



武汉芯源半导体有限公司

WUHAN XINYUAN SEMICONDUCTOR CO., LTD

CW32L083 Reference Manual

ARM® Cortex®-M0+ Low-power 32-bit MCU

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Statement

Important notice

This reference manual is aimed at application developers and provides complete information on how to use the CW32L083 microcontroller memory and peripherals. This operation applies only to CW32L083 devices.

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1 Documentation conventions

1.1 Typographical conventions

The typographical conventions used in this document are:

<i>Italic</i>	Indicates a special term or citation, or prompts a note.
Bold	Indicates a component or signal name, such as for title descriptions without chapter numbers, titles for diagrams, etc.
English uppercase	Used for terms that have a specific technical meaning and are included in the glossary, such as register or bit field names.

[Color text](#) Indicates a link. Including:

- URL external link, such as www.whxy.com
- Cross-references, internal chapters of this paper refer to each other
- Internal links, figures, tables or appendices, glossary entries



1.2 Register protocol

Symbol example	Describe
0x53CA	A numeric string prefixed with '0x' represents a hexadecimal number, and the value is composed of 0~9 or A~F.
REGNAME[n]	A specific bit of REGNAME, REGNAME can be a register or register field, for example, CR1[2] refers to bit 2 of the CR1 register (field).
REGNAME[m:n]	A specific bit of REGNAME, REGNAME can be a register or a register field, for example, CR1[7:5] refers to the 7th to 5th bits of the CR1 register (field).
RW	Read and write, software can read and write these bit fields.
RO	Read-only, software can only read these bit fields.
WO	Write-only, software can only write to this bit field, and invalid data will be returned when reading this bit field.
RW0	Software can read and write this bit field, only 0 can be written to this bit field, and writing 1 has no effect on this bit field.
RW1	Software can read and write this bit field, only 1 can be written to this bit field, and writing 0 has no effect on this bit field.
R0W1	When the software reads this bit field as 0, only 1 can be written to this bit field, and writing 0 has no effect on this bit field.
R1W0	When the software reads this bit field as 1, only 0 can be written to this bit field, and writing 1 has no effect on this bit field.
RFU	Reserved bit field, please keep the default value.
Word	The data length of a word is 32 bits.
Half Word	The data length of a half word is 16 bits.
Byte	The data length of one byte is 8bit.



2 System and memory overview

2.1 System architecture

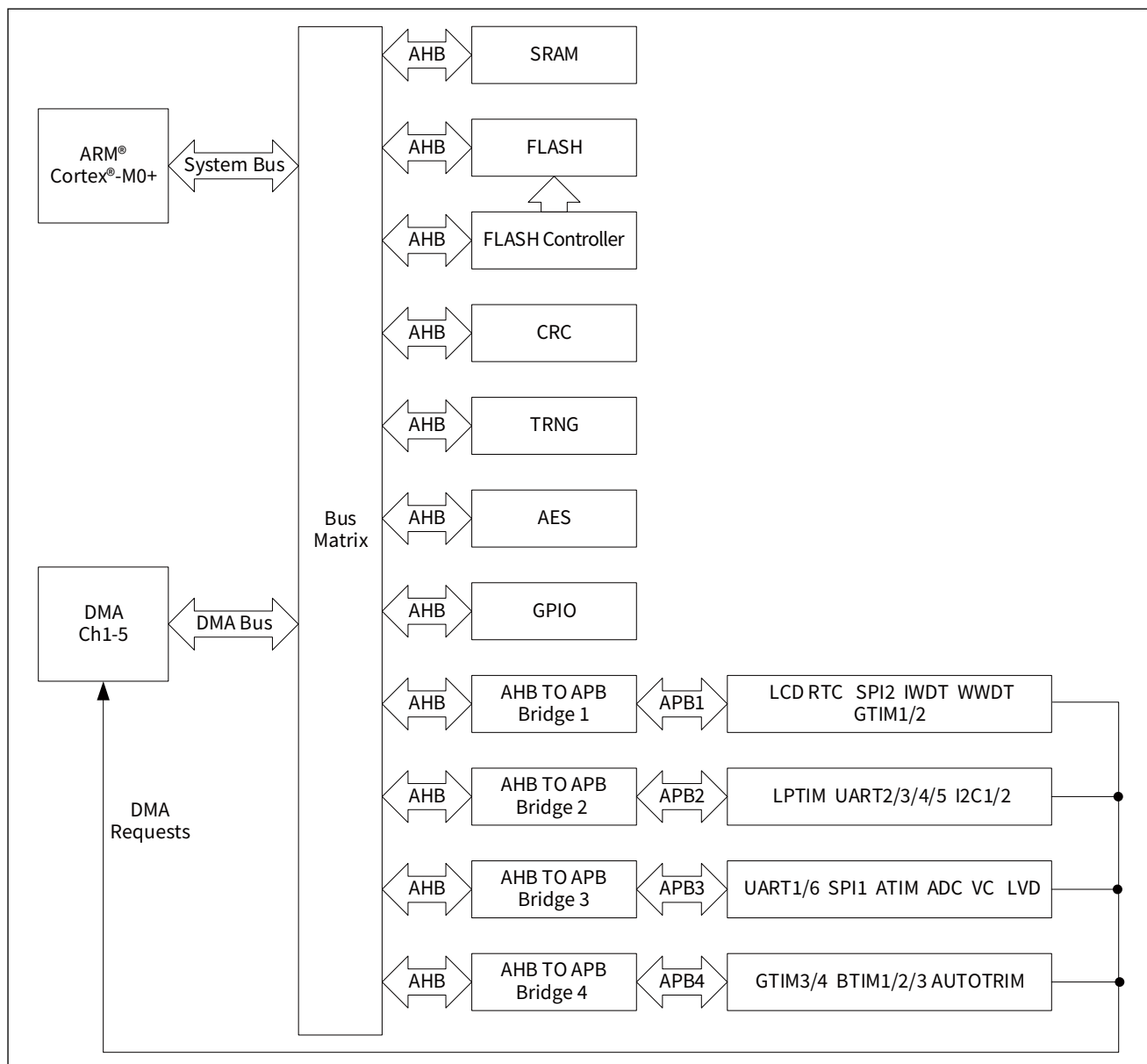
The consists of CW32L083 microcontroller system contains:

- 2 master device:
 - ARM® Cortex®-M0+ core
 - General-purpose DMA
- Multiple slave device:
 - On-chip SRAM
 - On-chip FLASH
 - FLASH controller
 - CRC redundancy calculation unit
 - TRNG true random number generator
 - AES Advanced Encryption Standard Module
 - GPIO port
 - AHB to APB1 conversion bridge and all devices on the APB1 bus
 - AHB to APB2 conversion bridge and all devices on the APB2 bus
 - AHB to APB3 conversion bridge and all devices on the APB3 bus
 - AHB to APB4 conversion bridge and all devices on the APB4 bus



The master and slave devices are connected through AHB bus matrix, and the system architecture is shown as follows:

Figure 2-1 System architecture



- **System bus**
Realize the connection of peripheral bus and bus matrix of M0+ microprocessor.
- **DMA bus**
AHB bus and bus matrix connection for DMA.
- **Bus matrix**
Manages the access arbitration between M0+ microprocessor and DMA to FLASH, SRAM and all peripherals. The arbitration control adopts the round-robin scheduling algorithm to balance the load and ensure the bus utilization efficiency.
- **AHB TO APB Bridge 1/2/3/4**
Provides a fully synchronized connection from the AHB bus to the APB1/APB2/APB3/APB4 bus, that is, the bridge between the AHB and APB buses.

2.2 Memory organization

2.2.1 Overview

The CW32L083 core is a 32-bit ARM® Cortex®-M0+ microprocessor with a maximum addressing space of 4GB. The built-in program memory, data memory, peripherals and port registers of the chip are uniformly addressed in the same 4GB linear address space.

Bytes in memory are organized in little-endian format. The lowest byte data of a word storage space is the least significant bit of the word, and the highest byte data is the most significant bit. E.g:

Store 0x1122 3344 in the memory space at address 0x2000 0000, the actual result is:

0x20000000 bytes store 0x44,

0x20000001 bytes store 0x33,

0x20000002 bytes store 0x22,

0x20000003 bytes store 0x11.

The system address allocation is shown in the figure below, RES is the reserved area.



Figure 2-2 System address assignment

0xFFFF FFFF	RES	A H B	0x4800 1400 - 0x4800 17FF	GPIOF
0xE0FF FFFF			0x4800 1000 - 0x4800 13FF	GPIOE
0xE000 0000	M0+ peripherals		0x4800 0C00 - 0x4800 0FFF	GPIOD
			0x4800 0800 - 0x4800 0BFF	GPIOC
0x4800 17FF	RES		0x4800 0400 - 0x4800 07FF	GPIOB
0x4002 0000	AHB		0x4800 0000 - 0x4800 03FF	GPIOA
0x4001 7FFF	RES		0x4002 6000 - 0x4002 63FF	AES
0x4001 4000	APB4		0x4002 5000 - 0x4002 53FF	TRNG
			0x4002 3000 - 0x4002 33FF	CRC
0x4001 0000	APB3		0x4002 2000 - 0x4002 23FF	FLASH CTRL
0x4000 7FFF	RES	0x4002 0000 - 0x4002 03FF	DMA	
0x4000 4000	APB2	A P B 4	0x4001 4C00 - 0x4001 4FFF	AUTOTRIM
			0x4001 4800 - 0x4001 4BFF	BTIM1/2/3
0x4001 4400 - 0x4001 47FF	GTIM4			
0x4001 4000 - 0x4001 43FF	GTIM3			
0x4000 0000	APB1	A P B 3	0x4001 3800 - 0x4001 3BFF	UART1
0x2000 5FFF	RES		0x4001 3000 - 0x4001 33FF	SPI1
			0x4001 2C00 - 0x4001 2FFF	ATIM
0x2000 0000	SRAM(24KB)		0x4001 2800 - 0x4001 2BFF	VC/LVD
0x0010 0BFF	OTP(128B)		0x4001 2400 - 0x4001 27FF	ADC
			0x4001 1400 - 0x4001 17FF	UART6
0x0010 0B80	RES	0x4001 0000 - 0x4001 03FF	SYSCTRL	
0x0010 09FF	Boot program memory (2.5KB)	A P B 2	0x4000 5800 - 0x4000 5BFF	I2C2
			0x4000 5400 - 0x4000 57FF	I2C1
0x4000 5000 - 0x4000 53FF	UART5			
0x4000 4C00 - 0x4000 4FFF	UART4			
0x4000 4800 - 0x4000 4BFF	UART3			
0x4000 4400 - 0x4000 47FF	UART2			
0x4000 3800 - 0x4000 3BFF	LPTIM			
0x0010 0000	RES	A P B 1	0x4000 3000 - 0x4000 33FF	IWDT
0x0003 FFFF	FLASH(256KB)		0x4000 2C00 - 0x4000 2FFF	WWDT
			0x4000 2800 - 0x4000 2BFF	RTC
0x0000 0000			0x4000 2400 - 0x4000 27FF	LCD
			0x4000 1000 - 0x4000 13FF	GTIM2
			0x4000 0400 - 0x4000 07FF	GTIM1

2.2.2 Memory map and register boundary addresses

The detailed starting address space allocation of on-chip memory and peripherals is shown in the following table:

Table 2-1 Memory and Peripheral Address Allocation

Device or Bus	Boundary address	Size	Peripherals
Main FLASH memory	0x0000 0000 - 0x0003 FFFF	256KB	Main FLASH
Boot program memory	0x0010 0000 - 0x0010 09FF	2.5KB	BootLoader
OTP memory	0x0010 0B80 - 0x0010 0BFF	128B	OTP
SRAM memory	0x2000 0000 - 0x2000 5FFF	24KB	SRAM
APB1 Peripheral	0x4000 0400 - 0x4000 07FF	1KB	GTIM1
	0x4000 1000 - 0x4000 13FF	1KB	GTIM2
	0x4000 2400 - 0x4000 27FF	1KB	LCD
	0x4000 2800 - 0x4000 2BFF	1KB	RTC
	0x4000 2C00 - 0x4000 2FFF	1KB	WWDT
	0x4000 3000 - 0x4000 33FF	1KB	IWDT
	0x4000 3800 - 0x4000 3BFF	1KB	SPI2
APB2 Peripheral	0x4000 2400 - 0x4000 27FF	1KB	LPTIM
	0x4000 4400 - 0x4000 47FF	1KB	UART2
	0x4000 4800 - 0x4000 4BFF	1KB	UART3
	0x4000 4C00 - 0x4000 4FFF	1KB	UART4
	0x4000 5000 - 0x4000 53FF	1KB	UART5
	0x4000 5400 - 0x4000 57FF	1KB	I2C1
	0x4000 5800 - 0x4000 5BFF	1KB	I2C2
APB3 Peripheral	0x4001 0000 - 0x4001 03FF	1KB	SYSCTRL
	0x4001 1400 - 0x4001 17FF	1KB	UART6
	0x4001 2400 - 0x4001 27FF	1KB	ADC
	0x4001 2800 - 0x4001 2BFF	1KB	VC/LVD
	0x4001 2C00 - 0x4001 2FFF	1KB	ATIM
	0x4001 3000 - 0x4001 33FF	1KB	SPI1
	0x4001 3800 - 0x4001 3BFF	1KB	UART1



Device or Bus	Boundary address	Size	Peripherals
APB4 Peripheral	0x4001 4000 - 0x4001 43FF	1KB	GTIM3
	0x4001 4400 - 0x4001 47FF	1KB	GTIM4
	0x4001 4800 - 0x4001 4BFF	1KB	BTIM1/2/3
	0x4001 4C00 - 0x4001 4FFF	1KB	AUTOTRIM
AHB Peripheral	0x4002 0000 - 0x4002 03FF	1KB	DMA
	0x4002 2000 - 0x4002 23FF	1KB	FLASH CTRL
	0x4002 3000 - 0x4002 33FF	1KB	CRC
	0x4002 5000 - 0x4002 53FF	1KB	TRNG
	0x4002 6000 - 0x4002 63FF	1KB	AES
	0x4800 0000 - 0x4800 03FF	1KB	GPIOA
	0x4800 0400 - 0x4800 07FF	1KB	GPIOB
	0x4800 0800 - 0x4800 0BFF	1KB	GPIOC
	0x4800 0C00 - 0x4800 0FFF	1KB	GPIOD
	0x4800 1000 - 0x4800 13FF	1KB	GPIOE
	0x4800 1400 - 0x4800 17FF	1KB	GPIOF
M0+ Peripheral	0xE000 0000 - 0xE00F FFFF	1MB	M0+ Core Peripheral



2.3 On-chip SRAM memory

CW32L083 integrates 24KB on-chip SRAM, and the starting address is 0x2000 0000. SRAM supports access in 3 widths of byte (8bit), half word (16bit) or full word (32bit), and can be accessed by CPU and DMA at the maximum system clock frequency with zero latency.

- Parity check

The SRAM supports the parity check function, which is enabled by default after the chip is powered on, and cannot be configured by the user.

The data bus of SRAM is 36 bits, including 32 bits of data bits and 4 bits of parity bits (each 8 bits of data bits is equipped with 1 bit of parity bits), which is used to increase the robustness of the memory.

The parity bits are computed and stored when the CPU writes to the SRAM, and they are automatically checked when reading. After the system detects that the parity check fails, it will generate the corresponding interrupt flag.

For a detailed introduction to SRAM, see chapter [6 RAM Memory](#).



2.4 On-chip FLASH memory

The on-chip FLASH memory consists of two physical areas: the main FLASH memory and the boot program memory.

- Main FLASH memory, a total of 256KB, the address space is 0x0000 0000 - 0x0003 FFFF. This area is mainly used to store application code and user data, which is programmable by the user.
- Boot program memory, a total of 2.5KB, the address space is 0x0010 0000 - 0x0010 09FF. This area is mainly used to store the BootLoader startup program, which has been programmed when the chip leaves the factory and cannot be changed by the user.

The FLASH controller implements various operations on FLASH (erase, write, read).

FLASH supports access with 3 widths of byte (8bit), half word (16bit) or full word (32bit), and the highest frequency of access is 24MHz. If the HCLK clock frequency of the system configuration is higher than 24MHz, a reasonable response waiting time must be configured through the WAIT bit field of the FLASH control register FLASH_CR2 to ensure that the FLASH is correctly accessed.

For a detailed introduction to FLASH, see chapter [7 FLASH Memory](#).



2.5 One-time programmable OTP memory

There is 128B memory space inside the chip as the OTP area, and the address space is 0x0010 0B80 – 0x0010 0BFF. This memory area can only be written to by ISP programming instructions, and can only be written once, and then can only be read, not erased and written. This area is mainly used to store unchangeable information, such as user-defined product UID, algorithm key, etc., which are written when the device leaves the factory.



2.6 System boot configuration

The device supports 2 different boot modes, which are selected by the BOOT pin state, as shown in the following table:

Table 2-2 Boot mode configuration

Boot mode configuration	Mode
BOOT = 0	Boot from main FLASH memory, run user program.
BOOT = 1	Start from the boot program memory, and fix the BootLoader program of the running chip. At this time, the user can use the ISP communication protocol to perform FLASH programming through the UART1 interface (PA13/PA14).

The boot mode selection circuit only samples the state of the BOOT pin when the chip is de-reset, so the user must set the level state of the BOOT pin as needed before the chip is de-reset to determine the startup mode after the chip is reset.

After the system is started, the CPU obtains the address of the top of the stack from the address 0x00000000 of the memory, and starts executing code from the address indicated by 0x00000004 of the memory.

The BootLoader program is located in the boot program memory area and is programmed by the equipment provider at production time. Users can use ISP communication protocol to perform FLASH programming through UART1 (pins are PA13/PA14).



2.7 Precautions

CW32L083 needs to pay attention to the following matters when using:

- A few registers such as FLASH, SRAM and GPIOx_ODR, CRC_DR support 8bit/16bit/32bit access mode, and other peripherals only support 32bit access mode. 8bit/16bit access to an address that does not support 8bit/16bit access mode will generate a HardFault hardware error exception.
- The RES areas in the system address allocation in [Figure 2-2 System address assignment](#) are reserved address spaces without corresponding physical devices. If these reserved address spaces are accessed, a HardFault hardware error exception will occur.
- After the chip is reset, all peripheral clocks except SYSTICK and SRAM are turned off. Before using these peripherals, the user must pass the peripheral clock enable control register (AHB peripheral clock enable control register SYSCTRL_AHBEN, APB peripheral clock Enable control register SYSCTRL_APBEN1/2) to open the configuration clock and working clock of the corresponding peripheral. Failure to turn on the peripheral configuration clock will result in an access failure: writing data fails, and no HardFault hardware error exception will be generated, and the result of reading data is not available. If the operating clock of the peripheral is not turned on, the main function of the peripheral is invalid.



3 Power Control (PWR) and Power Consumption

3.1 Overview

CW32L083 needs two sets of power supply when working: working power supply (VDD, VSS) and analog power supply (VDDA, VSSA). The user can choose to use the same power supply for the working power supply and the analog power supply, or use two different power supplies, but the difference between the two should not exceed 0.3V. Please refer to the relevant chapters of the datasheet for details of the power supply.

CW32L083 embeds a 1.5V low dropout LDO voltage regulator to supply power to the digital power domain inside the chip.

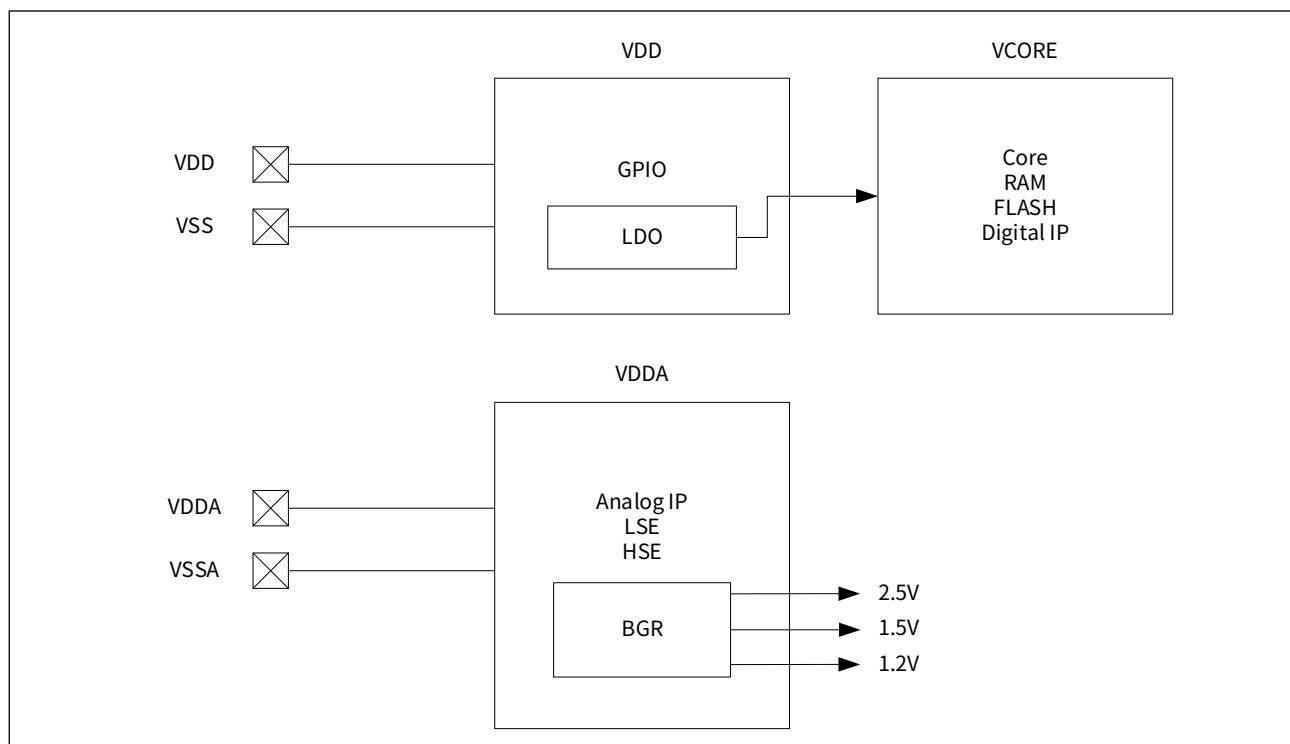
The chip has a built-in reference voltage generator (BGR) circuit, which can provide reference voltage for other analog modules.

Caution:

*The difference between the analog supply voltage and the reference voltage must be higher than 0.3V.
Please refer to the relevant section of the datasheet for detailed parameters of the voltage reference.*

The division and allocation of power domains within the chip are shown in the following figure:

Figure 3-1 System Power Distribution



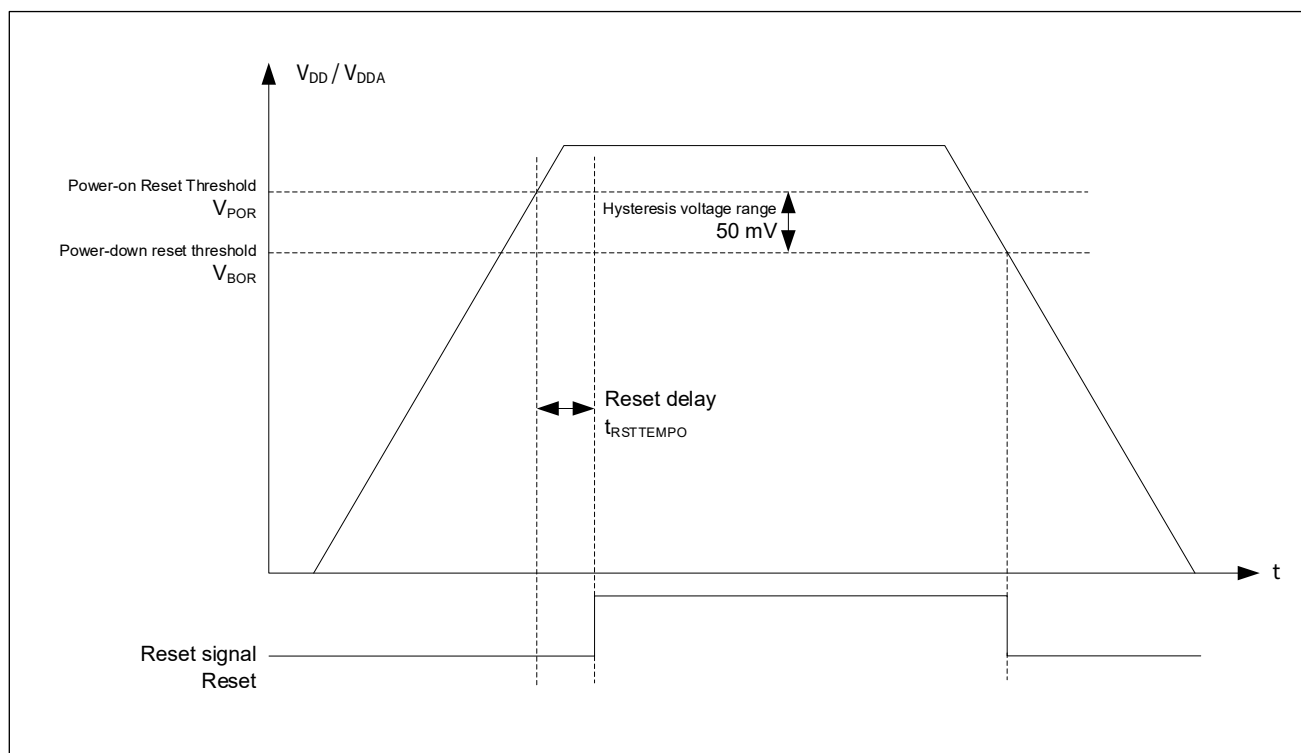
3.2 Power supply supervisor

Power on reset (POR)/ Brown-out reset (BOR)

CW32L083 integrates power-on reset (POR) and Brown-out reset (BOR) power monitoring circuits, and is always in working state after power-on. POR/BOR monitors both the VDD and VDDA power supply voltages. When the monitored power supply voltage is lower than the reset threshold (V_{BOR}), the system will enter the reset state. Users do not need to add an external hardware reset circuit.

The reset signal waveforms of the power-on and power-down phases are shown in the following figure:

Figure 3-2 Power on reset/power down reset waveform



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

3.3 Operating mode

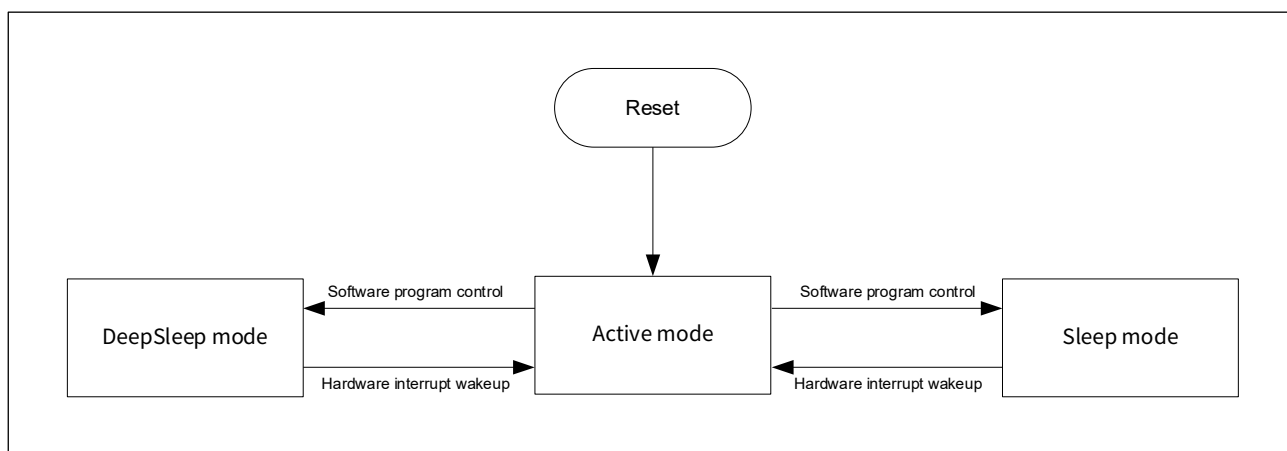
CW32L083 supports three operating modes, and the integrated power management module of the built-in power supply automatically completes the unified management. The three working modes are:

- Active mode
- Sleep mode
- DeepSleep mode

After the power is turned on, the system automatically enters the active mode. Users can enter two low-power operating states of sleep or deep sleep through software programs; In the low-power operating state, the wake-up mechanism can be triggered by a hardware interrupt to return the system to the active mode.

The conversion mechanism of the three operating modes is shown in the following figure:

Figure 3-3 The conversion mechanism of the operating modes



In the active mode, the CPU runs normally, and all module users can use it normally. In Sleep mode, the CPU stops running, all peripherals are unaffected, and all I/O pins remain in the same state. In DeepSleep mode, the CPU stops running, the high-speed clock (HSE, HSIO SC) is automatically turned off, and the low-speed clock (LSE, LSI, RC10K, RC150K) remains in the original state.

The CPU and clock states in different operating modes are shown in the following table:

Table 3-1 Operating mode and CPU and Clock States

Operating mode	CPU state	High-speed clock	Low-speed clock
Active mode	Run	ON/OFF	ON/OFF
Sleep mode	Stop	ON/OFF	ON/OFF
DeepSleep mode	Stop	OFF	ON

3.3.1 Entering Sleep mode or DeepSleep mode

Using the M0+ core's ARM waits for interrupt-specific instruction, WFI (Wait for Interrupt), in conjunction with the SLEEPONEXIT and SLEEPDEEP bit fields of the M0+ core's system control register (SCR, System Control Register), Sleep mode or DeepSleep mode can be entered or exited immediately (interrupt service routine).

- Entering immediately
Executing the WFI instruction, the MCU will immediately enter Sleep mode (when SLEEPDEEP is 0) or DeepSleep mode (when SLEEPDEEP is 1)
- Entering on exit
Setting the SLEEPONEXIT bit to 1, after exiting the lowest priority interrupt service routine, the MCU will enter Sleep mode (when SLEEPDEEP is 0) or DeepSleep mode (when SLEEPDEEP is 1), needn't execute the WFI instruction.

Table 3-2 Entering Sleep mode or DeepSleep mode

Entry method	SLEEPONEXIT bit	Condition	SLEEPDEEP bit	Enter mode
Entering immediately	-	Executing the WFI instruction	0	Sleep mode
			1	DeepSleep mode
Entering on exit	1	After exiting the lowest priority interrupt service routine	0	Sleep mode
			1	DeepSleep mode

Caution 1:

In DeepSleep mode, the system will automatically turn off the high-speed clock. If users need to keep some peripherals running in DeepSleep mode, they must start the corresponding low-speed clock and set the peripheral clock to this low-speed clock before entering DeepSleep mode.

Caution 2:

Before entering DeepSleep mode, if the FLASH is performing an erase/write operation, you must wait for the FLASH_CR1.BUSY flag bit to clear to 0, and make sure FLASH_CR1.MODE is 0 at the same time.



3.3.2 Exiting Sleep mode or DeepSleep mode

In Sleep mode or DeepSleep mode, the interrupt can be used to wake up the CPU and return to active mode. However, it is worth noting that if the user executes the WFI command in the interrupt service routine to enter Sleep (including DeepSleep), an interrupt with a higher priority than this interrupt is required to wake up the CPU, so we strongly recommend that the user is ready to enter sleep, all interrupt service routines should be processed and all interrupt requests and interrupt flags should be cleared.

In different operating modes, the types of interrupts that the CPU can respond to are shown in the following table:

Table 3-3 Operating Modes and Interrupt Sources

Interrupt Number	Interrupt Sources	Active mode	Sleep mode	DeepSleep mode
0	IWDT	Y	Y	Y
	WWDT	Y	Y	N
1	LVD	Y	Y	Y
2	RTC	Y	Y	Y
3	FLASH	Y	Y	N
	RAM	Y	Y	N
4	RCC	Y	Y	Y
5	GPIOA	Y	Y	Y
6	GPIOB	Y	Y	Y
7	GPIOC	Y	Y	Y
	GPIOD	Y	Y	Y
8	GPIOE	Y	Y	Y
	GPIOF	Y	Y	Y
9	DMA1	Y	Y	N
10	DMA2	Y	Y	N
	DMA3	Y	Y	N
11	DMA4	Y	Y	N
	DMA5	Y	Y	N
12	ADC	Y	Y	N
13	ATIM	Y	Y	N
14	VC1	Y	Y	Y
15	VC2	Y	Y	Y
16	GTIM1	Y	Y	N
17	GTIM2	Y	Y	N



Interrupt Number	Interrupt Sources	Active mode	Sleep mode	DeepSleep mode
18	GTIM3	Y	Y	N
19	GTIM4	Y	Y	N
20	BTIM1	Y	Y	N
21	BTIM2	Y	Y	N
	LPTIM	Y	Y	Y
22	BTIM3	Y	Y	N
23	I2C1	Y	Y	N
24	I2C2	Y	Y	N
25	SPI1	Y	Y	N
26	SPI2	Y	Y	N
27	UART1	Y	Y	Y
	UART4	Y	Y	Y
28	UART2	Y	Y	Y
	UART5	Y	Y	Y
29	UART3	Y	Y	Y
	UART6	Y	Y	Y
30	AUTOTRIM	Y	Y	Y
	LCD	Y	Y	Y
31	FAULT	Y	Y	Y

Exiting Sleep mode using an interrupt, the user must enable the enable bit for this interrupt before entering Sleep (including DeepSleep mode).

After the interrupt wakes up and exits Sleep mode, the CPU will immediately enter the interrupt service routine for this interrupt. If the user does not set this interrupt service routine, and when entering sleep immediately: the CPU will continue to execute the next statement of the WFI instruction that entered sleep; when entering sleep when exiting: continue to execute the next statement of the last entered interrupt service routine. In general, based on system reliability considerations, it is strongly recommended that the user set the service routine for this interrupt, and clear the interrupt request and interrupt flag in the interrupt service routine.

When the interrupt wakes up to exit the DeepSleep mode, the CPU operation state is the same as the exit from the Sleep mode.

In DeepSleep mode, the system will automatically turn off the high-speed clock. When exiting DeepSleep, CW32L083 adds an additional system clock option for users. Users can choose to continue to use the clock used when entering DeepSleep, or select HSI as the system clock. Configure the WAKEUPCLK bit field of the system control register SYSCTRL_CR2 to 1, then the internal high-speed clock HSI is automatically used as the system clock after the interrupt wakes up and exits the DeepSleep mode. Since the recovery time of the HSI clock is faster than that of the HSE, it can speed up the system wake-up.



3.3.3 Operating Modes and Reset Sources

Even in Sleep mode or DeepSleep mode, the CPU can respond to some reset sources. The hardware reset or software reset that the CPU can respond to in different working modes is shown in the following table:

Table 3-4 Operating Modes and Reset Sources

Reset Sources	Active mode	Sleep mode	DeepSleep mode
Power-on reset/Brown-out reset (POR/BOR)	Y	Y	Y
Pin input reset (NRST)	Y	Y	Y
LVD reset	Y	Y	Y
IWDT reset	Y	Y	Y
WWDT reset	Y	Y	N
Kernel LOCKUP fault reset	Y	N	N
Kernel SYSRESETREQ reset	Y	N	N



3.4 Low-power consumption applied

In Sleep mode, the CPU stops running, and all peripherals keep running, including ARM®Cortex®-M0+ core peripherals, such as NVIC, SysTick and other peripherals. Sleep mode consumes less power than active mode.

In DeepSleep mode, the CPU stops running, the high-speed clock is turned off, the low-speed clock remains unchanged, some peripherals can be configured to continue to run, and the NVIC interrupt processing still works. DeepSleep mode consumes much less power than Sleep mode.

Users can reduce system running power consumption by:

Decrease system clock frequency

- Use low-frequency high-speed clock HSI, HSE or low-speed clock LSI, LSE
- Reduce the frequency of SYSCLK, HCLK, PCLK by programming the prescaler registers
 - Set the SYSCLK bit field of the SYSTRL_CR0 register to select the appropriate clock source
 - Set the HCLKPRS bit field of the SYSTRL_CR0 register to reduce the HCLK frequency
 - Set the PCLKPRS bit field of the SYSTRL_CR0 register to reduce the PCLK frequency

Turn off clocks and peripherals which not in use during sleep

- AHB bus clock HCLK and APB bus clock PCLK, can be turned off as needed
- Turn off clocks to peripherals not related to wakeup
 - AHB peripheral clock enable control register, SYSTRL_AHBEN
 - APB peripheral clock enable control register 1, SYSTRL_AHBEN1
 - APB peripheral clock enable control register 2, SYSTRL_AHBEN2



3.5 Cortex®-M0+ kernel system control register (SCB->SCR)

Address: 0xE000 ED10 Reset value: 0x0000 0000

Bit filed	Name	Permission	Function description
31:5	RFU	-	Reserved bits, please keep the default value
4	SEVONPEND	RW	When set to 1, each new suspension of an interrupt generates an event, which can be used to wake up the processor if WFE sleep is used.
3	RFU	-	Reserved bits, please keep the default value
2	SLEEPDEEP	RW	When set to 1, enter DeepSleep mode when WFI or SLEEPONEXIT is 1 and all interrupt service routines are exited; When set to 0, enter Sleep mode when WFI or SLEEPONEXIT is 1 and all interrupt service routines are exited
1	SLEEPONEXIT	RW	When set to 1, the processor automatically enters Sleep mode (or DeepSleep mode) when all interrupt service routines are exited; When set to 0, the hibernation function on exit is disabled
0	RFU	-	Reserved bits, please keep the default value



4 Reset and clock control (RCC)

4.1 System reset

CW32L083 supports the following 6 system resets:

- Power on reset (POR)/ Brown-out reset (BOR)
- Pin input reset (NRST)
- IWDG/WWDT reset
- LVD reset
- Kernel SYSRESETREQ reset
- Kernel LOCKUP reset

The reset range of each system reset is shown in the following table:

Table 4-1 Reset method and range

Reset method	Reset range
Power on reset (POR)/ Brown-out reset (BOR)	Entire MCU
Pin input reset (NRST)	Entire MCU (Except RTC)
IWDG/WWDT reset	M0+ core/peripheral (Except RAM controller/RTC)
LVD reset	M0+ core/peripheral (Except LVD controlle section/RTC)
Kernel SYSRESETREQ reset	M0+ core (Except SWD debug logic) / Peripheral (Except RAM controller/LVD/RTC)
Kernel LOCKUP fault reset	M0+ core/peripheral (Except RAM controller/LVD/RTC)

After the system reset occurs, the CPU runs again, most of the registers are reset to default values, and the program starts to execute from the reset interrupt entry address of the interrupt vector table.

The user can query the reset source of this system reset through the system reset flag register SYSCTRL_RESETFLAG. The reset flag is set by hardware and cleared by software. It is recommended that users clear the relevant flag bits of this register to 0 after reading the flag bits to avoid confusion after the next reset.

4.1.1 Power on reset/Brown-out reset (POR/BOR)

The CW32L083 integrates special POR and BOR circuits to monitor the power supply voltage, and keeps the chip in the reset state when the power supply voltage is lower than the safe range to prevent the chip from malfunctioning during power-on/power-off. In order to ensure the stable operation of the system, the user must keep the power supply voltage within a safe range.

For the specific functions of POR and BOR, please refer to chapter [3 Power Control \(PWR\) and Power Consumption](#).

Caution:

In order to ensure that the chip works normally after the reset is released, the circuit design must ensure that VDD/VDDA are powered on and off at the same time.



4.1.2 Pin input reset (NRST)

CW32L083 has a special reset input pin, inputting a low-level signal of a certain width will cause the system to reset. A dedicated anti-shake circuit is designed inside the chip, and low-level pulse signals shorter than 20μs will be shielded.

The reset input pin has a built-in pull-up resistor. If the user needs to connect an external RC circuit, the influence of the internal pull-up resistor must be considered. For the circuit characteristics of the built-in pull-up resistor, please refer to the relevant section of the datasheet.

4.1.3 IWDG/WWDT reset

The CW32L083 integrates an independent watchdog (IWDG) and a window watchdog (WWDT). When the IWDG or WWDT meets the reset condition, a reset signal will be generated to cause a system reset.

For detailed functions of IWDG and WWDT reset, please refer to chapters [17 Independent watchdog timer \(IWDG\)](#) and [18 Window watchdog timer \(WWDT\)](#).

4.1.4 LVD low voltage detection reset

The CW32L083 integrates a low voltage detector (LVD), which can continuously compare the selected monitoring voltage with the set LVD threshold voltage. When the comparison result meets the trigger condition, an LVD reset signal will be generated to cause a system reset.

Compared with the POR/BOR reset method, the LVD low voltage detection reset function is more powerful. The reset threshold voltage, monitoring voltage source, pulse filter width and hysteresis time can be set through the relevant registers.

See chapter [25 Low voltage detector \(LVD\)](#) for LVD details.

4.1.5 Kernel SYSRESETREQ reset

The core SYSRESETREQ reset is a software reset, which is implemented by setting the SYSRESETREQ bit field of the Application Interrupt and Reset Control Status Register (AIRCR) of the ARM® Cortex®-M0+. Setting this bit to 1 by the application program will generate a core SYSRESETREQ reset, thereby implementing a software reset.

4.1.6 Kernel LOCKUP fault reset

When the CPU encounters a serious exception (such as the read instruction is invalid, the bit width does not match the target address when accessing FLASH), it will stop the PC pointer at the current address and lock it, and generate the kernel LOCKUP fault reset signal.

After the chip is powered on, the LOCKUP reset function is disabled by default, and the user needs to manually enable it. By setting the LOCKUP bit field of the system control register SYSCTRL_CR2 to 1, the LOCKUP reset function can be enabled.



4.2 Peripheral reset

Users can use software to reset various peripherals inside CW32L083 individually. Peripheral reset can restore the registers, state machines and various control logic of each peripheral to the default state after power-on reset. The user can perform the independent reset operation of each peripheral module by setting the three registers: `SYSCTRL_AHBRST`, `SYSCTRL_APB1RST1`, and `SYSCTRL_APB1RST2`.

For power-on reset/brown-off reset (POR/BOR), the internal peripheral modules are already in the default state after reset, and the module can be initialized and configured directly, and there is no need to independently reset each module.

For other types of system resets, some peripherals may retain the working state before the reset. If the user needs to restore the peripherals to the default state of power-on, they should reset the peripherals through the corresponding reset registers before using them. The RTC module is a typical peripheral that may need to retain the current state after reset. For specific judgment logic examples, please refer to the relevant routines.



4.3 Clock and Control

4.3.1 Overview

The CW32L083 has a built-in multi-channel clock generation circuit, which generates various clocks of different frequencies through the frequency divider and multiplexer for use by the CPU and various peripherals. The schematic diagram of the system clock tree structure is shown in the [Figure 4-1 System internal clock tree](#).

The internal clock SysClk of the system is divided to provide the advanced high-performance bus clock HCLK for the CPU core, and the HCLK clock is divided to provide the advanced peripheral clock PCLK for digital and analog peripherals.

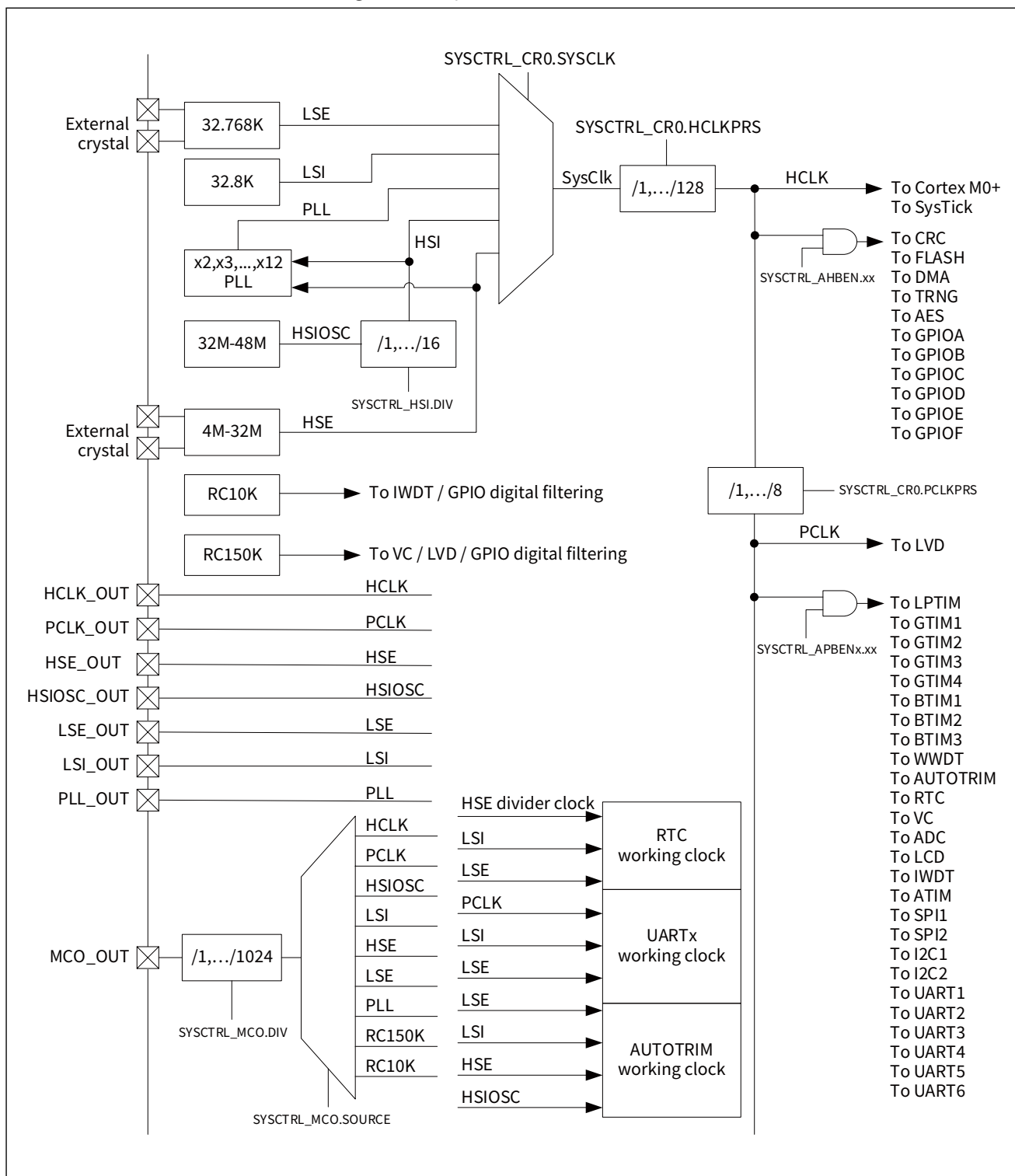
System clock SYSCLK has 5 clock sources:

- High-speed external oscillator clock (HSE)
- Low-speed external oscillator clock (LSE)
- The HSI clock is generated by dividing the internal high-speed RC oscillator clock (HSIOSC)
- Low-speed internal RC oscillator clock (LSI)
- PLL phase-locked loop clock, which is generated by the HSE clock or HSI clock by the phase-locked loop PLL frequency multiplication (2~12 times)

The system internal clock tree is shown in the following figure:



Figure 4-1 System internal clock tree



The high-speed internal RC oscillator clock HSIOSC is divided by the frequency divider to generate the HSI clock. The frequency division coefficient is set through the DIV bit field of the built-in high-frequency clock control register SYSCTRL_HSI, and the effective frequency division coefficients are 1, 2, 4, 6, 8, 10, 12, 14, and 16.

The system clock SysClk can be selected from 5 clock sources: HSE, LSE, HSI, LSI, PLL, which can be selected by the SYSCLK bit field of the system control register SYSCTRL_CR0.

Advanced high-performance bus clock HCLK is generated by the frequency division of the system clock SysClk, and is used as the configuration clock and working clock of the M0+ core, SysTick, DMA, FLASH, CRC, GPIO and other modules. The frequency division factor is set by the HCLKPRS bit field of the system control register SYSCTRL_CR0, and the effective frequency division factor is 2^n ($n = 0 \sim 7$).

Advanced peripheral clock PCLK, which is generated by frequency division of HCLK, is used as the configuration clock and working clock of peripherals such as timer, SPI, and I2C. The frequency division factor is set by the PCLKPRS bit field of the system control register SYSCTRL_CR0, and the effective frequency division factor is 2^n ($n = 0 \sim 3$).

In addition to the 5 clock sources used as the system clock, the CW32L083 also has 2 dedicated low-speed clock sources:

- Internal RC10K clock
Can be used as IWDG module count clock and filter clock for GPIO port interrupt input signal.
- Internal RC150K clock
Can be used as the filter clock of the digital filter module of LVD and VC, and the filter clock of the GPIO port interrupt input signal.

4.3.2 System Clock and Operating Mode

CW32L083 supports three operating modes: Active mode, Sleep mode and DeepSleep mode.

In the Active mode, the CPU runs normally, and all module users can use it normally.

In the Sleep mode, the CPU stops running, and the clock oscillators and peripherals remain unchanged.

In DeepSleep mode, the CPU stops running, and the high-speed clock HSE, HSIOSC oscillator and PLL are automatically turned off to save power; The oscillators of the low-speed clocks LSE, LSI, RC10K, RC150K remain unchanged; Whether the system clock SysClk and the HCLK and PCLK clocks are valid depends on the clock source status of the SysClk system clock.

After waking up from DeepSleep mode, if the WAKEUPCLK bit field of the system control register SYSCTRL_CR2 is configured as 1, the system will automatically use the HSI as the clock source of the system clock. If SYSCTRL_CR2.WAKEUPCLK is 0, the system will wait for the system clock source used before the system enters deep sleep to stabilize before starting to run; If the clock source of the system clock is HSE or PLL, the clock recovery speed and system response speed will be slower. Since the HSI starts up quickly and can quickly respond to user needs, it is recommended to switch the clock source of the system clock to the HSI clock or configure SYSCTRL_CR2.WAKEUPCLK to 1 before entering DeepSleep mode.



4.3.3 HSE clock

The high-speed external clock signal (HSE) supports two operating modes:

- For crystal/ceramic resonators, set the MODE bit field of the external high-frequency crystal control register SYSCTRL_HSE to 0, and configure the OSC_IN and OSC_OUT pins as analog functions.
- For external clock input, set the MODE bit field of the external high-frequency crystal control register SYSCTRL_HSE to 1, and configure the OSC_IN pin as a digital input function.

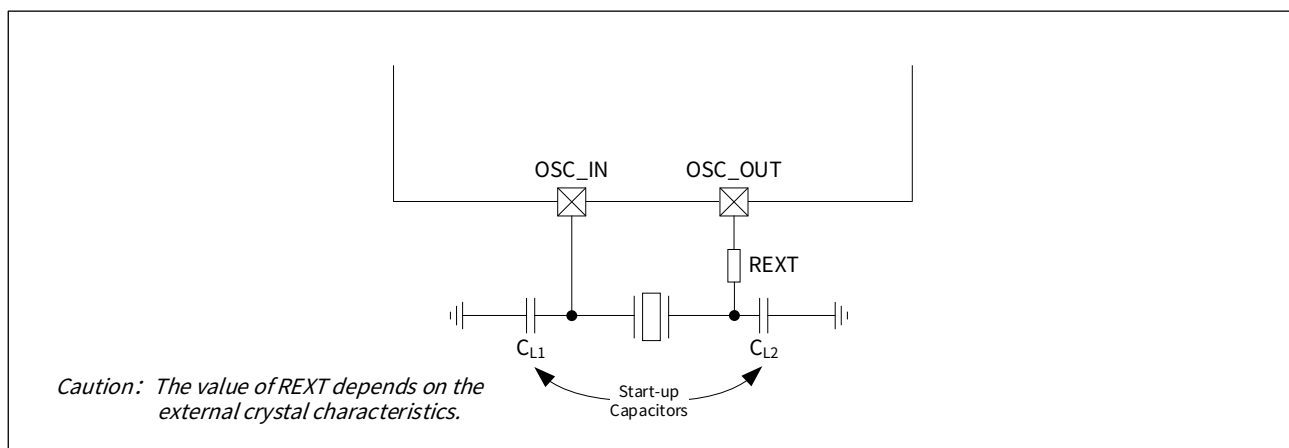
Table 4-2 HSE operating mode configuration

Work mode	SYSCTRL_HSE.MODE	OSC_IN	OSC_OUT
Crystal/Ceramic resonators	0	Analog	Analog
External clock input	1	Digital input	Can be used as general purpose GPIO

Crystal/Ceramic resonators clock mode

The external quartz crystal/ceramic resonator is connected between the OSC_IN and OSC_OUT pins, and cooperates with the start-up capacitor to generate a stable 4~32MHz clock signal. The circuit connection is shown in the following figure:

Figure 4-2 HSE external quartz crystal/ceramic resonator connection method



The crystal/ceramic resonator and start-up capacitor must be placed as close as possible to the chip oscillator pins to minimize oscillator output distortion and start-up time.

The value of the start-up capacitor must be adjusted according to the selected crystal/ceramic resonator. The calculation method is:

$$C_L = (C_{L1} \times C_{L2}) / (C_{L1} + C_{L2}) + C_0$$

Among them,

C_L is the nominal load capacitance of the crystal;

C_0 is the stray capacitance value, which is related to the design of the circuit board. Generally, the value can be 4pF ~ 6pF;

C_{L1} and C_{L2} are two external start-up capacitors, usually C_{L1} and C_{L2} are same;

If the user uses a crystal resonator with a nominal load capacitance value of 12.5pF, the common value of the two external starting capacitors for the crystal is 15pF.

Caution:

Since there are many crystal manufacturers, the crystal characteristics of each manufacturer are different. If the output clock signal of the HSE oscillator is not ideal, you can contact the crystal supplier for coordination.

In order to ensure the performance of the HSE oscillator, it is necessary to set the FREQRANGE bit field of the external high-frequency crystal control register SYSCTRL_HSE according to the nominal frequency of the external crystal, as shown in the following table:

Table 4-3 HSE external crystal frequency setting

External crystal nominal frequency	SYSCTRL_HSE.FREQRANGE
4MHz ~ 8MHz	00
8MHz ~ 16MHz	01
16MHz ~ 24MHz	10
24MHz ~ 32MHz	11

The user can adjust the drive capability by setting the DRIVER bit field of the external high-frequency crystal control register SYSCTRL_HSE. There are four levels of drive capability to choose from. The stronger the drive capability, the higher the power consumption. Users can balance clock reliability, startup time, and low power consumption as needed.

External clock input mode

In the external clock input mode, the external clock is input from the OSN_IN pin, and the OSC_OUT pin can be used as a general-purpose GPIO. The input clock signal can be square wave, sine wave or triangular wave, the duty cycle must be between 40%~60%, and the frequency is between 4~32MHz.

In the two working modes of HSE, the HSE clock oscillator is turned off by default after power-on, and is enabled by setting the HSEEN bit field of the system control register SYSCTRL_CR1 to 1.

After the HSE oscillator is started, when the internal clock monitoring module of the chip detects a certain number of HSE clock signals, the HSE clock is considered to be stable. The number of detection clocks can be set through the WAITCYCLE bit field of the external high-frequency crystal control register SYSCTRL_HSE, as shown in the following table:

Table 4-4 HSE Stability Detection Clock Signal Number

SYSCTRL_HSE.WAITCYCLE	Number of HSE detection clocks
00	8192
01	32768
10	131072 (Defaults)
11	262144

The start-up state of the HSE clock can be determined through the STABLE flag of the external high-frequency crystal control register SYSCTRL_HSE. If the STABLE flag is 1, the HSE clock is stable, and if it is 0, the HSE clock is not stable.

Caution:

All parameters of the HSE oscillator should be set before starting, and it is forbidden to modify the relevant parameters after starting.



4.3.4 HSIOSC clock

The HSIOSC clock is generated by the internal RC oscillator, no external circuit is required, the cost is lower than the HSE clock, and the startup speed is faster. The HSIOSC clock frequency is fixed at 48MHz, and the frequency accuracy is lower than that of the HSE clock.

The frequency of the RC oscillator output clock is affected by the chip processing process, operating voltage, ambient temperature and other factors. CW32L083 provides the HSIOSC clock frequency calibration function. Users can calibrate the HSIOSC clock by setting the TRIM bit field value of the built-in high-frequency clock control register SYSCTRL_HSI frequency, see section [4.4.2 Clock calibration](#) for details.

The HSIOSC internal high-speed RC oscillator is turned on by default after the chip is powered on. Users can turn it off by setting the HSIEN bit field of SYSCTRL_CR1 in the system control register to 0. If the user stops and restarts the HSIOSC oscillator, the STABLE flag of the built-in high-frequency clock control register SYSCTRL_HSI can be used to determine whether the HSI clock is stable. If the STABLE flag is 1, it means that the HSIOSC clock is stable, and if it is 0, it means that the HSIOSC clock is not stable yet.

Caution:

All parameters of the HSIOSC oscillator should be set before starting, and it is forbidden to modify the relevant parameters after starting.

The HSIOSC clock outputs the HSI clock after frequency division. The frequency division coefficient is set by the DIV bit field of the built-in high-frequency clock control register SYSCTRL_HSI. The effective frequency division coefficients are 1, 2, 4, 6, 8, 10, 12, 14, 16, The default value after power-on is 6, so the default frequency of the HSI clock is 8MHz.



4.3.5 LSE clock

External low-speed clock (LSE) supports two operating modes:

- For crystal/ceramic resonators, set the MODE bit field of the external low-frequency crystal control register SYSCTRL_LSE to 0, and configure the OSC32_IN and OSC32_OUT pins as analog functions.
- For external clock input, set the MODE bit field of the external low-frequency crystal control register SYSCTRL_LSE to 1, and configure the OSC32_IN pin as a digital input function.

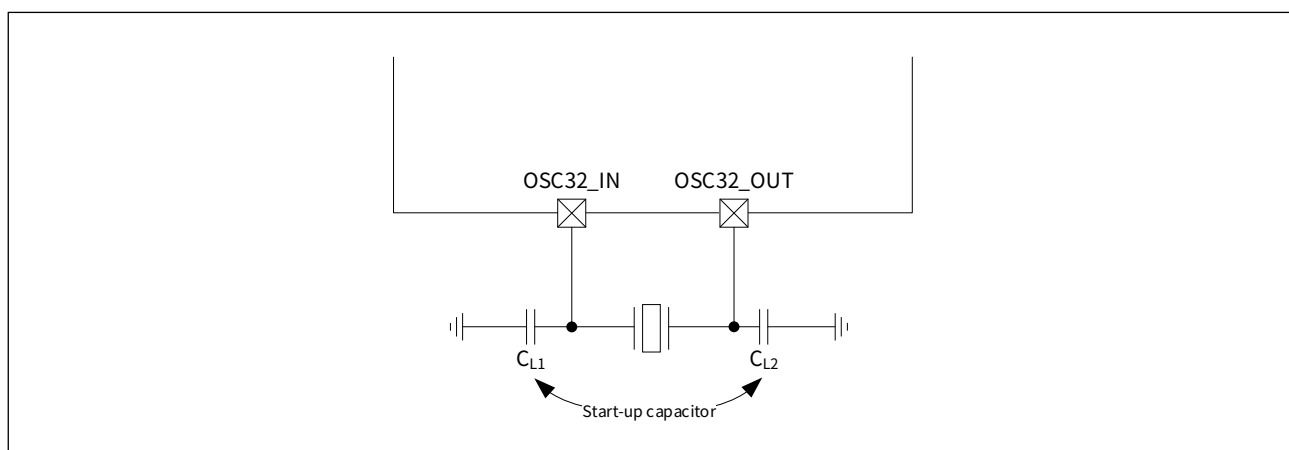
Table 4-5 LSE operating mode configuration

Operating mode	SYSCTRL_LSE.MODE	OSC32_IN	OSC32_OUT
Crystal/Ceramic Resonators	0	Analog	Analog
External clock input	1	Digital input	Can be used as general purpose GPIO

Crystal/Ceramic resonators clock mode

The external low-frequency quartz crystal/ceramic resonator is connected between the two pins of OSC32_IN and OSC32_OUT. With the start-up capacitor, a stable clock signal of up to 1MHz can be generated. LSE is usually used as the operating clock of the system real-time clock RTC. At this time, a quartz crystal/ceramic resonator with a frequency of 32.768kHz should be selected. The external circuit connection is shown in the figure below:

Figure 4-3 LSE external quartz crystal/ceramic resonator connection method



The quartz crystal/ceramic resonator and start-up capacitor must be placed as close as possible to the chip oscillator pins to minimize oscillator output distortion and start-up time.

The value of the start-up capacitor must be adjusted according to the selected crystal/ceramic resonator. The calculation method is:

$$C_L = (C_{L1} \times C_{L2}) / (C_{L1} + C_{L2}) + C_0$$

Among them,

C_L is the nominal load capacitance of the crystal;

C_0 is the stray capacitance value, which is related to the design of the circuit board. Generally, the value can be 4pF~6pF;

C_{L1} and C_{L2} are two external start-up capacitors, usually C_{L1} and C_{L2} are same;

If the user uses a crystal resonator with a nominal load capacitance value of 12.5pF, the common value of the two external starting capacitors for the crystal is 15pF.

Caution:

Since there are many crystal manufacturers, the crystal characteristics of each manufacturer are different. If the output clock signal of the LSE oscillator is not ideal, you can contact the crystal supplier for coordination.

Users can adjust the drive capability by setting the DRIVER bit field of the external low-frequency crystal control register SYSCTRL_LSE. There are four levels of drive capability to choose from. The stronger the drive capability, the higher the power consumption. The amplitude of the clock signal can be adjusted by setting the AMP bit field of the external low-frequency crystal control register SYSCTRL_LSE. There are four amplitudes to choose from. The larger the amplitude, the greater the power consumption. Users can balance clock reliability, startup time, and low power consumption as needed.

External clock input mode

In the external clock input mode, the external clock is input from the OSN32_IN pin, and the OSC32_OUT pin can be used as a general-purpose GPIO. The input clock signal can be square wave, sine wave or triangular wave, the duty cycle must be between 45%~55%, and the frequency can be up to 1MHz.

In the two working modes of HSE, the LSE clock oscillator is turned off by default after power-on, and is enabled by setting the LSEEN bit field of the system control register SYSCTRL_CR1 to 1.

After the LSE oscillator is started, when the internal clock monitoring module of the chip detects a certain number of LSE clock signals, the LSE clock is considered to be stable. The number of detection clocks can be set through the WAITCYCLE bit field of the external low-frequency crystal control register SYSCTRL_LSE, as shown in the following table:

Table 4-6 LSE Stability Detection Clock Signal Number

SYSCTRL_LSE.WAITCYCLE	Number of LSE detection clocks
00	256
01	1024
10	4096 (Defaults)
11	16384

The start-up state of the LSE clock can be determined through the STABLE flag of the external low-frequency crystal control register SYSCTRL_LSE. If the STABLE flag is 1, the LSE clock is stable, and if it is 0, the LSE clock is not stable.

Caution:

All parameters of the LSE oscillator should be set before starting, and it is forbidden to modify the relevant parameters after starting.

The LSE oscillator has a lock function. After the lock function is turned on, the software is prohibited from clearing the enable bit (SYSCTRL_CR1.LSEEN) of the LSE clock oscillator. That is, once the LSE is turned on, it cannot be turned off by software. The locking function is mainly designed to meet the requirements of some special application scenarios, such as application scenarios sensitive to RTC time loss, which can effectively prevent RTC time loss caused by misoperation. The lock function is disabled by default and is enabled by setting the LSELOCK bit field of the system control register SYSCTRL_CR1 to 1.



4.3.6 LSI clock

The LSI clock is generated by the internal low-speed RC oscillator with a default frequency of 32.8kHz. The internal low-speed RC oscillator requires no external circuitry and is less expensive than the LSE clock, but less accurate than the LSE clock.

The frequency of the RC oscillator output clock is affected by the chip processing process, operating voltage, ambient temperature and other factors. CW32L083 provides the LSI clock frequency calibration function. Users can calibrate the LSI clock frequency by setting the value of the TRIM bit field of the built-in low-frequency clock control register SYSCTRL_LSI. For details, please refer to [4.4.2 Clock calibration](#).

The LSI internal low-speed RC oscillator is disabled by default, and is enabled by setting the LSIEN bit field of the system control register SYSCTRL_CR1 to 1. After the LSI oscillator is started, if the internal clock monitoring module of the chip detects a certain number of LSI clock signals, the LSI clock is considered to be stable. The number of detection clocks can be set by the WAITCYCLE bit field of the built-in low-frequency oscillator control register SYSCTRL_LSI, as shown in the following table:

Table 4-7 LSI Stability Detection Clock Signal Number

SYSCTRL_LSI.WAITCYCLE	Number of LSI detection clocks
00	6 (Defaults)
01	18
10	66
11	258

The STABLE flag of the built-in low-frequency clock control register SYSCTRL_LSI can be used to determine whether the LSI clock is stable. If the STABLE flag is 1, it means that the LSI clock is stable, and if it is 0, it means that the LSI clock is not stable.

Caution:

All parameters of the LSI oscillator should be set before starting, and it is forbidden to modify the relevant parameters after starting.



4.3.7 PLL clock

The CW32L083 integrates a phase-locked loop PLL circuit, which can phase-lock and multiply the input clock source to output the PLL clock. The user can select the input reference clock source of the PLL through the SOURCE bit field of the built-in phase-locked loop control register SYSCTRL_PLL, as shown in the following table:

Table 4-8 PLL clock source selection

SYSCTRL_PLL.SOURCE	PLL input reference clock source
00	HSE oscillator clock ¹
01	HSE pin input clock ¹
11	HSI clock (clock divided by HSIOSC)

Caution 1:

Must be consistent with SYSCTRL_HSE.MODE.

The phase-locked loop frequency multiplication factor is set through the MUL bit field of the built-in phase-locked loop control register SYSCTRL_PLL. The setting range is 2~12, and the default value is 8.

To ensure the lock convergence speed of the PLL and the phase noise performance of the output clock, the user needs to set the values of the SYSCTRL_PLL.FREQIN and SYSCTRL_PLL.FREQOUT bit fields according to the actual input reference clock frequency and output clock frequency. The setting rules are shown in the following table:

Table 4-9 PLL input reference clock frequency

Input reference clock frequency	SYSCTRL_PLL.FREQIN
4MHz ~ 6MHz	00
6MHz ~ 12MHz	01
12MHz ~ 20MHz	10
20MHz ~ 24MHz	11

Table 4-10 PLL output clock frequency

Output clock frequency required	SYSCTRL_PLL.FREQOUT
12MHz ~ 18MHz	00
18MHz ~ 24MHz	01
24MHz ~ 36MHz	10
36MHz ~ 48MHz	11
48MHz ~ 72MHz	1xx



The PLL is disabled by default and is enabled by setting the PLEN bit field of the system control register SYCTRL_CR1 to 1. After the PLL is started, the internal clock monitoring module of the chip detects a certain number of PLL clock signals, and the PLL clock is considered to be stable. The number of detection clocks can be set by the WAITCYCLE bit field of the built-in phase-locked loop control register SYCTRL_PLL, as shown in the following table:

Table 4-11 Number of PLL stable detection clock signals

SYSCTRL_PLL.WAITCYCLE	Number of PLL detection clocks
000	128
001	256
010	512
011	1024 (Defaults)
100	2048
101	4096
110	8192
111	16384

Through the STABLE flag of the built-in phase-locked loop control register SYCTRL_PLL, you can determine whether the PLL clock is stable. The STABLE flag is 1 to indicate that the PLL clock is stable, and 0 indicates that the PLL clock is not stable.

Caution:

All parameters of the PLL oscillator should be set before starting, and it is forbidden to modify the relevant parameters after starting.

The process of modifying PLL parameters is as follows:

Step 1: Set SYCTRL_CR1.PLEN to 0, turn off the PLL;

Step 2: Wait for the SYCTRL_PLL.STABLE flag to be cleared by the system hardware;

Step 3: Change the parameters of the PLL;

Step 4: Set SYCTRL_CR1.PLEN to 1 to start the PLL;

Step 5: Wait for the SYCTRL_PLL.STABLE flag to be set by system hardware to indicate that the PLL clock is stable.



4.3.8 SysClk system clock

System clock SysClk can choose from 5 clock sources, including HSE, LSE, HSI, LSI, and PLL.

After the system power-on reset is completed, HSI is selected as the clock source of SysClk by default, and the default value of the clock frequency is 8MHz.

The user can select the system clock source through the SYSCLK bit field of the system control register SYSCTRL_CR0. After selecting a clock as the system clock source, the user cannot stop the clock by setting the enable bit SYSCTRL_CR1.xxxEN of the clock circuit to 0.

4.3.9 On-chip peripheral clock control

On-chip peripherals generally need the configuration clock and the working clock. The configuration clock is used to respond to the read and write operations of the peripheral registers by the CPU. The working clock is used for the function realization of each peripheral (such as the transmission clock of the UART, the count clock of the timer, etc.).

The configuration clock and working clock of the peripheral must be turned on before using the peripheral, otherwise the peripheral cannot work. By setting the corresponding bits of the AHB peripheral clock enable control register SYSCTRL_AHBEN and the APB peripheral clock enable control register SYSCTRL_APBEN1 and SYSCTRL_APBEN2 to 1, the configuration clock and working clock of the corresponding peripherals are turned on.

Peripherals such as RTC, UART, AUTOTRIM, and FLASH only open the configuration clock, and the working clock is configured through the clock source selection register of each module.

When the peripherals do not need to be used, the peripherals can be disabled by turning off the configuration clocks and operating clocks of the peripherals, which can effectively reduce the power consumption of the chip.

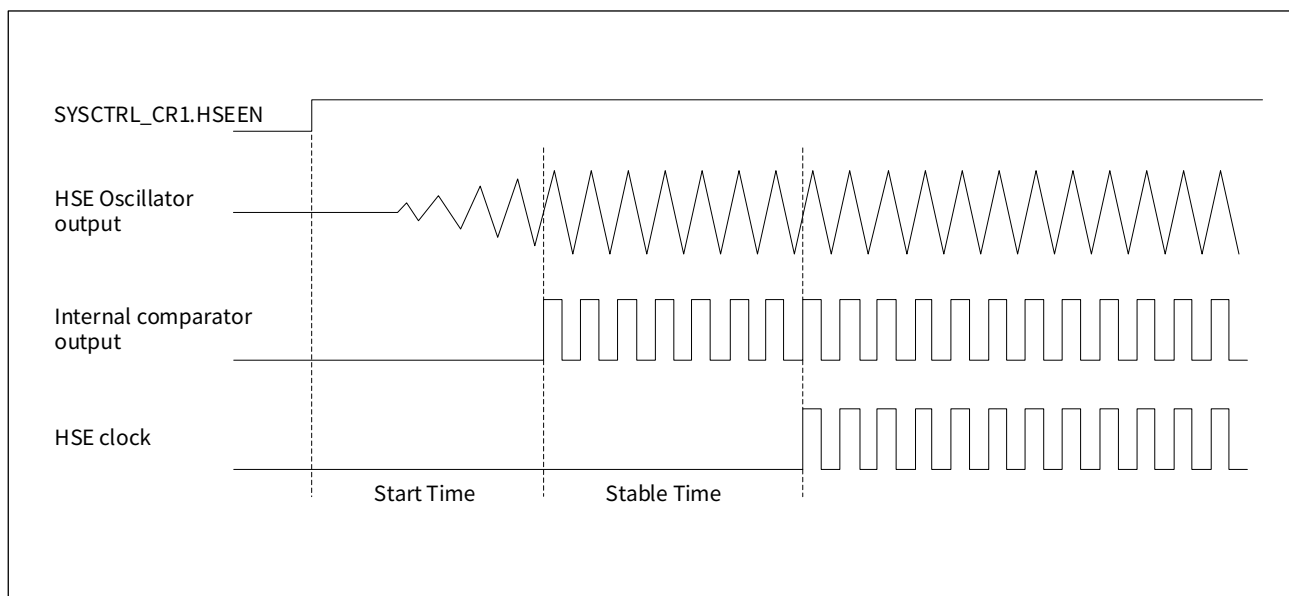


4.4 Clock Start, Calibration, and Status Detection

4.4.1 Clock start

The clock source startup process of CW32L083 is similar. Take HSE as an example to illustrate the stabilization process after clock startup, as shown in the following figure:

Figure 4-4 HSE clock startup process



When SYSCTRL_CR1.HSEEN is set to 1, the HSE clock oscillation circuit starts to work, but the output clock signal amplitude is very small at this time. After the start-up time stage, the amplitude and duty cycle of the output clock signal can meet the needs of the internal sampling circuit and enter the stabilization time stage. In the stable time stage, the internal clock monitoring circuit of the chip counts the clock signals output by the HSE. When the count value reaches the set number, the HSE clock signal is considered to be stable, and the HSE clock stability flag bit SYSCTRL_HSE.STABLE is set to 1; If SYSCTRL_HSE.WAITCYCLE clock signals are not detected within a certain period of time, it is considered that the HSE oscillator fails to start-up.

The clock start-up process of other clock oscillators is similar, but note that the number of detection clocks in the stable phase, the detection time and the number of detection clocks for start-up failure detection are different for each clock oscillator. For details, see the description of each clock oscillator.

4.4.2 Clock calibration

Clock calibration is mainly for HSIOSC clock and LSI clock. Clock frequency calibration is achieved by adjusting the TRIM value of the oscillator.

HSIOSC clock calibration

The safe working range of HSIOSC is 32~48MHz. If it exceeds the safe range, the chip may be abnormal. When the chip leaves the factory, the calibration parameters of the 48MHz frequency point have been pre-adjusted and stored in FLASH. The application program only needs to read and write the calibration value in FLASH to SYSCtrl_HSI.TRIM to obtain a precise 48MHz clock. The storage address of the 48MHz frequency calibration value is: 0x0010 0A00 – 0x0010 0A01. If other frequency clocks are needed, users need to adjust the value of SYSCtrl_HSI.TRIM by themselves.

