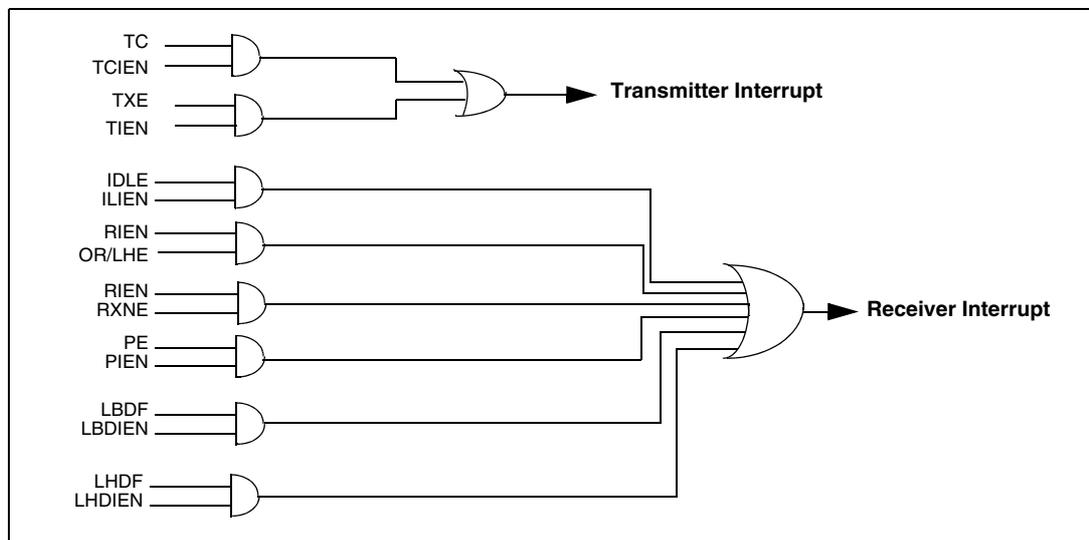
22.6 UART interrupts

Table 53. UART interrupt requests

Interrupt event	Event flag	Enable control bit	Exit from Wait	Exit from Halt
Transmit data register empty	TXE	TIEN	Yes	No
Transmission complete	TC	TCIEN	Yes	No
Received data ready to be read	RXNE	RIEN	Yes	No
Overrun error detected / LIN header error	OR/LHE		Yes	No
Idle line detected	IDLE	ILIEEN	Yes	No
Parity error	PE	PIEN	Yes	No
Break flag	LBDF	LBDIEN	Yes	No
Header Flag	LHDF	LHDIEN	Yes	No

- Note:*
- 1 The UART interrupt events are connected to two interrupt vectors (see [Figure 125](#)).
 - a) Transmission Complete or Transmit Data Register empty interrupt.
 - b) Idle Line detection, Overrun error, Receive Data register full, Parity error interrupt, and Noise Flag.
 - 2 These events generate an interrupt if the corresponding Enable Control Bit is set and the interrupt mask in the CC register is reset (RIM instruction).

Figure 125. UART interrupt mapping diagram



22.7 UART registers

22.7.1 Status register (UART_SR)

Address offset: 0x00

Reset value: 0xC0

7	6	5	4	3	2	1	0
TXE	TC	RXNE	IDLE	OR/LHE	NF	FE	PE
r	rc_w0	rc_w0	r	r	r	r	r

Bit 7 TXE: Transmit data register empty

This bit is set by hardware when the content of the TDR register has been transferred into the shift register. An interrupt is generated if the TIEN bit =1 in the UART_CR2 register. It is cleared by a write to the UART_DR register.

- 0: Data is not transferred to the shift register
- 1: Data is transferred to the shift register

Bit 6 TC: Transmission complete

This bit is set by hardware when transmission of a frame containing Data is complete. An interrupt is generated if TCIEN=1 in the UART_CR2 register. It is cleared by a software sequence (a read to the UART_SR register followed by a write to the UART_DR register). In UART2 and UART3, it can also be cleared by writing 0.

- 0: Transmission is not complete
- 1: Transmission is complete

Bit 5 RXNE: Read data register not empty

This bit is set by hardware when the content of the RDR shift register has been transferred to the UART_DR register. An interrupt is generated if RIEN=1 in the UART_CR2 register. It is cleared by a read to the UART_DR register. In UART2 and UART3, it can also be cleared by writing 0.

- 0: Data is not received
- 1: Received data is ready to be read.

Bit 4 IDLE: IDLE line detected ⁽¹⁾

This bit is set by hardware when an Idle Line is detected. An interrupt is generated if the ILIEN=1 in the UART_CR2 register. It is cleared by a software sequence (a read to the UART_SR register followed by a read to the UART_DR register).

- 0: No Idle Line is detected
- 1: Idle Line is detected

Bit 3 OR: Overrun error⁽²⁾

This bit is set by hardware when the word currently being received in the shift register is ready to be transferred into the RDR register while RXNE=1. An interrupt is generated if RIEN=1 in the UART_CR2 register. It is cleared by a software sequence (a read to the UART_SR register followed by a read to the UART_DR register).

- 0: No Overrun error
- 1: Overrun error is detected

LHE LIN Header Error (LIN slave mode)

During LIN Header reception, this bit signals three error types:

- Break delimiter too short
- Synch Field error
- Deviation error (if LASE=1)
- Identifier framing error

- 0: No LIN Header error
- 1: LIN Header error detected

Bit 2 NF: Noise flag⁽³⁾

This bit is set by hardware when noise is detected on a received frame. It is cleared by a software sequence (a read to the UART_SR register followed by a read to the UART_DR register).

- 0: No noise is detected
- 1: Noise is detected

Bit 1 FE: Framing error⁽⁴⁾

This bit is set by hardware when a de-synchronization, excessive noise or a break character is detected. It is cleared by a software sequence (a read to the UART_SR register followed by a read to the UART_DR register).

- 0: No Framing error is detected
- 1: Framing error or break character is detected

Bit 0 PE: Parity error

This bit is set by hardware when a parity error occurs in receiver mode. It is cleared by a software sequence (a read to the status register followed by a read to the UART_DR data register). You have to wait for the RXNE flag to be set before clearing it. An interrupt is generated if PIEN=1 in the UART_CR1 register.

- 0: No parity error
- 1: Parity error (or, in LIN slave mode, identifier parity error)

1. The IDLE bit will not be set again until the RXNE bit has been set itself (i.e. a new idle line occurs)
2. When this bit is set, the RDR register content will not be lost but the shift register will be overwritten.
3. This bit does not generate interrupt as it appears at the same time as the RXNE bit which itself generates an interrupt.
4. This bit does not generate interrupt as it appears at the same time as the RXNE bit which itself generates an interrupt. If the word currently being transferred causes both frame error and overrun error, it will be transferred and only the OR bit will be set.

22.7.2 Data register (UART_DR)

Address offset: 0x01

Reset value: Undefined

7	6	5	4	3	2	1	0
DR[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **DR[7:0]**: Data value

Contains the Received or Transmitted data character, depending on whether it is read from or written to.

The Data register performs a double function (read and write) since it is composed of two registers, one for transmission (TDR) and one for reception (RDR)

The TDR register provides the parallel interface between the internal bus and the output shift register.

The RDR register provides the parallel interface between the input shift register and the internal bus.

22.7.3 Baud rate register 1 (UART_BRR1)

The Baud Rate Registers are common to both the transmitter and the receiver. The baud rate is programmed using two registers BRR1 and BRR2. Writing of BRR2 (if required) should precede BRR1, since a write to BRR1 will update the baud counters.

See [Figure 105: How to code UART_DIV in the BRR registers on page 312](#) and [Table 49: Baud rate programming and error calculation on page 313](#)

Note: 1 The baud counters stop counting if the TEN or REN bits are disabled respectively.

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
UART_DIV[11:4]							
rw	rw	rw	rw	-	rw	rw	rw

Bits 7:0 **UART_DIV[11:4]** UART_DIV bits ⁽¹⁾

These 8 bits define the 2nd and 3rd nibbles of the 16-bit UART divider (UART_DIV).

1. BRR1 = 00h means UART clock is disabled.

22.7.4 Baud rate register 2 (UART_BRR2)

Address offset: 0x03

Reset value: 0x00

7	6	5	4	3	2	1	0
UART_DIV[15:12]				UART_DIV[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:4 **UART_DIV[15:12]**: MSB of UART_DIV.

These 4 bits define the MSB of the UART Divider (UART_DIV)

Bits 3:0 **UART_DIV[3:0]**: LSB of UART_DIV.

These 4 bits define the LSB of the UART Divider (UART_DIV)

22.7.5 Control register 1 (UART_CR1)

Address offset: 0x04

Reset value: 0x00

7	6	5	4	3	2	1	0
R8	T8	UARTD	M	WAKE	PCEN	PS	PIEN
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **R8**: *Receive Data bit 8.*

This bit is used to store the 9th bit of the received word when M=1

Bit 6 **T8**: *Transmit data bit 8.*

This bit is used to store the 9th bit of the transmitted word when M=1

Bit 5 **UARTD**: *UART Disable (for low power consumption).*

When this bit is set the UART prescaler and outputs are stopped at the end of the current byte transfer in order to reduce power consumption. This bit is set and cleared by software.

0: UART enabled

1: UART prescaler and outputs disabled

Bit 4 **M**: *word length.*

This bit determines the word length. It is set or cleared by software.

0: 1 Start bit, 8 Data bits, n Stop bit (n depending on STOP[1:0] bits in the UART_CR3 register)

1: 1 Start bit, 9 Data bits, 1 Stop bit

Note: The M bit must not be modified during a data transfer (both transmission and reception) In LIN slave mode, the M bit and the STOP[1:0] bits in the UART_CR3 register should be kept at 0.

Bit 3 **WAKE**: *Wakeup method.*

This bit determines the UART wakeup method, it is set or cleared by software.

0: Idle Line

1: Address Mark

Bit 2 **PCEN**: Parity control enable.

- **UART Mode**

This bit selects the hardware parity control (generation and detection). When the parity control is enabled, the computed parity is inserted at the MSB position (9th bit if M=1; 8th bit if M=0) and parity is checked on the received data. This bit is set and cleared by software. Once it is set, PCEN is active after the current byte (in reception and in transmission).

- 0: Parity control disabled
- 1: Parity control enabled

- **LIN slave mode**

This bit enables the LIN identifier parity check while the UART is in LIN slave mode.

- 0: Identifier parity check disabled
- 1: Identifier parity check enabled

Bit 1 **PS**: Parity selection.

This bit selects the odd or even parity when the parity generation/detection is enabled (PCEN bit set) in UART mode. It is set and cleared by software. The parity will be selected after the current byte.

- 0: Even parity
- 1: Odd parity

Bit 0 **PIEN**: Parity interrupt enable.

This bit is set and cleared by software.

- 0: Parity interrupt disabled
- 1: Parity interrupt is generated whenever PE=1 in the UART_SR register

22.7.6 Control register 2 (UART_CR2)

Address offset: 0x05

Reset value: 0x00

7	6	5	4	3	2	1	0
TIEN	TCIEN	RIEN	ILIEN	TEN	REN	RWU	SBK
rw	rw	rw	rw	rw	rw	rw	rw

Bit 7 **TIEN**: Transmitter interrupt enable

This bit is set and cleared by software.

- 0: Interrupt is inhibited
- 1: An UART interrupt is generated whenever TXE=1 in the UART_SR register

Bit 6 **TCIEN**: Transmission complete interrupt enable

This bit is set and cleared by software.

- 0: Interrupt is inhibited
- 1: An UART interrupt is generated whenever TC=1 in the UART_SR register

Bit 5 **RIEN**: Receiver interrupt enable

This bit is set and cleared by software.

- 0: Interrupt is inhibited
- 1: An UART interrupt is generated whenever OR=1 or RXNE=1 in the UART_SR register

Bit 4 **ILIEN**: IDLE Line interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: An UART interrupt is generated whenever IDLE=1 in the UART_SR register

Bit 3 **TEN**: Transmitter enable ⁽¹⁾ ⁽²⁾

This bit enables the transmitter. It is set and cleared by software.

0: Transmitter is disabled

1: Transmitter is enabled

Bit 2 **REN**: Receiver enable

This bit enables the receiver. It is set and cleared by software.

0: Receiver is disabled

1: Receiver is enabled and begins searching for a start bit

Bit 1 **RWU**: Receiver wakeup

- **UART Mode**

This bit determines if the UART is in mute mode or not. It is set and cleared by software and can be cleared by hardware when a wakeup sequence is recognized.⁽³⁾ ⁽⁴⁾

- **LIN mode**

While LIN is used in slave mode, setting the RWU bit allows the detection of Headers only and prevents the reception of any other characters. Refer to [Mute mode and errors on page 330](#). In LIN slave mode, when RDRF is set, the software can not set or clear the RWU bit.

0: Receiver in active mode

1: Receiver in mute mode

Bit 0 **SBK**: Send break

This bit set is used to send break characters. It can be set and cleared by software. It should be set by software, and will be reset by hardware during the stop bit of break.

0: No break character is transmitted

1: Break character will be transmitted

1. During transmission, a “0” pulse on the TEN bit (“0” followed by “1”) sends a preamble (idle line) after the current word.
2. When TEN is set there is a 1 bit-time delay before the transmission starts.
3. Before selecting Mute mode (by setting the RWU bit) the UART must first receive a data byte, otherwise it cannot function in Mute mode with wakeup by Idle line detection.
4. In Address Mark Detection wakeup configuration (WAKE bit=1) the RWU bit cannot be modified by software while the RXNE bit is set.

22.7.7 Control register 3 (UART_CR3)

Address offset: 0x06

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	LINEN	STOP[1:0]		CLKEN	CPOL	CPHA	LBCL
	rw	rw	rw	rw	rw	rw	rw

Bit 7 **Reserved**, must be kept cleared.

Bit 6 **LINEN**: LIN mode enable

This bit is set and cleared by software.

0: LIN mode disabled

1: LIN mode enabled

Bits 5:4 **STOP**: STOP bits.

These bits are used for programming the stop bits.

00: 1 Stop bit

01: Reserved

10: 2 Stop bits

11: 1.5 Stop bits

Note: For LIN slave mode, both bits should be kept cleared.

Bit 3 **CLKEN**: Clock enable

This bit allows the user to enable the SCLK pin.

0: SLK pin disabled

1: SLK pin enabled

Note: This bit is not available for UART3.

Bit 2 **CPOL**: Clock polarity ⁽¹⁾

This bit allows the user to select the polarity of the clock output on the SCLK pin. It works in conjunction with the CPHA bit to produce the desired clock/data relationship

0: SCK to 0 when idle

1: SCK to 1 when idle.

Note: This bit is not available for UART3.

Bit 1 **CPHA**: Clock phase ⁽¹⁾

This bit allows the user to select the phase of the clock output on the SCLK pin. It works in conjunction with the CPOL bit to produce the desired clock/data relationship

0: The first clock transition is the first data capture edge

1: The second clock transition is the first data capture edge

Note: This bit is not available for UART3.

1. These 3 bits (CPOL, CPHA, LBCL) should not be written while the transmitter is enabled.

Bit 0 **LBCL**: Last bit clock pulse.⁽¹⁾⁽¹⁾

This bit allows the user to select whether the clock pulse associated with the last data bit transmitted (MSB) has to be output on the SCLK pin.

0: The clock pulse of the last data bit is not output to the SCLK pin.

1: The clock pulse of the last data bit is output to the SCLK pin.

Note: This bit is not available for UART3.

1. The last bit is the 8th or 9th data bit transmitted depending on the 8 or 9 bit format selected by the M bit in the UART_CR1 register.

22.7.8 Control register 4 (UART_CR4)

Address offset: 0x07

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	LBDIEN	LBDL	LBDF	ADD[3:0]			
	rw	rw	rw	rw	rw	rw	rw

Bit 7 **Reserved**, must be kept cleared.

Bit 6 **LBDIEN**: LIN Break Detection Interrupt Enable.

Break interrupt mask (break detection using break delimiter).

0: LIN break detection interrupt disabled

1: LIN break detection interrupt enabled

Bit 5 **LBDL**: LIN Break Detection Length.

This bit is for selection between 11 bit or 10 bit break detection.

0: 10 bit break detection

1: 11 bit break detection

Bit 4 **LBDF**: LIN Break Detection Flag.

LIN Break Detection Flag (Status flag)

This bit is set by hardware and cleared by software writing 0.

0: LIN Break not detected

1: LIN Break detected

An interrupt is generated when LBDF=1 if LBDIEN=1

Bits 3:0 **ADD[3:0]**: Address of the UART node.

This bit-field gives the address of the UART node.

This is used in multi-processor communication during mute mode, for wakeup with address mark detection.

22.7.9 Control register 5 (UART_CR5)

Address offset: 0x08

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved		SCEN	NACK	HDSEL	IRLP	IREN	Reserved
		r	r	rw	rw	rw	

Bits 7:6 Reserved, must be kept cleared.

Bit 5 **SCEN**: Smartcard mode enable.

This bit is used for enabling Smartcard mode.

0: Smartcard Mode disabled

1: Smartcard Mode enabled

Note: This bit is not available for UART3.

Bit 4 **NACK**: Smartcard NACK enable

0: NACK transmission in case of parity error is disabled

1: NACK transmission during parity error is enabled.

Note: This bit is not available for UART3.

Bit 3 **HDSEL**: Half-Duplex Selection

Selection of Single-wire Half-duplex mode

0: Half duplex mode is not selected

1: Half duplex mode is selected

Note: This bit is not available for UART2 and UART3.

Bit 2 **IRLP**: IrDA Low Power

This bit is used for selected between normal and Low power IrDA mode

0: Normal mode

1: Low power mode

Note: This bit is not available for UART3.

Bit 1 **IREN**: IrDA mode Enable

This bit is set and cleared by software.

0: IrDA disabled

1: IrDA enabled

Note: This bit is not available for UART3.

Bit 0 Reserved, must be kept cleared.

22.7.10 Control register 6 (UART_CR6)

Address offset: 0x09

Reset value: 0x00

7	6	5	4	3	2	1	0
LDUM	Reserved	LSLV	LASE	Reserved	LHDIEN	LHDF	LSF
rw		rw	rw		rw	rc_w0	rc_w0

Note: This register is not available for UART1.

Bit 7 LDUM: LIN Divider Update Method

0: LDIV is updated as soon as BRR1 is written (if no automatic resynchronization update occurs at the same time).

1: LDIV is updated at the next received character (when RXNE=1) after a write to the BRR1 register. LDIV is coded using the two register BRR1 and BRR2

This bit is reset by hardware once LDIV is updated with the measured baud rate at the end of the synch field.

Bit 6 Reserved

Bit 5 LSLV: LIN Slave Enable

0: LIN Master Mode

1: LIN Slave Mode

Bit 4 LASE: LIN automatic resynchronisation enable

0: LIN automatic resynchronization disabled

1: LIN automatic resynchronization enabled

Bit 3 Reserved

Bit 2 LHDIEN: LIN Header Detection Interrupt Enable.

Header interrupt mask.

0: LIN header detection interrupt disabled

1: LIN header detection interrupt enabled

Bit 1 LHDF: LIN Header Detection Flag.

This bit is set by hardware when a LIN header is detected in LIN slave mode and cleared by software writing 0.

0: LIN Header not detected

1: LIN Header detected (Break+Sync+Ident)

An interrupt is generated when LHDF=1 if LHDIEN=1

Bits 0 LSF: LIN Sync Field

This bit indicates that the LIN Synch Field is being analyzed. It is only used in LIN Slave mode. In automatic resynchronization mode (LASE bit=1), when the UART is in the LIN Synch Field State it waits or counts the falling edges on the RDI line.

It is set by hardware as soon as a LIN Break is detected and cleared by hardware when the LIN Synch Field analysis is finished. This bit can also be cleared by software writing 0 to exit LIN Synch State and return to idle mode.

0: The current character is not the LIN Synch Field

1: LIN Synch Field State (LIN Synch Field undergoing analysis)

22.7.11 Guard time register (UART_GTR)

Address offset: 0x09 (UART1), 0x0A (UART2)

Reset value: 0x00

7	6	5	4	3	2	1	0
GT[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **GT[7:0]**: Guard time value.

This register gives the Guard time value in terms of number of baud clocks.

This is used in Smartcard mode. The Transmission Complete flag is set after this guard time value.

Note: These bits are not available for UART3.

22.7.12 Prescaler register (UART_PSCR)

Address offset: 0x0A (UART1), 0x0B (UART2)

Reset value: 0x00

Note: Care must be taken to program this register with correct value, when both Smartcard and IrDA interfaces are used in the application

7	6	5	4	3	2	1	0
PSC[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **PSC[7:0]**: *Prescaler value.*

- **In IrDA Low Power mode**

PSC[7:0] = IrDA Low Power Baud Rate ⁽¹⁾

Used for programming the prescaler for dividing the system clock to achieve the low power frequency:

The source clock is divided by the value given in the register (8 significant bits):

0000 0000: Reserved - do not program this value

0000 0001: divides the source clock by 1

0000 0010: divides the source clock by 2

...

- **In Smartcard mode**

PSC[4:0]: Prescaler value. ⁽²⁾ ⁽³⁾

Used for programming the prescaler for dividing the system clock to provide the smartcard clock.

The value given in the register (5 significant bits) is multiplied by 2 to give the division factor of the source clock frequency:

0 0000: Reserved - do not program this value

0 0001: divides the source clock by 2

0 0010: divides the source clock by 4

0 0011: divides the source clock by 6

...

Note: These bits are not available for UART3.

1. This prescaler setting has no effect if IrDA mode is not enabled.
2. This prescaler setting has no effect if Smartcard mode is not enabled.
3. Bits [7:5] have no effect even if Smartcard mode is enabled.