LSI clock calibration

The LSI output clock frequency range is $32.8\text{kHz} \pm 10\%$. If the LSI output clock frequency is adjusted outside this range, the clock may be abnormal. When the chip leaves the factory, the calibration parameters of the 32.8kHz frequency point are pre-adjusted and stored in the FLASH. The application program only needs to read the calibration value in the FLASH and write it into SYSCtrl_LSI.TRIM to obtain an accurate 32.8kHz clock. 32.8kHz frequency calibration value storage address: 0x0010 0A02 - 0x0010 0A03. If other frequency clocks are needed, users need to adjust the value of SYSCtrl_LSI.TRIM by themselves.



4.4.3 Clock state detection

The chip has the functions of clock stability detection, start-up failure detection, and clock failure detection during clock startup, and supports automatic clock source switching when the currently selected system clock source fails.

4.4.3.1 Clock stability detection

The 5 clock sources, HSE, LSE, HSIOSC, LSI, and PLL, all support the clock stability detection function. Users can determine the clock status through the stability flag of the corresponding clock source. The clock stable flag is cleared by hardware when the clock source is turned off, and set 1 by hardware after the clock source is enabled and stable.

Note that the clock stable flag is only for the clock start-up process. During the clock stable operation process, the detection of clock operation failure will not affect the clock stable flag.

Taking the HSE clock source as an example, the HSE clock stability flag and clock stability interrupt flag are described as follows:

- **SYSCTRL_HSE.STABLE**
Cleared by hardware when HSE is turned off, and set by hardware when it detects that the HSE clock is stable.
- **SYSCTRL_ISR.HSESTABLE**
It belongs to the same signal as SYSCTRL_HSE.STABLE. Although this signal is located in the interrupt flag register SYSCTRL_ISR, it will not cause an interrupt request after being set to 1 by hardware.
- **SYSCTRL_ISR.HSERDY**
When the hardware detects that the clock changes from an unstable state to a stable state (that is, the SYSCTRL_HSE.STABLE flag changes from 0 to 1), it is set to 1, which is the clock stability interrupt flag. Users can clear this flag by setting SYSCTRL_ICR.HSERDY to 0.



4.4.3.2 Clock start-up failure detection

CW32L083 supports external clock (HSE and LSE) start-up failure detection function. After the external clock is started, the clock detection logic counts the detected clock signals, and if a set number of clock signals are detected within the detection time, the clock starts to vibrate successfully, otherwise the start-up fails.

The number of clocks for HSE start-up failure detection is set through `SYSCTRL_HSE.WAITCYCLE`. The detection time does not need to be set by the user, but is automatically set by the system, as shown in the following table:

Table 4-12 HSE start-up failure detection time and number of detection clocks

<code>SYSCTRL_HSE.WAITCYCLE</code>	Detection time	Number of detection clocks
00	65ms	8192
01	65ms	32768
10	65ms	131072
11	130ms	262144

The number of clocks for LSE start-up failure detection is set through `SYSCTRL_LSE.WAITCYCLE`. The detection time does not need to be set by the user, but is automatically set by the system, as shown in the following table:

Table 4-13 LSE start-up failure detection time and number of detection clocks

<code>SYSCTRL_LSE.WAITCYCLE</code>	Detection time	Number of detection clocks
00	1s	256
01	1s	1024
10	1s	4096
11	2s	16384

The external clock (HSE and LSE) failure detection function is disabled by default, and the corresponding interrupt flag will not be generated if the HSE/LSE fails to start. By setting `SYSCTRL_CR1.HSECCS` to 1 and `SYSCTRL_CR1.LSECCS` to 1, enable the fault detection function of the HSE and LSE external clocks respectively.

After enabling the fault detection function of the external clock, if the HSE or LSE fails to start, a start-up failure interrupt flag will be generated (corresponding to `SYSCTRL_ISR.HSEFAIL` or `SYSCTRL_ISR.LSEFAIL` is set to 1); if the interrupt is enabled (corresponding to `SYSCTRL_IER.HSEFAIL` or `SYSCTRL_IER.LSEFAIL` is set to 1), the CPU will execute the interrupt service routine to handle the failure of clock start-up.



4.4.3.3 In-flight failure detection of clocks

CW32L083 supports external clock (HSE and LSE) in-flight detection function. During the stable operation of the external clock, the clock detection logic continues to count the HSE and LSE clock signals with a certain detection period: if a set number of clock signals are detected within the detection period, the operation is normal, otherwise the operation fails.

The running failure detection period of the HSE clock is configured by `SYSCTRL_HSE.DETCNT`, the actual time is $\text{SYSCTRL_HSE.DETCNT}/f_{\text{LSI}}$, and the number of detection clocks is 0x20000. Considering that the clock has a certain deviation, in order to ensure the reliability of the detection function, the configuration of the HSE detection period parameter `HSE.DETCNT` must leave a certain margin, generally according to the operating frequency of the HSE, the configuration is $8000/f_{\text{HSE}}$ (where f_{HSE} is the HSE clock frequency in MHz).

Example: If the HSE clock frequency is 4MHz, then `SYSCTRL_HSE.DETCNT` should be configured as 2000.

The running failure detection period of the LSE clock is not configurable, it is fixed at 256 LSI clock periods, and the number of detection clocks is 128.

The external clock failure detection function is disabled by default, and the corresponding interrupt flag will not be generated if the HSE/LSE fails during operation. By setting `SYSCTRL_CR1.HSECCS` to 1 and `SYSCTRL_CR1.LSECCS` to 1, the HSE and LSE clock fault detection functions are enabled respectively. HSE or LSE clock running failure detection also needs to set `SYSCTRL_CR1.LSIEN` to 1 to enable the internal low-speed clock LSI.

After the fault detection function of the external clock is enabled, if the HSE or LSE failure is detected during operation, a running failure flag will be generated (corresponding to `SYSCTRL_ISR.HSEFAULT` or `SYSCTRL_ISR.LSEFAULT` is set to 1), if the interrupt is enabled (corresponding to `SYSCTRL_IER.HSEFAULT` or `SYSCTRL_IER.LSEFAULT` is set to 1), the CPU will execute the interrupt service routine to handle the failure during clock operation.

If the current system clock source is HSE, set `SYSCTRL_CR1.CLKCCS` to 0, no action when HSE is running and fail; set `SYSCTRL_CR1.CLKCCS` to 1, system clock source will automatically switch to HSI clock when HSE is running and fail.

If the current system clock source is LSE, set `SYSCTRL_CR1.CLKCCS` to 0, no action when LSE is running and fail; set `SYSCTRL_CR1.CLKCCS` to 1, system clock source will automatically switch to HSI clock when LSE is running and fail.



4.4.4 Clock verification and output

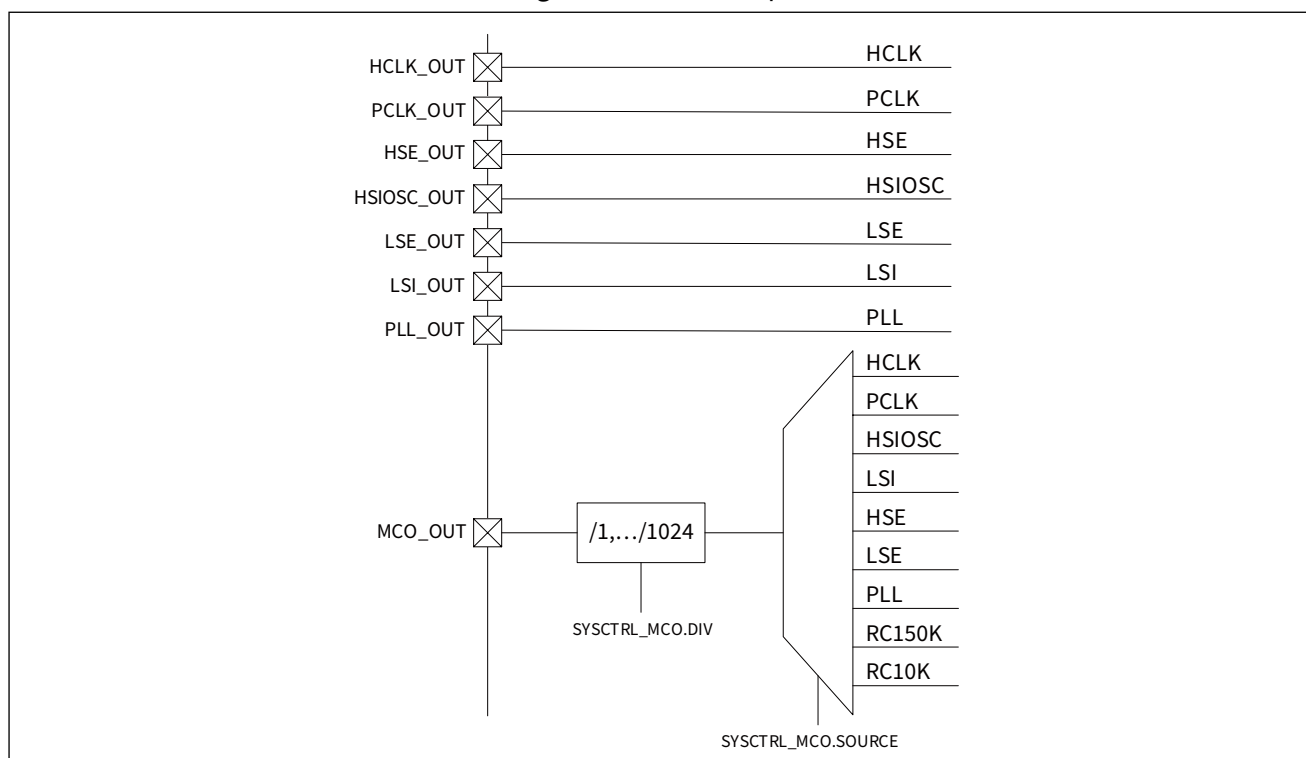
CW32L083 supports outputting various internal clock signals to external pins. Users can use this function to measure the current system's CPU operating frequency, system bus frequency, peripheral operating frequency, etc.

- HCLK_OUT pin
Output HCLK clock signal
- PCLK_OUT pin
Output PCLK clock signal
- HSE_OUT pin
Output HSE clock signal
- HSIOSC_OUT pin
Output HSIOSC clock signal
- LSE_OUT pin
Output LSE clock signal
- LSI_OUT pin
Output LSI clock signal
- PLL_OUT pin
Output PLL clock signal
- MCO_OUT pin

Output HCLK/PCLK/HSIOSC/LSI/HSE/LSE/PLL/RC150K/RC10K clock signal, before the clock is output to the MCO_OUT pin, it can be divided by a prescaler (effective frequency division factors are 1, 2, 8, 64, 128, 256, 512, 1024), so that the low-bandwidth instrument can accurately measure the signal.

The clock output block diagram is shown in the following figure:

Figure 4-5 Clock output



4.5 SysClk system clock switch

The system clock SysClk can select 5 clock sources, including HSE, LSE, PLL, HSI, and LSI. By setting the SYSCLK bit field of the system control register SYSCTRL_CR0, it can be switched between different clock sources.

The main application scenarios include:

- Automatic clock failover
When it is detected that the current system clock source fails, it can quickly and safely switch to other available clock sources to improve product reliability.
- Power management
Switch the clock source of SysClk to low-speed clock in standby state to reduce system power consumption, and switch the clock source of SysClk to high-speed clock in normal use state to quickly respond to user needs.

The rules for safe switching of clock sources are as follows:

- Any two of the four clock sources of HSE, LSE, HSI and LSI can be switched between each other
- The PLL can only be switched between the two clocks of HSE and HSI

The system clock switching operation must be performed in accordance with the seven clock switching procedures described below, otherwise an exception may occur.

Caution:

When the system clock is switched, the FLASH control register FLASH_CR2.WAIT needs to be configured synchronously to read the waiting period parameters: if the system clock frequency is not greater than 24MHz, the FLASH control register FLASH_CR2.WAIT should be set to 0; if the system clock frequency is greater than 24MHz, the FLASH control register FLASH_CR2.WAIT should be set to 1; if the system clock frequency is greater than 48MHz, the FLASH control register FLASH_CR2.WAIT should be set to 2.



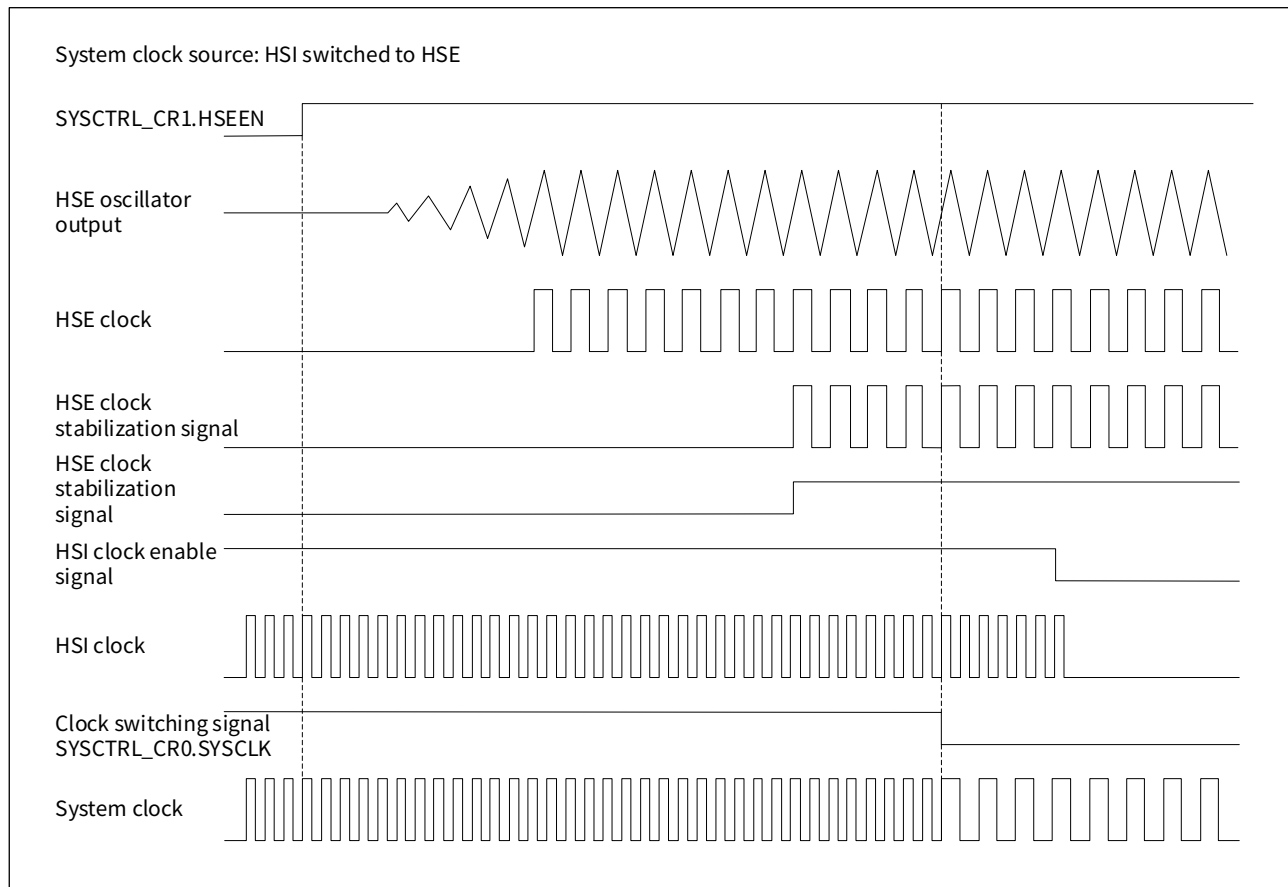
4.5.1 Standard Clock Switching Process

The standard clock switching operation flow is as follows:

- Step 1: If the new clock source is HSE or LSE, you need to configure the corresponding external pin to the appropriate mode: when connecting an external crystal, you need to configure it as an analog function, when connecting an external clock input, you need to set the GPIO as a digital input function and enable the port's input function;
- Step 2: Configure the oscillation parameters of the new clock source, such as drive capability, oscillation amplitude, stabilization period, etc.;
- Step 3: Set the new clock source oscillator enable bit to 1;
- Step 4: According to the higher frequency of the current clock source and the new clock source, configure the FLASH_CR2.WAIT read wait period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 5: Wait for the new clock source to output a stable frequency (the STABLE signal of the new clock source becomes 1);
- Step 6: Configure the system control register SYSCTRL_CR0.SYSCLK, and select the clock source of the system clock SysClk as the new clock source;
- Step 7: According to the frequency of the new clock source, configure the FLASH_CR2.WAIT read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 8: Turn off clock sources that are no longer in use.

Taking the system clock switching from HSI to HSE as an example, the switching process of the old and new clocks is shown in the following figure:

Figure 4-6 HSI clock switched to HSE clock



4.5.2 HSI clock switching process between different frequencies

Switching between different frequencies of the HSI clock does not require starting a new clock source, but only needs to change the frequency division ratio of the HSI clock prescaler. The switching speed is fast, and there is no need to wait for the clock stabilization time before and after switching. The switching operation process is as follows:

- Step 1: According to the higher frequency of the current clock source and the new clock source, configure the FLASH_CR2.WAIT read wait period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 2: Read the value of the built-in high-frequency clock control register SYSCTRL_HSI register as Value;
- Step 3: According to the required target frequency, set the built-in high-frequency clock control register SYSCTRL_HSI.DIV to the corresponding frequency division coefficient (note that the SYSCTRL_HSI.TRIM field should remain unchanged);
- Step 4: According to the frequency of the new clock source, configure the FLASH_CR2.WAIT read wait period parameter as required in the chapter [7 FLASH Memory](#).

4.5.3 Example of switching from other clocks to LSE

The switching operation process is as follows:

- Step 1: Set PC14 / PC15 pins as analog function ports;
- Step 2: According to the characteristics of the external crystal of the LSE oscillator, configure the oscillation parameters of the new clock source LSE, such as drive capability (set by the external low-frequency crystal control register SYSCTRL_LSE.DRIVER, it is recommended to configure 3), oscillation amplitude (by the external low-frequency crystal control register SYSCTRL_LSE.AMP setting, it is recommended to configure 2 or 3), stable period (set through the external low-frequency crystal control register SYSCTRL_LSE.WAITCYCLE, it is recommended to set to 3), etc.;

- Step 3: Set the system control register SYSCTRL_CR1.LSEEN to 1 to enable the LSE crystal oscillator circuit;

Caution:

The SYSCTRL_CR1 register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

- Step 4: Cyclic query and wait for the external low-frequency crystal control register SYSCTRL_LSE.STABLE stable flag to become 1, that is, wait for the LSE crystal oscillator circuit to output a stable clock;

- Step 5: Set the system control register SYSCTRL_CR0.SYSClk to 4, and switch the SysClk clock source to LSE;

Caution:

The SYSCTRL_CR0 register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

- Step 6: Configure the FLASH_CR2.WAIT read wait period parameter according to the requirements of the chapter [7 FLASH Memory](#);

- Step 7: Set the system control register SYSCTRL_CR1.xxxEN to 0 to turn off the original clock.



4.5.4 Example of switching from other clocks to HSE

The switching operation process is as follows:

Step 1: Set PF00/PF01 pins as analog function ports;

Step 2: According to the characteristics of the external crystal of the HSE oscillator, configure the oscillation parameters of the new clock source HSE, such as crystal operating frequency (configured through the external high-frequency crystal control register `SYSCTRL_HSE.FREQRANGE`), drive capability (through the external high-frequency crystal control register `SYSCTRL_HSE.DRIVER` configuration), stabilization period (configured through the external high-frequency crystal control register `SYSCTRL_HSE.WAITCYCLE`, it is recommended to set it to 3), etc.;

Step 3: Set the system control register `SYSCTRL_CR1.HSEEN` to 1 to enable the HSE crystal oscillator circuit;

Caution:

The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 4: According to the higher frequency of the current clock and HSE, configure the `FLASH_CR2.WAIT` read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);

Step 5: Cyclic query in a loop and wait for the stable flag of the external high-frequency crystal control register `SYSCTRL_HSE.STABLE` to become 1 to ensure that the crystal oscillator circuit outputs a stable clock;

Step 6: Set the system control register `SYSCTRL_CR0.SYSCLK` to 1, and switch the SysClk clock source to HSE;

Caution:

The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 7: According to the clock frequency of the HSE, configure the `FLASH_CR2.WAIT` read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);

Step 8: Set the system control register `SYSCTRL_CR1.xxxEN` to 0 to turn off the original clock.

4.5.5 Example of switching from other clocks to LSI

The switching operation process is as follows:

Step 1: Configure the built-in low-frequency clock control register `SYSCTRL_LSI.TRIM` and the built-in low-frequency clock control register `SYSCTRL_LSI.WAITCYCLE` to appropriate values;

Step 2: Set the system control register `SYSCTRL_CR1.LSIEN` to 1 to enable the LSIRC oscillator circuit;

Caution:

The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 3: Cyclic query and wait for the built-in low-frequency clock control register `SYSCTRL_LSI.STABLE` stable flag to become 1, that is, wait for the LSI to output a stable clock;

Step 4: Set the system control register `SYSCTRL_CR0.SYSCLK` to 3, and switch the SysClk clock source to LSI;

Caution:

The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 5: Configure the `FLASH_CR2.WAIT` read wait period parameter to 0;

Step 6: Set the system control register `SYSCTRL_CR1.xxxEN` to 0 to turn off the original clock.



4.5.6 Example of switching from other clocks to HSI

The switching operation process is as follows:

Step 1: Configure the built-in high-frequency clock control registers `SYSCTRL_HSI.TRIM`, `SYSCTRL_HSI.WAITCYCLE` and `SYSCTRL_HSI.DIV` to appropriate values;

Step 2: Set the system control register `SYSCTRL_CR1.HSIEN` to 1 to enable the `HSIOSC` clock oscillation circuit;

Caution:

The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 3: Cyclic query and wait for the built-in high-frequency clock control register `SYSCTRL_HSI.STABLE` stable flag to become 1, that is, wait for the `HSIOSC` to output a stable clock;

Step 4: According to the higher frequency of the current clock and HSI, configure the `FLASH_CR2.WAIT` read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);

Step 5: Set the system control register `SYSCTRL_CR0.SYSCLK` to 0, and switch the `SysClk` clock source to HSI;

Caution:

The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 6: According to the clock frequency of HSI, configure the `FLASH_CR2.WAIT` read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);

Step 7: Set the system control register `SYSCTRL_CR1.xxxEN` to 0 to turn off the original clock.



4.5.7 Example of switching between PLL and HSI, the input clock source of PLL is HSI

The operation flow of switching from HSI to PLL is as follows:

- Step 1: Set the phase-locked loop control register `SYSCTRL_PLL.SOURCE` to 3, and select the HSI clock as the input clock source of the PLL;
- Step 2: Calculate the HSI clock frequency according to the output clock frequency of the `HSIOSC` and the value of the `SYSCTRL_HSI.DIV` bit field; configure the phase-locked loop input frequency range `SYSCTRL_PLL.FREQIN` according to the HSI clock frequency value;
- Step 3: According to the clock frequency output by the PLL, configure the phase-locked loop frequency multiplication factor `SYSCTRL_PLL.MUL` and the output clock frequency range `SYSCTRL_PLL.FREQOUT`;
- Step 4: Set the phase-locked loop stabilization period `SYSCTRL_PLL.WAITCYCLE` to 7, and select the longest PLL stabilization time;
- Step 5: Set the system control register PLL enable bit `SYSCTRL_CR1.PLEN` to 1 to enable the PLL phase-locked loop circuit;

Caution:

The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

- Step 6: According to the PLL output clock frequency, configure the `FLASH_CR2.WAIT` read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 7: Cyclic query and wait for the phase-locked loop control register `SYSCTRL_PLL.STABLE` stable flag to become 1, that is, wait for the PLL to output a stable clock;
- Step 8: Set the system control register `SYSCTRL_CR0.SYSCLK` to 2 to switch the SysClk clock source to the PLL clock.

Caution:

- 1. The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written*
- 2. It is forbidden to change the value of the high frequency clock control register `SYSCTRL_HSI` during the clock source switching process.*

The operation flow of switching from PLL to HSI is as follows:

In this example, since the input reference clock of the phase-locked loop is HSI, the HSI clock is already in a stable state, so there is no need to enable the `HSIOSC` first and wait for the `HSIOSC` and HSI clocks to be stable, and can switch directly. If the input reference clock of the PLL is HSE, you need to increase the setting of the `HSIOSC` parameters, enable the `HSIOSC`, and then wait for the stabilization of the `HSIOSC` and HSI clocks.

- Step 1: Set `SYSCTRL_CR0.SYSCLK` to 0, and switch the SysClk clock source to HSI;

Caution:

The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

- Step 2: According to the frequency of the HSI clock, configure the `FLASH_CR2.WAIT` read wait period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 3: Set the system control register `SYSCTRL_CR1.PLEN` to 0 to turn off the PLL clock.

Caution:

- 1. The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.*
- 2. It is forbidden to change the value of the high frequency clock control register `SYSCTRL_HSI` during the clock source switching process.*



4.5.8 Example of switching between PLL and HSE, the input clock source of PLL is HSE

The operation flow of switching from HSE to PLL is as follows:

- Step 1: Set the phase-locked loop control register `SYSCTRL_PLL.SOURCE` to 0, and select the HSE clock as the PLL input clock source;
- Step 2: According to the output clock frequency of the HSE, configure the PLL input frequency range through the phase-locked loop control register `SYSCTRL_PLL.FREQIN`;
- Step 3: According to the required output clock frequency of the PLL, configure the phase-locked loop frequency multiplication factor and output frequency range through the phase-locked loop control registers `SYSCTRL_PLL.MUL` and `SYSCTRL_PLL.FREQOUT` respectively;
- Step 4: Set the phase-locked loop stabilization period `SYSCTRL_PLL.WAITCYCLE` to 7, and select the longest PLL stabilization time;
- Step 5: Set the system control register `SYSCTRL_CR1.PLEN` to 1 to enable the PLL phase-locked loop circuit;

Caution:

The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

- Step 6: Cyclic query and wait for the phase-locked loop control register `SYSCTRL_PLL.STABLE` stable flag to become 1, that is, wait for the PLL to output a stable clock;
- Step 7: According to the output clock frequency of the PLL, configure the `FLASH_CR2.WAIT` read wait period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 8: Set the system control register `SYSCTRL_CR0.SYSCLK` to 2 to switch the SysClk clock source to the PLL clock.

Caution:

The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

The operation flow of switching from PLL to HSE is as follows:

In this example, since the input reference clock of the phase-locked loop is HSE, the HSE clock is already in a stable state, so there is no need to enable the HSE first and wait for the HSE to be stable, and it can be switched directly. If the input reference clock of the PLL is HSI, you need to increase the setting of the HSE parameters, enable the HSE, and then wait for the HSE clock stabilization process.

- Step 1: Set the system control register `SYSCTRL_CR0.SYSCLK` to 1, and switch the SysClk clock source to HSE;

Caution:

The `SYSCTRL_CR0` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.

- Step 2: According to the output clock frequency of the HSE, configure the `FLASH_CR2.WAIT` read waiting period parameter according to the requirements of the chapter [7 FLASH Memory](#);
- Step 3: Set the system control register `SYSCTRL_CR1.PLEN` to 0 to turn off the PLL clock.

Caution:

The `SYSCTRL_CR1` register has the KEY protection feature. The upper 16-bit data of the written data must be 0x5A5A, otherwise it cannot be written.



4.6 List of registers

SYSCTRL base address: SYSCTRL_BASE = 0x4001 0000

Table 4-14 List of SYSCTRL registers

Register name	Register address	Register description
SYSCTRL_CR0	SYSCTRL_BASE + 0x00	System Control Register 0
SYSCTRL_CR1	SYSCTRL_BASE + 0x04	System Control Register 1
SYSCTRL_CR2	SYSCTRL_BASE + 0x08	System Control Register 2
SYSCTRL_IER	SYSCTRL_BASE + 0x0C	System Interrupt Enable Control Register
SYSCTRL_ISR	SYSCTRL_BASE + 0x10	System Interrupt Flag Register
SYSCTRL_ICR	SYSCTRL_BASE + 0x14	System Interrupt Flag Clear Register
SYSCTRL_HSI	SYSCTRL_BASE + 0x18	Internal high frequency clock control register
SYSCTRL_HSE	SYSCTRL_BASE + 0x1C	External high frequency crystal control register
SYSCTRL_LSI	SYSCTRL_BASE + 0x20	Internal low frequency clock control register
SYSCTRL_LSE	SYSCTRL_BASE + 0x24	External low frequency crystal control register
SYSCTRL_PLL	SYSCTRL_BASE + 0x28	Internal phase-locked loop control register
SYSCTRL_DEBUG	SYSCTRL_BASE + 0x2C	Debug Status Timer Control Register
SYSCTRL_AHBEN	SYSCTRL_BASE + 0x30	AHB Peripheral Clock Enable Control Register
SYSCTRL_APBEN2	SYSCTRL_BASE + 0x34	APB Peripheral Clock Enable Control Register 2
SYSCTRL_APBEN1	SYSCTRL_BASE + 0x38	APB Peripheral Clock Enable Control Register 1
SYSCTRL_AHBRST	SYSCTRL_BASE + 0x40	AHB Peripheral Reset Control Register
SYSCTRL_APBRST2	SYSCTRL_BASE + 0x44	APB Peripheral Reset Control Register 2
SYSCTRL_APBRST1	SYSCTRL_BASE + 0x48	APB Peripheral Reset Control Register 1
SYSCTRL_RESETFLAG	SYSCTRL_BASE + 0x4C	System Reset Flag Register
SYSCTRL_GTIM1CAP	SYSCTRL_BASE + 0x50	General-Purpose Timer 1 Input Capture Source Configuration Register
SYSCTRL_GTIM2CAP	SYSCTRL_BASE + 0x54	General-Purpose Timer 2 Input Capture Source Configuration Register
SYSCTRL_GTIM3CAP	SYSCTRL_BASE + 0x58	General-Purpose Timer 3 Input Capture Source Configuration Register
SYSCTRL_GTIM4CAP	SYSCTRL_BASE + 0x5C	General-Purpose Timer 4 Input Capture Source Configuration Register
SYSCTRL_ATIMETR	SYSCTRL_BASE + 0x60	Advanced Timer ETR Source Configuration Register
SYSCTRL_GTIMETR	SYSCTRL_BASE + 0x64	General Purpose Timer ETR Source Configuration Register
SYSCTRL_TIMITR	SYSCTRL_BASE + 0x6C	Timer ITR Source Configuration Register
SYSCTRL_MCO	SYSCTRL_BASE + 0x70	System Clock Output Control Register



4.7 Register description

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

4.7.1 SYSCTRL_CR0 System Control Register 0

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:8	RFU	-	Reserved bits, please keep the default value
7:5	HCLKPRS	RW	Configure the clock source of HCLK 000: Set the clock source of HCLK to SysClk 001: Set the clock source of HCLK to SysClk / 2 010: Set the clock source of HCLK to SysClk / 4 011: Set the clock source of HCLK to SysClk / 8 100: Set the clock source of HCLK to SysClk / 16 101: Set the clock source of HCLK to SysClk / 32 110: Set the clock source of HCLK to SysClk / 64 111: Set the clock source of HCLK to SysClk / 128
4:3	PCLKPRS	RW	Configure the clock source of PCLK 00: Set the clock source of PCLK to HCLK 01: Set the clock source of PCLK to HCLK / 2 10: Set the clock source of PCLK to HCLK / 4 11: Set the clock source of PCLK to HCLK / 8
2:0	SYSCLK	RW	Configure the clock source of SysClk 000: Set the clock source of SysClk to HSI 001: Set the clock source of SysClk to HSE 010: Set the clock source of SysClk to PLL 011: Set the clock source of SysClk to LSI 100: Set the clock source of SysClk to LSE



4.7.2 SYSCTRL_CR1 System Control Register 1

Address offset: 0x04 Reset value: 0x0000 0001

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:9	RFU	-	Reserved bits, please keep the default value
8	CLKCCS	RW	Configure the crystal oscillator for safe operation in the event of a failure in operation 0: No action 1: Automatically switch the clock source of SysClk to HSI
7	HSECCS	RW	High Frequency Crystal Oscillator Clock Detector Enable Configuration 0: Disable HSE Clock Detector 1: Enable HSE Clock Detector Caution 1: During operation, if the number of clocks output by the HSE within the duration of each HSE. DETCNT LSI clock is less than 0x20000, it is determined that the HSE is invalid during operation. Caution 2: During startup, if the conditions specified by HSE.WAITCYCLE are not met, it is determined that the HSE startup fails.
6	LSECCS	RW	Low Frequency Crystal Oscillator Clock Monitor Enable Configuration 0: Disable LSE Clock Monitor 1: Enable LSE Clock Monitor Caution 1: During operation, if the number of clocks output by the LSE is less than 128 within the duration of every 256 LSI clocks (about 7.8ms), it is determined that the LSE fails during operation. Caution 2: During startup, if the conditions specified by LSE.WAITCYCLE are not met, it is determined that the LSE has failed to start vibrating.
5	LSELOCK	RW	External low-speed clock LSE lock control 0: LSEEN can be set and cleared 1: LSEEN only settable
4	LSEEN	RW	External low-speed clock LSE enable control 0: Disable 1: Enable Caution 1: When the system enters DeepSleep, this low-speed clock will not automatically shut down. Caution 2: Only a power-on reset can reset this control bit.



Bit field	Name	Permission	Function description
3	LSIEN	RW	Internal low-speed clock LSI enable control 0: Disable 1: Enable Caution: When the system enters DeepSleep, this low-speed clock will not automatically shut down.
2	PLLEN	RW	Internal high-speed clock PLL enable control 0: Disable 1: Enable Caution: When the system enters DeepSleep, this high-speed clock will be automatically turned off.
1	HSEEN	RW	External high-speed clock HSE enable control 0: Disable 1: Enable Caution: When the system enters DeepSleep, this high-speed clock will be automatically turned off.
0	HSIEN	RW	Internal high-speed clock HSIOSC enable control 0: Disable 1: Enable Caution: When the system enters DeepSleep, this high-speed clock will be automatically turned off.



4.7.3 SYSCTRL_CR2 SYSCTRL_CR2 System Control Register 2

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:7	RFU	-	Reserved bits, please keep the default value
6:4	FLASHWAIT	RW	FLASH instruction fetches cycle configuration 000: 1 HCLK cycle for HCLK≤24MHz 001: 2 HCLK cycle for 24MHz<HCLK≤48MHz 010: 3 HCLK cycle for 48MHz<HCLK≤72MHz Caution: This control bit has the same function as FLASH_CR2[2:0].
3	WAKEUPCLK	RW	When DeepSleep wakes up, the source configuration of the system clock 0: Keep the original system clock source 1: Switch the system clock source to HSI 8MHz, keep the original system clock source enabled
2	LOCKUP	RW	Cortex-M0+ LockUp Functional configuration 0: Disable 1: Enable Caution: When this function is enabled, the CPU will reset the MCU when it reads an invalid instruction.
1	SWDIO	RW	SWD Port function configuration 0: PA14, PA13 are used as SWD ports, GPIO function is not available 1: PA14, PA13 are used as GPIO ports, SWD function is not available
0	RFU	-	Reserved bits, please keep the default value



4.7.4 SYSCTRL_HSI Internal high frequency clock control register

Address offset: 0x18 Reset value: 0x---- ----

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	STABLE	RO	HSIOSC Clock Stable Status Bits 0: HSIOSC clock has not stabilized 1: HSIOSC clock has stabilized
14:11	DIV	RW	HSI clock and HSIOSC clock division factor configuration 0101: HSI = HSIOSC / 6 (Default) 0110: HSI = HSIOSC / 1 1000: HSI = HSIOSC / 2 1001: HSI = HSIOSC / 4 1011: HSI = HSIOSC / 8 1100: HSI = HSIOSC / 10 1101: HSI = HSIOSC / 12 1110: HSI = HSIOSC / 14 1111: HSI = HSIOSC / 16
10:0	TRIM	RW	Clock frequency adjustment, changing the value of this register bit can adjust the oscillation frequency of the HSIOSC. Every time the TRIM value increases by 1, the oscillation frequency of the HSIOSC increases by about 0.2%, and the total adjustment range is 32 ~ 48MHz. The calibration value of 48MHz has been saved in FLASH, and the accurate frequency can be obtained by reading the calibration value in FLASH and writing it into SYSCTRL_HSI.TRIM. 48.00M Calibration value address: : 0x0010 0A00 – 0x0010 0A01



4.7.5 SYSCTRL_LSI Internal low frequency clock control register

Address offset: 0x20 Reset value: 0x---- ----

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	STABLE	RO	LSI Clock Stable Status Bit 0: LSI clock has not stabilized 1: LSI clock has stabilized
14:12	RFU	-	Reserved bits, please keep the default value
11:10	WAITCYCLE	RW	Internal low-speed clock LSI stabilization time selection 00: 6 cycles 01: 18 cycles 10: 66 cycles 11: 258 cycles
9:0	TRIM	RW	Internal low-speed clock frequency adjustment, 1 set of frequency calibration values are saved in FLASH. Read the calibration value in FLASH and write it to SYSCTRL_LSI.TRIM to get the exact frequency. 32.8K Calibration value address: 0x0010 0A02 - 0x0010 0A03



4.7.6 SYSCTRL_HSE External high frequency crystal control register

Address offset: 0x1C Reset value: 0x0007 FF22

Bit field	Name	Permission	Function description
31:20	RFU	-	Reserved bits, please keep the default value
19	STABLE	RO	HSE Clock Stable Status Bits 0: HSE clock has not stabilized 1: HSE clock has stabilized
18:8	DETCNT	RW	HSE operation failure detection cycle configuration Considering the clock error, the value of DETCNT should generally be set to $8000 / f_{HSE}$ Example: HSE is 4MHz, then DETCNT should be configured as 2000 Caution: DETCNT must be greater than 0.
7	FLT	RW	External high-speed clock HSE filter control 0: Disable HSE filtering 1: Enable HSE filter function, HSE frequency should not be greater than 8MHz Caution: Filters should only be used in high-interference scenarios.
6	MODE	RW	External high-speed clock HSE working mode configuration 0: HSE works in crystal mode, and its output clock is generated by crystal and internal circuit oscillation 1: HSE works in input mode, and its output clock comes from OSC_IN pin
5:4	WAITCYCLE	RW	Selection of the number of clock cycles for HSE stability detection and start-up failure detection 00: Waiting for 8192 HSE clock signals 01: Waiting for 32768 HSE clock signals 10: Waiting for 131072 HSE clock signals 11: Waiting for 262144 HSE clock signals Caution: When HSECCS is enabled, the start-up failure detection circuit will detect the number of HSE clock signals within a limited time, which is 65ms, 65ms, 65ms, 130ms respectively.
3:2	FREQRANGE	RW	External crystal operating frequency selection 00: 4M~8M 01: 8M~16M 10: 16M~24M 11: 24M~32M



Bit field	Name	Permission	Function description
1:0	DRIVER	RW	HSE crystal drive capability selection 00: Weakest drive capability 01: Weak drive ability 10: Default drive capability (recommended value) 11: The strongest driving ability Caution: The appropriate drive capability needs to be selected based on the crystal characteristics, load capacitance, and board parasitics. The stronger the driving ability, the greater the power consumption, and the weaker the driving ability, the smaller the power consumption.



4.7.7 SYSCTRL_LSE External low frequency crystal control register

Address offset: 0x24 Reset value: 0x0000 002B

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	STABLE	RO	LSE Clock Stable Status Bit 0: LSE clock has not stabilized 1: LSE clock has stabilized
14:7	RFU	-	Reserved bits, please keep the default value
6	MODE	RW	External low-speed clock LSE working mode configuration 0: LSE works in crystal mode, and its output clock is generated by crystal and internal circuit oscillation 1: LSE works in input mode, and its output clock comes from OSC32_IN pin
5:4	WAITCYCLE	RW	Selection of the number of clock cycles for LSE stability detection and start-up failure detection 00: Waiting for 256 LSE clock signals 01: Waiting for 1024 LSE clock signals 10: Waiting for 4096 LSE clock signals 11: Waiting for 16384 LSE clock signals Caution: When LSECCS is enabled, the start-up failure detection circuit will detect the number of LSE clock signals within a limited time. The four-stage limited time is 1s, 1s, 1s, and 2s respectively.
3:2	AMP	RW	LSE crystal oscillation amplitude configuration 00: Minimum amplitude 01: Small amplitude 10: Normal amplitude (recommended value) 11: Larger amplitude
1:0	DRIVER	RW	LSE crystal drive capability configuration 00: Minimum drive capacity 01: Less drive capacity 10: Normal drive capability 11: Strong driving ability (recommended value) Caution: The appropriate drive capability needs to be selected based on the crystal characteristics, load capacitance, and board parasitics. The stronger the driving ability, the greater the power consumption, and the weaker the driving ability, the smaller the power consumption.

Caution:*Only a power-on reset can reset this register.*

4.7.8 SYSCTRL_PLL Internal phase-locked loop control register

Address offset: 0x28 Reset value: 0x0005 3483

Bit field	Name	Permission	Function description
31:20	RFU	-	Reserved bits, please keep the default value
19:16	RFU	RW	Debug control bits, please keep the default value
15	STABLE	RO	PLL Clock Stability Status Bits 0: PLL clock has not stabilized 1: PLL clock has stabilized
14:12	WAITCYCLE	RW	PLL Settling time selection 000: 128 PLL clock cycles 001: 256 PLL clock cycles 010: 512 PLL clock cycles 011: 1024 PLL clock cycles 100: 2048 PLL clock cycles 101: 4096 PLL clock cycles 110: 8192 PLL clock cycles 111: 16384 PLL clock cycles
11:9	FREQOUT	RW	PLL Output Clock Frequency Range Configuration 000: 12M ~ 18M 001: 18M ~ 24M 010: 24M ~ 36M 011: 36M ~ 48M 1xx: 48M ~ 72M
8:4	MUL	RW	PLL multiplier configuration PLL output frequency = Input frequency × MUL MUL value is 0x02 ~ 0x0C
3:2	FREQIN	RW	PLL Input Clock Frequency Range Configuration 00: 4M ~ 6M 01: 6M ~ 12M 10: 12M ~ 20M 11: 20M ~ 24M
1:0	SOURCE	RW	Input clock source selection 00: Clock generated by HSE crystal 01: HSE clock input from pin 11: HSI clock (clock divided by HSIOSC)



4.7.9 SYSCTRL_IER System Interrupt Enable Control Register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:9	RFU	-	Reserved bits, please keep the default value
8	HSEFAULT	RW	HSE Fail-Run Interrupt Enable Control 0: Disable HSE run-fail interrupt 1: Enable HSE run-fail interrupt
7	LSEFAULT	RW	LSE Fail-Run Interrupt Enable Control 0: Disable LSE run-fail interrupt 1: Enable LSE run-fail interrupt
6	HSEFAIL	RW	HSE Start-up failure interrupt enable control 0: Disable HSE start failure interrupt 1: Enable HSE start failure interrupt
5	LSEFAIL	RW	LSE Start-up failure interrupt enable control 0: Disable LSE start failure interrupt 1: Enable LSE start failure interrupt
4	LSERDY	RW	LSE Stable Interrupt Enable Control 0: Disable LSE stable interrupt 1: Enable LSE stable interrupt
3	LSIRDY	RW	LSI Stable Interrupt Enable Control 0: Disable LSI stable interrupt 1: Enable LSI stable interrupt
2	PLLRDY	RW	PLL Stable Interrupt Enable Control 0: Disable PLL stable interrupt 1: Enable PLL stable interrupt
1	HSERDY	RW	HSE Stable Interrupt Enable Control 0: Disable HSE stable interrupt 1: Enable HSE stable interrupt
0	HSIRDY	RW	HSIOSC Stable Interrupt Enable Control 0: Disable HSIOSC stable interrupt 1: Enable HSIOSC stable interrupt

Caution 1:

The FAULT interrupt (vector number 47) is executed when the HSEFAULT interrupt or LSEFAULT interrupt is generated, and the RCC global interrupt (vector number 20) is executed when the other interrupt is generated.



4.7.10 SYSCTRL_ISR System Interrupt Flag Register

Address offset: 0x10 Reset value: 0x0000 0801

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	LSESTABLE	RO	LSE clock stable status bit; hardware set to clear 0: LSE clock has not stabilized 1: LSE clock has stabilized
14	LSISTABLE	RO	LSI clock stable status bit; hardware set to clear 0: LSI clock has not stabilized 1: LSI clock has stabilized
13	PLLSTABLE	RO	PLL clock stable status bit; hardware set to clear 0: PLL clock has not stabilized 1: PLL clock has stabilized
12	HSESTABLE	RO	HSE clock stable status bit; hardware set to clear 0: HSE clock has not stabilized 1: HSE clock has stabilized
11	HSISTABLE	RO	HSIOSC clock stable status bit; hardware set to clear 0: HSIOSC clock has not stabilized 1: HSIOSC clock has stabilized
10:9	RFU	-	Reserved bits, please keep the default value
8	HSEFAULT	RO	HSE Clock run failure flag 0: HSE clock is running fine 1: Oscillation stopped during HSE clock operation
7	LSEFAULT	RO	LSE Clock run failure flag 0: LSE clock is running fine 1: Oscillation stopped during LSE clock operation
6	HSEFAIL	RO	HSE Clock start-up failure flag 0: HSE Clock starts up successfully 1: HSE clock start-up failed
5	LSEFAIL	RO	LSE Clock start-up failure flag 0: LSE Clock starts up successfully 1: LSE clock start-up failed
4	LSERDY	RO	LSE Clock Stable Flag 0: LSE clock has not stabilized 1: LSE clock has stabilized
3	LSIRDY	RO	LSI Clock Stable Flag 0: LSI clock has not stabilized 1: LSI clock has stabilized
2	PLLRDY	RO	PLL Clock Stable Flag 0: PLL clock has not stabilized 1: PLLclock has stabilized



Bit field	Name	Permission	Function description
1	HSERDY	RO	HSE Clock Stable Flag 0: HSE clock has not stabilized 1: HSE clock has stabilized
0	HSIRDY	RO	HSIOSC Clock Stable Flag 0: HSIOSC clock has not stabilized 1: HSIOSC clock has stabilized

4.7.11 SYSCTRL_ICR System Interrupt Flag Clear Register

Address offset: 0x14 Reset value: 0x0000 01FF

Bit field	Name	Permission	Function description
31:9	RFU	-	Reserved bits, please keep the default value
8	HSEFAULT	R1W0	HSE Clock operation failure flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
7	LSEFAULT	R1W0	LSE Clock operation failure flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
6	HSEFAIL	R1W0	HSE Clock start-up failure flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
5	LSEFAIL	R1W0	LSE Clock start-up failure flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
4	LSERDY	R1W0	LSE Clock stable flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
3	LSIRDY	R1W0	LSI Clock stable flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
2	PLLRDY	R1W0	PLL Clock stable flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
1	HSERDY	R1W0	HSE Clock stable flag clear control W0: Clear the corresponding flag in the ISR register W1: No function
0	HSIRDY	R1W0	HSIOSC Clock stable flag clear control W0: Clear the corresponding flag in the ISR register W1: No function



4.7.12 SYSCTRL_AHBEN AHB Peripheral Clock Enable Control Register

Address offset: 0x30 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11	AES	RW	AES module configuration clock and working clock enable control 0: Disable 1: Enable
10	TRNG	RW	TRNG module configuration clock and working clock enable control 0: Disable 1: Enable
9	GPIOF	RW	GPIOF Port configuration clock and working clock enable control 0: Disable 1: Enable
8	GPIOE	RW	GPIOE Port configuration clock and working clock enable control 0: Disable 1: Enable
7	GIPOD	RW	GIPOD Port configuration clock and working clock enable control 0: Disable 1: Enable
6	GPIOC	RW	GPIOC Port configuration clock and working clock enable control 0: Disable 1: Enable
5	GPIOB	RW	GPIOB Port configuration clock and working clock enable control 0: Disable 1: Enable
4	GPIOA	RW	GPIOA Port configuration clock and working clock enable control 0: Disable 1: Enable
3	RFU	-	Reserved bits, please keep the default value
2	CRC	RW	CRC Module configuration clock and working clock enable control 0: Disable 1: Enable



Bit field	Name	Permission	Function description
1	FLASH	RW	FLASH Module configuration clock enable control 0: Disable 1: Enable
0	DMA	RW	DMA Module configuration clock and working clock enable control 0: Disable 1: Enable

4.7.13 SYSCTRL_APBEN1 APB Peripheral Clock Enable Control Register 1

Address offset: 0x38 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	LPTIM	RW	LPTIM module configuration clock and working clock enable control 0: Disable 1: Enable
14	RFU	-	Reserved bits, please keep the default value
13	LCD	RW	LCD module configuration clock and working clock enable control 0: Disable 1: Enable
12	I2C2	RW	I2C2 Module configuration clock and working clock enable control 0: Disable 1: Enable
11	I2C1	RW	I2C1 Module configuration clock and working clock enable control 0: Disable 1: Enable
10	UART5	RW	UART5 Module configuration clock enable control 0: Disable 1: Enable
9	UART4	RW	UART4 Module configuration clock enable control 0: Disable 1: Enable
8	UART3	RW	UART3 Module configuration clock enable control 0: Disable 1: Enable



Bit field	Name	Permission	Function description
7	UART2	RW	UART2 Module configuration clock enable control 0: Disable 1: Enable
6	SPI2	RW	SPI2 Module configuration clock and working clock enable control 0: Disable 1: Enable
5	IWDT	RW	IWDT Module configuration clock enable control 0: Disable 1: Enable
4	WWDT	RW	WWDT Module configuration clock and working clock enable control 0: Disable 1: Enable
3	RTC	RW	RTC Module configuration clock enable control 0: Disable 1: Enable
2	GTIM2	RW	GTIM2 Module configuration clock and working clock enable control 0: Disable 1: Enable
1	GTIM1	RW	GTIM1 Module configuration clock and working clock enable control 0: Disable 1: Enable
0	RFU	-	Reserved bits, please keep the default value



4.7.14 SYSCTRL_APBEN2 APB Peripheral Clock Enable Control Register 2

Address offset: 0x34 Reset value: 0x0000 8000

Bit field	Name	Permission	Function description
31:14	RFU	-	Reserved bits, please keep the default value
13	AUTOTRIM	RW	AUTOTRIM Module configuration clock enable control 0: Disable 1: Enable
12	BTIM	RW	BTIM1-3 Module configuration clock and working clock enable control 0: Disable 1: Enable
11	GTIM4	RW	GTIM4 Module configuration clock and working clock enable control 0: Disable 1: Enable
10	GTIM3	RW	GTIM3 Module configuration clock and working clock enable control 0: Disable 1: Enable
9	UART1	RW	UART1 Module configuration clock enable control 0: Disable 1: Enable
8	SPI1	RW	SPI1 Module configuration clock and working clock enable control 0: Disable 1: Enable
7	ATIM	RW	ATIM Module configuration clock and working clock enable control 0: Disable 1: Enable
6:5	RFU	-	Reserved bits, please keep the default value
4	VC	RW	VC Module configuration clock enable control 0: Disable 1: Enable
3	RFU	RW	Reserved bits, please keep the default value
2	ADC	RW	ADC Module configuration clock and working clock enable control 0: Disable 1: Enable
1	UART6	RW	UART6 module configuration clock enable control 0: Disable 1: Enable
0	RFU	-	Reserved bits, please keep the default value



4.7.15 SYSCTRL_AHBRST AHB Peripheral Reset Control Register

Address offset: 0x40 Reset value: 0x0000 0277

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11	AES	RW	AES module reset control 0: Module is in reset state 1: Module works fine
10	TRNG	RW	TRNG module reset control 0: Module is in reset state 1: Module works fine
9	GPIOF	RW	GPIOF Module reset control 0: Module is in reset state 1: Module works fine
8	GPIOE	RW	GPIOE Module reset control 0: Module is in reset state 1: Module works fine
7	GPIOD	RW	GPIOD Module reset control 0: Module is in reset state 1: Module works fine
6	GPIOC	RW	GPIOC Module reset control 0: Module is in reset state 1: Module works fine
5	GPIOB	RW	GPIOB Module reset control 0: Module is in reset state 1: Module works fine
4	GPIOA	RW	GPIOA Module reset control 0: Module is in reset state 1: Module works fine
3	RFU	-	Reserved bits, please keep the default value
2	CRC	RW	CRC Module reset control 0: Module is in reset state 1: Module works fine
1	FLASH	RW	FLASH Module reset control 0: Module is in reset state 1: Module works fine
0	DMA	RW	DMA Module reset control 0: Module is in reset state 1: Module works fine



4.7.16 SYSCTRL_APBIRST1 APB Peripheral Reset Control Register 1

Address offset: 0x48 Reset value: 0x0000 19FF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	LPTIM	RW	LPTIM module reset control 0: Module is in reset state 1: Module works fine
14	RFU	-	Reserved bits, please keep the default value
13	LCD	RW	LCD Module Reset Control 0: Module is in reset state 1: Module works fine
12	I2C2	RW	I2C2 Module reset control 0: Module is in reset state 1: Module works fine
11	I2C1	RW	I2C1 Module reset control 0: Module is in reset state 1: Module works fine
10	UART5	RW	UART5 Module reset control 0: Module is in reset state 1: Module works fine
9	UART4	RW	UART4 Module reset control 0: Module is in reset state 1: Module works fine
8	UART3	RW	UART3 Module reset control 0: Module is in reset state 1: Module works fine
7	UART2	RW	UART2 Module reset control 0: Module is in reset state 1: Module works fine
6	SPI2	RW	SPI2 Module reset control 0: Module is in reset state 1: Module works fine
5	IWDT	RW	IWDT Module reset control 0: Module is in reset state 1: Module works fine
4	WWDT	RW	WWDT Module reset control 0: Module is in reset state 1: Module works fine
3	RTC	RW	RTC Module reset control 0: Module is in reset state 1: Module works fine



Bit field	Name	Permission	Function description
2	GTIM2	RW	GTIM2 Module reset control 0: Module is in reset state 1: Module works fine
1	GTIM1	RW	GTIM1 Module reset control 0: Module is in reset state 1: Module works fine
0	RFU	-	Reserved bits, please keep the default value



4.7.17 SYSCTRL_APBRS2 APB Peripheral Reset Control Register 2

Address offset: 0x44 Reset value: 0x0000 BF9D

Bit field	Name	Permission	Function description
31:14	RFU	-	Reserved bits, please keep the default value
13	AUTOTRIM	RW	AUTOTRIM Module reset control 0: Module is in reset state 1: Module works fine
12	BTIM	RW	BTIM1-3 Module reset control 0: Module is in reset state 1: Module works fine
11	GTIM4	RW	GTIM4 Module reset control 0: Module is in reset state 1: Module works fine
10	GTIM3	RW	GTIM3 Module reset control 0: Module is in reset state 1: Module works fine
9	UART1	RW	UART1 Module reset control 0: Module is in reset state 1: Module works fine
8	SPI1	RW	SPI1 Module reset control 0: Module is in reset state 1: Module works fine
7	ATIM	RW	ATIM Module reset control 0: Module is in reset state 1: Module works fine
6:5	RFU	-	Reserved bits, please keep the default value
4	VC	RW	VC Module reset control 0: Module is in reset state 1: Module works fine
3	RFU	-	Reserved bits, please keep the default value
2	ADC	RW	ADC Module reset control 0: Module is in reset state 1: Module works fine
1	UART6	RW	UART1 Module reset control 0: Module is in reset state 1: Module works fine
0	RFU	-	Reserved bits, please keep the default value



4.7.18 SYSCTRL_RESETFLAG System Reset Flag Register

Address offset: 0x4C Reset value: 0x---- ----

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	SYSRESETREQ	RW0	Cortex-M0+ CPU SYSRESETREQ soft reset flag 0: No CPU SYSRESETREQ soft reset occurred 1: CPU SYSRESETREQ soft reset has occurred Write 0 to clear, write 1 to invalid
8	LOCKUP	RW0	Cortex-M0+ CPU Lockup reset flag 0: No Lockup reset occurred 1: Lockup reset has occurred Write 0 to clear, write 1 to invalid
7	RFU	-	Reserved bits, please keep the default value
6	RSTB	RW0	NRST pin reset flag 0: No Pin reset occurred 1: Pin reset has occurred Write 0 to clear, write 1 to invalid
5	WWDT	RW0	WWDT reset flag, requires software initialization and clearing 0: No WWDT reset occurred 1: WWDT reset has occurred Write 0 to clear, write 1 to invalid
4	IWDT	RW0	IWDT reset flag 0: No IWDT reset occurred 1: IWDT reset has occurred Write 0 to clear, write 1 to invalid
3	LVD	RW0	LVD reset flag 0: No LVD reset occurred 1: LVD reset has occurred Write 0 to clear, write 1 to invalid
2:1	RFU	-	Reserved bits, please keep the default value
0	POR	RW0	POR/BOR reset flag 0: No POR/BOR reset occurred 1: POR/BOR reset has occurred Write 0 to clear, write 1 to invalid



4.7.19 SYSCTRL_DEBUG Debug Status Timer Control Register

Address offset: 0x2C Reset value: 0x0000 07FF

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11	LPTIM	RW	In the debugging state, LPTIM count function configuration 0: Normal count 1: Pause count
10	WWDT	RW	In the debugging state, WWDT count function configuration 0: Normal count 1: Pause count
9	IWDT	RW	In the debugging state, IWDT count function configuration 0: Normal count 1: Pause count
8	RTC	RW	In the debugging state, RTC count function configuration 0: Normal count 1: Pause count
7	RFU	-	Reserved bits, please keep the default value
6	AUTOTRIM	RW	In the debugging state, AUTOTRIM count function configuration 0: Normal count 1: Pause count
5	BTIM123	RW	In the debugging state, BTIM1 / BTIM2 / BTIM3 count function configuration 0: Normal count 1: Pause count
4	GTIM4	RW	In the debugging state, GTIM4 count function configuration 0: Normal count 1: Pause count
3	GTIM3	RW	In the debugging state, GTIM3 count function configuration 0: Normal count 1: Pause count
2	GTIM2	RW	In the debugging state, GTIM2 count function configuration 0: Normal count 1: Pause count
1	GTIM1	RW	In the debugging state, GTIM1 count function configuration 0: Normal count 1: Pause count
0	ATIM	RW	In the debugging state, ATIM count function configuration 0: Normal count 1: Pause count



4.7.20 SYSCTRL_GTIM1CAP General-Purpose Timer 1 Input Capture Source Configuration Register

Address offset: 0x50 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:15	RFU	-	Reserved bits, please keep the default value
14:12	CH4	RW	CH4 input capture source configuration of GTIM1 See GTIM1CAP [10:8] for details
11	RFU	-	Reserved bits, please keep the default value
10:8	CH3	RW	CH3 input capture source configuration of GTIM1 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART6 100: RXD signal of UART5 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD
7	RFU	-	Reserved bits, please keep the default value
6:4	CH2	RW	CH2 input capture source configuration of GTIM1 See GTIM1CAP [2:0] for details
3	RFU	-	Reserved bits, please keep the default value
2:0	CH1	RW	CH1 input capture source configuration of GTIM1 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART3 100: RXD signal of UART4 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD



4.7.21 SYSCTRL_GTIM2CAP General-Purpose Timer 2 Input Capture Source Configuration Register

Address offset: 0x54 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:15	RFU	-	Reserved bits, please keep the default value
14:12	CH4	RW	CH4 input capture source configuration of GTIM2 See GTIM2CAP [10:8]
11	RFU	-	Reserved bits, please keep the default value
10:8	CH3	RW	CH3 input capture source configuration of GTIM2 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART6 100: RXD signal of UART5 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD
7	RFU	-	Reserved bits, please keep the default value
6:4	CH2	RW	CH2 input capture source configuration of GTIM2 See GTIM2CAP [2:0] for details
3	RFU	-	Reserved bits, please keep the default value
2:0	CH1	RW	CH1 input capture source configuration of GTIM1 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART3 100: RXD signal of UART4 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD



4.7.22 SYSCTRL_GTIM3CAP General-Purpose Timer 3 Input Capture Source Configuration Register

Address offset: 0x58 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:15	RFU	-	Reserved bits, please keep the default value
14:12	CH4	RW	CH4 input capture source configuration of GTIM3 See GTIM3CAP [10:8]
11	RFU	-	Reserved bits, please keep the default value
10:8	CH3	RW	CH3 input capture source configuration of GTIM3 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART6 100: RXD signal of UART5 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD
7	RFU	-	Reserved bits, please keep the default value
6:4	CH2	RW	CH2 input capture source configuration of GTIM3 See GTIM3CAP [2:0] for details
3	RFU	-	Reserved bits, please keep the default value
2:0	CH1	RW	CH1 input capture source configuration of GTIM3 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART3 100: RXD signal of UART4 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD



4.7.23 SYSCTRL_GTIM4CAP General-Purpose Timer 4 Input Capture Source Configuration Register

Address offset: 0x5C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:15	RFU	-	Reserved bits, please keep the default value
14:12	CH4	RW	CH4 input capture source configuration of GTIM4 See GTIM4CAP [10:8]
11	RFU	-	Reserved bits, please keep the default value
10:8	CH3	RW	CH3 input capture source configuration of GTIM4 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART6 100: RXD signal of UART5 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD
7	RFU	-	Reserved bits, please keep the default value
6:4	CH2	RW	CH2 input capture source configuration of GTIM4 See GTIM4CAP [2:0] for details
3	RFU	-	Reserved bits, please keep the default value
2:0	CH1	RW	CH1 input capture source configuration of GTIM4 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART3 100: RXD signal of UART4 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: Output signal of LVD



4.7.24 SYSCTRL_ATIMETR Advanced Timer ETR Source Configuration

Address offset: 0x60 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:3	RFU	-	Reserved bits, please keep the default value
2:0	ATIMETR	RW	ETR Source Configuration of ATIM 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART3 100: RXD signal of UART4 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: LVD output signal



4.7.25 SYSCTRL_GTIMETR General Purpose Timer ETR Source Configuration Register

Address offset: 0x64 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:15	RFU	-	Reserved bits, please keep the default value
14:12	GTIM4ETR	RW	ETR source configuration for GTIM4 See GTIMETR [10:8]
11	RFU	-	Reserved bits, please keep the default value
10:8	GTIM3ETR	RW	ETR Source Configuration of GTIM3 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART6 100: RXD signal of UART5 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: LVD output signal
7	RFU	-	Reserved bits, please keep the default value
6:4	GTIM2ETR	RW	ETR source configuration for GTIM2 See GTIMETR [2:0]
3	RFU	-	Reserved bits, please keep the default value
2:0	GTIM1ETR	RW	ETR Source Configuration of GTIM1 000: Configured by GPIOx_AFRH and GPIOx_AFRL 001: RXD signal of UART1 010: RXD signal of UART2 011: RXD signal of UART3 100: RXD signal of UART4 101: Comparison output signal of VC1 110: Comparison output signal of VC2 111: LVD output signal



4.7.26 SYSCTRL_TIMTR Timer ITR Source Configuration Register

Address offset: 0x6C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:24	RFU	-	Reserved bits, please keep the default value
23:21	BTIM3ITR	RW	ITR source configuration for BTIM3 See TIMTR [2:0]
20:18	BTIM2ITR	RW	ITR source configuration for BTIM2 See TIMTR [2:0]
17:15	BTIM1ITR	RW	ITR source configuration for BTIM1 See TIMTR [2:0]
14:12	GTIM4ITR	RW	ITR source configuration for GTIM4 See TIMTR [2:0]
11:9	GTIM3ITR	RW	ITR source configuration for GTIM3 See TIMTR [2:0]
8:6	GTIM2ITR	RW	ITR source configuration for GTIM2 See TIMTR [2:0]
5:3	GTIM1ITR	RW	ITR source configuration for GTIM1 See TIMTR [2:0]
2:0	ATIMTR	RW	ITR source configuration for ATIM 000: The overflow signal of BTIM1 001: The overflow signal of BTIM2 010: The overflow signal of BTIM3 011: The overflow signal of GTIM1 100: The overflow signal of GTIM2 101: The overflow signal of GTIM3 110: The overflow signal of GTIM4 111: Master mode output signal of ATIM

Caution:*The ITR source of the TIM cannot be configured as its own overflow signal.*

4.7.27 SYSCTRL_MCO System Clock Output Control Register

Address offset: 0x70 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6:4	DIV	RW	MCO output frequency division control 000: 1 Frequency Division 001: 2 Frequency Division 010: 8 Frequency Division 011: 64 Frequency Division 100: 128 Frequency Division 101: 256 Frequency Division 110: 512 Frequency Division 111: 1024 Frequency Division
3:0	SOURCE	RW	MCO output signal source configuration 0000: Zero output 0001: HCLK 0010: PCLK 0011: HSIOSC 0100: LSI 0101: HSE 0110: LSE 0111: PLL 1000: RC150K 1001: RC10K



5 Interrupt

5.1 Overview

Nested Vectored Interrupt Controller (NVIC) for the ARM® Cortex®-M0+ core to manage interrupts and exceptions. The NVIC is tightly coupled to the processor core, enabling low-latency exception and interrupt handling.

The processor supports up to 32 interrupt request (IRQ) inputs and supports multiple internal exceptions.

This chapter only introduces the 32 external interrupt requests (IRQ0 ~ IRQ31) of the processor. Please refer to the "ARM® Cortex®-M0+ Technical Reference Manual" and "ARM® v6-M Architecture Reference Manual" for details of the processor's internal exceptions.

5.2 Main features

- 16 inner exceptions
- 32 maskable external interrupts
- 4 programmable priorities
- Low-latency exception and interrupt handling
- Support for interrupt nesting
- Interrupt vector table remapping

5.3 Interrupt priority

The external interrupt can be set to 4 levels of priority, the highest priority is "0", the lowest priority is "3", and the default value is "0".

If a higher priority interrupt occurs while the processor is executing an interrupt handler, the interrupt is preempted. If an interrupt occurs with the same or lower priority as the interrupt being processed, the interrupt will not be preempted, but the state of the new interrupt will change to pending. If multiple pending interrupts have the same priority, the pending interrupt with the smaller interrupt number takes precedence. For example, if both IRQ [0] and IRQ [1] are pending, and both have the same priority, then IRQ [0] is processed first.



5.4 Interrupt vector table

When the ARM® Cortex®-M0+ responds to an interrupt, the processor automatically fetches the start address of the Interrupt Service Routine (ISR) from the interrupt vector table in the memory. The interrupt vector table includes the initial value of the main stack pointer (MSP), the entry address of the service routine for internal exceptions and external interrupts. Each interrupt vector occupies 1 word (4 bytes), and the storage address of the interrupt vector is the vector number multiplied by 4, as shown in the following table:

Table 5-1 Interrupt vector table

Vector number	External interrupt number (IRQ#)	Priority	Interrupt source	Introduction	Address
0	-	-	-	MSP initial value	0x0000 0000
1	-	-3	Reset	Reset vector	0x0000 0004
2	-	-2	NMI	Non-maskable interrupt ²	0x0000 0008
3	-	-1	HardFault	Hardware error exception (fault)	0x0000 000C
4-10	-	-	-	Reserved	0x0000 0010~002B
11	-	Configurable	SVCall	Hypervisors invoked via SWI instructions	0x0000 002C
12-13	-	-	-	Reserved	0x0000 0030~0037
14	-	Configurable	PendSV	Suspendable requests for system services	0x0000 0038
15	-	Configurable	SysTick	System tick timer	0x0000 003C
16	0	Configurable	WDT	Windowed watchdog and independent watchdog interrupts ¹	0x0000 0040
17	1	Configurable	LVD	LVD global interrupt	0x0000 0044
18	2	Configurable	RTC	RTC global interrupt	0x0000 0048
19	3	Configurable	FLASHRAM	FLASH/RAM global interrupt ¹	0x0000 004C
20	4	Configurable	RCC	RCC global interrupt ³	0x0000 0050
21	5	Configurable	GPIOA	GPIOA global interrupt	0x0000 0054
22	6	Configurable	GPIOB	GPIOB global interrupt	0x0000 0058
23	7	Configurable	GPIOC/ GPIOD	GPIOC/GPIOD global interrupt ¹	0x0000 005C
24	8	Configurable	GPIOE/ GPIOF	GPIOE/GPIOF global interrupt ¹	0x0000 0060
25	9	Configurable	DMA1	DMA channel 1 global interrupt	0x0000 0064
26	10	Configurable	DMA23	DMA channel 2, DMA channel 3 global interrupt ¹	0x0000 0068



Vector number	External interrupt number (IRQ#)	Priority	Interrupt source	Introduction	Address
27	11	Configurable	DMA45	DMA channel 4, DMA channel 5 global interrupt ¹	0x0000 006C
28	12	Configurable	ADC	ADC global interrupt	0x0000 0070
29	13	Configurable	ATIM	ATIM global interrupt	0x0000 0074
30	14	Configurable	VC1	VC1 global interrupt	0x0000 0078
31	15	Configurable	VC2	VC2 global interrupt	0x0000 007C
32	16	Configurable	GTIM1	GTIM1 global interrupt	0x0000 0080
33	17	Configurable	GTIM2	GTIM2 global interrupt	0x0000 0084
34	18	Configurable	GTIM3	GTIM3 global interrupt	0x0000 0088
35	19	Configurable	GTIM4	GTIM4 global interrupt	0x0000 008C
36	20	Configurable	BTIM1	BTIM1 global interrupt	0x0000 0090
37	21	Configurable	BTIM2/ LPTIM	BTIM2/LPTIM global interrupt ¹	0x0000 0094
38	22	Configurable	BTIM3	BTIM3 global interrupt	0x0000 0098
39	23	Configurable	I2C1	I2C1 global interrupt	0x0000 009C
40	24	Configurable	I2C2	I2C2 global interrupt	0x0000 00A0
41	25	Configurable	SPI1	SPI1 global interrupt	0x0000 00A4
42	26	Configurable	SPI2	SPI2 global interrupt	0x0000 00A8
43	27	Configurable	UART1/ UART4	UART1/UART4 global interrupt ¹	0x0000 00AC
44	28	Configurable	UART2/ UART5	UART2/UART5 global interrupt ¹	0x0000 00B0
45	29	Configurable	UART3/ UART6	UART3/UART6 global interrupt ¹	0x0000 00B4
46	30	Configurable	AUTOTRIM/ LCD	AUTOTRIM/LCD global interrupt ¹	0x0000 00B8
47	31	Configurable	FAULT	HSE/LSE operation fail interrupt ⁴	0x0000 00BC

Caution 1:

Since the interrupts of some peripherals multiplex an IRQ interrupt source, the user should first check the interrupt flag bit in the interrupt service routine to determine the peripheral that generates the interrupt.



Caution 2:

NMI is not used in CW32L083.

Caution 3:

HSE, LSE clock signal start-up failure and LSI, LSE, HSIOSC, HSE, PLL clock signal stability correspond to RCC global interrupt.

Caution 4:

The failure of the HSE or LSE clock signal during operation corresponds to a FAULT interrupt.



5.5 Interrupt related registers

5.5.1 NVIC interrupt enable and disable enable

The ARM® Cortex-M0+ processor supports up to 32 external interrupt sources, corresponding to the 32 enable bits of the interrupt enable setting register NVIC_ISER and the 32 disable bits of the interrupt enable clear register NVIC_ICER. Setting the enable bit to 1 enables interrupts; Set the disable bit to 1, disable interrupts.

The above NVIC interrupt enable is only for the processor NVIC, whether the interrupt of the peripheral is enabled is also controlled by the interrupt control register of the corresponding peripheral.

5.5.2 NVIC interrupt pending and clear pending

When an interrupt occurs, if the system is processing an interrupt of the same priority or higher, the system will not process the interrupt immediately, but will set the interrupt status to pending and save it in the interrupt pending status register; The pending state will remain valid until the processor enters this interrupt processing, unless the pending state is manually cleared. When the processor begins to enter the interrupt processing, the hardware will automatically clear the corresponding interrupt pending state.

The user can set the status of this interrupt to the pending state by setting the corresponding bit of the interrupt pending setting register NVIC_ISPR. If the system is not processing an interrupt with the same priority or higher priority, the interrupt will be immediately responded and deal with.

The user can set the state of this interrupt to the pending clear state by setting the corresponding bit of the interrupt pending clear register NVIC_ICPR.

5.5.3 NVIC interrupt priority

The interrupt priority control registers NVIC_IPR0~NVIC_IPR7 are used to set the interrupt priority of IRQ0~IRQ31. Each interrupt source uses 8 bits. In CW32L083, only the upper two bits are used, and up to 4 interrupt priorities can be set.

Caution:

The setting of the interrupt priority register of ARM® Cortex-M0+ should be before the interrupt is enabled. The user cannot change the interrupt priority after the interrupt is enabled, which will lead to unpredictable results.



5.5.4 NVIC interrupt mask

In some special occasions, all interrupts need to be disabled, which can be realized by using the interrupt mask register PRIMASK. Only the lowest 1 bit of PRIMASK is valid. If this bit is set to 1, all external interrupts and exceptions except NMI and hardware error exceptions are disabled; after clearing to 0, it is allowed to respond to interrupts and exceptions. This bit defaults to 0 after reset.

ARM® Cortex-M0+ has dedicated ARM instructions for modifying PRIMASK register, CPSIE i and CPSID i, please refer to "ARM® v6-M Architecture Reference Manual" for details.

Assembly instruction example reference:

```
CPSIE i      ; Clear PRIMASK (Enable interrupt)
CPSID i      ; Set up PRIMASK (Disable interrupts)
```

C-language (Calling the CMSIS device driver library) Example reference:

```
void __enable_irq(void);    //Clear PRIMASK
void __disable_irq(void);   //Set up PRIMASK
```

5.5.5 Peripheral interrupt enable

Peripheral modules generally have their own interrupt enable registers. When using interrupts, you must first enable the peripheral interrupt enable, and refer to [Table 5-1 Interrupt vector table](#) to enable the NVIC interrupt for the interrupt source. For the interrupt enable of specific peripherals, please refer to the description of the relevant peripheral modules.