22.7.13 UART register map and reset values

Table 54. UART1 register map

Address	Register name	7	6	5	4	3	2	1	0	
0x00	UART1_SR Reset Value	TXE 1	TC 1	RXNE 0	IDLE 0	OR 0	NF 0	FE 0	PE 0	
0x01	UART1_DR Reset Value	DR7 x	DR6 x	DR5 x	DR4 x	DR3 x	DR2 x	DR1 x	DR0 x	
0x02	UART1_BRR1 Reset Value	UART_DIV[11:4] 00000000								
0x03	UART1_BRR2 Reset Value	UART_DIV[15:12] 0000				UART_DIV[3:0] 0000				
0x04	UART1_CR1 Reset Value	R8 0	T8 0	UARTD 0	M 0	WAKE 0	PCEN 0	PS 0	PIEN 0	
0x05	UART1_CR2 Reset Value	TIEN 0	TCIEN 0	RIEN 0	ILIEN 0	TEN 0	REN 0	RWU 0	SBK 0	
0x06	UART1_CR3 Reset Value	- 0	LINEN 0	STOP 00		CKEN 0	CPOL 0	CPHA 0	LBCL 0	
0x07	UART1_CR4 Reset Value	- 0	LBDIEN 0	LBDL 0	LBDF 0	ADD[3:0] 0000				
0x08	UART1_CR5 Reset Value	- 0	- 0	SCEN 0	NACK 0	HDSEL 0	IRLP 0	IREN 0	0	
0x09	UART1_GTR Reset Value	GT7 0	GT6 0	GT5 0	GT4 0	GT3 0	GT2 0	GT1 0	GT0 0	
0x0A	UART1_PSCR Reset Value	PSC7 0	PSC6 0	PSC5 0	PSC4 0	PSC3 0	PSC2 0	PSC1 0	PSC0 0	

Table 55. UART2 register map

Address	Register name	7	6	5	4	3	2	1	0	
0x00	UART2_SR Reset Value	TXE 1	TC 1	RXNE 0	IDLE 0	OR 0	NF 0	FE 0	PE 0	
0x01	UART2_DR Reset Value	DR7 x	DR6 x	DR5 x	DR4 x	DR3 x	DR2 x	DR1 x	DR0 x	
0x02	UART2_BRR1 Reset Value	UART_DIV[11:4] 00000000								
0x03	UART2_BRR2 Reset Value	UART_DIV[15:12] 0000				UART_DIV[3:0] 0000				
0x04	UART2_CR1 Reset Value	R8 0	T8 0	UARTD 0	M 0	WAKE 0	PCEN 0	PS 0	PIEN 0	
0x05	UART2_CR2 Reset Value	TIEN 0	TCIEN 0	RIEN 0	ILIEN 0	TEN 0	REN 0	RWU 0	SBK 0	
0x06	UART2_CR3 Reset Value	- 0	LINEN 0	STOP 00		CKEN 0	CPOL 0	CPHA 0	LBCL 0	
0x07	UART2_CR4 Reset Value	- 0	LBDIEN 0	LBDL 0	LBDF 0	ADD[3:0] 0000				
0x08	UART2_CR5 Reset Value	- 0	- 0	SCEN 0	NACK 0	HDSEL 0	IRLP 0	IREN 0	0	
0x09	UART2_CR6 Reset Value	LDUM 0	- 0	LSLV 0	LASE 0	- 0	LHDIEN 0	LHDF 0	LSF 0	

Table 55. UART2 register map

Address	Register name	7	6	5	4	3	2	1	0
0x0A	UART2_GTR Reset Value	GT7 0	GT6 0	GT5 0	GT4 0	GT3 0	GT2 0	GT1 0	GT0 0
0x0B	UART2_PSCR Reset Value	PSC7 0	PSC6 0	PSC5 0	PSC4 0	PSC3 0	PSC2 0	PSC1 0	PSC0 0

Table 56. UART3 register map

Address	Register name	7	6	5	4	3	2	1	0	
0x00	UART3_SR Reset Value	TXE 1	TC 1	RXNE 0	IDLE 0	OR 0	NF 0	FE 0	PE 0	
0x01	UART3_DR Reset Value	DR7 x	DR6 x	DR5 x	DR4 x	DR3 x	DR2 x	DR1 x	DR0 x	
0x02	UART3_BRR1 Reset Value	UART_DIV[11:4] 00000000								
0x03	UART3_BRR2 Reset Value	UART_DIV[15:12] 0000				UART_DIV[3:0] 0000				
0x04	UART3_CR1 Reset Value	R8 0	T8 0	UARTD 0	M 0	WAKE 0	PCEN 0	PS 0	PIEN 0	
0x05	UART3_CR2 Reset Value	TIEN 0	TCIEN 0	RIEN 0	ILIEN 0	TEN 0	REN 0	RWU 0	SBK 0	
0x06	UART3_CR3 Reset Value	- 0	LINEN 0	STOP 00		- 0	- 0	- 0	- 0	
0x07	UART3_CR4 Reset Value	- 0	LBDIEN 0	LBDL 0	LBDF 0	ADD[3:0] 0000				
0x08	Reserved									
0x09	UART2_CR6 Reset Value	LDUM 0	- 0	LSLV 0	LASE 0	- 0	LHDIEN 0	LHDF 0	LSF 0	

23 Controller area network (beCAN)

23.1 Introduction

The Basic Enhanced CAN peripheral, named beCAN, interfaces the CAN network. It supports the CAN protocol version 2.0A and B. It has been designed to manage high number of incoming messages efficiently with a minimum CPU load. It also meets the priority requirements for transmit messages.

For safety-critical applications the CAN controller provides all hardware functions for supporting the CAN Time triggered Communication option.

23.2 beCAN main features

- Supports CAN protocol version 2.0 A, B Active
- Bit rates up to 1 Mbit/s
- Supports the Time Triggered Communication option
- Selectable clock source (f_{MASTER} or f_{CANEXT})

Transmission

- Three transmit mailboxes
- Configurable transmit priority
- Time Stamp on SOF transmission

Reception

- One receive FIFO with three stages
- Six scalable filter banks
- Identifier list feature
- Configurable FIFO overrun
- Time Stamp on SOF reception

Time triggered communication option

- Disable automatic retransmission mode
- 16-bit free running timer
- Configurable timer resolution
- Time Stamp sent in last two data bytes

Management

- Maskable interrupts
- Software-efficient mailbox mapping at a unique address space

23.3 beCAN general description

In today's CAN applications, the number of nodes in a network is increasing and often several networks are linked together via gateways. Typically the number of messages in the system (and thus to be handled by each node) has significantly increased. In addition to the

application messages, Network Management and Diagnostic messages have been introduced.

- An enhanced filtering mechanism is required to handle each type of message.

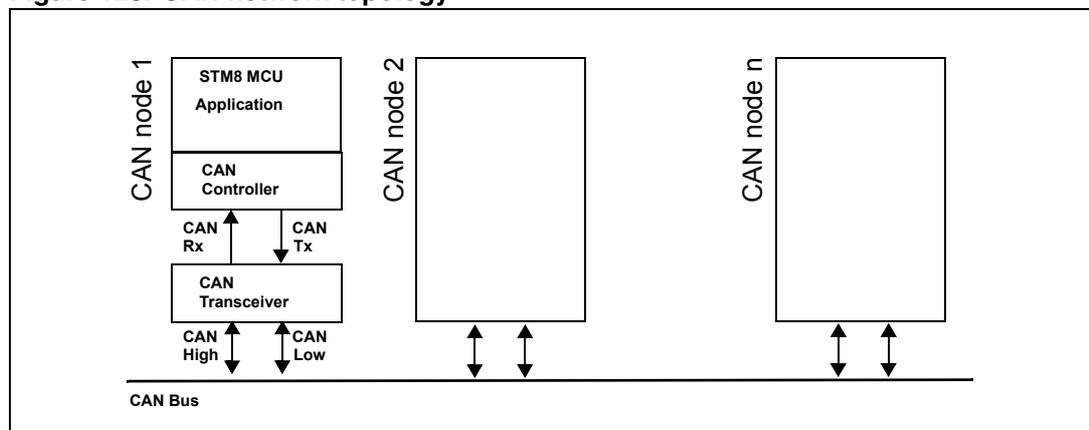
Furthermore, application tasks require more CPU time, therefore real-time constraints caused by message reception have to be reduced.

- A receive FIFO scheme allows the CPU to be dedicated to application tasks for a long time period without losing messages.

The standard HLP (Higher Layer Protocol) based on standard CAN drivers requires an efficient interface to the CAN controller.

- All mailboxes and registers are organized in 16-byte pages mapped at the same address and selected via a page select register.

Figure 126. CAN network topology



23.3.1 CAN 2.0B active core

The beCAN module handles the transmission and the reception of CAN messages fully autonomously. Standard identifiers (11-bit) and extended identifiers (29-bit) are fully supported by hardware.

23.3.2 Control, status and configuration registers

The application uses these registers to:

- Configure CAN parameters, e.g. baud rate
- Request transmissions
- Handle receptions
- Manage interrupts
- Get diagnostic information

23.3.3 Tx mailboxes

Three transmit mailboxes are provided to the software for setting up messages. The Transmission Scheduler decides which mailbox has to be transmitted first.

23.3.4 Acceptance filters

The beCAN provides six scalable/configurable identifier filter banks for selecting the incoming messages the software needs and discarding the others.

Receive FIFO

The receive FIFO is used by the CAN controller to store the incoming messages. Three complete messages can be stored in the FIFO. The software always accesses the next available message at the same address. The FIFO is managed completely by hardware.

Figure 127. beCAN block diagram

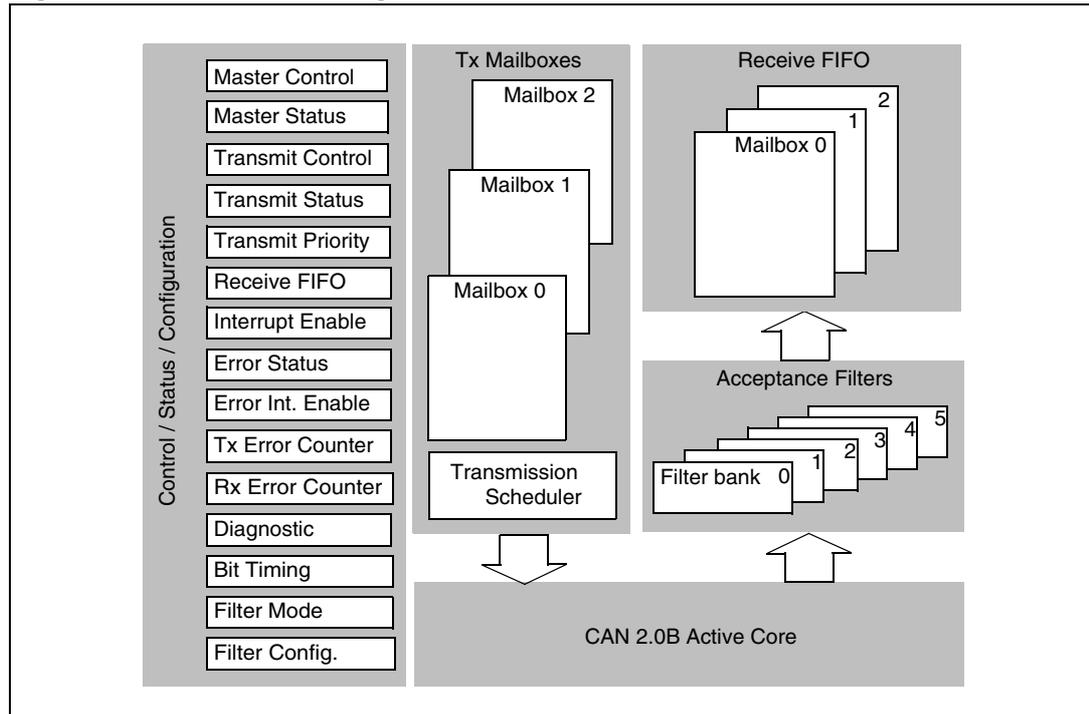
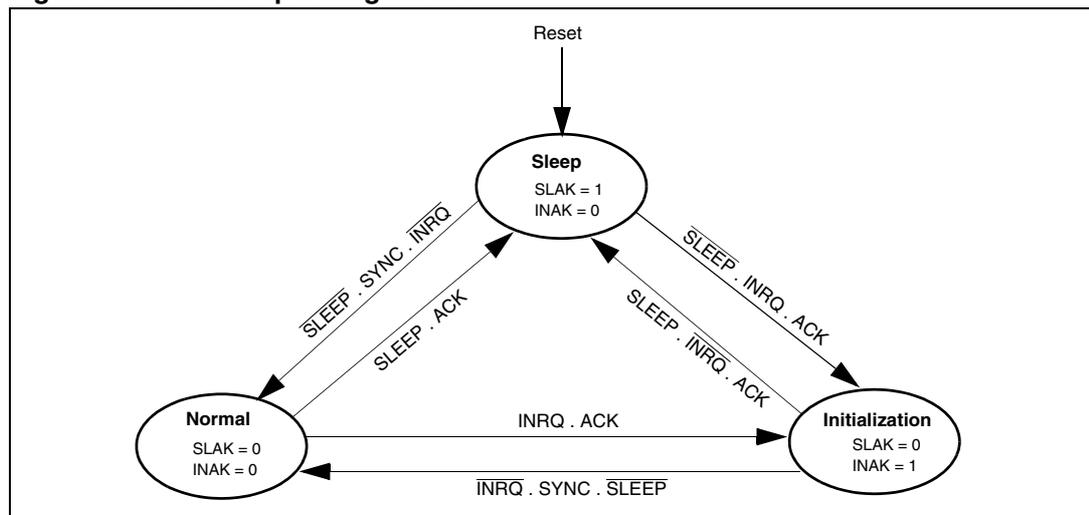


Figure 128. beCAN operating modes



23.4 Operating modes

beCAN has three main operating modes: **Initialization**, **Normal** and **Sleep**. After a hardware reset, beCAN is in sleep mode to reduce power consumption. The software requests beCAN to enter **Initialization** or **Sleep** mode by setting the INRQ or SLEEP bits in the CAN_MCR register. Once the mode has been entered, beCAN confirms it by setting the INAK or SLAK bits in the CAN_MSR register. When neither INAK nor SLAK are set, beCAN is in **Normal** mode. Before entering **Normal** mode beCAN always has to **synchronize** on the CAN bus. To synchronize, beCAN waits until the CAN bus is idle, this means 11 consecutive recessive bits have been monitored on CANRX.

23.4.1 Initialization mode

The software initialization can be done while the hardware is in Initialization mode. To enter this mode the software sets the INRQ bit in the CAN_MCR register and waits until the hardware has confirmed the request by setting the INAK bit in the CAN_MSR register.

To leave Initialization mode, the software clears the INQR bit. beCAN has left Initialization mode once the INAK bit has been cleared by hardware. However the Rx line has to be in recessive state to leave this mode.

While in Initialization mode, all message transfers to and from the CAN bus are stopped and the status of the CAN bus output CANTX is recessive (high).

Entering Initialization Mode does not change any of the configuration registers.

To initialize the CAN Controller, software has to set up the Bit Timing registers and the filter banks. If a filter bank is not used, it is recommended to leave it non active (leave the corresponding FACT bit in the CAN_FCRx register cleared).

23.4.2 Normal mode

Once the initialization has been done, the software must request the hardware to enter Normal mode, to synchronize on the CAN bus and start reception and transmission. Entering Normal mode is done by clearing the INRQ bit in the CAN_MCR register and waiting until the hardware has confirmed the request by clearing the INAK bit in the CAN_MSR register. Afterwards, the beCAN synchronizes with the data transfer on the CAN bus by waiting for the occurrence of a sequence of 11 consecutive recessive bits (Bus Idle state) before it can take part in bus activities and start message transfer.

The initialization of the filter values is independent from Initialization mode but must be done while the filter bank is not active (corresponding FACTx bit cleared). The filter bank scale and mode configuration must be configured in initialization mode.

23.4.3 Sleep mode (low power)

To reduce power consumption, beCAN has a low power mode called Sleep mode. This mode is entered on software request by setting the SLEEP bit in the CAN_MCR register. In this mode, the beCAN clock is stopped, however software can still access the beCAN mailboxes.

Note: If software requests entry to **initialization** mode by setting the INRQ bit while beCAN is in **sleep** mode, it must also clear the SLEEP bit.

beCAN can be woken up (exit Sleep mode) either by software clearing the SLEEP bit or on detection of CAN bus activity.

On CAN bus activity detection, hardware automatically performs the wakeup sequence by clearing the SLEEP bit if the AWUM bit in the CAN_MCR register is set. If the AWUM bit is cleared, software has to clear the SLEEP bit when a wakeup interrupt occurs, in order to exit from sleep mode.

Note: If the wakeup interrupt is enabled (WKUIE bit set in CAN_IER register) a wakeup interrupt will be generated on detection of CAN bus activity, even if the beCAN automatically performs the wakeup sequence.

After the SLEEP bit has been cleared, Sleep mode is exited once beCAN has synchronized with the CAN bus, refer to [Figure 128: beCAN operating modes](#). However the Rx line has to be in recessive state to leave this mode. Sleep mode is exited once the SLAK bit has been cleared by hardware.

23.4.4 Time triggered communication mode

In this mode, the internal counter of the CAN hardware is activated and used to generate the Time Stamp value stored in the CAN_MTSRH and CAN_MTSRL registers (for Rx and Tx mailboxes). The internal counter is captured on the sample point of the Start Of Frame bit in both reception and transmission.

The TGT bit (Transmit Global Time in CAN_MDLCR) enables automatic transmission of the contents of both CAN_MTSRH and CAN_MTSRL in the two last data bytes of the message (refer to the TTCAN specification ISO 11898-4). In this case, the TTCM (Time Triggered Communication Mode in CAN_MCR) bit has to be set to enable the Time Triggered Communication mechanism.

23.5 Test modes

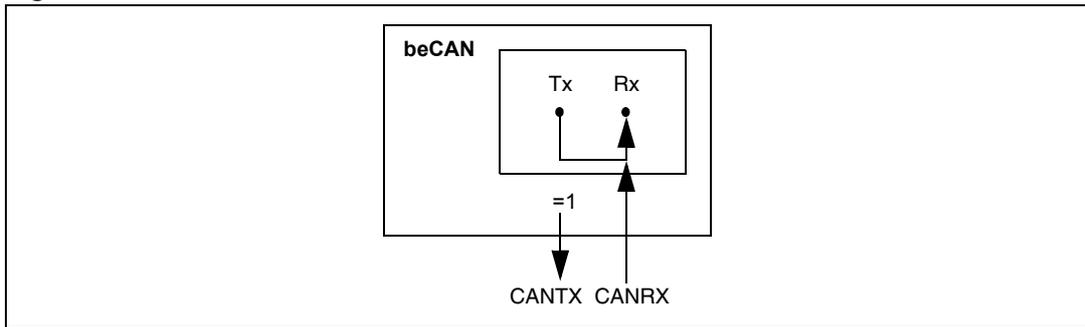
Test modes can be selected by the SILM and LBKM bits in the CAN_DGR register. These bits must be configured while beCAN is in Initialization mode. Once a test mode has been selected, the INRQ bit in the CAN_MCR register must be reset to enter Normal mode.

23.5.1 Silent mode

The beCAN can be put in Silent mode by setting the SILM bit in the CAN_DGR register.

In Silent mode, the beCAN is able to receive valid data frames and valid remote frames, but it sends only recessive bits on the CAN bus and it cannot start a transmission. If the beCAN has to send a dominant bit (ACK bit, overload flag, active error flag), the bit is rerouted internally so that the CAN Core monitors this dominant bit, although the CAN bus may remain in recessive state. Silent mode can be used to analyze the traffic on a CAN bus without affecting it by the transmission of dominant bits (Acknowledge Bits, Error Frames).

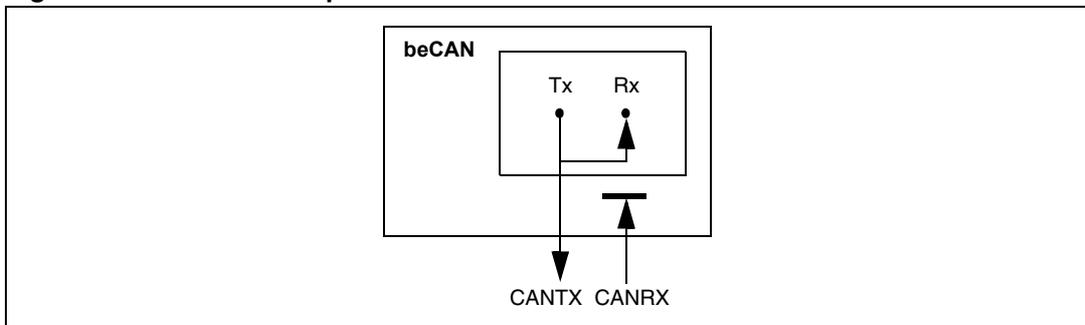
Figure 129. beCAN in silent mode



23.5.2 Loop back mode

The beCAN can be set in Loop Back Mode by setting the LBKM bit in the CAN_DGR register. In Loop Back Mode, the beCAN treats its own transmitted messages as received messages and stores them (if they pass acceptance filtering) in the FIFO.

Figure 130. beCAN in loop back mode



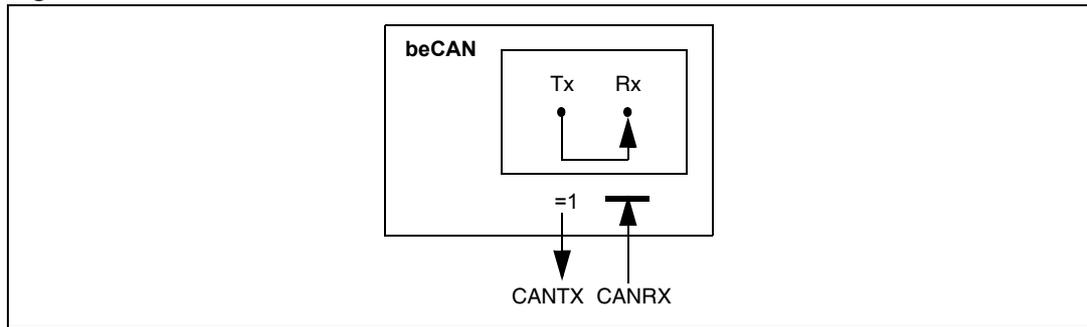
This mode is provided for self-test functions. To be independent of external events, the CAN Core ignores acknowledge errors (no dominant bit sampled in the acknowledge slot of a data / remote frame) in Loop Back Mode. In this mode, the beCAN performs an internal feedback from its Tx output to its Rx input. The actual value of the CANRX input pin is disregarded by the beCAN. The transmitted messages can be monitored on the CANTX pin.

Note: As the Tx line is still active in this mode, be aware that it can disturb the communication on the CAN bus.

23.5.3 Loop back combined with silent mode

It is also possible to combine Loop Back mode and Silent mode by setting the LBKM and SILM bits in the CAN_DGR register. This mode can be used for a “Hot Selftest”, meaning the beCAN can be tested like in Loop Back mode but without affecting a running CAN system connected to the CANTX and CANRX pins. In this mode, the CANRX pin is disconnected from the beCAN and the CANTX pin is held recessive.

Figure 131. beCAN in combined mode



23.6 Functional description

23.6.1 Transmission handling

In order to transmit a message, the application must select one **empty** transmit mailbox, set up the identifier, the data length code (DLC) and the data before requesting the transmission by setting the corresponding TXRQ bit in the CAN_MCSR register. Once the mailbox has left **empty** state, the software no longer has write access to the mailbox registers. Immediately after the TXRQ bit has been set, the mailbox enters **pending** state and waits to become the highest priority mailbox, see *Transmit Priority*. As soon as the mailbox has the highest priority it will be **scheduled** for transmission. The transmission of the message of the scheduled mailbox will start (enter **transmit** state) when the CAN bus becomes idle. Once the mailbox has been successfully transmitted, it will become **empty** again. The hardware indicates a successful transmission by setting the RQCP and TXOK bits in the CAN_MCSR and CAN_TSR registers.

If the transmission fails, the cause is indicated by the ALST bit in the CAN_MCSR register in case of an Arbitration Lost, and/or the TERR bit, in case of transmission error detection.

Transmit priority

By identifier:

When more than one transmit mailbox is pending, the transmission order is given by the identifier of the message stored in the mailbox. The message with the lowest identifier value has the highest priority according to the arbitration of the CAN protocol. If the identifier values are equal, the lower mailbox number will be scheduled first.

By transmit request order:

The transmit mailboxes can be configured as a transmit FIFO by setting the TXFP bit in the CAN_MCR register. In this mode the priority order is given by the transmit request order.

This mode is very useful for segmented transmission.

Abort

A transmission request can be aborted by the user setting the ABRQ bit in the CAN_MCSR register. In **pending** or **scheduled** state, the mailbox is aborted immediately. An abort request while the mailbox is in **transmit** state can have two results. If the mailbox is transmitted successfully the mailbox becomes **empty** with the TXOK bit set in the CAN_MCSR and CAN_TSR registers. If the transmission fails, the mailbox becomes **scheduled**, the transmission is aborted and becomes **empty** with TXOK cleared. In all cases the mailbox will become **empty** again at least at the end of the current transmission.