5.6 List of registers

NVIC base address: NVIC_BASE = 0xE000 E000

Table 5-2 List of NVIC registers

Register name	Register address	Register description
NVIC_ISER	NVIC_BASE + 0x100	IRQ0~IRQ31 Interrupt Enable Setting Register
NVIC_ICER	NVIC_BASE + 0x180	IRQ0~IRQ31 Interrupt Enable Clear Register
NVIC_ISPR	NVIC_BASE + 0x200	IRQ0~IRQ31 Interrupt Pending Setup Register
NVIC_ICPR	NVIC_BASE + 0x280	IRQ0~IRQ31 Interrupt Pending Clear Register
NVIC_IPR0	NVIC_BASE + 0x400	IRQ0~IRQ3 Interrupt Priority Control Register 0
NVIC_IPR1	NVIC_BASE + 0x404	IRQ4~IRQ7 Interrupt Priority Control Register 1
NVIC_IPR2	NVIC_BASE + 0x408	IRQ8~IRQ11 Interrupt Priority Control Register 2
NVIC_IPR3	NVIC_BASE + 0x40C	IRQ12~IRQ15 Interrupt Priority Control Register 3
NVIC_IPR4	NVIC_BASE + 0x410	IRQ16~IRQ19 Interrupt Priority Control Register 4
NVIC_IPR5	NVIC_BASE + 0x414	IRQ20~IRQ23 Interrupt Priority Control Register 5
NVIC_IPR6	NVIC_BASE + 0x418	IRQ24~IRQ27 Interrupt Priority Control Register 6
NVIC_IPR7	NVIC_BASE + 0x41C	IRQ28~IRQ31 Interrupt Priority Control Register 7



5.7 Register description

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

5.7.1 NVIC_ISER Interrupt Enable Setting Register

Address offset: 0x100 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:0	SETIRQ	RW	Set to enable external interrupt IRQ0~IRQ31; write "1" to set, write "0" is invalid. [0]: IRQ0 [1]: IRQ1 [2]: IRQ2 [31]: IRQ31 The read value indicates the current interrupt enable state

5.7.2 NVIC_ICER Interrupt Enable Clear Register

Address offset: 0x180 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:0	CLRIRQ	RW	Set to disable external interrupt IRQ0~IRQ31; write "1" to set, write "0" is invalid. [0]: IRQ0 [1]: IRQ1 [2]: IRQ2 [31]: IRQ31 The read value indicates the current interrupt enable state

5.7.3 NVIC_ISPR Interrupt Pending Setup Register

Address offset: 0x200 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:0	SETPEND	RW	Set the pending state of external interrupt IRQ0~IRQ31; write "1" to set, write "0" is invalid. [0]: IRQ0 [1]: IRQ1 [2]: IRQ2 [31]: IRQ31 The read value indicates the current interrupt pending state



5.7.4 NVIC_ICPR Interrupt Pending Clear Register

Address offset: 0x280 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:0	CLRPEND	RW	Clear the pending state of external interrupt IRQ0~IRQ31; write "1" to clear, write "0" is invalid. [0]: IRQ0 [1]: IRQ1 [2]: IRQ2 [31]: IRQ31 The read value indicates the current interrupt pending state

5.7.5 NVIC_IPR0 Interrupt Priority Control Register 0

Address offset: 0x400 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ3	RW	The priority of interrupt IRQ3, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ2	RW	The priority of interrupt IRQ2, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ1	RW	The priority of interrupt IRQ1, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ0	RW	The priority of interrupt IRQ0, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value



5.7.6 NVIC_IPR1 Interrupt Priority Control Register 1

Address offset: 0x404 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ7	RW	The priority of interrupt IRQ7, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ6	RW	The priority of interrupt IRQ6, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ5	RW	The priority of interrupt IRQ5, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ4	RW	The priority of interrupt IRQ4, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value

5.7.7 NVIC_IPR2 Interrupt Priority Control Register 2

Address offset: 0x408 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ11	RW	The priority of interrupt IRQ11, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ10	RW	The priority of interrupt IRQ10, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ9	RW	The priority of interrupt IRQ9, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ8	RW	The priority of interrupt IRQ8, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value



5.7.8 NVIC_IPR3 Interrupt Priority Control Register 3

Address offset: 0x40C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ15	RW	The priority of interrupt IRQ15, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ14	RW	The priority of interrupt IRQ14, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ13	RW	The priority of interrupt IRQ13, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ12	RW	The priority of interrupt IRQ12, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value

5.7.9 NVIC_IPR4 Interrupt Priority Control Register 4

Address offset: 0x410 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ19	RW	The priority of interrupt IRQ19, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ18	RW	The priority of interrupt IRQ18, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ17	RW	The priority of interrupt IRQ17, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ16	RW	The priority of interrupt IRQ16, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value



5.7.10 NVIC_IPR5 Interrupt Priority Control Register 5

Address offset: 0x414 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ23	RW	The priority of interrupt IRQ23, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ22	RW	The priority of interrupt IRQ22, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ21	RW	The priority of interrupt IRQ21, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ20	RW	The priority of interrupt IRQ20, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value

5.7.11 NVIC_IPR6 Interrupt Priority Control Register 6

Address offset: 0x418 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ27	RW	The priority of interrupt IRQ27, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ26	RW	The priority of interrupt IRQ26, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ25	RW	The priority of interrupt IRQ25, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ24	RW	The priority of interrupt IRQ24, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value



5.7.12 NVIC_IPR7 Interrupt Priority Control Register 7

Address offset: 0x41C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:30	IPRIRQ31	RW	The priority of interrupt IRQ31, 00 has the highest priority and 11 has the lowest priority
29:24	RFU	-	Reserved bits, please keep the default value
23:22	IPRIRQ30	RW	The priority of interrupt IRQ30, 00 has the highest priority and 11 has the lowest priority
21:16	RFU	-	Reserved bits, please keep the default value
15:14	IPRIRQ29	RW	The priority of interrupt IRQ29, 00 has the highest priority and 11 has the lowest priority
13:8	RFU	-	Reserved bits, please keep the default value
7:6	IPRIRQ28	RW	The priority of interrupt IRQ28, 00 has the highest priority and 11 has the lowest priority
5:0	RFU	-	Reserved bits, please keep the default value



6 RAM Memory

6.1 Overview

CW32L083 integrates 24KB embedded RAM for users to use, which is used to store various data in the process of program execution. The starting address of the RAM is 0x2000 0000, and the data is stored in the little-endian mode in the RAM, that is, the lowest byte address space stores the least significant byte data of the data.

6.2 Main features

- Support access in 3 widths of byte (8bit), half word (16bit) or full word (32bit)
- Zero latency, can be accessed by CPU and DMA at maximum system clock frequency
- Support parity check function



6.3 RAM Memory operation

The RAM memory operations that the user can perform include: read operations and write operations.

The read and write operations of RAM support three-bit widths of 8bit, 16bit and 32bit. The user program can complete the read and write by directly accessing the absolute address, but it should be noted that the data bit width of read and write must be aligned with the corresponding address boundary, otherwise read and write the operation is invalid and will result in a HardFault hardware error exception.

6.3.1 Read operation

The read operation supports 3 different bit widths, which can be read by direct access to the absolute address, but it should be noted that the read data bit width must be aligned with the corresponding address boundary.

Code example:

8bit read:

```
tempdata = * ( ( uint8_t * ) 0x2000 0001 );
```

16bit read:

```
tempdata = * ( ( uint16_t * ) 0x2000 0002 );
```

32bit read:

```
tempdata = * ( ( uint32_t * ) 0x2000 0004 );
```

6.3.2 Write operation

The write operation supports 3 different bit widths, and data can be written by directly accessing the absolute address, but it should be noted that the written data bit width must be aligned with the corresponding address boundary.

Code example:

8bit write:

```
* ( ( uint8_t * ) 0x2000 0001 ) = 0x12;
```

16bit write:

```
* ( ( uint16_t * ) 0x2000 0002 ) = 0x1234;
```

32bit write:

```
* ( ( uint32_t * ) 0x2000 0004 ) = 0x1234 5678.
```



6.4 Parity check function

CW32L083 supports the parity check function of RAM. After power-on, the parity check function is enabled by default and cannot be configured by the user.

Each byte of RAM data is actually stored in a 9bit physical space, including 8bit data bits and 1bit parity bits.

When the CPU writes to the RAM, the parity check unit of the RAM calculates the check digit and writes it into the corresponding check digit space. When reading RAM data, the data is read together with the check digit. The CPU performs parity check on each byte of the data, and compares the calculated check digit with the read check digit. If they are consistent, it means that the data in the RAM is correct. If it is inconsistent, the parity error flag RAM_ISR.PARITY is set. If the RAM parity error interrupt enables control bit RAM_IER.PARITY is set to 1, the CPU will respond to the interrupt service. The user program can set RAM_ICR.PARITY to 0 to clear the parity error flag.

The user can obtain the RAM address where the parity error occurs by reading the parity error address register RAM_ADDR.



6.5 List of registers

RAM base address: RAM_BASE = 0x4002 2400

Table 6-1 List of RAM registers

Register name	Register address	Register description
RAM_IER	RAM_BASE + 0x00	Interrupt Enable Control Register
RAM_ADDR	RAM_BASE + 0x04	Parity Error Address Register
RAM_ISR	RAM_BASE + 0x08	Interrupt Flag Register
RAM_ICR	RAM_BASE + 0x0C	Interrupt Flag Clear Register



6.6 Register description

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

6.6.1 RAM_ADDR Parity Error Address Register

Address offset: 0x04 Reset value: 0x2000 0000

Bit field	Name	Permission	Function description
31:0	ADDR	RO	The address of the RAM where the parity error is located

6.6.2 RAM_IER Interrupt Enable Control Register

Address offset: 0x00 Reset value: 0x0000 0001

Bit field	Name	Permission	Function description
31:2	RFU	-	Reserved bits, please keep the default value
1	PARITY	RW	RAM parity error interrupt enable control 0: Disable 1: Enable
0	EN	RO	RAM parity enable flag 0: Disable 1: Enable

6.6.3 RAM_ISR Interrupt Flag Register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:1	RFU	-	Reserved bits, please keep the default value
0	PARITY	RO	Parity error flag 0: No parity error occurred 1: A parity error has occurred



6.6.4 RAM_ICR Interrupt Flag Clear Register

Address offset: 0x0C Reset value: 0x0000 0001

Bit field	Name	Permission	Function description
31:1	RFU	-	Reserved bits, please keep the default value
0	PARITY	R1W0	Parity Error Flag Clear Control W0: Clear parity error flag W1: No function



7 FLASH Memory

7.1 Overview

CW32L083 integrates 256KB embedded FLASH for users to use, which can be used to store application programs and user data. The chip supports read, erase and write operations of FLASH memory, and supports erase and write protection and read protection; the chip has a built-in high-voltage BOOST circuit required for FLASH programming, and no additional programming voltage is required.

7.2 Main features

- Support access in 3 widths of byte (8bit), half word (16bit) or full word (32bit)
- Supports read, erase and write operations
- Support erase and write protection, read protection
- Support low-power mode

7.3 FLASH Memory organization

CW32L083 integrates 256KB user-accessible FLASH memory, which is managed by paging of 512 bytes per page, with a total of 512 pages. Users can perform full-page erasing and byte-by-byte programming operations on FLASH.

In addition to the user-accessible 256KB FLASH memory, the CW32L083 also integrates a 2.5KB startup program memory, which solidified with BootLoader and other codes when it leaves the factory, and the user cannot access this memory.

7.4 FLASH memory read wait cycle configuration

The internal FLASH memory of CW32L083 supports the operation clock with the fastest frequency of 24MHz. When the configured HCLK frequency is greater than 24MHz, the number of inserted waiting HCLK cycles needs to be configured through the WAIT bit field of the FLASH control register FLASH_CR2. The configuration rules are shown in the following table:

Table 7-1 FLASH read wait cycle configuration

FLASH_CR2.WAIT	The number of HCLK cycles waiting for the instruction fetch cycle	HCLK Frequency
000	0	$HCLK \leq 24MHz$
001	1	$HCLK \leq 48MHz$
010	2	$HCLK \leq 72MHz$

Caution:

When configuring the FLASH read wait period, the FLASH configuration clock must be enabled first.



7.5 FLASH Memory operation

User-executable FLASH memory operations include: read operations, erase operations, and write (programming) operations.

The read and write operations of FLASH support 3 widths of 8bit, 16bit and 32bit. The user program can complete the read and write by directly accessing the absolute address, but it should be noted that the data bit width of read and write must be aligned with the corresponding address boundary, otherwise it will cause HardFault hardware error exception.



7.5.1 Page Erase

The minimum unit of the page erase operation of FLASH is 1 page, that is, 512 bytes. After the page erase operation is completed, the data content of all address spaces of the page is 0xFF.

If the page erase operation is performed on the unlocked FLASH page, the operation will fail, and the FLASH_ISR.PAGELOCK flag will be set by hardware. If the FLASH_IER.PAGELOCK is set to 1, the CPU will execute the corresponding interrupt service routine. User can clear the FLASH_ISR.PAGELOCK interrupt flag by setting FLASH_ICR.PAGELOCK to 0.

If the program runs in FLASH, and the page erase operation is performed on the storage space of the page where the PC (program pointer) is located, the operation will fail, and the FLASH_ISR.PC flag will be set by hardware. If FLASH_IER.PC is set to 1, then The CPU will execute the corresponding interrupt service routine. The user can clear the FLASH_ISR.PC interrupt flag by setting FLASH_ICR.PC to 0.

FLASH page erase operation steps are as follows:

Step 1: Set the FLASH operation mode to page erase mode, and write 0x02 to the working mode bit field MODE of the FLASH control register FLASH_CR1;

Caution:

The FLASH_CR1 register has the KEY protection feature. The upper 16bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 2: To unlock the erasure protection of the page to be erased, see [Table 7-2 FLASH_PAGELOCK Erase lock protection](#), write 1 to the lock bit field LOCKx corresponding to the erasing lock register FLASH_PAGELOCK;

Caution:

The FLASH_PAGELOCK register has the KEY protection feature. The upper 16bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 3: Write any data to any address in the page to be erased, triggering the erase operation of the page.

Caution:

The write data bit width needs to be aligned with the corresponding address boundary.

Code example:

```
*( ( uint8_t * ) 0x0000 0001 ) = 0x55;
```

Step 4: Wait for the erase to complete, and query the FLASH busy flag bit FLASH_CR1.BUSY becomes 0;

Step 5: To erase other pages, repeat steps 2 to 4;

Step 6: After the erase operation is completed, if you want to restore the lock protection of FLASH, you need to write 0 to the lock bit field LOCKx corresponding to the erase/write lock register FLASH_PAGELOCK to activate the lock protection function to protect the FLASH content from being erased by mistake;

Step 7: Set the FLASH operation mode to read mode, and write 0x00 to the working mode bit field MODE of the FLASH control register FLASH_CR1.



7.5.2 Write operation

Based on the characteristics of embedded FLASH, the write operation can only rewrite the bit data in the FLASH memory from '1' to '0', but cannot be rewritten from '0' to '1'. Therefore, before writing data, the page where the corresponding address is located must be erased.

The following three principles must be followed for the FLASH write operation:

- Cannot write to the address whose data bit content is '0'
- Addresses within the locked area cannot be written to
- Cannot write to the address of the page where the PC (Program Pointer) is located

When the CW32L083 performs a write operation, it will check whether the contents of the storage space are all '1'. FLASH has three write operation bit widths of 8bit, 16bit and 32bit, and the number of bytes to be checked is 1Byte, 2Byte and 4Byte respectively.

If the internal storage space is not all '1', the write operation will fail, and the FLASH_ISR.PROG flag will be set by hardware. If FLASH_IER.PROG is set to 1, the CPU will execute the corresponding interrupt service routine. User can clear the FLASH_ISR.PROG interrupt flag by setting FLASH_ICR.PROG to 0.

If the storage space of the unlocked FLASH page is written, the operation will fail, and the FLASH_ISR.PAGELOCK flag will be set by hardware. If FLASH_IER.PAGELOCK is set to 1, the CPU will execute the corresponding interrupt service routine. User can clear the FLASH_ISR.PAGELOCK interrupt flag by setting FLASH_ICR.PAGELOCK to 0.

If the program runs in FLASH, and the write operation is performed on the storage space of the page where the PC (program pointer) is located, the operation will fail, and the FLASH_ISR.PC flag will be set by hardware. If FLASH_IER.PC is set to 1, the CPU will Execute the corresponding interrupt service routine. The user can clear the FLASH_ISR.PC interrupt flag by setting FLASH_ICR.PC to 0.



The FLASH write operation steps are as follows:

Step 1: Set the FLASH operation mode to write (programming) mode, and write 0x01 to the working mode bit field MODE of the FLASH control register FLASH_CR1;

Caution:

The FLASH_CR1 register has the KEY protection feature, the high 16bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 2: To unlock the erasure protection of the page to be written, see [Table 7-2 FLASH_PAGELOCK Erase lock protection](#), write 1 to the lock bit field LOCKx corresponding to the erasing lock register FLASH_PAGELOCK;

Caution:

The FLASH_PAGELOCK register has the KEY protection feature. The upper 16bit data of the written data must be 0x5A5A, otherwise it cannot be written.

Step 3: Write the data to be written into the target address and trigger the FLASH write operation. Note that the bit width of the written data needs to be aligned with the corresponding address boundary;
8bit width code example:

```
*( ( uint8_t * ) 0x0000 0001 ) = 0x55;
```

16bit width code example:

```
*( ( uint16_t * ) 0x0000 0002 ) = 0x1234;
```

32bit width code example:

```
*( ( uint32_t * ) 0x0000 0004 ) = 0x1234 5678;
```

Step 4: Wait for the programming to be completed, query and wait for the FLASH busy flag bit FLASH_CR1.BUSY to become 0;

Step 5: If you need to write more data to the address range of the currently unlocked area, repeat steps 4 to 5; if the write address exceeds the address range of the current unlocked area, repeat steps 3 to 5;

Step 6: After the write operation is completed, if you need to restore the lock protection of the FLASH, write 0 to the lock bit field LOCKx corresponding to the erase/write lock register FLASH_PAGELOCK to activate the lock protection function to protect the FLASH content from being erased by mistake;

Step 7: Set the FLASH operation mode to read mode, and write 0x00 to the working mode bit field MODE of the FLASH control register FLASH_CR1.



7.5.3 Read operation

CW32L083 supports 3 different bit widths for the FLASH read operation, which can be read by direct access to the absolute address. Note that the read data bit width must be aligned with the corresponding address boundary.

8bit width code example:

```
tempdata = *((uint8_t *) 0x0000 0001);
```

16bit width code example:

```
tempdata = *((uint16_t *) 0x0000 0002);
```

32bit width code example:

```
tempdata = *((uint32_t *) 0x0000 0004);
```



7.6 FLASH Memory protection

FLASH memory has erase and write protection and read protection functions.

The erasure protection includes lock page erasure protection and PC address page erasure protection. Pages in the protected state cannot be erased and written, which can avoid accidental rewriting of FLASH content.

The read protection takes the entire FLASH as the protection object, and does not support single-page protection, which can prevent the user code from being illegally read.

7.6.1 Erase and write protection

CW32L083 realizes the erasing and writing locking of FLASH pages by setting the erasing and writing lock register FLASH_PAGELOCK. Pages in the locked state cannot be page erased or written.

The internal FLASH memory of CW32L083 is divided into 512 pages, and each 8 pages corresponds to a LOCKx lock bit of the FLASH_PAGELOCK register. The LOCKx field has a total of 64 bits, which can realize the lock protection of all 512 pages of FLASH memory. The correspondence between the fields of the erasing lock register FLASH_PAGELOCK and the FLASH lock page is shown in the following table:

Table 7-2 FLASH_PAGELOCK Erase lock protection

FLASH_PAGELOCK bit field name	Lock page
LOCK63	Page504 – Page511
LOCK62	Page496 – Page503
LOCK61	Page488 – Page495
LOCK60	Page480 – Page487
LOCK59	Page472 – Page479
LOCK58	Page464 – Page471
LOCK57	Page456 – Page463
LOCK56	Page448 – Page455
...	...
LOCK7	Page56 - Page63
LOCK6	Page48 - Page55
LOCK5	Page40 - Page47
LOCK4	Page32 - Page39
LOCK3	Page24 - Page31
LOCK2	Page16 - Page23
LOCK1	Page8 - Page15
LOCK0	Page0 - Page7



When performing page erasing and writing operations on FLASH, you must first unlock the corresponding page by setting the corresponding FLASH_PAGELOCK.LOCKx bit field to 1. An example of the unlock operation is as follows:

Lock Page0-Page7 code example:

```
CW_FLASH->PAGELOCK1 = 0x5A5A 0000 | ( CW_FLASH->PAGELOCK1 & 0x0000 FFFE );
```

Unlock Page32-Page39 code example:

```
CW_FLASH->PAGELOCK1 = 0x5A5A 0000 | ( CW_FLASH->PAGELOCK1 | 0x0000 0010 );
```

Caution:

The FLASH_PAGELOCK register has the KEY protection feature. The upper 16bit data of the written data must be 0x5A5A, otherwise it cannot be written.

If the page erase or write operation is performed directly on the unlocked FLASH page, the operation will fail and an interrupt flag will be generated. Please refer to section [7.5.1 Page Erase](#) and section [7.5.2 Write operation](#).

7.6.2 Erase and write PC page protection

The FLASH memory of CW32L083 supports the function of erasing and writing PC page protection.

When the user program runs FLASH, if the current program pointer PC is just within the range of the FLASH address page to be erased, the erase operation will fail, and the FLASH_ISR.PC flag will be set by hardware. If FLASH_IER.PC is set to 1, the CPU will execute the corresponding interrupt service routine. The user can clear the FLASH_ISR.PC interrupt flag by setting FLASH_ICR.PC to 0.



7.6.3 Read protection

The CW32L083 supports the FLASH read protection function. After the read protection is set, the FLASH cannot be read by ISP or SWD. Read protection only supports whole-chip FLASH protection, and does not support page-by-page protection.

The read protection is divided into 4 protection levels. The current protection level can be obtained by reading the security bit field SECURITY of the FLASH control register FLASH_CR1. The security bit field is a read-only attribute and cannot be modified. The read protection level can be set by the ISP command, please refer to the ISP programming documentation.

The CPU fetches instructions from FLASH and the program's read operation to FLASH is not affected by the FLASH read protection function.

The read protection function of FLASH is shown in the following table:

Table 7-3 FLASH read protection

Protection level	FLASH_CR1.SECURITY	Function description
Level0	00	Read protection is not set. The FLASH can be read by SWD or ISP.
Level1	01	FLASH content cannot be read by SWD or ISP. The protection level can be reduced to Level 0 through ISP or SWD. After the downgrade, the content in the FLASH is all 0xFF, that is, it is in the empty chip state of the whole chip erasing.
Level2	10	FLASH content cannot be read by SWD or ISP. The protection level can only be lowered by ISP, but after the downgrade, the content in the FLASH is all 0xFF, that is, it is in an empty chip state of whole chip erasing.
Level3	11	FLASH content cannot be read by SWD or ISP. Both ISP and SWD downgrade functions are disabled. At this protection level, the chip can only be programmed once.

7.6.4 FLASH memory programming

CW32L083 internal integrated FLASH memory supports FLASH erasing and programming through SWD or ISP. The SWD method is to use the debugging tool to erase and program the FLASH through the SWD interface. The ISP method is to erase and program the FLASH through the BootLoader code pre-installed before the chip leaves the factory. ISP provides fast and efficient in-circuit erasing and programming methods, please refer to ISP programming documentation.



7.7 Precautions

In order to operate FLASH correctly and improve the access efficiency and service life of FLASH, users need to pay attention to the following matters when programming applications:

- Address Alignment Requirements

The address boundary is aligned, that is, the address when accessing FLASH with a 16-bit width must be an even address, and when using a 32-bit width, the address must be an address that is a multiple of 4.

Code example for correct address alignment:

8bit read:

```
tempdata = *((uint8_t *) 0x0000 0001);
```

16bit read:

```
tempdata = *((uint16_t *) 0x0000 0002);
```

32bit read:

```
tempdata = *((uint32_t *) 0x0000 0004);
```

Code example with wrong address alignment:

16bit read:

```
tempdata = *((uint16_t *) 0x0000 0001);
```

32bit read:

```
tempdata = *((uint32_t *) 0x0000 0003);
```

- Operation complete flag query

When the CPU fetches instructions from FLASH and runs, if the page erase/write operation to FLASH is performed, the CPU will automatically stop the next instruction access, and the hardware will automatically wait for the erase and write operation to complete (the FLASH_CR1.BUSY status bit becomes 0), so the user program does not need to loop through the query operation completion flag to determine whether the operation is completed.

When the CPU fetches instructions from RAM and runs, if a page erase/write operation to FLASH is performed, the CPU will access the next instruction while performing the operation. In order to ensure the correct execution of the next instruction of the program, The user program must query the FLASH_CR1.BUSY flag cyclically after the FLASH erase and write operations, until the FLASH_CR1.BUSY flag becomes 0, and then the subsequent tasks can be performed.

Before entering DeepSleep mode, if the FLASH is performing an erase/write operation, you must wait for the FLASH_CR1.BUSY flag bit to clear to 0, and make sure FLASH_CR1.MODE is 0 at the same time.

- Service life

Based on the characteristics of embedded FLASH, the number of operations and storage time of FLASH are limited. Users should try to avoid frequent erasing and writing operations on the FLASH memory of a certain page or address in the application program to ensure reliable data storage. Please refer to the datasheet for specific life data.

- Data storage mode

The application of CW32L083 stipulates that data is stored in FLASH in little-endian mode, that is, the least significant byte data of the data is stored in the lowest byte address space.



- Low power features

FLASH has the characteristics of low power consumption. By setting FLASH_CR1.STANDBY to 1, FLASH can automatically enter a low power consumption state after the system enters DeepSleep mode, ensuring that the product has lower power consumption in low power consumption mode.



7.8 List of registers

FLASH base address: FLASH_BASE = 0x4002 2000

Table 7-4 List of FLASH registers

Register name	Register address	Register description
FLASH_CR1	FLASH_BASE + 0x00	Control register 1
FLASH_CR2	FLASH_BASE + 0x04	Control register 2
FLASH_PAGELOCK1	FLASH_BASE + 0x08	Erase lock register 1
FLASH_PAGELOCK2	FLASH_BASE + 0x0C	Erase lock register 2
FLASH_PAGELOCK3	FLASH_BASE + 0x10	Erase lock register 3
FLASH_PAGELOCK4	FLASH_BASE + 0x14	Erase lock register 4
FLASH_IER	FLASH_BASE + 0x20	Interrupt Enable Register
FLASH_ISR	FLASH_BASE + 0x24	Interrupt Flag Register
FLASH_ICR	FLASH_BASE + 0x28	Interrupt Flag Clear Register



7.9 Register description

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

7.9.1 FLASH_CR1 Control register 1

Address offset: 0x00 Reset value: 0x0000 0010

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:8	RFU	-	Reserved bits, please keep the default value
7:6	SECURITY	RO	Current protection level 00: Level0, ISP can read and write, SWD can read and write 01: Level1, ISP downgradable, SWD downgradable; Data cannot be read 10: Level2, ISP downgradable, SWD has no function; Data cannot be read 11: Level3, ISP has no function, SWD has no function; Data cannot be read
5	BUSY	RO	Erase status flag 0: Erase operation completed 1: Erase operation is not completed
4	STANDBY	RW	Low power enable control 0: When the system enters DeepSleep mode, FLASH does not enter low power consumption mode 1: When the system enters DeepSleep mode, FLASH enters low power consumption mode Caution: It is recommended to configure this value to 1, otherwise it will cause the power consumption of DeepSleep mode to be too large
3:2	RFU	-	Reserved bits, please keep the default value
1:0	MODE	RW	Operation Mode Configuration 00: Read mode, Read 01: Write mode, Program 10: Page erase mode, PageErase 11: Chip erase mode, ChipErase



7.9.2 FLASH_CR2 Control register 2

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:3	RFU	-	Reserved bits, please keep the default value
2:0	WAIT	RW	FLASH instruction fetches cycle configuration 000: 1 HCLK cycle for HCLK ≤ 24MHz 001: 2 HCLK cycle for 24MHz < HCLK ≤ 48MHz 010: 3 HCLK cycle for 48MHz < HCLK ≤ 72MHz Caution: This control bit has the same function as SYSCTRL_CR2[6:4].

7.9.3 FLASH_PAGELOCK1 Erase lock register 1

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15	LOCK15	RW	Page120 – Page127 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
14	LOCK14	RW	Page112 – Page119 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
...
1	LOCK1	RW	Page8 – Page15 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
0	LOCK0	RW	Page0 – Page7 erase lock configuration 0: locked, non-rewritable 1: open, rewritable



7.9.4 FLASH_PAGELOCK2 Erase lock register 2

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15	LOCK31	RW	Page248 – Page255 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
14	LOCK30	RW	Page240 – Page247 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
...
1	LOCK17	RW	Page136 – Page143 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
0	LOCK16	RW	Page128 – Page135 erase lock configuration 0: locked, non-rewritable 1: open, rewritable

7.9.5 FLASH_PAGELOCK3 Erase lock register 3

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15	LOCK47	RW	Page376 – Page383 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
14	LOCK46	RW	Page368 – Page375 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
...
1	LOCK33	RW	Page264 – Page271 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
0	LOCK32	RW	Page256 – Page263 erase lock configuration 0: locked, non-rewritable 1: open, rewritable



7.9.6 FLASH_PAGELOCK4 Erase lock register 4

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15	LOCK63	RW	Page504 – Page511 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
14	LOCK62	RW	Page496 – Page503 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
...
1	LOCK49	RW	Page392 – Page399 erase lock configuration 0: locked, non-rewritable 1: open, rewritable
0	LOCK48	RW	Page384 – Page391 erase lock configuration 0: locked, non-rewritable 1: open, rewritable

7.9.7 FLASH_IER Interrupt Enable Register

Address offset: 0x20 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:5	RFU	-	Reserved bits, please keep the default value
4	PROG	RW	Programming Error Interrupt Enable Control 0: Disable 1: Enable
3:2	RFU	-	Reserved bits, please keep the default value
1	PAGELOCK	RW	Erase and write PAGELOCK locked page interrupt enable control 0: Disable 1: Enable
0	PC	RW	Erase and write the page where the PC is located, interrupt enable control 0: Disable 1: Enable



7.9.8 FLASH_ISR Interrupt Flag Register

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:5	RFU	-	Reserved bits, please keep the default value
4	PROG	RO	Programming error flag 0: The content of each byte of the current address to be written is all 0xFF 1: The content of each byte of the current address to be written is not all 0xFF
3:2	RFU	-	Reserved bits, please keep the default value
1	PAGELOCK	RO	Erase and write PAGELOCK locked page interrupt flag 0: The current erase address is outside the page locked by PAGELOCK 1: The current erase address is within the page locked by PAGELOCK
0	PC	RO	Erase and write the interrupt flag of the page where the PC pointer is located 0: The current erase address is outside the page where the PC pointer is located 1: The current erase address is within the page where the PC pointer is located

7.9.9 FLASH_ICR Interrupt Flag Clear Register

Address offset: 0x28 Reset value: 0x0000 001F

Bit field	Name	Permission	Function description
31:5	RFU	-	Reserved bits, please keep the default value
4	PROG	WO	Programming error flag clear W0: Clear programming error flag W1: No function
3:2	RFU	-	Reserved bits, please keep the default value
1	PAGELOCK	R1W0	Erase and write PAGELOCK locked page interrupt flag clear W0: Clear the page interrupt flag locked by erasing PAGELOCK W1: No function
0	PC	R1W0	Erase and write the page where the PC pointer is located to clear the interrupt flag W0: Clear and erase the interrupt flag of the page where the PC pointer is located W1: No function



8 Direct memory access (DMA)

8.1 Overview

The CW32L083 supports Direct Memory Access (DMA), which enables high-speed data transfer between peripherals and memory, between peripherals and peripherals, and between memory and memory without CPU intervention. The priority arbiter inside the DMA controller can realize the arbitration of DMA and CPU control of peripheral bus, as well as the scheduling execution between multiple DMA channels.

8.2 Main features

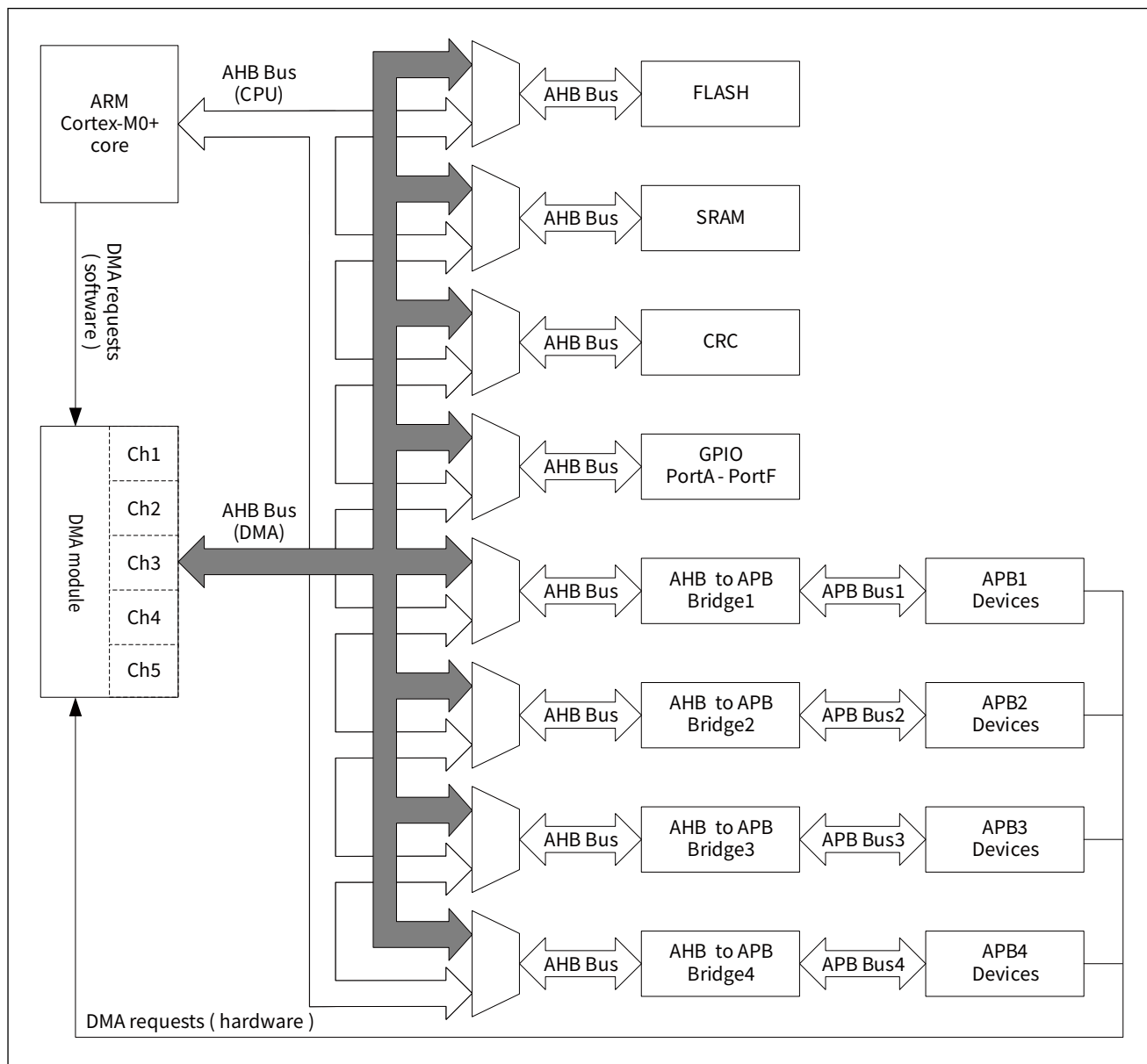
- 5 independent DMA channels
- 3 data transfer widths: 8bit, 16bit, 32bit
- 4 transfer modes: Software BLOCK, Software BULK, Hardware BLOCK, Hardware BULK
- Source address and destination address type: peripherals, memory
- Address increment method: fixed, auto-increasing
- Number of data blocks to be transferred: 1~65535
- Addressing range: 0x0000 0000 ~ 0xFFFF FFFF



8.3 Functional block diagram

The AHB bus of the DMA controller is connected to the AHB bus of the peripheral through the bus matrix to realize the data interconnection between the DMA and the peripheral, including FLASH, SRAM, CRC, GPIO and various APB devices. The functional block diagram of the DMA controller is shown in the following figure:

Figure 8-1 DMA functional block diagram



- DMA controller

5 independent DMA channels, the channel priority is bound to the channel number, the smaller the channel number, the higher the priority, and the larger the channel number, the lower the priority.

- Bus Matrix

Both the CPU system bus and the DMA bus interface are connected to the bus matrix, and are switched and connected to peripherals through the bus matrix. When the CPU and DMA access different AHB bus devices or AHB to APB bridges, data transfer can be performed simultaneously; When the CPU and DMA access the same AHB device at the same time (different devices under the AHB to APB bridge are also considered to be the same AHB device), the CPU has a higher priority than the DMA.

- AHB to APB bridge

DMA can achieve access to APB devices through the bus matrix and AHB to APB bridges. All APB devices under the same AHB-to-APB bridge share the same AHB bus and are therefore regarded as the same AHB device. When the CPU and DMA access the APB device under the same AHB to APB bridge at the same time (whether accessing the same APB device or a different APB device), the priority of the CPU is higher than that of the DMA.



8.4 DMA transfer modes

8.4.1 Overview of Transfer Modes

DMA supports 4 transfer modes: software-triggered BLOCK transfer mode, software-triggered BULK transfer mode, hardware-triggered BLOCK transfer mode, and hardware-triggered BULK transfer mode.

- Software and hardware triggering

Some peripherals support hardware DMA. When they are configured as the trigger source of the DMA channel, a DMA request (DMA request) can be generated, and the hardware triggers the DMA transfer without CPU participation. Peripherals that do not support hardware DMA can only be configured as software-triggered DMA transfers.

The trigger mode is controlled by the TYPE bit field of the DMA trigger source control register DMA_TRIGy (y is the DMA channel number, y=1~5, the same below), TYPE is 0 for software trigger mode, TYPE is 1 for hardware trigger mode.

- Transfer modes of BLOCK and BULK

The difference between BLOCK and BULK transfer modes is whether the transfer is allowed to be interrupted by a higher priority transfer request (high priority DMA or CPU). The TRANS bit field of the DMA control and status register DMA_CSRy is 1 for the BLOCK transmission mode, and 0 for the BULK transmission mode.

In BULK transmission mode, all data transmission will be completed at one time. No transfer gaps are inserted during data transfer, and the transfer process is not interrupted by CPU or other high-priority DMA channel transfer requests.

In the BLOCK transmission mode, a transmission gap is inserted after each data block is transmitted, and the arbiter performs transmission priority arbitration in the transmission gap. If a CPU or higher priority DMA channel wants to access the peripheral occupied by the current DMA channel, the arbiter will release the control right of the current DMA channel to the device, allowing the CPU or higher priority DMA channel to have priority access, etc. After completion, resume the previously interrupted DMA channel transfer.

The transfer modes of DMA as shown in the following table:

Table 8-1 DMA transfer mode

Transfer mode	DMA_TRIGy.TYPE	DMA_CSRy.TRANS	Can it be interrupted by a higher priority DMA channel or CPU ?
Software BLOCK	0	1	YES
Software BULK	0	0	NO
Hardware BLOCK	1	1	YES
Hardware BULK	1	0	NO



DMA transfer process

For a complete DMA transfer process, the user needs to do the following settings:

- Step 1: Set the transfer mode, DMA_CSRy.TRANS is set to 1 for the BLOCK transfer mode, and 0 for the BULK transfer mode;
- Step 2: Set the trigger mode, DMA_TRIGy.TYPE is set to 0 for software trigger, and 1 is for hardware trigger mode;
- Step 3: Configure DMA channel data transmission bit width, DMA_CSRy.SIZE, select 8, 16, 32bit;
- Step 4: Configure the number of DMA channels to transmit data blocks, DMA_CNTy.CNT, the valid range is 1~65535;
- Step 5: Configure the DMA channel transfer data block size, DMA_CNTy.REPEAT, please write 1;
- Step 6: Configure the DMA transfer source address, DMA_SRCADDRy;
- Step 7: Configure the DMA transfer destination address, DMA_DSTADDRy;
- Step 8: Configure the DMA source address increment method, DMA_CSRy.SRCINC, fixed or automatically incremented;
- Step 9: Configure the DMA destination address increment method, DMA_CSRy.DSTINC, fixed or automatically increased;
- Step 10: Set DMA_CSRy.EN to 1 to enable the corresponding DMA channel;
- Step 11: For software-triggered DMA transfer, set DMA_TRIGy.SOFTSRC to start DMA transfer. For hardware-triggered DMA transfer, no setting is required, but only the peripherals used to start DMA need to be set correctly.



8.4.2 Software trigger BLOCK transfer mode

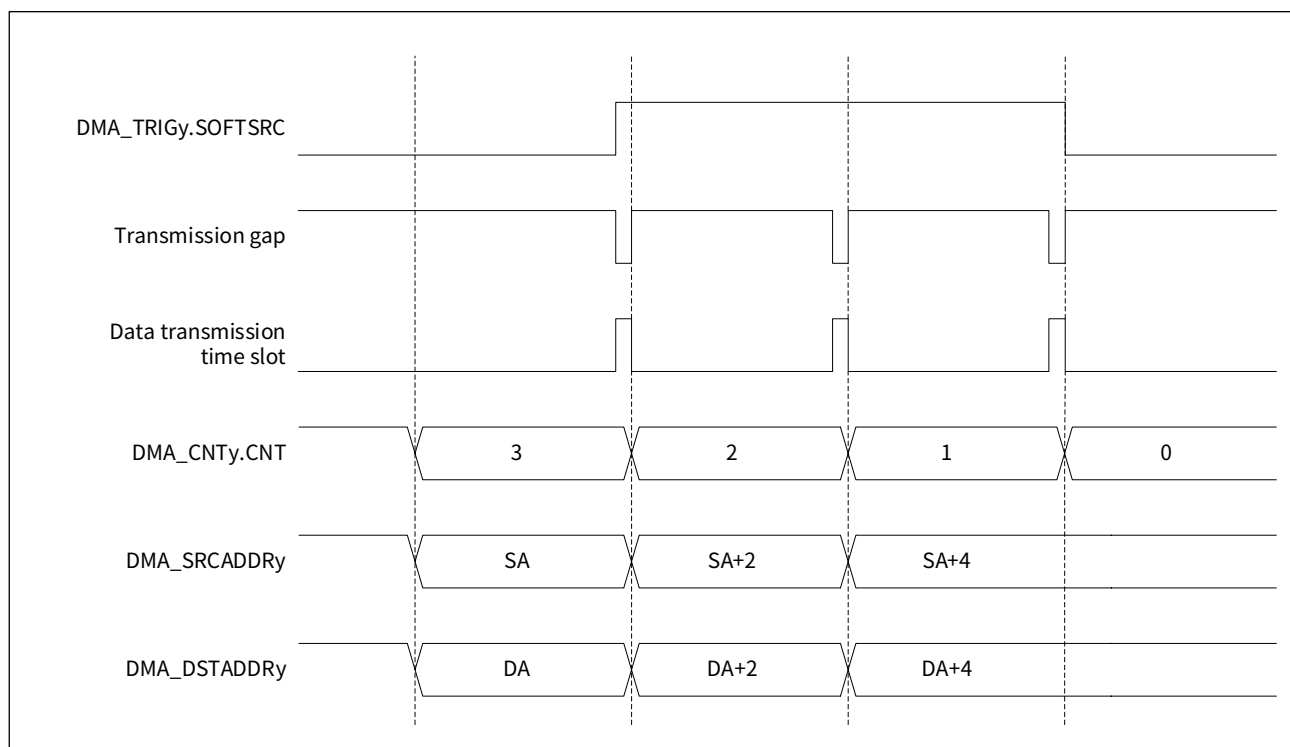
Setting DMA_TRIGy.SOFTSRC to 1 will immediately trigger the DMA channel for data transfer.

Each time a DMA channel completes a data block transmission, the DMA inserts a transmission gap, and the arbiter performs transmission priority arbitration in the transmission gap. If there is a CPU or higher priority DMA request to access the AHB device occupied by the current DMA channel during the transmission gap, the arbiter will release the control right of the current DMA channel to the device, allowing the CPU or higher priority DMA channel to have priority access; when the CPU or a higher priority DMA channel releases the device access right, the unfinished data transfer of this DMA channel will continue.

DMA_TRIGy.SOFTSRC is automatically cleared after the transfer is completed.

The software triggers the BLOCK transmission mode, and transmits 3 data with a data width of 16 bits (DMA_CNTy.REPEAT=1, DMA_CNTy.CNT=3), where SA represents the source address, DA represents the destination address, and both the source address and the destination address are addresses. In auto-increment mode, the transmission process is shown in the following figure:

Figure 8-2 Software trigger BLOCK transfer mode



8.4.3 Software trigger BULK transfer mode

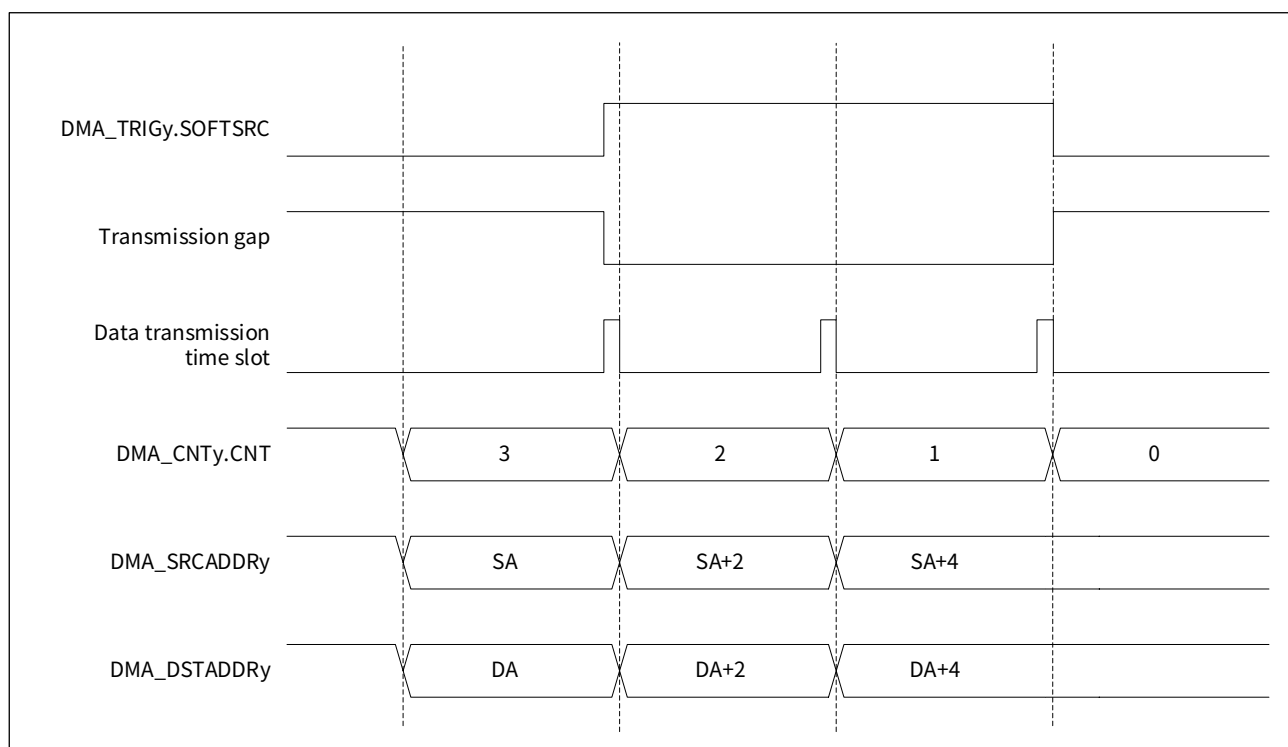
Setting DMA_TRIGy.SOFTSRC to 1 will immediately trigger DMA for data transfer. After the DMA channel transmits DMA_CNTy.CNT data blocks, stop the transfer and release the peripheral occupancy rights. After the transfer is completed, DMA_TRIGy.SOFTSRC is automatically cleared to zero.

Software-triggered BULK transfer mode has no transfer gap. Before the DMA_CNTy.CNT data block transfer is completed, the DMA channel will always occupy the peripheral. The CPU or higher priority DMA channel can only access the peripheral after the DMA transfer is completed. Assume.

In user applications, it is recommended not to transfer too much data at a time, otherwise the CPU may be completely unable to access the peripherals occupied by the DMA channel for a period of time.

The software triggers the BULK transfer mode, and transmits 3 data with a data width of 16 bits (DMA_CNTy.REPEAT=1, DMA_CNTy.CNT=3), where SA represents the source address, DA represents the destination address, and both the source address and the destination address are addresses. In auto-increment mode, the transmission process is shown in the following figure:

Figure 8-3 Software trigger BULK transfer mode



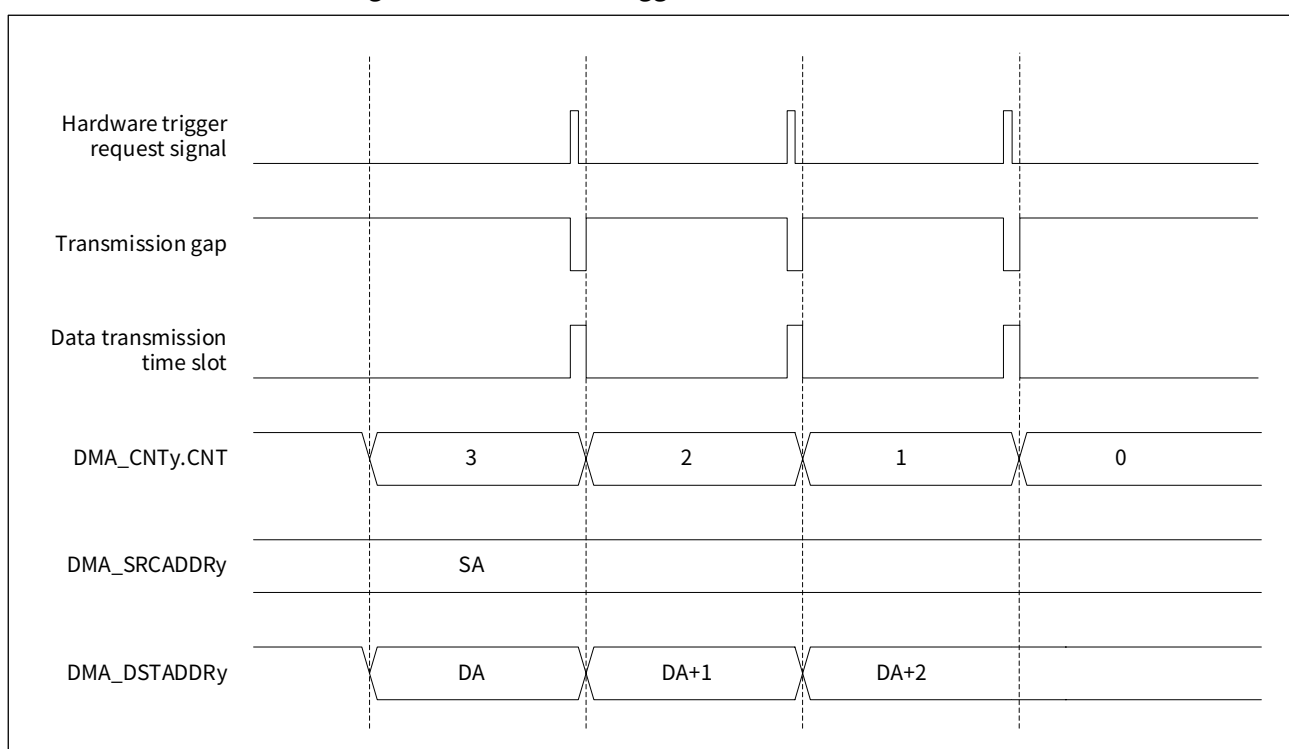
8.4.4 Hardware trigger BLOCK transfer mode

When the peripheral corresponding to the DMA channel generates a hardware trigger request signal, the DMA will transmit one data block, and then wait for the next hardware trigger request signal until all the data volume configured in the DMA controller is transmitted. For the hardware trigger request signal supported by the DMA channel, please refer to the HARDSRC bit field of the trigger source control register DMA_TRIGy.

Like the software BLOCK transmission mode, DMA will insert a transmission gap while the hardware BLOCK transmission mode a data block is completed, allowing the CPU or higher-priority DMA channel transmission requests to preempt peripheral control.

The hardware triggers the BLOCK transmission mode, and transmits 3 data with a data width of 8 bits (DMA_CNTy.REPEAT=1, DMA_CNTy.CNT=3), where SA represents the source address, DA represents the destination address, the source address is fixed, and the destination address is incremented automatically, the transmission process is shown in the following figure:

Figure 8-4 Hardware trigger BLOCK transfer mode



8.4.5 Hardware trigger BULK transfer mode

When the peripheral corresponding to the DMA channel generates a hardware trigger request signal, it will immediately trigger the DMA for data transmission. After the DMA channel transmits DMA_CNTy.CNT data blocks, the transmission will be stopped and the peripheral occupancy will be released.

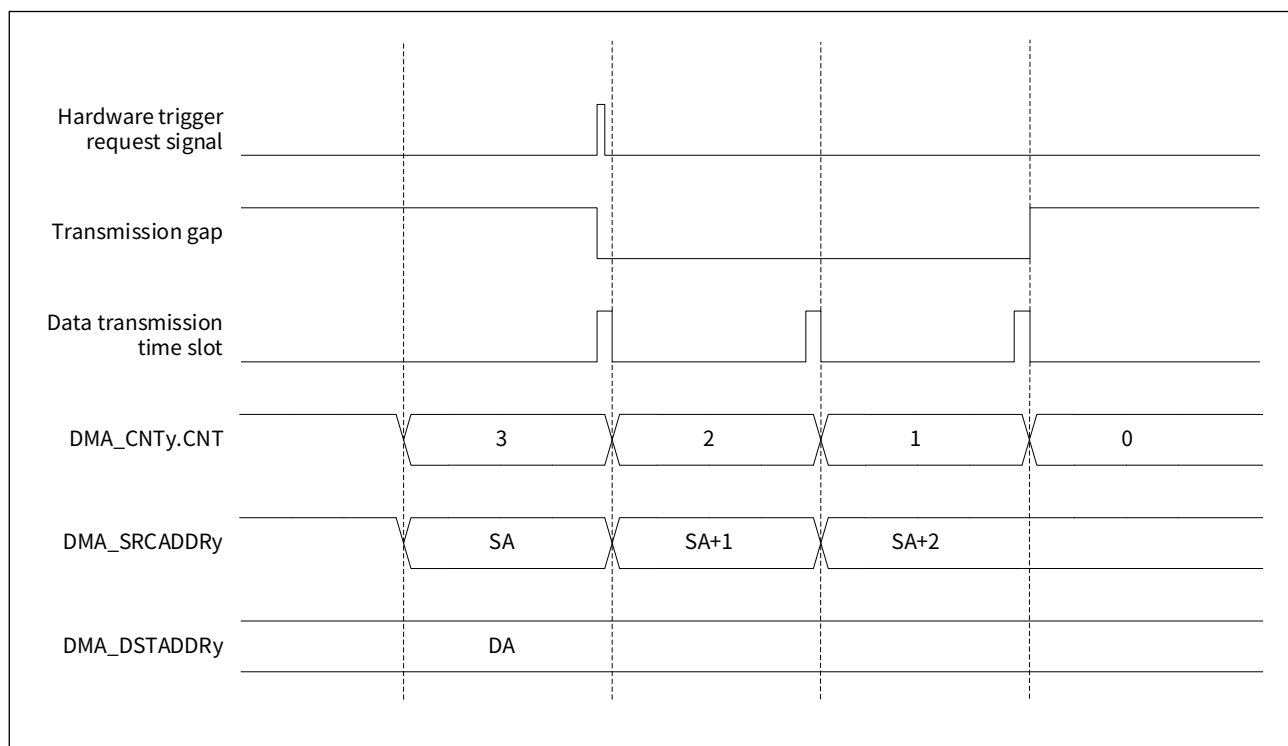
There is no transmission gap in the hardware-triggered BULK transfer mode. Before the transfer of DMA_CNTy.CNT data block is completed, the DMA will always occupy the peripheral access right. The CPU or higher priority DMA channel can only access the peripheral after the operation is completed.

In user applications, it is recommended not to transfer too much data at a time, otherwise the CPU may be completely unable to access the peripherals occupied by the DMA channel for a period of time.

For the hardware trigger request signal supported by the DMA channel, see HARDSRC bit field in section [8.8.4 DMA_TRIGy channel y trigger source control register](#).

The hardware triggers the BULK transmission mode, and transmits 3 data with a data width of 8 bits (DMA_CNTy.REPEAT=1, DMA_CNTy.CNT=3), where SA represents the source address, DA represents the destination address, the source address is auto-increasing, and the destination address is fixed, the transmission process is shown in the following figure:

Figure 8-5 Hardware trigger BULK transfer mode



8.5 Other configuration of DMA

8.5.1 Data width

The data bit width can be set to 8bit, 16bit, 32bit, which can be set through the SIZE bit field of the DMA_CSRy register. The data bit width should be exactly the same as the bit width of the source address and destination address of the DMA channel.

8.5.2 Data block size

The data block size is configured through the REPEAT bit field of the DMA_CNTy register, and it is recommended to write 1.

Caution:

The value of this bit field will automatically become 0 after each transfer, and needs to be written to 1 before the next DMA transfer.

8.5.3 Number of data blocks

The number of data blocks to be transferred can be set from 1 to 65535, which is configured through the CNT bit field of the DMA_CNTy register.

8.5.4 Channel priority

The priority of the 5 DMA channels is bound to the channel number. The smaller the channel number, the higher the priority, and the larger the channel number, the lower the priority.



8.6 DMA interrupt

The DMA channel can generate two interrupt flags during the transfer process: the transfer error interrupt flag and the transfer completion interrupt flag.

The interrupts of different DMA channels are independent, and the interrupt flag of each channel can be obtained through the interrupt flag register DMA_ISR. The channel transmission error interrupt flag corresponds to multiple possible causes. The specific causes need to query the DMA_CSRy.STATUS status bit, as shown in the following table:

Table 8-2 DMA Interrupt Flag Status Bits

DMA_CSRy.STATUS status bit	DMA Current state of channel y
000	Initial state
001	Transmission error, transmission address out of addressing range
010	Transmission error, aborted by transmission stop request
011	Transmission error, error accessing the transmission source address
100	Transmission error, error accessing the transmission destination address
101	Transfer completed

When the transmission error interrupt flag or the transmission completion interrupt flag is set, if the corresponding interrupt request is enabled, the CPU will execute the interrupt service routine. Before exiting the interrupt service routine, the corresponding flag should be cleared to avoid repeatedly entering the interrupt service routine.

The DMA interrupt trigger conditions, interrupt enable and interrupt flag clearing methods are shown in the following table:

Table 8-3 DMA Interrupt flag and clear method

DMA interrupt type	Triggering conditions	Interrupt enable method	Interrupt flag clearing method
Transmission error	The transfer address is out of the addressing range; Or, the peripheral requests to abort the DMA transfer; Or, there is an error accessing the transfer source/destination address	Set DMA_CSRy.TEIE to 1	Set DMA_ICR.TEy to 0
Transfer completed	The data transfer is all done correctly	Set DMA_CSRy.TCIE to 1	Set DMA_ICR.TCy to 0



8.7 List of registers

DMA base address: DMA_BASE = 0x4002 0000

Table 8-4 List of DMA registers

Register name	Register address	Register description
DMA_ISR	DMA_BASE + 0x00	Interrupt Flag Register
DMA_ICR	DMA_BASE + 0x04	Interrupt Flag Clear Register
DMA_CSR _y	DMA_BASE + 0x00 + 32 × y	Channel y control and status register, y = 1~5
DMA_CNT _y	DMA_BASE + 0x04 + 32 × y	Channel y transfer number register, y = 1~5
DMA_SRCADDR _y	DMA_BASE + 0x08 + 32 × y	Channel y transfer source address register, y = 1~5
DMA_DSTADDR _y	DMA_BASE + 0x0C + 32 × y	Channel y transfer destination address register, y = 1~5
DMA_TRIG _y	DMA_BASE + 0x10 + 32 × y	Channel y trigger source control register, y = 1~5



8.8 Register description

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

8.8.1 DMA_ISR Interrupt Flag Register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:18	RFU	-	Reserved bits, please keep the default value
17	TE5	RO	Channel 5 Transmission Error Flag See TE1 description
16	TC5	RO	Channel 5 Transfer Complete Flag See TC1 description
15:14	RFU	-	Reserved bits, please keep the default value
13	TE4	RO	Channel 4 Transmission Error Flag See TE1 description
12	TC4	RO	Channel 4 Transfer Complete Flag See TC1 description
11:10	RFU	-	Reserved bits, please keep the default value
9	TE3	RO	Channel 3 Transmission Error Flag See TE1 description
8	TC3	RO	Channel 3 Transfer Complete Flag See TC1 description
7:6	RFU	-	Reserved bits, please keep the default value
5	TE2	RO	Channel 2 Transmission Error Flag See TE1 description
4	TC2	RO	Channel 2 Transfer Complete Flag See TC1 description
3:2	RFU	-	Reserved bits, please keep the default value
1	TE1	RO	Channel 1 Transmission Error Flag 0: Normal transmission 1: Transmission error
0	TC1	RO	Channel 1 Transfer Complete Flag 0: Transfer not complete 1: Transfer completed



8.8.2 DMA_ICR Interrupt Flag Clear Register

Address offset: 0x04 Reset value: 0xFFFF FFFF

Bit field	Name	Permission	Function description
31:18	RFU	-	Reserved bits, please keep the default value
17	TE5	R1W0	Channel 5 Transmission Error Flag Clear See TE1 description
16	TC5	R1W0	Channel 5 Transfer Complete Flag Cleared See TC1 description
15:14	RFU	-	Reserved bits, please keep the default value
13	TE4	R1W0	Channel 4 Transmission Error Flag Clear See TE1 description
12	TC4	R1W0	Channel 4 Transfer Complete Flag Cleared See TC1 description
11:10	RFU	-	Reserved bits, please keep the default value
9	TE3	R1W0	Channel 3 Transmission Error Flag Clear See TE1 description
8	TC3	R1W0	Channel 3 Transfer Complete Flag Cleared See TC1 description
7:6	RFU	-	Reserved bits, please keep the default value
5	TE2	R1W0	Channel 2 Transmission Error Flag Clear See TE1 description
4	TC2	R1W0	Channel 2 Transfer Complete Flag Cleared See TC1 description
3:2	RFU	-	Reserved bits, please keep the default value
1	TE1	R1W0	Channel 1 Transmission Error Flag Clear W0: Clear channel 1 transmission error flag W1: No function
0	TC1	R1W0	Channel 1 Transfer Complete Flag Cleared W0: Clear channel 1 transfer completion flag W1: No function



8.8.3 DMA_CSRy Channel y Control and Status Register

Address offset: $0x00 + 32 \times y$ Reset value: 0x0000 0000 ($y = 1 \sim 5$)

Bit field	Name	Permission	Function description
31:11	RFU	-	Reserved bits, please keep the default value
10:8	STATUS	RW	Current state of channel y 000: Initial state 001: Transmission error, transmission address out of addressing range 010: Transmission error, aborted by transmission stop request 011: Transmission error, error accessing the transmission source address 100: Transmission error, error accessing the transmission destination address 101: Transfer completed
7:6	SIZE	RW	Channel y transmission data bit width configuration 00: 8bit 01: 16bit 10: 32bit
5	DSTINC	RW	Channel y destination address incremental configuration 0: Fixed destination address 1: Destination address auto increment
4	SRCINC	RW	Channel y source address incremental configuration 0: Source address fixed 1: Source address auto increment
3	TRANS	RW	Channel y transfer mode configuration 0: Bulk transfer (BULK) 1: Block transfer (BLOCK)
2	TEIE	RW	Channel y transmission error interrupt enable control 0: Disable 1: Enable
1	TCIE	RW	Channel y transfer completion interrupt enable control 0: Disable 1: Enable
0	EN	RW	Channel y enable control 0: Disable 1: Enable



8.8.4 DMA_TRIGy channel y trigger source control register

Address offset: $0x10 + 32 \times y$ Reset value: 0x0000 0000 ($y = 1 \sim 5$)

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:2	HARDSRC	RW	Channel y hardware trigger signal trigger source configuration 000000: UART1 receive Buf non-empty flag 000001: UART1 send Buf empty flag 000010: UART2 receive Buf non-empty flag 000011: UART2 send Buf empty flag 000100: UART3 receive Buf non-empty flag 000101: UART3 send Buf empty flag 000110: SPI1 receive Buf non-empty flag 000111: SPI1 send Buf empty flag 001000: SPI2 receive Buf non-empty flag 001001: SPI2 send Buf empty flag 001010: ADC conversion complete flag 001011: BTIM1 overflow interrupt flag 001100: BTIM1 trigger interrupt flag 001101: BTIM2 overflow interrupt flag 001110: BTIM2 trigger interrupt flag 001111: BTIM3 overflow interrupt flag 010000: BTIM3 trigger interrupt flag 010001: ATIM CHxA, CH4 compare capture flags, event update flag 010010: ATIM CHxB compare capture flags, event update flag 010011: GTIM1 overflow interrupt flag 010100: GTIM1 trigger interrupt flag 010101: GTIM1 channel 1 compare capture interrupt flag 010110: GTIM1 channel 2 compare capture interrupt flag 010111: GTIM1 channel 3 compare capture interrupt flag 011000: GTIM1 channel 4 compare capture interrupt flag 011001: GTIM2 overflow interrupt flag 011010: GTIM2 trigger interrupt flag 011011: GTIM2 channel 1 compare capture interrupt flag 011100: GTIM2 channel 2 compare capture interrupt flag 011101: GTIM2 channel 3 compare capture interrupt flag 011110: GTIM2 channel 4 compare capture interrupt flag 011111: GTIM3 overflow interrupt flag 100000: GTIM3 trigger interrupt flag 100001: GTIM3 channel 1 compare capture interrupt flag 100010: GTIM3 channel 2 compare capture interrupt flag 100011: GTIM3 channel 3 compare capture interrupt flag 100100: GTIM3 channel 4 compare capture interrupt flag 100101: GTIM4 overflow interrupt flag 100110: GTIM4 trigger interrupt flag 100111: GTIM4 channel 1 compare capture interrupt flag 101000: GTIM4 channel 2 compare capture interrupt flag



Bit field	Name	Permission	Function description
7:2 (continue)	HARDSRC (continue)	RW (continue)	101001: GTIM4 channel 3 compare capture interrupt flag 101010: GTIM4 channel 4 compare capture interrupt flag 101011: UART4 receive Buf non-empty flag 101100: UART4 send Buf empty flag 101101: UART5 receive Buf non-empty flag 101110: UART5 send Buf empty flag 101111: UART6 receive Buf non-empty flag 110000: UART6 send Buf empty flag 110001: LCD Frame interrupt flag 110010: ADC single conversion complete flag
1	SOFTSRC	RW	Channel y software trigger control R0: Transfer completed R1: Transfer in progressing W0: No function W1: Trigger the channel immediately to start the transmission
0	TYPE	RW	Channel y trigger type configuration 0: Software trigger mode, the transmission is initiated by the SOFTSRC signal 1: In hardware trigger mode, the transmission is initiated by the trigger signal of the trigger source configured by HARDSRC



8.8.5 DMA_CNTy Channel y transfer number register

Address offset: $0x04 + 32 \times y$ Reset value: $0x0000\ 0000$ ($y = 1 \sim 5$)

Bit field	Name	Permission	Function description
31:20	RFU	-	Reserved bits, please keep the default value
19:16	REPEAT	RW	Please write 1
15:0	CNT	RW	Configure the amount of data to be transmitted by channel y as CNT During the transmission process, the value of this register is decremented by 1 each time the transmission is completed

8.8.6 DMA_SRCADDRy Channel y transfer source address register

Address offset: $0x08 + 32 \times y$ Reset value: $0x0000\ 0000$ ($y = 1 \sim 5$)

Bit field	Name	Permission	Function description
31:0	SRCADDR	RW	Channel y transmission source address

Caution:

The destination address cannot be a DMA register, a FLASH register, a RAM register, a TRNG register, or a AES register.

8.8.7 DMA_DSTADDRy Channel y transfer destination address register

Address offset: $0x0C + 32 \times y$ Reset value: $0x0000\ 0000$ ($y = 1 \sim 5$)

Bit field	Name	Permission	Function description
31:0	DSTADDR	RW	Channel y transmission destination address

Caution:

The destination address cannot be a DMA register, a FLASH register, a RAM register, a TRNG register, or a AES register.



9 General-purpose input/output (GPIO)

9.1 Overview

The GPIO controller realizes the connection between various digital and analog circuits inside the chip and the physical pins.

GPIO can be configured as digital input and output and analog functions, supports peripheral function multiplexing, supports 4 interrupt sources of high level, low level, rising edge and falling edge, can wake up the MCU return to active mode through external interrupt in DeepSleep mode.

9.2 Main features

- All registers are read and written through the AHB bus interface
- With digital input and output and analog function
- Digital input and output support common GPIO and function multiplexing
- The analog function can be used as the input signal of ADC, VC, LVD
- Support a variety of internal clock signal output
- Digital input supports internal pull-up, pull-down and high-impedance modes
- Digital outputs support push-pull and open-drain modes
- The digital output supports atomic bit operations of bit setting, bit clearing, and bit flipping
- Interrupt function supports high level, low level, rising edge, falling edge trigger mode
- Interrupts with digital filtering, selectable from 8 clock sources
- Supports wake-up of MCU via external interrupt in DeepSleep mode

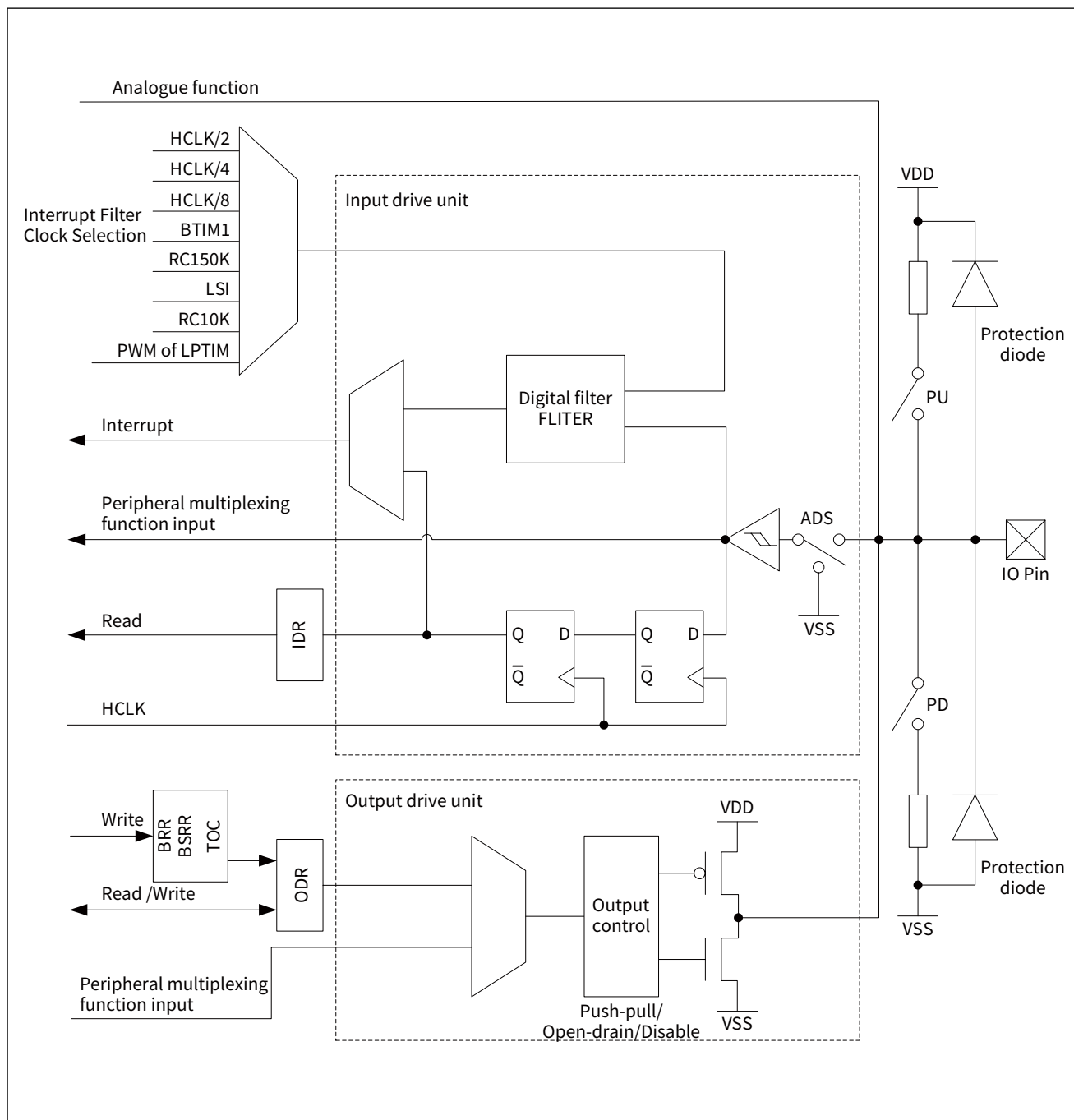


9.3 Function description

9.3.1 Functional block diagram

The functional block diagram of the GPIO controller is shown in the following figure:

Figure 9-1 GPIO functional block diagram



9.3.2 Digital output

Clear the analog-digital configuration register GPIOx_ANALOG[y] (x is the GPIO port number, x=A, B, C, D, E, F; y is the pin number, y=0~15; the same below), and configure the corresponding GPIO port as Digital function; clear the input and output direction register GPIOx_DIR[y] to configure the GPIO port as output mode. Digital output signal sources can be

- Output data register GPIOx_ODR
- On-chip digital peripherals

Configure the output mode through the output mode register GPIOx_OPENDRAIN, which can select push-pull output or open-drain output.



9.3.3 Digital input

Clear the analog-digital configuration register `GPIOx_ANALOG[y]` to configure the GPIO port as a digital function; set the input and output direction register `GPIOx_DIR[y]` to configure the corresponding GPIO port as input mode. Digital input signals are configurable:

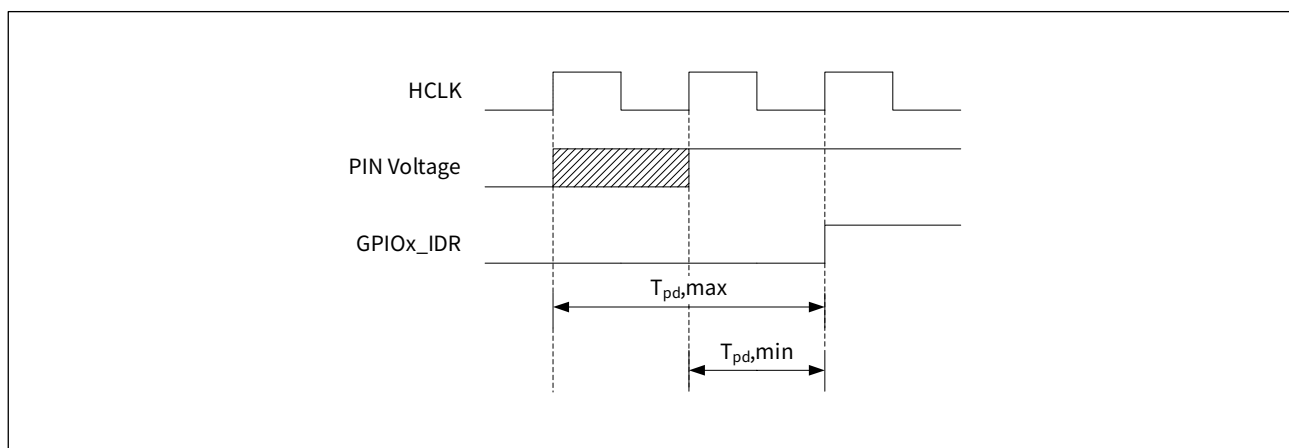
- Reach the input data register `GPIOx_IDR`
- Reach on-chip digital peripherals
- Trigger interrupt

In this mode, the digital input signal is directed to the internal digital input circuit through the ADS switch.

After the level state is confirmed by the Schmitt trigger, it can be directly sent to the input of the digital peripheral pointed to by the on-chip multiplexing function, or through an HCLK-based synchronizer, present on the input data register `GPIOx_IDR [y]`.

The bits of the `GPIOx_IDR` register and the previous latch form a synchronizer, which can avoid the signal instability caused by the pin level jumping during the system clock change, but it will cause a certain read delay. The synchronization timing of the read port pins is shown in the following figure:

Figure 9-2 Read Port Pin Synchronization Timing



In the clock cycle after the rising edge of the system clock, the pin level signal will be latched in the internal register, as shown in the shaded part in the figure, after the next rising edge of the system clock, the stable pin level signal is read, and then a on the rising edge of the system clock, the data is latched into the `GPIOx_IDR` register. The signal delay T_{pd} is 1~2 system clocks.

The built-in hardware filter circuit can also be enabled if this input signal is considered for triggering an interrupt. The filter circuit is implemented based on a double D flip-flop synchronizer, which has seven clock sources, some of which are specific to the low-power mode. For example, a key debounce operation without software intervention can be easily implemented. For specific clock source options and edge/level trigger options, see section [9.3.6 Interrupt Function](#).

In this mode, the internal pull-up and pull-down functions can be individually selected to be turned on or off through the pull-up resistor register `GPIOx_PUR` and the pull-down resistor register `GPIOx_PDR`.

9.3.4 Analogue function

For a GPIO port configured with analog function, you can open the GPIO analog signal channel by setting the analog digital configuration register `GPIOx_ANALOG[y]` to 1. When the GPIO analog signal channel is turned on, the digital function of the port is turned off, the internal pull-up and pull-down are disconnected, the internal digital input signal is shorted to VSS through the ADS switch, and the internal digital output function is disabled.

9.3.5 Multiplexing function

The multiplexing function of the input and output ports can be realized through the multiplexing function registers (`GPIOx_AFRH` and `GPIOx_AFRL`). Each 4-bit bit field in the multiplexing function register corresponds to the multiplexing function selection of a GPIO port, and up to 16 input and output signal targets can logically be selected. The specific definition of GPIO multiplexing function is shown in the following table:

Table 9-1 GPIO Multiplexing function settings

<code>GPIOx_AFRL[4×y]</code>	Multiplexing function	<code>GPIOx_AFRH[4×(z-8)]</code>	Multiplexing function
0000	GPIO	0000	GPIO
0001	AF1	0001	AF1
0010	AF2	0010	AF2
0011	AF3	0011	AF3
0100	AF4	0100	AF4
0101	AF5	0101	AF5
0110	AF6	0110	AF6
0111	AF7	0111	AF7

Caution:

y, z are pin numbers: y=0~7 corresponding to `GPIOx_AFRL`; z=8~15 corresponding to `GPIOx_AFRH`.

The specific peripheral functions corresponding to each AF are shown in the following table:

Table 9-2 GPIO multiplexing function assignment table

Pin name	Multiplexing function							
	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PA00	GPIO	UART3_CTS	UART6_CTS	RTC_TAMP	VC1_OUT	SPI2_MISO	GTIM2_CH1	GTIM2_ETR
PA01	GPIO	UART3_RTS	UART6_RTS	I2C2_SCL	LVD_OUT	SPI2_MOSI	GTIM2_CH2	RTC_TAMP
PA02	GPIO	UART3_TXD	UART6_TXD	I2C2_SDA	VC2_OUT	SPI2_SCK	GTIM2_CH3	AUTOTRIM_ETR
PA03	GPIO	UART3_RXD	UART6_RXD	GTIM2_CH2	PCLK_OUT	SPI2_CS	GTIM2_CH4	ATIM_CH3A
PA04	GPIO	UART4_TXD	UART2_CTS	I2C2_SCL	HCLK_OUT	SPI1_CS	GTIM2_ETR	ATIM_CH2A
PA05	GPIO	GTIM2_ETR	UART2_RTS	I2C2_SDA	BTIM2_TOGN	SPI1_SCK	GTIM2_CH1	ATIM_CH1A
PA06	GPIO	GTIM3_CH1	UART2_TXD	VC1_OUT	BTIM2_TOGP	SPI1_MISO	GTIM1_CH1	ATIM_BK



Pin name	Multiplexing function							
	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PA07	GPIO	GTIM4_CH1	UART2_RXD	VC2_OUT	BTIM1_TOGN	SPI1_MOSI	GTIM1_CH2	ATIM_CH1B
PA08	GPIO	LPTIM_ETR	UART1_TXD	BTIM2_TOGP	MCO_OUT	LVD_OUT	GTIM3_ETR	ATIM_CH1A
PA09	GPIO	UART3_TXD	UART1_RXD	I2C1_SCL	BTIM1_TOGN	SPI1_CS	GTIM3_CH1	ATIM_CH2A
PA10	GPIO	UART3_RXD	UART1_CTS	I2C1_SDA	BTIM1_TOGP	SPI1_SCK	GTIM3_CH2	ATIM_CH3A
PA11	GPIO	UART3_CTS	UART1_RTS	I2C2_SCL	VC1_OUT	SPI1_MISO	GTIM3_CH3	
PA12	GPIO	UART3_RTS	BTIM_ETR	I2C2_SDA	VC2_OUT	SPI1_MOSI	GTIM3_CH4	ATIM_ETR
PA13	GPIO		I2C1_SDA	UART1_RXD	UART2_TXD	I2C2_SCL	IR_OUT	
PA14	GPIO	UART3_TXD	I2C1_SCL	UART1_TXD	UART2_RXD	I2C2_SDA		
PA15	GPIO	UART3_RXD	GTIM2_CH1	UART1_RXD	UART2_TXD	SPI1_CS	GTIM2_ETR	ATIM_CH1B
PB00	GPIO	UART5_RXD	UART1_CTS	I2C2_SCL	BTIM1_TOGP	HSI_OUT	GTIM1_CH3	ATIM_CH2B
PB01	GPIO	UART5_TXD	UART1_RTS	I2C2_SDA	GTIM4_TOGP	BTIM3_TOGN	GTIM1_CH4	ATIM_CH3B
PB02	GPIO	UART2_CTS	UART1_TXD	LPTIM_OUT	GTIM4_TOGN	BTIM3_TOGP	GTIM1_ETR	ATIM_CH1A
PB03	GPIO	UART3_RTS	GTIM2_CH2	UART4_CTS	UART2_TXD	SPI1_SCK	GTIM1_ETR	ATIM_CH2B
PB04	GPIO	UART3_CTS	GTIM4_ETR	UART4_RTS	UART2_RXD	SPI1_MISO	GTIM1_CH1	ATIM_CH3B
PB05	GPIO	UART4_RXD	GTIM3_CH4	LPTIM_CH1	UART2_RTS	SPI1_MOSI	GTIM1_CH2	ATIM_CH1A
PB06	GPIO	UART6_TXD	GTIM3_CH3	LPTIM_ETR	I2C1_SCL	SPI2_MOSI	GTIM1_TOGP	ATIM_CH2A
PB07	GPIO	UART6_RXD	GTIM3_CH2	LPTIM_CH2	I2C1_SDA	SPI2_MISO	GTIM1_TOGN	ATIM_CH3A
PB08	GPIO	I2C1_SCL	GTIM3_CH1	UART5_TXD	GTIM4_CH2	SPI2_SCK	GTIM1_CH3	ATIM_ETR
PB09	GPIO	I2C1_SDA	GTIM4_CH1	UART5_RXD	IR_OUT	SPI2_CS	GTIM1_CH4	ATIM_BK
PB10	GPIO	UART2_RTS	UART4_RXD	I2C1_SCL	I2C2_SCL	SPI2_SCK	GTIM2_CH3	ATIM_CH2A
PB11	GPIO	GTIM4_ETR	UART4_TXD	I2C1_SDA	I2C2_SDA	BTIM_ETR	GTIM2_CH4	ATIM_CH3A
PB12	GPIO	GTIM2_TOGP	GTIM4_CH4	LSE_OUT	SPI2_CS	SPI1_CS	GTIM1_TOGP	ATIM_BK
PB13	GPIO	GTIM2_TOGN	GTIM4_CH3	I2C2_SCL	SPI2_SCK	SPI1_SCK	GTIM1_TOGN	ATIM_CH1B
PB14	GPIO	GTIM2_CH1	GTIM4_CH2	I2C2_SDA	SPI2_MISO	SPI1_MISO	RTC_OUT	ATIM_CH2B
PB15	GPIO	GTIM2_CH2	GTIM4_CH1	BTIM2_TOGN	SPI2_MOSI	SPI1_MOSI	RTC_1Hz	ATIM_CH3B
PC00	GPIO	UART4_CTS	GTIM2_CH4	SPI1_CS	LPTIM_CH1	UART5_RXD	ATIM_CH1A	I2C2_SCL
PC01	GPIO	UART4_RTS	GTIM2_CH3	SPI1_SCK	LPTIM_OUT	UART5_TXD	ATIM_CH2A	I2C2_SDA
PC02	GPIO	UART4_RXD	GTIM2_CH2	SPI1_MISO	LPTIM_CH2	UART1_TXD	ATIM_CH3A	
PC03	GPIO	UART4_TXD	GTIM2_CH1	SPI1_MOSI	LPTIM_ETR	UART1_RXD	ATIM_BK	
PC04	GPIO	UART1_TXD	UART6_RXD	IR_OUT			LSI_OUT	
PC05	GPIO	UART1_RXD	UART6_TXD	MCO	LPTIM_ETR	LPTIM_OUT		
PC06	GPIO	UART4_RXD	UART3_TXD	BTIM2_TOGP		GTIM2_CH4	ATIM_CH1B	
PC07	GPIO	UART4_TXD	UART3_RXD	BTIM2_TOGN		GTIM2_CH3	ATIM_CH2B	



Pin name	Multiplexing function							
	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PC08	GPIO	UART4_CTS	UART6_TXD	GTIM4_ETR		GTIM2_CH2	ATIM_CH3B	
PC09	GPIO	UART4_RTS	UART6_RXD	I2C1_SDA		GTIM2_CH1	ATIM_ETR	
PC10	GPIO	UART4_TXD	GTIM3_CH1	HCLK_OUT	BTIM1_TOGP	VC1_OUT	LPTIM_CH1	ATIM_CH2B
PC11	GPIO	UART4_RXD	GTIM3_CH2	IR_OUT	BTIM1_TOGN	VC2_OUT	LPTIM_CH2	ATIM_CH3B
PC12	GPIO	UART5_TXD	PCLK_OUT	LVD_OUT	UART6_RXD	PLL_OUT	HSI_OUT	
PC13	GPIO	PLL_OUT	RTC_1Hz	UART1_CTS	RTC_OUT	BTIM_ETR	GTIM3_ETR	RTC_TAMP
PC14	GPIO	AUTOTRIM_ETR	GTIM4_CH4	UART1_RTS	UART4_TXD	SPI2_MISO	GTIM3_TOGP	GTIM3_CH1
PC15	GPIO	HSE_OUT	GTIM4_CH3	GTIM4_ETR	UART4_RXD	SPI2_MOSI	GTIM3_TOGN	GTIM3_CH2
PD00	GPIO	UART6_RXD		I2C2_SCL	AUTOTRIM_ETR	SPI2_CS	MCO_OUT	
PD01	GPIO	UART6_TXD		I2C2_SDA	RTC_1Hz	SPI2_SCK	RTC_TAMP	
PD02	GPIO	UART5_RXD	GTIM4_CH1	BTIM_ETR	UART6_TXD	RTC_1Hz	GTIM3_ETR	ATIM_ETR
PD03	GPIO	UART6_CTS		I2C2_SCL	VC1_OUT	SPI2_MISO	GTIM1_CH3	ATIM_BK
PD04	GPIO	UART6_RTS		I2C2_SDA	VC2_OUT	SPI2_MOSI	GTIM1_CH4	ATIM_CH3A
PD05	GPIO	UART4_TXD	GTIM2_CH1	UART3_TXD	LPTIM_CH1	BTIM2_TOGP	LSI_OUT	ATIM_CH2A
PD06	GPIO	I2C1_SCL	GTIM2_CH4	UART3_RXD	LPTIM_CH2	BTIM2_TOGN	GTIM2_TOGP	ATIM_CH1A
PD07	GPIO	I2C1_SDA	GTIM2_CH3	MCO_OUT	UART2_RXD	SPI1_CS	GTIM2_TOGN	ATIM_CH1B
PD08	GPIO	GTIM2_CH3	LPTIM_OUT	UART1_TXD	SPI2_CS	GTIM1_CH1	ATIM_CH1A	
PD09	GPIO	GTIM2_CH4	LPTIM_CH2	UART1_RXD	SPI2_SCK	GTIM1_CH2	ATIM_CH2A	
PD10	GPIO	UART5_TXD	LPTIM_CH1	GTIM4_CH1	SPI2_MISO	GTIM1_CH3	ATIM_CH3A	
PD11	GPIO	UART5_RXD	LPTIM_ETR	GTIM4_CH2	SPI2_MOSI	GTIM1_CH4	ATIM_BK	
PD12	GPIO	UART5_CTS	UART4_RXD	GTIM4_CH3	SPI1_CS	BTIM3_TOGP	AUTOTRIM_ETR	
PD13	GPIO	UART5_RTS	UART4_TXD	GTIM4_CH4	SPI1_SCK	BTIM3_TOGN		
PD14	GPIO	UART2_TXD	HCLK_OUT	GTIM2_ETR	SPI1_MISO			
PD15	GPIO	UART2_RXD	PCLK_OUT	BTIM_ETR	SPI1_MOSI			
PE00	GPIO	I2C2_SCL	GTIM4_CH2	LPTIM_ETR	PCLK_OUT	GTIM2_TOGP	GTIM1_CH1	GTIM4_TOGP
PE01	GPIO	I2C2_SDA	GTIM4_CH3	LPTIM_OUT	HCLK_OUT	GTIM2_TOGN	GTIM1_CH2	GTIM4_TOGN
PE02	GPIO	LPTIM_ETR		LVD_OUT	IR_OUT	GTIM1_ETR	ATIM_BK	
PE03	GPIO	LPTIM_CH1	UART5_RXD	I2C2_SCL	SPI1_CS	GTIM1_CH4	ATIM_CH1B	
PE04	GPIO	LPTIM_CH2	UART5_TXD	I2C2_SDA	SPI1_SCK	GTIM1_CH3	ATIM_CH2B	
PE05	GPIO		UART5_CTS	UART6_RXD	SPI1_MISO	GTIM1_CH2	ATIM_CH3B	
PE06	GPIO		UART5_RTS	UART6_TXD	SPI1_MOSI	GTIM1_CH1	ATIM_ETR	
PE07	GPIO	UART2_RTS	LPTIM_CH1	GTIM1_CH4	GTIM4_ETR	BTIM_ETR	ATIM_CH2A	



Pin name	Multiplexing function							
	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PE08	GPIO	UART1_TXD	LPTIM_CH2	GTIM1_CH3	SPI1_CS	GTIM4_CH1	ATIM_CH3A	
PE09	GPIO	UART1_RXD	LPTIM_OUT	GTIM1_ETR	SPI1_SCK	GTIM3_CH1	ATIM_BK	
PE10	GPIO	UART4_TXD	LPTIM_ETR	GTIM1_CH2	SPI1_MISO	GTIM3_CH2	ATIM_ETR	
PE11	GPIO	UART4_RXD	UART1_RXD	GTIM1_CH1	SPI1_MOSI	GTIM3_CH3		
PE12	GPIO	UART3_TXD		GTIM2_CH4	SPI2_CS	GTIM3_CH4	ATIM_CH1B	
PE13	GPIO	UART3_RXD		GTIM2_CH3	SPI2_SCK	GTIM4_CH2	ATIM_CH2B	
PE14	GPIO	UART2_TXD		GTIM2_CH2	SPI2_MISO	GTIM4_CH3	ATIM_CH3B	
PE15	GPIO	UART2_RXD		GTIM2_CH1	SPI2_MOSI	GTIM4_CH4	ATIM_BK	
PF00	GPIO	AUTOTRIM_ETR	GTIM4_CH2	I2C1_SDA	BTIM1_TOGN	SPI2_SCK	GTIM2_TOGP	GTIM3_CH3
PF01	GPIO	LSE_OUT	GTIM4_CH1	I2C1_SCL	BTIM1_TOGP	SPI2_CS	GTIM2_TOGN	GTIM3_CH4
PF02	GPIO	UART5_CTS		LVD_OUT	LSI_OUT	GTIM3_TOGP	MCO_OUT	
PF04	GPIO	UART1_TXD	GTIM4_CH2		UART5_RXD			
PF05	GPIO	UART1_RXD	BTIM_ETR		UART5_TXD	AUTOTRIM_ETR		
PF06	GPIO	UART6_CTS	I2C1_SCL	GTIM4_TOGP	UART2_CTS	I2C2_SCL	GTIM3_TOGP	BTIM3_TOGN
PF07	GPIO	UART6_RTS	I2C1_SDA	GTIM4_TOGN	UART2_RTS	I2C2_SDA	GTIM3_TOGN	BTIM3_TOGP
PF08	GPIO	UART5_RTS		PLL_OUT	PCLK_OUT	GTIM3_TOGN		
PF09	GPIO	UART2_TXD	UART3_RXD		BTIM3_TOGP	RTC_OUT	GTIM1_CH1	HCLK_OUT
PF10	GPIO	UART2_RXD	UART3_TXD		BTIM3_TOGN	HSI_OUT	GTIM1_CH2	MCO_OUT



9.3.6 Interrupt Function

When each GPIO is set to digital input mode, it can be used as an external interrupt signal source, and the interrupt signal source can be set to four types: high level, low level, rising edge, and falling edge. Interrupt triggering methods can be used in combination, but share the same interrupt flag bit.

After the interrupt is triggered, the corresponding bit of the interrupt flag register GPIOx_ISR will be set by hardware, and the program can determine which port generated the interrupt by querying GPIOx_ISR. Through the interrupt flag clear register GPIOx_ICR[y], the corresponding interrupt flag bit can be cleared.

The internal interrupt digital filter can digitally filter the input signal on the pin, providing 8 filter clock options, as shown in the following table:

Table 9-3 Digital Filter Clock Selection

GPIOx_FILTER.FLTCLK	Digital Filter Clock Frequency
000	HCLK / 2
001	HCLK / 4
010	HCLK / 8
011	BTIM1 overflow
100	RC150K (About 150kHz)
101	LSI (About 32.8kHz)
110	RC10K (About 10kHz)
111	PWM output of LPTIM

Due to the wide range of selected filter clock cycles, users can easily implement flexible input interrupt debounce functions. Changes in input levels that are not maintained for more than one full filter clock cycle will not be communicated through the hardware filter to the internal interrupt trigger circuitry. Changes in input levels that persist for more than two complete filter clock cycles must pass through the hardware filter.

For the edge trigger type, considering the sensitivity to the time of the trigger edge, it is recommended to disable the hardware filter function in the interrupt digital filter configuration register GPIOx_FILTER[y], because the hardware filter can improve signal stability while also inserting certain delay.

When CW32L083 works in Sleep mode or DeepSleep mode, the external interrupt function of GPIO can still be used. When an external interrupt is generated, the chip can be woken up from Sleep mode or DeepSleep mode to Active mode.

Caution:

The same group of GPIOx.PINy shares a hardware filter clock source selection register, so the same group of GPIOs can only filter input signal jitter with the same filter clock.



9.3.7 Other functions

Atomic bit operation

The GPIO controller supports bit-setting, bit-clearing and bit-flipping functions.

Writing 1 to the GPIO bit clear register GPIOx_BSRR[y] or the bit clear register GPIOx_BRR[y] will directly change the state of the corresponding bit of the output data register GPIOx_ODR, thereby indirectly affecting the final output level without affecting the Status of other bits in this register.

Writing 1 to the GPIO bit toggle register GPIOx_TOG[y] will toggle the level state of the output port.

Port configuration lock

When the corresponding bit of the configuration lock register GPIOx_LCKR is set to 1, the corresponding bit of the configuration register cannot be modified, including the following configuration registers:

GPIOx_ANALOG、GPIOx_DIR、GPIOx_OPENDRAIN、GPIOx_PUR、GPIOx_PDR、GPIOx_AFRH、GPIOx_AFRL、GPIOx_RISEIE、GPIOx_FALLIE、GPIOx_HIGHIE、GPIOx_LOWIE.

After the GPIO initialization is completed, the user can lock the corresponding bits of the configuration lock register of the important port to prevent the program from running away and the abnormal operation of the port.

Example:

Write 0x5A5A0201 to GPIOA_LCKR to unlock the port-related configuration registers of GPIOA except PA09 and PA00, and at the same time, lock the port-related configuration registers of PA09 and PA00.

Port reset state

After power-on or reset, SWCLK (PA14) and SWDIO (PA13) default to digital pull-up, BOOT (PF03) default to digital function. Other ports are analog high-resistance input by default, and pull-up or pull-down are not turned on by default.



9.4 Programming example

When configuring the GPIO port, you must first set `SYSCTRL_AHBEN.GPIOx` to 1, enable the corresponding GPIO configuration clock and working clock, and write '0x5A5Aiiii' to the `GPIOx_LCKR` lock register to unlock the GPIO related configuration registers. If necessary, the `GPIOx_LCKR` lock register can be set to protect the settings from accidental rewriting.

9.4.1 Digital output programming example

Step 1: Set `GPIOx_ANALOG.PINy` to 0 to configure the port as a digital function;

Step 2: Set `GPIOx_DIR.PINy` to 0, configure the port as output;

Step 3: Configure the `GPIOx_OPENDRAIN` register to set the port output mode;

Step 4: Configure the `GPIOx_ODR` register to set the port output level.

9.4.2 Digital input programming example

Step 1: Set `GPIOx_ANALOG.PINy` to 0, configure the port as a digital function;

Step 2: Set `GPIOx_DIR.PINy` to 1, configure the port as input;

Step 3: Configure the `GPIOx_PUR` register and select whether to enable the internal pull-up resistor;

Step 4: Configure `GPIOx_PDR` register, select whether to enable the internal pull-down resistor;

Step 5: Read the `GPIOx_IDR` register and read the port input level.

9.4.3 Analog functional programming example

Step 1: Set `GPIOx_ANALOG.PINy` to 1 to configure the port for analog function.

9.4.4 Multiplexed function programming example

Step 1: Configure the port as digital output or digital input according to application requirements. For specific register configuration steps, please refer to section [9.4.1 Digital output programming example](#) and section [9.4.2 Digital input programming example](#);

Step 2: Configure the `GPIOx_AFRH` or `GPIOx_AFRL` register to set the port multiplexing function, see [Table 9-2 GPIO multiplexing function assignment table](#).



9.4.5 Interrupt function programming example

- Step 1: Configure the port as a digital input. For the specific register configuration steps, see section [9.4.2 Digital input programming example](#);
- Step 2: Configure GPIOx_FILTER.FLTCLK, and select the port interrupt filter clock;
- Step 3: Set GPIOx_FILTER.PINy to 1 to enable the corresponding port filter Clock;
- Step 4: Configure the NVIC controller, see chapter [5 Interrupt](#);
- Step 5: Configure the GPIOx_RISEIE, GPIOx_FALLIE, GPIOx_HIGHIE, GPIOx_LOWIE registers according to the application requirements, and select the GPIO interrupt trigger mode;
- Step 6: The port interrupt input signal triggers the GPIO interrupt, execute the interrupt service function.



9.5 List of registers

GPIOA base address: GPIOA_BASE = 0x4800 0000

GPIOB base address: GPIOB_BASE = 0x4800 0400

GPIOC base address: GPIOC_BASE = 0x4800 0800

GPIOD base address: GPIOD_BASE = 0x4800 0C00

GPIOE base address: GPIOE_BASE = 0x4800 1000

GPIOF base address: GPIOF_BASE = 0x4800 1400

Table 9-4 List of GPIO registers

Register name	Register address	Register description
GPIOx_DIR	GPIOx_BASE + 0x00	GPIOx I/O direction register
GPIOx_OPENDRAIN	GPIOx_BASE + 0x04	GPIOx output mode register
GPIOx_PDR	GPIOx_BASE + 0x0C	GPIOx pull-down Resistor Register
GPIOx_PUR	GPIOx_BASE + 0x10	GPIOx pull-up Resistor Register
GPIOx_AFRH	GPIOx_BASE + 0x14	GPIOx Multiplexing function register high segment
GPIOx_AFRL	GPIOx_BASE + 0x18	GPIOx Multiplexing function register low segment
GPIOx_ANALOG	GPIOx_BASE + 0x1C	GPIOx Analog Digital Configuration Register
GPIOx_RISEIE	GPIOx_BASE + 0x24	GPIOx Rising edge interrupt enable register
GPIOx_FALLIE	GPIOx_BASE + 0x28	GPIOx Falling edge interrupt enable register
GPIOx_HIGHIE	GPIOx_BASE + 0x2C	GPIOx High level interrupt enable register
GPIOx_LOWIE	GPIOx_BASE + 0x30	GPIOx Low level interrupt enable register
GPIOx_ISR	GPIOx_BASE + 0x34	GPIOx Interrupt flag register
GPIOx_ICR	GPIOx_BASE + 0x38	GPIOx Interrupt flag clear register
GPIOx_LCKR	GPIOx_BASE + 0x3C	GPIOx Configuration lock register
GPIOx_FILTER	GPIOx_BASE + 0x40	GPIOx Interrupt digital filter configuration register
GPIOx_IDR	GPIOx_BASE + 0x50	GPIOx input data register
GPIOx_ODR	GPIOx_BASE + 0x54	GPIOx output data register
GPIOx_BRR	GPIOx_BASE + 0x58	GPIOx bit clear register
GPIOx_BSRR	GPIOx_BASE + 0x5C	GPIOx bit-setting clear register
GPIOx_TOG	GPIOx_BASE + 0x60	GPIOx bit flip register



9.6 Register description

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

9.6.1 GPIOx_DIR GPIO I/O direction register (x =A, B, C, D, E, F)

Address offset: 0x00 Reset value: 0x0000 FFFF(GPIOA)

0x0000 FFFF(GPIOB)

0x0000 FFFF(GPIOC)

0x0000 FFFF(GPIOD)

0x0000 FFFF(GPIOE)

0x0000 07FF(GPIOF)

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port input and output direction control 0: Configure the port as output 1: Configure the port as input

9.6.2 GPIOx_OPENDRAIN GPIO output mode register (x =A, B, C, D, E, F)

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port output mode control bit 0: Push-pull output 1: Open-drain output



9.6.3 GPIOx_PDR GPIO Pull-down resistor register (x =A, B, C, D, E, F)

Address offset: 0x0C Reset value: 0x0000 0000(GPIOA)

0x0000 0000(GPIOB)

0x0000 0000(GPIOC)

0x0000 0000(GPIOD)

0x0000 0000(GPIOE)

0x0000 0008(GPIOF)

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port pull-down resistor enable control 0: Disable pull-down resistors 1: Enable pull-down resistors Caution: When GPIOx_PDR.PINy and GPIOx_PUR.PINy are set to 1 at the same time, the port state is to enable the pull-up resistor.

9.6.4 GPIOx_PUR GPIO Pull-up resistor register (x =A, B, C, D, E, F)

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port pull-up resistor enable control 0: Disable pull-up resistors 1: Enable pull-up resistors Caution: When GPIOx_PDR.PINy and GPIOx_PUR.PINy are set to 1 at the same time, the port state is to enable the pull-up resistor.



9.6.5 GPIOx_AFRH GPIO Multiplexing function register high segment (x =A, B, C, D, E, F)

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:28 27:24 23:20 19:16 15:12 11:8 7:4 3:0	AFRy y = 8 ~ 15	RW	Port digital multiplexing function control 0000: GPIO 0001: AF1 0010: AF2 0011: AF3 0100: AF4 0101: AF5 0110: AF6 0111: AF7

9.6.6 GPIOx_AFRL GPIO Multiplexing function register low segment (x =A, B, C, D, E, F)

Address offset: 0x18 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:28 27:24 23:20 19:16 15:12 11:8 7:4 3:0	AFRy y = 0 ~ 7	RW	Port digital multiplexing function control 0000: GPIO 0001: AF1 0010: AF2 0011: AF3 0100: AF4 0101: AF5 0110: AF6 0111: AF7

9.6.7 GPIOx_ANALOG GPIO Analog Digital Configuration Register (x =A, B, C, D, E, F)

Address offset: 0x1C Reset value: 0x0000 9FFF(GPIOA)

0x0000 FFFF(GPIOB)

0x0000 FFFF(GPIOC)

0x0000 FFFF(GPIOD)

0x0000 FFFF(GPIOE)

0x0000 07F7(GPIOF)

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port analog/digital function configuration 0: Configure the port as a digital function 1: Configure the port as an analog function



9.6.8 GPIOx_RISEIE GPIO Rising edge interrupt enable register (x =A, B, C, D, E, F)

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port rising edge interrupt enable control 0: Disable the rising edge interrupt of the corresponding port 1: Enable the rising edge interrupt of the corresponding port

9.6.9 GPIOx_FALLIE GPIO Falling edge interrupt enable register (x =A, B, C, D, E, F)

Address offset: 0x28 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port falling edge interrupt enable control 0: Disable the falling edge interrupt of the corresponding port 1: Enable the falling edge interrupt of the corresponding port

9.6.10 GPIOx_HIGHIE GPIO High level interrupt enable register (x =A, B, C, D, E, F)

Address offset: 0x2C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port high level interrupt enable control 0: Disable the high-level interrupt of the corresponding port 1: Enable the high-level interrupt of the corresponding port



9.6.11 GPIOx_LOWIE GPIO Low level interrupt enable register (x =A, B, C, D, E, F)

Address offset: 0x30 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Port low level interrupt enable control 0: Disable the low-level interrupt of the corresponding port 1: Enable the low-level interrupt of the corresponding port

9.6.12 GPIOx_ISR GPIO Interrupt flag register (x =A, B, C, D, E, F)

Address offset: 0x34 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RO	Port interrupt status flag 0: Enabled interrupt not detected 1: Enabled interrupt has been detected

9.6.13 GPIOx_ICR GPIO Interrupt flag clear register (x =A, B, C, D, E, F)

Address offset: 0x38 Reset value: 0x0000 FFFF(GPIOA)

0x0000 FFFF(GPIOB)

0x0000 FFFF(GPIOC)

0x0000 FFFF(GPIOD)

0x0000 FFFF(GPIOE)

0x0000 07FF(GPIOF)

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	R1W0	Port interrupt status flag clear W0: Clear the corresponding interrupt flag bit W1: No function



9.6.14 GPIOx_LCKR GPIO Configuration lock register (x =A, B, C, D, E, F)

Address offset: 0x3C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	KEY	WO	Only when KEY is 0x5A5A, the write operation of this register is valid
15:0	PINy y=0 ~ 15	RW	Port configuration lock 0: The corresponding bits of the configuration register can be modified 1: The corresponding bits of the configuration register can not be modified Caution: The configuration registers are as follows: GPIOx_ANALOG、GPIOx_DIR、GPIOx_OPENDRAIN、GPIOx_PDR、GPIOx_PUR、GPIOx_AFRH、GPIOx_AFRL、GPIOx_RISEIE、GPIOx_FALLIE、GPIOx_HIGHIE、GPIOx_LOWIE

9.6.15 GPIOx_FILTER GPIO Interrupt digital filter configuration register (x =A, B, C, D, E, F)

Address offset: 0x40 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:19	RFU	-	Reserved bits, please keep the default value
18:16	FLTCLK	RW	Port interrupt filter clock selection 000: HCLK / 2 001: HCLK / 4 010: HCLK / 8 011: BTIM1 overflow 100: RC150K (About 150KHz) 101: LSI (About 32.8KHz) 110: RC10K (About 10KHz) 111: PWM output of LPTIM
15:0	PINy y=0 ~ 15	RW	Port filter clock enable control 0: Disable the corresponding port to filter the clock 1: Enable the corresponding port to filter the clock Caution: Filter out pulses with a width less than the FLTCLK clock width



9.6.16 GPIOx_IDR GPIO input data register (x =A, B, C, D, E, F)

Address offset: 0x50 Reset value: 0x0000 6000(GPIOA)

0x0000 0000(GPIOB)

0x0000 0000(GPIOC)

0x0000 0000(GPIOD)

0x0000 0000(GPIOE)

0x0000 0000(GPIOF)

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RO	Read port input level status 0: The port is low level 1: The port is high level

9.6.17 GPIOx_ODR GPIO output data register (x =A, B, C, D, E, F)

Address offset: 0x54 Reset value: 0x---- ----

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	RW	Set the port output level 0: Set port output low level 1: Set port output high level

9.6.18 GPIOx_BRR GPIO port bit set clear register (x =A, B, C, D, E, F)

Address offset: 0x58 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	BRRy y=0 ~ 15	R0W1	Port bit clear control 0: Does not affect the corresponding bits of the GPIOx_ODR register 1: Set the corresponding bit of the GPIOx_ODR register to 0



9.6.19 GPIOx_BSRR GPIO port bit-setting clear register (x =A, B, C, D, E, F)

Address offset: 0x5C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	BRRy y=0 ~ 15	R0W1	Port bit-setting clear control 0: Does not affect the corresponding bits of the GPIOx_ODR register 1: Set the corresponding bit of the GPIOx_ODR register to 0
15:0	BSSy y=0 ~ 15	R0W1	Port bit-setting control 0: Does not affect the corresponding bits of the GPIOx_ODR register 1: Set the corresponding bit of the GPIOx_ODR register to 1 Caution: When BRRy and BSSy are both set 1, BSSy has higher priority

9.6.20 GPIOx_TOG GPIO Port Bit Flip Register (x =A, B, C, D, E, F)

Address offset: 0x60 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PINy y=0 ~ 15	R0W1	Port Bit Flip Control 0: Does not affect the corresponding bits of the GPIOx_ODR register 1: Invert the corresponding bit of the GPIOx_ODR register



10 Cyclic redundancy check (CRC)

10.1 Overview

Cyclic Redundancy Check (CRC) is mainly used to verify the correctness and integrity of data transmission or data storage. The CW32L083 integrates a CRC calculation unit, which supports the use of multiple CRC algorithms to perform CRC calculation on the input data.

10.2 Main features

- 8bit input data bit width
- Two kinds of polynomials
CRC-16 polynomial 1: $x^{16} + x^{15} + x^2 + 1$
CRC-16 polynomial 2: $x^{16} + x^{12} + x^5 + 1$
- Eight kinds of commonly used algorithms
Combination based on polynomial, initial value, result XOR value, input/output inversion



10.3 Functional description

The CRC unit obtains the CRC calculation result by performing a 'division' operation on the input data (or the inversion of the input data) and the selected polynomial value, and then inverting or not inverting the obtained remainder, as well as XOR processing.

Before the CRC unit is used, it is necessary to set SYSCTRL_AHBEN.CRC to 1, and turn on the configuration clock and working clock of the CRC unit, which are generally set during system initialization.

10.3.1 Algorithmic modes

The CRC unit of CW32L083 supports multiple algorithm modes. Different CRC algorithms have different parameters such as polynomial, initial value, input data inversion, output data inversion, and result XOR value, as shown in the following table:

Table 10-1 CRC algorithm modes

Algorithm name	Polynomial value	Initial value	Input inversion	Output inversion	Result XOR value
CRC16_IBM	0x8005	0x0000	True	True	0x0000
CRC16_MAXIM	0x8005	0x0000	True	True	0xFFFF
CRC16_USB	0x8005	0xFFFF	True	True	0xFFFF
CRC16_MODBUS	0x8005	0xFFFF	True	True	0x0000
CRC16_CCITT	0x1021	0x0000	True	True	0x0000
CRC16_CCITT_False	0x1021	0xFFFF	False	False	0x0000
CRC16_X25	0x1021	0xFFFF	True	True	0xFFFF
CRC16_XMODEM	0x1021	0x0000	False	False	0x0000



The meaning of each parameter is as follows:

- Polynomial value

The polynomial is the description of the code group, such as CRC-16 polynomial 2: $x^{16} + x^{12} + x^5 + 1$, the corresponding code group is 1 0001 0000 0010 0001. Because the highest bit of the polynomial code group is fixed to 1, and the position of the highest bit is known, the code group after removing the highest bit 1 is generally called a polynomial value. For example, the value of CRC-16 polynomial 2 is 0001 0000 0010 0001, that is 0x1021.

- Initial value

The initial value of the CRC register before calculating the CRC check value.

- Input data inversion

That is, before the calculation starts, the high and low order bits of the data that need to calculate the CRC check value are reversed, such as the data bit 1011, which is 1101 after the inversion.

- Output data inversion

After the CRC calculation is completed, before the XOR value is performed with the result, the high and low order bits of the calculated value are reversed. If the calculation result is 1011, it will be 1101 after inversion.

- Result XOR value

After the CRC calculation is completed, the obtained CRC calculation value is XORed with the result XOR value to obtain the final CRC check value.



10.3.2 Input data bit width

The CRC calculation unit supports 8bit input data bit width. When inputting data, input the low byte first and then the high byte.

For example, the user needs to calculate the CRC check value of the group of data 0x00, 0x11, 0x22, 0x33, 0x44, 0x55, 0x66, 0x77, and the writing sequence is 0x00, 0x11, 0x22, 0x33, 0x44, 0x55, 0x66, 0x77

Code example:

```
CW_CRC -> DR = 0x00 ;  
CW_CRC -> DR = 0x11 ;  
CW_CRC -> DR = 0x22 ;  
CW_CRC -> DR = 0x33 ;  
CW_CRC -> DR = 0x44 ;  
CW_CRC -> DR = 0x55 ;  
CW_CRC -> DR = 0x66 ;  
CW_CRC -> DR = 0x77 ;
```



10.4 Programming examples

10.4.1 CRC16_CCITT algorithm mode

Step 1: Set CRC_CR.MODE to 0x04, select the CRC16_CCITT algorithm mode, and the initial value of the CRC register is automatically configured by hardware to 0x0000;

Step 2: Write the raw data to be encoded into the data register CRC_DR in turn, and the input data bit width can be selected from 8bit, 16bit, and 32bit. See the code example in section [10.3.2 Input data bit width](#);

Step 3: Read CRC_RESULT to get the CRC check value.

Code example:

```
tempdata = CW_CRC -> RESULT ;
```



10.5 List of registers

CRC base address: CRC_BASE = 0x4002 3000

Table 10-2 List of CRC registers

Register name	Register address	Register description
CRC_CR	CRC_BASE + 0x00	Control register
CRC_DR	CRC_BASE + 0x08	Data register
CRC_RESULT	CRC_BASE + 0x0C	Result register



10.6 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

10.6.1 CRC_CR control register

Address offset: 0x00 Reset value: 0x0000 0004

Bit field	Name	Permission	Function description
31:4	RFU	-	Reserved bits, please keep the default value
3:0	MODE	RW	CRC algorithm mode configuration 0000: CRC16_IBM 0001: CRC16_MAXIM 0010: CRC16_USB 0011: CRC16_MODBUS 0100: CRC16_CCITT 0101: CRC16_CCITT_False 0110: CRC16_X25 0111: CRC16_XMODEM

10.6.2 CRC_DR data register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	DR	RW	Data write register, bit width 8bit

10.6.3 CRC_RESULT result register

Address offset: 0x0C Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	CRC calculation result



11 Clock Calibration Timer (AUTOTRIM)

11.1 Overview

The clock calibration timer (AUTOTRIM) has 2 working modes: Automatic wake-up timer mode and clock calibration timer mode. In automatic wake-up timer mode, it has a general timing function and can choose from 5 counting clock sources. When the counter clock source is LSE or LSI, it can keep running in deep sleep mode, and the counter underflow interrupt can wake up the MCU and return to running mode. In clock calibration timer mode, it supports HSIOSC/LSI automatic real-time calibration and automatic single calibration, so that the accuracy of HSIOSC/LSI output frequency is no longer affected by environmental changes.

11.2 Main features

- 16bit counter
- Programmable Prescaler: 2, 4, ..., 32768 frequency division
- Automatic wake-up timer mode
 - 5 count clock sources: LSE/HSE/LSI/HSIOSC/ETR
 - Support to keep running in deep sleep mode, interrupt wake-up MCU
 - When the counting clock source is LSI, the wake-up period is 60μs~65536s
- Clock Calibration Timer Mode
 - Support HSIOSC/LSI automatic real-time calibration
 - Support HSIOSC/LSI automatic single calibration



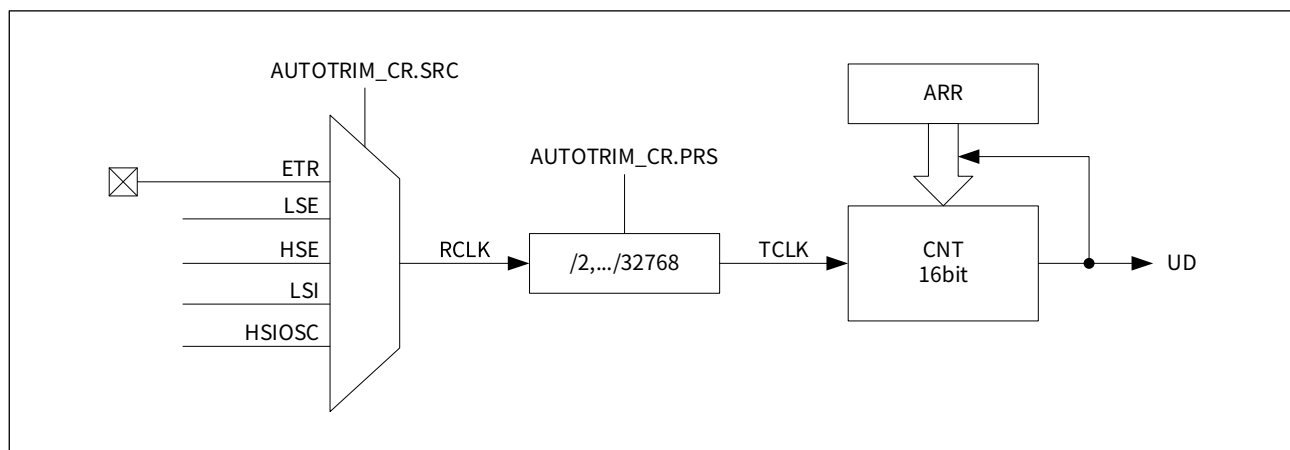
11.3 Functional description

11.3.1 Automatic wake-up timer mode

Set AUTOTRIM_CR.MD to 0x03 to make the timer work in automatic wake-up timer mode. This mode has a general timing function, and when the counter clock source is LSE or LSI, the timer can keep running in deep sleep mode, and the counter underflow interrupt can wake the MCU back to active mode.

The functional block diagram of the automatic wake-up timer mode is shown in the following figure:

Figure 11-1 Automatic wake-up timer mode functional block diagram



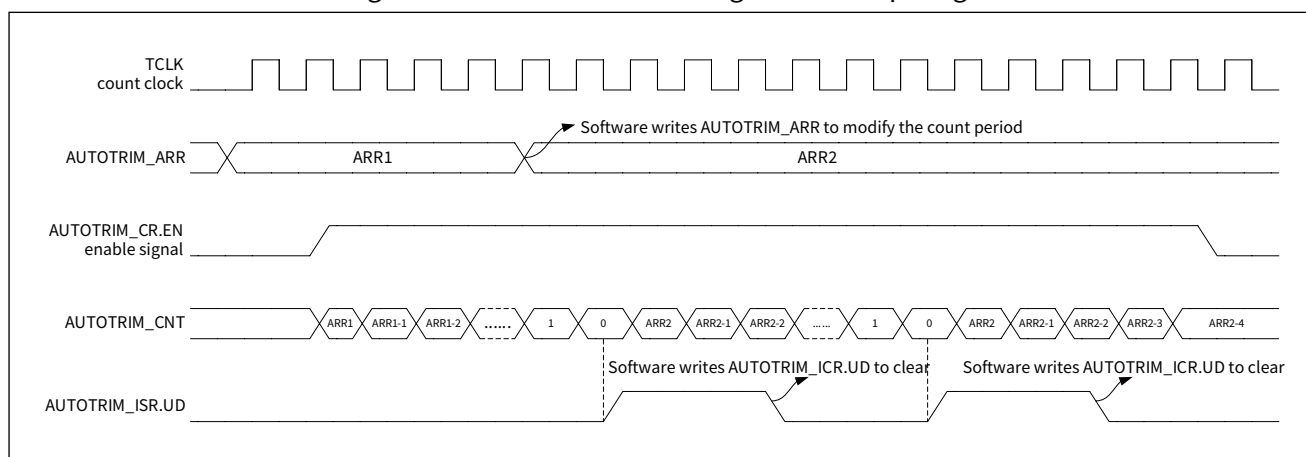
In this mode, 5 kinds of counter clock sources RCLK can be selected: LSE/HSE/LSI/HSIOSC and the ETR signal input from the external AUTOTRIM_ETR pin, which is selected by the SRC bit field of the control register AUTOTRIM_CR. The clock source is divided by the prescaler as the counter clock, and the specific frequency division coefficient is selected through the PRS bit field of the AUTOTRIM_CR register.

Set AUTOTRIM_CR.EN to 1 to enable the timer, and the counter CNT starts to count down from the reload value ARR under the drive of the counting clock TCLK. When it decreases to 0, an underflow occurs, and the underflow interrupt flag bit AUTOTRIM_ISR.UD will be set by hardware bit, the counter CNT reloads the value of the ARR register and restarts the countdown for the next cycle.

The user can set the value of the reload value register ARR at any time, but it does not affect the current count value of CNT, and the newly set value will take effect in the next timing or counting cycle.

The count timing diagram is shown in the following figure:

Figure 11-2 AUTOTRIM counting and interrupt flags



Timing time T calculation formula:

$$T = (2^{\text{PRS}} / \text{RCLK}) \times (\text{ARR} + 1)$$

Among them, RCLK is the counter clock source, PRS is the prescaler coefficient, and ARR is the reload value.

Example:

When the counter clock source RCLK is LSE (the clock frequency is 32768Hz), the timing is required to be 200ms.

If the prescaler coefficient PRS is set to 0x01, calculate

$$T = 200 \text{ ms} = (2^1 / 32768) \times (\text{ARR} + 1)$$

that

ARR=3275.8, the nearest integer is: 3276 (0xCCC)

That is, it is necessary to set the reload value ARR to 0xCCC.

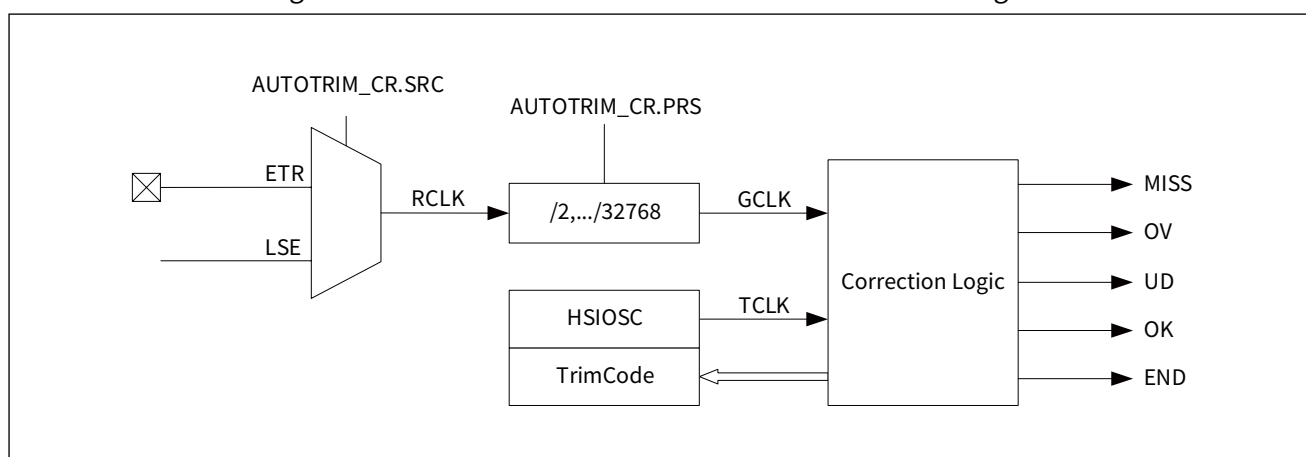
11.3.2 HSIOSC Clock Calibration Mode

Set AUTOTRIM_CR.MD to 0x00 to make the timer work in HSIOSC calibration mode. This mode supports automatic real-time calibration of the output frequency of the HSIOSC, so that the accuracy of the output frequency of the HSIOSC is no longer affected by environmental changes.

The HSIOSC clock calibration needs to provide a precise low-frequency reference clock to the timer. The source can be the low-speed precise clock signal input from the LSE or external ETR pin, which is selected by the SRC bit field of the control register AUTOTRIM_CR.

The functional block diagram of the HSIOSC calibration mode is shown in the following figure:

Figure 11-3 HSIOSC Calibration Mode Functional Block Diagram



Set AUTOTRIM_CR.AUTO to 1 to enable automatic calibration, set AUTOTRIM_CR.EN to 1 to enable the timer and start the automatic calibration process.

After the automatic calibration starts to work, the count value register AUTOTRIM_CNT counts down the HSIOSC clock TCLK from the reload value ARR in each GCLK clock cycle, and starts to count up after the count reaches 0. When the counter has run for 1.5 times of ARR period, the counter stops running, and the AUTOTRIM_ISR.MISS flag is set to 1 by hardware, indicating that the counting fails. Each time the rising edge of the GCLK clock arrives, the counter restarts counting down from ARR.

If the count value of the counter is greater than the allowable error value AUTOTRIM_FLIM within the GCLK clock cycle, the TrimCode will be adjusted automatically until the count value of the counter is less than the allowable error value AUTOTRIM_FLIM, and the AUTOTRIM_ISR.OK flag will be set to 1 by hardware, indicating that the calibration accuracy has reached the standard, the TrimCode register can be read and written to SYSCTRL_HSI.TRIM to calibrate the HSIOSC clock frequency.

The maximum value of the TrimCode register can be adjusted to 0x1FF, so when the TrimCode value is written to SYSCTRL_HSI.TRIM, the highest 2 bits need to be written according to the initial calibration value of the TRIM bit field. The code example is as follows:

```
CW_SYSCTRL->HSI = (CW_SYSCTRL->HSI & 0xFE00) | CW_AUTOTRIM->TVAL;
```

The allowable error value FLIM is automatically configured when the reload value ARR is set, and the calibration accuracy is 0.4%, which cannot be written by the user. The formula for setting the reload register AUTOTRIM_ARR is as follows:

$$ARR = TCLK \times 2^{PRS} / RCLK - 1$$

Among them, RCLK is the reference clock source, PRS is the prescale factor, and TCLK is the count clock source HSIOSC clock.

Example:

When the reference clock source RCLK is LSE (the clock frequency is 32768Hz), the prescaler coefficient PRS is 0x1, the calibration HSIOSC clock frequency is 48MHz. Calculate

$$ARR = 48000000 \times 2^1 / 32768 - 1 = 2928.6875$$

The closest integer is: 2929 (0xB71)

That is, you need to set AUTOTRIM_ARR to 0xB71.

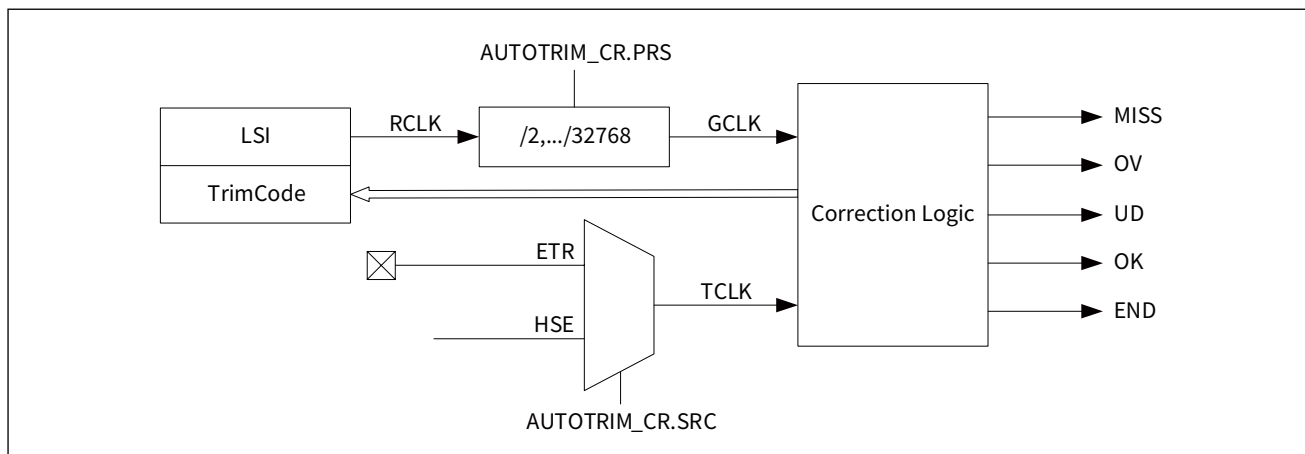
11.3.3 LSI clock calibration

Set AUTOTRIM_CR.MD to 0x01 to make the timer work in LSI calibration mode. This mode supports automatic real-time calibration of the LSI output frequency, so that the accuracy of the LSI output frequency is no longer affected by environmental changes.

For LSI clock calibration, it is necessary to provide an accurate high-frequency count clock to the timer. The source can be the high-speed precision clock signal input by HSE (crystal mode) or external ETR pin, which is selected by the SRC bit field of the control register AUTOTRIM_CR.

The functional block diagram of the LSI calibration mode is shown in the following figure:

Figure 11-4 LSI Calibration Mode Functional Block Diagram



Set AUTOTRIM_CR.AUTO to 1 to enable automatic calibration, set AUTOTRIM_CR.EN to 1 to enable the timer and start the automatic calibration process.

After the automatic calibration starts to work, the count value register AUTOTRIM_CNT counts down the count clock TCLK from the reload value ARR in each GCLK clock cycle, and starts to count up after the count reaches 0. When the counter has run for 1.5 times of ARR period, the counter stops running, and the AUTOTRIM_ISR.MISS flag is set to 1 by hardware, indicating that the counting fails. Each time the rising edge of the GCLK clock arrives, the counter restarts counting down from ARR.

If the count value of the counter is greater than the allowable error value AUTOTRIM_FLIM within the GCLK clock cycle, the TrimCode will be adjusted automatically until the count value of the counter is less than the allowable error value AUTOTRIM_FLIM, and the AUTOTRIM_ISR.OK flag will be set to 1 by hardware, indicating that the calibration accuracy has reached the standard, you can read the TrimCode register and write SYSCTRL_LSI.TRIM to calibrate the LSI clock frequency.

The TrimCode register can be adjusted to a maximum of 0x1FF, so when the TrimCode value is written to SYSCTRL_LSI.TRIM, the highest 1bit needs to be written according to the initial calibration value of the TRIM bit field. The code example is as follows:

```
CW_SYSCTRL->LSI = (CW_SYSCTRL->LSI & 0xFE00) | CW_AUTOTRIM->TVAL;
```

The allowable error value FLIM is automatically configured when the reload value ARR is set, and the calibration accuracy is 0.4%, which cannot be written by the user. The formula for setting the reload register AUTOTRIM_ARR is as follows:

$$ARR = TCLK \times 2^{PRS} / RCLK - 1$$

Among them, RCLK is the LSI clock, PRS is the prescaler coefficient, and TCLK is the counting clock source.

Example:

When the count clock source TCLK is HSE (clock frequency is 16MHz), the prescaler coefficient PRS is 0x1, the calibration LSI clock frequency is 32kHz. Calculate

$$ARR = 16000000 \times 2^1 / 32000 - 1 = 999$$

That is, you need to set AUTOTRIM_ARR to 0x3E7.



11.4 AUTOTRIM interrupt

The AUTOTRIM module supports 5 interrupt sources. When the AUTOTRIM interrupt trigger event occurs, the interrupt flag bit will be set by hardware. If the corresponding interrupt enable control bit is set, an interrupt request will be generated.

In the user's AUTOTRIM interrupt service routine, the relevant AUTOTRIM interrupt flag bit should be queried for corresponding processing. Before exiting the interrupt service routine, the interrupt flag bit must be cleared to avoid repeatedly entering the interrupt service routine.

The flag bits, interrupt enable bits, interrupt flag clear bits or clear methods of each interrupt source of AUTOTRIM are shown in the following table:

Table 11-1 AUTOTRIM interrupt control

Interrupt event	Interrupt flag bit	Interrupt enable bit	Flag clear method
Count failed	ISR.MISS	IER.MISS	Write 0 to ICR.MISS
TrimCode overflow	ISR.OV	IER.OV	Write 0 to ICR.OV
Counter underflow	ISR.UD	IER.UD	Write 0 to ICR.UD
Accuracy at the end of Auto Trim	ISR.OK	IER.OK	Write 0 to ICR.OK
Auto Trim ends	ISR.END	IER.END	Write 0 to ICR.END



11.5 Debugging support

AUTOTRIM supports stopping or continuing counting in debug mode, which is set by the AUTOTRIM bit field of the debug status timer control register SYSCTRL_DEBUG.

Set SYSCTRL_DEBUG.AUTOTRIM to 1, suspend the AUTOTRIM counter counting in debug state;

Set SYSCTRL_DEBUG.AUTOTRIM to 0, then the AUTOTRIM counter continues to count in debug state.

In the debug state, the program stops running. If the count of the AUTOTRIM counter is not stopped, the ISR.UD interrupt flag will be generated soon, which will cause the program to jump to the interrupt service routine and affect the debugging of other functions. It is recommended to enable the AUTOTRIM counter stop counting function in debug mode.



11.6 Programming example

11.6.1 Automatic Wake-Up Timer Mode Programming Example

The timing function configuration process is as follows

When the selected clock source is LSE/HSE/LSI/HSIOSC, steps 1 and 2 do not need to be performed:

- Step 1: Set the relevant bit of the peripheral clock enable control register SYSCTRL_AHBEN to 1, and enable the configuration clock and working clock of the GPIO port corresponding to AUTOTRIM_ETR;
- Step 2: Set the relevant bits of the GPIO multiplexing function registers GPIOx_AFRH and GPIOx_AFRL, and configure the corresponding pin as the AUTOTRIM_ETR function of the AUTOTRIM timer;
- Step 3: Set the peripheral clock enable control register SYSCTRL_APBEN2.AUTOTRIM to 1, turn on the configuration clock of the AUTOTRIM module;
- Step 4: Set AUTOTRIM_CR.MD to 0x03 to make the timer work in automatic wake-up timer mode;
- Step 5: Configure the control register AUTOTRIM_CR.SRC, select the AUTOTRIM count clock source;
- Step 6: Configure the control register AUTOTRIM_CR.PRS, select the AUTOTRIM count clock frequency division factor;
- Step 7: Set the interrupt enable register AUTOTRIM_IER.UD to 1 to enable the counter CNT underflow event to trigger an interrupt request;
- Step 8: Configure the reload value register AUTOTRIM_ARR to set the timing period. For specific configuration, please refer to the relevant description in this section;
- Step 9: Set the control register AUTOTRIM_CR.EN to 1, and start the timer to start timing;
- Step 10: The counter CNT overflows, enters the interrupt service function, and sets AUTOTRIM_ICR.UD to 0 to clear the interrupt flag;
- Step 11: If you do not want to continue timing, set the control register AUTOTRIM_CR.EN to 0 to close the timer timing function.

The configuration process of the counting function is as follows:

- Step 1: Set the relevant bit of the peripheral clock enable control register SYSCTRL_AHBEN to 1, and enable the configuration clock and working clock of the GPIO port corresponding to AUTOTRIM_ETR;
- Step 2: Set the relevant bits of the GPIO multiplexing function registers GPIOx_AFRH and GPIOx_AFRL, and configure the corresponding pin as the AUTOTRIM_ETR function of the AUTOTRIM timer;
- Step 3: Set the peripheral clock enable control register SYSCTRL_APBEN2.AUTOTRIM to 1, turn on the configuration clock of the AUTOTRIM module;
- Step 4: Set AUTOTRIM_CR.MD to 0x03 to make the timer work in automatic wake-up timer mode;
- Step 5: Set the control register AUTOTRIM_CR.SRC to 0x04, and select the AUTOTRIM count clock source as ETR;
- Step 6: Configure the control register AUTOTRIM_CR.PRS, select the AUTOTRIM count clock frequency division factor;
- Step 7: Set the interrupt enable register AUTOTRIM_IER.UD to 1 to enable the counter CNT underflow event to trigger an interrupt request;
- Step 8: According to the number N to be counted, set the value of the reload value register AUTOTRIM_ARR to N-1;
- Step 9: Set the control register AUTOTRIM_CR.EN to 1, start the counter and start counting;
- Step 10: The counter CNT overflows, enters the interrupt service function, and sets AUTOTRIM_ICR.UD to 0 to clear the interrupt flag;
- Step 11: If you do not want to continue counting, set the AUTOTRIM control register AUTOTRIM_CR.EN to 0 to turn off the counter counting function.



11.6.2 HSIOSC Clock Calibration Programming Example

The HSIOSC clock calibration process is as follows. When the reference clock source is selected as LSE, steps 1 and 2 do not need to be performed:

- Step 1: Set the relevant bit of the peripheral clock enable control register SYSCTRL_AHBEN to 1, and enable the configuration clock and working clock of the GPIO port corresponding to AUTOTRIM_ETR;
- Step 2: Set the relevant bits of the GPIO multiplexing function registers GPIOx_AFRH and GPIOx_AFRL, and configure the corresponding pin as the AUTOTRIM_ETR function of the AUTOTRIM timer;
- Step 3: Set the peripheral clock enable control register SYSCTRL_APBEN2.AUTOTRIM to 1, turn on the configuration clock of the AUTOTRIM module;
- Step 4: Set AUTOTRIM_CR.MD to 0x00 to make the timer work in HSIOSC clock calibration mode;
- Step 5: Configure the control register AUTOTRIM_CR.OST to select real-time calibration mode or single-shot calibration mode;
- Step 6: Configure the control register AUTOTRIM_CR.SRC to select the AUTOTRIM reference clock source;
- Step 7: Configure the control register AUTOTRIM_CR.PRS to select the AUTOTRIM reference clock frequency division factor;
- Step 8: Set the reload value register AUTOTRIM_ARR according to the ARR configuration formula in section [11.3.2 HSIOSC Clock Calibration Mode](#), and the automatic configuration calibration accuracy is 0.4%;
- Step 9: Set AUTOTRIM_CR.AUTO to 1 to enable automatic calibration;
- Step 10: Set AUTOTRIM_CR.EN to 1, enable the timer, and start automatic calibration;
- Step 11: The query waits for the AUTOTRIM_ISR.END and AUTOTRIM_ISR.OK flags to be set to 1, the automatic calibration is completed and the accuracy is up to standard;
- Step 12: Read the TrimCode register and write the TrimCode value to SYSCTRL_HSI.TRIM.

Code example:

```
CW_SYSCTRL->HSI = (CW_SYSCTRL->HSI & 0xFE00) | CW_AUTOTRIM->TVAL;
```



11.6.3 LSI Clock Calibration Programming Example

The LSI clock calibration process is as follows. When the counting clock source is selected as HSE, steps 1 and 2 do not need to be performed:

- Step 1: Set the relevant bit of the peripheral clock enable control register SYSCTRL_AHBEN to 1, and enable the configuration clock and working clock of the GPIO port corresponding to AUTOTRIM_ETR;
- Step 2: Set the relevant bits of the GPIO multiplexing function registers GPIOx_AFRH and GPIOx_AFRL, and configure the corresponding pins as the AUTOTRIM_ETR function of the AUTOTRIM timer;
- Step 3: Set the peripheral clock enable control register SYSCTRL_APBEN2.AUTOTRIM to 1, turn on the configuration clock of the AUTOTRIM module;
- Step 4: Set AUTOTRIM_CR.MD to 0x01 to make the timer work in LSI clock calibration mode;
- Step 5: Configure the control register AUTOTRIM_CR.OST to select real-time calibration mode or single-shot calibration mode;
- Step 6: Configure the control register AUTOTRIM_CR.SRC, select the AUTOTRIM count clock source;
- Step 7: Configure the control register AUTOTRIM_CR.PRS to select the AUTOTRIM reference clock frequency division factor;
- Step 8: Set the reload value register AUTOTRIM_ARR according to the ARR configuration formula in Section [11.3.3 LSI clock calibration](#), and the automatic configuration calibration accuracy is 0.4%;
- Step 9: Set AUTOTRIM_CR.AUTO to 1 to enable automatic calibration;
- Step 10: Set AUTOTRIM_CR.EN to 1, enable the timer, and start automatic calibration;
- Step 11: The query waits for the AUTOTRIM_ISR.END and AUTOTRIM_ISR.OK flags to be set to 1, the automatic calibration is completed and the accuracy is up to standard;
- Step 12: Read the TrimCode register and write the TrimCode value to SYSCTRL_LSI.TRIM.

Code example:

```
CW_SYSCTRL->LSI = (CW_SYSCTRL->LSI & 0xFE00) | CW_AUTOTRIM->TVAL;
```



11.7 List of registers

AUTOTRIM base address: AUTOTRIM_BASE = 0x4001 4C00

Table 11-2 List of AUTOTRIM registers

Register name	Register address	Register description
AUTOTRIM_CR	AUTOTRIM_BASE + 0x00	Control register
AUTOTRIM_ARR	AUTOTRIM_BASE + 0x04	Reload value register
AUTOTRIM_CNT	AUTOTRIM_BASE + 0x08	Count value register
AUTOTRIM_IER	AUTOTRIM_BASE + 0x10	Interrupt enable register
AUTOTRIM_ISR	AUTOTRIM_BASE + 0x14	Interrupt flag register
AUTOTRIM_ICR	AUTOTRIM_BASE + 0x1C	Interrupt flag clear register
AUTOTRIM_FCAP	AUTOTRIM_BASE + 0x80	Actual Error Value Register
AUTOTRIM_TVAL	AUTOTRIM_BASE + 0x84	TrimCode Register
AUTOTRIM_FLIM	AUTOTRIM_BASE + 0x88	Target error value register



11.8 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

11.8.1 AUTOTRIM_CR control register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11	OST	RW	Calibration Mode Configuration 0: Real-time calibration mode, TRIM process continues 1: One-shot calibration mode
10:8	SRC	RW	Counting clock source selection 000: HSIOSC 001: LSI 010: HSE 011: LSE 100: ETR Caution: In automatic wake-up timer mode, when the clock source is LSI/LSE, the timer can work in DeepSleep mode.
7:4	PRS	RW	Counting clock prescaler configuration 0000: Reserved, not configurable 1000: 256 Frequency division 0001: 2 Frequency division 1001: 512 Frequency division 0010: 4 Frequency division 1010: 1024 Frequency division 0011: 8 Frequency division 1011: 2048 Frequency division 0100: 16Frequency division 1100: 4096 Frequency division 0101: 32 Frequency division 1101: 8192 Frequency division 0110: 64 Frequency division 1110: 16384 Frequency division 0111: 128 Frequency division 1111: 32768 Frequency division
3	AUTO	RW	HSIOSC / LSI Automatic TRIM enable configuration 0: Disable 1: Enable
2:1	MD	RW	Please write 11
0	EN	RW	Timer enable control 0: Disabled 1: Enabled Caution: The EN bit field can be set to 1 only after the configuration of AUTOTRIM_CR[11:1] is completed..



11.8.2 AUTOTRIM_ARR reload value register

Address offset: 0x04 Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	Counter reload value

11.8.3 AUTOTRIM_CNT count value register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CNT	RO	Counter count value

11.8.4 AUTOTRIM_IER interrupt enable register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	MISS	RW	Count Failure Interrupt Enable Configuration 0: Disabled 1: Enabled
4	OV	RW	TrimCode Overflow Interrupt Enable Configuration 0: Disabled 1: Enabled
3	UD	RW	Counter Underflow Interrupt Enable Configuration 0: Disabled 1: Enabled
2	RFU	-	Reserved bits, please keep the default value
1	OK	RW	Accuracy Interrupt Enable Configuration at End of Auto Trim 0: Disabled 1: Enabled
0	END	RW	Auto Trim End Interrupt Enable Configuration 0: Disabled 1: Enabled



11.8.5 AUTOTRIM_ISR interrupt flag register

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	MISS	RO	Count failure flag 0: In one cycle of the GCLK clock, the counter has not run for 1.5 times the ARR cycle 1: In one cycle of the GCLK clock, the counter has run for 1.5 times the ARR cycle
4	OV	RO	TrimCode overflow interrupt flag 0: TrimCode of HSIOSC/LSI is not 0x000 or 0x1FF 1: TrimCode of HSIOSC/LSI has been adjusted to 0x000 or 0x1FF
3	UD	RO	Counter underflow interrupt flag 0: The timer has not overflowed 1: The timer has overflowed
2	RFU	-	Reserved bits, please keep the default value
1	OK	RO	Accuracy target interrupt flag at the end of Trim 0: Accuracy does not meet FLIM requirements when Trim is done 1: Accuracy meets FLIM requirements when Trim is completed
0	END	RO	Auto Trim end marker 0: Auto Trim in progress 1: Auto Trim completed



11.8.6 AUTOTRIM_ICR interrupt flag clear register

Address offset: 0x1C Reset value: 0x0000 003F

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	MISS	R1W0	Count failure flag clear W0: Clear count failure flag W1: No function
4	OV	R1W0	TrimCode Overflow Interrupt Flag Clear W0: Clear TrimCode overflow flag W1: No function
3	UD	R1W0	Counter underflow interrupt flag clear W0: Clear overflow flag W1: No function
2	RFU	-	Reserved bits, please keep the default value
1	OK	R1W0	Accuracy target interrupt flag is cleared at the Trim end W0: Clear the accuracy mark W1: No function
0	END	R1W0	Automatic Trim end flag clearing W0: Clear Auto Trim end flag W1: No function

11.8.7 AUTOTRIM_FCAP Actual Error Value Register

Address offset: 0x80 Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	FCAP	RO	Frequency error capture value



11.8.8 AUTOTRIM_TVAL TrimCode register

Address offset: 0x84 Reset value: 0x0000 0100

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
15:0	TVAL	RO	<p>Value of TrimCode</p> <p>The user needs to write this value into the TRIM register of the corresponding oscillator.</p> <p>Caution: The TrimCode register can be adjusted to a maximum of 0x1FF, so when the TrimCode value is written to SYSCTRL_HSI.TRIM, it needs to write the highest 2 bits according to the initial calibration value of the TRIM bit field; when the TrimCode value is written to SYSCTRL_LSI.TRIM, it needs to be written according to the initial calibration value of the TRIM bit field Write up to 1bit. The code example is as follows:</p> <p>Calibrate HSIOSC: CW_SYSCTRL->HSI = (CW_SYSCTRL->HSI & 0xFE00) CW_AUTOTRIM->TVAL;</p> <p>Calibrate LSI: CW_SYSCTRL->LSI = (CW_SYSCTRL->LSI & 0xFE00) CW_AUTOTRIM->TVAL;</p>

11.8.9 AUTOTRIM_FLIM target error value register

Address offset: 0x88 Reset value: 0x0000 0100

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	FLIM	RO	<p>Error tolerance</p> <p>Caution: The allowable error value FLIM is automatically configured when the reload value ARR is set, and the calibration accuracy is 0.4%, which cannot be written by the user.</p>



12 Real time clock (RTC)

12.1 Overview

The Real time clock (RTC) is a dedicated counter/timer that provides calendar information including hours, minutes, seconds, day, month, year, and week.