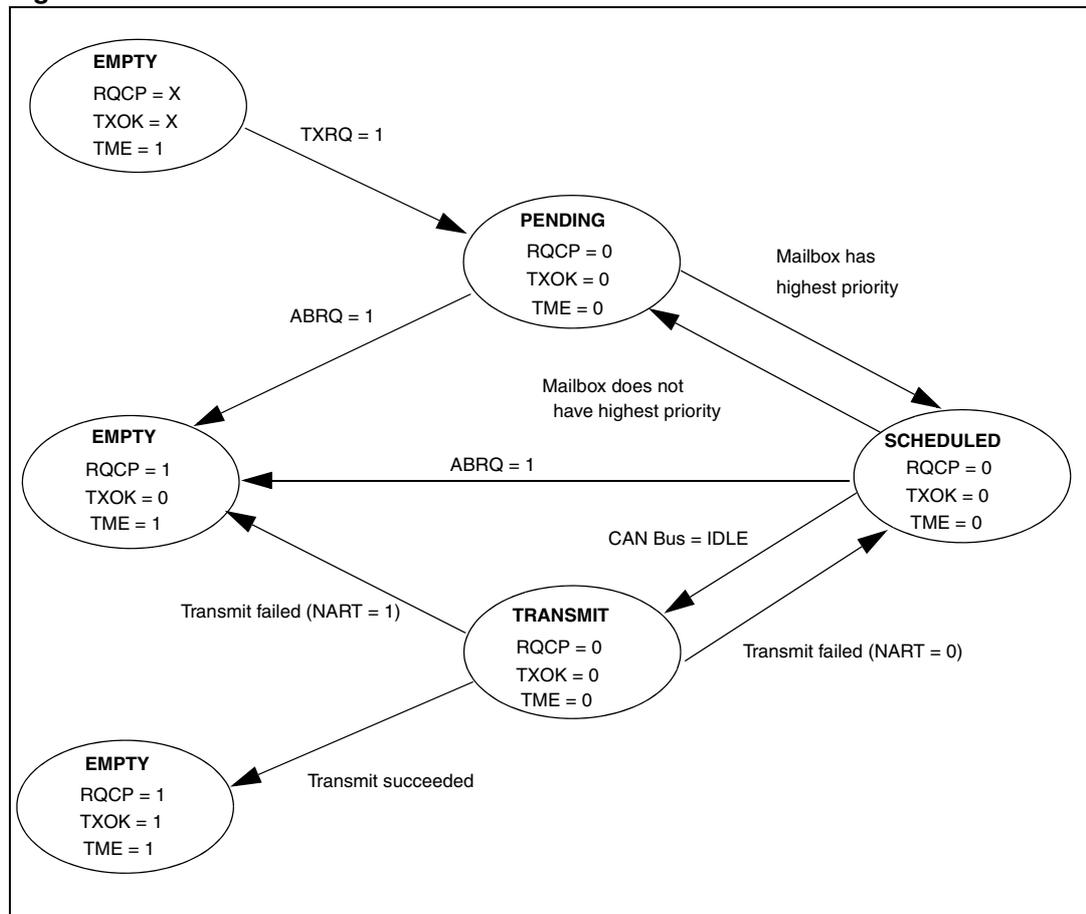
Non-automatic retransmission mode

This mode has been implemented in order to fulfil the requirement of the Time Triggered Communication option of the CAN standard. To configure the hardware in this mode the NART bit in the CAN_MCR register must be set.

In this mode, each transmission is started only once. If the first attempt fails, due to an arbitration loss or an error, the hardware will not automatically restart the message transmission.

At the end of the first transmission attempt, the hardware considers the request as completed and sets the RQCP bit in the CAN_MCSR register. The result of the transmission is indicated in the CAN_MCSR register by the TXOK, ALST and TERR bits.

Figure 132. Transmit mailbox states



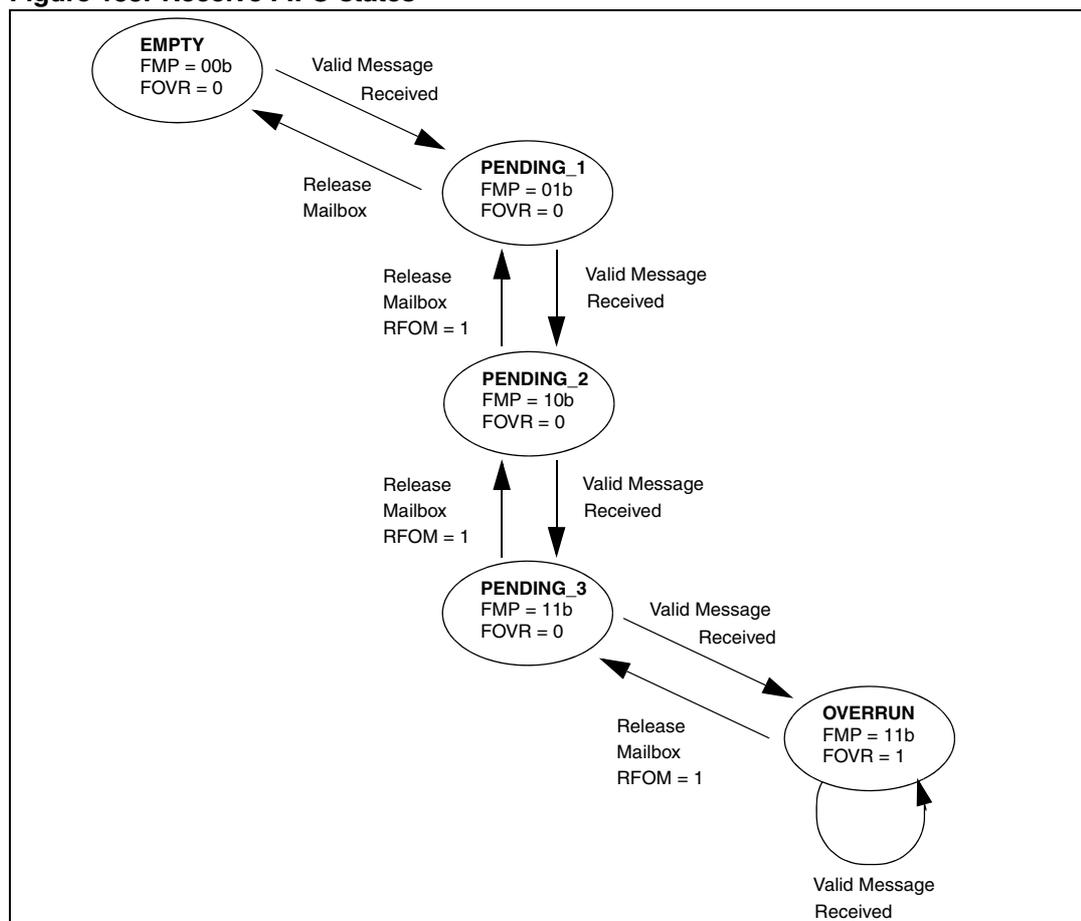
23.6.2 Reception handling

For the reception of CAN messages, three mailboxes organized as a FIFO are provided. In order to save CPU load, simplify the software and guarantee data consistency, the FIFO is managed completely by hardware. The application accesses the messages stored in the FIFO through the FIFO output mailbox.

Valid message

A received message is considered as valid **when** it has been received correctly according to the CAN protocol (no error until the last but one bit of the EOF field) **and** it passed through the identifier filtering successfully, see [Section 23.6.3: Identifier filtering](#).

Figure 133. Receive FIFO states



FIFO management

Starting from the **empty** state, the first valid message received is stored in the FIFO which becomes **pending_1**. The hardware signals the event setting the FMP[1:0] bits in the CAN_RFR register to the value 0b01. The message is available in the FIFO output mailbox. The software reads out the mailbox content and releases it by setting the RFOM bit in the CAN_RFR register. The FIFO becomes **empty** again. If a new valid message has been received in the meantime, the FIFO stays in **pending_1** state and the new message is available in the output mailbox.

If the application does not release the mailbox, the next valid message will be stored in the FIFO which enters **pending_2** state (FMP[1:0] = 0b10). The storage process is repeated for the next valid message putting the FIFO into **pending_3** state (FMP[1:0] = 0b11). At this point, the software must release the output mailbox by setting the RFOM bit, so that a mailbox is free to store the next valid message. Otherwise the next valid message received will cause a loss of message.

Refer also to [Section 23.6.4: Message storage](#).

Overrun

Once the FIFO is in **pending_3** state (i.e. the three mailboxes are full) the next valid message reception will lead to an **overrun** and a message will be lost. The hardware signals the overrun condition by setting the FOVR bit in the CAN_RFR register. Which message is lost depends on the configuration of the FIFO:

- If the FIFO lock function is disabled (RFLM bit in the CAN_MCR register cleared) the last message stored in the FIFO will be overwritten by the new incoming message. As a result, the last message is always available to the application.

Note: The previously received messages will stay in their positions in the FIFO, only the last one will be overwritten.

- If the FIFO lock function is enabled (RFLM bit in the CAN_MCR register set) the most recent message will be discarded and the software will have the three oldest messages in the FIFO available.

Reception related interrupts

On the storage of the first message in the FIFO - FMP[1:0] bits change from 0b00 to 0b01 - an interrupt is generated if the FMPIE bit in the CAN_IER register is set.

When the FIFO becomes full (i.e. a third message is stored) the FULL bit in the CAN_RFR register is set and an interrupt is generated if the FFIE bit in the CAN_IER register is set.

On overrun condition, the FOVR bit is set and an interrupt is generated if the FOVIE bit in the CAN_IER register is set.

23.6.3 Identifier filtering

In the CAN protocol the identifier of a message is not associated with the address of a node but related to the content of the message. Consequently a transmitter broadcasts its message to all receivers. On message reception a receiver node decides - depending on the identifier value - whether the software needs the message or not. If the message is needed, it is copied into the RAM. If not, the message must be discarded without intervention by the software.

To fulfil this requirement, the beCAN Controller provides 6 configurable and scalable filter banks (5:0) in order to receive only the messages the software needs. This hardware filtering saves CPU resources which would be otherwise needed to perform filtering by software. Each filter bank x consists of eight 8-bit registers, CAN_FxR[8:1].

Scalable width

To optimize and adapt the filters to the application needs, each filter bank can be scaled independently. Depending on the filter scale a filter bank provides:

- One 32-bit filter for the STDID[10:0] / EXID[28:18], IDE, EXID[17:0] and RTR bits.
- Two 16-bit filters for the STDID[10:0] / EXID[28:18], RTR and IDE bits.
- Four 8-bit filters for the STDID[10:3] / EXID[28:21] bits. The other bits are considered as don't care.
- One 16-bit filter and two 8-bit filters for filtering the same set of bits as the 16 and 8-bit filters described above.

Refer to [Figure 134](#) through [Figure 137](#).

Furthermore, the filters can be configured in mask mode or in identifier list mode.

Mask mode

In **mask** mode the identifier registers are associated with mask registers specifying which bits of the identifier are handled as “must match” or as “don't care”.

Identifier list mode

In **identifier list** mode, the mask registers are used as identifier registers. Thus instead of defining an identifier and a mask, two identifiers are specified, doubling the number of single identifiers. All bits of the incoming identifier must match the bits specified in the filter registers.

Filter bank scale and mode configuration

The filter banks are configured by means of the corresponding CAN_FCRx register. To configure a filter bank this must be deactivated by clearing the FACT bit in the CAN_FCRx register. The filter scale is configured by means of the FSC[1:0] bits in the corresponding CAN_FCRx register. The **identifier list** or **identifier mask** mode for the corresponding Mask/Identifier registers is configured by means of the FMLx and FMHx bits in the CAN_FMRx register. The FMLx bit defines the mode for the lower half (registers CAN_FxR1-4), and the FMHx bit the mode for the upper half (registers CAN_FxR5-8) of filter bank x. Refer to [Figure 134](#) through [Figure 137](#) for details.

Examples:

- If filter bank 1 is configured as two 16-bit filters, then the FML1 bit defines the mode of the CAN_F1R3 and CAN_F1R4 registers and the FMH1 bit defines the mode of the CAN_F1R7 and CAN_F1R8 registers.
- If filter bank 1 is configured as four 8-bit filters, then the FML1 bit defines the mode of the CAN_F1R2 and CAN_F1R4 registers and the FMH1 bit defines the mode of the CAN_F1R6 and CAN_F1R8 registers.

Note: In 32-bit configuration, the FMLx and FMHx bits must have the same value to ensure that the four Mask/Identifier registers are in the same mode.

When a standard identifier is received (IDE bit is zero), the extended part of 32-bit or 16-bit filters is not compared.

To filter a group of identifiers, configure the Mask/Identifier registers in mask mode.

To select single identifiers, configure the Mask/Identifier registers in identifier list mode.

Filters not used by the application should be left deactivated.

Each filter within a filter bank is numbered (called the Filter Number) from 0 to a maximum dependent on the mode and the scale of each of the 6 filter banks.

For the filter configuration, refer to [Figure 134](#) through [Figure 137](#).

Figure 134. 32-bit filter bank configuration (FSCx bits = 0b11 in CAN_FCRx register)

Filter registers								Filter mode ¹			
Mapping	STID[10:3] / EXID[28:21]	STID [2:0] / EXID[20:18]	R R	E E	EXID [17:15]	EXID [14:7]	EXID[6:0]	0	FMHx = 0 FMLx = 0	FMHx = 1 FMLx = 1	
Identifier	CAN_FxR1	CAN_FxR2		CAN_FxR3		CAN_FxR4		ID	n	ID n	
Identifier/Mask	CAN_FxR5	CAN_FxR6		CAN_FxR7		CAN_FxR8		M	n	ID n+1	

ID= Identifier n = Filter number
M = Mask x = Filter bank number

¹ The FMHx and FMLx bits are located in the CAN_FMR1 and CAN_FMR2 registers

Figure 135. 16-bit filter bank configuration (FSCx bits = 0b10 in CAN_FCRx register)

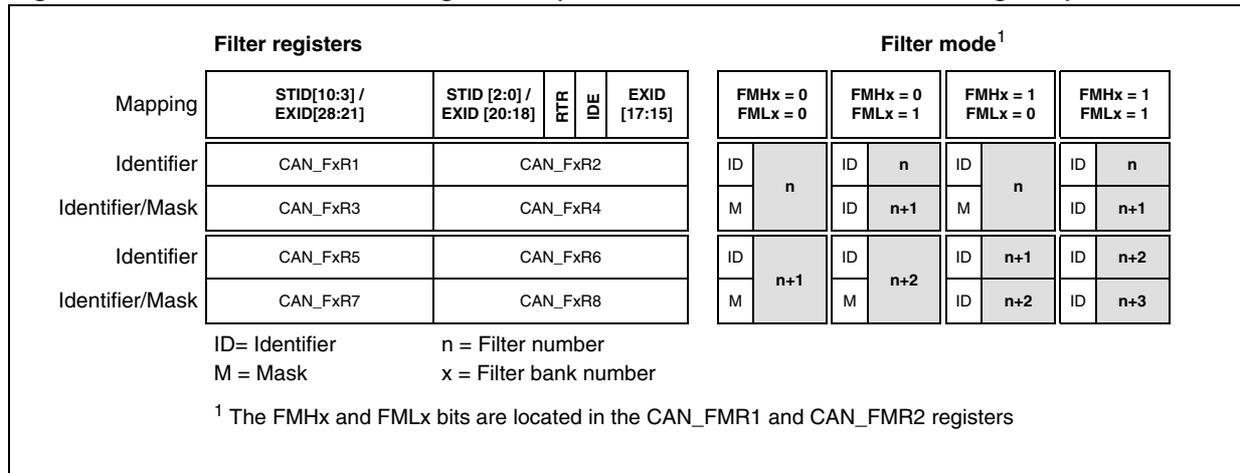


Figure 136. 16/8-bit filter bank configuration (FSCx bits = 0b01 in CAN_FCRx register)

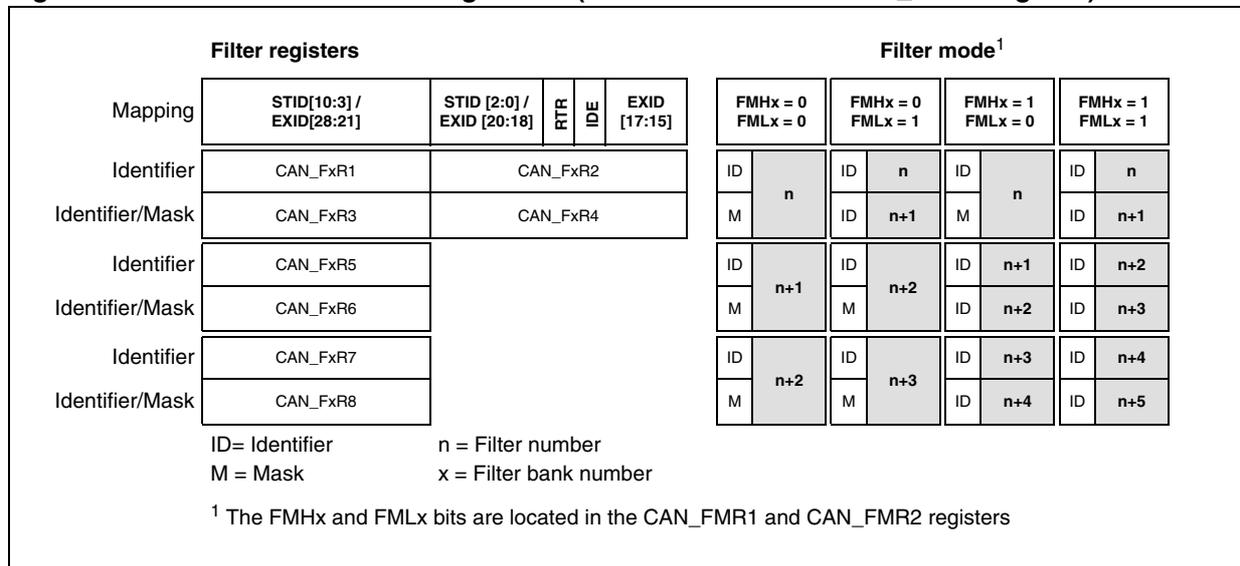
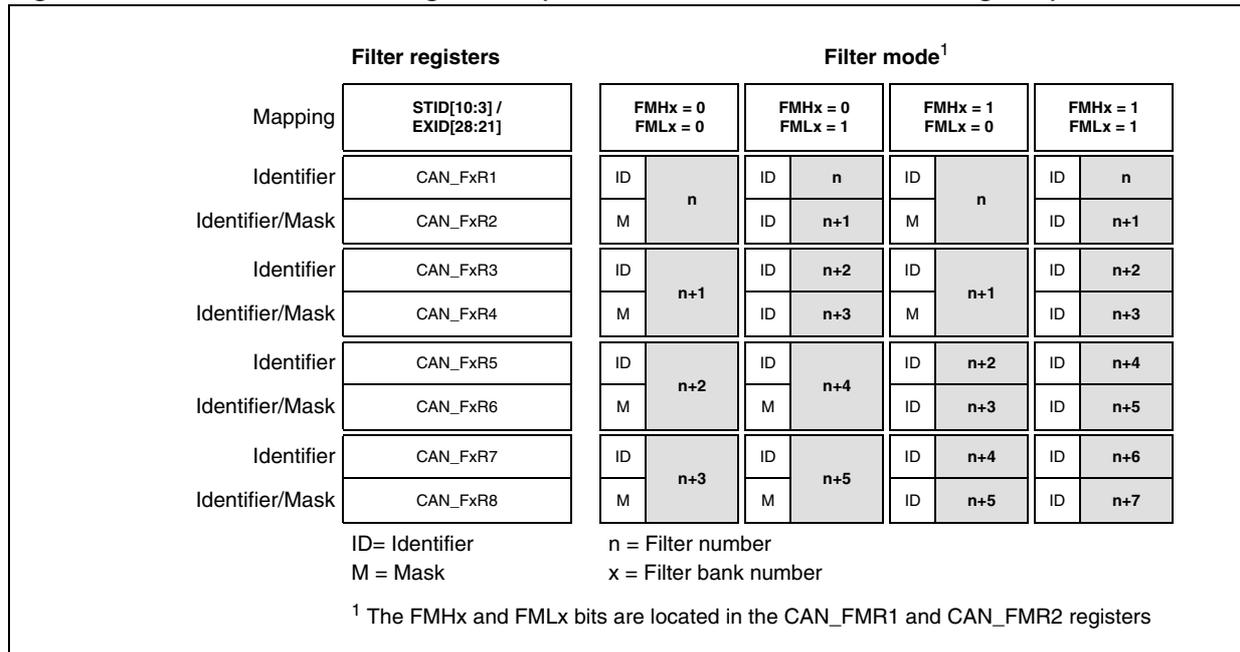


Figure 137. 8-bit filter bank configuration (FSCx bits = 0b00 in CAN_FCRx register)



Filter match index

Once a message has been received in the FIFO it is available to the application. Typically application data are copied into RAM locations. To copy the data to the right location the application has to identify the data by means of the identifier. To avoid this and to ease the access to the RAM locations, the CAN controller provides a Filter Match Index.

This index is stored in the mailbox together with the message according to the filter priority rules. Thus each received message has its associated Filter Match Index.

The Filter Match Index can be used in two ways:

- Compare the Filter Match Index with a list of expected values.
- Use the Filter Match Index as an index on an array to access the data destination location.

For non-masked filters, the software no longer has to compare the identifier.

If the filter is masked the software reduces the comparison to the masked bits only.

Note: The index value of the filter number does not take into account the activation state of the filter banks.

Table 57. Example of filter numbering

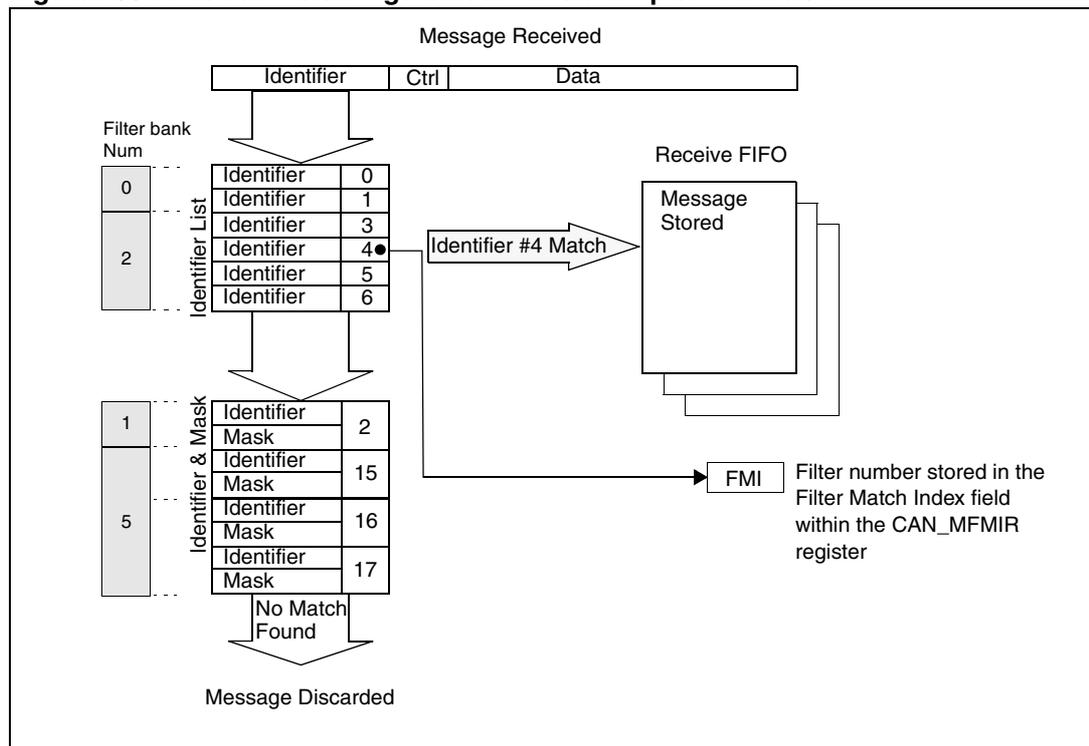
Number	Filter bank				Configuration	Filter number
	FCS	FMH	FML	FACT		
0	0b11	1	1	1	Identifier list (32-bit)	0 1
1	0b11	0	0	1	Identifier mask (32-bit)	2
2	0b10	1	1	1	Identifier list (16-bit)	3 4 5 6
3	0b00	0	1	0	Deactivated Identifier List/Identifier mask (8-bit)	7 8 9 10 11 12
4	0b10	0	0	0	Deactivated Identifier Mask (16-bit)	13 14
5	0b01	0	0	1	Identifier Mask (16/8-bit)	15 16 17

Filter priority rules

Depending on the filter combination it may occur that an identifier passes successfully through several filters. In this case the filter match value stored in the receive mailbox is chosen according to the following rules:

- A 32-bit filter takes priority over 16-bit filter which takes itself priority over 8-bit filter.
- For filters of equal scale, priority is given to the identifier List mode over the identifier Mask mode.
- For filters of equal scale and mode, priority is given by the filter number (the lower the number, the higher the priority).