RTC has two independent alarm clocks, the time and date can be set in combination, and the alarm clock interrupt can be generated and output through the pin; it supports the time stamp function, which can be triggered by the pin, record the current date and time, and generate a time stamp interrupt at the same time; Support periodic interrupt; support automatic wake-up function, which can generate interrupts and output through pins; support 1Hz square wave and RTCOUT output functions; support internal clock calibration compensation.

The CW32L083 has a built-in independently calibrated RC clock source with a frequency of 32KHz to provide the drive clock for the RTC. The RTC can run in DeepSleep mode and is suitable for applications requiring low power consumption.

12.2 Main features

- Calendar function (BCD code format)
 - Seconds, minutes, hours (support 12/24 time system)
 - Week, day, month and year, support automatic leap year correction
- Interrupt function
 - Alarm clock A, B interrupt, can be output through pin
 - Cycle interruption, wide range: 0.5s to 1 month
 - Automatic wake-up interrupt, range: 61μs ~ 145h, can be output through pins
 - Timestamp interruption
- Calibration compensation function
 - Minimum clock error compensation step size, 0.119ppm
 - 1Hz square wave output pin
- Register lock protection to prevent accidental modification
- Operates in Active mode, Sleep mode, and DeepSleep mode

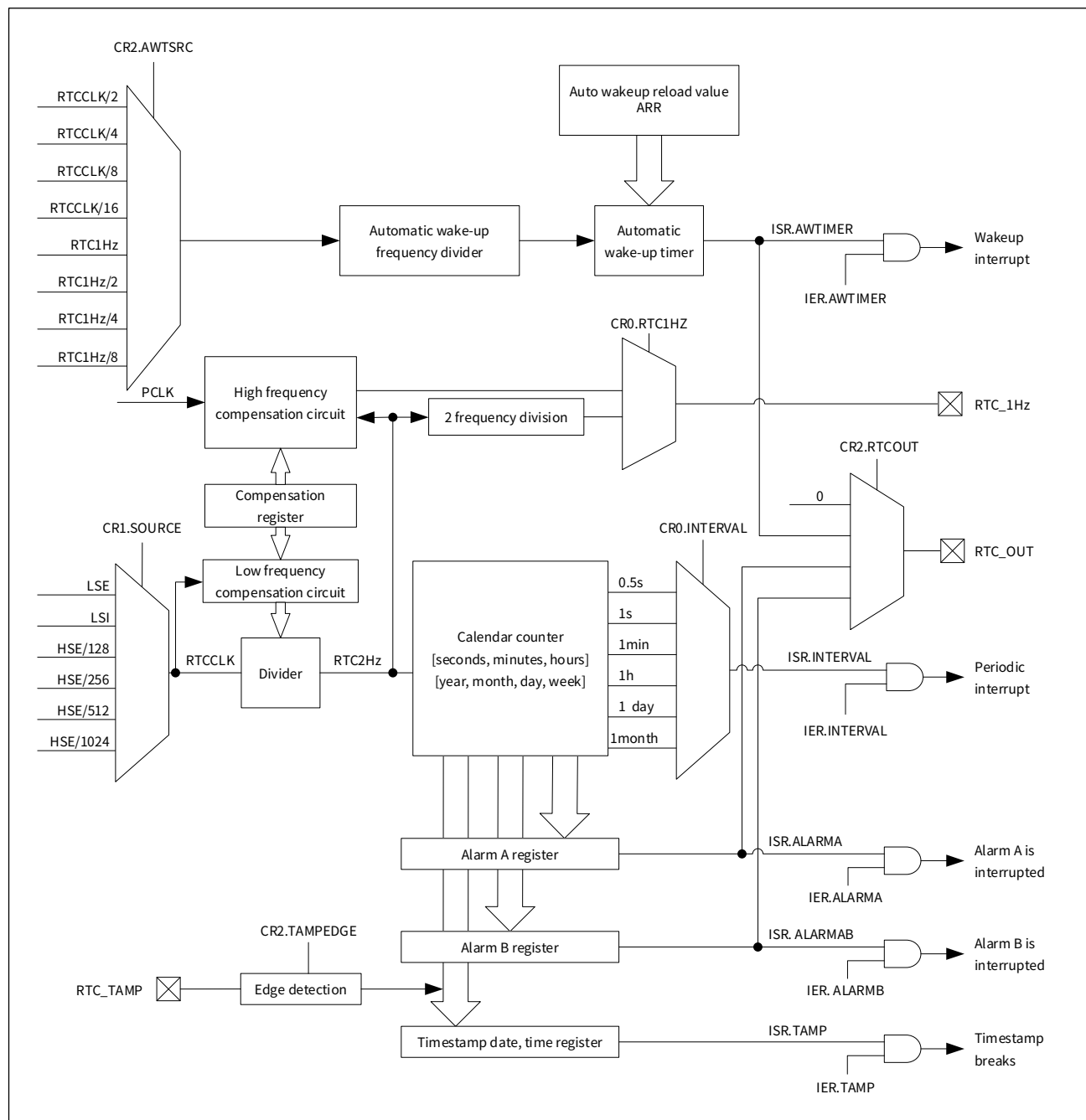


12.3 Functional description

12.3.1 Functional block diagram

The functional block diagram of the real-time clock (RTC) is shown in the following figure:

Figure 12-1 RTC functional block diagram



12.3.2 Functional overview

The real-time clock (RTC) is mainly composed of a dedicated high-precision RTC timer. The clock source can be selected from the external low-speed clock LSE or the internal low-speed clock LSI. When the external high-speed clock HSE is selected, it can only be used for general timing/ counter.

The time register RTC_TIME and the date register RTC_DATE respectively record the current time and date value in BCD code format, and will automatically check the validity when writing them, any illegal time or date value will not be written, such as the 32 days, 2A hours, 61 seconds, 13 months, etc.

In the date register RTC_DATE, the YEAR bit field represents the year, the valid value is 0 to 99; the MONTH bit field represents the month, the valid value is 1 to 12; the DAY bit field represents the day, the valid value is 1 to 31; the WEEK bit field represents the week, the valid value is 0 ~6, where 0 means Sunday and 1 to 6 means Monday to Saturday.

In the time register RTC_TIME, the SECOND bit field represents seconds, with a valid value of 0 to 59; the MINUTE bit field represents minutes, with a valid value of 0 to 59; the HOUR bit field represents hours, with a valid value of 1 to 12 or 0 to 23, and 12 hours can be selected. system or 24-hour format. The H24 bit field of the control register RTC_CR0 selects 12 or 24 hours:

- When H24 is '1', select 24-hour clock
- When H24 is '0', 12 o'clock is selected, and the highest bit of the HOUR bit field represents AM/PM:
 - '0' means AM
 - '1' means PM

The HOUR bit field value is detailed in the following table:

Table 12-1 HOUR bit field values in 12/24 time system

12 time system (RTC_CR0.H24=0)				24 time system (RTC_CR0.H24=1)			
Time	HOUR bit field	Time	HOUR bit field	Time	HOUR bit field	Time	HOUR bit field
AM12 o'clock	0x12	PM12 o'clock	0x32	00 o'clock	0x00	12 o'clock	0x12
AM1 o'clock	0x01	PM1 o'clock	0x21	01 o'clock	0x01	13 o'clock	0x13
AM2 o'clock	0x02	PM2 o'clock	0x22	02 o'clock	0x02	14 o'clock	0x14
AM3 o'clock	0x03	PM3 o'clock	0x23	03 o'clock	0x03	15 o'clock	0x15
AM4 o'clock	0x04	PM4 o'clock	0x24	04 o'clock	0x04	16 o'clock	0x16
AM5 o'clock	0x05	PM5 o'clock	0x25	05 o'clock	0x05	17 o'clock	0x17
AM6 o'clock	0x06	PM6 o'clock	0x26	06 o'clock	0x06	18 o'clock	0x18
AM7 o'clock	0x07	PM7 o'clock	0x27	07 o'clock	0x07	19 o'clock	0x19
AM8 o'clock	0x08	PM8 o'clock	0x28	08 o'clock	0x08	20 o'clock	0x20
AM9 o'clock	0x09	PM9 o'clock	0x29	09 o'clock	0x09	21 o'clock	0x21
AM10 o'clock	0x10	PM10 o'clock	0x30	10 o'clock	0x10	22 o'clock	0x22
AM11 o'clock	0x11	PM11 o'clock	0x31	11 o'clock	0x11	23 o'clock	0x23



12.3.3 RTC initialization settings

Step 1: Write 0xCA and 0x53 to the RTC_KEY register sequentially to unlock the RTC register;

Step 2: Configure RTC_CR0.H24 bit field, select 12/24 time system;

Step 3: Configure the RTC_CR1.SOURCE bit field and select the RTC clock source;

Caution:

If you select LSE or LSI, you need to enable and start LSE or LSI first, and wait for the clock to stabilize.

Step 4: Set the correct time and date values, write the time and date registers;

Step 5: Configure the required periodic interrupt unit, automatic wake-up unit, alarm clock A, and alarm clock B;

Step 6: Configure the RTC_IER register, set the periodic interrupt, automatic wake-up interrupt, alarm A, alarm B interrupt;

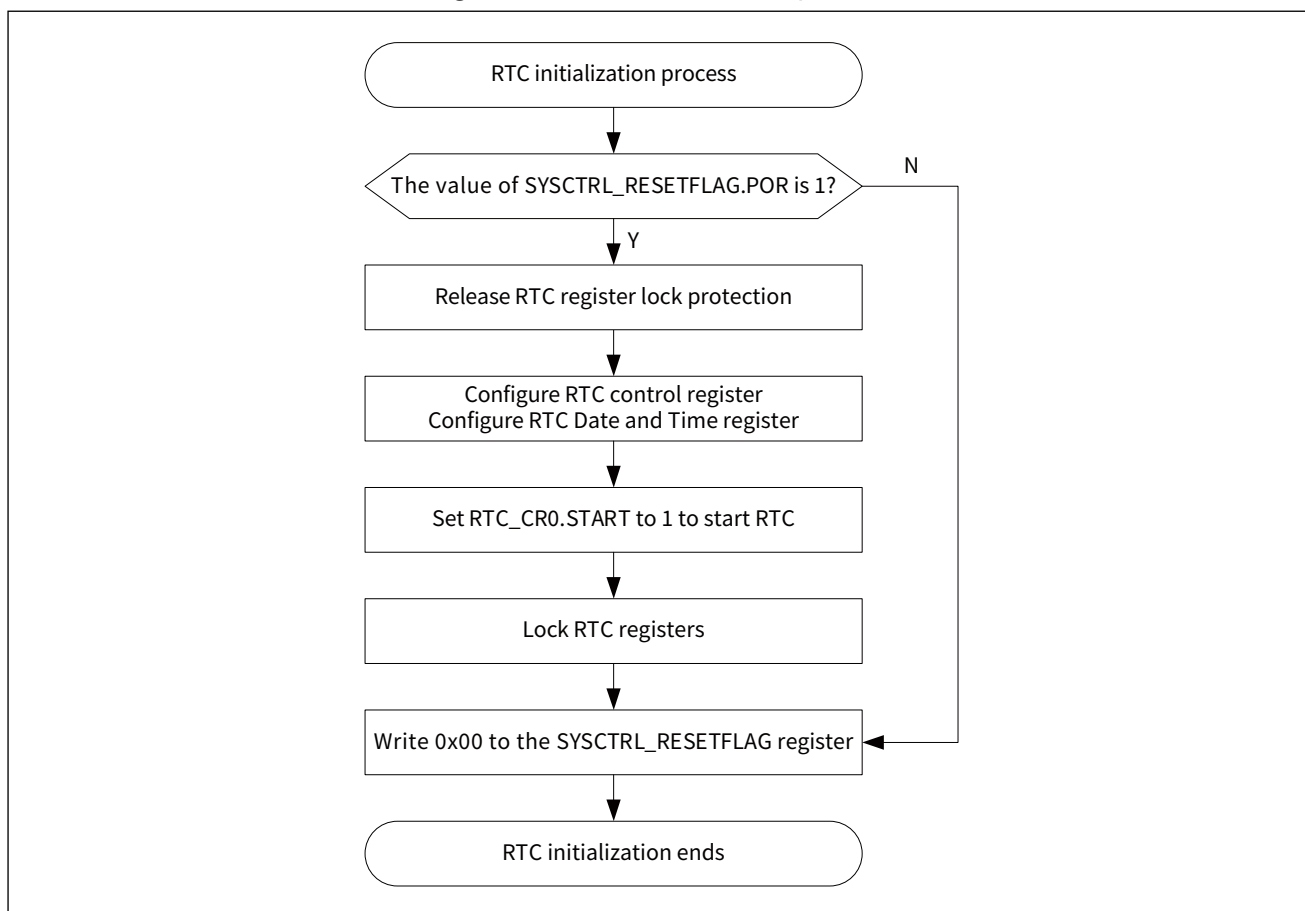
Step 7: Configure the time stamp function and configure the time stamp interruption;

Step 8: The RTC_CR0.START bit field is set to 1 to start the RTC timer;

Step 9: Write 0xCA, 0x-- to the RTC_KEY register sequentially to start the RTC register lock protection.

In user applications, when initializing the RTC, the reset state (SYSCTRL_RESETFLAG) of the MCU should be checked first. If it is a power-on reset (SYSCTRL_RESETFLAG.POR=1), the RTC registers will be reset to their default values. It is necessary to reconfigure the RTC control registers, RTC date and time registers, and restart the RTC; other reset conditions will not reset the RTC registers, the RTC continues to time normally.

Figure 12-2 RTC initialization process



12.3.4 Register lock function

After the CW32L083 is powered on and reset, the RTC registers except RTC_KEY and RTC_ICR are in lock protection state and cannot be modified. Write 0xCA and 0x53 keywords to the key value register RTC_KEY in sequence to release the RTC register lock protection; write 0xCA and 0x-- to the RTC_KEY register in sequence, the RTC register will be locked.

12.3.5 Register access operations

Since the running clock of the RTC counter may be out of sync with the clock of the RTC control register, when the RTC is running, in order to ensure that the register contents can be accessed correctly without affecting the operation of the RTC, the WINDOW bit field and the ACCESS bit of the control register RTC_CR1 should be adjusted. The combined use of the fields ensures that the access operation to the RTC register does not affect the timing accuracy of the RTC.

To access the RTC registers when the RTC is already running, the following operating specifications must be followed:

Step 1: Circularly check whether the WINDOW bit is 1, if it is 0, wait for 10ms to check again, lasting 1000 times, if 1 is still not detected after 1000 times, exit, and the return operation is not completed correctly;

Step 2: Write 0xCA and 0x53 to the RTC_KEY register sequentially to unlock the RTC register;

Step 3: Write 1 to ACCESS to set up the access flag;

Step 4: Execute normal RTC register access operation;

Caution:

This step can implement multiple RTC register access instructions, but the total execution time cannot exceed 1s.

Step 5: Write 0 to ACCESS to clear the access flag;

Step 6: Write 0xCA, 0x-- to the RTC_KEY register sequentially to enable the write protection of the RTC register.

Caution:

If the user needs to read the RTC time and date information more quickly, he can choose to read the time or date register twice in a row. As long as the content of the two reads is the same, the read data can be considered valid.



12.3.6 RTCCOUT output

By setting the RTCCOUT bit field of the control register RTC_CR2, the RTC_OUT output source can be selected, as shown in the following table:

Table 12-2 RTC_OUT output configuration

RTC_CR2.RTCCOUT	RTC_OUT output
00	Always output low level
01	Alarm clock A match flag
10	Alarm clock B match flag
11	Wake-up timer overflow flag

12.3.7 1Hz signal output

The RTC1HZ bit field of the control register RTC_CR0 is used to set the RTC_1Hz pin to output a compensated or uncompensated 1Hz signal, as shown in the following table:

Table 12-3 RTC_1Hz output configuration

	RTC_CR0.RTC1HZ	RTC_CR1.SOURCE	RTC_1Hz output
Disable error compensation (RTC_COMPEN.EN=0)	01	000	32768 frequency division signal of LSE
		010	32768 frequency division signal of LSI
Enable error compensation (RTC_COMPEN.EN=1)	01	-	1Hz signal with LSE error compensation



12.3.8 Clock error compensation

The RTC has a built-in clock compensation circuit. When the LSE accuracy cannot meet the requirements, the RTC clock can be compensated to achieve higher precision RTC timing.

The RTC clock error compensation register RTC_COMPEN has three bit fields for implementing error compensation:

- SIGN, compensation direction
 - When the actual LSE clock frequency is greater than 32768Hz, SIGN is set to 0 to compensate downward
 - When the actual LSE clock frequency is less than 32768Hz, SIGN is set to 1, upward compensation
- STEP, compensation period, 32, 128, 256 seconds can be selected as a compensation period
 - 32 seconds is a compensation period, which can achieve fast calibration but the accuracy is low, and the compensation accuracy is 0.950ppm;
 - When 128 is selected, the compensation accuracy is 0.238ppm;
 - When 256 is selected, the adjustment process is the smoothest, and the compensation accuracy is 0.119ppm;
- COMP, compensation value
 - When STEP is selected as 32, the valid range of COMP is 1 ~ 511
 - When STEP selects 128, the valid range of COMP is 1 ~ 2047
 - When STEP selects 256, the valid range of COMP is 1 ~ 4095

The operation steps of clock calibration are as follows:

Step 1: Turn off the error compensation function and set RTC_COMPEN.EN to 0;

Step 2: According to [Table 9-2 GPIO multiplexing function assignment table](#), configure a GPIO port as RTC_1Hz output, output uncompensated 1Hz signal;

Step 3: According to section [12.3.3 RTC initialization settings](#), configure LSE as the RTC clock source;

Step 4: The RTC_CR0.START bit field is set to 1 to start the RTC;

Step 5: Use a high-precision frequency meter to measure the 1Hz signal output by the RTC_1Hz pin, record the actual measurement frequency f_0 ;

The calculation method of the compensation value COMP:

Assuming the measured value $f_0 = 0.9999888\text{Hz}$, the actual frequency of the RTC clock f_z :

$$f_z = 32768 \times 0.9999888 \approx 32767.63\text{Hz}$$

$$\text{Frequency error } \Delta f = 32768 - 32767.63 = 0.37$$

Select the compensation period as 256, the calibration accuracy is the highest, and calculate the compensation value:

$$\text{COMP} = \Delta f \times \text{STEP} = 0.37 \times 256 = 94.72 \approx 95 = 0x5F$$

Step 6: According to section [12.3.5 Register access operations](#), configure the RTC_COMPEN compensation register. In this example, write 1 to the SIGN bit field, write 10 to the STEP bit field, and the COMP bit field is 0x5F;

Step 7: Write RTC_COMPEN.EN to 1 to start clock error compensation.

Caution:

Steps 6 and 7 can also be combined, directly operate by halfword, and write 0xE05F to RTC_COMPEN.



12.3.9 Alarm clock A and alarm clock B

RTC supports 2 independent alarm clocks (alarm clock A and alarm clock B), which can generate alarm events at any time of the week, and generate alarm interrupts, and output the alarm matching events through the external RTC_OUT pin. Set the ALARMAEN and ALARMBEN bit fields of the control register RTC_CR2 to 1 to enable the alarm clock A and the alarm clock B respectively.

By setting the hour, minute, second match control bits HOUREN, MINUTEEN, SECONDEN and the hour, minute, second count value HOUR, MINUTE, SECOND of the alarm clock A and B control registers (RTC_ALARMA and RTC_ALARMB), the alarm clock can be set at 'xx time xx Minutes xx seconds', or 'xx minutes xx seconds' or 'xx hours xx minutes' or 'xx hours' and other combinations to generate alarm events; the alarm week enable control bit WEEKMASK can select any day of the week to generate an alarm event, bit0 represents Sunday, and bits 1 to 6 represent Monday to Saturday.

Using 12 or 24 time system, the setting value of the alarm control register RTC_ALARMx (x=A,B) may be different. The example is as follows:

Table 12-4 Examples of timed alarm clocks

Timing requirement	Time system	RTC_ALARMx value	Alarm clock time
Alarm clock at 6:30 a.m. every morning	12/24 time	0x7F06 3000	06: 30: 00
Alarm clock at 7:00 every weekday	12/24 time	0x3E07 0000	07: 00: 00
Occurs every hour at 50 minutes	12/24 time	0x7F80 5000	xx: 50: 00
Occurs every 10 seconds per minute	12/24 time	0x7F80 8010	xx: xx: 10
Every Monday, it occurs every five seconds per minute at 12 noon.	12 time	0x0232 8005	12PM: xx: 05
Every Monday, it occurs every five seconds per minute at 12 noon.	24 time	0x0212 8005	12: xx: 05
Every Sunday, it occurs per second at 12: 30 p.m.	12 time	0x0112 3080	12AM: 30: xx
Every Sunday, it occurs per second at 12: 30 p.m.	24 time	0x0100 3080	00: 30: xx

When an alarm event occurs, the corresponding alarm match flag bit RTC_ISR.ALARMx will be set to 1 by hardware. If the alarm interrupt enable bit RTC_IER.ALARMx is set to 1, an interrupt request will be generated.

The match flag of alarm A or alarm B can be output through RTC_OUT pin, please refer to section [12.3.6 RTCOUT output](#).



12.3.10 Period interrupt function

The RTC has a built-in period interrupt module, which can generate fixed-period interrupt signals. The timing period is configured by the INTERVAL bit field of the control register RTC_CR0, as shown in the following table:

Table 12-5 Timing period configuration

RTC_CR0. INTERVAL	Period of Period Interrupt
000	No period interrupt is generated
001	0.5 seconds, generated every 1 second and 0.5 seconds
010	1 second, generated when the seconds counter changes
011	1 minute, generated when the minute counter changes
100	1 hour, generated when the hour counter changes
101	1 day, generated when the day counter changes
11x	1 month, generated when the month counter changes

Through the INTERVAL bit field of the RTC interrupt enable register RTC_IER, it is possible to set whether the period interrupt generates an interrupt request.



12.3.11 Automatic wake-up function

The automatic wake-up timer is a 16-bit programmable automatic reload subtraction counter, with a selectable clock source, and the timing range is: 61μs ~ 145h. When the counter overflows, it can generate an automatic wake-up interrupt and output the overflow flag through the RTC_OUT pin.

Set the AWTEN bit field of the control register RTC_CR2 to 1 to enable the automatic wake-up function, which is specially designed for low-power applications and can work in all working modes of the MCU.

The AWTSRC bit field of the RTC control register RTC_CR2 is used to select the count clock source of the automatic wake-up timer, as shown in the following table:

Table 12-6 Automatic wake-up timer clock source selection

RTC_CR2.AWTSRC	Clock source of period interrupt
000	RTCCLK/2 (~ 16384Hz)
001	RTCCLK/4 (~ 8192Hz)
010	RTCCLK/8 (~ 4096Hz)
011	RTCCLK/16 (~ 2048Hz)
100	RTC1Hz/1 (~ 1Hz) ¹
101	RTC1Hz/2 (~ 0.5Hz) ¹
110	RTC1Hz/4 (~ 0.25Hz) ¹
111	RTC1Hz/8 (~ 0.125Hz) ¹

Caution1:

RTC must be running when RTC1Hz is selected as clock source (RTC_CR0.START = 1)

The count period of the automatic wake-up timer is determined by the count clock source and the reload register RTC_AWTARR. The formula for calculating the timing duration is:

Auto wake-up timer period = (RTC_AWTARR+1) / wake-up timer clock frequency

Shortest timing: (0+1) / 16384Hz = 61μs

Longest timing: (65535+1) / 0.125Hz = 524288s = 8738min ≈ 145.63h

Through the AWTIMER bit field of the RTC interrupt enable register RTC_IER, you can select whether to generate an interrupt request when the automatic wake-up timer overflows. The overflow flag of the automatic wake-up timer can be output through the RTC_OUT pin, see section [12.3.6 RTCOUT output](#).



12.3.12 Timestamp function

The RTC supports the timestamp function, that is, triggered by the RTC_TAMP pin, the current time and date are saved to the timestamp date register RTC_TAMPDATE and the timestamp time register RTC_TAMPTIM, and a timestamp interrupt can be generated at the same time.

The TAMPEDGE bit field of the control register RTC_CR2 is used to select whether the signal triggering the timestamp is valid on the rising edge or the falling edge, and the TAMPEN bit field of the RTC_CR2 register is used to enable the timestamp function.

Users can flexibly select the trigger pin RTC_TAMP, and need to configure this pin as a digital input and multiplexing function, please refer to the pin definition in the datasheet for more details.

When a timestamp event occurs, the timestamp event flag bit RTC_ISR.TAMP will be set to 1. If the timestamp interrupt enable bit RTC_IER.TAMP is set to 1, an interrupt request will be generated.

If after the first timestamp event occurs, the RTC_ISR.TAMP flag is not cleared by software, and the second timestamp event occurs, the timestamp overflow flag RTC_ISR.TAMPOV will be set to 1. If the timestamp overflow interrupt is set, the When the enable bit RTC_IER.TAMPOV is 1, an interrupt request will be generated.

12.3.13 RTC Interrupts

RTC supports 6 interrupt sources: wake-up interrupt, alarm A interrupt, alarm B interrupt, period interrupt, timestamp interrupt and timestamp overflow interrupt.

The opening of the interrupt is controlled by the interrupt enable register RTC_IER. Write '1' to the corresponding bit field to enable the interrupt, and write '0' to disable the interrupt; when an interrupt occurs, the hardware will automatically set the corresponding bit of the interrupt flag register RTC_ISR; Write '0' to the corresponding bit of the register RTC_ICR to clear the corresponding interrupt flag.

In the user application, after the RTC interrupt function is enabled, the same interrupt service routine will be called from the RTC interrupt entry (RTC_IRQHandler) when all RTC interrupt events occur. The specific RTC interrupt source.

After the interrupt event processing is completed, before exiting the interrupt service routine, you must write '0' to the corresponding bit of the RTC interrupt flag clear register RTC_ICR to clear the interrupt flag and avoid repeatedly entering the interrupt service routine.



12.4 List of registers

RTC base address: RTC_BASE = 0x4000 2800

Table 12-7 List of RTC registers

Register name	Register address	Register description
RTC_KEY	RTC_BASE + 0x00	Key value register
RTC_CR0	RTC_BASE + 0x04	Control register 0
RTC_CR1	RTC_BASE + 0x08	Control register 1
RTC_CR2	RTC_BASE + 0x0C	Control register 2
RTC_COMPEN	RTC_BASE + 0x10	Clock error compensation register
RTC_DATE	RTC_BASE + 0x14	Date register
RTC_TIME	RTC_BASE + 0x18	Time register
RTC_ALARMA	RTC_BASE + 0x1C	Alarm clock A control register
RTC_ALARMB	RTC_BASE + 0x20	Alarm clock B control register
RTC_TAMPDATE	RTC_BASE + 0x24	Timestamp date register
RTC_TAMPTIME	RTC_BASE + 0x28	Timestamp time register
RTC_AWTARR	RTC_BASE + 0x2C	Wake-up timer reload register
RTC_IER	RTC_BASE + 0x30	Interrupt enable register
RTC_ISR	RTC_BASE + 0x34	Interrupt flag register
RTC_ICR	RTC_BASE + 0x38	Interrupt flag clear register



12.5 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

12.5.1 RTC_KEY key value register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	KEY	WO	Key value register Write "0x00CA" and "0x0053" to this register in turn to modify the register of the RTC module. Write "0x00CA" and "0x----" to this register in turn, and the registers of the RTC module cannot be modified except for KEY and ICR. Caution: "0x----" is any value except "0x0053".



12.5.2 RTC_CR0 control register 0

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	START	RW	RTC timer operation control 0: Stop RTC timer 1: Start RTC timer
6:5	RTC1HZ	RW	RTC_1Hz output configuration 01: 1Hz signal compensated by LSE clock Others: Reserved Caution: If RTC_ COMPEN.EN is 0, 32768 frequency division of LSE or LSI is output
4	RFU	-	Reserved bits, please keep the default value
3	H24	RW	Timing system setting 0: 12 time system 1: 24 time system
2:0	INTERVAL	RW	Timing period setting 000: No timing period is generated 001: 0.5 second, generated when the second timer changes and the 0.5 second moment 010: one second, generated when the second timer changes 011: one minute, generated when the minute timer changes 100: one hour, generated when the hour timer changes 101: one day, generated when the day timer changes 11x: January, generated when the month timer changes



12.5.3 RTC_CR1 control register 1

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:11	RFU	-	Reserved bits, please keep the default value
10:8	SOURCE	RW	Timing clock RTCCLK source configuration 000: External low frequency clock LSE 010: Built-in low frequency clock LSI 100: External high-speed clock HSE, 128 frequency division 101: External high-speed clock HSE, 256 frequency division 110: External high-speed clock HSE, 512 frequency division 111: External high-speed clock HSE, 1024 frequency division
7:2	RFU	-	Reserved bits, please keep the default value
1	WINDOW	RO	RTC register access window status 0: Non-read and write window, it is not recommended to read and write registers 1: Read and write window, you can read and write registers
0	ACCESS	RW	RTC timing related register access control 0: Normal counting mode 1: Write/read mode Caution: This control bit needs to be set when read and write access to the register is required, and the write/read operation is completed within 1 second, and then this bit is cleared to 0. If ACCESS is set to 1 for more than 1 second, it may cause timing errors.



12.5.4 RTC_CR2 control register 2

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:11	RFU	-	Reserved bits, please keep the default value
10	ALARMBEN	RW	Alarm clock B enable control 0: Disabled 1: Enabled
9	ALARMAEN	RW	Alarm clock A enable control 0: Disabled 1: Enabled
8	RFU	-	Reserved bits, please keep the default value
7	AWTEN	RW	Wake-up timer enable control 0: Wake-up timer disabled 1: Wake-up timer enabled
6	TAMPEN	RW	Timestamp enable control 0: Timestamp function disabled 1: Timestamp function enabled
5:4	RTCOUT	RW	RTC_OUT output configuration 00: Output low level 01: Alarm clock A match flag 10: Alarm clock B match flag 11: Wake-up timer overflow flag
3	TAMPEDGE	RW	Timestamp signal edge configuration 0: Record the current time on the rising edge of the RTC_TAMP pin 1: Record the current time on the falling edge of the RTC_TAMP pin
2:0	AWTSRC	RW	Wake-up timer count clock source configuration 000: RTCCLK / 2 ~ 16384Hz 001: RTCCLK / 4 ~ 8192Hz 010: RTCCLK / 8 ~ 4096Hz 011: RTCCLK / 16 ~ 2048Hz 100: RTC1Hz / 1 ~ 1Hz 101: RTC1Hz / 2 ~ 0.5Hz 110: RTC1Hz / 4 ~ 0.25Hz 111: RTC1Hz / 8 ~ 0.125Hz Caution: 0.125Hz ~ 1Hz need to enable RTC



12.5.5 RTC_COMPEN clock error compensation register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	EN	RW	Clock error compensation enable control 0: Clock error compensation disabled 1: Clock error compensation enabled
14	SIGN	RW	Clock compensation direction 0: Increase the count value (LSE oscillation frequency is greater than 32768Hz) 1: Decrease the count value (LSE oscillation frequency is less than 32768Hz)
13:12	STEP	RW	Compensation step selection 00: 0.950ppm, the compensation rate is COMP[08:0] / 32768 / 32 01: 0.238ppm, the compensation rate is COMP[10:0] / 32768 / 128 10: 0.119ppm, the compensation rate is COMP[11:0] / 32768 / 256 Caution: The compensation accuracy is half of the compensation step size
11:0	COMP	RW	Compensation value Compensable range is ± 488.0 ppm



12.5.6 RTC_DATE date register

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:27	RFU	-	Reserved bits, please keep the default value
26:24	WEEK	RW	Week count value BCD code format, valid value range is 0 ~ 6 0 represents Sunday, 1~6 represents Monday to Saturday
23:16	YEAR	RW	Year count value BCD code format, valid value range is 00~99
15:8	MONTH	RW	Month count value BCD code format, valid value range is 1 ~ 12
7:0	DAY	RW	Day count value BCD code format, the valid value range is 1 ~ 28, 1 ~ 29, 1 ~ 30, 1 ~ 31

12.5.7 RTC_TIME time register

Address offset: 0x18 Reset value: 0x0012 0000

Bit field	Name	Permission	Function description
31:22	RFU	-	Reserved bits, please keep the default value
21:16	HOUR	RW	Hour count value 24 time system, the valid value range of hour count BCD code is 0 ~ 23 12 time system, the valid value range of BCD code for hour count is 1 ~ 12(AM), 21 ~ 32(PM) bit21 is 0 for AM, 1 for PM
15	RFU	-	Reserved bits, please keep the default value
14:8	MINUTE	RW	Minute count value BCD code format, valid value range is 0 ~ 59
7	RFU	-	Reserved bits, please keep the default value
6:0	SECOND	RW	Second count value BCD code format, valid value range is 0 ~ 59



12.5.8 RTC_ALARMMA alarm clock A control register

Address offset: 0x1C Reset value: 0x0012 0000

Bit field	Name	Permission	Function description
31	RFU	-	Reserved bits, please keep the default value
30:24	WEEKMASK	RW	Alarm clock week enable control bit0 represents Sunday, bit1 ~ bit6 represent Monday to Saturday respectively If the corresponding bit is 1, the alarm clock is enabled
23	HOUREN	RW	Alarm clock hour bit mask control 0: The alarm clock needs to check the hour count value 1: The alarm clock has nothing to do with the hour count value
22	RFU	-	Reserved bits, please keep the default value
21:16	HOUR	RW	Alarm clock hour count value, BCD format
15	MINUTEEN	RW	Alarm clock minute bit mask control 0: The alarm clock needs to check the minute count value 1: The alarm clock has nothing to do with the minute count value
14:8	MINUTE	RW	Alarm clock minute count value, BCD format
7	SECONDEN	RW	Alarm clock second bit mask control 0: The alarm clock needs to check the second count value 1: The alarm has nothing to do with the second count value
6:0	SECOND	RW	Alarm clock second count value, BCD format



12.5.9 RTC_ALARMB alarm clock B control register

Address offset: 0x20 Reset value: 0x0012 0000

Bit field	Name	Permission	Function description
31	RFU	-	Reserved bits, please keep the default value
30:24	WEEKMASK	RW	Alarm clock week enable control bit0 represents Sunday, bit1 ~ bit6 represent Monday to Saturday respectively If the corresponding bit is 1, the alarm clock is enabled
23	HOUREN	RW	Alarm clock hour bit mask control 0: The alarm has nothing to do with the hour count value 1: The alarm clock needs to check the hour count value
22	RFU	-	Reserved bits, please keep the default value
21:16	HOUR	RW	Alarm hour count value in BCD format
15	MINUTEEN	RW	Alarm clock minute bit mask control 0: The alarm has nothing to do with the minute count value 1: The alarm clock needs to check the minute count value
14:8	MINUTE	RW	Alarm clock minute count value, BCD format
7	SECONDEN	RW	Alarm clock second bit mask control 0: The alarm has nothing to do with the second count value 1: The alarm clock needs to check the second count value
6:0	SECOND	RW	Alarm clock second count value, BCD format

12.5.10 RTC_TAMPDATE timestamp date register

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:13	WEEK	RO	Week count value when time stamp signal occurs
12:8	MONTH	RO	Month count value when timestamp signal occurs
7:6	RFU	-	Reserved bits, please keep the default value
5:0	DAY	RO	Day count value when timestamp signal occurs



12.5.11 RTC_TAMPTIME timestamp time register

Address offset: 0x28 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:22	RFU	-	Reserved bits, please keep the default value
21:16	HOUR	RO	Hour count value when timestamp signal occurs
15	RFU	-	Reserved bits, please keep the default value
14:8	MINUTE	RO	The minute count value when timestamp signal occurs
7	RFU	-	Reserved bits, please keep the default value
6:0	SECOND	RO	The second count value when timestamp signal occurs

12.5.12 RTC_AWTARR wake-up timer reload value

Address offset: 0x2C Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	Wake-up timer reload value



12.5.13 RTC_IER interrupt enable register

Address offset: 0x30 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	INTERVAL	RW	Timing period interrupt enable control 0: Disabled 1: Enabled
5	RFU	-	Reserved bits, please keep the default value
4	TAMPOV	RW	Timestamp overflow interrupt enable control 0: Disabled 1: Enabled
3	TAMP	RW	Timestamp interrupt enable control 0: Disabled 1: Enabled
2	AWTIMER	RW	Wake up timer interrupt enable control 0: Disabled 1: Enabled
1	ALARMB	RW	Alarm clock B interrupt enable control 0: Disabled 1: Enabled
0	ALARMA	RW	Alarm clock A interrupt enable control 0: Disabled 1: Enabled



12.5.14 RTC_ISR interrupt flag register

Address offset: 0x34 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	INTERVAL	RO	Periodic timing completion flag 0: No periodic timing completion event occurred 1: The periodic timing completion event has occurred
5	RFU	-	Reserved bits, please keep the default value
4	TAMPOV	RO	Timestamp overflow flag 0: No timestamp overflow event occurred 1: The timestamp overflow event has occurred
3	TAMP	RO	Timestamp event flag 0: No timestamp event occurred 1: Timestamp event has occurred
2	AWTIMER	RO	Wake-up timer timing completion flag 0: No wake-up timer timing completion event occurred 1: The wake-up timer timing completion event has occurred
1	ALARMB	RO	Alarm clock B match flag 0: No alarm clock B match event occurred. 1: The alarm clock B match event has occurred
0	ALARMA	RO	Alarm clock A match flag 0: No alarm clock A match event occurred. 1: Alarm clock A match event has occurred



12.5.15 RTC_ICR interrupt flag clear register

Address offset: 0x38 Reset value: 0x0000 007F

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	INTERVAL	R1W0	Periodic timing completion flag cleared W0: Clear the periodic timing completion flag W1: No function
5	RFU	-	Reserved bits, please keep the default value
4	TAMPOV	R1W0	Timestamp overflow flag cleared W0: Clear timestamp overflow flag W1: No function
3	TAMP	R1W0	Timestamp event flag cleared W0: Clear timestamp event flag W1: No function
2	AWTIMER	R1W0	Wake-up timer timing completion flag cleared W0: Clear wake-up timer timing completion flag W1: No function
1	ALARMB	R1W0	Alarm clock B match flag cleared W0: Clear alarm clock B match flag W1: No function
0	ALARMA	R1W0	Alarm clock A match flag cleared W0: Clear alarm clock A match flag W1: No function



13 Basic timer (BTIM)

13.1 Overview

CW32L083 integrates three basic timers (BTIM), each BTIM is completely independent and has the same function, each contains a 16-bit automatic reload counter and is driven by a programmable prescaler. BTIM supports four working modes: timer mode, counter mode, trigger start mode and gate control mode, and supports overflow event trigger interrupt request and DMA request. Thanks to the fine processing design of the trigger signal, the BTIM can automatically perform the filtering operation of the trigger signal by the hardware, and can also cause the trigger event to generate interrupts and DMA requests.

13.2 Main features

- 16-bit auto-reload up counter
- Programmable prescaler supports 1, 2, 3, 4, ..., 65536 frequency division
- Supports single counting mode and continuous counting mode
- Counting function for internal ITR or external ETR signal
- Internal ITR or external ETR signal triggers to start counting
- Gated function controlled by external ETR input signal
- Flexible external ETR signal filter processing
- Overflow event triggers digital output level transition
- Internal cascade ITR and external interconnect ETR
- Counter overflow triggers interrupt/DMA request
- Internal ITR or external ETR signal triggers interrupt/DMA request

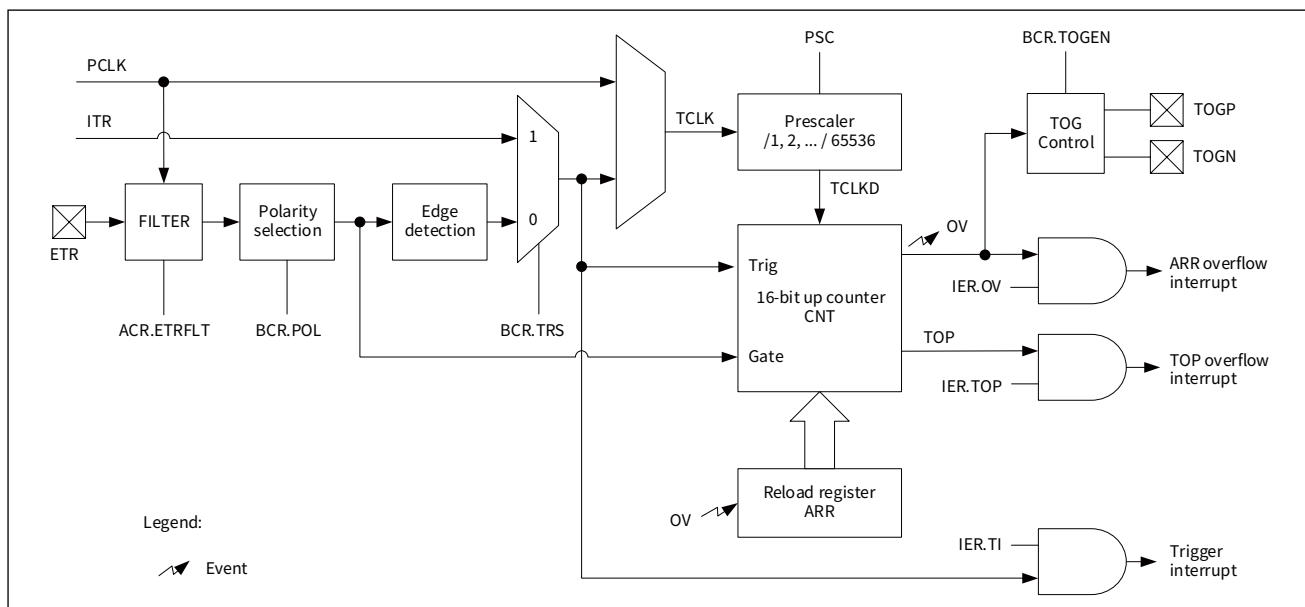


13.3 Functional description

13.3.1 Functional block diagram

The functional block diagram of BTIM is shown in the following figure:

Figure 13-1 BTIM functional block diagram



13.3.1.1 Filter unit

BTIM supports filtering the signal input from external BTIM_ETR pin. The filter samples the ETR signal at a certain sampling frequency. When N consecutive samples of the same level are obtained, the signal is valid, otherwise the signal is invalid, so as to filter out high-frequency clutter signals.

The sampling clock of the filter unit is PCLK or a frequency division of PCLK. The frequency division ratio of PCLK and the number of sampling points N can be selected through the ETRFLT bit field of the advanced control register BTIMx_ACR.

Caution:

Since the hardware samples the signal input from the external BTIM_ETR pin with the PCLK clock or the frequency division of the PCLK clock, the input signal whose frequency is higher than half of the actual sampling frequency may be missed.

The following example illustrates the relationship between the configuration of BTIMx_ACR.ETRFLT and the cutoff frequency.

Example:

When the PCLK clock frequency is 24MHz, set BTIMx_ACR.ETRFLT to 0x05 (ie $F_{\text{sample}} = \text{PCLK} / 4$ and $N = 6$), then

$$F_{\text{sample}} = 6\text{MHz}, N = 6$$

Continuous sampling to 6 valid levels, the required time is:

$$6 \times T_{\text{sample}} = 1\mu\text{s}$$

Therefore, input signals with frequencies above 0.5MHz will be filtered out.

13.3.1.2 Polarity selection unit

When the BTIM is configured in gated mode, the polarity selection unit is used to select whether the signal input by the external BTIM_ETR pin is active high or active low, which is selected by the POL bit field of the basic control register BTIMx_BCR.

When setting BTIMx_BCR.POL to 0, the ETR signal is valid when it is high; when setting BTIMx_BCR.POL to 1, it is valid when the ETR signal is low level.

13.3.1.3 Edge detection unit

When the BTIM is configured in the trigger start mode, the edge detection unit is used to select the edge trigger timing of the signal input by the external BTIM_ETR pin. Specifically, it is selected through the POL bit field of the basic control register BTIMx_BCR.

When BTIMx_BCR.POL is set to 0, the ETR signal is valid when the rising edge is set; when BTIMx_BCR.POL is set to 1, the ETR signal is valid when the falling edge is set.

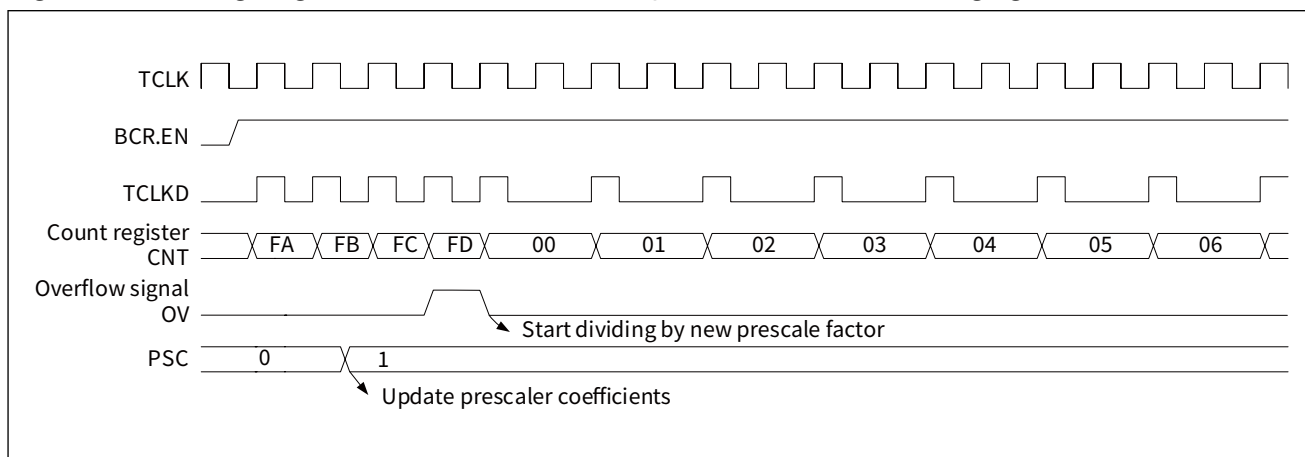
13.3.1.4 Prescaler

The prescaler coefficient is configured by the BTIMx_PSC register, and the specific frequency division coefficient is related to the counter clock source TCLK. When the counter clock source is PCLK, the frequency division coefficient is PSC+1; when the counter clock source is TRS, the frequency division coefficient is PSC (PSC>0).

It is allowed to modify BTIMx_PSC during the timer operation, but the new prescale factor will not take effect immediately. When the timer overflows or the running control bit BTIMx_BCR.EN changes from 0 to 1, the new prescale factor takes effect.

An example of changing the prescaler coefficient during operation is shown in the following figure:

Figure 13-2 Timing diagram of the counter with the prescaler coefficient changing from 1 to 2 (ARR=0xFD)



13.3.1.5 Counting unit

The core component of the counting unit is a 16-bit up counter CNT and a 16-bit automatic reload register ARR.

It is allowed to modify the reload register ARR while the timer is running, and the value of ARR will take effect immediately. When the value of the counter CNT is less than the value of ARR, after modifying the current ARR value to be less than the current CNT value, the ARR overflow signal OV will not be generated, and restart counting from 0x0000.

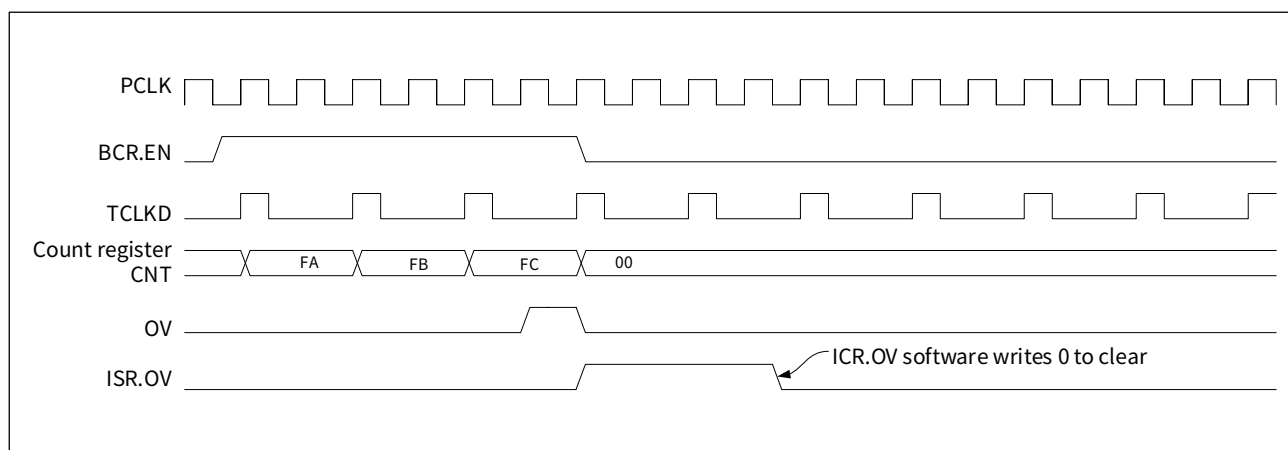
The counter can work in single counting or continuous counting mode, which is selected by the ONESHOT bit field of the basic control register BTIMx_BCR.

Single counting mode

Set BTIMx_BCR.ONESHOT to 1 to make the timer work in one-shot counting mode. Set BTIMx_BCR.EN to 1 to enable BTIMx, and the counter CNT counts up under the drive of the count clock TCLKD. When the count value reaches the reload value ARR, the overflow signal OV is generated (the overflow signal OV is kept for one PCLK cycle and then automatically cleared), when the OV signal is cleared, the counter ARR overflow flag bit BTIMx_ISR.OV is set by hardware, and the counter stops counting at the same time, BTIMx_BCR.EN is automatically reset by hardware.

The following figure is an example of single counting mode:

Figure 13-3 Single counting mode(PSC=0x01, ARR=0xFC)

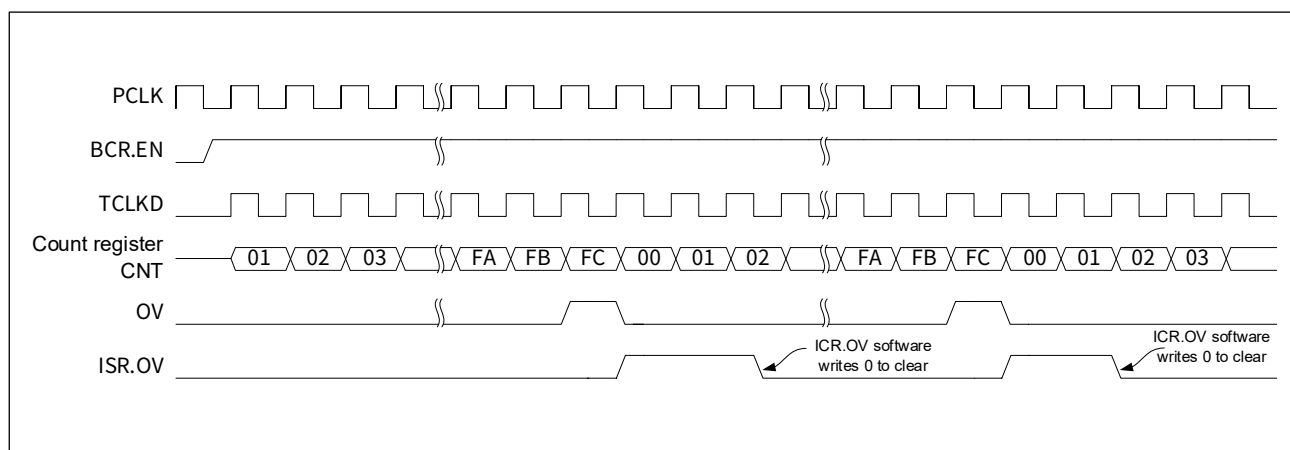


Continuous counting mode

Set BTIMx_BCR.ONESHOT to 0 to make the timer work in continuous counting mode. Set BTIMx_BCR.EN to 1 to enable BTIMx, and the counter CNT counts up under the drive of the count clock TCLKD. When the count value reaches the reload value ARR, an overflow signal OV is generated (the overflow signal OV remains for one PCLK cycle, and then automatically cleared). When the count value changes from ARR to 0, the counter ARR overflow flag bit BTIMx_ISR.OV is set by hardware, and the counter starts to count up in the next period.

The following figure is an example of continuous counting mode:

Figure 13-4 Continuous counting mode (PSC=0x00, ARR=0xFC)



13.3.1.6 Flip output unit

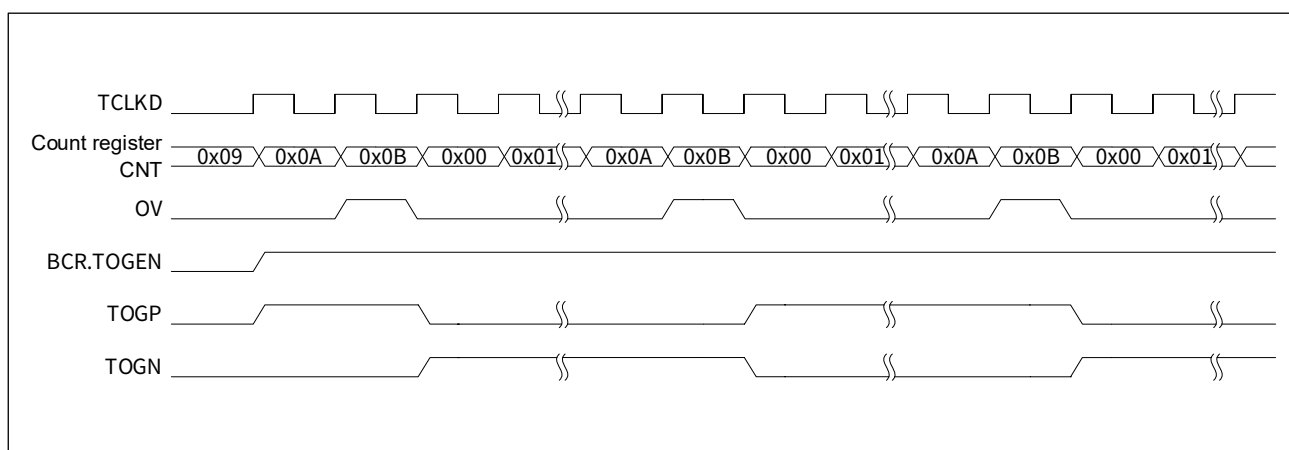
The flip output unit can control the external BTIMx_TOGP and BTIMx_TOPN pins to output the flip signal through the ARR overflow signal OV.

When BTIMx_BCR.TOGEN is set to 0, both BTIMx_TOGP and BTIMx_TOPN pins output low level.

When BTIMx_BCR.TOGEN is set to 1, the BTIMx_TOGP and BTIMx_TOPN pins output signals with opposite levels (BTIMx_TOGP default level is high); when the counter ARR overflows (BTIMx_ISR.OV is 1), the output levels of BTIMx_TOGP and BTIMx_TOPN pins will flip.

The following figure shows the schematic diagram of BTIMx_TOGP and BTIMx_TOPN pins level flip output in continuous counting mode:

Figure 13-5 Schematic diagram of level flip output (continuous counting mode, ARR=0x0B)



The TOGP/TOGN pins supported by BTIM are shown in the following table, and the corresponding GPIOs need to be multiplexed during application.

Table 13-1 BTIM toggle output pins

TOGP/TOGN	Pin	AFR
BTIM1_TOGP	PA10/PB00/PC10/PF01	0x04
BTIM1_TOGN	PA07/PA09/PC11/PF00	0x04
BTIM2_TOGP	PD05	0x05
	PA06	0x04
	PA08/PC06	0x03
BTIM2_TOGN	PD06	0x05
	PA05	0x04
	PB15/PC07	0x03
BTIM3_TOGP	PF07	0x07
	PB03/PD12	0x05
	PF09	0x04
BTIM3_TOGN	PF06	0x07
	PB01/PD13	0x05
	PF10	0x04



13.3.2 Operating modes

BTIM supports 4 operating modes: timer mode, counter mode, trigger start mode and gated mode. Configured through the MODE bit field of the basic control register BTIMx_BCR.

Table 13-2 BTIM operating modes

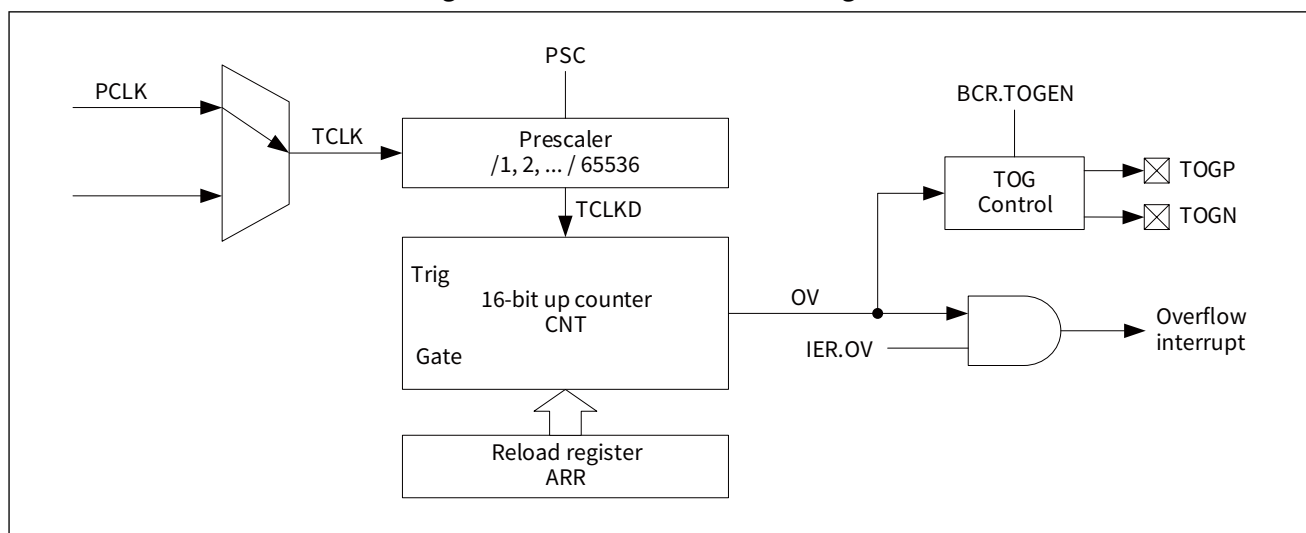
Basic timer	MODE bit field value	Operating mode	Description
BTIMx_BCR (x=1,2,3)	00	Timer mode	The clock source is PCLK
	01	Counter mode	The counting source is TRS signal
	10	Trigger start mode	The clock source is PCLK, and the TRS signal triggers the counter to start
	11	Gated mode	The clock source is PCLK, and the ETR input signal is used as the gate control signal



13.3.2.1 Timer mode

The timer mode is mainly used to generate a time base signal with a fixed time interval. In this mode, the counter clock source is the internal system clock PCLK, which is divided by the prescaler to obtain the count clock TCLKD to drive the counter CNT to count. The functional block diagram of timer mode is shown in the following figure:

Figure 13-6 Timer mode block diagram



Set BTIMx_BCR.MODE to 0x00 to make BTIMx work in timer mode. Set BTIMx_BCR.EN to 1 to enable BTIMx, and the counter CNT will count up under the drive of the count clock TCLKD. When the count value reaches the reload value ARR, an overflow occurs, and the counter ARR overflow flag bit BTIMx_ISR.OV is set by hardware. If the interrupt is enabled (set the interrupt enable register BTIMx_IER.OV to 1), the CPU will respond to the interrupt service routine. Before exiting the interrupt service routine, the interrupt flag clear register BTIMx_ICR.OV should be set to 0 to clear this flag.

In practical applications, the frequency of the system clock PCLK is known. By setting the prescaler coefficient PSC reasonably, the clock with a fixed duration can be counted, and the setting of the reload value ARR and the use of the counter ARR overflow interrupt flag bit, you can accurately obtain a specific time period, so as to achieve the purpose of timing.

Timing time T calculation formula:

$$T = ((PSC+1)/PCLK) \times (ARR+1)$$

Where, PCLK is the counter clock source, PSC is the prescaler coefficient, and ARR is the reload value.

Example:

When the frequency of the counter clock source PCLK is 24MHz, the timing is required to be 100ms.

If the prescaler coefficient PSC is set to 0xFF, calculate:

$$T = 100ms = ((255+1)/24MHz) \times (ARR+1)$$

then

$$ARR = 9374 \text{ (0x249E)}$$

That is, you need to set the reload value ARR to 0x249E.

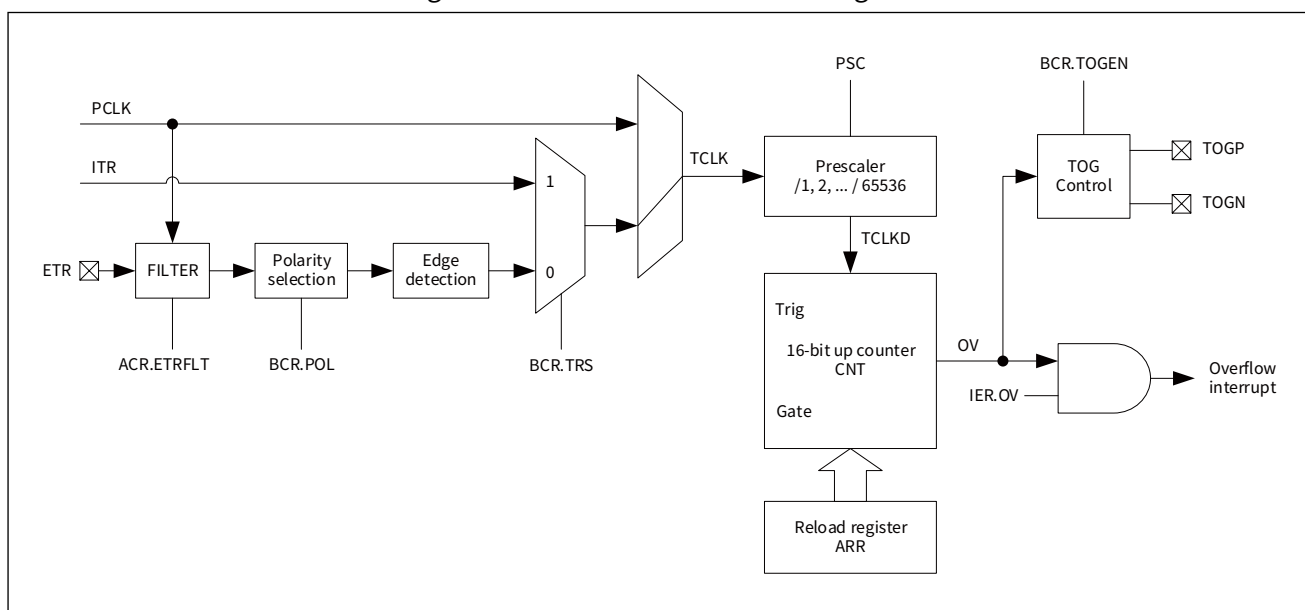
13.3.2.2 Counter mode

The counter mode is mainly used to measure the number of occurrences of an event. It can choose to count the signal input by the internal ITR or external BTIM_ETR pin, which is selected by the TRS bit field of the basic control register BTIMx_BCR.

When BTIMx_BCR.TRS is set to 1, the counting source is the internal ITR signal (refer to [Table 13-10 ITR source configuration](#)); when BTIMx_BCR.TRS is set to 0, the counting source is the signal input from the external BTIM_ETR pin, and this counting is selected. When the source is used, the filter can be configured through BTIMx_ACR.ETRFLT, and the rising or falling edge of the ETR signal can be selected through BTIMx_BCR.POL to count.

The functional block diagram of counter mode is shown in the following figure:

Figure 13-7 Counter mode block diagram



Set BTIMx_BCR.MODE to 0x01 to make BTIMx work in counter mode. Set BTIMx_BCR.EN to 1 to enable BTIMx, and the counter CNT counts up the divided TCLKD signal. When the count value reaches the reload value ARR, an overflow occurs, and the counter ARR overflow flag bit BTIMx_ISR.OV is set by hardware. If the interrupt is enabled (set the interrupt enable register BTIMx_IER.OV to 1), the CPU will respond to the interrupt service routine. Before exiting the interrupt service routine, the interrupt flag clear register BTIMx_ICR.OV should be set to 0 to clear this flag.

For the specific register configuration process in counter mode, see section [13.5 Programming examples](#).

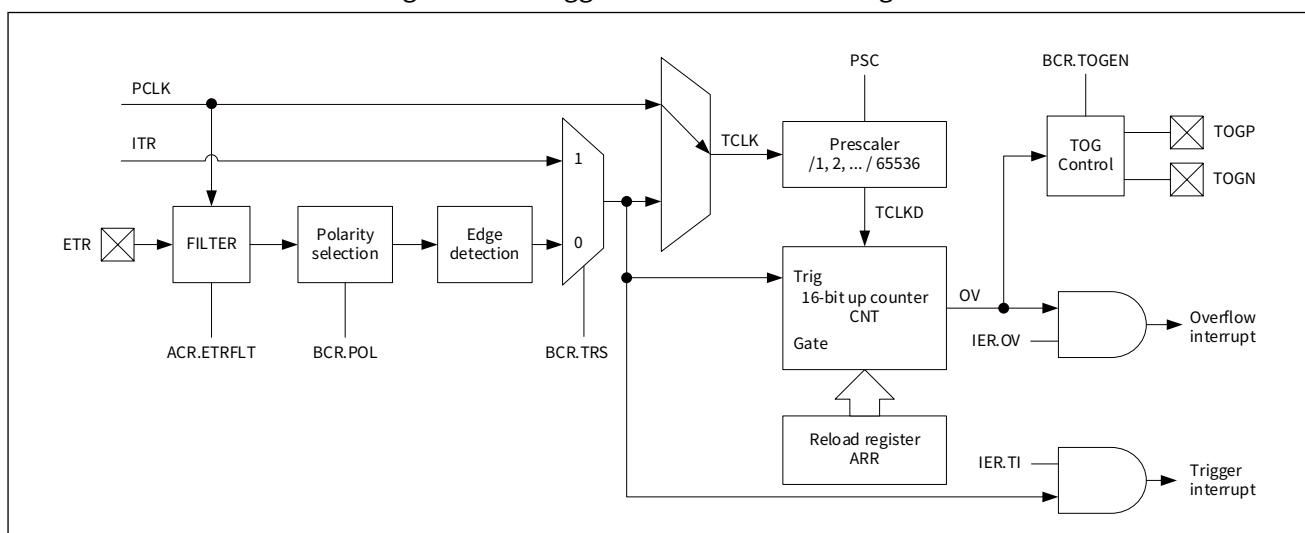
13.3.2.3 Trigger start mode

Set BTIMx_BCR.MODE to 0x02 to make BTIMx work in trigger start mode. In this mode, when BTIMx_BCR.EN is set to 1 or the trigger signal is valid, the counter CNT will be started to count the TCLKD signal after the internal clock PCLK is divided by the prescaler.

The trigger signal can be selected from the internal ITR signal or the signal input from the external BTIM_ETR pin, which is selected by the TRS bit field of the basic control register BTIMx_BCR. When BTIMx_BCR.TRS is set to 1, the trigger source is the internal ITR signal (see [Table 13-10 ITR source configuration](#)); when BTIMx_BCR.TRS is set to 0, the trigger source is the external BTIM_ETR pin input signal, select When this trigger source is used, the filter can be configured through BTIMx_ACR.ETRFLT, and the ERT signal can be selected through BTIMx_BCR.POL to be valid on rising or falling edges.

The functional block diagram of trigger start mode is shown in the following figure:

Figure 13-8 Trigger start mode block diagram



When a valid trigger signal is detected, the following effects occur:

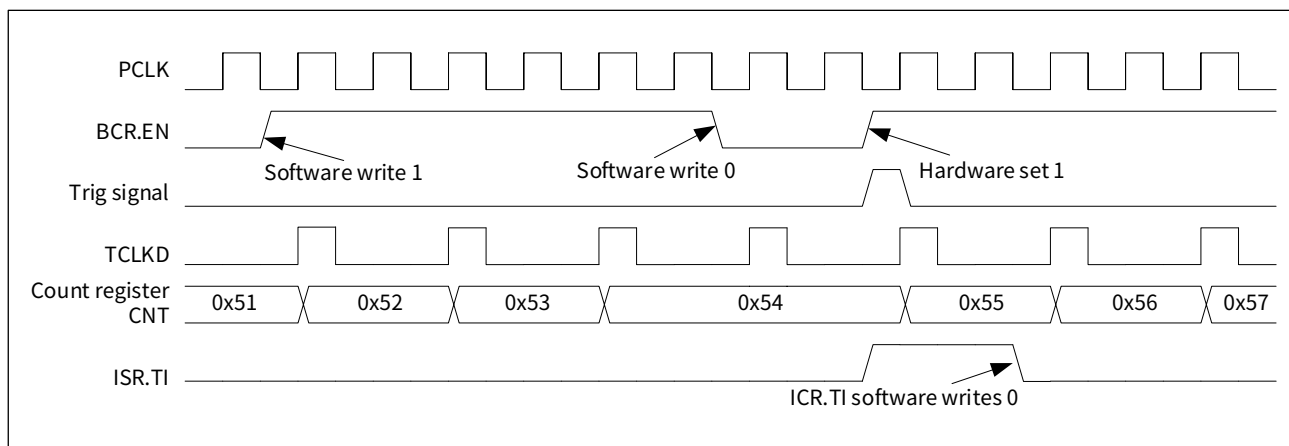
1. BTIMx_BCR.EN is set by hardware;
2. Trigger flag bit BTMx_ISR.TI is set by hardware;
3. The counter starts and starts counting.

After the counter starts, the counter starts to count up from the initial value. When the count value reaches the reload value ARR, an overflow occurs, and the counter ARR overflow flag bit BTIMx_ISR.OV is set by hardware. If the interrupt is enabled (set the interrupt enable register BTIMx_IER.OV to 1), the CPU will respond to the interrupt service routine. Before exiting the interrupt service routine, the interrupt flag clear register BTIMx_ICR.OV should be set to 0 to clear this flag.

After setting the run control bit BTIMx_BCR.EN to 0 at any time, the counter stops counting immediately. When the running control bit BTMx_BCR.EN is set to 1 again or the trigger signal is valid, the counter continues to count according to the previous setting.

The trigger start mode timing diagram is shown in the following figure:

Figure 13-9 Trigger start mode timing diagram (frequency division ratio is 2, PSC=0x01)



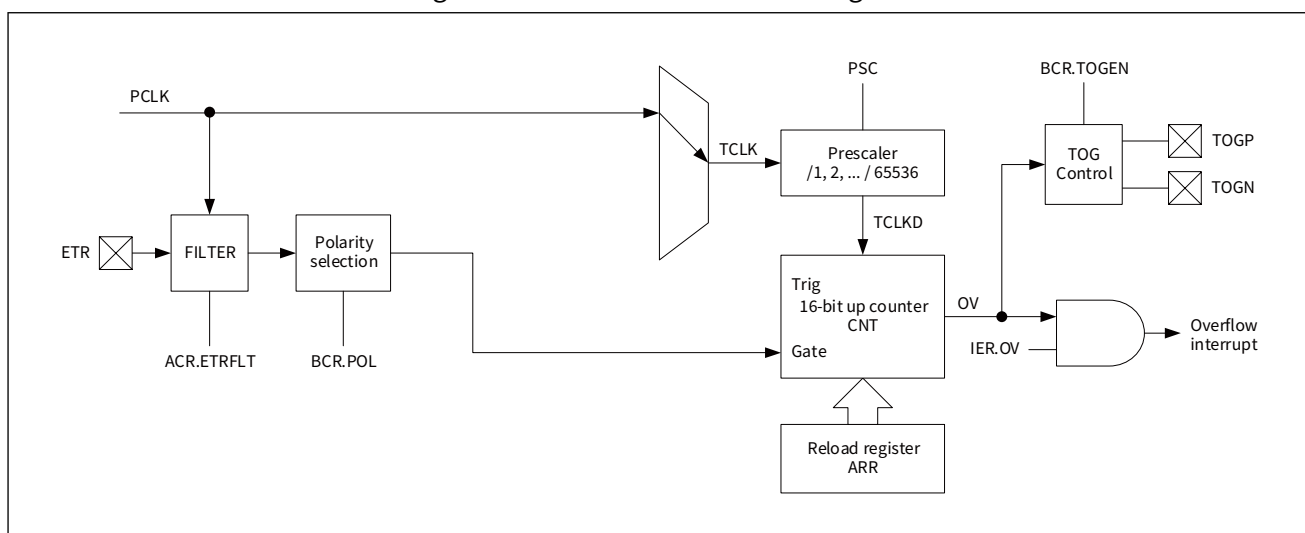
13.3.2.4 Gated mode

Set BTIMx_BCR.MODE to 0x03 to make BTIMx work in gated mode. In this mode, when BTIMx_BCR.EN is set to 1 and the gate control signal is valid, the counter CNT will be started to count the TCLKD signal after the internal clock PCLK is divided by the prescaler.

The gate control signal is fixed as the signal input from the external BTIM_ETR pin. Set the POL bit field of the basic control register BTIMx_BCR to select whether the gate control signal is a high level or a low level as an active level. You can also use the ETRFLT bit of the advanced control register BTIMx_ACR. The domain configures whether to filter and the bandwidth of the filter.

The function block diagram of gated mode is shown in the following figure:

Figure 13-10 Gated mode block diagram

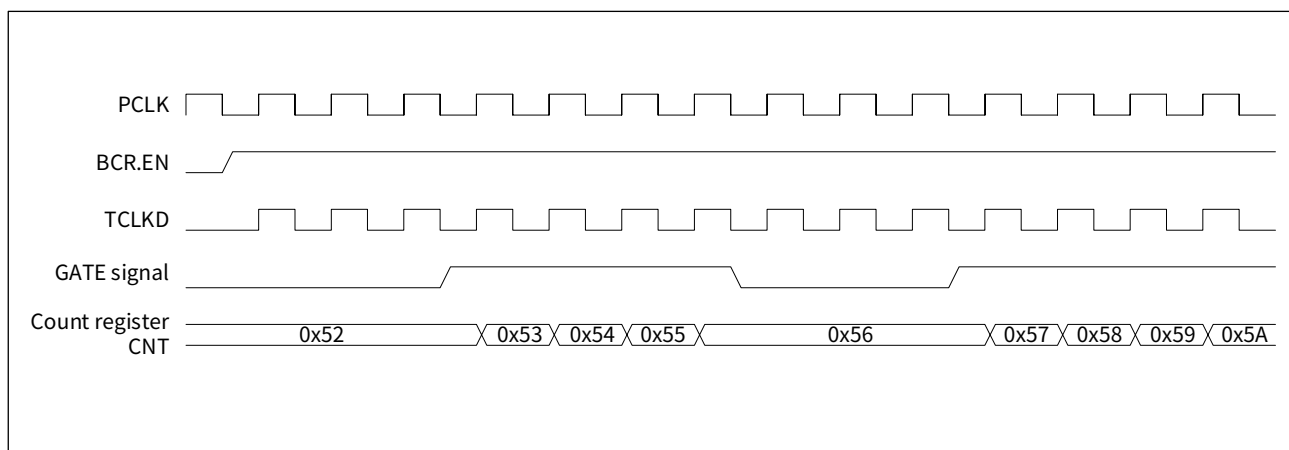


After the counter starts, the counter starts to count up from the initial value. When the count value reaches the reload value ARR, an overflow occurs, and the counter ARR overflow flag bit BTIMx_ISR.OV is set by hardware. If the interrupt is enabled (set the interrupt enable register BTIMx_IER.OV to 1), the CPU will respond to the interrupt service routine. Before exiting the interrupt service routine, the interrupt flag clear register BTIMx_ICR.OV should be set to 0 to clear this flag.

When the running control bit BTIMx_BCR.EN is set to 0 at any time or the gate control signal is invalid, the counter immediately stops counting. When the running control bit BTIMx_BCR.EN is set to 1 again and the gate control signal is valid, the counter continues to count according to the previous setting.

The gated mode timing diagram is shown in the following figure:

Figure 13-11 Gated mode timing diagram (PSC=0x00, POL=0x00)

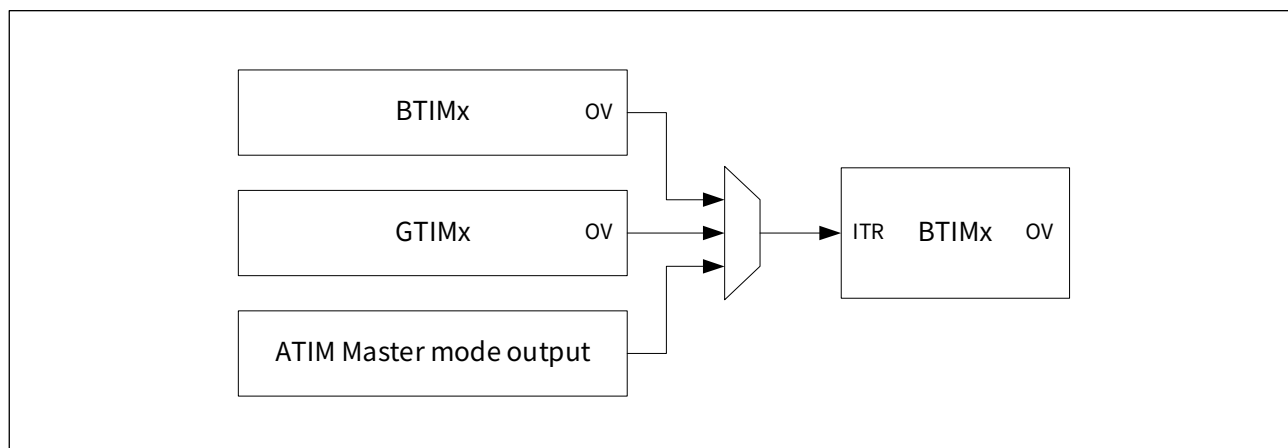


13.3.3 Internal cascade ITR

The timers can be cascaded to increase the bit width of the timer. For example, two 16-bit timers can be cascaded as a 32-bit timer, and the counting clock source PCLK can be 1~65535 by ITR cascade. Divide by any number in between.

The schematic diagram of BTIM two stage cascade is shown in the following figure:

Figure 13-12 Two stage cascade ITR



When used in cascade, the counting clock source of the first-level timer can be the signal input from the PCLK or external ETR pin, and the counting clock source of the subsequent-level timer is the ARR overflow signal OV of the previous-level timer or the advanced timer (ATIM) master mode output signal.

The ITR source of the timer can be selected through the timer ITR source configuration register SYSCTRL_TIMITR. The specific configuration is shown in the following table:

Table 13-3 ITR source configuration

SYSCTRL_TIMITR bit field	Value	ITR source
BTIM3ITR BTIM2ITR BTIM1ITR GTIM4ITR GTIM3ITR GTIM2ITR GTIM1ITR ATIMITR	000	Overflow signal of BTIM1
	001	Overflow signal of BTIM2
	010	Overflow signal of BTIM3
	011	Overflow signal of GTIM1
	100	Overflow signal of GTIM2
	101	Overflow signal of GTIM3
	110	Overflow signal of GTIM4
	111	Master mode output signal of ATIM

Caution:

The timer's ITR source cannot select its own overflow signal OV.

13.3.4 External interconnection ETR

The ETR signal source of BTIM can only be the external BTIM_ETR pin, and all BTIMs share one ETR signal, which is configured by the GPIO multiplexing function registers (GPIOx_AFRH and GPIOx_AFRL), as shown in the following table:

Table 13-4 External BTIM_ETR pin multiplexing

ETR	Pin	AFR
BTIM_ETR	PA12/PF05	0x02
	PD02/PD15	0x03
	PB11/PC13/PE07	0x05



13.4 Debugging support

BTIM supports to stop or continue counting in debug mode, which is set by the BTIM123 bit field of the debug status timer control register SYSCTRL_DEBUG.

Set SYSCTRL_DEBUG.BTIM123 to 1, then suspend the counter counting of BTIM1, BTIM2 and BTIM3 in the debug state;

Set SYSCTRL_DEBUG.BTIM123 to 0, then the counters of BTIM1, BTIM2 and BTIM3 continue to count in the debug state.



13.5 Programming examples

13.5.1 Timer mode programming example

Step 1: Set `SYSCTRL_APBEN2.BTIM` to 1, turn on the configuration clock and working clock of `BTIM1`, `BTIM2` and `BTIM3`;

Caution:

`BTIM1`, `BTIM2` and `BTIM3` share the `SYSCTRL_APBEN2.BTIM` bit.

Step 2: Set `BTIMx_BCR.MODE` to 0x00 to make `BTIMx` work in timer mode;

Step 3: Configure `BTIMx_BCR.ONESHOT` to select single or continuous counting mode. If it is configured as 0, it is continuous counting mode, and if it is configured as 1, it is single counting mode;

Step 4: Configure `BTIMx_BCR.PSC` and select the prescaler ratio;

Step 5: Configure `BTIMx_ARR`, set `BTIMx` count overflow time;

Step 6: Set `BTIMx_CNT` to 0x0000 for counting;

Step 7: If you want the `ARR` overflow event to trigger an interrupt, set `BTIMx_IER.OV` to 1;

Step 8: Set `BTIMx_BCR.EN` to 1, start `BTIMx`;

Step 9: If an interrupt occurs, set `BTIMx_ICR.OV` to 0 to clear the interrupt flag.

13.5.2 Counter mode programming examples

13.5.2.1 Count external ETR signals

To count the signals input by the external `BTIM_ETR` pin, the steps are as follows:

Step 1: Set `SYSCTRL_AHBEN.GPIOx` to 1, and enable the configuration clock and working clock of the GPIO port corresponding to the `BTIM_ETR` pin;

Step 2: Set the relevant bits of the GPIO multiplexing function registers (`GPIOx_AFRH` and `GPIOx_AFRL`), and configure the source of the ETR to the required hardware pins;

Step 3: Set the `SYSCTRL_APBEN2.BTIM` bit to 1, and turn on the configuration clock and working clock of `BTIM1`, `BTIM2` and `BTIM3`;

Caution:

`BTIM1`, `BTIM2` and `BTIM3` share the `SYSCTRL_APBEN2.BTIM` bit.

Step 4: Configure `BTIMx_BCR.MODE` to 0x01 to make `BTIMx` work in counter mode;

Step 5: Configure `BTIMx_BCR.ONESHOT` to select single or continuous counting mode. If it is configured as 0, it is continuous counting mode, and if it is configured as 1, it is single counting mode;

Step 6: Configure `BTIMx_BCR.TRS` to be 0, and select the counting source as the signal input from the external `BTIM_ETR` pin;

Step 7: Configure `BTIMx_ACR.ETRFLT`, choose whether to filter or filter bandwidth;

Step 8: Configure `BTIMx_BCR.POL` to select the ETR signal count edge. When configured as 0, the rising edge counts, and when configured as 1, the falling edge counts;

Step 9: Configure `BTIMx_BCR.PSC` and select the prescaler ratio;

Step 10: Configure `BTIMx_ARR`, set `BTIMx` count overflow time;

Step 11: If you want the `ARR` overflow event to trigger an interrupt, set `BTIMx_IER.OV` to 1;

Step 12: Set `BTIMx_BCR.EN` to 1, start `BTIMx`;

Step 13: If an interrupt occurs, set `BTIMx_ICR.OV` to 0 to clear the interrupt flag.



13.5.2.2 Count internal ITR signals

Step 1: Set the SYSCTRL_APBEN2.BTIM bit to 1, and turn on the configuration clock and working clock of BTIM1, BTIM2 and BTIM3;

Caution:

BTIM1, BTIM2 and BTIM3 share the SYSCTRL_APBEN2.BTIM bit.

Step 2: Configure BTIMx_BCR.MODE to 0x01, select BTIMx to work in counter mode;

Step 3: Configure BTIMx_BCR.ONESHOT to select single or continuous counting mode. If it is configured as 0, it is continuous counting mode, and if it is configured as 1, it is single counting mode;

Step 4: Configure BTIMx_BCR.TRS to 1, select the count signal from the internal ITR signal;

Step 5: Configure the SYSCTRL_TIMITR register and select the ITR source of the corresponding timer;

Step 6: Configure BTIMx_BCR.PSC and select the prescaler ratio;

Step 7: Configure BTIMx_ARR, select BTIMx count overflow time;

Step 8: If you want the ARR overflow event to trigger an interrupt, configure BTIMx_IER.OV to 1;

Step 9: Set BTIMx_BCR.EN to 1, start BTIMx;

Step 10: If an interrupt occurs, set BTIMx_ICR.OV to 0 to clear the interrupt flag.

13.5.3 Trigger start mode programming example

Step 1: Set the SYSCTRL_APBEN2.BTIM bit to 1, and turn on the configuration clock and working clock of BTIM1, BTIM2 and BTIM3;

Caution:

BTIM1, BTIM2 and BTIM3 share the SYSCTRL_APBEN2.BTIM bit.

Step 2: Configure BTIMx_BCR.TRS and select the trigger source. When configured as 0, the trigger signal comes from the external BTIM_ETR pin input signal; when configured as 1, the trigger signal comes from the internal cascaded ITR signal;

Step 3: If the trigger signal is input from the BTIM_ETR pin, BTIMx_ACR.ETRFLT can be configured to select whether to filter or filter bandwidth;

Step 4: If the trigger signal is input from the BTIM_ETR pin, configure BTIMx_BCR.POL and select the ETR signal to trigger the edge. If it is configured as 0, the rising edge counting starts, and if it is configured as 1, the falling edge counting starts;

Step 5: Configure BTIMx_BCR.PSC and select the prescaler ratio;

Step 6: Configure BTIMx_BCR.ONESHOT to select single or continuous counting mode. If it is configured as 0, it is continuous counting mode, and if it is configured as 1, it is single counting mode;

Step 7: If you want the trigger event to trigger an interrupt, set BTIMx_IER.IT to 1;

Step 8: If you want the ARR overflow event to cause an interrupt, set BTIMx_IER.OV to 1;

Step 9: Configure BTIMx_ARR, select BTIMx count overflow time;

Step 10: Configure BTIMx_BCR.MODE to 0x10, select BTIMx to work in trigger start mode;

Step 11: Determine whether to write 1 to BTIMx_BCR.EN as needed to immediately start BTIMx for counting;

Step 12: If an interrupt occurs, write 0 to the corresponding bit of the BTIMx_ICR register to clear the interrupt flag according to the event of the interrupt.

Caution:

Set the polarity of the trigger signal first, and then set the timer mode, otherwise it will cause false triggering.



13.5.4 Gated mode programming example

The signal input from the external BTIM_ETR pin is used as the gate control signal to control the count of the counter. The operation steps are as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, and enable the configuration clock and working clock of the GPIO port corresponding to the BTIM_ETR pin;

Step 2: Set the relevant bits of the GPIO multiplexing function registers (GPIOx_AFRH and GPIOx_AFRL), and configure the source of the ETR to the required hardware pins;

Step 3: Set the corresponding bit of the GPIOx_ANALOG register of the corresponding GPIO pin to 0, and configure it as a digital function;

Step 4: Set the corresponding bit of the GPIOx_DIR register of the corresponding GPIO pin to 1, and configure the port as an input;

Step 5: Set the SYSCTRL_APBEN2.BTIM bit to 1, and turn on the configuration clock and working clock of BTIM1, BTIM2 and BTIM3;

Caution:

BTIM1, BTIM2 and BTIM3 share the SYSCTRL_APBEN2.BTIM bit.

Step 6: Configure BTIMx_BCR.MODE to 0x03, select BTIMx to work in gated mode;

Step 7: Configure BTIMx_ACR.ETRFLT, choose whether to filter or filter bandwidth;

Step 8: Configure BTIMx_BCR.POL to select ETR signal polarity. When configured as 0, the gate control mode is active at high level, and when configured as 1, the gated mode is active at low level;

Step 9: Configure BTIMx_BCR.PSC and select the prescaler ratio;

Step 10: Configure BTIMx_BCR.ONESHOT to select single or continuous counting mode. When configured as 0, it is continuous counting mode, and when configured as 1, it is single counting mode;

Step 11: If you want the ARR overflow event to trigger an interrupt, configure BTIMx_IER.OV to 1;

Step 12: Configure the BTIMx_ARR register and select the BTIMx count overflow time;

Step 13: Set BTIMx_BCR.EN to 1, start BTIMx;

Step 14: If an interrupt occurs, set BTIMx_ICR.OV to 0 to clear the interrupt flag.



13.6 List of registers

BTIM1 base address: BTIM1_BASE = 0x4001 4800

BTIM2 base address: BTIM2_BASE = 0x4001 4900

BTIM3 base address: BTIM3_BASE = 0x4001 4A00

Table 13-5 List of BTIM registers

Register name	Register address	Register description
BTIMx_ARR	BTIMx_BASE + 0x00	Reload register
BTIMx_CNT	BTIMx_BASE + 0x04	Count register
BTIMx_ACR	BTIMx_BASE + 0x0C	Advanced control register
BTIMx_BCR	BTIMx_BASE + 0x10	Basic control register
BTIMx_IER	BTIMx_BASE + 0x14	Interrupt enable register
BTIMx_ISR	BTIMx_BASE + 0x18	Interrupt flag register
BTIMx_ICR	BTIMx_BASE + 0x1C	Interrupt flag clear register
BTIMx_DMA	BTIMx_BASE + 0x20	DMA trigger register
BTIMx_PSC	BTIMx_BASE + 0x24	Prescaler register



13.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

13.7.1 BTIMx_BCR basic control register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	TOGEN	RW	TOG pin output enable control 0: TOGP, TOGN output level is 0 1: TOGP, TOGN output signals with opposite levels
5	ONESHOT	RW	Single/continuous counting mode control 0: Continuous counting mode 1: Single counting mode
4	POL	RW	ETR signal polarity selection for external pin input 0: ETR is positive (the rising edge of trigger mode is valid, and the gated mode is valid at high level) 1: ETR is reversed (the falling edge of trigger mode is valid, and the gated mode is valid at low level)
3	TRS	RW	Trigger source selection 0: The signal input by the ETR pin 1: ITR, see section 13.3.3 Internal cascade ITR
2:1	MODE	RW	Basic timing mode configuration 00: Timer mode, counting clock source is PCLK 01: Counter mode, counting clock source is TRS signal 10: 10: Trigger start mode, the counting clock source is PCLK, and the TRS signal triggers the counter to start 11: Gated mode, the counting clock source is PCLK, and the ETR pin input signal is used as gate control Caution: When in counter mode, the BTIMx_PSC register value must be greater than 0.
0	EN	RW	Timer running control 0: Timer stopped 1: Timer running



13.7.2 BTIMx_ACR advanced control register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6:4	ETRFLT	RW	<p>The ETR pin input signal filtering configuration; the sampling clock is PCLK or PCLK frequency division, the number of sampling points is N, and N consecutive levels are valid.</p> <p>000: no filter</p> <p>001: $F_{\text{sample}} = \text{PCLK}$, $N=2$</p> <p>010: $F_{\text{sample}} = \text{PCLK}$, $N=4$</p> <p>011: $F_{\text{sample}} = \text{PCLK}$, $N=6$</p> <p>100: $F_{\text{sample}} = \text{PCLK}/4$, $N=4$</p> <p>101: $F_{\text{sample}} = \text{PCLK}/4$, $N=6$</p> <p>110: $F_{\text{sample}} = \text{PCLK}/16$, $N=4$</p> <p>111: $F_{\text{sample}} = \text{PCLK}/16$, $N=6$</p>
3:0	RFU	-	Reserved bits, please keep the default value

13.7.3 BTIMx_PSC Prescaler register

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	<p>Prescaler value</p> <p>When the count clock is PCLK: $\text{TCLKD} = \text{TCLK} / (\text{PSC} + 1)$</p> <p>When the count clock is TRS: $\text{TCLKD} = \text{TCLK} / \text{PSC}$, $\text{PSC} > 0$</p>

13.7.4 BTIMx_ARR reload register

Address offset: 0x00 Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	Timer reloads value



13.7.5 BTIMx_CNT count register

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CNT	RW	Timer count value

13.7.6 BTIMx_IER interrupt enable register

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:3	RFU	-	Reserved bits, please keep the default value
2	TOP	RW	Counter TOP overflow interrupt enable control 0: TOP overflow interrupt disabled 1: TOP overflow interrupt enabled
1	TI	RW	Trigger interrupt enable control 0: Trigger interrupt disabled 1: Trigger interrupt enabled
0	OV	RW	Counter ARR overflow interrupt enable control 0: ARR overflow interrupt disabled 1: ARR overflow interrupt enabled

13.7.7 BTIMx_ISR interrupt flag register

Address offset: 0x18 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:3	RFU	-	Reserved bits, please keep the default value
2	TOP	RO	Counter TOP overflow flag 0: The counter has not TOP overflowed 1: The counter has TOP overflowed
1	TI	RO	Trigger flag 0: No trigger event occurred 1: The trigger event has occurred
0	OV	RO	Counter ARR overflow flag 0: The counter has not ARR overflowed 1: The counter has ARR overflowed



13.7.8 BTIMx_ICR interrupt flag clear register

Address offset: 0x1C Reset value: 0x0000 0007

Bit field	Name	Permission	Function description
31:3	RFU	-	Reserved bits, please keep the default value
2	TOP	R1W0	Counter TOP overflow flag cleared W0: Counter TOP overflow flag cleared W1: No function
1	TI	R1W0	Trigger flag cleared W0: Trigger flag cleared W1: No function
0	OV	R1W0	Counter ARR overflow flag cleared W0: Counter ARR overflow flag cleared W1: No function

13.7.9 BTIMx_DMA DMA trigger register

Address offset: 0x20 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:2	RFU	-	Reserved bits, please keep the default value
1	TRS	RW	Synchronous trigger DMA enable control when the counter is triggered to start 0: No function 1: DMA is triggered synchronously when the counter is triggered to start
0	OV	RW	Counter ARR overflow triggers DMA enable control 0: No function 1: Counter ARR overflow triggers DMA



14 Low power timer (LPTIM)

14.1 Overview

The CW32L083 integrates a 16-bit low-power timer (LPTIM), which can realize the function of timing or counting external pulses with very low power consumption. By selecting an appropriate clock source and trigger signal, the function of waking up the system when it is in low-power sleep mode can be realized. There is a compare register inside the LPTIM, which can realize the compare output and PWM output, and can control the polarity of the output waveform. In addition, LPTIM can also be connected with a quadrature encoder to automatically count up and down.

14.2 Main features

- 16bit auto-reload counter
- Programmable prescaler supports 1, 2, 4, 8, 16, 32, 64, 128 division
- Working clock optional:
 - Internal clock: PCLK、LSI、LSE
 - External clock: LPTIM_CH1
- Support single mode and continuous mode
- Rich software and hardware trigger sources
- Clockless external pulse counting
- Input and output polarity selection
- Configurable input port filters
- Output Configurable as Single Pulse, Single Set or PWM Wave
- Quadrature code count function

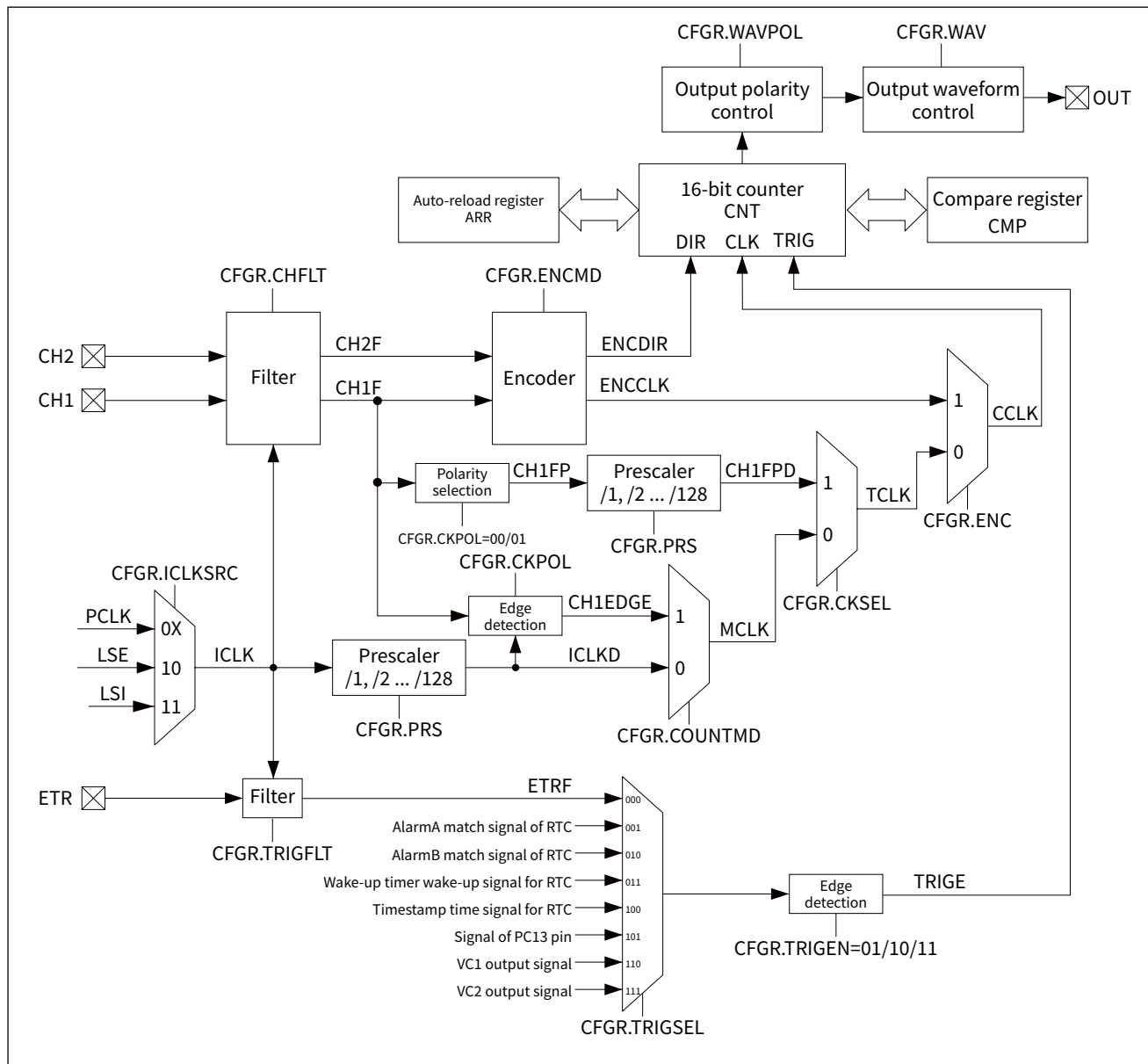


14.3 Function description

14.3.1 Functional block diagram

The functional block diagram of LPTIM is shown in the following figure:

Figure 14-1 LPTIM functional block diagram



14.3.1.1 Clock source

The counting clock source of LPTIM can be selected from PCLK, LSE, LSI, or an external clock input on the LPTIM_CH1 pin, which is configured through the ICLKSRC, COUNTMD and CKSEL bit fields of the configuration register LPTIM_CFGR.

When the external clock input on the LPTIM_CH1 pin is selected as the counting clock source, the LPTIM can work in the following two configuration modes:

- The first configuration mode (CKSEL=0, COUNTMD=1): The external clock input by CH1 is used as the count clock of LPTIM, and the internal clock module also needs to provide clock to LPTIM for filtering and edge detection;
- The second configuration mode (CKSEL=1): The external clock input by CH1 is used as the only clock of the LPTIM. This configuration can be used to implement the timeout function or pulse counter function when all the internal oscillators are turned off in the low power mode.

When configured to use an external clock source, the CKPOL bit field is used to set the valid edge of the external clock signal. If configured to be active on both upper and lower edges, the internal clock signal should also be provided (first configuration). In this case, the frequency of the internal clock signal should be at least four times the frequency of the external clock signal.

14.3.1.2 Prescaler

The prescaler divides the frequency of the counter clock source by a multiple of 2, and the maximum frequency division factor is 128. The prescaler coefficient is configured by the PRS bit field of the configuration register LPTIM_CFGR. The frequency division coefficient configuration is shown in the following table:

Table 14-1 Frequency division coefficient configuration table

PRS	Frequency division factor
000	1
001	2
010	4
011	8
100	16
101	32
110	64
111	128



14.3.1.3 Filter unit

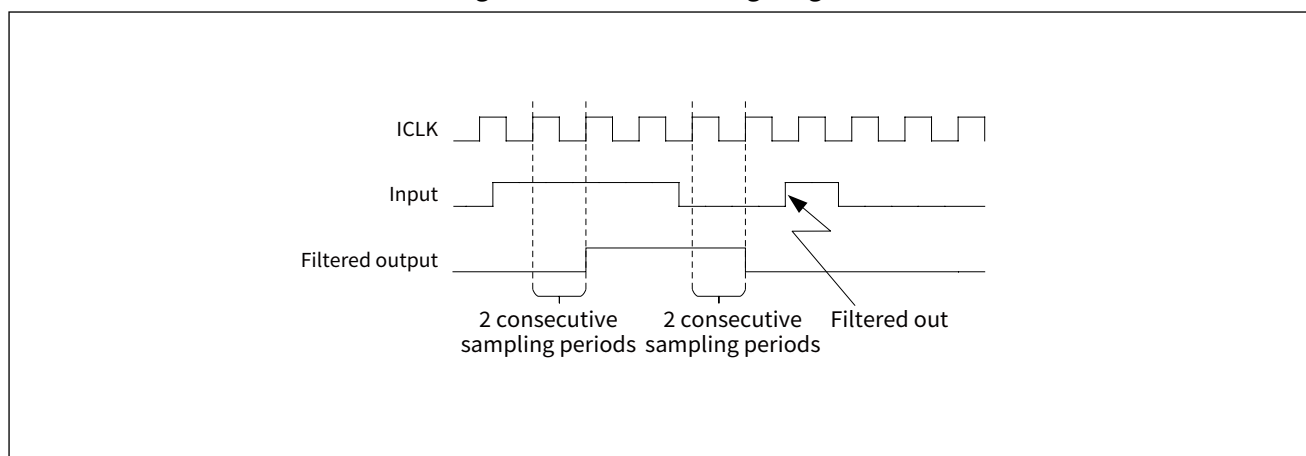
LPTIM inputs, whether external (mapped to GPIO) or internal (mapped on-chip to other on-chip peripherals), can be filtered through a digital filter to prevent glitches and noise perturbations from causing false LPTIM counts or triggering.

In order for the filter to work properly, an internal clock source should first be provided to the LPTIM. This is a necessary condition to ensure the normal operation of the filter. Digital filters can be divided into two groups:

- The first group of digital filters is used for the external input of LPTIM (CH1, CH2), and the sensitivity of the digital filters is controlled by the CHFLT bit;
- The first group of digital filters is used for the external input of LPTIM (CH1, CH2), and the sensitivity of the digital filters is controlled by the CHFLT bit;

The sensitivity of the filter can be changed by changing the number of active level holds that the filter continuously samples the input signal. For example, when the filter is set to an active level for 2 sampling periods, the filtered output waveform is shown in the following figure:

Figure 14-2 Filter Timing Diagram



Caution:

If no internal clock signal is provided, the digital filter must be disabled by setting the CHFLT and TRGFLT bit fields to '00'. In this case, an external analog filter can be used to shield the LPTIM external input from disturbances.

14.3.2 Start method

The EN bit field of the control register LPTIM_CR is used to enable/disable the LPTIM core. After setting the EN bit to 1, a delay of two count clock cycles is required before the LPTIM actually starts counting.

The LPTIM counter can be started by software or by a trigger event, set by the TRIGEN bit field of the configuration register LPTIM_CFGR.

When setting LPTIM_CFGR.TRIGEN to 00, it is configured for software startup. After starting LPTIM, setting the CNTSTART or SNGSTART bit field to 1 will start the LPTIM counter to count.

When LPTIM_CFGR.TRIGEN is set to 01/10/11, it is configured to trigger the event to start. After starting LPTIM and configuring the operating mode (single or continuous mode), once a valid edge of the trigger input is detected, the LPTIM counter is started to count. For specific trigger input signals, please refer to section 14.3.3 Trigger Source.

Caution 1:

The LPTIM_CFGR and LPTIM_IER registers can only be modified when the EN bit field is 0 and LPTIM is disabled.

Caution 2:

LPTIM must be enabled (EN=1) before setting the CNTSTART or SNGSTART bit fields. When LPTIM is disabled, any writes to these bits will be discarded by hardware.

Caution 3:

When configured for software startup, after setting the CNTSTART or SNGSTART bit field, the counter does not actually start until after a delay of 3 core clock cycles.

Caution 4:

Since the trigger signal and the timing clock of the LPTIM are not synchronized, after the trigger detects the trigger signal, the timer needs to delay two timing clock cycles before it starts running.



14.3.3 Trigger source

The LPTIM counter can be started by software or after a valid edge of the trigger input is detected. LPTIM supports 8 trigger sources, which are set by the TRIGSEL bit field of the configuration register LPTIM_CFGR, as shown in the following table:

Table 14-2 LPTIM trigger input source table

TRIGSEL bit field	Trigger source
000	LPTIM_ETR pin signal
001	ALARMA match signal for RTC
010	ALARMB match signal for RTC
011	Wake-up timer wake-up signal for RTC
100	Timestamp event signal for RTC
101	Signal of PC13 pin
110	VC1 output signal
111	VC2 output signal

The TRIGEN bit field is used to set the trigger enable and polarity, as shown in the following table:

Table 14-3 LPTIM trigger enable and polarity

TRIGEN	Trigger Mode and Polarity
00	Software start, software writes CNTSTART or SNGSTART to start the counter
01	Hardware trigger, start the counter on the rising edge of the trigger signal
10	Hardware trigger, start the counter on the falling edge of the trigger signal
11	Start the counter on the rising or falling edge of the trigger signal



14.3.4 Operating mode

LPTIM supports two modes of operation:

- Single mode: the counter is started by software or triggered by an event, and stops when the count value reaches the reload value ARR;
- Continuous mode: The counter is started by software or by a trigger event, the counter counts continuously and stops until the timer is disabled.

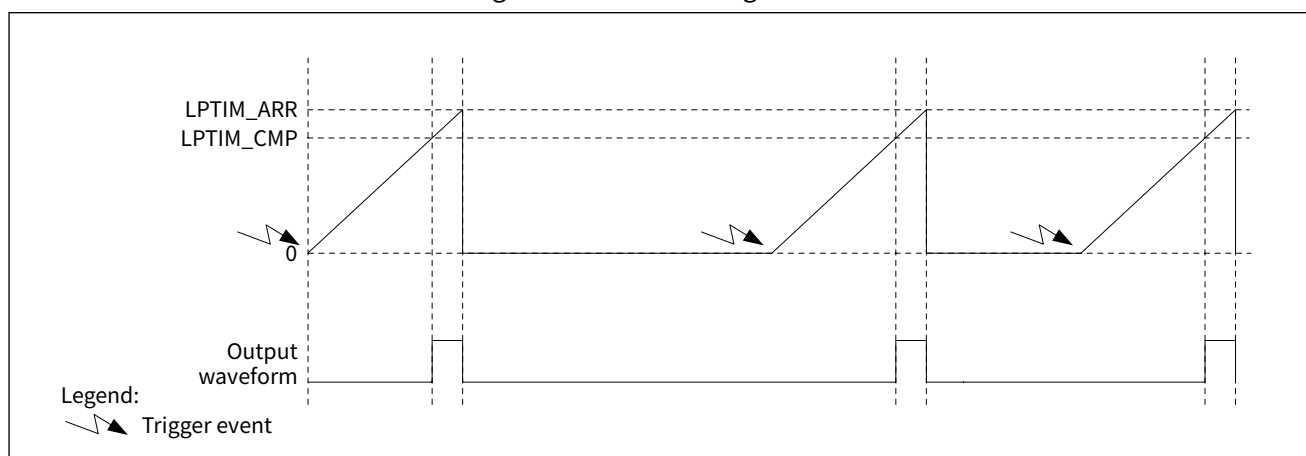
Single mode

In the single-counting mode, the counter can be started by software or triggered by an event, and the counter CNT is driven by the TCLK clock to count up. When the count value is equal to the reload value ARR, the automatic reload match flag LPTIM_ISR.ARRM is set by hardware, and the counter stops counting at the same time.

If it is set to software start, after setting LPTIM_CR.EN to 1, set LPTIM_CR.SNGSTART to 1 to start the counter to count.

If set to trigger event start, set LPTIM_CR.EN to 1 and set LPTIM_CR.SNGSTART to 1 to make LPTIM run in single shot mode. After that, a trigger event will start the counter to count. Any trigger events after the counter starts and before the counter reaches the ARR will be discarded. After the counter is stopped, a new trigger event will start the counter again and start counting. As shown below:

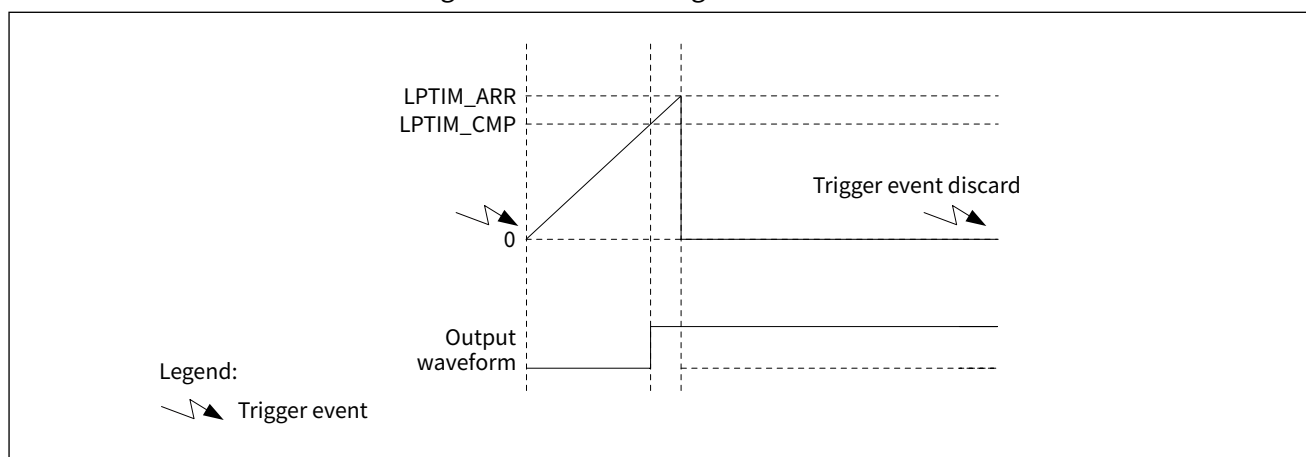
Figure 14-3 LPTIM Single Mode



Single set output

It should be noted that when the WAVE bit field of the configuration register LPTIM_CFGR is set to 1, the single set mode will be activated. In one-shot mode, the counter is only started once on the first trigger event, and any subsequent trigger events will be discarded, as shown in the following figure:

Figure 14-4 LPTIM Single Set Waveform



If it is set to software start (TRIGEN='00'), after SNGSTART is set to 1, it will start the counter for one count.

Continuous mode

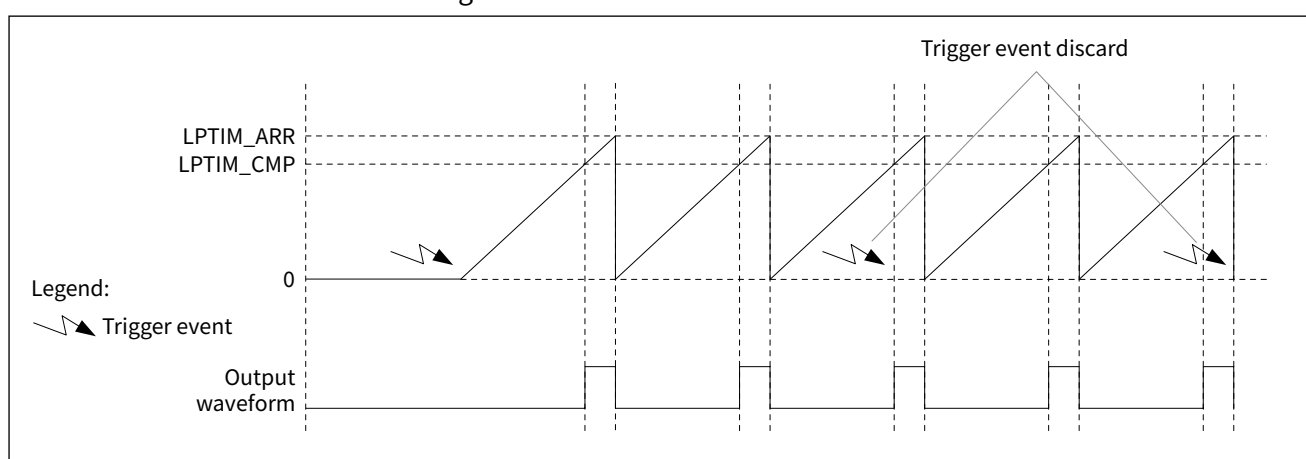
In continuous counting mode, the counter can be started by software or triggered by an event, and the counter CNT counts up under the drive of the TCLK clock. When the count value is equal to the reload value ARR, the automatic reload match flag LPTIM_ISR.ARRM is set by hardware, the counter overflows and starts to count up in the next cycle, and it stops counting until LPTIM_CR.EN is set to 0.

If it is set to software start, after setting LPTIM_CR.EN to 1, set LPTIM_CR.CNTSTART to 1 to start the counter for continuous counting.

If set to trigger event start, set LPTIM_CR.EN to 1 and set LPTIM_CR.CNTSTART to 1 to make LPTIM run in continuous mode. Thereafter, a trigger event will start the counter to count continuously and any subsequent trigger events will be discarded.

The figure below shows an example of counting and output in continuous mode.

Figure 14-5 LPTIM Continuous Mode



Single mode and continuous mode can be switched between each other during operation.

If previously configured for continuous mode, setting the SNGSTART bit field will cause the LPTIM to switch to one-shot mode. The counter (if activated) will stop as soon as the reload value ARR is reached.

If previously configured for continuous mode, setting the SNGSTART bit field will cause the LPTIM to switch to one-shot mode. The counter (if activated) will stop as soon as the reload value ARR is reached.

Setting the CNTSTART bit field will cause the LPTIM to switch to continuous mode if previously configured for single-shot mode. The counter (if activated) will restart as soon as the reload value ARR is reached.

14.3.5 Timeout function

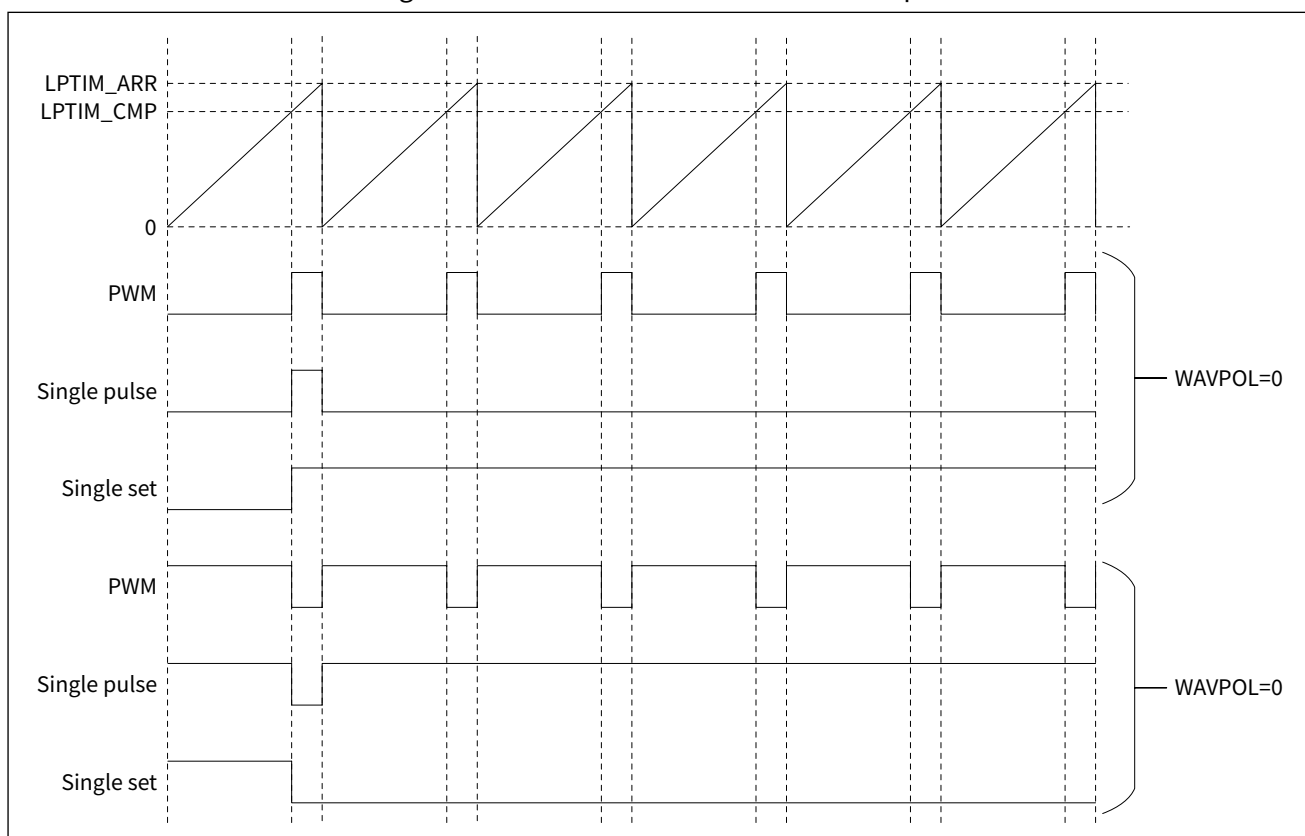
If the TIMOUT bit field is set to 1, when LPTIM is counting, the counter can be reset by a trigger signal, and the counter will start to count again from 0.

This feature can implement a low-power timeout wake-up function, and the timeout threshold is determined by the compare register LPTIM_CMP. When the trigger signal is not generated within the expected time range, that is, after the trigger signal times out, the counter counts to the comparison value CMP, and LPTIM will generate a compare match interrupt to wake up the MCU.

14.3.6 Waveform output control

LPTIM can output PWM wave in continuous mode, single pulse wave or single set waveform can be output in single mode, and the polarity of output waveform can be controlled by WAVPOL bit. When the WAVPOL bit is 0, it is a forward output; when the WAVPOL bit is 1, it is a reverse output. Change the WAVPOL bit field and the polarity change of the output waveform will take effect immediately. When LPTIM is not enabled, modifying the value of WAVPOL will also change the default level polarity of the output. The figure below shows the three waveforms that can be generated on the LPTIM output, in addition, it shows the effect of the WAVPOL bit on the polarity change.

Figure 14-6 Three waveforms of LPTIM output



14.3.7 Register update

The PRELOAD bit field of the configuration register LPTIM_CFGR is used to set the data loading time of the auto-reload register LPTIM_ARR and the compare register LPTIM_CMP. When PRELOAD is set to 0, the LPTIM_ARR and LPTIM_CMP registers will be updated immediately after the write operation; when PRELOAD is set to 1, the value of the write operation is loaded when the count value reaches the previous ARR value (if the timer has already started).

Since the APB interface of LPTIM and the core of LPTIM use different clocks, when writing the LPTIM_ARR register and the LPTIM_CMP register, there is some delay between writing the value to the register and updating the value of the register to the ARR and CMP of the LPTIM.

During this delay period, any additional writes to these registers must be avoided. Whether the ARR and CMP are updated can be judged by the ARROK flag and the CMPOK flag in the LPTIM_ISR register.

The ARROK flag and the CMPOK flag in the LPTIM_ISR register are 0, indicating that the value of the corresponding register is being updated. Any writing to the LPTIM_ARR register and the LPTIM_CMP register at this time will lead to unpredictable results. A new write operation to the same register must wait until the ARROK flag and the CMPOK flag in the LPTIM_ISR register are 1, that is, when the register has been updated.

14.3.8 Count function

LPTIM can count the signal input on the external LPTIM_CH1 pin, and can also count the internal clock signal. The count clock source is configured through the CKSEL and COUNTMD bit fields of the configuration register LPTIM_CFGR.

- When CKSEL is 0, LPTIM operation requires an internal clock ICLK
If COUNTMD is 0, LPTIM counts the pulses of the internal clock source;
If COUNTMD is 1, the LPTIM samples the input signal on the LPTIM_CH1 pin with the internal clock. Therefore, in order not to miss any events, the CH1 signal should not change more frequently than the internal clock supplied to the LPTIM. Also, the internal clock supplied to LPTIM cannot be prescaled (PRS=000). By setting the value of the CKPOL bit field, you can choose to count on the rising edge, falling edge or upper and lower edges of the CH1 signal.
- When CKSEL is 1, LPTIM operation is provided by an external clock source
In this mode, the value of the COUNTMD bit field has no effect on LPTIM, which does not require an internal clock source (unless the filter is enabled). The external signal input on CH1 of LPTIM is used as the count of LPTIM. For this configuration, the LPTIM counter can count on the rising or falling edge of the clock signal on CH1, but cannot be updated on both the rising and falling edges. Since the signal input to LPTIM's CH1 is also used to clock the LPTIM core logic, after starting LPTIM, the first 3 count clock edges are used for the configuration of the core, and the counter will not start counting until the 4th count clock edge (see 14.5. 1 external pulse count routine).



14.3.9 Encoding mode

LPTIM can process signals from quadrature encoders. The quadrature encoder indicates the position and rotation direction of the rotating element by outputting two pulse signals with a phase difference of 90 degrees. LPTIM in encoder mode is equivalent to connecting an external clock with direction selection, which means that the counter only counts continuously between 0 and the auto-reload value ARR (counting up from 0 to ARR depending on the direction, or counts down from ARR to 0). Therefore, the auto-reload register LPTIM_ARR must be configured before startup.

The two output signals of the encoder generate clock signals through the two external input ports CH1 and CH2 of the LPTIM as the LPTIM counter clock. The phase between these two signals determines the count direction. In encoding mode, the LPTIM must be clocked by the internal clock source, and the frequency of the signals input to CH1 and CH2 must not exceed the 4-frequency division of the LPTIM internal clock frequency, otherwise the LPTIM will not work properly.

Direction changes are indicated by the UP and DOWN flag bits in the LPTIM_ISR register. In addition, if the corresponding enable bit in the LPTIM_IER register is set, an interrupt will be triggered when both direction change events occur.

Before using encoder mode, the LPTIM must first be configured for continuous mode, and then set the ENC bit to 1 to enable encoder mode. After enabling, the LPTIM counter will automatically modify the count value of LPTIM_CNT according to the speed and direction of the encoder. Therefore, the count value of LPTIM_CNT represents the position of the encoder. The counting direction is indicated by the UP and DOWN signs, corresponding to the direction of rotation of the connected sensor.

LPTIM supports 3 encoding counting modes: set LPTIM_CFGR.ENCMD to 0x00, the counter will only count on the edge of CH1; set LPTIM_CFGR.ENCMD to 0x01, the counter will only count on the edge of CH2; set LPTIM_CFGR.ENCMD to 0x02, the counter will count on both CH1 and CH2. The edge count of CH2.

The relationship between counting direction and encoder signal is shown in the following table:

Table 14-4 Quadrature Encoding Mode Count and Direction

Model	Signal level		CH1		CH2	
	CH1	CH2	Rise	Decline	Rise	Decline
Model 1	-	High	Count down	Count up	Does not count	Does not count
	-	Low	Count up	Count down	Does not count	Does not count
Model 2	High	-	Does not count	Does not count	Count up	Count down
	Low	-	Does not count	Does not count	Count down	Count up
Model 3	High	High	Count down	Count up	Count up	Count down
	Low	Low	Count up	Count down	Count down	Count up

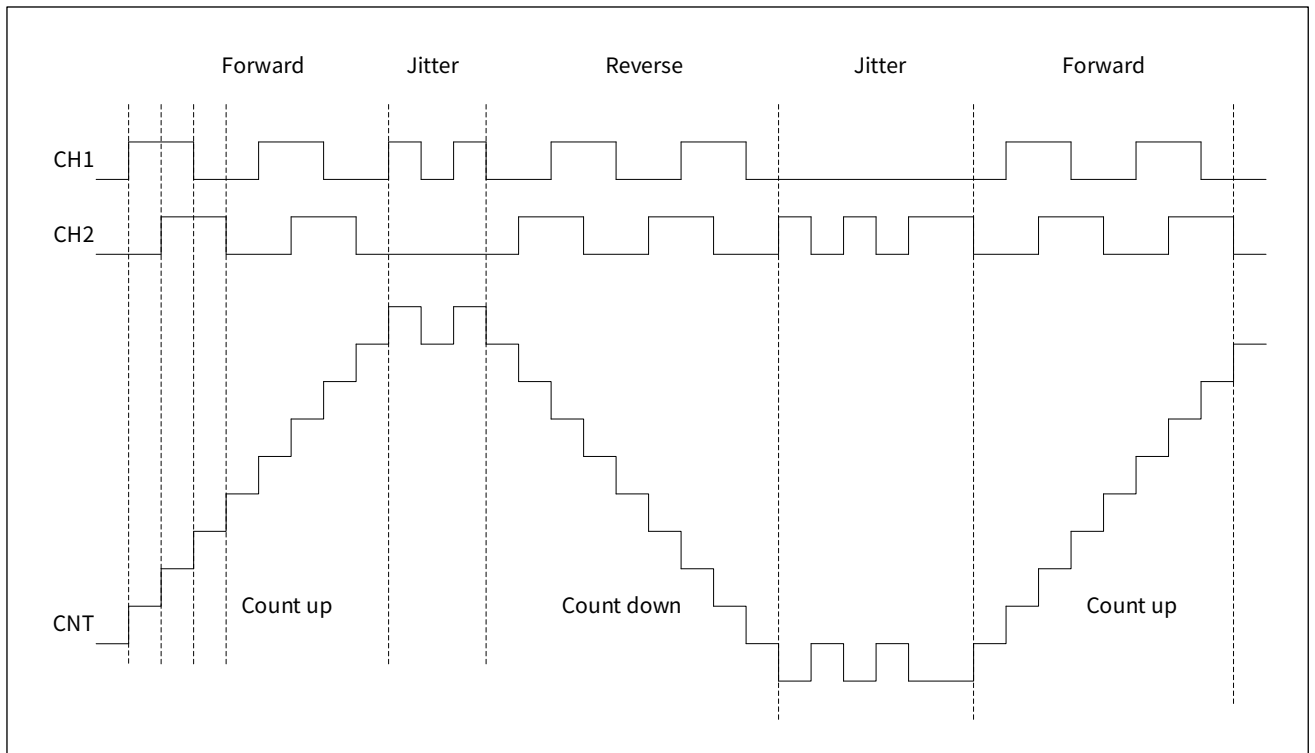
Caution:

In this mode, the LPTIM must be clocked by an internal clock source, so the CKSEL bits must remain at their reset value of 0. In addition, the prescaler division ratio must be equal to its reset value of 1 (PRS bit field must be "000").

The figure below is an example of encoder mode counting, showing the generation and direction control of the count signal.



Figure 14-7 Encoder mode count example



14.4 Debug support

LPTIM supports stop or continue counting in debug mode, which is set by the LPTIM bit field of the debug status timer control register SYSCTRL_DEBUG.

Set SYSCTRL_DEBUG.LPTIM to 1 to suspend the counter count of LPTIM in debug state;

Set SYSCTRL_DEBUG.LPTIM to 0, the counter of LPTIM continues to count in debug state.



14.5 Programming example

14.5.1 External Pulse Counting Routine

Step 1: Set SYSCTRL_APBEN1.LPTIM to 1 to enable the configuration clock of LPTIM;

Step 2: Configure the GPIO corresponding to the LPTIM_CH1 pin to the multiplexed input mode. For the specific register configuration, please refer to Chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set LPTIM_CFGR.COUNTMD, LPTIM_CFGR.CKSEL to 1, configure LPTIM counting mode, the counting clock is provided by CH1;

Step 4: Set LPTIM_IER.ARRM to 1 to enable ARR auto-reload matching interrupt;

Step 5: Set LPTIM_ARR to 6, the purpose is to trigger the ARR automatic reload matching interrupt after obtaining 10 external count pulses, because the first 5 pulses, CNT does not count;

Step 6: Set LPTIM_CR.EN to 1 to enable LPTIM.



14.6 List of registers

LPTIM base address: LPTIM_BASE = 0x4000 7800

Table 14-5 List of LPTIM registers

Register name	Register address	Register description
LPTIM_ISR	LPTIM_BASE + 0x00	Interrupt and Status Register
LPTIM_ICR	LPTIM_BASE + 0x04	interrupt clear register
LPTIM_IER	LPTIM_BASE + 0x08	Interrupt Enable Register
LPTIM_CFGR	LPTIM_BASE + 0x0C	Configuration register
LPTIM_CR	LPTIM_BASE + 0x10	Control register
LPTIM_CMP	LPTIM_BASE + 0x14	Compare register
LPTIM_ARR	LPTIM_BASE + 0x18	Auto-reload register
LPTIM_CNT	LPTIM_BASE + 0x1C	Counter register



14.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

14.7.1 PTIM_CFGR configuration register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:27	RFU	-	Reserved bits, please keep the default value
26:25	ICKSRC	RW	ICLK source configuration 00: PCLK 01: PCLK 10: LSE 11: LSI
24	ENC	RW	Encoder Mode Enable 0: Disable 1: Enable Caution: Encoding circuits require ICLK to function properly
23	COUNTMD	RW	Counting Mode Configuration 0: Timing mode, the divided clock of ICLK drives the counter to count 1: Counting mode, the edge of the CH1 pin drives the counter to count
22	PRELOAD	RW	ARR and CMP register update mode 0: Update registers immediately 1: Update the registers when the LPTIM cycle ends
21	WAVPOL	RW	Polarity Configuration of Output Waveforms 0: PWM positive output, $CNT \geq CMP$ output high level 1: PWM reverse output, $CNT < CMP$ output high level
20	WAVE	RW	Waveform Control 0: Single start SNGSTRT corresponds to single pulse waveform, continuous start CNTSTRT corresponds to PWM waveform 1: Single Set Waveform
19	TIMOUT	RW	Trigger timeout enable 0: Trigger events that occur while counting are ignored 1: A trigger event that occurs while counting is in progress will clear the count and restart counting



Bit field	Name	Permission	Functional description
18:17	TRIGEN	RW	Trigger Enable and Polarity 00: Software trigger, start the counter by software writing to the register 01: Hardware trigger, start the counter on the rising edge of the trigger signal 10: Hardware trigger, start the counter on the falling edge of the trigger signal 11: Hardware trigger, start the counter on the rising or falling edge of the trigger signal
16	RFU	-	Reserved bits, please keep the default value
15:13	TRIGSEL	RW	Trigger source selection 000: Signal of LPTIM_ETR pin 001: ALARMA match signal for RTC 010: ALARMB match signal for RTC 011: Wake-up timer wake-up signal for RTC 100: Timestamp event signal for RTC 101: Signal of PC13 pin 110: VC1 output signal 111: VC2 output signal
12	RFU	-	Reserved bits, please keep the default value
11:9	PRS	RW	ICLK/CH1FP signal frequency division configuration 000: DIV1 001: DIV2 010: DIV4 011: DIV8 100: DIV16 101: DIV32 110: DIV64 111: DIV128 Caution: When COUNTMD is 1 and CKSEL is 0, only configurable to 000
8	RFU	-	Reserved bits, please keep the default value
7:6	TRIGFLT	RW	Trigger signal digital filter configuration 00: No filtering 01: 2 ICLK clock cycles 10: 4 ICLK clock cycles 11: 8 ICLK clock cycles Caution: Configurable only for no filtering when ICLK is stopped
5	RFU	-	Reserved bits, please keep the default value



Bit field	Name	Permission	Functional description
4:3	CHFLT	RW	CH1 / CH2 channel digital filter configuration 00: No filter functions 01: 2 ICLK clock cycles 10: 4 ICLK clock cycles 11: 8 ICLK clock cycles Caution: Configurable only for no filtering when ICLK is stopped
2:1	ENCMD	RW	Encoder working mode configuration 00: Code counting mode 1, CH1 signal change edge counting 01: Code counting mode 2, CH2 signal change edge counting 10: Code counting mode 3, CH1/CH2 signal change edge counting 11: Reserved
2:1	CKPOL	RW	CH1 signal count edge configuration 00: The counter increments on the rising edge of the CH1 signal 01: The counter increments on the falling edge of CH1 signal 10: The counter increments when the CH1 signal rises or falls 11: Reserved Caution: When CKSEL is 1, only configurable as 00/01
0	CKSEL	RW	Counter count clock TCLK source configuration 0: The count clock comes from MCLK and counts PCLK / LSE / LSI / CH1 edges 1: The count clock comes from CH1FPD, and counts the clock input by CH1 Caution: In encoder mode, only 0 can be configured

Caution:

This register can only be set when LPTIM is disabled



14.7.2 LPTIM_CR control register

Address offset: 0x10 Reset value: 0x0000 0018

Bit field	Name	Permission	Functional description
31:5	RFU	-	Reserved bits, please keep the default value
4	ARST	RW	Asynchronous reset of counter count value W0: Reset counter count value W1: No function R0: The counter count value is being reset R1: Counter count value reset completed Caution: 0 can be written to reset only when this control bit is read as 1
3	SRST	RW	Synchronous reset of counter count value W0: Reset counter count value W1: No function R0: The counter count value is being reset R1: Counter count value reset completed Caution: 0 can be written to reset only when this control bit is read as 1
2	CNTSTART	RW	Continuous Mode Operation Control W0: No function W1: Start continuous mode
1	SNGSTART	RW	One-shot mode operation control W0: No function W1: Start single-pulse mode
0	EN	RW	LPTIM enable control 0: Disable LPTIM 1: Enable LPTIM

14.7.3 LPTIM_ARR auto-reload register

Address offset: 0x18 Reset value: 0x0000 0001

Bit field	Name	Permission	Functional description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	Auto-reload value



14.7.4 LPTIM_CNT counter register

Address offset: 0x1C Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CNT	RO	Counter value Caution: Reading the same value twice in a row is considered read data

14.7.5 LPTIM_CMP compare register

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CMP	RW	Comparison value



14.7.6 LPTIM_IER interrupt enable register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:7	RFU	-	Reserved bits, please keep the default value
6	DOWN	RW	Counting direction changes to reverse interrupt enable control 0: Disable 1: Enable
5	UP	RW	Counting direction changes to positive interrupt enable control 0: Disable 1: Enable
4	ARROK	RW	Auto-reload register update complete interrupt enable control 0: Disable 1: Enable
3	CMPOK	RW	Compare register update completion interrupt enable control 0: Disable 1: Enable
2	EXTTRIG	RW	Trigger completion interrupt enable control 0: Disable 1: Enable
1	ARRM	RW	Auto-reload match interrupt enable control 0: Disable 1: Enable
0	CMPM	RW	Compare match interrupt enable control 0: Disable 1: Enable

Caution:*This register can only be set when LPTIM is disabled.*

14.7.7 LPTIM_ISR interrupt and status register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:9	RFU	-	Reserved bits, please keep the default value
8:7	DIR	RO	Encoder count direction 00: The encoder stops counting, and the current counting direction is decrement 01: The encoder stops counting, and the current counting direction is incrementing 10: The encoder is counting, the current counting direction is decrement 11: The encoder is counting, and the current counting direction is incrementing
6	DOWN	RO	Encoder counting direction becomes reverse sign 0: The counting direction has not changed 1: Counting direction changes from incrementing to decrementing
5	UP	RO	Encoder counting direction changes to positive sign 0: The counting direction has not changed 1: Counting direction changes from decrementing to incrementing
4	ARROK	RO	Auto-reload register update completion flag 0: Auto-reload registers are being updated 1: Auto-reload registers has been updated
3	CMPOK	RO	Compare Register Update Completion Flag 0: Compare registers are being updated 1: The compare register has been updated
2	EXTTRIG	RO	Trigger completion flag 0: No trigger event occurred 1: Triggering event has occurred
1	ARRM	RO	Auto-reload match flag 0: The counter count value is not equal to the ARR register value 1: The counter count value is equal to the ARR register value
0	CMPM	RO	Compare match flags 0: The count value of the counter is not equal to the value of the CMP register 1: The count value of the counter is equal to the value of the CMP register



14.7.8 LPTIM_ICR interrupt clear register

Address offset: 0x04 Reset value: 0x0000 007F

Bit field	Name	Permission	Functional description
31:7	RFU	-	Reserved bits, please keep the default value
6	DOWN	R1W0	Counting direction changes to reverse flag clear W0: Clear the count direction to reverse flag W1: No function
5	UP	R1W0	Counting direction changes to positive flag clear W0: Clear the count direction to positive flag W1: No function
4	ARROK	R1W0	Auto-reload register update complete flag cleared W0: Clear auto-reload register update done flag W1: No function
3	CMPOK	R1W0	Compare register update complete flag is cleared W0: Clear compare register update complete flag W1: No function
2	EXTTRIG	R1W0	Trigger completion flag clear W0: Clear trigger completion flag W1: No function
1	ARRM	R1W0	Auto-reload match flag clear W0: Clear auto-reload match flag W1: No function
0	CMPM	R1W0	Compare match flag clear W0: Clear compare match flag W1: No function



15 General-purpose timer (GTIM)

15.1 Overview

CW32L083 integrates 4 general-purpose timers (GTIM), each GTIM is completely independent and has the same function, each contains a 16-bit automatic reload counter and is driven by a programmable prescaler. GTIM supports 4 basic working modes: timer mode, counter mode, trigger start mode and gate control mode. Each group has 4 independent capture/compare channels, which can measure the pulse width of input signals (input capture) or generate output waveforms (output compare and PWM).

15.2 Main features

- Programmable prescaler supports 1,2,3,4,...,65536 frequency division
- 16-bit auto-reload counter
- Supports single counting mode and continuous counting mode
- Counting function for internal ITR or ETR input signal
- Internal ITR or ETR input signal triggers start counting
- 4 independent input capture and output compare channels
- Supports incremental (quadrature) encoders for positioning
- Overflow event triggers digital output level transition
- Internal cascade ITR and on-chip peripheral interconnect ETR
- Interrupt/DMA generated when various events occur
 - Counter count overflow
 - The counter is triggered to start
 - Input capture
 - Output compare

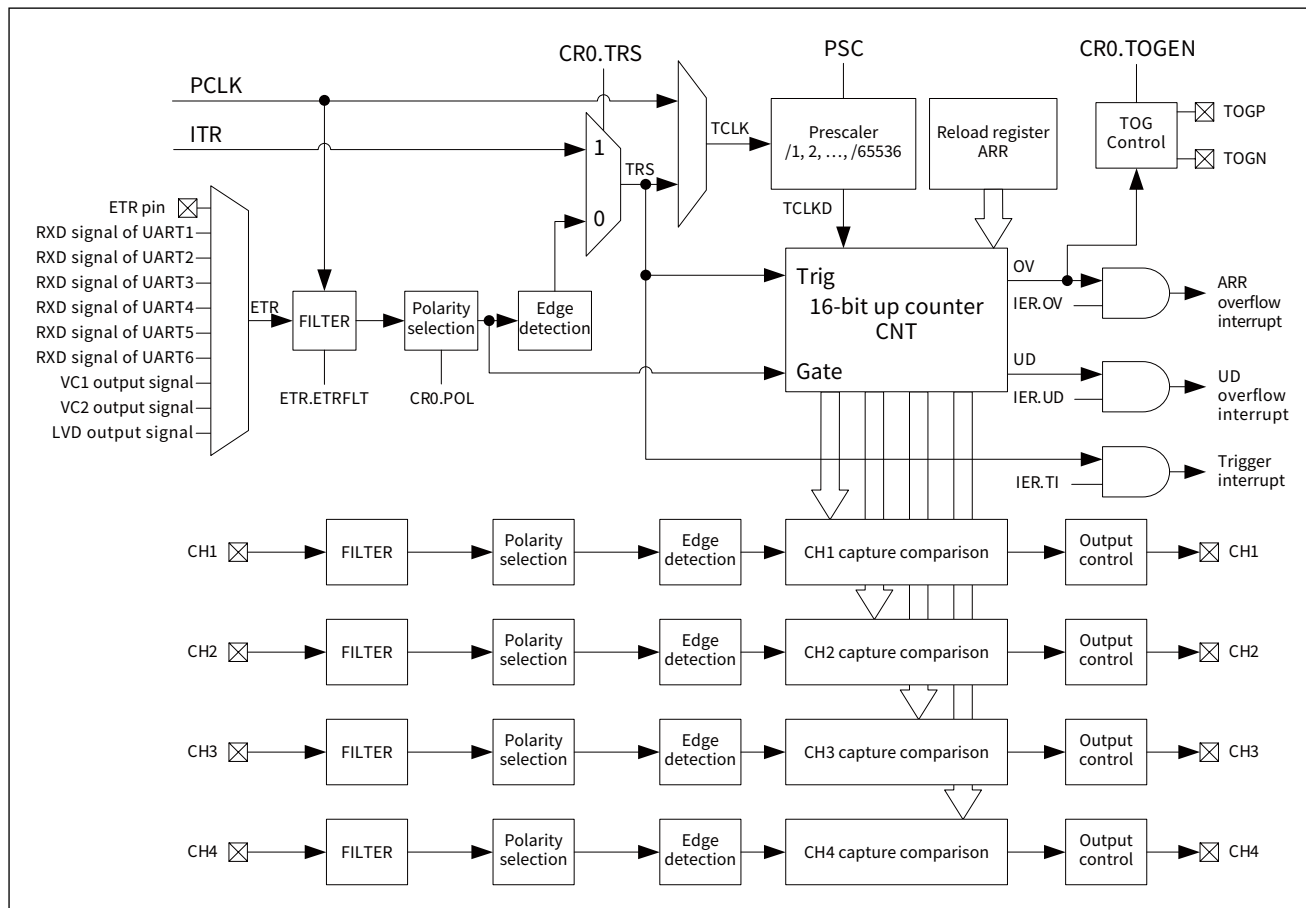


15.3 Functional description

15.3.1 Functional block diagram

The functional block diagram of GTIM is shown in the following figure:

Figure 15-1 GTIM functional block diagram



15.3.1.1 Prescaler

The prescaler coefficient is configured by the GTIMx_PSC register, and the specific frequency division coefficient is related to the counter clock source TCLK. When the counter clock source is PCLK, the frequency division coefficient is PSC+1; when the counter clock source is TRS, the frequency division coefficient is PSC (PSC>0).

It is allowed to modify GTIMx_PSC during the timer operation, but the new prescale factor will not take effect immediately. When the timer overflows or the running control bit GTIMx_CR0.EN changes from 0 to 1, the new prescale factor takes effect.



15.3.1.2 Counting unit

The core component of the counting unit is a 16-bit counter CNT and a 16-bit automatic reload register ARR.

It is allowed to modify the reload register ARR while the timer is running, and the value of ARR will take effect immediately. The correct counting range of the counter CNT is between 0 and the reload value ARR. Therefore, when setting the reload register ARR, ensure that the value of CNT is less than the set value of the ARR register.

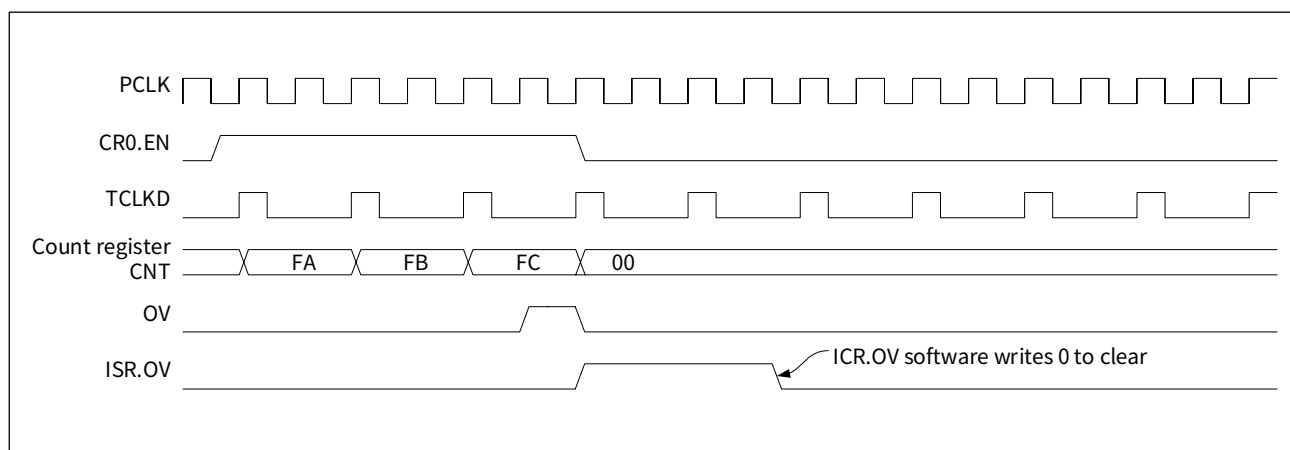
The counter can work in single count or continuous count mode, which is selected by the ONESHOT bit field of the control register GTIMx_CR0.

Single counting mode

Set GTIMx_CR0.ONESHOT to 1 to make the timer work in single counting mode. Set GTIMx_CR0.EN to 1 to enable GTIMx, and the counter CNT counts up under the drive of the TCLKD clock. When the count value reaches the reload value ARR, an overflow signal OV is generated (the overflow signal OV remains for one PCLK cycle, and then automatically cleared), and the counter stops counting, and GTIMx_CR0.EN is automatically reset by hardware.

The following figure is an example of single counting mode:

Figure 15-2 Single counting mode (PSC=0x01, ARR=0xFC)

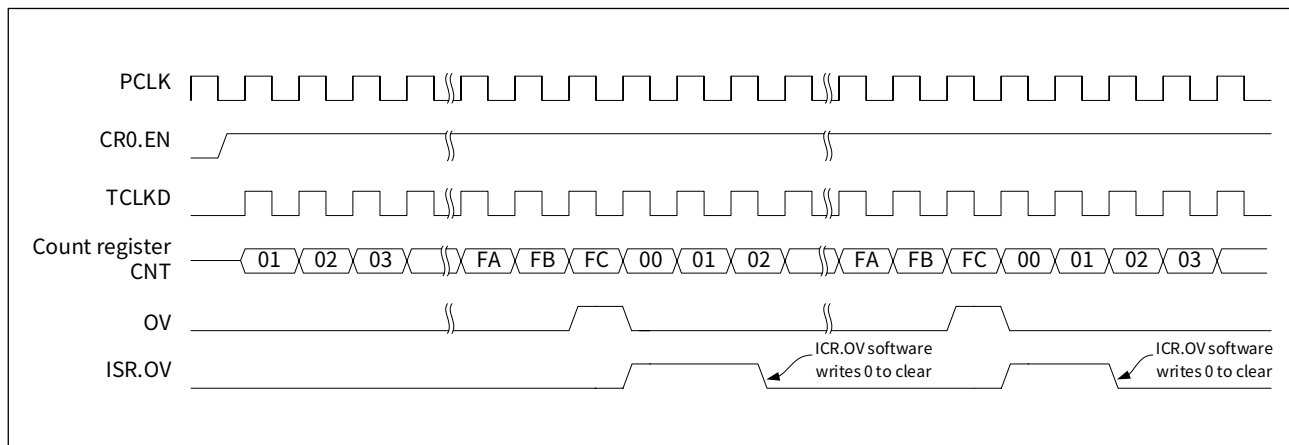


Continuous counting mode

Set GTIMx_CR0.ONESHOT to 0 to make the timer work in continuous counting mode. Set GTIMx_CR0.EN to 1 to enable GTIMx, and the counter CNT counts up under the drive of the TCLKD clock. When the count value reaches the reload value ARR, an overflow signal OV is generated (the overflow signal OV remains for one PCLK cycle, and then automatically cleared). When the count value changes from ARR to 0, the counter ARR overflow flag bit GTIMx_ISR.OV is set by hardware, the counter starts to count up in the next cycle, and stops counting until GTIMx_CR0.EN is set to 0.