Figure 138. Filter banks configured as in the example in Table 57.



The example above shows the filtering principle of the beCAN. On reception of a message, the identifier is compared first with the filters configured in identifier list mode. If there is a match, the message is stored in the FIFO and the index of the matching filter is stored in the Filter Match Index. As shown in the example, the identifier matches with Identifier #4 thus the message content and FMI 4 is stored in the FIFO.

If there is no match, the incoming identifier is then compared with the filters configured in mask mode.

If the identifier does not match any of the identifiers configured in the filters, the message is discarded by hardware without disturbing the software.

23.6.4 Message storage

The interface between the software and the hardware for the CAN messages is implemented by means of mailboxes. A mailbox contains all information related to a message; identifier, data, control, status and time stamp information.

Transmit mailbox

The software sets up the message to be transmitted in an empty transmit mailbox. The status of the transmission is indicated by hardware in the CAN_MCSR register.

Table 58. Transmit mailbox mapping

Offset to Transmit Mailbox base address (bytes)	Register name
0	CAN_MCSR
1	CAN_MDLCR
2	CAN_MIDR1
3	CAN_MIDR2
4	CAN_MIDR3
5	CAN_MIDR4
6	CAN_MDAR1
7	CAN_MDAR2
8	CAN_MDAR3
9	CAN_MDAR4
10	CAN_MDAR5
11	CAN_MDAR6
12	CAN_MDAR7
13	CAN_MDAR8
14	CAN_MTSRL
15	CAN_MTSRH

Receive mailbox

When a message has been received, it is available to the software in the FIFO output mailbox. Once the software has handled the message (e.g. read it) the software must release the FIFO output mailbox by means of the RFOM bit in the CAN_RFR register to make the next incoming message available. The filter match index is stored in the CAN_MFMIR register. The 16-bit time stamp value is stored in the CAN_MTSRH and CAN_MTSRL registers.

Table 59. Receive mailbox mapping

Offset to Receive Mailbox base address (bytes)	Register name
0	CAN_MFMIR
1	CAN_MDLCR
2	CAN_MIDR1
3	CAN_MIDR2
4	CAN_MIDR3
5	CAN_MIDR4
6	CAN_MDAR1
7	CAN_MDAR2
8	CAN_MDAR3
9	CAN_MDAR4
10	CAN_MDAR5
11	CAN_MDAR6
12	CAN_MDAR7
13	CAN_MDAR8
14	CAN_MTSRL
15	CAN_MTSRH

23.6.5 Error management

The error management as described in the CAN protocol is handled entirely by hardware using a Transmit Error Counter (CAN_TECR register) and a Receive Error Counter (CAN_RECR register), which get incremented or decremented according to the error condition. For detailed information about TEC and REC management, please refer to the CAN standard.

Both of them may be read by software to determine the stability of the network. Furthermore, the CAN hardware provides detailed information on the current error status in CAN_ESR register. By means of CAN_EIER register and ERRIE bit in CAN_IER register, the software can configure the interrupt generation on error detection in a very flexible way.

Bus-Off Recovery

The Bus-Off state is reached when TEC is greater than 255, this state is indicated by BOFF bit in CAN_ESR register. In Bus-Off state, the beCAN is no longer able to transmit and receive messages.

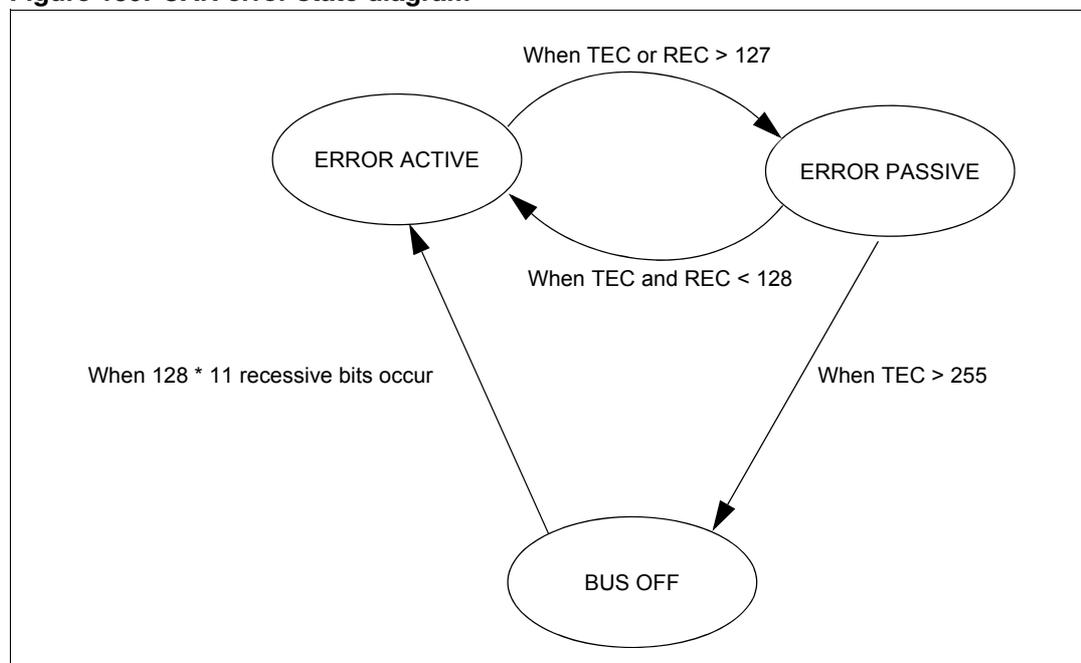
Depending on the ABOM bit in the CAN_MCR register beCAN will recover from Bus-Off (become error active again) either automatically or on software request. But in both cases the beCAN has to wait at least for the recovery sequence specified in the CAN standard (128 x 11 consecutive recessive bits monitored on CANRX).

If ABOM is set, the beCAN will start the recovering sequence automatically after it has entered Bus-Off state.

If ABOM is cleared, the software must initiate the recovering sequence by requesting beCAN to enter initialization mode. Then beCAN starts monitoring the recovery sequence when the beCAN is requested to leave the initialisation mode.

Note: In initialization mode, beCAN does not monitor the CANRX signal, therefore it cannot complete the recovery sequence. **To recover, beCAN must be in normal mode.**

Figure 139. CAN error state diagram



23.6.6 Bit timing

The bit timing logic monitors the serial bus-line and performs sampling and adjustment of the sample point by synchronizing on the start-bit edge and resynchronizing on the following edges.

Its operation may be explained simply by splitting nominal bit time into three segments as follows:

- **Synchronization segment (SYNC_SEG):** a bit change is expected to occur within this time segment. It has a fixed length of one time quantum ($1 \times t_{CAN}$).
- **Bit segment 1 (BS1):** defines the location of the sample point. It includes the PROP_SEG and PHASE_SEG1 of the CAN standard. Its duration is programmable between 1 and 16 time quanta but may be automatically lengthened to compensate for positive phase drifts due to differences in the frequency of the various nodes of the network.
- **Bit segment 2 (BS2):** defines the location of the transmit point. It represents the PHASE_SEG2 of the CAN standard. Its duration is programmable between 1 and 8 time quanta but may also be automatically shortened to compensate for negative phase drifts.

The reSynchronization Jump Width (SJW) defines an upper bound to the amount of lengthening or shortening of the bit segments. It is programmable between 1 and 4 time quanta.

To guarantee the correct behaviour of the CAN controller, SYNC_SEG + BS1 + BS2 must be greater than or equal to 5 time quanta.

Note: For a detailed description of the CAN bit timing and resynchronization mechanism, please refer to the ISO 11898 standard.

As a safeguard against programming errors, the configuration of the Bit Timing Registers CAN_BTR1 and CAN_BTR2 is only possible while the device is in Initialization mode.

Figure 140. Bit timing

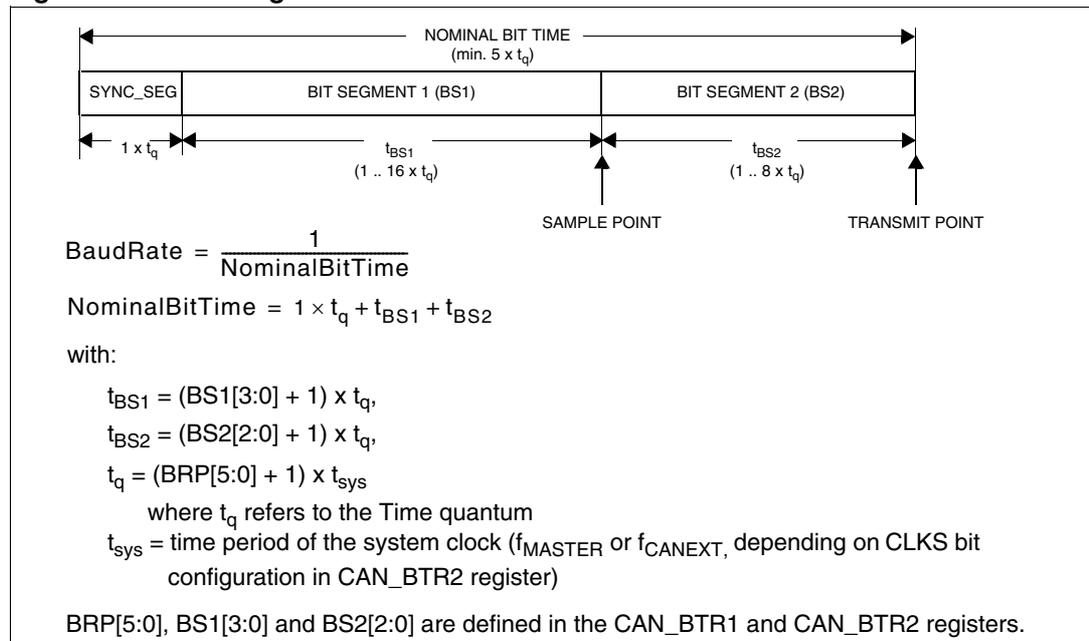
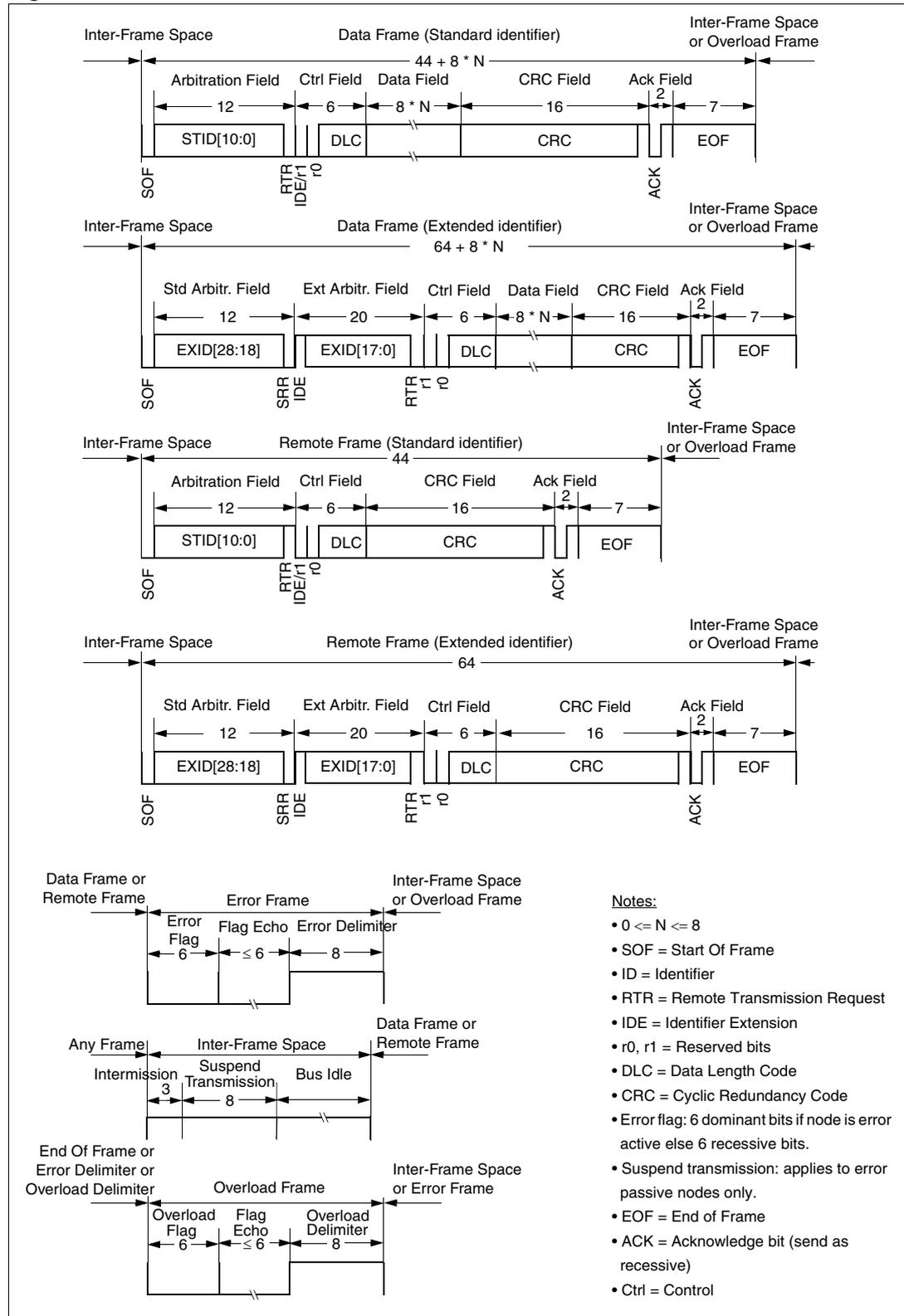


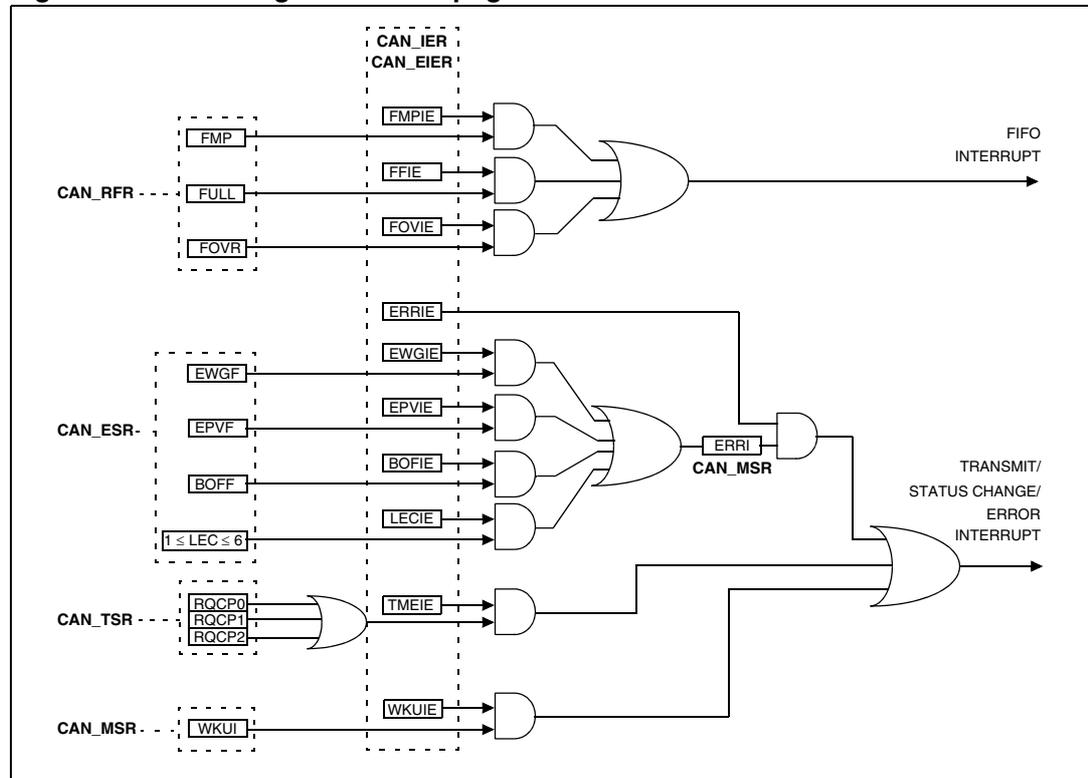
Figure 141. CAN frames



23.7 Interrupts

Two interrupt vectors are dedicated to beCAN. Each interrupt source can be independently enabled or disabled by means of the CAN Interrupt Enable Register (CAN_IER) and CAN Error Interrupt Enable register (CAN_EIER).

Figure 142. Event flags and interrupt generation



- The **FIFO interrupt** can be generated by the following events:
 - Reception of a new message, FMP bits in the CAN_RFR register incremented.
 - FIFO full condition, FULL bit in the CAN_RFR register set.
 - FIFO overrun condition, FOVR bit in the CAN_RFR register set.
- The **transmit, error and status change interrupt** can be generated by the following events:
 - Transmit mailbox 0 becomes empty, RQCP0 bit in the CAN_TSR register set.
 - Transmit mailbox 1 becomes empty, RQCP1 bit in the CAN_TSR register set.
 - Transmit mailbox 2 becomes empty, RQCP2 bit in the CAN_TSR register set.
 - Error condition, for more details on error conditions please refer to the CAN Error Status register (CAN_ESR).
 - Wakeup condition, SOF monitored on the CAN Rx signal.

23.8 Register access protection

Erroneous access to certain configuration registers can cause the hardware to temporarily disturb the whole CAN network. Therefore the following registers can be modified by software only while the hardware is in initialization mode:

CAN_BTR1, CAN_BTR2, CAN_FCR1, CAN_FCR2, CAN_FMR1, CAN_FMR2 and CAN_DGR registers.

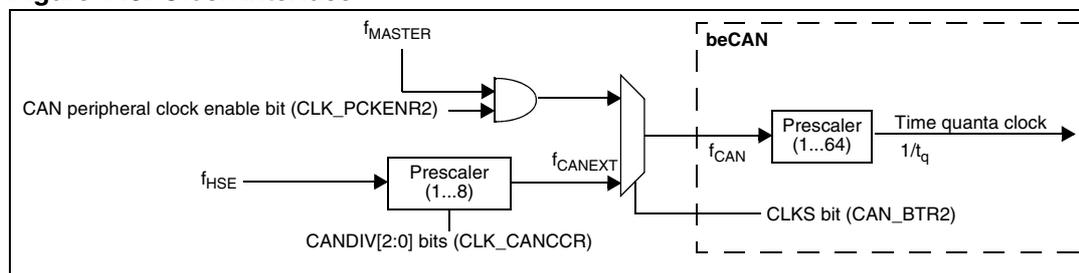
Although the transmission of incorrect data will not cause problems at the CAN network level, it can severely disturb the application. A transmit mailbox can be only modified by software while it is in empty state, refer to [Figure 132: Transmit mailbox states](#).

The filters must be deactivated before their value can be modified by software. The modification of the filter configuration (scale or mode) can be done by software only in initialization mode.

23.9 Clock system

The clock tolerance limit as specified in CAN protocol is 1.58 % at speeds of up to 125 Kbps. For higher baud rates, it is suggested to use a crystal oscillator. In order to allow beCAN to be used with the full range of baud rates, an interface is provided to allow beCAN to work with two different clock domains: f_{MASTER} or an accurate external clock (HSE). The interface between beCAN and the CPU is done at CPU clock speed whereas the various nodes in the CAN network communicate using a Baud rate clock generated from an external clock. Refer to the description of the CLKS bit in the CAN_BTR2 register.

Figure 143. Clock interface



The frequency of the external clock f_{CANEXT} must be less than that of the CPU clock (f_{CPU}).

There are two ways to configure the beCAN clock:

1. By selecting f_{MASTER} as CAN clock. In this case, the clock can be stopped at peripheral level ([Peripheral clock gating register 2 \(CLK_PCKENR2\)](#)) during low power mode. Obviously, f_{MASTER} must be driven by a crystal oscillator for CAN high speed applications.
2. Or, by selecting f_{CANEXT} (CLKS bit set) as CAN clock. In this case, the clock cannot be stopped by the peripheral clock gating register.

Note: *If the clock security system feature is enabled in the CLK controller (Refer to the description of the CSSEN bit in the [Clock security system register \(CLK_CSSSR\)](#) on page 79), there is a way to put CAN automatically into the recessive state when a main clock failure occurs, so that the CAN network does not get stuck by the device. However to ensure this, the PG0 I/O pin must be configured in pull-up mode prior to using the beCAN. In this way, when a failure occurs and the I/O alternate function is disabled, the line is pulled-up instead of floating.*

23.10 beCAN low power modes

Table 60. beCAN behavior in low power modes

Mode	Description
WAIT	No effect on beCAN, except that accesses to Tx/Rx mailboxes and filter values are not possible (CPU clock is stopped). beCAN interrupts cause the device to exit from WAIT mode.
SLOW	No effect on beCAN. Frequency of the external clock (if selected) must be less than f_{CPU} . See CLKS bit in CAN bit timing register 2 (CAN_BTR2) on page 385 .
HALT/ Active HALT	beCAN is halted. A beCAN Rx interrupt causes the device to exit from HALT/Active HALT modes (in fact, any falling edge driven externally on the Rx pin will wake-up the microcontroller).

Note: If a CAN frame is received in WAIT, HALT or Active HALT modes, the microcontroller will be woken-up but the CAN frame will be lost.

23.11 beCAN registers

23.11.1 CAN master control register (CAN_MCR)

Address offset: 0x00

Reset value: 0x02

7	6	5	4	3	2	1	0
TTCM	ABOM	AWUM	NART	RFLM	TXFP	SLEEP	INRQ
rw	rw						

Bit 7 **TTCM** Time Triggered Communication Mode

- 0: Time Triggered Communication mode disabled.
- 1: Time Triggered Communication mode enabled

Note: For more information on Time Triggered Communication mode, please refer to [Section 23.4.4: Time triggered communication mode](#).

Bit 6 **ABOM** Automatic Bus-Off Management

This bit controls the behaviour of the CAN hardware on leaving the Bus-Off state.

- 0: The Bus-Off state is left on software request.
- 1: The Bus-Off state is left automatically by hardware once 128 x 11 recessive bits have been monitored.

Note: For detailed information on the Bus-Off state please refer to [Section 23.6.5: Error management](#).

Bit 5 **AWUM** Automatic wakeup Mode

This bit controls the behaviour of the CAN hardware on message reception during sleep mode.

- 0: The sleep mode is left on software request by clearing the SLEEP bit in the CAN_MCR register.
- 1: The sleep mode is left automatically by hardware on CAN message detection. The SLEEP bit of the CAN_MCR register and the SLAK bit of the CAN_MSR register are cleared by hardware.

Bit 4 **NART** No Automatic Retransmission

- 0: The CAN hardware will automatically retransmit the message until it has been successfully transmitted according to the CAN standard.
- 1: A message will be transmitted only once, independently of the transmission result (successful, error or arbitration lost).

Bit 3 **RFLM** Receive FIFO Locked Mode

- 0: Receive FIFO not locked on overrun. Once a receive FIFO is full the next incoming message will overwrite the previous one.
- 1: Receive FIFO locked against overrun. Once a receive FIFO is full the next incoming message will be discarded.

Bit 2 **TXFP** Transmit FIFO Priority

This bit controls the transmission order when several mailboxes are pending at the same time.

- 0: Priority driven by the identifier of the message
- 1: Priority driven by the request order (chronologically)

Bit 1 **SLEEP** Sleep Mode Request

This bit is set by software to request the CAN hardware to enter the sleep mode. Sleep mode will be entered as soon as the current CAN activity (transmission or reception of a CAN frame) has been completed.

This bit is cleared by software to exit sleep mode.

This bit is cleared by hardware when the AWUM bit is set and a SOF bit is detected on the CAN Rx signal.

Bit 0 **INRQ** Initialization Request

The software clears this bit to switch the hardware into normal mode. Once 11 consecutive recessive bits have been monitored on the Rx signal the CAN hardware is synchronized and ready for transmission and reception. Hardware signals this event by clearing the INAK bit in the CAN_MSR register.

Software sets this bit to request the CAN hardware to enter initialization mode. Once software has set the INRQ bit, the CAN hardware waits until the current CAN activity (transmission or reception) is completed before entering the initialization mode. Hardware signals this event by setting the INAK bit in the CAN_MSR register.

23.11.2 CAN master status register (CAN_MSR)

Address offset: 0x01

Reset value: 0x002

7	6	5	4	3	2	1	0
Reserved		RX	TX	WKUI	ERRI	SLAK	INAK
		r	r	rc_w1	rc_w1	r	r

Bits 7:6 Reserved, read as 0.

Bit 5 **RX** Receive

1: The CAN hardware is currently receiver.

Bit 4 **TX** Transmit

1: The CAN hardware is currently transmitter.

Bit 3 **WKUI** Wakeup Interrupt

This bit is set by hardware to signal that a SOF bit has been detected while the CAN hardware was in sleep mode. Setting this bit generates a status change interrupt if the WKUIE bit in the CAN_IER register is set.

This bit is cleared by software writing 1.

Bit 2 **ERRI** Error Interrupt

This bit is set by hardware when a bit of the CAN_ESR has been set on error detection and the corresponding interrupt in the CAN_EIER is enabled. Setting this bit generates a status change interrupt if the ERRIE bit in the CAN_EIER register is set.

This bit is cleared by software writing 1.

Bit 1 **SLAK** Sleep Acknowledge

This bit is set by hardware and indicates to the software that the CAN hardware is now in sleep mode. This bit acknowledges the sleep mode request from the software (set SLEEP bit in CAN_MCR register).

This bit is cleared by hardware when the CAN hardware has left sleep mode. Sleep mode is left when the SLEEP bit in the CAN_MCR register is cleared. Please refer to the AWUM bit of the CAN_MCR register description for detailed information for clearing SLEEP bit.

Bit 0 **INAK** Initialization Acknowledge

This bit is set by hardware and indicates to the software that the CAN hardware is now in initialization mode. This bit acknowledges the initialization request from the software (set INRQ bit in CAN_MCR register).

This bit is cleared by hardware when the CAN hardware has left the initialization mode and is now synchronized on the CAN bus. To be synchronized the hardware has to monitor a sequence of 11 consecutive recessive bits on the CAN RX signal.

23.11.3 CAN transmit status register (CAN_TSR)

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	TXOK2	TXOK1	TXOK0	Reserved	RQCP2	RQCP1	RQCP0
	r	r	r		rc_w1	rc_w1	rc_w1

Bit 7 Reserved, read as 0.

Bit 6 **TXOK2** Transmission OK for mailbox 2

This bit is set by hardware when the transmission request on mailbox 2 has been completed successfully. Please refer to [Figure 132](#).

This bit is cleared by hardware when mailbox 2 is requested for transmission or when the software clears the RQCP2 bit.

Bit 5 **TXOK1** Transmission OK for mailbox 1

This bit is set by hardware when the transmission request on mailbox 1 has been completed successfully. Please refer to [Figure 132](#).

This bit is cleared by hardware when mailbox 1 is requested for transmission or when the software clears the RQCP1 bit.

Bit 4 **TXOK0** Transmission OK for mailbox 0

This bit is set by hardware when the transmission request on mailbox 0 has been completed successfully. Please refer to [Figure 132](#).

This bit is cleared by hardware when mailbox 1 is requested for transmission or when the software clears the RQCP0 bit.

Bit 3 Reserved, read as 0.

Bit 2 **RQCP2** Request Completed for Mailbox 2

This bit is set by hardware to signal that the last request for mailbox 2 has been completed. The request could be a transmit or an abort request.

This bit is cleared by software writing 1.

Bit 1 **RQCP1** Request Completed for Mailbox 1

This bit is set by hardware to signal that the last request for mailbox 1 has been completed. The request could be a transmit or an abort request.

This bit is cleared by software writing 1.

Bit 0 **RQCP0** Request Completed for Mailbox 0

This bit is set by hardware to signal that the last request for mailbox 0 has been completed. The request could be a transmit or an abort request.

This bit is cleared by software writing 1.

23.11.4 CAN transmit priority register (CAN_TPR)

Address offset: 0x03

Reset value: 0x1C

7	6	5	4	3	2	1	0
LOW2	LOW1	LOW0	TME2	TME1	TME0	CODE1	CODE0
r	r	r	r	r	r	r	r

Bit 7 **LOW2** Lowest Priority Flag for Mailbox 2

This bit is set by hardware when more than one mailbox is pending for transmission and mailbox 2 has the lowest priority.

Note: It is set to zero when only one mailbox is pending.

Bit 6 **LOW1** Lowest Priority Flag for Mailbox 1

This bit is set by hardware when more than one mailbox is pending for transmission and mailbox 1 has the lowest priority.

Note: It is set to zero when only one mailbox is pending.

Bit 5 **LOW0** Lowest Priority Flag for Mailbox 0

This bit is set by hardware when more than one mailbox is pending for transmission and mailbox 0 has the lowest priority.

Note: It is set to zero when only one mailbox is pending.

Bit 4 **TME2** Transmit Mailbox 2 Empty

This bit is set by hardware when no transmit request is pending for mailbox 2.

Note: This bit is reserved, forced to 0 by hardware in ST7 beCAN compatibility mode (TXM2E bit = 0 in CAN_DGR register).

Bit 3 **TME1** Transmit Mailbox 1 Empty

This bit is set by hardware when no transmit request is pending for mailbox 1.

Bit 2 **TME0** Transmit Mailbox 0 Empty

This bit is set by hardware when no transmit request is pending for mailbox 0.

Bits 1:0 **CODE[1:0]** Mailbox Code

When at least one transmit mailbox is free, this field contains the number of the next free transmit mailbox.

When all transmit mailboxes are pending, this field contains the number of the transmit mailbox with the lowest priority.

Note: CODE1 is always 0 in ST7 beCAN compatibility mode (TXM2E bit = 0 in CAN_DGR register).

23.11.5 CAN receive FIFO register (CAN_RFR)

Address offset: 0x04

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved		RFOM	FOVR	FULL	Reserved		FMP[1:0]
		rs	rc_w1	rc_w1			r r

Bit 7:6 Reserved, read as 0.

Bit 5 **RFOM** Release FIFO Output Mailbox

Set by software to release the output mailbox of the FIFO. The output mailbox can only be released when at least one message is pending in the FIFO. Setting this bit when the FIFO is empty has no effect. If more than one message is pending in the FIFO, the software has to release the output mailbox to access the next message.

Cleared by hardware when the output mailbox has been released.

Bit 4 **FOVR** FIFO Overrun

This bit is set by hardware when a new message has been received and passed the filter while the FIFO was full.

This bit is cleared by software writing '1'.

Bit 3 **FULL** FIFO Full

Set by hardware when three messages are stored in the FIFO.

This bit can be cleared by software writing '1' or by releasing the FIFO by means of RFOM.

Bit 2 Reserved, read as 0.

Bits 1:0 **FMP[1:0]** FIFO Message Pending

These bits indicate how many messages are pending in the receive FIFO.

FMP is increased each time the hardware stores a new message in to the FIFO. FMP is decreased each time the FIFO output mailbox has been released by hardware (RFOM bit has been cleared after prior setting by software).

23.11.6 CAN interrupt enable register (CAN_IER)

Address offset: 0x05

Reset value: 0x00

7	6	5	4	3	2	1	0
WKUIE	Reserved			FOVIE	FFIE	FMPIE	TMEIE
rw				rw	rw	rw	rw

Bit 7 **WKUIE** Wakeup Interrupt Enable

0: No interrupt when WKUI is set.

1: Interrupt generated when WKUI bit is set.

Bit 6:4 Reserved, read as 0.

Bit 3 **FOVIE** FIFO Overrun Interrupt Enable

0: No interrupt when FOVR bit is set.

1: Interrupt generated when FOVR bit is set.

- Bit 2 **FFIE** FIFO Full Interrupt Enable
 - 0: No interrupt when FULL bit is set.
 - 1: Interrupt generated when FULL bit is set.
- Bit 1 **FMPiE** FIFO Message Pending Interrupt Enable
 - 0: No interrupt on FMP[1:0] bits transition from 0b00 to 0b01.
 - 1: Interrupt generated on FMP[1:0] bits transition from 0b00 to 0b01.
- Bit 0 **TMEiE** Transmit Mailbox Empty Interrupt Enable
 - 0: No interrupt when RQCPx bit is set.
 - 1: Interrupt generated when RQCPx bit is set.

23.11.7 CAN diagnostic register (CAN_DGR)

Address offset: 0x06

Reset value: 0x0C

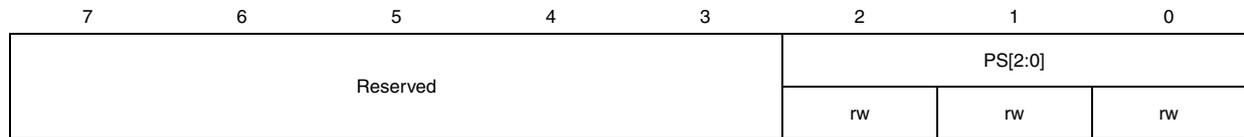
7	6	5	4	3	2	1	0
Reserved			TXM2E	RX	SAMP	SILM	LBKM
			rw	r	r	rw	rw

- Bit 7:5 Reserved, read as 0.
- Bit 4 **TXM2E** TX Mailbox 2 enable
 - 0: Force compatibility with ST7 beCAN (2 TX Mailboxes) - reset value
 - 1: Enables the third TX Mailbox (Mailbox number 2)
- Bit 3 **RX** CAN Rx Signal
 - Monitors the actual value of the **CAN_RX** Pin.
- Bit 2 **SAMP** Last sample point
 - The value of the last sample point.
- Bit 1 **SILM** Silent mode
 - 0: Normal operation
 - 1: Silent mode
- Bit 0 **LBKM** Loop back mode
 - 0: Loop back mode disabled
 - 1: Loop back mode enabled

23.11.8 CAN page select register (CAN_PSR)

Address offset: 0x07

Reset value: 0x00



Bits 7:3 Reserved, read as 0.

Bits 2:0 **PS[2:0]** Page select

This register is used to select the register page.

000: Tx Mailbox 0

001: Tx Mailbox 1

010: Acceptance Filter 0:1

011: Acceptance Filter 2:3

100: Acceptance Filter 4:5

101: Tx Mailbox 2

110: Configuration/Diagnostic

111: Receive FIFO

Refer to [Figure 145](#) for more details.

23.11.9 CAN error status register (CAN_ESR)

Address offset: See [Table 63](#).

Reset value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
Reserved	LEC[2:0]			Reserved	BOFF	EPVF	EWGF
	rw	rw	rw		r	r	r

Bit 7 Reserved, read as 0.

Bit 6:4 **LEC[2:0]** Last error code

This field holds a code which indicates the type of the last error detected on the CAN bus. If a message has been transferred (reception or transmission) without error, this field will be cleared to '0'. The code 7 is unused and may be written by the CPU to check for update.

- 000: No Error
- 001: Stuff Error
- 010: Form Error
- 011: Acknowledgment Error
- 100: Bit recessive Error
- 101: Bit dominant Error
- 110: CRC Error
- 111: Set by software

Bit 3 Reserved, read as 0.

Bit 2 **BOFF** Bus-off flag

This bit is set by hardware when it enters the bus-off state. The bus-off state is entered on CAN_TECR overrun, TEC greater than 255, refer to [Section 23.6.5 on page 369](#).

Bit 1 **EPVF** Error passive flag

This bit is set by hardware when the Error Passive limit has been reached (Receive Error Counter or Transmit Error Counter greater than 127).

Bit 0 **EWGF** Error warning flag

This bit is set by hardware when the warning limit has been reached. Receive Error Counter or Transmit Error Counter greater than 96.

23.11.10 CAN error interrupt enable register (CAN_EIER)

Address offset: See [Table 63](#).

Reset value: 0000 0000 (00h)

7	6	5	4	3	2	1	0	
ERRIE	Reserved		LECIE	Reserved		BOFIE	EPVIE	EWGIE
rw			rw			rw	rw	rw

Bit 7 **ERRIE** Error interrupt enable

0: No interrupt is generated when an error condition is pending in the CAN_ESR (ERRI bit in CAN_MSR is set).

1: An interrupt is generated when an error condition is pending in the CAN_ESR (ERRI bit in CAN_MSR is set).

Refer to [Figure 142](#) for more details.

Bit 6:5 Reserved, read as 0.

Bit 4 **LECIE** Last error code interrupt enable

0: ERRI bit is not set when the error code in LEC[2:0] is set by hardware on error detection.

1: ERRI bit is set when the error code in LEC[2:0] is set by hardware on error detection.

Bit 3 Reserved, read as 0.

Bit 2 **BOFIE** Bus-Off interrupt enable

0: ERRI bit is not set when BOFF is set.

1: ERRI bit is set when BOFF is set.

Bit 1 **EPVIE** Error passive interrupt enable

0: ERRI bit is not set set when EPVF is set.

1: ERRI bit is set when EPVF is set.

Bit 0 **EWGIE** Error warning interrupt enable

0: ERRI bit is not set when EWGF is set.

1: ERRI bit is set when EWGF is set.

23.11.11 CAN transmit error counter register (CAN_TECR)

Address offset: See [Table 63](#).

Reset value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
TEC[7:0]							
r	r	r	r	r	r	r	r

Bits 7:0 **TEC[7:0]** Transmit error counter

In case of an error during transmission, this counter is incremented by 8 depending on the error condition as defined by the CAN standard. After every successful transmission the counter is decremented by 1 or reset to 0 if the CAN controller exited from bus-off to error active state. When the counter value exceeds 127, the CAN controller enters the error passive state. When the counter value exceeds 255, the CAN controller enters the bus-off state.

23.11.12 CAN receive error counter register (CAN_RECR)

Address offset: See [Table 63](#).

Reset value: 0000 0000 (00h)

7	6	5	4	3	2	1	0
REC[7:0]							
r	r	r	r	r	r	r	r

Bits 7:0 **REC[7:0]** Receive error counter

This is the Receive Error Counter implementing part of the fault confinement mechanism of the CAN protocol. In case of an error during reception, this counter is incremented by 1 or by 8 depending on the error condition as defined by the CAN standard. After every successful reception the counter is decremented by 1 or reset to 120 if its value was higher than 128. When the counter value exceeds 127, the CAN controller enters the error passive state.

23.11.13 CAN bit timing register 1 (CAN_BTR1)

Address offset: See [Table 63](#).

Reset value: 0100 0000 (40h)

7	6	5	4	3	2	1	0
SJW[1:0]		BRP[5:0]					
rw	rw	rw	rw	rw	rw	rw	rw

This register can only be accessed by the software when the CAN hardware is in initialization mode.

Bits 7:6 **SJW[1:0]** Resynchronization jump width

These bits define the maximum number of time quanta the CAN hardware is allowed to lengthen or shorten a bit to perform the resynchronization. Resynchronization Jump Width = (SJW+1).

Bits 5:0 **BRP[5:0]** Baud rate prescaler

These bits define the length of a time quantum.

$$tq = (BRP+1)/f_{CAN}$$

where $f_{CAN} = f_{CANEXT}$ or f_{MASTER} (refer to CLKS bit configuration in the CAN_BTR2 register)

For more information on bit timing, please refer to [Section 23.6.6: Bit timing](#).

23.11.14 CAN bit timing register 2 (CAN_BTR2)

Address offset: See [Table 63](#).

Reset value: 0x23

7	6	5	4	3	2	1	0
CLKS	BS2[2:0]			BS1[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw

This register can only be accessed by the software when the CAN hardware is in initialization mode.

Bit 7 **CLKS** Clock input selection

- 0: CPU clock selected ($f_{CAN} = f_{MASTER}$)
- 1: External clock selected ($f_{CAN} = f_{CANEXT}$)

Note:

Bits 6:4 **BS2[2:0]** Bit Segment 2

These bits define the number of time quanta in Bit Segment 2.
 Bit Segment 2 = (BS2+1)

Bits 3:0 **BS1[3:0]** Bit Segment 1

These bits define the number of time quanta in Bit Segment 1
 Bit Segment 1 = (BS1+1)

For more information on bit timing, please refer to [Section 23.6.6: Bit timing](#).

23.11.15 Mailbox registers

This chapter describes the registers of the transmit and receive mailboxes. Refer to [Section 23.6.4: Message storage](#) for detailed register mapping.

Transmit and receive mailboxes have the same registers except:

- CAN_MCSR register in a transmit mailbox is replaced by CAN_MFMIR register in a receive mailbox.
- A receive mailbox is always write protected.
- A transmit mailbox is write enabled only while empty (the corresponding TME bit in the CAN_TPR register is set).

CAN message control/status register (CAN_MCSR)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: 0x00

	7	6	5	4	3	2	1	0
	Reserved		TERR	ALST	TXOK	RQCP	ABRQ	TXRQ
			r	r	r	rc_w1	rs	rs

Note: This register is implemented only in transmit mailboxes. In receive mailboxes, the CAN_MFMIR register is mapped at this location.

Bits 7:6 Reserved, read as 0.

Bit 5 **TERR** Transmission error

This bit is updated by hardware after each transmission attempt.

0: The previous transmission was successful

1: The previous transmission failed due to an error

Bit 4 **ALST** Arbitration lost

This bit is updated by hardware after each transmission attempt.

0: The previous transmission was successful

1: The previous transmission failed due to an arbitration lost

Bit 3 **TXOK** Transmission OK

The hardware updates this bit after each transmission attempt.

0: The previous transmission failed

1: The previous transmission was successful

Note: This bit has the same value as the corresponding TXOKx bit in the CAN_TSR register.

Bit 2 **RQCP** Request completed

Set by hardware when the last request (transmit or abort) has been performed.

Cleared by software writing a “1” or by hardware on transmission request.

Note: This bit has the same value as the corresponding RQCPx bit of the CAN_TSR register.

Clearing this bit clears all the status bits (TXOK, ALST and TERR) in the CAN_MCSR register and the corresponding RQCPx and TXOKx bits in the CAN_TSR register.

Bit 1 **ABRQ** Abort request for mailbox

Set by software to abort the transmission request for the corresponding mailbox.

Cleared by hardware when the mailbox becomes empty.

Setting this bit has no effect when the mailbox is not pending for transmission.

Bit 0 **TXRQ** Transmit mailbox request

Set by software to request the transmission for the corresponding mailbox.
Cleared by hardware when the mailbox becomes empty.

CAN mailbox filter match index register (CAN_MFMIR)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
FMI[7:0]							
r	r	r	r	r	r	r	r

Note: This register is implemented only in receive mailboxes. In transmit mailboxes, the CAN_MCSR register is mapped at this location.

Bits 7:0 **FMI[7:0]** Filter match index

This register contains the index of the filter the message stored in the mailbox passed through. For more details on identifier filtering please refer to [Section 23.6.3: Identifier filtering - Filter Match Index](#) paragraph.

CAN mailbox identifier register 1 (CAN_MIDR1)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
Reserved	IDE	RTR	STID[10:6] / EXID[28:24]				
	rw	rw	rw	rw	rw	rw	rw

Bit 7 Reserved, read as 0.

Bit 6 **IDE** Extended identifier

This bit defines the identifier type of message in the mailbox.
0: Standard identifier.
1: Extended identifier.

Bit 5 **RTR** Remote transmission request

0: Data frame
1: Remote frame

Bits 4:0 **STID[10:6]** Standard identifier

5 most significant bits of the standard part of the identifier.

or

EXID[28:24] Extended identifier

5 most significant bits of the “Base” part of extended identifier.

CAN mailbox identifier register 2 (CAN_MIDR2)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
STID[5:0] / EXID[23:18]						EXID[17:16]	
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:2 **STID[5:0]** Standard Identifier
 6 least significant bits of the standard part of the identifier.
 or
EXID[23:18] Extended Identifier
 6 least significant bits of the “Base” part of extended identifier.

Bits 1:0 **EXID[17:16]** Extended Identifier
 2 most significant bits of the “Extended” part of the extended identifier.

CAN mailbox identifier register 3 (CAN_MIDR3)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
EXID[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **EXID[15:8]** Extended identifier
 Bit 15 to 8 of the “Extended” part of the extended identifier.

CAN mailbox identifier register 4 (CAN_MIDR4)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
EXID[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **EXID[7:0]** Extended identifier
 8 least significant bits of the “Extended” part of the extended identifier.

CAN mailbox data length control register (CAN_MDLCR)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
TGT	Reserved			DLC[3:0]			
rw				rw	rw	rw	rw

Bit 7 **TGT** Transmit global time

This bit is active only when the hardware is in the Time Trigger Communication mode, TTCM bit in the CAN_MCR register is set.

0: CAN_MTSRH and CAN_MTSRL registers are not sent.

1: CAN_MTSRH and CAN_MTSRL registers are sent in the last two data bytes of the message.

Bits 6:4 Reserved, read as 0.

Bits 3:0 **DLC[3:0]** Data length code

This field defines the number of data bytes in a data frame or a remote frame request.

CAN mailbox data register x (CAN_MDAR) (x= 1 .. 8)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
DATA[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **DATA[7:0]** Data

A data byte of the message. A message can contain from 0 to 8 data bytes.

Note: These bits are write protected when the mailbox is not in empty state.

CAN mailbox time stamp register low (CAN_MTSRL)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
TIME[7:0]							
r	r	r	r	r	r	r	r

Bits 7:0 **TIME[7:0]** Message time stamp low

This field contains the low byte of the 16-bit timer value captured at the SOF detection.

CAN mailbox time stamp register high (CAN_MTSRH)

Address offset: See [Table 58](#). and [Table 59](#).

Reset value: undefined

7	6	5	4	3	2	1	0
TIME[15:8]							
r	r	r	r	r	r	r	r

Bits 7:0 **TIME[15:8]** Message time stamp high
 This field contains the high byte of the 16-bit timer value captured at the SOF detection.

23.11.16 CAN filter registers

CAN filter mode register 1 (CAN_FMR1)

Address offset: See [Table 63](#).

Reset value: 0x00

7	6	5	4	3	2	1	0
FMH3	FML3	FMH2	FML2	FMH1	FML1	FMH0	FML0
rw							

- Bit 7 **FMH3** Filter 3 mode high
 Mode of the high identifier/mask registers of Filter 3.
 0: High registers are in mask mode
 1: High registers are in identifier list mode
- Bit 6 **FML3** Filter 3 mode low
 Mode of the low identifier/mask registers of Filter 3.
 0: Low registers are in mask mode
 1: Low registers are in identifier list mode
- Bit 5 **FMH2** Filter 2 mode high
 Mode of the high identifier/mask registers of Filter 2.
 0: High registers are in mask mode
 1: High registers are in identifier list mode
- Bit 4 **FML2** Filter 2 mode low
 Mode of the low identifier/mask registers of Filter 2.
 0: Low registers are in mask mode
 1: Low registers are in identifier list mode
- Bit 3 **FMH1** Filter 1 mode high
 Mode of the high identifier/mask registers of Filter 1.
 0: High registers are in mask mode
 1: High registers are in identifier list mode

- Bits 2 **FML1** Filter 1 mode low
 Mode of the low identifier/mask registers of filter 1.
 0: Low registers are in mask mode
 1: Low registers are in identifier list mode
- Bit 1 **FMH0** Filter 0 mode high
 Mode of the high identifier/mask registers of filter 0.
 0: High registers are in mask mode
 1: High registers are in identifier list mode
- Bit 0 **FML0** Filter 0 mode low
 Mode of the low identifier/mask registers of filter 0.
 0: Low registers are in mask mode
 1: Low registers are in identifier list mode

CAN filter mode register 2 (CAN_FMR2)

Address offset: See [Table 63](#).