The following figure is an example of continuous counting mode:

Figure 15-3 Continuous counting mode (PSC=0x00, ARR=0xFC)



Encoding counting mode

When the register bit GTIMx_CR0.ENCMODE is not 0x00, the counter works in the encoding counting mode. At this time, the counting direction of the counter is specified by the hardware, which can count up or count down. The counter CNT is automatically incremented or decremented by 1 according to GTIMx_ISR.DIR. Whenever counting up to ARR, the counter will generate an overflow signal OV, and automatically start counting up from 0 again; whenever counting down to 0, the counter will generate an underflow signal UD, and start counting down from 0xFFFF.

15.3.1.3 Input control unit

The ETR input signal and the four compare input signals CH1~CH4 all have their own input control units. The input control unit consists of filters, polarity selection and edge detection.

Filter

The filter adopts a digital filtering method to sample the input signal at a certain frequency. When N consecutive samples of the same level are obtained, the signal is valid, otherwise the signal is invalid, so as to filter out high-frequency clutter signals.

Caution:

Since the hardware samples the input signal with the PCLK clock or the frequency division of the PCLK clock, the input signal whose frequency is higher than half of the actual sampling frequency may be missed.

The filter of the ETR input signal is configured by the external trigger control register GTIMx_ETR.ETRFLT to configure the sampling clock frequency and the number of sampling points. The filter of the comparison input CHy is configured by the control register GTIMx_CR1.CHyFLT to configure the sampling clock frequency and the number of sampling points (y=1, 2, 3, 4).

Polarity selection

Polarity selection is used to select whether to invert the input signal. The ETR input signal is selected to be inverted through the control register GTIMx_CR0.POL and applied to the gated mode. The input signal of the compare input CHy is selected by the control register GTIMx_CR1.CHyPOL whether to invert or not.

Edge detection

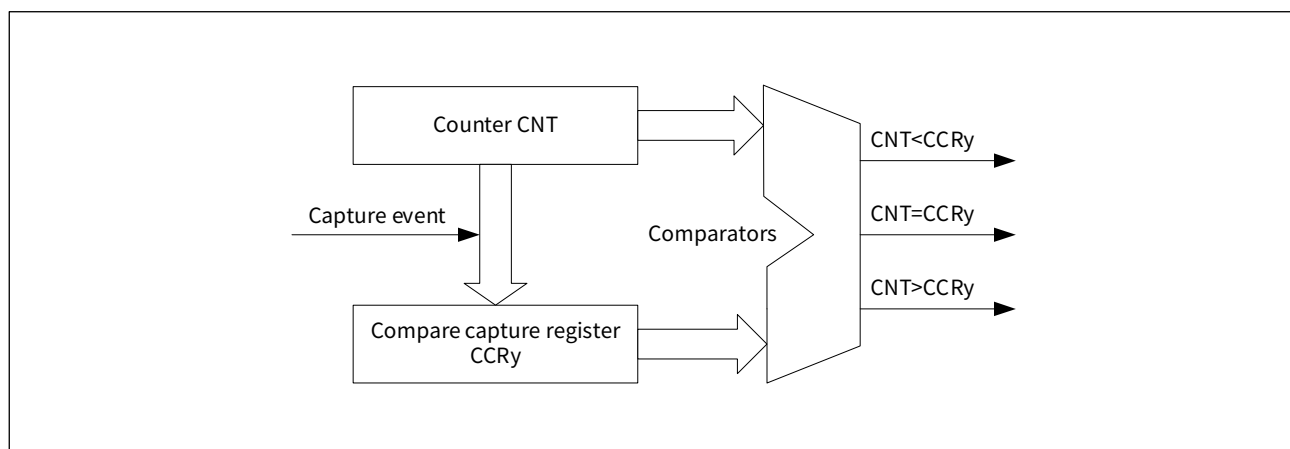
Edge detection is used to detect the transition of the input signal and whether the direction of the transition is rising or falling.



15.3.1.4 Capture compare channel

The capture compare channel consists of a compare capture register and a comparator, as shown in the following figure:

Figure 15-4 Schematic diagram of the capture compare channel



When the input is captured, once the corresponding channel has a capture event, the current value of the counter CNT is immediately transferred to the compare capture register CCRy to save, if the corresponding capture compare interrupt is enabled, an interrupt request will be generated.

When the output is compared, the value of the counter CNT is always compared with the value of the compare capture register CCRy. When the compare result is the set requirement, a signal can be generated to control the output to change. An interrupt request will be generated if the corresponding capture compare interrupt is enabled.

15.3.1.5 Output control unit

The output control unit is used to control the waveform of the output port when comparing and matching. The compare output mode of the corresponding channel is configured through the CCyM bit field of the compare capture control register GTIMx_CMMR. For the specific configuration and application, see section [15.3.4 Output compare function](#).

15.3.1.6 Flip output unit

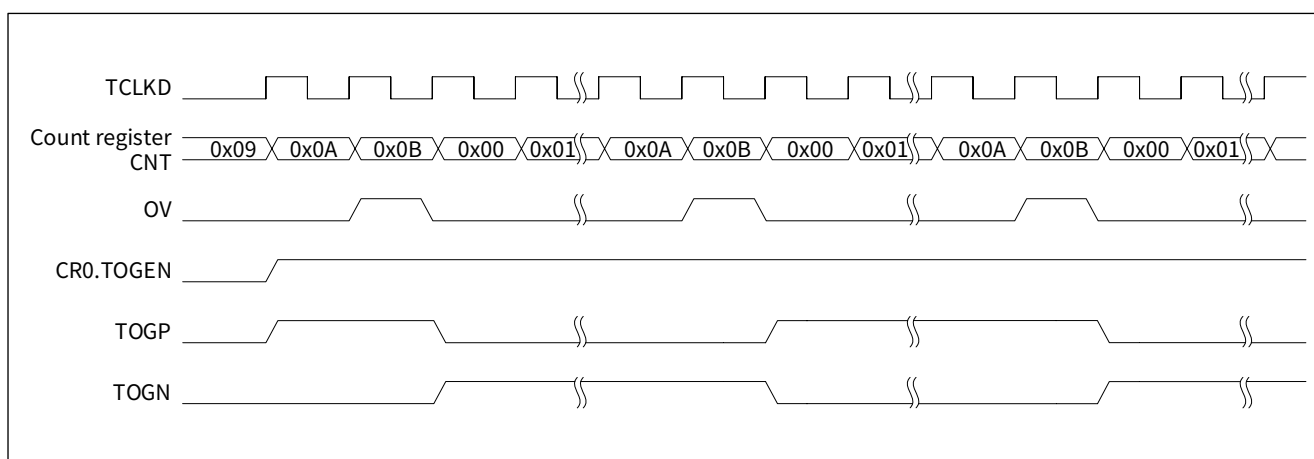
The flip output unit can control the external GTIMx_TOGP and GTIMx_TOPN pins to output the toggle signal through the ARR overflow signal OV.

When GTIMx_CR0.TOGEN is set to 0, both GTIMx_TOGP and GTIMx_TOPN pins output low level.

When GTIMx_CR0.TOGEN is set to 1, the GTIMx_TOGP and GTIMx_TOPN pins output signals with opposite levels (the default level of GTIMx_TOGP is high); when the counter ARR overflows (GTIMx_ISR.OV is 1), the GTIMx_TOGP and GTIMx_TOPN pins output The level will flip.

The following figure shows the schematic diagram of GTIMx_TOGP and GTIMx_TOPN pin level flip output in continuous counting mode:

Figure 15-5 Schematic diagram of level flip output (continuous counting mode, ARR=0x0B)



The TOGP/TOGN pins supported by GTIM are shown in the following table:

Table 15-1 GTIM flip output pins

TOGP/TOGN	Pin	AFR
GTIM1_TOGP	PB06/PB12	0x06
GTIM1_TOGN	PB07/PB13	0x06
GTIM2_TOGP	PB12	0x01
	PE00	0x05
	PD06/PF00	0x06
GTIM2_TOGN	PB13	0x01
	PE01	0x05
	PD07/PF01	0x06
GTIM3_TOGP	PF02	0x05
	PC14/PF06	0x06
GTIM3_TOGN	PF08	0x05
	PC15/PF07	0x06
GTIM4_TOGP	PF06	0x03
	PB01	0x04
	PE00	0x07
GTIM4_TOGN	PF07	0x03
	PB02	0x04
	PE01	0x07



15.3.2 Basic operating modes

GTIM supports 4 basic operating modes: timer mode, counter mode, trigger start mode and gated mode. Configured by the MODE bit field of the control register GTIMx_CR0.

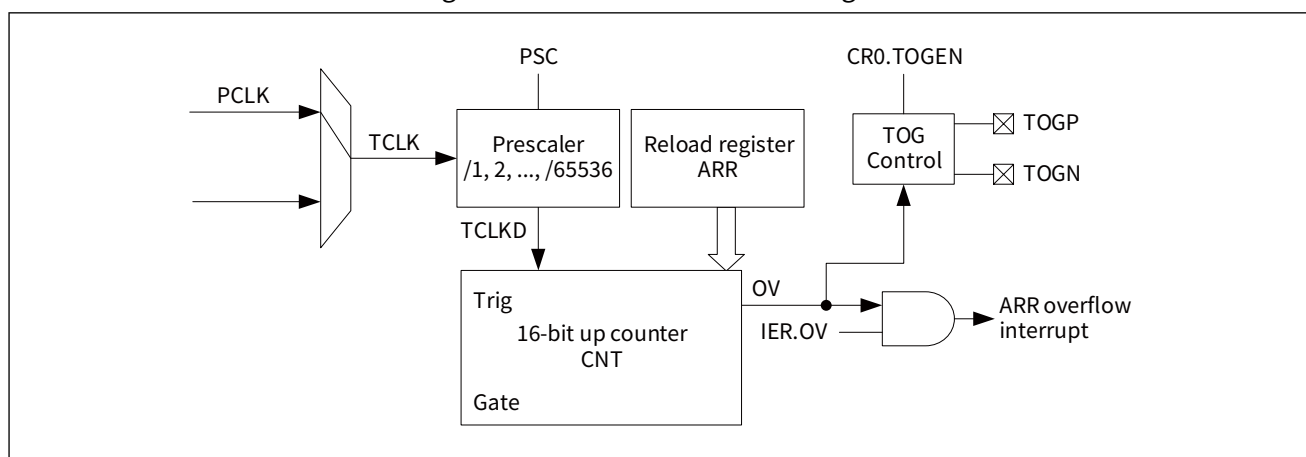
Table 15-2 GTIM basic operating modes

General-purpose timer	MODE bit field value	Basic operating mode	Description
GTIMx_CR0 (x=1,2,3,4)	00	Timer mode	The clock source is PCLK
	01	Counter mode	The counting source is TRS signal
	10	Trigger start mode	The clock source is PCLK, and the TRS signal triggers the counter to start
	11	Gated mode	The clock source is PCLK, and the ETR input signal is used as the gate control signal

15.3.2.1 Timer mode

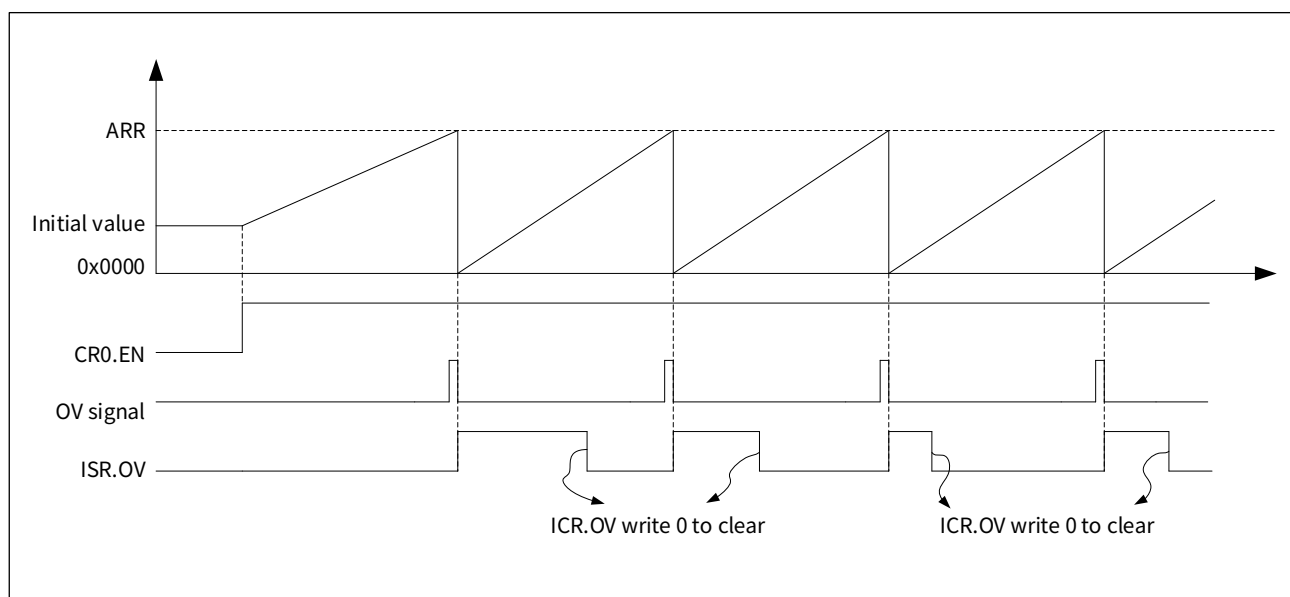
Set the MODE bit field of the control register GTIMx_CR0 to 0x00 to make GTIMx work in timer mode. In this mode, the counter clock source is the internal system clock PCLK, which is divided by the prescaler to obtain the count clock TCLKD to drive the counter CNT to count. The function block diagram of timer mode is shown in the following figure:

Figure 15-6 Timer mode block diagram



In practical applications, the frequency of the system clock PCLK is known. By setting the prescaler coefficient PSC reasonably, the clock with a fixed duration can be counted, in conjunction with the setting of the reload value ARR and the use of the counter ARR overflow interrupt flag bit, you can accurately obtain a specific duration, so as to achieve the purpose of timing. The following figure is the timing waveform of the timer in continuous counting mode:

Figure 15-7 Continuous counting, timer mode waveform



Timing time T calculation formula:

$$T = ((PSC+1)/PCLK) \times (ARR+1)$$

Where, PCLK is the counter clock source, PSC is the prescaler coefficient, and ARR is the reload value.

Example:

When the frequency of the counter clock source PCLK is 24MHz, the timing is required to be 10ms.

If the prescaler coefficient PSC is set to 0xFF,

calculate:

$$T = 10ms = ((255+1)/24MHz) \times (ARR+1)$$

then

$$ARR = 936.5$$

That is, the reload value ARR can be set to 937(0x3A9).

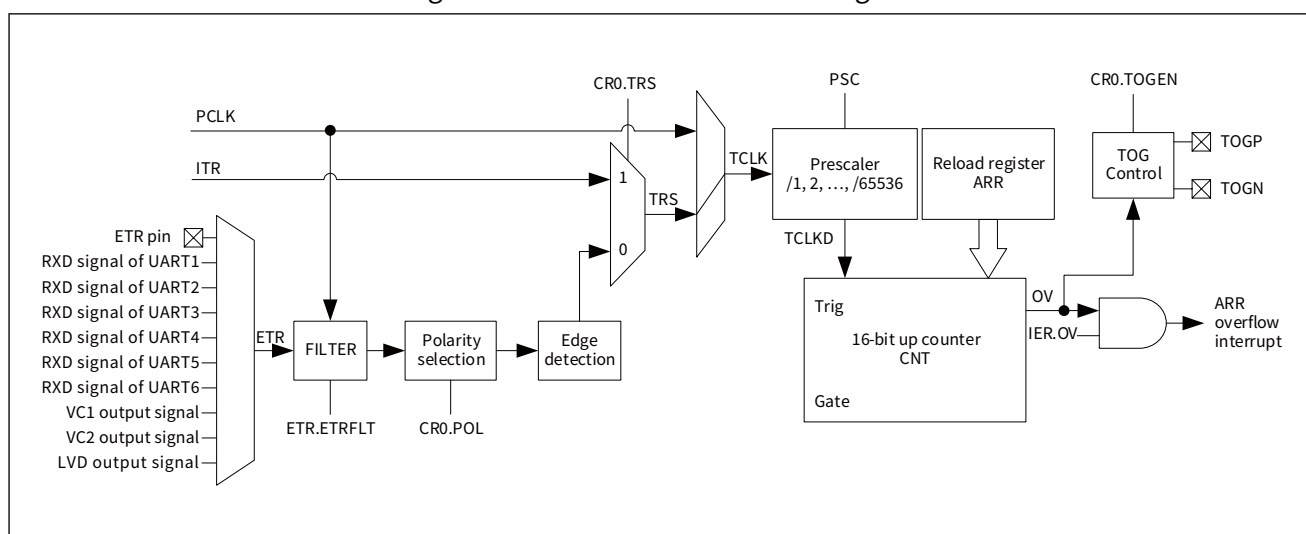
15.3.2.2 Counter mode

Set the MODE bit field of the control register GTIMx_CR0 to 0x01 to make GTIMx work in counter mode. In this mode, the counter clock source is the TRS signal, and the source of the TRS can be selected as the internal ITR signal or the ETR input signal through the TRS bit field of the control register GTIMx_CR0.

When setting the TRS bit field of the control register GTIMx_CR0 to 0, the source of the TRS signal is the ETR input signal. By setting the POL bit field of the control register GTIMx_CR0, you can choose to count on the rising or falling edge of the ETR input signal; when setting the control register When the TRS bit field of the register GTIMx_CR0 is 1, the source of the TRS signal is the internal ITR signal, and the ITR signal is the output signal of other timers (refer to [Table 15-12 ITR source configuration](#)).

The functional block diagram of counter mode is shown in the following figure:

Figure 15-8 Counter mode block diagram



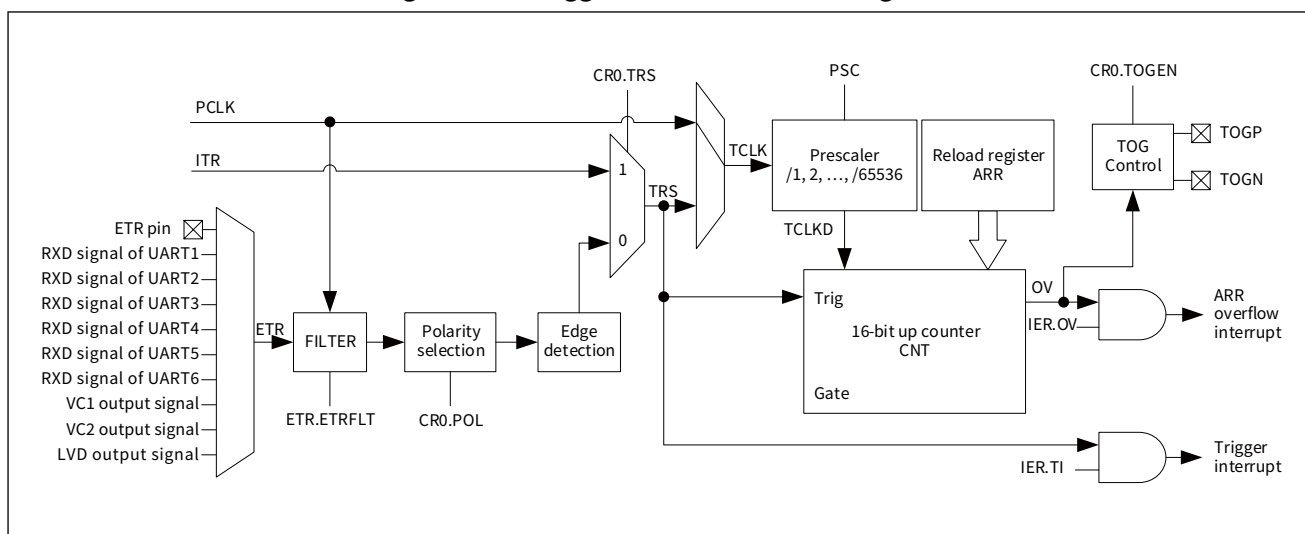
When the EN bit field of the control register GTIMx_CR0 is set to 1, the counter accumulates the counted TCLKD signal after frequency division, overflows after counting to the ARR value, and starts counting from 0 again. For the specific register configuration process in counter mode, please refer to section [15.6 Programming examples](#).

15.3.2.3 Trigger start mode

Set the MODE bit field of the control register GTIMx_CR0 to 0x02 to make GTIMx work in trigger start mode. In this mode, the counting clock of the counter is the signal TCLKD after the system clock PCLK is divided by the prescaler. When GTIMx_CR0.EN is set to 1 or the trigger signal is valid, the counter will start to count.

The source of the trigger signal TRS can be the internal ITR signal or the ETR input signal, which is selected by the TRS bit field of the control register GTIMx_CR0. When the TRS bit field of the control register GTIMx_CR0 is set to 0, the source of the TRS signal is the ETR input signal. By setting the POL bit field of the control register GTIMx_CR0, the ETR input signal can be selected to be valid on the rising edge or falling edge; when setting the control register GTIMx_CR0 When the TRS bit field is 1, the source of the TRS signal is the internal ITR signal, and the ITR signal is the output signal of other timers (refer to [Table 15-12 ITR source configuration](#)). The function block diagram of trigger start mode is shown in the following figure:

Figure 15-9 Trigger start mode block diagram

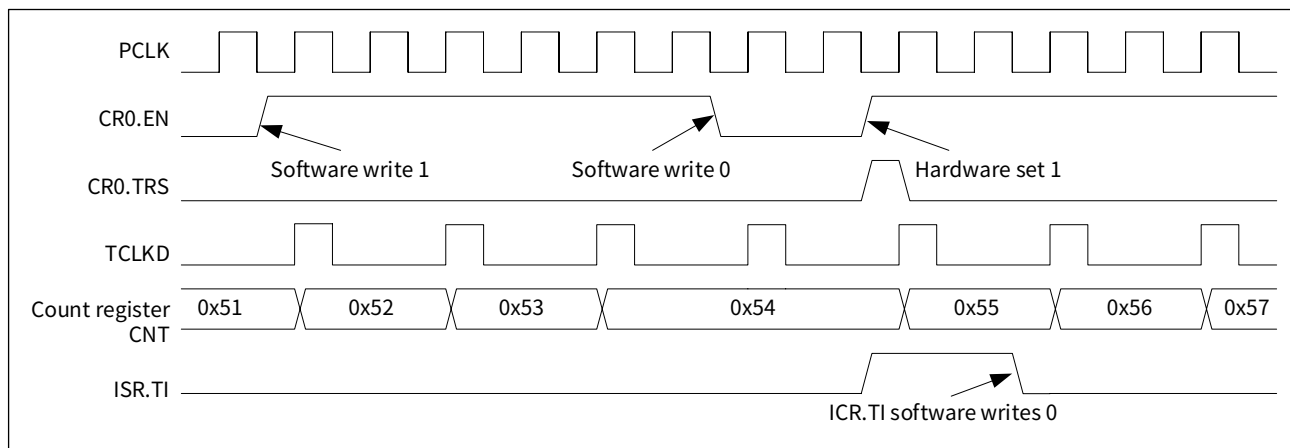


When a valid trigger signal is detected, the following effects occur:

1. GTIMx_CR0.EN is set by hardware;
2. Trigger flag bit GTIMx_ISR.TI is set by hardware;
3. The counter starts and starts counting.

After the counter is started, the counter starts to count up from the initial value. When the software sets GTIMx_CR0.EN to 0, the counter suspends counting, and sets GTIMx_CR0.EN to 1 again or when the trigger signal TRS is a valid transition, the counter resumes counting and generates a Trigger sign. The following figure shows an example of the trigger start mode timing diagram:

Figure 15-10 Timing diagram of trigger start mode (frequency division ratio is 2, PSC=0x01)



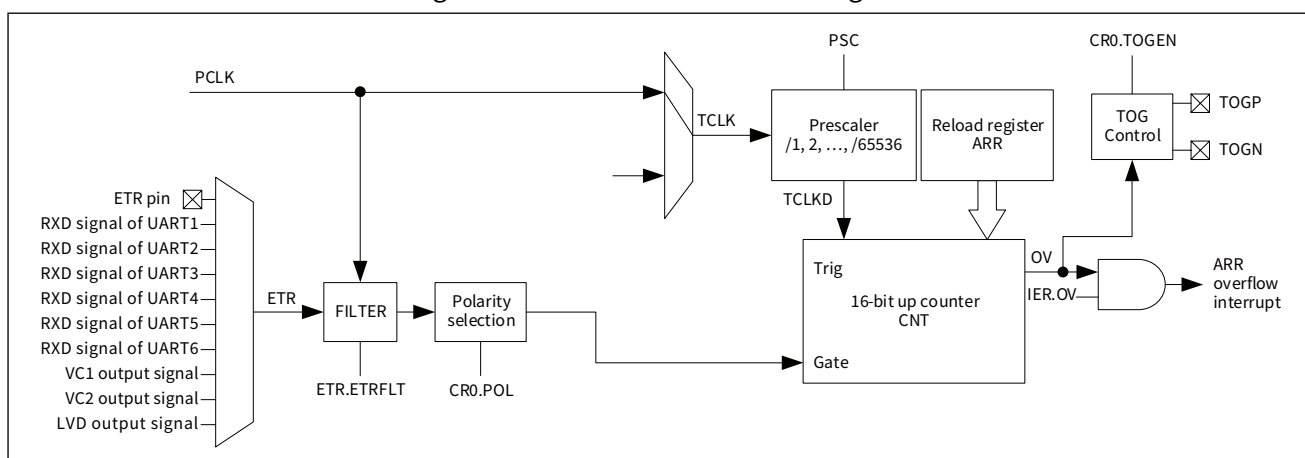
15.3.2.4 Gated mode

Set the MODE bit field of the control register GTIMx_CR0 to 0x03 to make GTIMx work in gated mode. In this mode, the counting clock of the counter is the signal TCLKD after the system clock PCLK is divided by the prescaler. When GTIMx_CR0.EN is set to 1 and the gate control signal is valid, the counter will start to count.

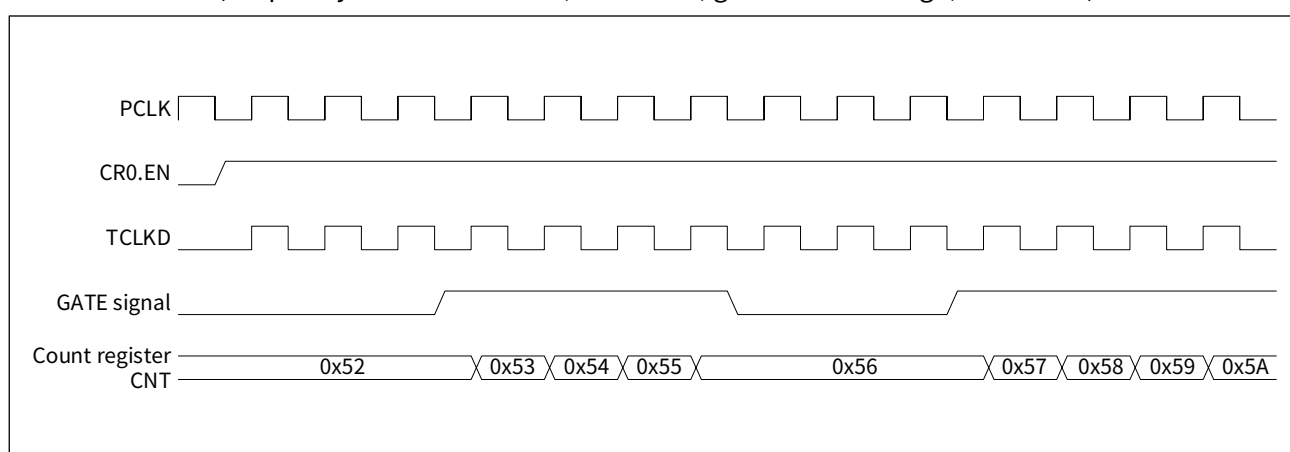
The source of the gate control signal is the ETR input signal. The source of the ETR signal can be the external GTIMx_ETR pin or other on-chip peripherals, which can be selected through the general-purpose timer ETR source configuration register SYSCTRL_GTIMETR (see section [15.3.7 On-chip peripheral interconnect ETR](#)). By setting the POL bit field of the control register GTIMx_CR0, it is possible to select whether the polarity of the ETR signal is reversed, so as to select whether the effective polarity of the gate control signal is a high level or a low level.

The function block diagram of gated mode is shown in the following figure:

Figure 15-11 Gated mode block diagram



The following figure is used to illustrate that in the gated mode, when the gated level is an invalid level, even if GTIMx_CR0.EN is set to 1, the counter will not count, only when the gated level is a valid level, the counter will count. Once the gated level is invalid, the counting will be suspended immediately.

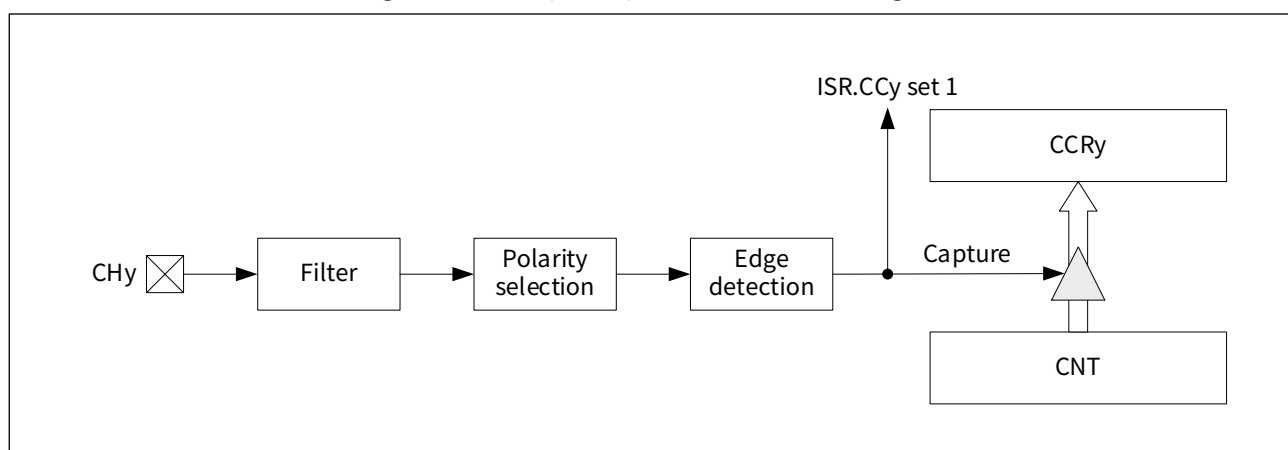
Figure 15-12 Timing diagram of gated mode
(frequency division ratio is 1, PSC=0x00, gated is active high, POL=0x00)

15.3.3 Input capture function

15.3.3.1 Input capture

When the signal on the capture compare channel CHy transitions (rising edge or falling edge), the hardware automatically stores the value of the current count register GTIMx_CNT in the compare capture register GTIMx_CCRy of the corresponding channel to complete a capture. The input capture function can be used to measure pulse width or frequency. Its functional block diagram is shown in the following figure:

Figure 15-13 Input capture mode block diagram



The conditions for triggering capture on each channel are determined by the compare capture control register GTIMx_CMMR, as shown in the following table:

Table 15-3 Input capture mode configuration

General-purpose timer	Channel CHy	CCyM bit field value	Capture mode configuration
GTIMx_CMMR (x=1,2,3,4)	CCyM (y=1,2,3,4)	0001	CHy rising edge capture
		0010	CHy falling edge capture
		0011	The rising and falling edges of CHy are captured at the same time

When a capture occurs, the channel CHy compare capture interrupt flag GTIMx_ISR.CCy is set by hardware. If the interrupt is enabled (set the interrupt enable register GTIMx_IER.CCy to 1), the CPU will respond to the interrupt service routine. Before exiting the interrupt service routine, the interrupt flag clear register GTIMx_ICR.CCy should be set to 0 to clear this flag.

15.3.3.2 Input capture sources

The input capture source of GTIM can be external GTIMx_CHy pin or other on-chip peripherals, which can be configured through the general-purpose timer input capture source configuration register SYSCTRL_GTIMxCAP.

When SYSCTRL_GTIMxCAP.CHy is 0x00, the external input port to which the capture signal is input is configured by the GPIO multiplexing function registers (GPIOx_AFRH and GPIOx_AFRL).

When SYSCTRL_GTIMxCAP.CHy is 0x01~0x07, the input capture signal comes from other on-chip peripherals, as shown in the following table:

Table 15-4 General-purpose timer input capture sources

SYSCTRL_GTIMxCAP bit field	Value	Input capture source of GTIMx
CHy (y=1, 2)	000	Configured by GPIOx_AFRH and GPIOx_AFRL
	001	RXD signal of UART1
	010	RXD signal of UART2
	011	RXD signal of UART3
	100	RXD signal of UART4
	101	Compare output signal of VC1
	110	Compare output signal of VC2
	111	LVD output signal
CHy (y=3, 4)	000	Configured by GPIOx_AFRH and GPIOx_AFRL
	001	RXD signal of UART1
	010	RXD signal of UART2
	011	RXD signal of UART6
	100	RXD signal of UART5
	101	Compare output signal of VC1
	110	Compare output signal of VC2
	111	LVD output signal

Under this configuration, the interconnection of external input can be realized inside the chip. For example, the RXD signal of the UART is used as the input capture source, and the automatic detection of the UART baud rate can be realized.

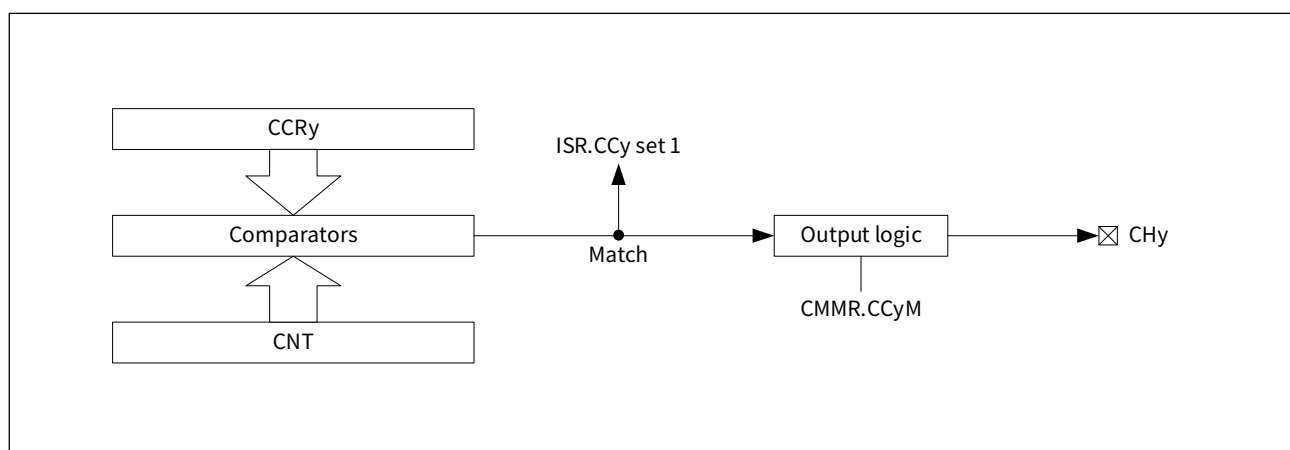


15.3.4 Output compare function

15.3.4.1 Output compare

In the output compare mode, the value of the current count register GTIMx_CNT is compared with the value of the compare capture register GTIMx_CCRy of the corresponding channel CHy. When the two match, the compare capture channel CHy can output a high level or a low level and generate a compare interrupt at the same time. The output compare function can be used to control an output waveform or indicate that a given time has arrived. Its functional block diagram is shown in the following figure:

Figure 15-14 Output compare mode block diagram



The output action of the CHy pin depends on the CCyM bit field of the compare capture control register GTIMx_CMMR, as shown in the following table:

Table 15-5 Output compare mode configuration

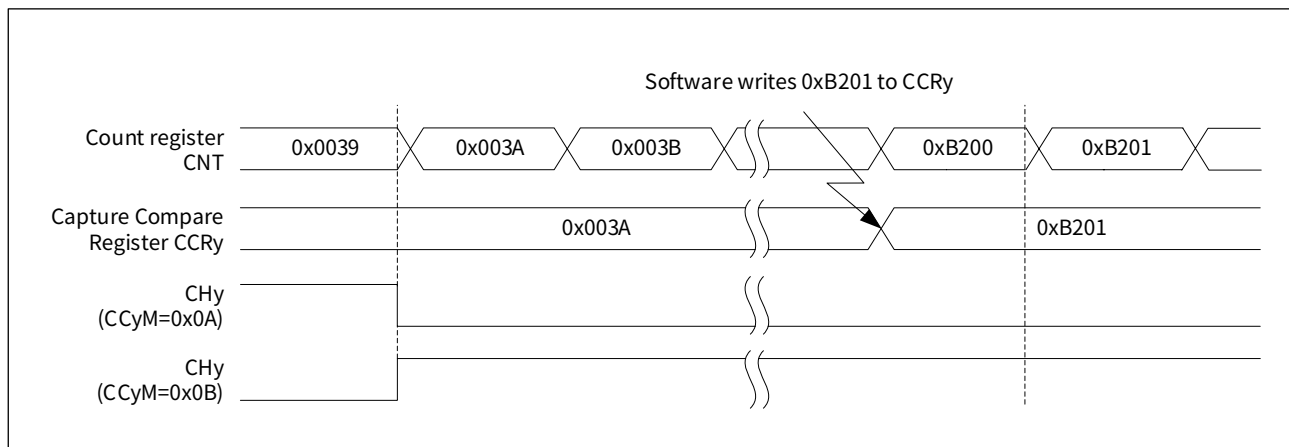
General-purpose timer	Channel CHy	CCyM bit field value	Compare mode configuration
GTIMx_CMMR (x=1,2,3,4)	CCyM (y=1,2,3,4)	1000	Force CHy to output low level
		1001	Force CHy to output high level
		1010	CHy is set to 0 on compare match
		1011	CHy is set to 1 on compare match
		1110	PWM positive output (CNT >= CCR output high)
		1111	PWM reverse output (CNT < CCR output high level)

When the value of the CCyM bit of the GTIMx_CMMR register is 0x0A, when a compare match occurs, the CHy pin outputs a low level, and the CCy bit of the GTIMx_ISR register is set to 1.

When the value of the CCyM bit in the GTIMx_CMMR register is 0x0B, when a compare match occurs, the CHy pin outputs a high level, and the CCy bit in the GTIMx_ISR register is set to 1.

The following figure shows two compare output modes: set low level and set high level, where CCRy is preset to 0x003A.

Figure 15-15 Two compare output modes



15.3.4.2 Force output function

In forced output mode, the output compare signal can be forced to a high or low state directly by software, without depending on the compare result of the compare capture register GTIMx_CCRy and the count register GTIMx_CNT.

Set the corresponding CCyM bit field in the GTIMx_CMMR register to 0x8 to force the CHy channel to output a low level. Set the corresponding CCyM bit field in the GTIMx_CMMR register to 0x9 to force the CHy channel to output a high level.

In this mode, the comparison between the GTIMx_CCRy register and the counter GTIMx_CNT is still in progress, the corresponding flags are also modified, and corresponding interrupts and DMA requests are also generated.

15.3.4.3 PWM output function

Pulse width modulation (PWM) mode can generate a signal whose frequency is determined by the reload register GTIMx_ARR and the duty cycle is determined by the compare capture register GTIMx_CCRy.

Writing 0xE or 0xF to the CCyM bits in the GTIM_CCMR register can independently set each CHy output channel to generate a PWM.

Set GTIMx_CCMR.CCyM to 0xE, when $GTIMx_CNT \geq GTIMx_CCRy$, the CHy channel outputs a high level, otherwise it outputs a low level.

Caution:

If the compare value in GTIMx_CCRy is greater than the value of the reload register GTIMx_ARR, the CHy channel output remains low;

If the compare value in GTIMx_CCRy is 0, the CHy channel output remains high.

Set GTIMx_CCMR.CCyM to 0xF, when $GTIMx_CNT < GTIMx_CCRy$, the CHy channel outputs a high level, otherwise it outputs a low level.

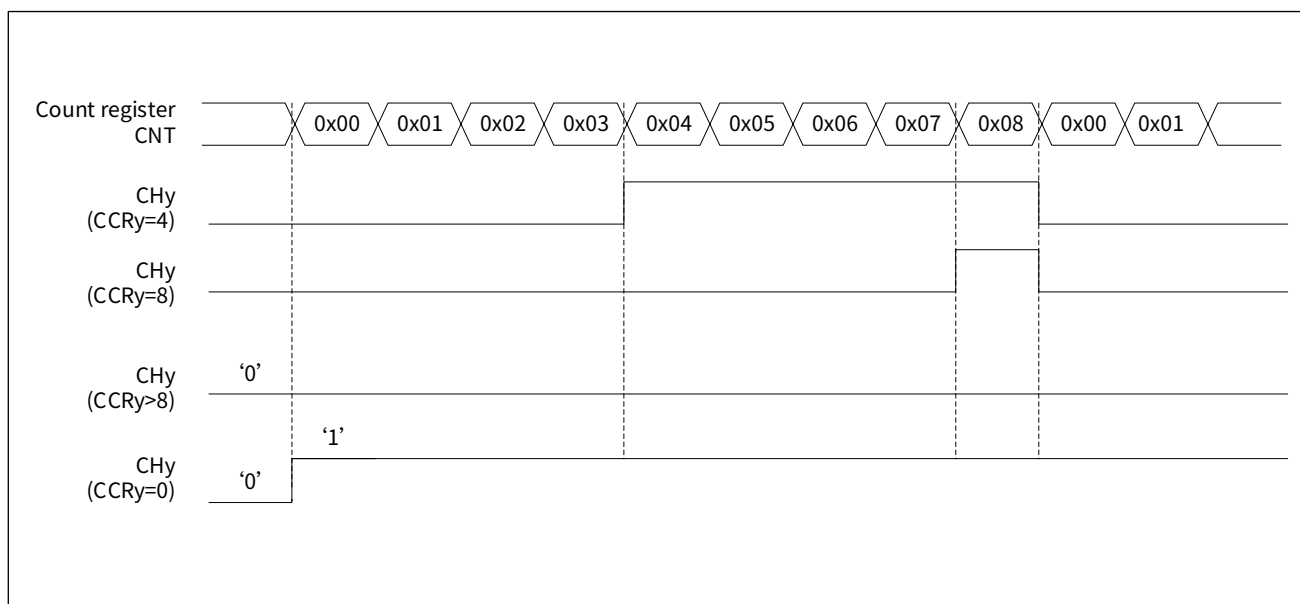
Caution:

If the compare value in GTIMx_CCRy is greater than the value of the reload register GTIMx_ARR, the CHy channel output remains high;

If the compare value in GTIMx_CCRy is 0, the CHy channel output remains low.

The following figure is an example of PWM waveform when GTIMx_CCMR.CCyM is 0xE and GTIMx_ARR is 0x08:

Figure 15-16 PWM waveform example



15.3.5 Encoding counting mode

The capture/compare channel CH1 and CH2 pins of GTIM can be connected with the encoder as the interface of the quadrature encoder. When the ENCMODE bit field of the control register GTIMx_CR0 is set to a value other than 0x00, the GTIMx works in the quadrature encoding mode, and the count clock of the counter is input by the CH1 and CH2 pins.

GTIM supports 3 encoding counting modes: set GTIMx_CR0.ENCMODE to 0x01, the counter will only count on the edge of CH1; set GTIMx_CR0.ENCMODE to 0x02, the counter will only count on the edge of CH2; set GTIMx_CR0.ENCMODE to 0x03, the counter will count at the edges of CH1 and CH2 at the same time.

Through the CH1POL and CH2POL bit fields of the control register GTIMx_CR1, you can select the polarity of the channel CH1 and CH2 input signals sent to the internal circuit. The input filters of channels CH1 and CH2 can be configured through the CH1FLT and CH2FLT bit fields of the control register GTIMx_CR1.

Setting GTIMx_CR0.EN to 1 starts the counter, which will be driven by each valid transition of the filtered and polarity controlled input signals of the channel CH1 and CH2 pins. According to the transition sequence of the two input signals, a count pulse and a direction signal are generated. The encoder's current counting direction flag GTIMx_ISR.DIR is automatically set by hardware. When the counting direction is changed, the encoder counting direction change interrupt flag bit GTIMx_ISR.DIRCHANGE will be set by hardware. If the interrupt is enabled (set GTIMx_IER.DIRCHANGE to 1), the CPU will respond to the interrupt service routine. Before exiting the interrupt service routine, GTIMx_ICR.DIRCHANGE should be set to 0 to clear this flag.

The relationship between counting direction and encoder signal is shown in the following table:

Table 15-6 Relationship between counting direction and encoder signal

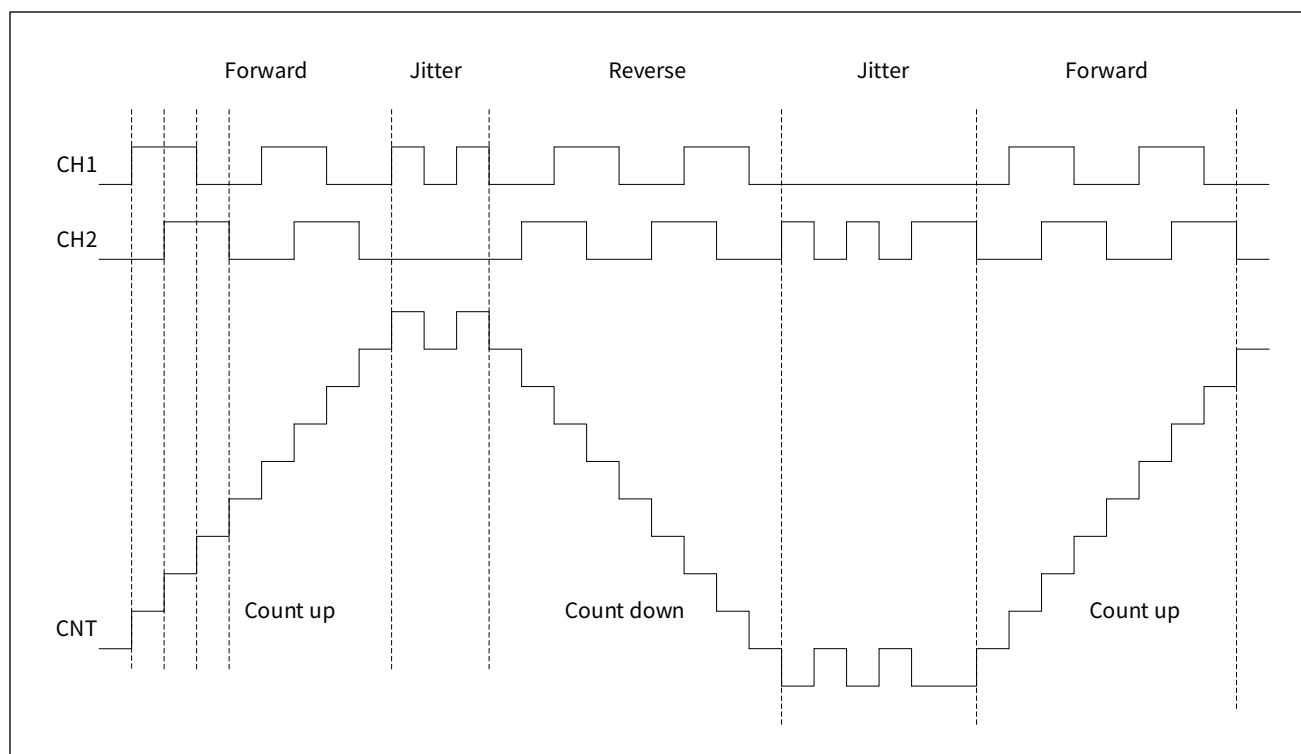
	Signal level		CH1		CH2	
	CH2	CH1	Rising	Falling	Rising	Falling
Mode 1	High	-	Downcounting	Upcounting	No counting	No counting
	Low	-	Upcounting	Downcounting	No counting	No counting
Mode 2	-	High	No counting	No counting	Upcounting	Downcounting
	-	Low	No counting	No counting	Downcounting	Upcounting
Mode 3	High	High	Downcounting	Upcounting	Upcounting	Downcounting
		Low	Upcounting	Downcounting	Downcounting	Upcounting

The third signal output by the encoder represents the mechanical zero point, which can be connected to the CH3 channel. Through the ENCRELOAD bit field of the control register GTIMx_CR0, you can choose to reload the value of the counter CNT on the rising or falling edge. You can also choose to reset the value of the counter CNT on the rising or falling edge through the ENCRESET bit field of the control register GTIMx_CR0 (the reset operation makes the value of the CNT register is 0x0000).

The following figure is an example of the operation of the encoding counting mode, showing the generation and direction control of the count signal. It also shows how input jitter is suppressed when dual edge is selected; jitter can occur when the sensor is positioned close to a transition point.



Figure 15-17 Example of counter operation in encoder mode



15.3.6 Internal cascade ITR

The timer can be cascaded through the ITR signal, thereby expanding the counting range of the timer, and it can also divide the count clock source PCLK by any number between 1 and 65535.

The source of the cascaded input ITR of GTIM is BTIM, the overflow signal of GTIM and the main mode output signal of ATIM, which can be selected by the timer ITR source configuration register SYSCTRL_TIMITR. The specific configuration is shown in the following table:

Table 15-7 ITR source configuration

SYSCTRL_TIMITR bit field	Value	ITR source
BTIM3ITR BTIM2ITR BTIM1ITR GTIM4ITR GTIM3ITR GTIM2ITR GTIM1ITR ATIMITR	000	Overflow signal of BTIM1
	001	Overflow signal of BTIM2
	010	Overflow signal of BTIM3
	011	Overflow signal of GTIM1
	100	Overflow signal of GTIM2
	101	Overflow signal of GTIM3
	110	Overflow signal of GTIM4
	111	Master mode output signal of ATIM

Caution:

The timer's ITR source cannot select its own overflow signal OV.



15.3.7 On-chip peripheral interconnect ETR

The source of the ETR signal of GTIM can be the external GTIMx_ETR pin or other on-chip peripherals, which can be selected through the general-purpose timer ETR source configuration register SYSCTRL_GTIMETR.

When SYSCTRL_GTIMETR.GTIMxETR is 0x00, the external input port of the ETR signal is configured by the GPIO multiplexing function registers (GPIOx_AFRH and GPIOx_AFRL), as shown in the following table:

Table 15-8 External GTIMx_ETR pin multiplexing

ETR	Pin	AFR
GTIM1_ETR	PE09	0x03
	PE02	0x05
	PB02/PB03	0x06
GTIM2_ETR	PA05	0x01
	PD14	0x03
	PA04/PA15	0x06
	PA00	0x07
GTIM3_ETR	PA08/PC13/PD02	0x06
GTIM4_ETR	PB11	0x01
	PB04	0x02
	PC08/PC15	0x03
	PE07	0x04

When SYSCTRL_GTIMETR.GTIMxETR is 0x01~0x07, the ETR signal comes from other on-chip peripherals to realize the interconnection between on-chip peripherals, as shown in the following table:

Table 15-9 ETR sources for GTIMx

General purpose timer	SYSCTRL_GTIMETR.GTIMxETR	ETR source for GTIMx
GTIMx (x=1, 2)	000	Configured by GPIOx_AFRH and GPIOx_AFRL
	001	RXD signal of UART1
	010	RXD signal of UART2
	011	RXD signal of UART3
	100	RXD signal of UART4
	101	Compare output signal of VC1
	110	Compare output signal of VC2
	111	LVD output signal



General purpose timer	SYSCTRL_GTIMETR.GTIMxETR	ETR source for GTIMx
GTIMx (x=3, 4)	000	Configured by GPIOx_AFRH and GPIOx_AFRL
	001	RXD signal of UART1
	010	RXD signal of UART2
	011	RXD signal of UART6
	100	RXD signal of UART5
	101	Compare output signal of VC1
	110	Compare output signal of VC2
	111	LVD output signal



15.4 Direct memory access (DMA)

Through the DMA trigger register GTIMx_DMA, you can select GTIMx to trigger the DMA function when ARR overflow occurs, trigger start, and capture compare match. Using the DMA function, data can be written to the timer from other locations, or read from the timer and written to other locations. Can be applied to automatic data handling after data capture and changing the period or pulse width of the PWM output.



15.5 Debugging support

GTIM supports stop or continue counting in debug mode, which is set by the GTIMx bit field of the debug status timer control register SYSCTRL_DEBUG.

Set SYSCTRL_DEBUG.GTIMx to 1, then suspend the counter count of GTIMx in the debug state;

Set SYSCTRL_DEBUG.GTIMx to 0, then the counter of GTIMx continues to count in the debug state.



15.6 Programming examples

15.6.1 Timer mode programming example

The following is a programming example of timer mode. In this programming example, set the frequency of the system clock PCLK to 24MHz. After starting the timer for 10ms (9.99ms), an ARR overflow interrupt request will be generated and the counting will stop.

The configuration process is as follows:

Step 1: Set the SYSCTRL_APBEN1.GTIMx bit or the SYSCTRL_APBEN2.GTIMx bit to 1, and turn on the configuration clock and working clock of GTIMx;

Caution:

GTIM1 and GTIM2 are controlled by SYSCTRL_APBEN1, and GTIM3 and GTIM4 are controlled by SYSCTRL_APBEN2.

Step 2: Set GTIMx_CR0.MODE to 0x00 to make GTIMx work in timer mode;

Step 3: Set GTIMx_CR0.ONESHOT to 0x01 to make the counter work in single counting mode;

Step 4: Set GTIMx_CR0.PSC to 0xFF and the frequency division ratio to 256, then one cycle of the count clock TCLKD is about 10.67μs;

Step 5: Set GTIMx_ARR to 0x03A9 (937), then the ARR overflow period is about 10.008ms (ARR+1);

Step 6: Set GTIMx_CNT to 0x0000 for counting;

Step 7: Set GTIMx_IER.OV to 1 to allow ARR overflow interrupt;

Step 8: Set GTIMx_CR0.EN to 1 and start GTIMx;

Step 9: ARR overflow interrupt is generated, enter the interrupt service routine, set GTIMx_ICR.OV to 0 to clear the interrupt flag.

15.6.2 Counter mode programming examples

15.6.2.1 Count external ETR signals

The steps to measure the number of rising edges of the signal input from the external GTIMx_ETR pin are as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.GTIMx to 1, turn on the GPIO clock corresponding to the GTIMx_ETR pin and the GTIMx configuration clock and working clock;

Step 2: Configure the GPIO corresponding to the GTIMx_ETR pin to the multiplexed input mode. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set GTIMx_CR0.MODE to 0x01 to make GTIMx work in counter mode;

Step 4: Set GTIMx_CR0.TRS to 0x0, and select the counting source as the ETR input signal;

Step 5: Configure GTIMx_ETR.ETRFLT, choose whether to filter or filter bandwidth;

Step 6: Set GTIMx_CR0.POL to 0x0, and select the rising edge to count as valid;

Step 7: Set GTIMx_CR0.PSC to 0x01. In this example, the input ETR signal is not divided;

Step 8: Set GTIMx_ARR to 0xFFFF, and set the ARR overflow period to the maximum;

Step 9: Set GTIMx_CNT to 0x0000 for counting;

Step 10: Set GTIMx_CR0.EN to 0x1 to start GTIMx.



15.6.2.2 Count internal ITR signal

In the following example, BTIM1 is used as the frequency divider of GTIM1 to divide the PCLK clock by 13. The operation steps are as follows:

- Step 1: Set the SYSCTRL_APBEN1.GTIM1 bit to 1, and turn on the configuration clock and working clock of GTIM1;
- Step 2: Set GTIM1_CR0.MODE to 0x01 to make GTIM1 work in counter mode;
- Step 3: Set GTIM1_CR0.TRS to 0x1, and select the counting source as the internal ITR signal;
- Step 4: Set SYSCTRL_TIMITR.GTIM1ITR to 0x00, select the ITR source of GTIM1 as the overflow signal of BTIM1;
- Step 5: Set GTIM1_CR0.PSC to 0x01, do not divide the ITR signal, and complete the frequency division through BTIM1;
- Step 6: Set GTIM1_ARR to 0xFFFF, and set the ARR overflow period to the maximum;
- Step 7: Set the initial value of GTIM1_CNT to 0x0000 for counting;
- Step 8: Set GTIM1_CR0.EN to 0x1 and start the timer;
- Step 9: Set the SYSCTRL_APBEN2.BTIM bit to 1, and turn on the configuration clock and working clock of BTIM1;
- Step 10: Set BTIM1_BCR.MODE to 0x00, select BTIM1 to work in timer mode, and use PCLK clock to count;
- Step 11: Set BTIM1_BCR.PSC to 0x00, do not divide the frequency of the PCLK clock signal;
- Step 12: Set BTIM1_BCR.ONESHOT to 0x00, BTIM1 is continuous counting mode;
- Step 13: Set the BTIM1_ARR register to 0xC, so that BTIM1 will generate an overflow signal OV after counting (ARR+1) PCLK cycles, that is, 13 PCLK cycles. This OV signal is used as the input signal ITR of GTIM1, causing 1 of GTIM1 count;
- Step 14: Set the initial value of BTIM1_CNT to 0x0000 for counting;
- Step 15: Set BTIM1_BCR.EN to 0x1 to start BTIM1.



15.6.3 Trigger start mode programming example

The counter is triggered to start counting by the signal input from the external GTIMx_ETR pin. The operation steps are as follows:

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.GTIMx to 1, turn on the GPIO clock corresponding to the GTIMx_ETR pin and the GTIMx configuration clock and working clock;
- Step 2: Configure the GPIO corresponding to the GTIMx_ETR pin to the multiplexed input mode. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set GTIMx_CR0.TRS to 0x0, and select the trigger signal as the ETR input signal;
- Step 4: Configure GTIMx_ETR.ETRFLT, choose whether to filter or filter bandwidth;
- Step 5: Configure GTIMx_CR0.POL, and set whether the trigger signal is valid on the rising or falling edge;
- Step 6: Set GTIMx_CR0.PSC to 0x00. In this example, the PCLK clock is not divided;
- Step 7: Set GTIMx_ARR to 0xFFFF, and set the ARR overflow period to the maximum;
- Step 8: Set the initial value of GTIMx_CNT to 0x0000 for counting;
- Step 9: Set GTIMx_ICR.TI to 0x0, clear interrupt flag;
- Step 10: If you need to enable the trigger interrupt request, set the register GTIMx_IER.TI bit to 1;
- Step 11: Set GTIMx_CR0.MODE to 0x02 to make GTIMx work in trigger mode. When a valid trigger signal is input, the counter will start to work.

Caution:

Set the polarity of the trigger signal first, and then set the timer mode, otherwise it will cause false triggering.



15.6.4 Gated mode programming example

The signal input from the external GTIMx_ETR pin is used as the gate control signal to control the count of the counter. The operation steps are as follows:

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.GTIMx to 1, turn on the GPIO clock corresponding to the GTIMx_ETR pin and the GTIMx configuration clock and working clock;
- Step 2: Configure the GPIO corresponding to the GTIMx_ETR pin to the multiplexed input mode. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set GTIMx_CR0.MODE to 0x03 to make GTIMx work in gated mode;
- Step 4: Set GTIMx_CR0.TRS to 0x0, and select the gate control signal as the ETR input signal;
- Step 5: Configure GTIMx_ETR.ETRFLT, choose whether to filter or filter bandwidth;
- Step 6: Configure GTIMx_CR0.POL, and set whether the gate control signal is active at high level or low level;
- Step 7: Set GTIMx_CR0.PSC to 0x00. In this example, the PCLK clock is not divided;
- Step 8: Set GTIMx_ARR to 0xFFFF, and set the ARR overflow period to the maximum;
- Step 9: Set the initial value of GTIMx_CNT to 0x0000 for counting;
- Step 10: Set GTIMx_CR0.EN to 0x01 to start the timer. When the gate control signal is valid, the counter will start to work.

15.6.5 Input capture programming example

In timer mode, the steps to measure the width of a pulse are as follows:

- Step 1: Set the SYSCTRL_APBEN1.GTIMx bit or the SYSCTRL_APBEN2.GTIMx bit to 1, and turn on the configuration clock and working clock of GTIMx;

Caution:

GTIM1 and GTIM2 are controlled by SYSCTRL_APBEN1, and GTIM3 and GTIM4 are controlled by SYSCTRL_APBEN2.

- Step 2: Set GTIMx_CR0.MODE to 0x00 to make GTIMx work in timer mode;
- Step 3: Set GTIMx_CR0.PSC and select the appropriate frequency division coefficient;
- Step 4: Set GTIMx_ARR to an appropriate value according to the characteristics of the signal. If GTIMx_ARR is set smaller, the counter clock frequency is faster, and the input pulse width is longer, GTIMx_ARR may overflow. If an overflow occurs, the overflow flag needs to be cleared in time, and the pulse width time is calculated according to the number of times the overflow flag is generated;
- Step 5: Configure GTIMx_CR1.CHyPOL and select the polarity of the signal sent to the internal circuit by channel CHy;
- Step 6: Configure GTIMx_CR1.CHyFLT, configure channel CHy input filter;
- Step 7: Set GTIMx_CMMR.CCyM to 0x01, select rising edge capture;
- Step 8: Set GTIMx_IER.CCy to 0x01, allowing capture;
- Step 9: Set GTIMx_CR0.EN to 0x1 and start the timer;
- Step 10: Wait for the capture interrupt to be generated, and read the current value in GTIMx_CCRy. Then set the corresponding bit of GTIMx_ICR.CCy to 0x0, clear the interrupt flag;
- Step 11: Set GTIMx_CMMR.CCyM to 0x02 and select falling edge capture;
- Step 12: Wait for the next capture interrupt to be generated, and read the current value in GTIMx_CCRy. The difference between the GTIMx_CCRy values read twice in this way is the length of the input pulse width.



15.6.6 Output compare programming example

In timer mode, the external output of low level through channel CH1 indicates that the timing time is up. The operation steps are as follows:

Step 1: Set the `SYSCTRL_APBEN1.GTIMx` bit or the `SYSCTRL_APBEN2.GTIMx` bit to 1, and turn on the configuration clock and working clock of GTIMx;

Caution:

GTIM1 and GTIM2 are controlled by `SYSCTRL_APBEN1`, and GTIM3 and GTIM4 are controlled by `SYSCTRL_APBEN2`.

Step 2: Set `GTIMx_CR0.MODE` to 0x00 to make GTIMx work in timer mode;

Step 3: Set `GTIMx_CR0.PSC` and select the appropriate frequency division coefficient;

Step 4: Set `GTIMx_CMMR.CC1M` to 0x0A, so that the CH1 channel of GTIMx is set to 0 when it is compared and matched;

Step 5: Set `GTIMx_CNT` to 0x0000, clear the counter;

Step 6: Set `GTIMx_CCR1`, set timing time;

Step 7: Set `GTIMx_CR0.EN` to 0x1 to start the timer. When the count value in `GTIMx_CNT` is equal to the value of `GTIMx_CCR1`, the output level on CH1 changes from high to low.

15.6.7 PWM output programming example

In timer mode, the operation steps to output a PWM waveform are as follows:

Step 1: Set the `SYSCTRL_APBEN1.GTIMx` bit or the `SYSCTRL_APBEN2.GTIMx` bit to 1, and turn on the configuration clock and working clock of GTIMx;

Caution:

GTIM1 and GTIM2 are controlled by `SYSCTRL_APBEN1`, and GTIM3 and GTIM4 are controlled by `SYSCTRL_APBEN2`.

Step 2: Set `GTIMx_CR0.MODE` to 0x00 to make GTIMx work in timer mode;

Step 3: Set `GTIMx_CR0.PSC` and select the appropriate frequency division coefficient;

Step 4: According to the period requirement of the output PWM waveform, set `GTIMx_ARR` to an appropriate value, that is, `GTIMx_ARR` can change the period of PWM;

Step 5: According to the pulse width requirement of the output PWM waveform, set `GTIMx_CCRy` to an appropriate value, that is, `GTIMx_CCRy` can change the duty cycle of PWM;

Step 6: Set `GTIMx_CMMR.CCyM` to 0x0E, select PWM forward output, that is `GTIMx_CNT` \geq `GTIMx_CCRy` output high level;

Step 7: Set `GTIMx_IER.CCy` to 0x01, enable compare interrupt;

Step 8: Set `GTIMx_CR0.EN` to 0x1 and start the timer;

Step 9: Wait for the compare interrupt to be generated, modify the value of `GTIMx_CCRy` as required to change the duty cycle of the PWM waveform, and then set the corresponding bit of `GTIMx_ICR.CCy` to 0x0 to clear the interrupt flag.



15.6.8 Encoder mode programming example

The steps to configure GTIMx to work in encoder mode 3 are as follows:

Step 1: Set the SYSCTRL_APBEN1.GTIMx bit or the SYSCTRL_APBEN2.GTIMx bit to 1, and turn on the configuration clock and working clock of GTIMx;

Caution:

GTIM1 and GTIM2 are controlled by SYSCTRL_APBEN1, and GTIM3 and GTIM4 are controlled by SYSCTRL_APBEN2.

Step 2: Set the register GTIMx_CR0.ENCMODE to 0x03, so that GTIMx works in encoding mode 3, and the counter counts on the edges of CH1 and CH2 at the same time;

Step 3: Set the register GTIMx_ARR and select the appropriate value;

Step 4: Set the CH1POL and CH2POL bits in the GTIMx_CR1 register to select the polarity of the CH1 and CH2 pin input signals sent to the internal circuit;

Step 5: Set the CH1FLT and CH2FLT bits in the GTIMx_CR1 register to select the appropriate filter configuration;

Step 6: If you need to set the DIRCHANGE bit in the register GTIMx_IER to enable, turn on the direction change interrupt;

Step 7: Set GTIMx_CR0.EN to 0x1 to start the timer.



15.7 List of registers

GTIM1 base address: GTIM1_BASE = 0x4000 0400

GTIM2 base address: GTIM2_BASE = 0x4000 1000

GTIM3 base address: GTIM3_BASE = 0x4001 4000

GTIM4 base address: GTIM4_BASE = 0x4001 4400

Table 15-10 List of GTIM registers

Register name	Register address	Register description
GTIMx_ARR	GTIMx_BASE + 0x300	Reload register
GTIMx_CNT	GTIMx_BASE + 0x304	Count register
GTIMx_CMMR	GTIMx_BASE + 0x308	Compare capture control register
GTIMx_ETR	GTIMx_BASE + 0x30C	External trigger control register
GTIMx_CR0	GTIMx_BASE + 0x310	Control register 0
GTIMx_IER	GTIMx_BASE + 0x314	Interrupt enable register
GTIMx_ISR	GTIMx_BASE + 0x318	Interrupt flag register
GTIMx_ICR	GTIMx_BASE + 0x31C	Interrupt flag clear register
GTIMx_CCR1	GTIMx_BASE + 0x320	Compare capture register 1
GTIMx_CCR2	GTIMx_BASE + 0x324	Compare capture register 2
GTIMx_CCR3	GTIMx_BASE + 0x328	Compare capture register 3
GTIMx_CCR4	GTIMx_BASE + 0x32C	Compare capture register 4
GTIMx_CR1	GTIMx_BASE + 0x330	Control register 1
GTIMx_PSC	GTIMx_BASE + 0x334	Prescaler register
GTIMx_DMA	GTIMx_BASE + 0x340	DMA trigger register



15.8 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

15.8.1 GTIMx_CR0 control register 0

Address offset: 0x310 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:21	RFU	-	Reserved bits, please keep the default value
20:19	ENCRELOAD	RW	Encoding mode, count register external reload condition configuration 00: No function 01: CH3 rising edge reload count register CNT 10: CH3 falling edge reload count register CNT Caution: The reload operation makes the value of the CNT register equal to the value of the ARR register
18:17	ENCRESET	RW	Encoding mode, count register external reset condition configuration 00: No function 01: CH3 rising edge reset count register CNT 10: CH3 falling edge reset count register CNT Caution 1: The reset operation makes the value of the CNT register equal to 0x0000; Caution 2: ENCRESET is valid when ENCRESET and ENCRELOAD are configured for the same edge.
16:15	ENCMODE	RW	Encoding counting mode enable configuration 00: The timer function is configured by the MODE bits 01: Encoding counting mode 1, CH1 signal change edge counting 10: Encoding counting mode 2, CH2 signal change edge counting 11: Encoding counting mode 3, CH1/CH2 signal change edge counting
14:7	RFU	-	Reserved bits, please keep the default value
6	TOGEN	RW	TOG pin output enable control 1: TOGP, TOGN output level is 0 1: TOGP, TOGN output signals with opposite levels
5	ONESHOT	RW	Single/continuous counting mode control 0: Continuous counting mode 1: Single counting mode



Bit field	Name	Permission	Function description
4	POL	RW	ETR input signal polarity selection 0: ETR is positive (the rising edge of trigger mode is valid, and the gated mode is valid at high level) 1: ETR is reversed (the falling edge of trigger mode is valid, and the gated mode is valid at low level)
3	TRS	RW	Trigger source selection 0: ETR input signal 1: ITR, see section 15.3.6 Internal cascade ITR
2:1	MODE	RW	Basic timing mode configuration 00: Timer mode, counting clock source is PCLK 01: Counter mode, counting clock source is TRS signal 10: Trigger start mode, the counting clock source is PCLK, and the TRS signal triggers the counter to start 11: Gated mode, counting clock source is PCLK, ETR input signal is used as gated Caution: In counter mode, the GTIMx_PSC register value must be greater than 0.
0	EN	RW	Timer running control 0: Timer stopped 1: Timer running



15.8.2 GTIMx_CR1 control register 1

Address offset: 0x330 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	CH4POL	RW	CH4 channel input signal polarity configuration 0: The in-phase signal of the CH4 pin is sent to the internal circuit 1: The inverted signal of the CH4 pin is sent to the internal circuit
14:12	CH4FLT	RW	CH4 input signal filter configuration See CH1FLT for functional description
11	CH3POL	RW	CH3 channel input signal polarity configuration 0: The in-phase signal of the CH3 pin is sent to the internal circuit 1: The inverted signal of the CH3 pin is sent to the internal circuit
10:8	CH3FLT	RW	CH3 input signal filter configuration See CH1FLT for functional description
7	CH2POL	RW	CH2 channel input signal polarity configuration 0: The in-phase signal of the CH2 pin is sent to the internal circuit 1: The inverted signal of the CH2 pin is sent to the internal circuit
6:4	CH2FLT	RW	CH2 input signal filter configuration See CH1FLT for functional description
3	CH1POL	RW	CH1 channel input signal polarity configuration 0: The in-phase signal of the CH1 pin is sent to the internal circuit 1: The inverted signal of the CH1 pin is sent to the internal circuit
2:0	CH1FLT	RW	CH1 input signal filtering configuration; sampling clock is PCLK or PCLK frequency division, the number of sampling points is N 000: no filtering 001: $F_{\text{sample}} = \text{PCLK}$, N=2 010: $F_{\text{sample}} = \text{PCLK}$, N=4 011: $F_{\text{sample}} = \text{PCLK}$, N=6 100: $F_{\text{sample}} = \text{PCLK}/4$, N=4 101: $F_{\text{sample}} = \text{PCLK}/4$, N=6 110: $F_{\text{sample}} = \text{PCLK}/8$, N=4 111: $F_{\text{sample}} = \text{PCLK}/8$, N=6



15.8.3 GTIMx_PSC Prescaler register

Address offset: 0x334 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	PSC	RW	Prescaler value When the count clock is PCLK: $TCLKD = TCLK / (PSC + 1)$ When the count clock is TRS: $TCLKD = TCLK / PSC$, $PSC > 0$

15.8.4 GTIMx_ETR external trigger control register

Address offset: 0x30C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6:4	ETRFLT	RW	ETR input signal filtering configuration; the sampling clock is PCLK or PCLK frequency division, and the number of sampling points is N 000: no filtering 001: $F_{sample} = PCLK$, $N=2$ 010: $F_{sample} = PCLK$, $N=4$ 011: $F_{sample} = PCLK$, $N=6$ 100: $F_{sample} = PCLK/4$, $N=4$ 101: $F_{sample} = PCLK/4$, $N=6$ 110: $F_{sample} = PCLK/8$, $N=4$ 111: $F_{sample} = PCLK/8$, $N=6$
3:0	RFU	-	Reserved bits, please keep the default value



15.8.5 GTIMx_CMMR compare capture control register

Address offset: 0x308 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:12	CC4M	RW	CH4 capture compare mode configuration See CC1M for functional description
11:8	CC3M	RW	CH3 capture compare mode configuration See CC1M for functional description
7:4	CC2M	RW	CH2 capture compare mode configuration See CC1M for functional description
3:0	CC1M	RW	CH1 capture compare mode configuration 0000: No function 0001: Capture on rising edge 0010: Capture on falling edge 0011: Capture the rising and falling edges at the same time 1000: Force output low level 1001: Force output high level 1010: Set to 0 on compare match 1011: Set to 1 on compare match 1110: PWM positive output (CNT >= CCR output high level) 1111: PWM reverse output (CNT < CCR output high level)

15.8.6 GTIMx_ARR reload register

Address offset: 0x300 Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	Timer reload value Caution: In encoding counting mode, ARR should be set to 0xFFFF.