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved				FMH5	FML5	FMH4	FML4
				rw	rw	rw	rw

- Bits 7:4 Reserved, read as 0.
- Bit 3 **FMH5** Filter 5 mode high
 Mode of the high identifier/mask registers of Filter 5.
 0: High registers are in mask mode
 1: High registers are in identifier list mode
- Bits 2 **FML5** Filter 5 mode low
 Mode of the low identifier/mask registers of filter 5.
 0: Low registers are in mask mode
 1: Low registers are in identifier list mode
- Bit 1 **FMH4** Filter 4 mode high
 Mode of the high identifier/mask registers of filter 4.
 0: High registers are in mask mode
 1: High registers are in identifier list mode
- Bit 0 **FML4** Filter 4 mode low
 Mode of the low identifier/mask registers of filter 4.
 0: Low registers are in mask mode
 1: Low registers are in identifier list mode

CAN filter configuration register 1 (CAN_FCR1)

Address offset: See [Table 63](#).

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	FSC11	FSC10	FACT1	Reserved	FSC01	FSC00	FACT0
	rw	rw	rw		rw	rw	rw

Bit 7 Reserved, read as 0.

Bits 6:5 **FSC1[1:0]** Filter scale configuration

These bits define the scale configuration of Filter 1.

Bit 4 **FACT1** Filter Active

The software sets this bit to activate Filter 1. To modify the Filter 1 registers (CAN_F1Rx), the FACT1 bit must be cleared.

0: Filter 1 is not active

1: Filter 1 is active

Bit 3 Reserved, read as 0.

Bits 2:1 **FSC0[1:0]** Filter scale configuration

These bits define the scale configuration of Filter 0.

Bit 0 **FACT0** Filter active

The software sets this bit to activate Filter 0. To modify the Filter 0 registers (CAN_F0Rx), the FACT0 bit must be cleared.

0: Filter 0 is not active

1: Filter 0 is active

CAN filter configuration register 2 (CAN_FCR2)

Address offset: See [Table 63](#).

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	FSC31	FSC30	FACT3	Reserved	FSC21	FSC20	FACT2
	rw	rw	rw		rw	rw	rw

Bit 7 Reserved, read as 0.

Bits 6:5 **FSC3[1:0]** Filter scale configuration

These bits define the scale configuration of Filter 3.

Bit 4 **FACT3** Filter active

The software sets this bit to activate Filter 3. To modify the Filter 3 registers (CAN_F3Rx) the FACT3 bit must be cleared.

0: Filter 3 is not active

1: Filter 3 is active

Bit 3 Reserved, read as 0.

Bits 2:1 **FSC2[1:0]** Filter scale configuration

These bits define the scale configuration of Filter 2.

Bit 0 **FACT2** Filter active

The software sets this bit to activate Filter 2. To modify the Filter 2 registers (CAN_F2Rx), the FACT2 bit must be cleared.

0: Filter 2 is not active

1: Filter 2 is active

CAN filter configuration register 3 (CAN_FCR3)

Address offset: See [Table 63](#).

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	FSC51	FSC50	FACT5	Reserved	FSC41	FSC40	FACT4
	rw	rw	rw		rw	rw	rw

Bit 7 Reserved, read as 0.

Bits 6:5 **FSC5[1:0]** Filter scale configuration

These bits define the scale configuration of Filter 5.

Bit 4 **FACT5** Filter active

The software sets this bit to activate Filter 5. To modify the Filter 5 registers (CAN_F5Rx) the FACT5 bit must be cleared.

0: Filter 5 is not active

1: Filter 5 is active

Bit 3 Reserved, read as 0.

Bits 2:1 **FSC4[1:0]** Filter scale configuration

These bits define the scale configuration of Filter 4.

Bit 0 **FACT4** Filter active

The software sets this bit to activate Filter 4. To modify the Filter 4 registers (CAN_F4Rx), the FACT4 bit must be cleared.

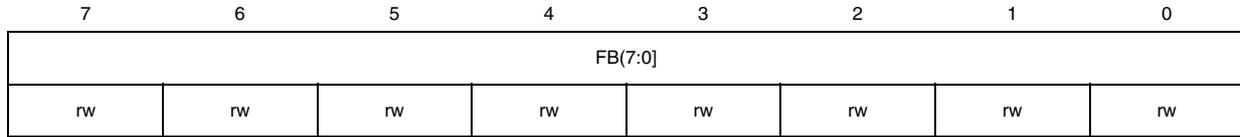
0: Filter 4 is not active

1: Filter 4 is active

CAN filter bank i register x (CAN_FiRx) (i = 0 .. 5, x = 1 .. 8)

Address offset: See [Figure 145](#).

Reset value: undefined



Bits 7:0 **FB[7:0]**: Filter bits

- **Identifier**

Each bit of the register specifies the level of the corresponding bit of the expected identifier.

- 0: Dominant bit is expected
- 1: Recessive bit is expected

- **Mask**

Each bit of the register specifies whether the bit of the associated identifier register must match with the corresponding bit of the expected identifier or not.

- 0: Don't care, the bit is not used for the comparison
- 1: Must match, the bit of the incoming identifier must have the same level as specified in the corresponding identifier register of the filter.

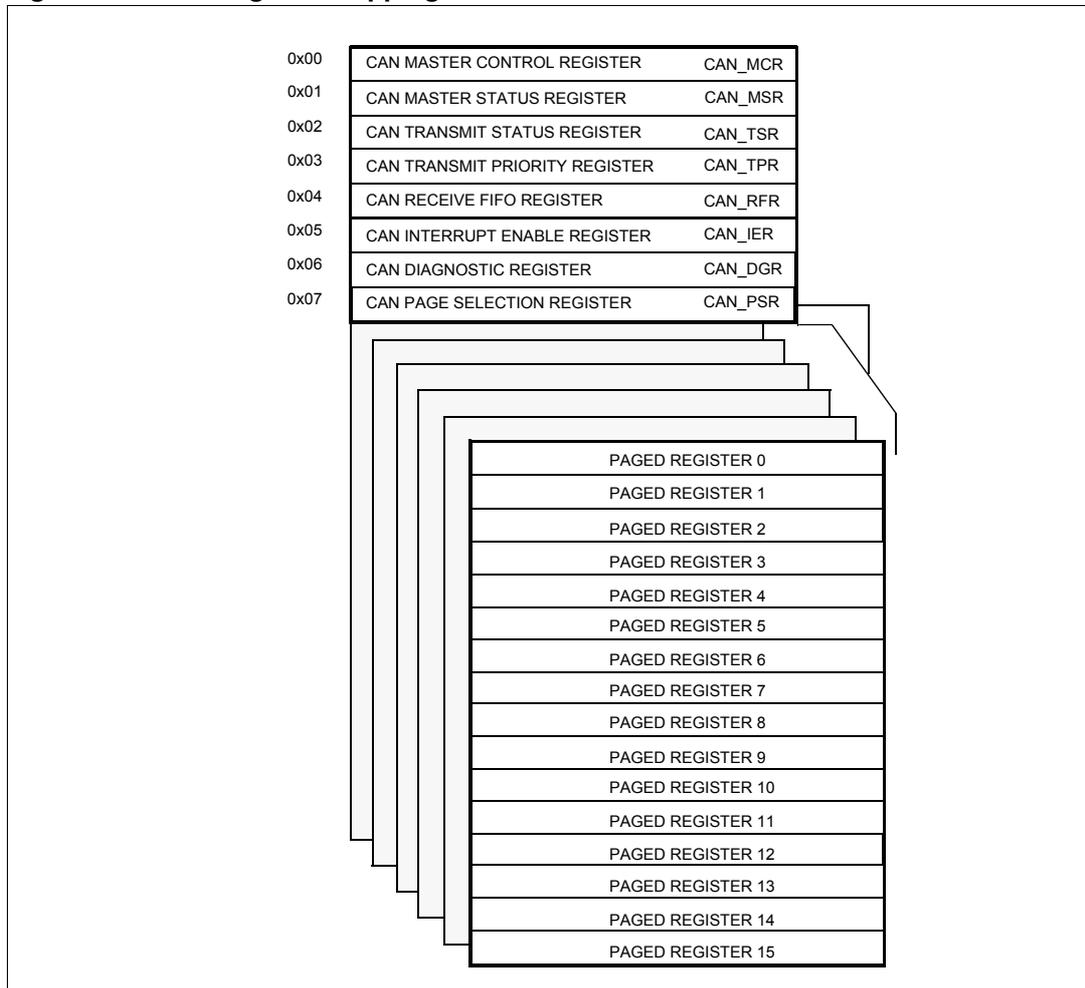
Note: Each filter i is composed of 8 registers, CAN_FiR1..8. Depending on the scale and mode configuration of the filter the function of each register can differ. For the filter mapping, functions description and mask registers association, refer to Section [Figure 23.6.3: Identifier filtering](#).

*A Mask/Identifier register in **mask mode** has the same bit mapping as in **identifier list mode**.*

Note: To modify these registers, the corresponding **FACT** bit in the CAN_FCRx register must be cleared.

23.12 CAN register map

Figure 144. CAN register mapping



23.12.1 Page mapping for CAN

Figure 145. CAN page mapping

	PAGE 0	PAGE 1	PAGE 2	PAGE 3	PAGE 4
0x00	CAN_MCSR	CAN_MCSR	CAN_F0R1	CAN_F2R1	CAN_F4R1
0x01	CAN_MDLCR	CAN_MDLCR	CAN_F0R2	CAN_F2R2	CAN_F4R2
0x02	CAN_MIDR1	CAN_MIDR1	CAN_F0R3	CAN_F2R3	CAN_F4R3
0x03	CAN_MIDR2	CAN_MIDR2	CAN_F0R4	CAN_F2R4	CAN_F4R4
0x04	CAN_MIDR3	CAN_MIDR3	CAN_F0R5	CAN_F2R5	CAN_F4R5
0x05	CAN_MIDR4	CAN_MIDR4	CAN_F0R6	CAN_F2R6	CAN_F4R6
0x06	CAN_MDAR1	CAN_MDAR1	CAN_F0R7	CAN_F2R7	CAN_F4R7
0x07	CAN_MDAR2	CAN_MDAR5	CAN_F0R8	CAN_F2R8	CAN_F4R8
0x08	CAN_MDAR3	CAN_MDAR6	CAN_F1R1	CAN_F3R1	CAN_F5R1
0x09	CAN_MDAR4	CAN_MDAR4	CAN_F1R2	CAN_F3R2	CAN_F5R2
0x0A	CAN_MDAR5	CAN_MDAR5	CAN_F1R3	CAN_F3R3	CAN_F5R3
0x0B	CAN_MDAR6	CAN_MDAR6	CAN_F1R4	CAN_F3R4	CAN_F5R4
0x0C	CAN_MDAR7	CAN_MDAR7	CAN_F1R5	CAN_F3R5	CAN_F5R5
0x0D	CAN_MDAR8	CAN_MDAR8	CAN_F1R6	CAN_F3R6	CAN_F5R6
0x0E	CAN_MTSRL	CAN_MTSRL	CAN_F1R7	CAN_F3R7	CAN_F5R7
0x0F	CAN_MTSRH	CAN_MTSRH	CAN_F1R8	CAN_F3R8	CAN_F5R8
	Tx Mailbox 0	Tx Mailbox 1	Acceptance Filter 0:1	Acceptance Filter 2:3	Acceptance Filter 4:5
	PAGE 5	PAGE 6	PAGE 7		
0x00	CAN_MCSR	CAN_ESR	CAN_MFMIR		
0x01	CAN_MDLCR	CAN_EIER	CAN_MDLCR		
0x02	CAN_MIDR1	CAN_TECR	CAN_MIDR1		
0x03	CAN_MIDR2	CAN_RECR	CAN_MIDR2		
0x04	CAN_MIDR3	CAN_BTR1	CAN_MIDR3		
0x05	CAN_MIDR4	CAN_BTR2	CAN_MIDR4		
0x06	CAN_MDAR1	Reserved	CAN_MDAR1		
0x07	CAN_MDAR2	Reserved	CAN_MDAR2		
0x08	CAN_MDAR3	CAN_FMR1	CAN_MDAR3		
0x09	CAN_MDAR4	CAN_FMR2	CAN_MDAR4		
0x0A	CAN_MDAR5	CAN_FCR1	CAN_MDAR5		
0x0B	CAN_MDAR6	CAN_FCR2	CAN_MDAR6		
0x0C	CAN_MDAR7	CAN_FCR3	CAN_MDAR7		
0x0D	CAN_MDAR8	Reserved	CAN_MDAR8		
0x0E	CAN_MTSRL	Reserved	CAN_MTSRL		
0x0F	CAN_MTSRH	Reserved	CAN_MTSRH		
	Tx Mailbox 2 (if TXM2E=1 in CAN_DGR register)	Configuration/Diagnostic	Receive FIFO		

Table 61. beCAN control and status page - register map and reset values

Address Offset	Register name	7	6	5	4	3	2	1	0
0x00	CAN_MCR Reset Value	TTCM 0	ABOM 0	AWUM 0	NART 0	RFLM 0	TXFP 0	SLEEP 1	INRQ 0
0x01	CAN_MSR Reset Value	0	0	RX 0	TX 0	WKUI 0	ERRI 0	SLAK 1	INAK 0
0x02	CAN_TSR Reset Value	0	TXOK2 0	TXOK1 0	TXOK0 0	0	RQCP2 0	RQCP1 0	RQCP0 0
0x03	CAN_TPR Reset Value	LOW2 0	LOW1 0	LOW0 0	TME2 1	TME1 1	TME0 1	CODE1 0	CODE0 0
0x04	CAN_RFR Reset Value	0	0	RFOM 0	FOVR 0	FULL 0	0	FMP1 0	FMP0 0
0x05	CAN_IER Reset Value	WKUIE 0	0	0	0	FOVIE 0	FFIE 0	FMPIE 0	TMEIE 0
0x06	CAN_DGR Reset Value	0	0	0	TXM2E 0	RX 1	SAMP 1	SILM 0	LBKM 0
0x07	CAN_PSR Reset Value	0	0	0	0	0	PS2 0	PS1 0	PS0 0

Table 62. beCAN mailbox pages - register map and reset values

Address Offset	Register name	7	6	5	4	3	2	1	0
0x00 Receive	CAN_MFMIR Reset Value	FMI7 x	FMI6 x	FMI5 x	FMI4 x	FMI3 x	FMI2 x	FMI1 x	FMI0 x
0x00 Transmit	CAN_MCSR Reset Value	0	0	TERR 0	ALST 0	TXOK 0	RQCP 0	ABRQ 0	TXRQ 0
0x01	CAN_MDLCR Reset Value	TGT x	x	x	x	DLC3 x	DLC2 x	DLC1 x	DLC0 x
0x02	CAN_MIDR1 Reset Value	x	IDE x	RTR x	STID10 / EXID28 x	STID9 / EXID27 x	STID8 / EXID26 x	STID7 / EXID25 x	STID6 / EXID24 x
0x03	CAN_MIDR2 Reset Value	STID5 / EXID23 x	STID4 / EXID22 x	STID3 / EXID21 x	STID2 / EXID20 x	STID1 / EXID19 x	STID0 / EXID18 x	EXID17 x	EXID16 x
0x04	CAN_MIDR3 Reset Value	EXID15 x	EXID14 x	EXID13 x	EXID12 x	EXID11 x	EXID10 x	EXID9 x	EXID8 x
0x05	CAN_MIDR4 Reset Value	EXID7 x	EXID6 x	EXID5 x	EXID4 x	EXID3 x	EXID2 x	EXID1 x	EXID0 x
0x06:0D	CAN_MDAR1:8 Reset Value	MDAR7 x	MDAR6 x	MDAR5 x	MDAR4 x	MDAR3 x	MDAR2 x	MDAR1 x	MDAR0 x

Table 62. beCAN mailbox pages - register map and reset values (continued)

Address Offset	Register name	7	6	5	4	3	2	1	0
0x0E	CAN_MTSRL Reset Value	TIME7 x	TIME6 x	TIME5 x	TIME4 x	TIME3 x	TIME2 x	TIME1 x	TIME0 x
0x0F	CAN_MTSRH Reset Value	TIME15 x	TIME14 x	TIME13 x	TIME12 x	TIME11 x	TIME10 x	TIME9 x	TIME8 x

Table 63. beCAN filter configuration page - register map and reset values

Address Offset	Register name	7	6	5	4	3	2	1	0
0x00	CAN_ESR Reset Value	0	LEC2 0	LEC1 0	LEC0 0	0	BOFF 0	EPVF 0	EWGF 0
0x01	CAN_EIER Reset Value	ERRIE 0	0	0	LECIE 0	0	BOFIE 0	EPVIE 0	EWGIE 0
0x02	CAN_TECR Reset Value	TEC7 0	TEC6 0	TEC5 0	TEC4 0	TEC3 0	TEC2 0	TEC1 0	TEC0 0
0x03	CAN_RECR Reset Value	REC7 0	REC6 0	REC5 0	REC4 0	REC3 0	REC2 0	REC1 0	REC0 0
0x04	CAN_BTR1 Reset Value	SJW1 0	SJW0 1	BRP5 0	BRP4 0	BRP3 0	BRP2 0	BRP1 0	BRP0 0
0x05	CAN_BTR2 Reset Value	CLKS 0	BS22 0	BS21 1	BS20 0	BS13 0	BS12 0	BS11 1	BS10 1
0x06	Reserved	X	X	X	X	X	X	X	X
0x07	Reserved	X	X	X	X	X	X	X	X
0x08	CAN_FMR1 Reset Value	FMH3 0	FML3 0	FMH2 0	FML2 0	FMH1 0	FML1 0	FMH0 0	FML0 0
0x09	CAN_FMR2 Reset Value	0	0	0	0	FMH5 0	FML5 0	FMH4 0	FML4 0
0x0A	CAN_FCR1 Reset Value	0	FSC11 0	FSC10 0	FACT1 0	0	FSC01 0	FSC00 0	FACT0 0
0x0B	CAN_FCR2 Reset Value	0	FSC31 0	FSC30 0	FACT3 0	0	FSC21 0	FSC20 0	FACT2 0
0x0C	CAN_FCR3 Reset Value	0	FSC51 0	FSC50 0	FACT5 0	0	FSC41 0	FSC40 0	FACT4 0

24 Analog/digital converter (ADC)

24.1 Introduction

ADC1 and ADC2 are 10-bit successive approximation Analog to Digital Converters. They have up to 16 multiplexed input channels (the exact number of channels is indicated in the datasheet pin description). A/D Conversion of the various channels can be performed in single, and continuous modes.

ADC1 has extended features for scan mode, buffered continuous mode and analog watchdog. Refer to the datasheet for information about availability ADC1 and ADC2 in specific product types.

24.2 ADC main features

These features are available in ADC1 and ADC2.

- 10-bit resolution
- Single and continuous conversion modes
- Programmable prescaler: f_{MASTER} divided by 2 to 18
- External trigger option using external interrupt (ADC_ETR) or timer trigger (TRGO)
- Analog zooming (in devices with V_{REF} pins)
- Interrupt generation at End of Conversion
- Data alignment with in-built data coherency
- ADC input range: $V_{\text{SSA}} \leq V_{\text{IN}} \leq V_{\text{DDA}}$

24.3 ADC extended features

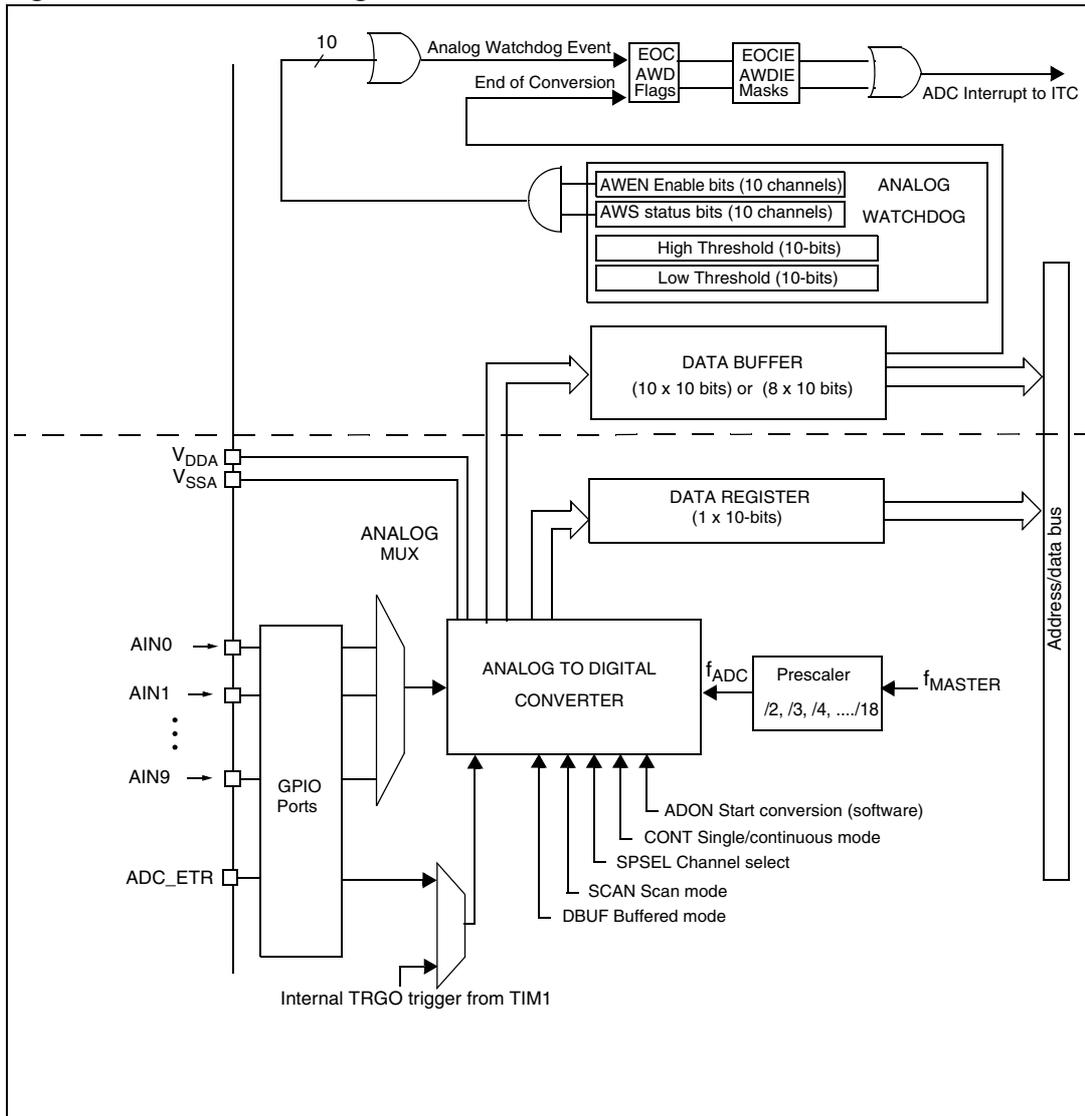
These features are available in ADC1.

- Buffered continuous conversion mode⁽¹⁾
- Scan mode for single and continuous conversion
- Analog watchdog with upper and lower thresholds
- Interrupt generation at analog watchdog event

The block diagrams of ADC1 and ADC2 are shown in [Figure 146](#) and [Figure 147](#)

1. Data buffer size is product dependent (10 x 10 bits or 8 x 10 bits). Please refer to the datasheet.

Figure 146. ADC1 block diagram



24.4 ADC pins

Table 64. ADC pins

Name	Signal type	Remarks
V _{DDA}	Input, Analog supply	Analog power supply. This input is bonded to V _{DD} in devices that have no external V _{DDA} pin.
V _{SSA}	Input, Analog supply ground	Ground for analog power supply. This input is bonded to V _{SS} in devices that have no external V _{SSA} pin.
V _{REF-}	Input, Analog Reference negative	The lower/negative reference voltage for the ADC, ranging from V _{SSA} to (V _{SSA} + 500 mV). This input is bonded to V _{SSA} in devices that have no external VREF- pin (packages with 48 pins or less)
V _{REF+}	Input, Analog Reference positive	The higher/positive reference voltage for the ADC, ranging from 2.75 V to V _{DDA} . This input is bonded to V _{DDA} in devices that have no external VREF+ pin (packages with 48 pins or less)
AIN[15:0]	Analog input signals	Up to 16 analog input channels, which are converted by the ADC one at a time.
ADC_ETR	Digital input signals	External trigger.

24.5 ADC functional description

24.5.1 ADC on-off control

The ADC can be powered-on by setting the ADON bit in the ADC_CR1 register. When the ADON bit is set for the first time, it wakes up the ADC from power down mode. To start conversion, set the ADON bit in the ADC_CR1 register with a second write instruction.

At the end of conversion, the ADC remains powered on and you have to set the ADON bit only once to start the next conversion.

If the ADC is not used for a long time, it is recommended to switch it to power down mode to decrease power consumption. This is done by clearing the ADON bit.

When the ADC is powered on, the output stage of the selected channel is disabled, therefore it is recommended to select the channel first before powering-on the ADC.

24.5.2 ADC clock

The clock supplied to the ADC can be by a prescaled f_{MASTER} clock. The prescaling factor of the clock depends on the SPSEL[2:0] bits in the ADC_CR1 register.

24.5.3 Channel selection

There are up to 16 external input channels. The number of external channels depends on the MCU package size.

If the channel selection is changed during a conversion, the current conversion is reset and a new start pulse is sent to the ADC.

24.5.4 Conversion modes

The ADC supports five conversion modes: single mode, continuous mode, buffered continuous mode, single scan mode, continuous scan mode.

Single mode

In Single conversion mode, the ADC does one conversion on the channel selected by the CH[3:0] bits in the ADC_CSR register. This mode is started by setting the ADON bit in the ADC_CR1 register, while the CONT bit is 0.

Once the conversion is complete, the converted data are stored in the ADC_DR register, the EOC (End of Conversion) flag is set and an interrupt is generated if the EOCIE bit is set.

Continuous and buffered continuous modes

In continuous conversion mode, the ADC starts another conversion as soon as it finishes one. This mode is started by setting the ADON bit in the ADC_CR1 register, while the CONT bit is set.

- If buffering is not enabled (DBUF bit = 0 in the ADC_CR3 register), the converted data is stored in the ADC_DR register and the EOC (End of Conversion) flag is set. An interrupt is generated if the EOCIE bit is set. Then a new conversion starts automatically.
- If buffering is enabled (DBUF bit =1) the data buffer is filled with the results of 8 or 10 consecutive conversions performed on a single channel. When the buffer is full, the EOC (End of Conversion) flag is set and an interrupt is generated if the EOCIE bit is set. Then a new set of 8 or 10 conversions starts automatically. The OVR flag is set if one of the data buffer registers is overwritten before it has been read (see [Section 24.5.5](#)).

To stop continuous conversion, reset the CONT bit to stop conversion or reset the ADON bit to power off the ADC.

Single scan mode

This mode is used to convert a sequence of analog channels from AIN0 to AINn where 'n' is the channel number defined by the CH[3:0] bits in the ADC_CSR register. During the scan conversion sequence the CH[3:0] bits are updated by hardware and contain the channel number currently being converted.

Single scan mode is started by setting the ADON bit while the SCAN bit is set and the CONT bit is cleared.

Note: When using scan mode, it is not possible to use channels AIN0 to AINn in output mode because the output stage of each channel is disabled when it is selected by the ADC multiplexer.

A single conversion is performed for each channel starting with AIN0 and the data is stored in the data buffer registers ADC_DBxR. When the last channel (channel 'n') has been converted, the EOC (End of Conversion) flag is set and an interrupt is generated if the EOCIE bit is set.

The converted values for each channel can be read from the data buffer registers. The OVR flag is set if one of the data buffer registers is overwritten before it has been read (see [Section 24.5.5](#)).

Do not clear the SCAN bit while the conversion sequence is in progress. Single scan mode can be stopped immediately by clearing the ADON bit.

To start a new SCAN conversion, clear the EOC bit and set the ADON bit in the ADC_CR1 register.

Continuous scan mode

This mode is like single scan mode except that each time the last channel has been converted, a new scan conversion from channel 0 to channel n starts automatically. The OVR flag is set if one of the data buffer registers is overwritten before it has been read (see [Section 24.5.5](#)).

Continuous scan mode is started by setting the ADON bit while the SCAN and CONT bits are set.

Do not clear the SCAN bit while scan conversion is in progress.

Continuous scan mode can be stopped immediately by clearing the ADON bit. Alternatively if the CONT bit is cleared while conversion is ongoing, conversion stops the next time the last channel has been converted.

Caution: In scan mode, do not use a bit manipulation instruction (BRES) to clear the EOC flag. This is because this performs a read-modify-write on the whole ADC_CSR register, reading the current channel number from the CH[3:0] register and writing it back, which changes the last channel number for the scan sequence.

The correct way to clear the EOC flag in continuous scan mode is to load a byte in the ADC_CSR register from a RAM variable, clearing the EOC flag and reloading the last channel number for the scan sequence

24.5.5 Overrun flag

The OVR error flag is set by hardware in buffered continuous mode, single scan or continuous scan modes. It indicates that one of the ten data buffer registers was overwritten by a new converted value before the previous value was read. In this case, it is recommended to start a new conversion.

Note: *Setting the ADON bit automatically clears the OVR flag.*

24.5.6 Analog watchdog

The analog watchdog is enabled for single conversion and non-buffered continuous conversion modes by setting the AWDEN bit in the ADC_CSR register.

The AWD analog watchdog flag is set if the analog voltage converted by the ADC is below a low threshold or above a high threshold as shown in [Figure 148](#). These thresholds are programmed in the ADC_HTR and ADC_LTR 10-bit registers. An interrupt can be enabled by setting the AWDIE bit in the ADC_CSR register.

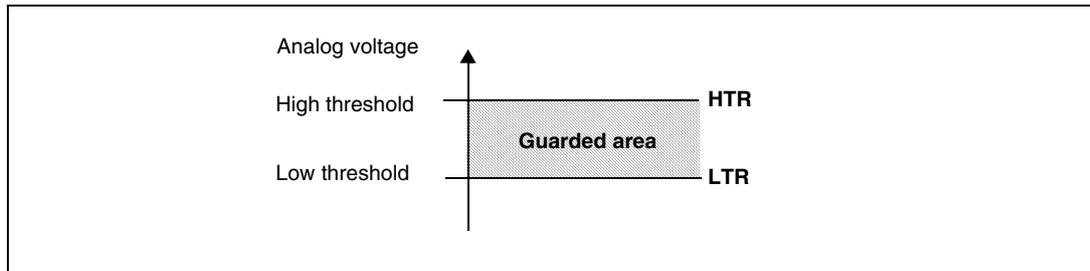
For Scan mode, the analog watchdog can be enabled on selected channels using the AWENx bits in the ADC_AWCRH and ADC_AWCRL registers. The watchdog status for each channel is obtained by reading the AWSx bits in the ADC_AWSRH and ADC_AWSRL registers. If any of the AWS flags are set, this also sets the AWD flag. Depending on the AWDIE interrupt enable bit, an interrupt is generated at the end of the SCAN sequence. The interrupt routine should then clear the AWS flag and the global AWD flag in the ADC_CSR register.

For Buffered continuous mode, the analog watchdog can be enabled on selected buffers, and is managed as described for scan mode, with the difference the buffers contain the results of continuous conversions performed on a single channel.

Refer to [Section 24.7](#) for more details on interrupts.

Note: To optimize analog watchdog interrupt latency in scan or buffered continuous mode, it is recommended to use the last channels in the conversion sequence.

Figure 148. Analog watchdog guarded area



24.5.7 Conversion on external trigger

Conversion can be triggered by a rising edge event on the ADC_ETR pin or a TRGO event from a timer. Refer to the datasheet for details on the timer trigger, as this is product dependent). If the EXTTRIG control bit is set then either of the external events can be used to trigger a conversion. The EXTSEL[1:0] bits are used to select the two possible sources of events that can trigger conversion.

To use external trigger mode:

1. The ADC is in off state (ADON=0) and EOC bit is cleared.
2. Select trigger source (EXTSEL [1:0]).
3. Set external trigger mode EXTTRIG=1 using a BSET instruction in order not to change other bits in the register.
4. If the trigger source is in high state, this switches on the ADC. For this reason, test if ADC is switched off (ADON=0), then switch on ADC (ADON=1).
5. Wait for the stabilisation time (t_{STAB}). If an external trigger occurs before t_{STAB} elapses, the result will not be accurate.
6. Conversion starts when an external trigger event occurs.

- Note:*
- 1 If timer trigger mode is selected (timer event as trigger source, not external pin) it is recommended to start the timer only when the ADC is completely set - and stop the timer before the ADC is switched off.
 - 2 External trigger mode must be disabled (EXTTRIG=0) before executing a HALT instruction.

24.5.8 Analog zooming

Analog zooming is supported in devices with external reference voltage pins (V_{REF+} and V_{REF-}). In analog zooming, the reference voltage is chosen to allow increased resolution in a reduced voltage range. Refer to the datasheet for details on the allowed reference voltage range.

24.5.9 Timing diagram

As shown in [Figure 149](#), after ADC power on, the ADC needs a stabilization time t_{STAB} (equivalent to one conversion time t_{CONV}) before it starts converting accurately. For subsequent conversions there is no stabilization delay and ADON needs to be set only once. The ADC conversion time takes 14 clock cycles. After conversion the EOC flag is set and the 10-bit ADC Data register contains the result of the conversion.

Figure 149. Timing diagram in single mode (CONT =0)

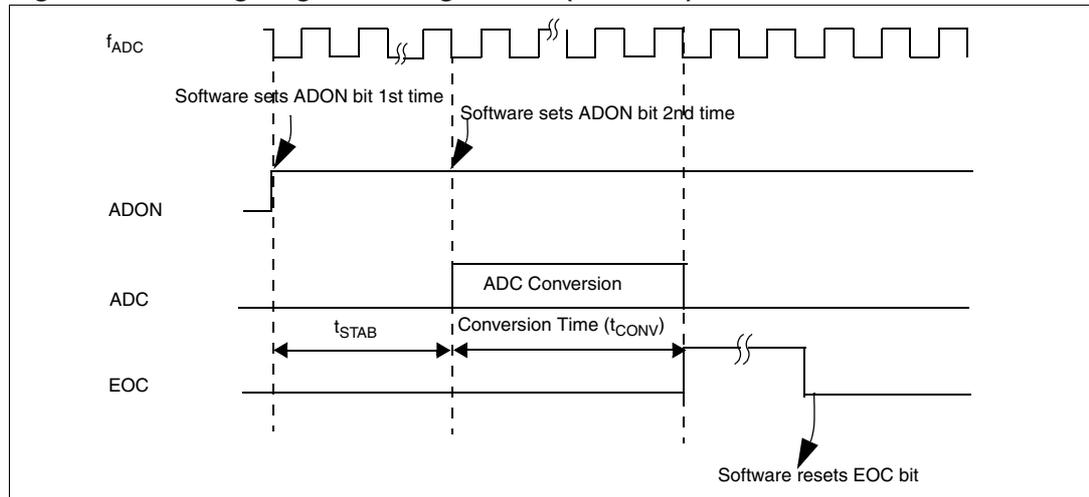
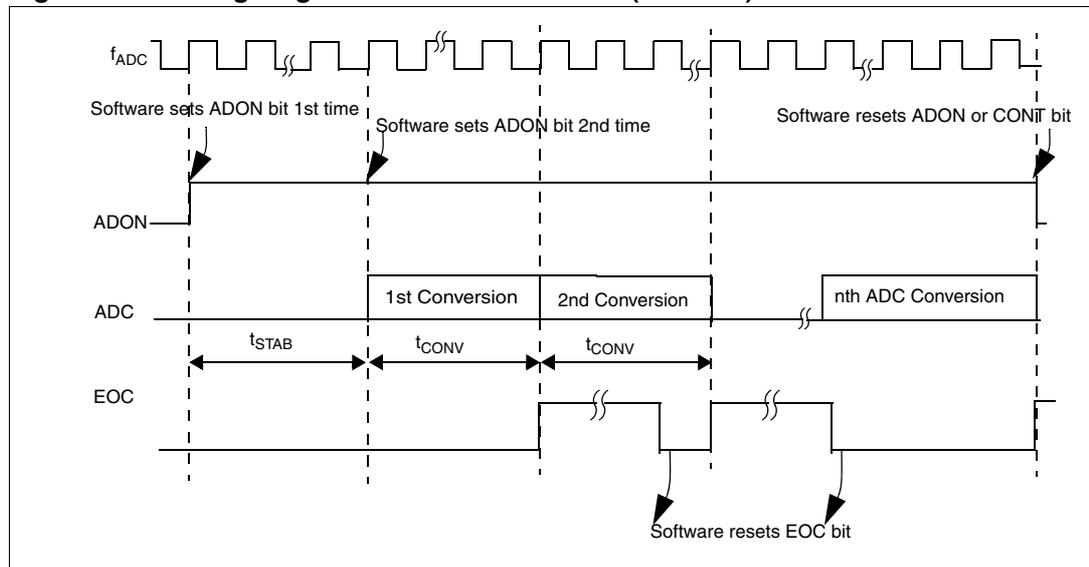


Figure 150. Timing diagram in continuous mode (CONT=1)



24.6 ADC low power modes

Table 65. Low power modes

Mode	Description
WAIT	No effect on ADC
HALT/ Fast Active HALT/ Slow Active HALT	In devices with extended features, the ADC is automatically switched off before entering HALT/Active HALT mode. After waking up from HALT/Fast Active HALT or Slow Active HALT mode, the ADON bit must be set by software to power on the ADC, and a delay of 7 μ s is needed before starting a new conversion.

The ADC does not have the capability to wake the device from Active Halt or Halt Mode.

24.7 ADC interrupts

The ADC interrupt control bits are summarized in [Table 66](#), [Table 67](#) and [Table 68](#)

Table 66. ADC Interrupts in single and non-buffered continuous mode (ADC1 and ADC2)

Enable bits			Status flags			Exit from Wait	Exit from Halt
AWDENX	AWDIE	EOCIE	AWSx	AWDG	EOC		
Don't care	0	0	Don't care	Flag is set if the channel crosses the programmed thresholds.	Flag is set at the end of each conversion.	No	No
	0	1		Flag is set if the channel crosses the programmed thresholds.	Flag is set at the end of each conversion and an interrupt is generated.	Yes	No
	1	0		Flag is set if the channel crosses the programmed thresholds. An interrupt is generated but continuous conversion is not stopped.	Flag is set at the end of each conversion.	Yes	No
	1	1		Flag is set if the channel crosses the programmed thresholds. An interrupt is generated but continuous conversion is not stopped.	Flag is set at the end of each conversion and an interrupt is generated.	Yes	no

Table 67. ADC interrupts in buffered continuous mode (ADC1)

Enable bits			Status flags			Exit from Wait	Exit from Halt
AWE _{Nx}	AWDIE	EOCIE	AWS _x	AWD	EOC		
0	Don't care	0	0	0	The flag is set at the end of BSIZE conversions	No	No
0	Don't care	1	0		The flag is set at the end of BSIZE conversions and an interrupt is generated.	Yes	No
1	0	0	Flag is set if conversion on buffer "x" crosses the thresholds programmed in the ADC_HTR and ADC_LTR registers	The flag is set at the end of BSIZE conversions if at least one of the AWS _x bits is set	The flag is set at the end of BSIZE conversions (Data Buffer Full)	No	No
1	1	0		The flag is set and an interrupt is generated at the end of BSIZE conversions if at least one of the AWS _x bits is set. Continuous conversion is not stopped.		Yes	No
1	0	1		The flag is set at the end of BSIZE conversions if at least one of the AWS _x bits is set	The flag is set at the end of BSIZE conversions and an interrupt is generated.	Yes	No
1	1	1		The flag is set immediately as soon as one of the AWS _x bits is set. In interrupt is generated and continuous conversion is stopped.	The flag is set at the end of BSIZE conversions and an interrupt is generated.	Yes	No
1	1	1		The flag is set immediately as soon as one of the AWS _x bits is set. In interrupt is generated and continuous conversion is stopped.	The flag is set at the end of BSIZE conversions and an interrupt is generated.	Yes	No

Note: BSIZE = Data buffer size (8 or 10 depending on the product).

Table 68. ADC interrupts in scan mode (ADC1)

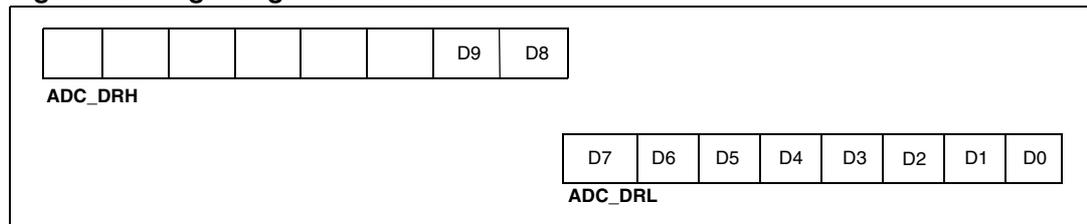
Control bits			Status bits			Exit from Wait	Exit from Halt
AWE _{Nx}	AWDIE	EOCIE	AWS _x	AWD	EOC		
0	Don't care	0	0	0	The flag is set at the end of the scan sequence	No	No
0	Don't care	1	0	0	The flag is set at the end of the scan sequence and an interrupt is generated.	Yes	No
1	0	0	Flag is set if conversion on channel "x" crosses the thresholds programmed in the ADC_HTR and ADC_LTR registers	The flag is set at the end of the scan sequence if at least one of the AWS _x bits is set	The flag is set at the end of the scan sequence	No	No
1	1	0		The flag is set and an interrupt is generated at the end of the SCAN sequence if at least one of the AWS _x bits is set. SCAN conversion is not stopped.	The flag is set to 1 at the end of the scan sequence	Yes	No
1	0	1		The flag is set at the end of the scan sequence if at least one of the AWS _x bits is set	The flag is set to 1 at the end of the scan sequence and an interrupt is generated.	Yes	No
1	1	1		The flag is set immediately as soon as one of the AWS _x bits is set. In interrupt is generated and scan conversion is stopped.	The flag is set at the end of the scan sequence and an interrupt is generated.	Yes	No

24.8 Data alignment

ALIGN bit in the ADC_CR2 register selects the alignment of data stored after conversion. Data can be aligned in the following ways.

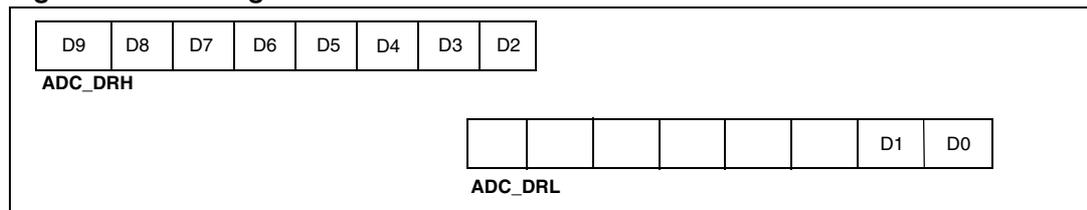
Right Alignment: 8 Least Significant bits are written in the ADC_DL register, then the remaining Most Significant bits are written in the ADC_DH register. The Least Significant Byte must be read first followed by the Most Significant Byte.

Figure 151. Right alignment of data



Left Alignment: 8 Most Significant bits are written in the ADC_DH register, then the remaining Least Significant bits are written in the ADC_DL register. The Most Significant Byte must be read first followed by the Least Significant Byte.

Figure 152. Left alignment of data



24.9 Reading the conversion result

When reading the ADC conversion result, it's important to know that the ADC data registers must be read in two consecutive instructions and in a specific order depending on the selected data alignment.

For data coherency, an internal locking mechanism is implemented, and one data register is not updated with the conversion result until the other one is read. For this reason, reading registers in the wrong order returns an incorrect result.

The register reading order depends on the data alignment setting (see [Section 24.8](#))

For correct results:

- In left alignment mode, read the MSB register (ADC_DRH) first, then the LSB register (ADC_DRL)
- In right alignment mode, read the LSB register (ADC_DRL) first, then the MSB register (ADC_DRH). In this case you can use the LDW instruction that has the same reading order.

24.10 Schmitt trigger disable registers

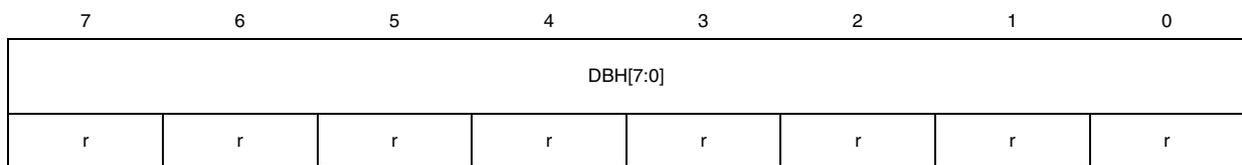
The ADC_TDRH and ADC_TDRL registers are used to disable the Schmitt triggers available in the AIN analog input pins. Disabling the Schmitt trigger lowers the power consumption in the I/Os.

24.11 ADC registers

24.11.1 ADC data buffer register x high (ADC_DBxRH) (x=0..7 or 0..9)

Address offset: 0x00 + 2 * channel number

Reset value: 0x00



Note: Data buffer registers are not available for ADC2. The data buffer size is device dependent and is specified in the corresponding datasheet.

Bits 7:0 DBH[7:0] Data bits high

These bits are set/reset by hardware and are read only. When the ADC is in buffered continuous or scan mode, they contain the high part of the converted data. The data is in right-aligned or left-aligned format depending on the ALIGN bit.

Left Data Alignment

These bits contain the 8 MSB bits of the converted data. The MSB must be read first before reading the LSB (see [Section 24.9: Reading the conversion result](#) and [Figure 152](#).)

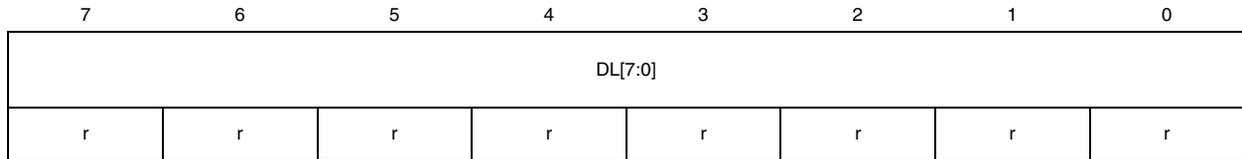
Right Data Alignment

These bits contain the (ADC data width - 8) MSB bits of the converted data. Remaining bits are tied to zero. See [Figure 151](#).

24.11.2 ADC data buffer register x low (ADC_DBxRL) (x=or 0..7 or 0..9)

Address offset: 0x01 + 2 * channel number

Reset value: 0x00



Note: Data buffer registers are not available for ADC2. The data buffer size is device dependent and is specified in the corresponding datasheet.

Bits 7:0 **DL[7:0]** Data bits low

These bits are set/reset by hardware and are read only. When the ADC is in buffered continuous or scan mode, they contain the low part of the A/D conversion result, in right-aligned or left-aligned format depending on the ALIGN bit.

- **Left Data Alignment**

These bits contain the (ADC data width - 8) LSB bits of the converted data, remaining bits of the register are tied to zero.

See [Figure 152](#).

- **Right Data Alignment**

These bits contain the 8 LSB bits of the converted data. The LSB must be read first before reading the MSB (see [Section 24.9: Reading the conversion result](#) and [Figure 151](#).)

24.11.3 ADC control/status register (ADC_CSR)

Address offset: 0x00

Reset value: 0x00

7	6	5	4	3	2	1	0
EOC	AWD	EOCIE	AWDIE	CH[3:0]			
rw	rc_w0	rw	rw	rw	rw	rw	rw

Bit 7 **EOC**: End of conversion

This bit is set by hardware at the end of conversion. It is cleared by software by writing '0'.

- 0: Conversion is not complete
- 1: Conversion complete

Bit 6 **AWD**: Analog Watchdog flag

- 0: No analog watchdog event
- 1: An analog watchdog event occurred. In buffered continuous or scan mode you can read the ADC_AWSR register to determine the data buffer register related to the event. An interrupt request is generated if AWDIE=1.

Note: This bit is not available for ADC2

Bit 5 **EOCIE**: Interrupt enable for EOC

This bit is set and cleared by software. It enables the interrupt for End of Conversion.

- 0: EOC interrupt disabled
- 1: EOC interrupt enabled. An interrupt is generated when the EOC bit is set.

Bit 4 **AWDIE**: Analog watchdog interrupt enable

- 0: AWD interrupt disabled.
- 1: AWD interrupt enabled

Note: This bit is not available for ADC2

Bits 3:0 **CH[3:0]**: Channel selection bits

These bits are set and cleared by software. They select the input channel to be converted.

- 0000: Channel AIN0
- 0001: Channel AIN1
-
- 1111: Channel AIN15

24.11.4 ADC configuration register 1 (ADC_CR1)

Address offset: 0x01

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	SPSEL[2:0]			Reserved		CONT	ADON
	rw	rw	rw			rw	rw

Bit 7 Reserved, always read as 0.

Bits 6:4 **SPSEL[2:0]**: Prescaler selection

These control bits are written by software to select the prescaler division factor.

000: $f_{ADC} = f_{MASTER}/2$

001: $f_{ADC} = f_{MASTER}/3$

010: $f_{ADC} = f_{MASTER}/4$

011: $f_{ADC} = f_{MASTER}/6$

100: $f_{ADC} = f_{MASTER}/8$

101: $f_{ADC} = f_{MASTER}/10$

110: $f_{ADC} = f_{MASTER}/12$

111: $f_{ADC} = f_{MASTER}/18$

See [Section 24.5.2 on page 402](#).

Note: It is recommended to change the SPSEL bits when ADC is in power down. This is because internally there can be a glitch in the clock during this change. Otherwise the user is required to ignore the 1st converted result if the change is done when ADC is not in power down.

Bits 3:2 Reserved, always read as 0.

Bit 1 **CONT**: Continuous conversion

This bit is set and cleared by software. If set, conversion takes place continuously till this bit is reset by software.

0: Single conversion mode

1: Continuous conversion mode

Bit 0 **ADON**: A/D Converter on/off

This bit is set and reset by software. This bit must be written to wake up the ADC from power down mode and to trigger the start of conversion. If this bit holds a value of 0 and a 1 is written to it then it wakes the ADC from power down mode. Conversion starts when this bit holds a value of 1 and a 1 is written to it. As soon as the ADC is powered on, the output stage of the selected channel is disabled.

0: Disable ADC conversion/calibration and go to power down mode.

1: Enable ADC and to start conversion

Note: If any other bit in this register apart from ADON is changed at the same time, then conversion is not triggered. This is to prevent triggering an erroneous conversion.

24.11.5 ADC configuration register 2 (ADC_CR2)

Address offset: 0x02

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved	EXTTRIG	EXTSEL[1:0]		ALIGN	Reserved	SCAN	Reserved
	rw	rw	rw	rw		rw	

Bit 7 **Reserved**, must be kept cleared.

Bit 6 **EXTTRIG**: External trigger enable

This bit is set and cleared by software. It is used to enable an external trigger to trigger a conversion.

0: Conversion on external event disabled

1: Conversion on external event enabled

Note: To avoid a spurious trigger event, use the BSET instruction to set EXTTRIG without changing other bits in the register.

Bits 5:4 **EXTSEL[1:0]**: External event selection

The two bits are written by software. They select one of four types of event used to trigger the start of ADC conversion.

00: Internal TIM1 TRGO event

01: External interrupt on ADC_ETR pin

10: Reserved

11: Reserved

Bit 3 **ALIGN**: Data alignment

This bit is set and cleared by software.

0: Left alignment (8 MSB bits are written in the ADC_DRH register then the remaining LSB bits in the ADC_DRL register). Reading order should be MSB first and then LSB.

1: Right alignment (8 LSB bits are written in the ADC_DRL register then the remaining MSB bits in the ADC_DH register). Reading order should be LSB first and then MSB.

Bit 2 **Reserved**, must be kept cleared.

Bit 1 **SCAN**: Scan mode enable

This bit is set and cleared by software.

0: Scan mode disabled

1: Scan mode enabled

Note: This bit is not available for ADC2

Bit 0 **Reserved**, must be kept cleared.

24.11.6 ADC configuration register 3 (ADC_CR3)

Address offset: 0x03

Reset value: 0x00

7	6	5	4	3	2	1	0
DBUF	OVR	Reserved					
rw	rc_w0						

Note: This register is not available for ADC2.

Bit 7 DBUF: Data buffer enable

This bit is set and cleared by software. It is used together with the CONT bit enable buffered continuous mode (DBUF=1, CONT=1). When DBUF is set, converted values are stored in the ADC_DBxRH and ADC_DBxRL registers instead of the ADC_DRH and ADC_DRL registers.

0: Data buffer disabled

1: Data buffer enabled

Bit 6 OVR: Overrun flag

This bit is set by hardware and cleared by software.

0: No overrun

1: An overrun was detected in the data buffer registers.

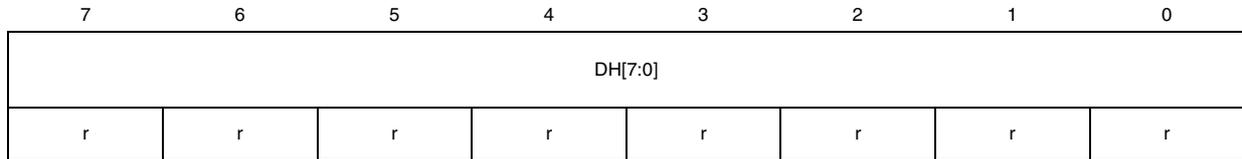
Refer to [Section 24.5.5 on page 404](#) for more details.

Bits 5:0 Reserved, must be kept cleared.

24.11.7 ADC data register high (ADC_DRH)

Address offset: 0x04

Reset value: undefined



Bits 7:0 **DH[7:0]** Data bits high

These bits are set/reset by hardware and are read only. When the ADC is in single or non-buffered continuous mode, they contain the high part of the converted data, in right-aligned or left-aligned format depending on the ALIGN bit.

- **Left Data Alignment**

These bits contain the 8 MSB bits of the converted data. The MSB must be read first before reading the LSB (see [Section 24.9: Reading the conversion result](#) and [Figure 152](#).)

- **Right Data Alignment**

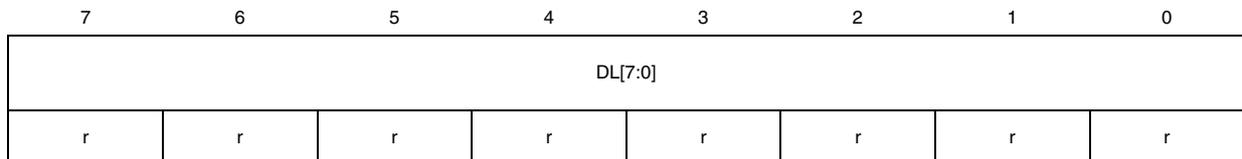
These bits contain the (ADC data width - 8) MSB bits of the converted data. Remaining bits are tied to zero.

See [Figure 151](#).

24.11.8 ADC data register low (ADC_DRL)

Address offset: 0x05

Reset value: undefined



Bits 7:0 **DL[7:0]** Data bits low

These bits are set/reset by hardware and are read only. When the ADC is in single or non-buffered continuous mode, they contain the low part of the A/D conversion result, in right-aligned or left-aligned format depending on the ALIGN bit.

- **Left Data Alignment**

These bits contain the (ADC data width - 8) LSB bits of the converted data, remaining bits of the register are tied to zero.

See [Figure 152](#).

- **Right Data Alignment**

These bits contain the 8 LSB bits of the converted data. The LSB must be read first before reading the MSB (see [Section 24.9: Reading the conversion result](#) and [Figure 151](#).)

24.11.9 ADC Schmitt trigger disable register high (ADC_TDRH)

Address offset: 0x06

Reset value: 0x00

7	6	5	4	3	2	1	0
TD[15:8]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **TD[15:8]** Schmitt trigger disable high

These bits are set and cleared by software. When a TDx bit is set, it disables the I/O port input Schmitt trigger of the corresponding ADC input channel x even if this channel is not being converted. This is needed to lower the static power consumption of the I/O port.

0: Schmitt trigger enabled

1: Schmitt trigger disabled

24.11.10 ADC Schmitt trigger disable register low (ADC_TDRL)

Address offset: 0x07

Reset value: 0x00

7	6	5	4	3	2	1	0
TD[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Bits 7:0 **TD[7:0]** Schmitt trigger disable low

These bits are set and cleared by software. When a TDx bit is set, it disables the I/O port input Schmitt trigger of the corresponding ADC input channel x even if this channel is not being converted. This is needed to lower the static power consumption of the I/O port.

0: Schmitt trigger enabled

1: Schmitt trigger disabled

24.11.11 ADC high threshold register high (ADC_HTRH)

Address offset: 0x08

Reset value: 0x03

7	6	5	4	3	2	1	0
Reserved						HT[9:8]	
						rw	rw

Note: This register is not available for ADC2.

Bits 7:2 Reserved, must be kept cleared.

Bits 1:0 **HT[9:8]** Analog Watchdog High Voltage threshold MSB

These bits are set and cleared by software. They define the MSB of the high threshold (V_{REFH}) for the Analog Watchdog.

24.11.12 ADC high threshold register low (ADC_HTRL)

Address offset: 0x09

Reset value: 0xFF

7	6	5	4	3	2	1	0
HT[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Note: This register is not available for ADC2.

Bits 7:0 **HT[7:0]** Analog watchdog high voltage threshold LSB

These bits are set and cleared by software. They define the LSB of the high threshold (V_{REFH}) for the Analog Watchdog.

24.11.13 ADC low threshold register high (ADC_LTRH)

Address offset: 0x0A

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved						LT[9:8]	
						rw	rw

Note: This register is not available for ADC2.

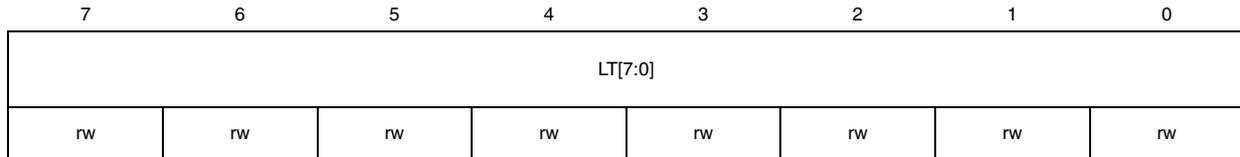
Bits 7:2 Reserved, must be kept cleared.

Bits 1:0 **LT[9:8]** Analog watchdog low voltage threshold MSB
 These bits are set and cleared by software. They define the MSB of the low Threshold (V_{REFL}) for the Analog Watchdog.

24.11.14 ADC low threshold register low (ADC_LTRL)

Address offset: 0x0B

Reset value: 0x00



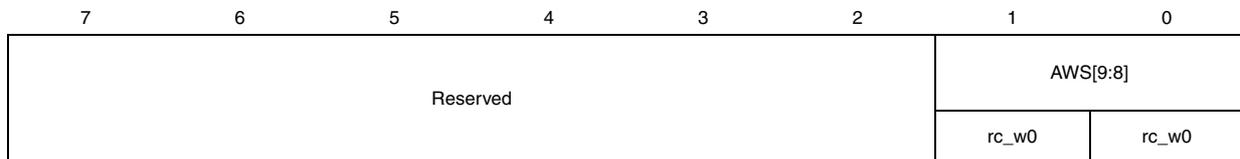
Note: This register is not available for ADC2.

Bits 7:0 **LT[7:0]** Analog watchdog low voltage threshold LSB
 These bits are set and cleared by software. They define the LSB of the low threshold (V_{REFL}) for the Analog Watchdog.

24.11.15 ADC watchdog status register high (ADC_AWSRH)

Address offset: 0x0C

Reset value: 0x00



Note: This register is not available for ADC2.

Bits 7:2 Reserved, must be kept cleared.

Bits 1:0 **AWS[9:8]** Analog watchdog status flags 9:8
 These bits are set by hardware and cleared by software.

- In buffered continuous mode (DBUF=1, CONT=1) AWS flags behave as described in [Table 67](#).
- In scan mode (SCAN=1) AWS flags behave as described in [Table 68](#).

0: No analog watchdog event in data buffer register x.
 1: Analog watchdog event occurred in data buffer register x.

24.11.16 ADC watchdog status register low (ADC_AWSRL)

Address offset: 0x0D

Reset value: 0x00

7	6	5	4	3	2	1	0
AWS[7:0]							
rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0

Note: This register is not available for ADC2.

Bits 7:0 **AWS[7:0]** Analog watchdog status flags 7:0

These bits are set by hardware and cleared by software.

- In buffered continuous mode (DBUF=1, CONT=1) AWS flags behave as described in [Table 67](#).
- In scan mode (SCAN=1) AWS flags behave as described in [Table 68](#).

0: No analog watchdog event in data buffer register x.

1: Analog watchdog event occurred in data buffer register x.

24.11.17 ADC watchdog control register high (ADC_AWCRH)

Address offset: 0x0E

Reset value: 0x00

7	6	5	4	3	2	1	0
Reserved						AWEN[9:8]	
						rw	rw

Note: This register is not available for ADC2.

Bits 7:2 Reserved, must be kept cleared.

Bits 1:0 **AWEN[9:8]** Analog watchdog enable bits 9:8

These bits are set and cleared by software.

In buffered continuous mode (DBUF=1, CONT=1) and in scan mode (SCAN=1) the AWENx bits enable the analog watchdog function for each of the 10 data buffer registers.

0: Analog watchdog disabled in data buffer register x.

1: Analog watchdog enabled in data buffer register x.

24.11.18 ADC watchdog control register low (ADC_AWCRL)

Address offset: 0x0F

Reset value: 0x00

7	6	5	4	3	2	1	0
AWEN[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw

Note: This register is not available for ADC2.

Bits 7:0 **AWEN[7:0]** Analog watchdog enable bits 7:0

These bits are set and cleared by software.

In buffered continuous mode (DBUF=1, CONT=1) and in scan mode (SCAN=1) the AWENx bits enable the analog watchdog function for each of the 10 data buffer registers.

0: Analog watchdog disabled in data buffer register x.

1: Analog watchdog enabled in data buffer register x.

24.12 ADC register map and reset values

Table 69. ADC1 register map and reset values

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	ADC1_DB0RH Reset value	- 0	- 0	- 0	- 0	- 0	- 0	DATA9 0	DATA8 0
0x01	ADC1_DB0RL Reset value	DATA7 0	DATA6 0	DATA5 0	DATA4 0	DATA3 0	DATA2 0	DATA1 0	DATA0 0
.	
0x0E	ADC1_DB7RH Reset value	- 0	- 0	- 0	- 0	- 0	- 0	DATA9 0	DATA8 0
0x0Fh	ADC1_DB7RL Reset value	DATA7 0	DATA6 0	DATA5 0	DATA4 0	DATA3 0	DATA2 0	DATA1 0	DATA0 0
0x10	ADC1_DB8RH ⁽¹⁾ Reset value	- 0	- 0	- 0	- 0	- 0	- 0	DATA9 0	DATA8 0
0x11	ADC1_DB8RL ⁽¹⁾ Reset value	DATA7 0	DATA6 0	DATA5 0	DATA4 0	DATA3 0	DATA2 0	DATA1 0	DATA0 0
0x12	ADC1_DB9RH ⁽¹⁾ Reset value	- 0	- 0	- 0	- 0	- 0	- 0	DATA9 0	DATA8 0
0x13h	ADC1_DB9RL ⁽¹⁾ Reset value	DATA7 0	DATA6 0	DATA5 0	DATA4 0	DATA3 0	DATA2 0	DATA1 0	DATA0 0
0x00	ADC1_CSR Reset value	EOC 0	AWD 0	EOCIE 0	AWDIE 0	CH3 0	CH2 0	CH1 0	CH0 0
0x01	ADC1_CR1 Reset value	- 0	SPSEL2 0	SPSEL1 0	SPSEL0 0	- 0	- 0	CONT 0	ADON 0
0x02	ADC1_CR2 Reset value	- 0	EXTTRIG 0	EXTSEL1 0	EXTSEL0 0	ALIGN 0	- 0	SCAN 0	- 0
0x03	ADC1_CR3 Reset value	DBUF 0	OVR 0	- 0	- 0	- 0	- 0	- 0	- 0
0x04	ADC1_DRH Reset value	- x	- x	- x	- x	- x	- x	DATA9 x	DATA8 x
0x05	ADC1_DRL Reset value	DATA7 x	DATA6 x	DATA5 x	DATA4 x	DATA3 x	DATA2 x	DATA1 x	DATA0 x
0x06	ADC1_TDRH ⁽²⁾ Reset value	TD15 0	TD14 0	TD13 0	TD12 0	TD11 0	TD10 0	TD9 0	TD8 0
0x07	ADC1_TDRL Reset value	TD7 0	TD6 0	TD5 0	TD4 0	TD3 0	TD2 0	TD1 0	TD0 0

Table 69. ADC1 register map and reset values (continued)

Address offset	Register name	7	6	5	4	3	2	1	0
0x08	ADC1_HTRH Reset value	- 0	- 0	- 0	- 0	- 0	- 0	HT9 1	HT8 1
0x09	ADC1_HTRL Reset value	HT7 1	HT6 1	HT5 1	HT4 1	HT3 1	HT2 1	HT1 1	HT0 1
0x0A	ADC1_LTRH Reset value	- 0	- 0	- 0	- 0	- 0	- 0	LT9 0	LT8 0
0x0B	ADC1_LTRL Reset value	LT7 0	LT6 0	LT5 0	LT4 0	LT3 0	LT2 0	LT1 0	LT0 0
0x0C	ADC1_AWSRH ⁽²⁾ Reset value	- 0	- 0	- 0	- 0	- 0	- 0	AWS9 0	AWS8 0
0x0D	ADC1_AWSRL Reset value	AWS7 0	AWS6 0	AWS5 0	AWS4 0	AWS3 0	AWS2 0	AWS1 0	AWS0 0
0x0E	ADC1_AWCRH ⁽²⁾ Reset value	- 0	- 0	- 0	- 0	- 0	- 0	AWEN9 0	AWEN8 0
0x0F	ADC1_AWCRL Reset value	AWEN7 0	AWEN6 0	AWEN5 0	AWEN4 0	AWEN3 0	AWEN2 0	AWEN1 0	AWEN0 0

1. This register is reserved in devices with buffer size 8 x 10 bits.
2. This register is reserved in devices without ADC channels 8 and 9.

Table 70. ADC2 register map and reset values

Address offset	Register name	7	6	5	4	3	2	1	0
0x00	ADC2_CSR Reset value	EOC 0	AWD 0	EOCIE 0	AWDIE 0	CH3 0	CH2 0	CH1 0	CH0 0
0x01	ADC2_CR1 Reset value	- 0	SPSEL2 0	SPSEL1 0	SPSEL0 0	- 0	- 0	CONT 0	ADON 0
0x02	ADC2_CR2 Reset value	- 0	EXTTRIG 0	EXTSEL1 0	EXTSEL0 0	ALIGN 0	- 0	- 0	- 0
0x03	ADC2_CR3 Reset value	DBUF 0	OVR 0	- 0	- 0	- 0	- 0	- 0	- 0
0x04	ADC2_DRH Reset value	- 0	- 0	- 0	- 0	- 0	- 0	DATA9 0	DATA8 0
0x05	ADC2_DRL Reset value	DATA7 0	DATA6 0	DATA5 0	DATA4 0	DATA3 0	DATA2 0	DATA1 0	DATA0 0
0x06	ADC2_TDRH Reset value	TD15 0	TD14 0	TD13 0	TD12 0	TD11 0	TD10 0	TD9 0	TD8 0
0x07	ADC2_TDRL Reset value	TD7 0	TD6 0	TD5 0	TD4 0	TD3 0	TD2 0	TD1 0	TD0 0

25 Revision history

Table 71. Document revision history

Date	Revision	Changes
27-May-2008	1	Initial release.
13-Aug-2008	2	<p>Updated Section 2: Memory and register map on page 27: introduced high, medium and low density categories; modified end address for option bytes; updated RAM, data EEPROM and Flash program memory densities.</p> <p>Updated Figure 11: Reset circuit on page 55</p> <p>Update min reset pulse from 300 to 500 ns in Section 7.1: Reset circuit description on page 55</p> <p>Updated Table 5: Memory access versus programming method on page 44.</p> <p>Reorganised Section 16 on page 133 to Section 19 on page 245</p> <p>Renamed USART and LINUART to UART1, UART2 and UART3 combined in new Section 22 on page 299.</p> <p>Updated CAN filter and external clock description in Section 23 on page 351.</p> <p>Renamed ADC to ADC1 and ADC2 in Section 24 on page 399</p> <p>Updated Continuous scan mode on page 404</p> <p>Updated Conversion on external trigger on page 405</p>

Table 71. Document revision history (continued)

Date	Revision	Changes
22-Sep-2008	3	<p>Updated Section 4: Flash program memory and data EEPROM (FLASH).</p> <p>Changed name of SWUAH bit to REGAH in Section 8.9.1: Internal clock register (CLK_ICKR) on page 71.</p> <p>Modified Section 11.8.2: Slope control on page 109.</p> <p>Added description of TIM5, TIM6 in Section 16: Timer overview, Section 18: 16-bit general purpose timers (TIM2, TIM3, TIM5) and Section 19: 8-bit basic timer (TIM4, TIM6).</p> <p>Updated Section 24.5.6: Analog watchdog.</p>
15-Jan-2009	4	<p>Removed memory and register map (information transferred to datasheets)</p> <p>Register absolute addresses replaced by offsets. (refer now to register map in datasheet for the base addresses).</p> <p>Added Note 3 related to TLI interrupt in Section 10.2.1 on page 91.</p> <p>Added TLI in Section 10.5: Concurrent and nested interrupt management.</p> <p>Updated Flash program density to 32 - 128 Kbytes for high density STM8S devices in Section 4: Flash program memory and data EEPROM (FLASH).</p> <p>Updated size of STM8S option byte area in Section 4.4: Memory organization and Figure 3, Figure 4, and Figure 5.</p> <p>Updated maximum value of UBC in Figure 8. Added information on DATA area programming on devices with and without RWW capability in Section 4.7.1: Byte programming and Section 4.7.3: Block programming.</p> <p>Added HVOFF in: Fast block programming, Fast block programming, and Section 4.9.8: Flash Status register (FLASH_IAPSR). Updated bitfield access types in Section 4.9.8: Flash Status register (FLASH_IAPSR) on page 51.</p> <p>Table 5: Memory access versus programming method: removed NMI and TRAP vectors, modified access for option bytes in ICP/SWIM mode/ROP enabled, and UBC ROP disabled.</p> <p>Updated Table 26: Watchdog timeout period (with 64 kHz counter clock) on page 124</p> <p>Updated Table 26: Approximate timeout duration on page 129</p> <p>Table 27: Window watchdog timing diagram on page 130</p> <p>Updated Note 7 on page 291</p>

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