15.8.7 GTIMx_CNT count register

Address offset: 0x304 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CNT	RW	Timer count value



15.8.8 GTIMx_CCR1 compare capture register 1

Address offset: 0x320 Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR	RW	CH1 channel compare/capture value

15.8.9 GTIMx_CCR2 compare capture register 2

Address offset: 0x324 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR	RW	CH2 channel compare/capture value

15.8.10 GTIMx_CCR3 compare capture register 3

Address offset: 0x328 Reset value: 0x0000 FFFF

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR	RW	CH3 channel compare/capture value

15.8.11 GTIMx_CCR4 compare capture register 4

Address offset: 0x32C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR	RW	CH4 channel compare/capture value



15.8.12 GTIMx_IER interrupt enable register

Address offset: 0x314 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	DIRCHANGE	RW	Encoder counting direction change interrupt control 0: Disabled 1: Enabled
8:7	RFU	-	Reserved bits, please keep the default value
6	CC4	RW	CH4 capture compare interrupt enable control 0: Disabled 1: Enabled
5	CC3	RW	CH3 capture compare interrupt enable control 0: Disabled 1: Enabled
4	CC2	RW	CH2 capture compare interrupt enable control 0: Disabled 1: Enabled
3	CC1	RW	CH1 capture compare interrupt enable control 0: Disabled 1: Enabled
2	UD	RW	Underflow interrupt enable control 0: Underflow interrupt disabled 1: Underflow interrupt enabled Caution: Only available in encoding counting mode
1	TI	RW	Trigger interrupt enable control 0: Trigger interrupt disabled 1: Trigger interrupt enabled
0	OV	RW	Counter ARR overflow interrupt enable control 0: ARR overflow interrupt disabled 1: ARR overflow interrupt enabled



15.8.13 GTIMx_ISR interrupt flag register

Address offset: 0x318 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:11	RFU	-	Reserved bits, please keep the default value
10	DIR	RO	Encoder current counting direction flag 0: forward counting 1: reverse counting
9	DIRCHANGE	RO	Encoder counting direction change interrupt flag 0: The counting direction has not changed 1: The counting direction has been changed
8:7	RFU	-	Reserved bits, please keep the default value
6	CC4	RO	CH4 compare capture interrupt flag 0: No compare capture event occurred 1: The compare capture event has occurred
5	CC3	RO	CH3 compare capture interrupt flag 0: No compare capture event occurred 1: The compare capture event has occurred
4	CC2	RO	CH2 compare capture interrupt flag 0: No compare capture event occurred 1: The compare capture event has occurred
3	CC1	RO	CH1 compare capture interrupt flag 0: No compare capture event occurred 1: The compare capture event has occurred
2	UD	RO	Counter underflow flag 0: The counter has not underflowed 1: The counter has underflowed Caution: Only available in encoding counting mode
1	TI	RO	Trigger flag 0: No trigger event occurred 1: The trigger event has occurred
0	OV	RO	Counter ARR overflow flag 0: The counter has not ARR overflowed 1: The counter has ARR overflowed Caution: This flag is generated when the counter value changes from ARR to 0



15.8.14 GTIMx_ICR interrupt flag clear register

Address offset: 0x31C Reset value: 0x0000 03FF

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	DIRCHANGE	R1W0	Encoder counting direction change interrupt control W0: The encoder counting direction change interrupt flag cleared W1: No function
8:7	RFU	-	Reserved bits, please keep the default value
6	CC4	R1W0	CH4 compare capture interrupt flag cleared W0: Compare capture interrupt flag cleared W1: No function
5	CC3	R1W0	CH3 compare capture interrupt flag cleared W0: Compare capture interrupt flag cleared W1: No function
4	CC2	R1W0	CH2 Compare capture interrupt flag cleared W0: Compare capture interrupt flag cleared W1: No function
3	CC1	R1W0	CH1 compare capture interrupt flag cleared W0: Compare capture interrupt flag cleared W1: No function
2	UD	R1W0	Counter underflow flag cleared W0: Counter underflow flag cleared W1: No function Caution: Only available in encoder counting mode
1	TI	R1W0	Trigger flag cleared W0: Trigger flag cleared W1: No function
0	OV	R1W0	Counter ARR overflow flag cleared W0: Counter ARR overflow flag cleared W1: No function



15.8.15 GTIMx_DMA DMA trigger register

Address offset: 0x340 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	CC4	RW	CH4 capture compare interrupt trigger DMA enable control 0: Disabled 1: Enabled
4	CC3	RW	CH3 capture compare interrupt trigger DMA enable control 0: Disabled 1: Enabled
3	CC2	RW	CH2 capture compare interrupt trigger DMA enable control 0: Disabled 1: Enabled
2	CC1	RW	CH1 capture compare interrupt trigger DMA enable control 0: Disabled 1: Enabled
1	TRS	RW	Synchronous trigger DMA enable control when the counter is triggered to start 0: No function 1: DMA is triggered synchronously when the counter is triggered to start
0	OV	RW	Counter ARR overflow triggers DMA enable control 0: No function 1: Counter ARR overflow triggers DMA



16 Advanced-control timer (ATIM)

16.1 Overview

The Advanced-control Timer (ATIM) consists of a 16-bit auto-reload counter and 7 compare units, driven by a programmable prescaler. ATIM supports 6 independent capture/compare channels, which can realize 6 independent PWM outputs or 3 pairs of complementary PWM outputs or capture 6 inputs. Can be used for basic timing/counting, measuring pulse width and period of input signals, generating output waveforms (PWM, single pulse, complementary PWM with dead time inserted, etc.).

16.2 Main features

- 16-bit up, down, up/down autoloader counter
- 6 independent channels for input capture and output compare
- PWM generation (Edge- and Center-aligned modes)
- Complementary PWM outputs with programmable dead-time
- Brake function
- One-pulse mode output
- Quadrature encoding counting function
- Supports for interrupt and events
 - Counter overflow/underflow
 - Capture and compare events
 - Capture data loss
 - Break event
 - Update event
 - Trigger event

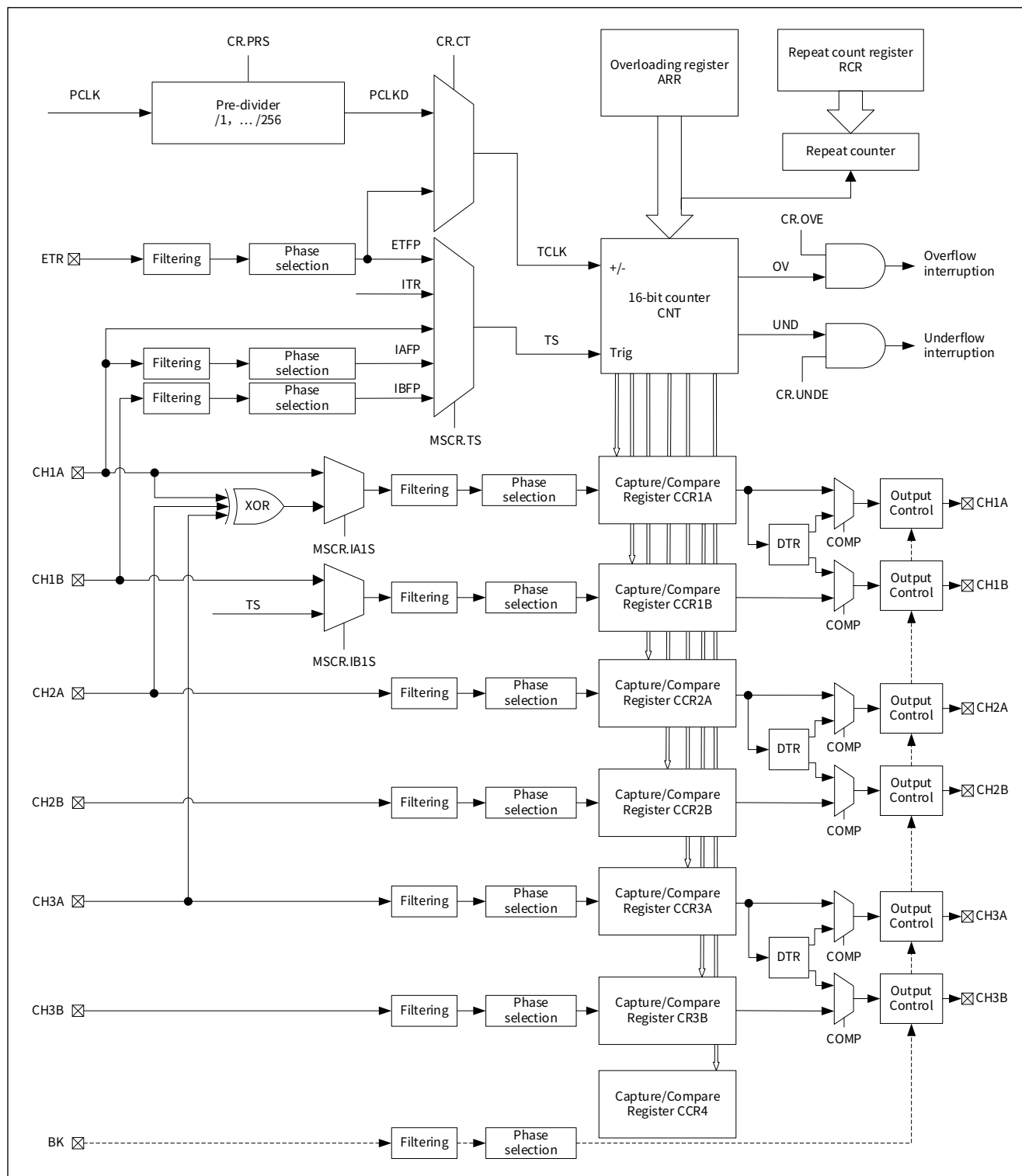


16.3 Functional description

16.3.1 Functional block diagram

The functional block diagram of ATIM is shown in the following figure:

Figure 16-1 ATIM functional block diagram



Through the combination of 16-bit counter and 7 comparison unit, the functions of input capture and output comparison can be realized, which can be used to measure pulse width and period of input signal, and can output PWM waveform.

16.3.1.1 Clock sources selection

The counting clock source of the counting unit can be selected from the internal system clock PCLK or the ETR input signal, which is specifically selected by the CT bit field of the control register ATIM_CR.

When ATIM_CR.CT is set to 0, the counting clock source is the internal system clock PCLK, and the internal clock PCLK can be divided by ATIM_CR.PRS.

When ATIM_CR.CT is set to 1, the counting clock source is the ETR input signal (for the specific source of the ETR signal, please refer to section [16.3.9 On-chip peripheral interconnect ETR](#)). The filter can be controlled by ATIM_FLTR.FLTET, and the ETR input phase can be selected by ATIM_FLTR.ETP.

16.3.1.2 Update Event (UEV)

The update source of update event UEV (Event) is set through the URS bit field of the control register ATIM_CR, as shown in the following table:

Table 16-1 Update source settings

ATIM_CR.URS	Update source
0	The counter overflow and underflow (and the number of repetition counts ATIM_RCR is 0); UG is set by software; Reset from slave mode
1	The counter overflow and underflow (and the number of repetition counts ATIM_RCR is 0)

When an update event occurs (the internal UEV signal is held for one PCLK cycle), the ATIM performs the following actions:

1. The counter is reset:
Edge-aligned mode: initialize to 0 when counting up, reload ATIM_ARR when counting down;
Center Aligned Mode: change the counting direction.
2. If the cache register function is used, ATIM_ARR, ATIM_CHxCCRy will be updated to its cache register.
3. The prescaler counter is cleared, but does not affect the prescaler value in ATIM_CR.PRS.
When an update event UEV occurs, the event update interrupt flag ATIM_ISR.UIF will be set by hardware. If the interrupt is enabled (set ATIM_CR.UIE to 1), an update interrupt request will be generated. Set ATIM_ICR.UIE to 0 to clear the flag bit.

Caution:

If the repetition counter is used (ATIM_RCR.RCR is not 0), the update event UEV will only be generated when the count reaches the repeat count (ATIM_RCR.RCR reaches 0).



16.3.1.3 Counting modes

The counter can be set to upcounting (edge-aligned mode), downcounting (edge-aligned mode), or up/down counting bidirectionally (center-aligned mode).

Upcounting mode

When the DIR bit of the control register ATIM_CR is set to 0 in edge-aligned mode, the counter works in the upcounting mode.

Setting ATIM_CR.EN to 1 enables ATIM, and the counter CNT starts to count up. When the count value reaches the reload value ARR, the overflow signal OV is generated (the overflow signal OV remains for one PCLK cycle, and then automatically cleared). At the next PCLK, the counter is initialized to 0, and the counter overflow interrupt flag bit ATIM_ISR.OVF is set by hardware. If the interrupt is enabled (set ATIM_CR.OVE to 1), an interrupt request will be generated, set ATIM_ICR.OVF to 0 to clear this flag bit.

If the repetition counter is used, the update event (UEV) is generated when upcounting reaches the programmed number of repeat times(ATIM_RCR.RCR), else the update event is generated at each counter overflow.

The following figures show some examples of the counter behavior for different clock frequencies, where ATIM_ARR = 0x36.

Figure 16-2 Upcounting, internal clock divided by 1

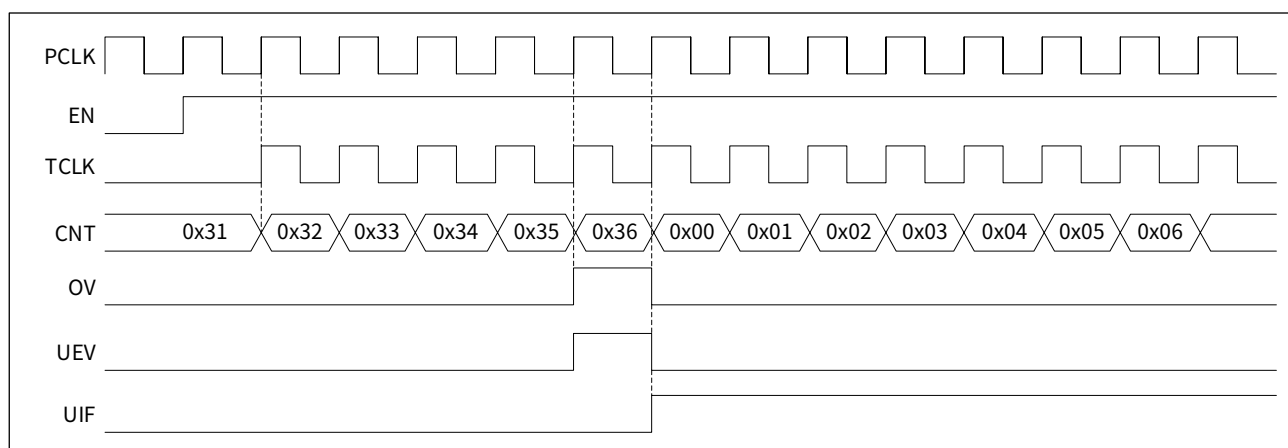


Figure 16-3 Upcounting, internal clock divided by 2

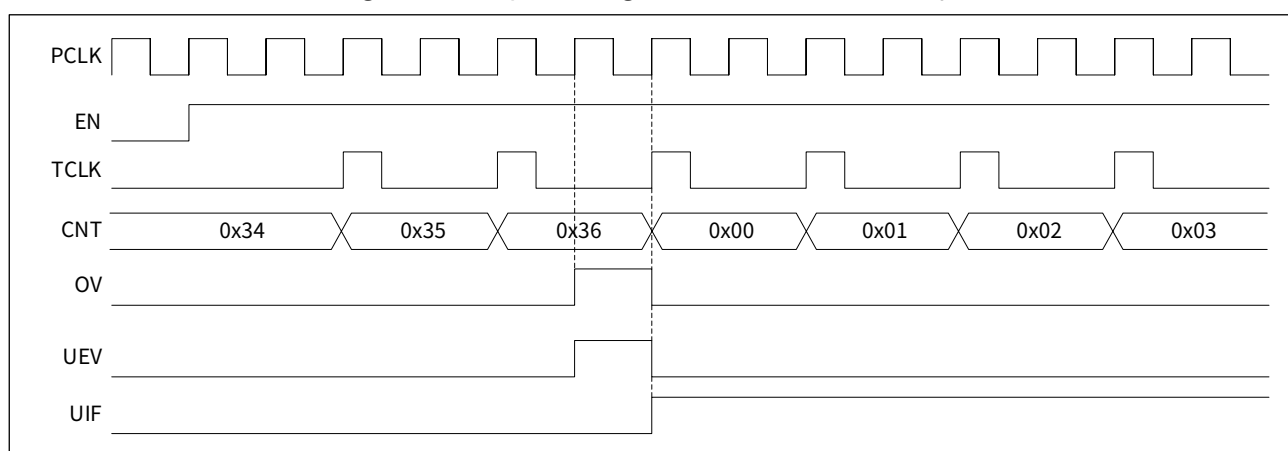


Figure 16-4 Upcounting, internal clock divided by 4

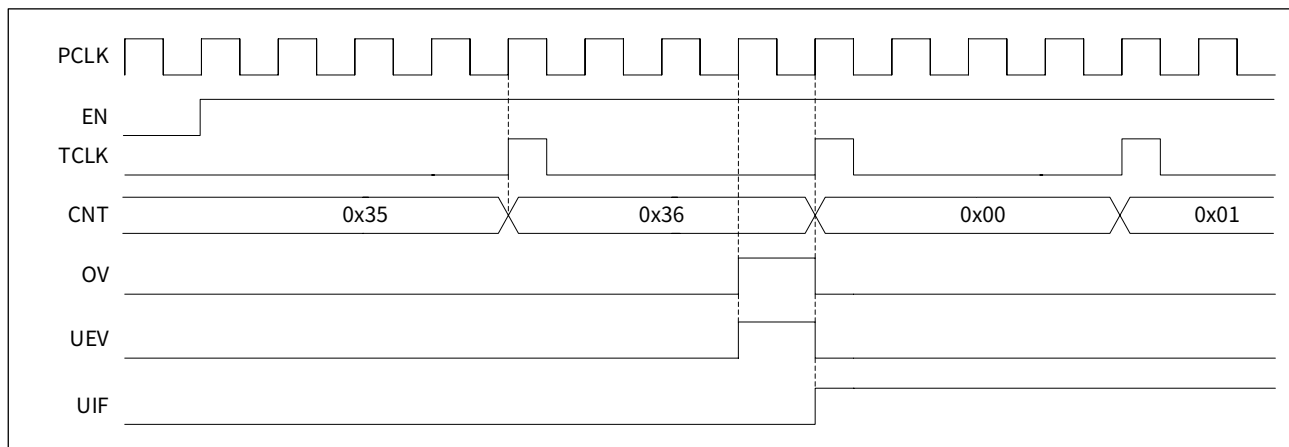


Figure 16-5 Upcounting, internal clock divided by N

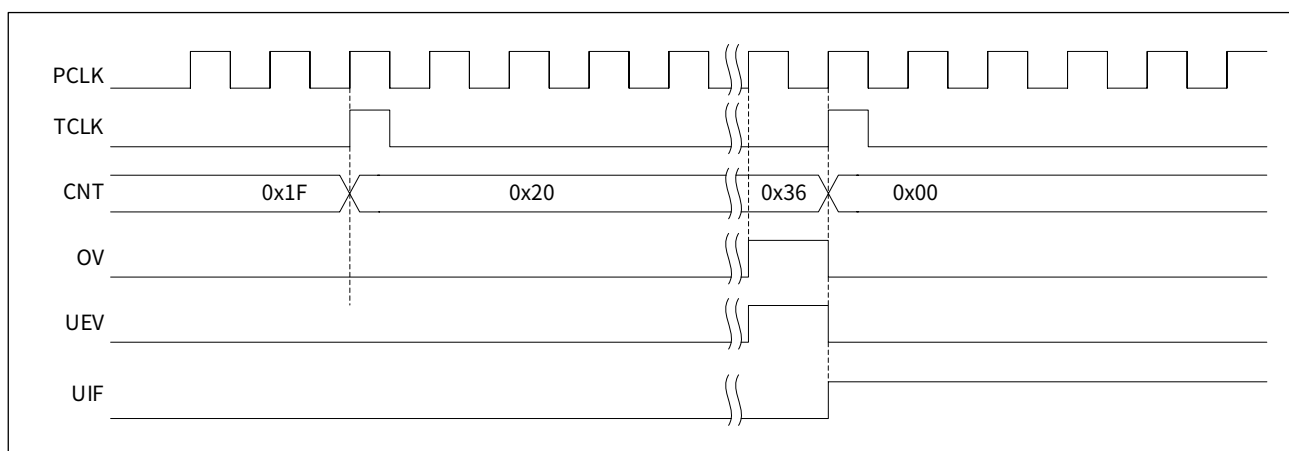


Figure 16-6 Upcounting, update event when reload buffer is disabled (ATIM_CR.BUFPEN=0x0)

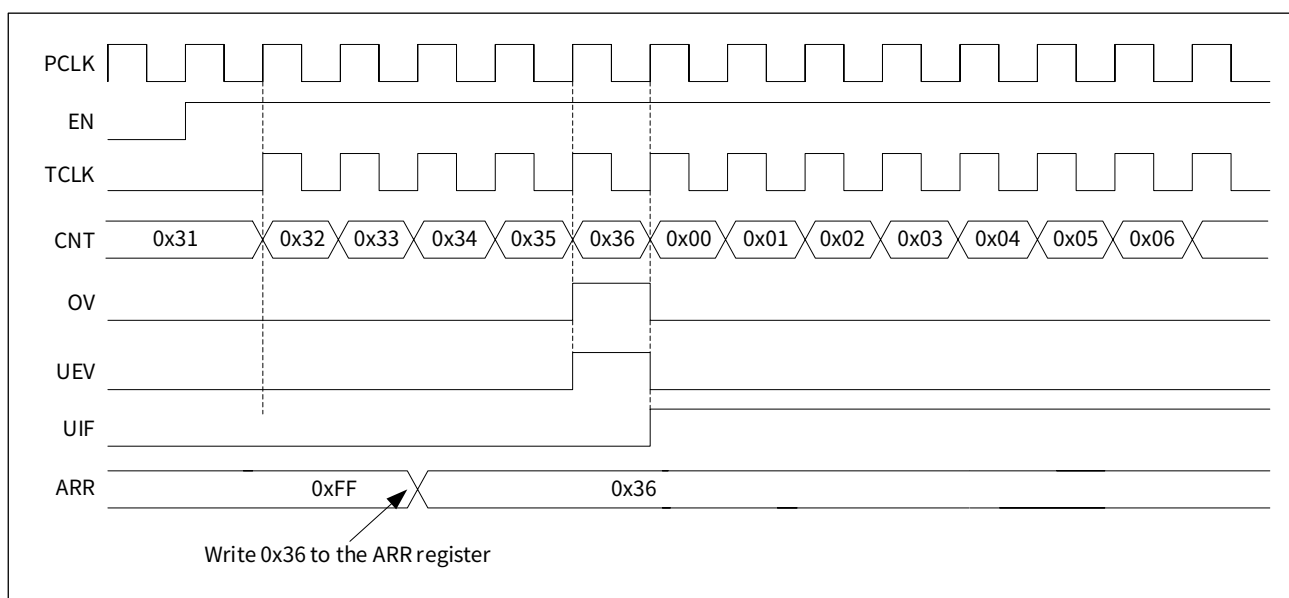
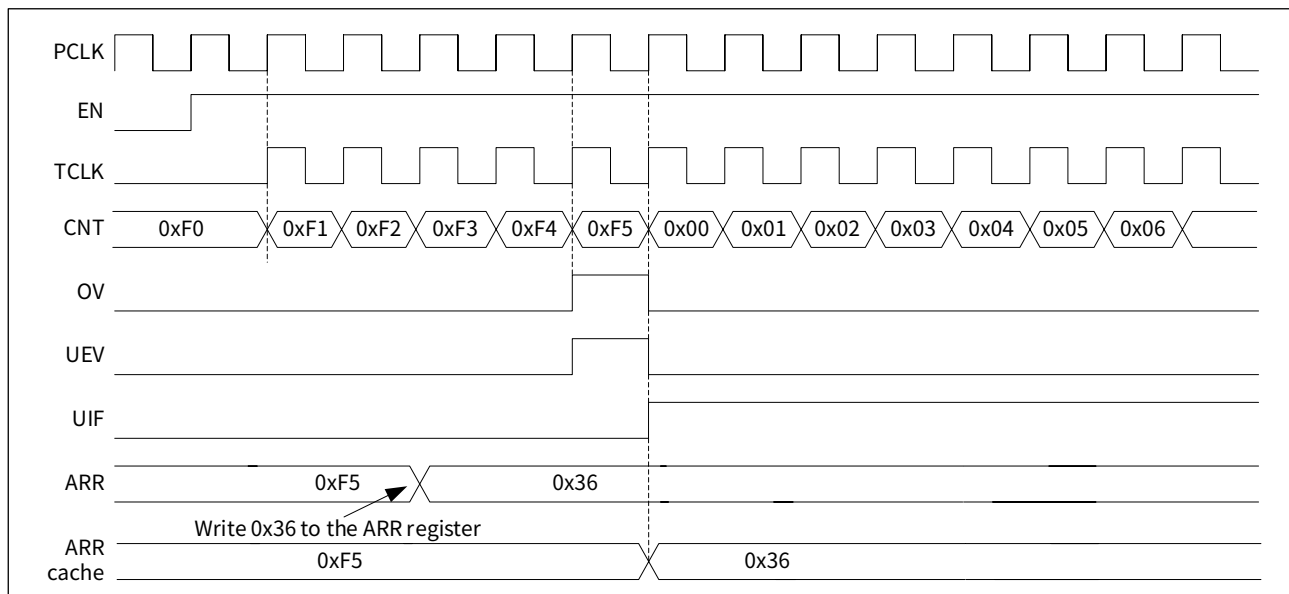


Figure 16-7 Upcounting, update event when reload buffer is enabled (ATIM_CR.BUFPEN=0x1)



Downcounting mode

When the DIR bit of the control register ATIM_CR is set to 1 in edge-aligned mode, the counter works in the downcounting mode.

Set ATIM_CR.EN to 1 to start ATIM, the hardware automatically loads ARR to the counter CNT, and the counter starts to count down. When the count value reaches 0, the overflow signal UND is generated (the overflow signal UND remains for one PCLK cycle, and then automatically cleared). One PCLK after overflow, the counter is reloaded with the value of ARR, the counter underflow interrupt flag ATIM_ISR.UNDF is set by hardware, if interrupt is enabled (set ATIM_CR.UNDE to 1), an interrupt request will be generated, set ATIM_ICR.UNDF to 0 to clear this flag bit.

If the repetition counter is used, the update event (UEV) is generated when upcounting reaches the programmed number of repeat times(ATIM_RCR.RCR), else the update event is generated at each counter downflow.

The following figures show some examples of the counter behavior for different clock frequencies, where ATIM_ARR = 0x36.

Figure 16-8 Downcounting, internal clock divided by 1

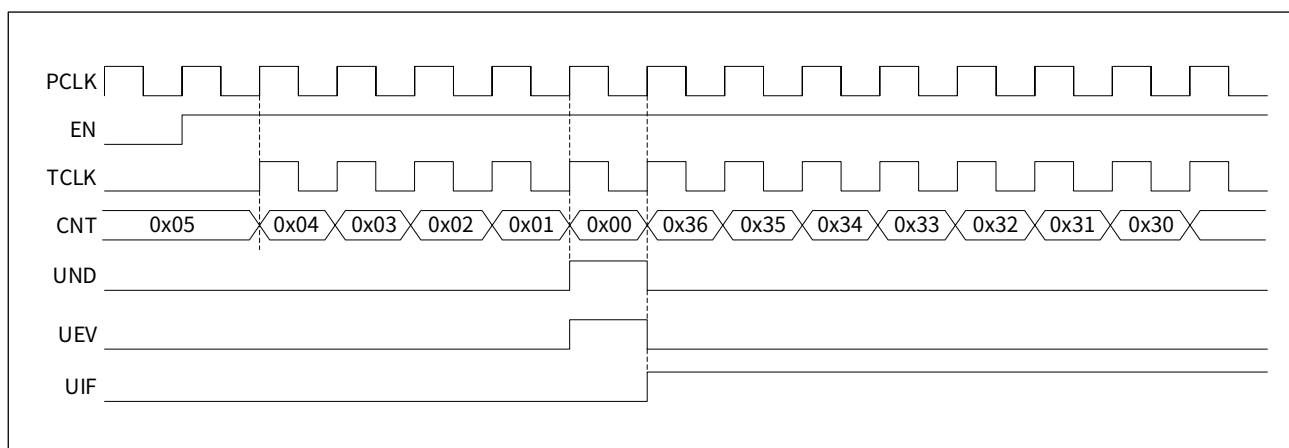


Figure 16-9 Downcounting, internal clock divided by 2

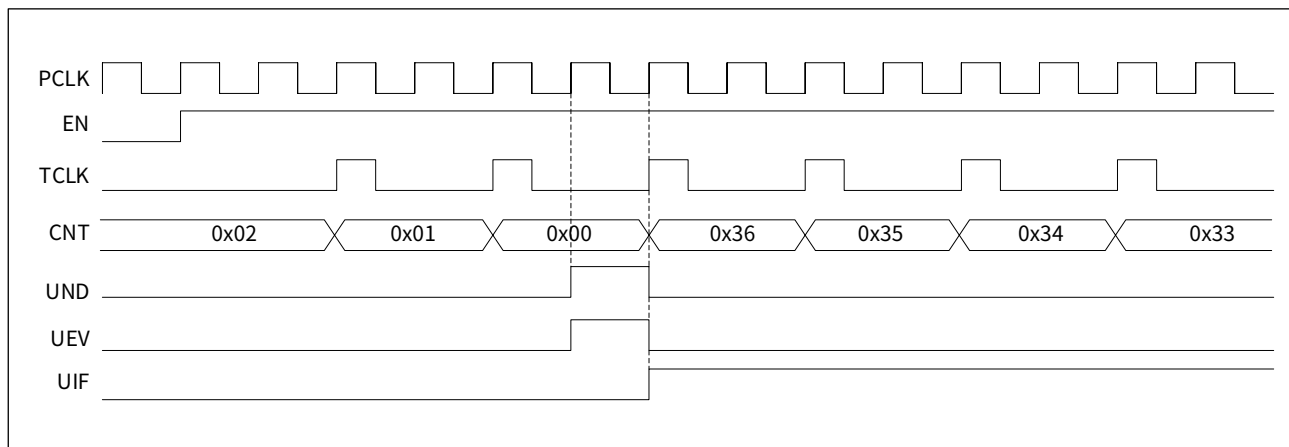


Figure 16-10 Downcounting, internal clock divided by 4

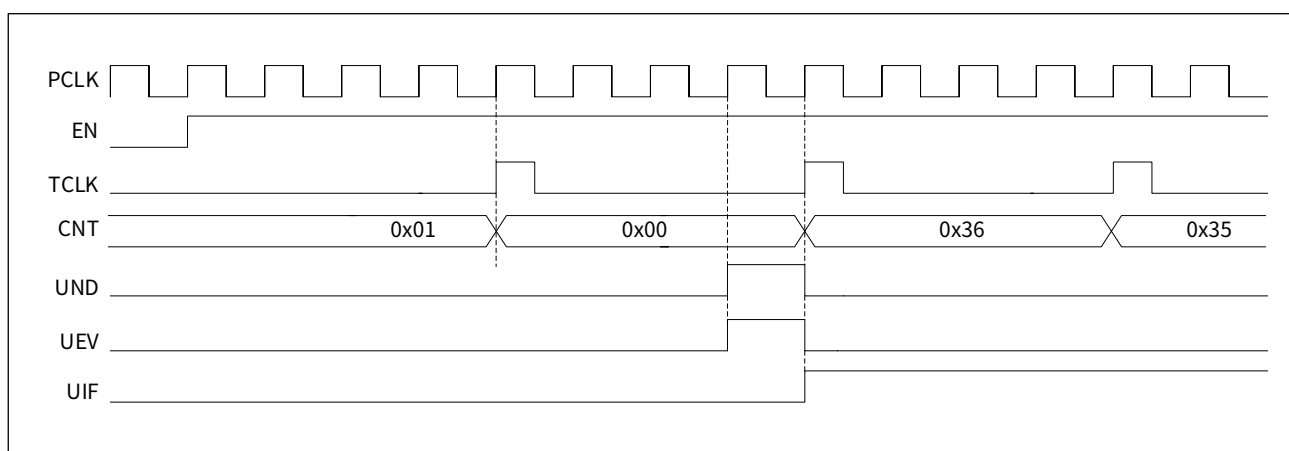


Figure 16-11 Downcounting, internal clock divided by N

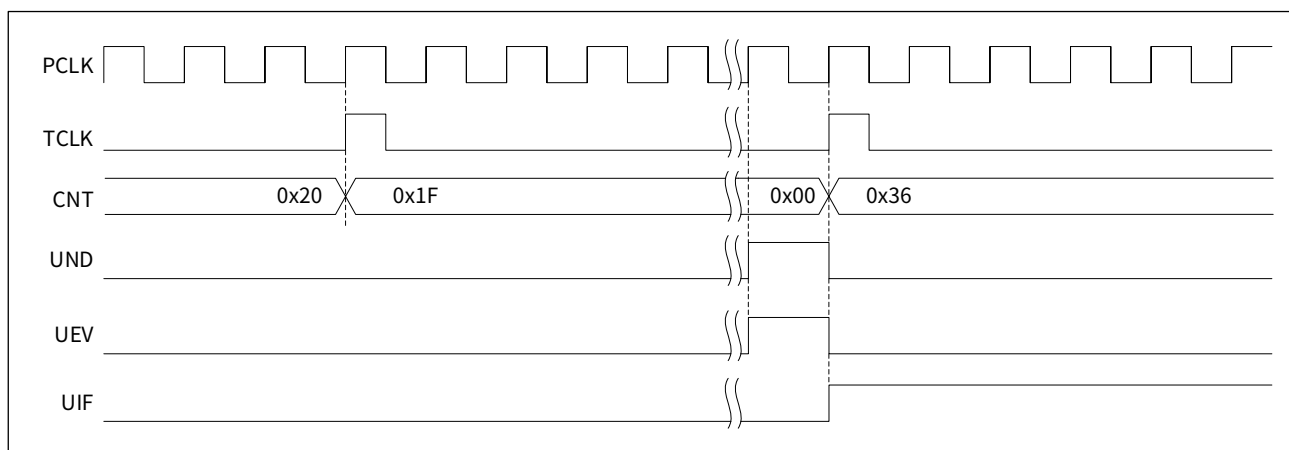
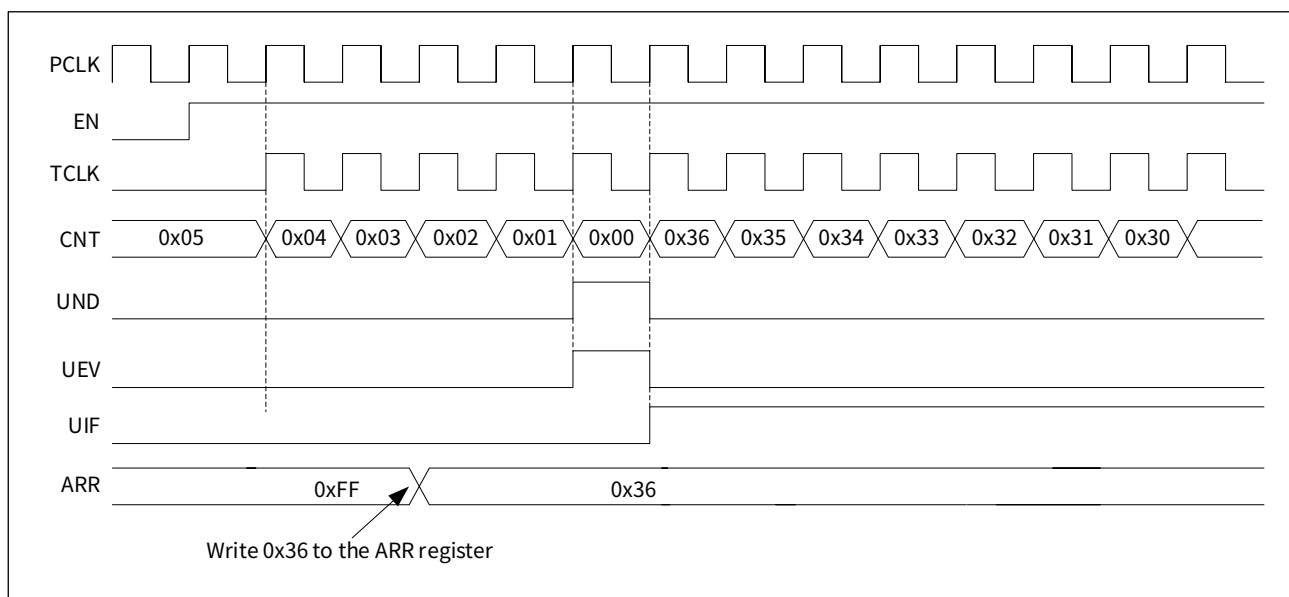


Figure 16-12 Downcounting, update event when reload buffer enabled is not used



Center-aligned mode (up/down counting)

In center-aligned mode, the counter counts from 0 to the reload value ARR, generates a counter overflow event, then counts down to 0 and generates a counter underflow event. Then it restarts counting up from 0.

In center-aligned mode, the DIR direction bit in the ATIM_CR register cannot be written but can be read. It is updated by hardware and gives the current direction of the counter. The DIR bit is automatically cleared to 0 when switching from other modes to center-aligned mode.

If the repetition counter is used, the update event (UEV) is generated when up/down counting reaches the programmed number of repeat times (ATIM_RCR.RCR), else the update event is generated at each counter overflow/downflow.

The following figures show some examples of the counter behavior for different clock frequencies:

Figure 16-13 Center-aligned mode, internal clock divided by 1, ARR=0x06

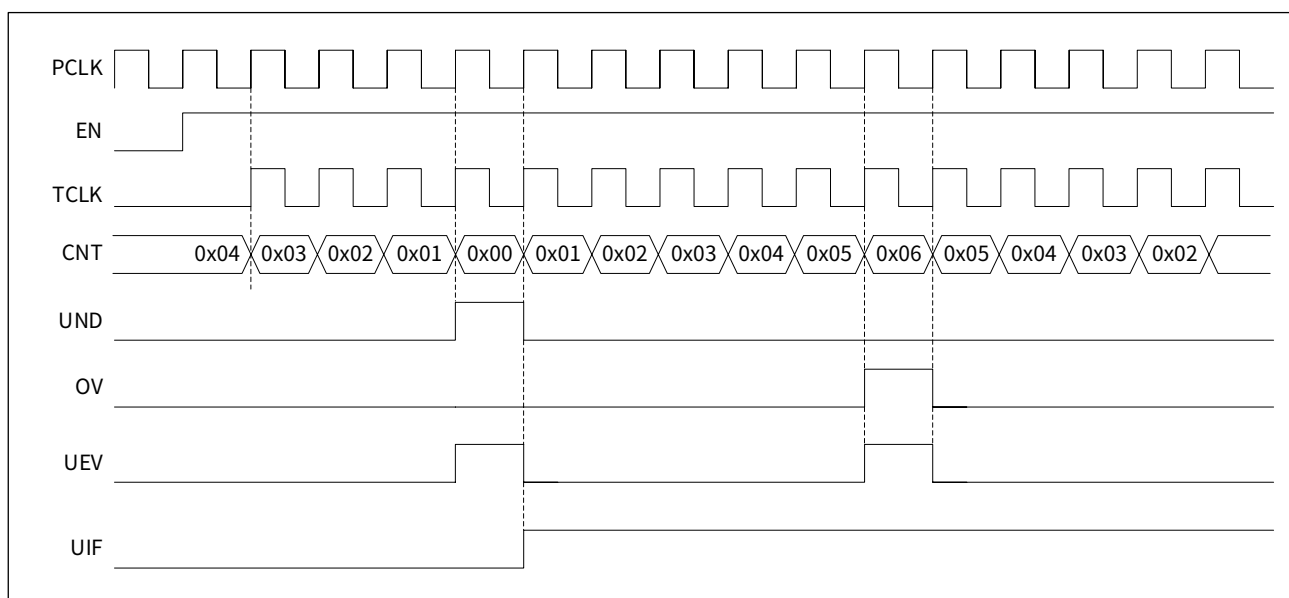


Figure 16-14 Center-aligned mode, internal clock divided by 2

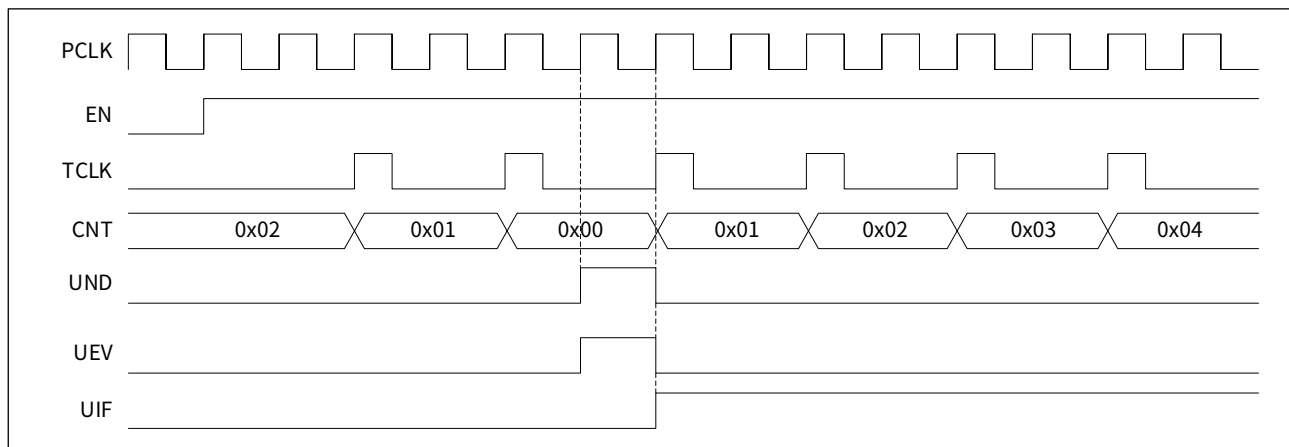


Figure 16-15 Center-aligned mode, internal clock divided by 4, ARR=0x36

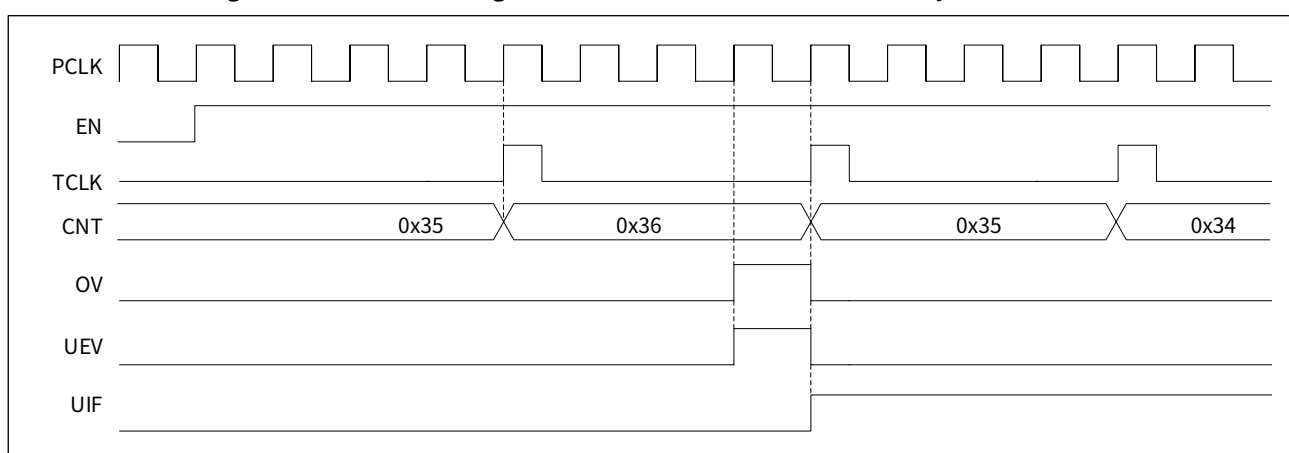


Figure 16-16 Center-aligned mode, internal clock divided by N

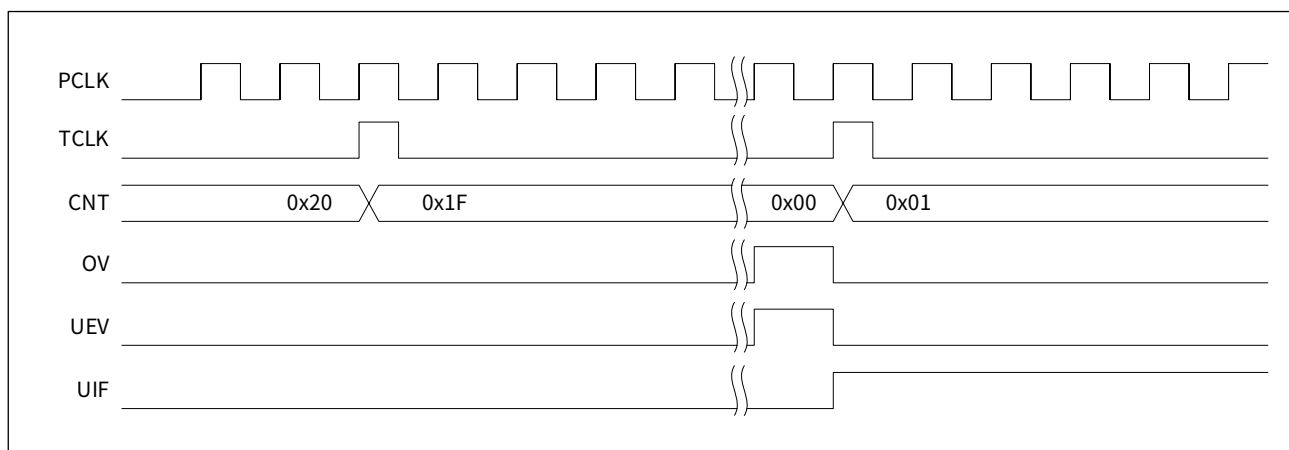


Figure 16-17 Center-aligned mode, update event when reload buffer is disabled (ATIM_CR.BUFPEN=0x0)

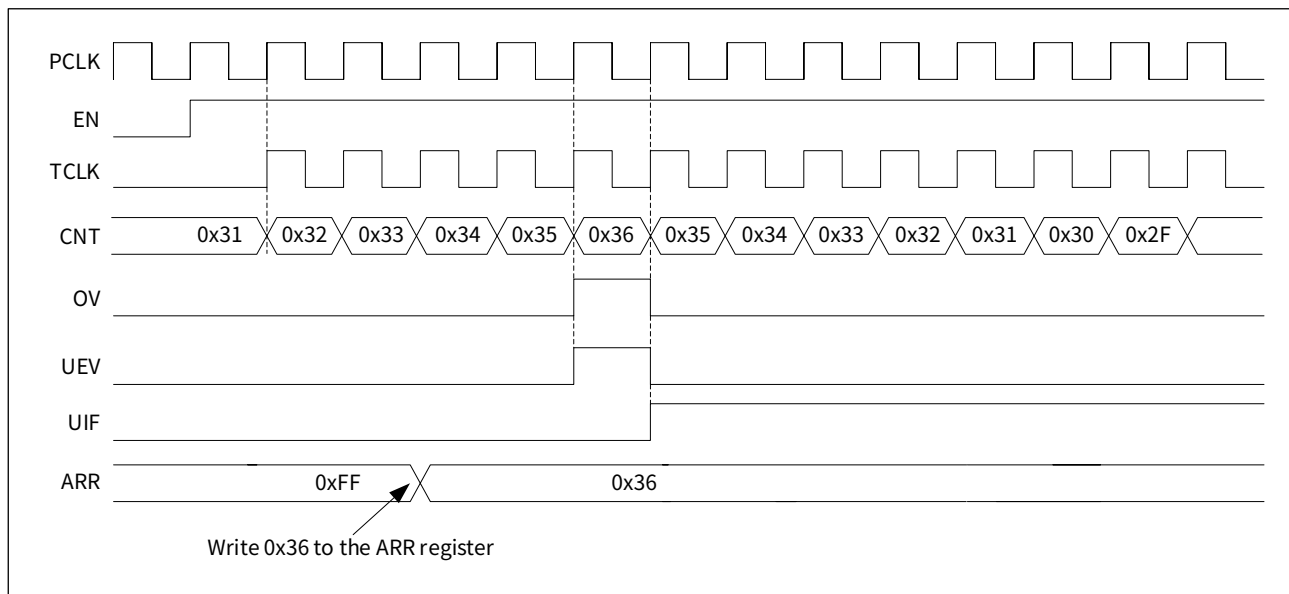
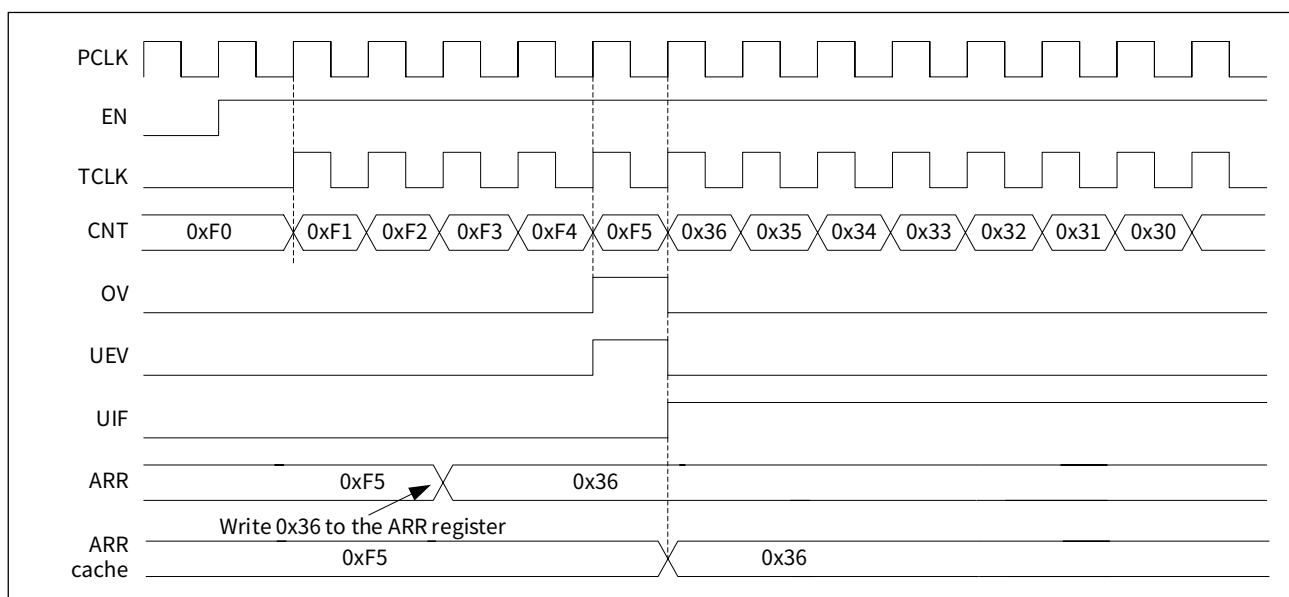


Figure 16-18 Center-aligned mode, update event when reload buffer is enabled (ATIM_CR.BUFPEN=0x1)



16.3.1.4 Reload register

The auto-reload register ATIM_ARR has a buffer function, which is started or closed by the BUFPEN bit field of the control register ATIM_CR.

When the counter is stopped or the buffer function is disabled, updating the reload register ARR will immediately update the buffer register. When the timer is running and the buffer function is valid, updating the reload register ARR will not update the buffer register immediately, and will only update the value of the reload register ARR to the buffer register when there is an update event UEV.

16.3.1.5 Repetition counter

Starting ATIM will auto-load the RCR of the repeat count register ATIM_RCR to the repetition counter. When the main counter overflows, it will automatically decrease by one according to the UD and OV enable bits of the ATIM_RCR register, as shown in the following table:

Table 16-2 Repetition counter count configuration

Main counter overflow type	Working mode	ATIM_CR.DIR	ATIM_RCR.UD	ATIM_RCR.OV	Repetition counter action
Overflow	Edge-aligned mode	0, upcounting	-	0	Minus one
			-	1	No count
	Center-aligned mode	-	-	0	Minus one
			-	1	No count
Underflow	Edge-aligned mode	1, downcounting	0	-	Minus one
			1	-	No count
	Center-aligned mode	-	0	-	Minus one
			-	-	No count

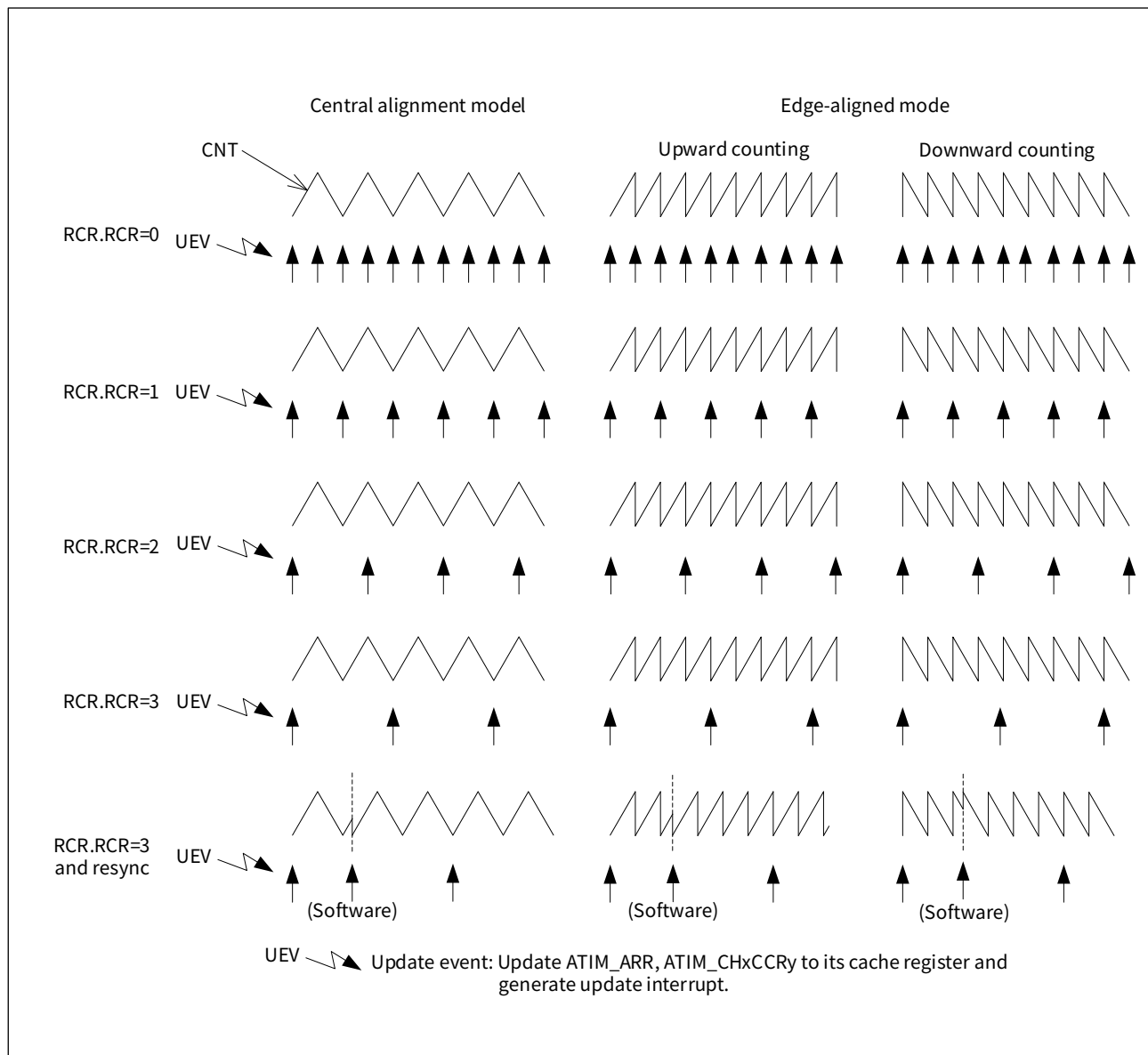
When using the repeat counter function (the RCR of ATIM_RCR is not set to 0), the overflow of the main counter will generate the update event (UEV) only when the repeat counter is decremented to 0.

When UG is updated by software or reset from slave mode, the update event (UEV) will be generated immediately, regardless of the current value of the repetition counter, and the content of the RCR in the ATIM_RCR register will be loaded into the repetition counter immediately.

The following figure is example of different repetition count values, and the update event (UEV) is generated in different counting modes:



Figure 16-19 Repetition counting example



16.3.1.6 Compare/capture channels

ATIM has 3 independent compare/capture channels CH1, CH2, CH3, each channel has A and B compare/capture registers and their buffer registers, as well as input signal processing units (digital filtering and phase detection), comparison units, and matching output unit.

Therefore, ATIM can realize 6-channel input capture, or 6-channel independent PWM output, or 3 pairs of complementary PWM output. Channel CH4 of ATIM is an internal channel of the chip, with no external pins, only one compare/capture register (ATIM_CH4CCR), which can only be used for comparison and cannot be used for capture.

The corresponding pins of the compare/capture channel supported by ATIM are shown in the following table, and the function multiplexing needs to be configured in the application.

Table 16-3 ATIM compare/capture channel pins

ATIM	Pin	AFR
ATIM_CH1A	PC00/PD08	0x06
	PA05/PA08/PB02/PB05/PD06	0x07
ATIM_CH1B	PC06/PE03/PE12	0x06
	PA07/PA15/PB13/PD07	0x07
ATIM_CH2A	PC01/PD09/PE07	0x06
	PA04/PA09/PB06/PB10/PD05	0x07
ATIM_CH2B	PC07/PE04/PE13	0x06
	PB00/PB03/PB14/PC10	0x07
ATIM_CH3A	PC02/PD10/PE08	0x06
	PA03/PA10/PB07/PB11/PD04	0x07
ATIM_CH3B	PC08/PE05/PE14	0x06
	PB01/PB04/PB15/PC11	0x07



16.3.2 Input capture mode

16.3.2.1 Input capture

Input capture is supported in both edge-aligned and center-aligned modes. Set the CSy bit field of the channel x control register ATIM_CHxCR to 1, so that the channel CHxy (x=1~3, y=A, B) works in the input capture mode, and the input capture can be triggered by software or hardware.

Software trigger: When ATIM_CHxCR.CCGy is set to 1, the software triggers a capture immediately, the value of main count register ATIM_CNT is latched into the compare/capture register ATIM_CHxCCRy of the corresponding channel, and a capture is completed. After the capture is completed, the CCGy bit is automatically cleared by hardware.

Hardware trigger: When the valid edge on the channel CHxy is detected, the value of main count register ATIM_CNT is latched into the compare capture register ATIM_CHxCCRy of the corresponding channel to complete a capture. The valid edge that triggers the capture is selected by the BKSy bit field of the ATIM_CHxCR register, as shown in the following table:

Table 16-4 Input capture mode configuration

Advanced Timer	ChannelCHxy	BKSy bit field value	Capture trigger condition
ATIM_CHxCR (x=1,2,3)	BKSy (y=A,B)	00	Prohibit
		01	Capture on rising edge
		10	Capture on falling edge
		11	Capture on both rising and falling edges

When a capture occurs, the capture interrupt flag bit ATIM_ISR.CxyF of the corresponding channel is set by hardware. If the interrupt is enabled (set ATIM_CHxCR.CIEy to 1), an interrupt request will be generated; if DMA is enabled (set ATIM_CHxCR.CDEy to 1), a DMA request will be generated. If the ATIM_ISR.CxyF flag is already high when a capture event occurs, the recapture flag ATIM_ISR.CxyE will be set by hardware. Set ATIM_ICR.CxyF to 0 to clear the ATIM_ISR.CxyF flag, set ATIM_ICR.CxyE to 0 to clear the ATIM_ISR.CxyE flag.

Caution:

Even if ATIM is not started and ATIM_CNT does not start counting, when the valid edge of channel CHxy is detected, the capture will still be triggered and the capture action will be executed.

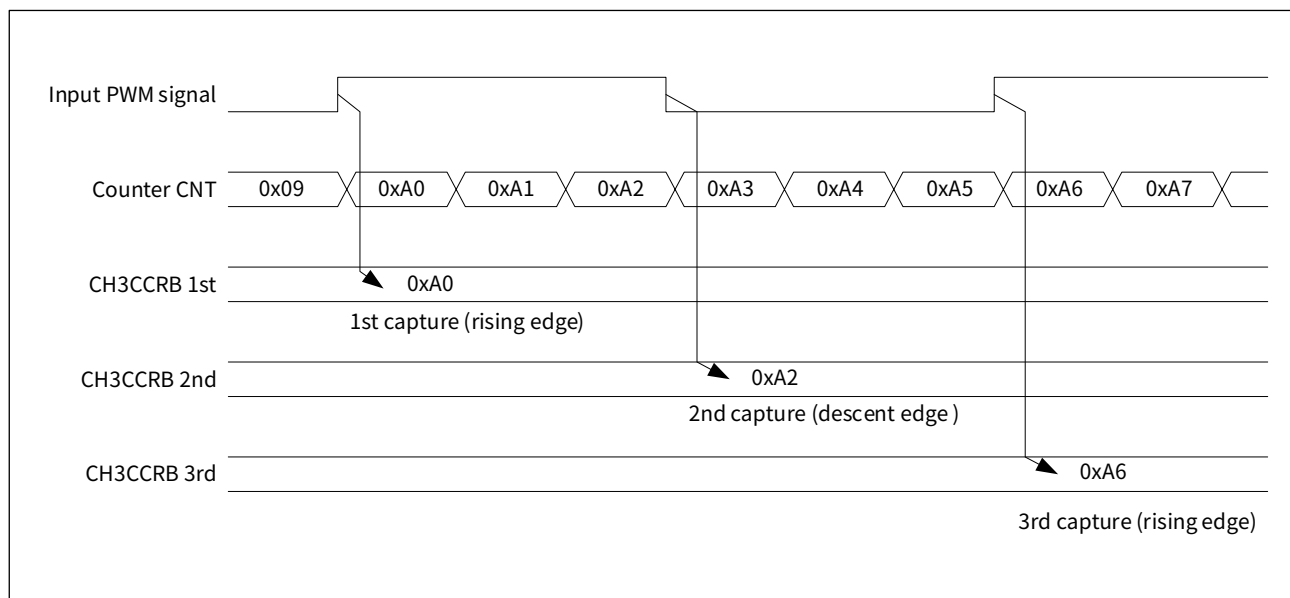


16.3.2.2 PWM input mode

PWM input mode is an application of input capture mode. Set the BKSy bit field of the channel x control register ATIM_CHxCR to 0x03, so that the timer captures both rising and falling edges of PWM input signal. After three captures, the pulse width and period of the PWM signal can be calculated.

The schematic diagram of PWM signal measurement of CH3B channel is shown in the following figure:

Figure 16-20 Schematic diagram of PWM measurement



16.3.2.3 Input capture trigger source

The input capture trigger source of ATIM can choose the external CHxy pin input signal, or the internal trigger TS signal.

The input capture of channels CH2A, CH2B, CH3A, and CH3B can only select the corresponding external GPIO pin input. The channel filter setting can be performed through the OCMxyFLTxy bit field of the filter register ATIM_FLTR, and the phase setting can be performed through the ATIM_CHxCR.BKSy bit field.

CH1 of ATIM is an input channel with advanced functions. Input terminals CH1A and CH1B can be used as trigger capture and trigger start of main counter.

The input capture of CH1A is determined by the IA1S bit field of the master-slave mode control register ATIM_MSCR, and the input of CH1A or the exclusive OR input of CH1A, CH2A and CH3A can be selected.

Select CH1A input when ATIM_MSCR.IA1S is set to 0, the channel filter can be set by ATIM_FLTR.OCM1AFLT1A, and the phase can be set by ATIM_CH1CR.BKSA; when ATIM_MSCR.IA1S is set to 1, the XOR input of CH1A, CH2A, and CH3A can be selected. This feature is used for Connect the hall sensor.

The input capture of CH1B is determined by the IB1S bit field of the master-slave mode control register ATIM_MSCR, and the CH1B input or the internal trigger TS signal can be selected.

When ATIM_MSCR.IB1S is set to 0, the CH1B input is selected, the channel filter can be set by ATIM_FLTR.OCM1BFLT1B, and the phase can be set by ATIM_CH1CR.BKSB; when ATIM_MSCR.IB1S is set to 1, the internal trigger TS signal is selected, and the TS signal is configured by ATIM_MSCR.TS source, as shown in the following table:

Table 16-5 TS signal sources

ATIM_MSCR.TS	TS signal
000	ETR filtered and phase-selected signal ETFP
001	Internal interconnect signal ITR
101	Edge signal of port CH1A
110	Filtered and phase-selected signal IAFP at port CH1A
111	Filtered and phase-selected signal IBFP at port CH1B



16.3.3 Output compare function

16.3.3.1 Output compare

Set the CSy bit field of the channel x control register ATIM_CHxCR to 0, so that the channel CHxy works in the output compare mode. In the output compare mode, compare the value of the count register ATIM_CNT with the value of the compare/capture register ATIM_CHxCCRy of the corresponding channel CHxy. When the two match, the compare/capture channel CHxy outputs a settable level state.

The output state of the compare channel is set by the OCMxyFLTxy bit field of the ATIM_FLTR register, as shown in the following table:

Table 16-6 Output compare mode configuration

ATIM_FLTR.OCMxyFLTxy	Compare mode configuration
000	Force CHxy to output low level
001	Force CHxy to output high level
010	CHxy is set to 0 on compare match
011	CHxy is set to 1 on compare match
100	CHxy flips output on compare match
101	Output high level for one count period on compare match
110	PWM mode 1
111	PWM mode 2

The output polarity control bit CCPxy in the ATIM_FLTR register sets the output polarity of CHxy.

When a compare match occurs, the hardware sets the channel compare/match interrupt flag ATIM_ISR.CxyF, and at the same time:

- If the interrupt is enabled, that is, ATIM_CHxCR.CIEy is 1, an interrupt request will be generated;
- If DMA is allowed to be triggered, that is, ATIM_MSCR.CCDS is 0, the compare match triggers a DMA request;
- If the DMA is allowed to be enabled, that is, ATIM_CHxCR.CDEy is 1, the compare/match enables the DMA;
- If ADC triggering is enabled, that is, ATIM_TRIG.ADTE is 1, and ATIM_TRIG.CMxyE is 1, a compare match will trigger an ADC conversion request.

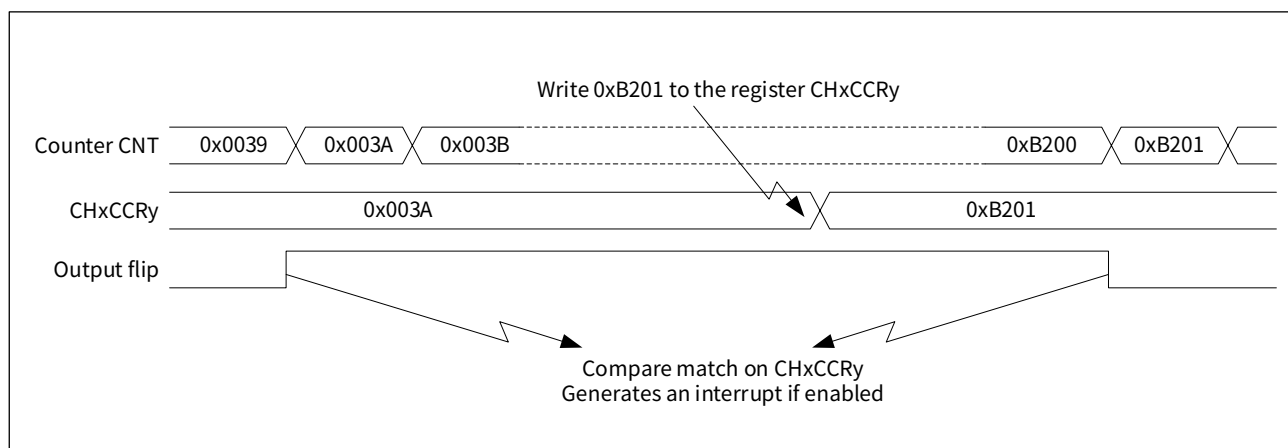
The compare/capture register ATIM_CHxCCRy has a cache function, and whether to use the buffer function is selected by the BUFEy bit of the ATIM_CHxCR register.

When ATIM_CHxCR.BUFEy is 0, the compare cache function of channel CHxy is disabled, and the ATIM_CHxCCRy register can be updated by software at any time, and the updated value takes effect immediately and affects the output waveform; when ATIM_CHxCR.BUFEy is 1, the compare cache of channel CHxy is enabled function, updating the ATIM_CHxCCRy register will not update the cache register immediately, only when the update event UEV occurs, the value of the ATIM_CHxCCRy register will be updated to the cache register.

The example of the compare/capture register cache function is shown in the following figure:



Figure 16-21 Compare/capture register cache function



16.3.3.2 Forced output

In forced output mode, the output state of the compare channel CH_{xy} is directly forced to be 0 or 1 by the software, without depending on the comparison result. The OCM_{xy}FLTx_y bit field in the ATIM_FLTR register is set to 0x0, and the corresponding CH_{xy} channel is forced to output low level; the OCM_{xy}FLTx_y bit field in the ATIM_FLTR register is set to 0x1, and the corresponding CH_{xy} channel is forced to output high level.

In forced output mode, the ATIM_CHxCCRy register and the counter ATIM_CNT are continuously compared, and the comparison result will affect the corresponding flag bit, and also generate corresponding interrupts and DMA requests.

16.3.3.3 Single pulse mode

The single pulse mode is a kind of PWM output mode. After the counter responds to the trigger, one pulse output is generated after a delay. The delay time and pulse width can be controlled by a program.

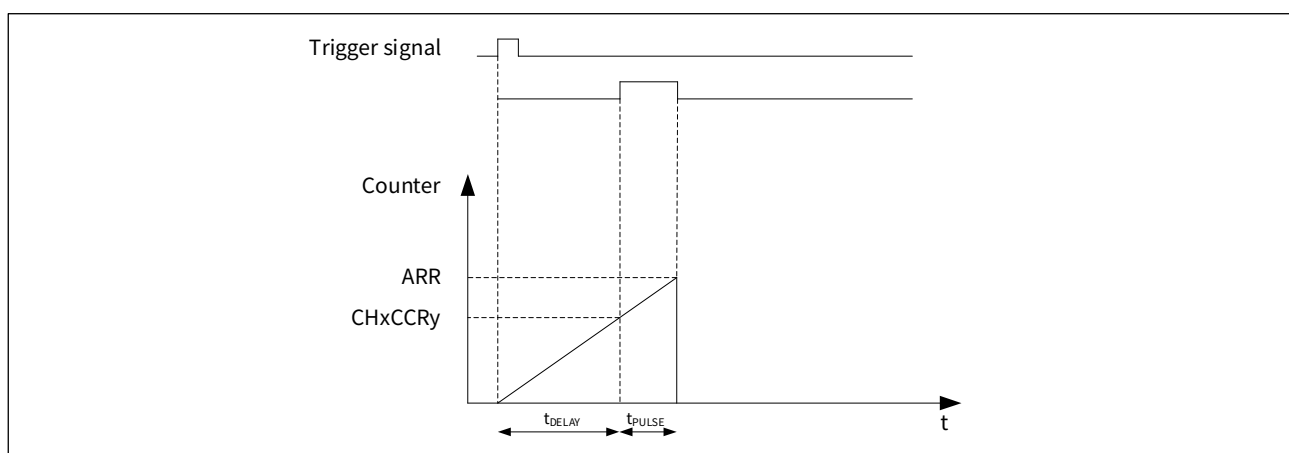
The single pulse mode needs to set the ATIM slave mode. For the slave mode and its trigger conditions, please refer to section [16.3.7 Slave mode](#).

The OCMxyFLTx bit field of the output control/input filter register ATIM_FLTR should be set to output compare mode or PWM output mode. At the same time, set the ONESHOT bit field of the control register ATIM_CR to 0x1, and select the single transmitting mode, the counter will generate the next update Stop counting on event UEV.

Before starting the single pulse mode, pay attention to the current value of the counter CNT, the reload value ARR, and the compare value CHxCCRy, which should meet the following conditions:

- Upcounting method: $CNT < CHxCCRy \leq ARR$
- Downcounting method: $CNT > CHxCCRy$

Figure 16-22 Example of single pulse output (upcounting method)



After starting the timer with the slave mode trigger, the timer starts counting when it detects the valid edge of the trigger signal, and after a delay of t_{DELAY} , a positive pulse with a width of t_{PULSE} is generated on the compare output port. Among them, t_{DELAY} is determined by the difference between the initial value of the counting register ATIM_CNT and the compare/capture register ATIM_CHxCCRy, and t_{PULSE} is determined by the reload register ATIM_ARR and the compare/capture register ATIM_CHxCCRy.

16.3.3.4 Independent PWM output

The PWM (pulse width modulation) output mode of ATIM can generate a PWM waveform with programmable frequency and duty cycle. The frequency is determined by the reload register ATIM_ARR, and the duty cycle is determined by compare/capture register ATIM_CHxCCRy.

The PWM output mode needs to set the control register ATIM_CR, filter register ATIM_FLTR and dead-time register ATIM_DTR, as shown in the following table:

Table 16-7 PWM output mode

PWM mode	Registers	Bit field	Bit field value	Description
PWM mode 1	ATIM_CR	COMP	0	Independent PWM output mode
	ATIM_FLTR	OCMxyFLTxy	110	PWM mode 1
	ATIM_DTR	MOE	1	Enable PWM output
PWM mode 2	ATIM_CR	COMP	0	Independent PWM output mode
	ATIM_FLTR	OCMxyFLTxy	111	PWM mode 2
	ATIM_DTR	MOE	1	Enable PWM output

In PWM mode, channel A of the compare channel CHx can be configured as single-point compare or double-point compare through the PWM2S bit field of the control register ATIM_CR. In the single-point compare mode, use the compare/capture register ATIM_CHxCCRA to control the compare output; in the double-point compare mode, use the compare/capture registers ATIM_CHxCCRA and ATIM_CHxCCRB to control the compare output. The channel B of the compare channel can only use single-point compare, and the compare output is controlled by the compare/capture register ATIM_CHxCCRB.

The output states of PWM modes 1 and 2 in different compare modes are shown in the following table:

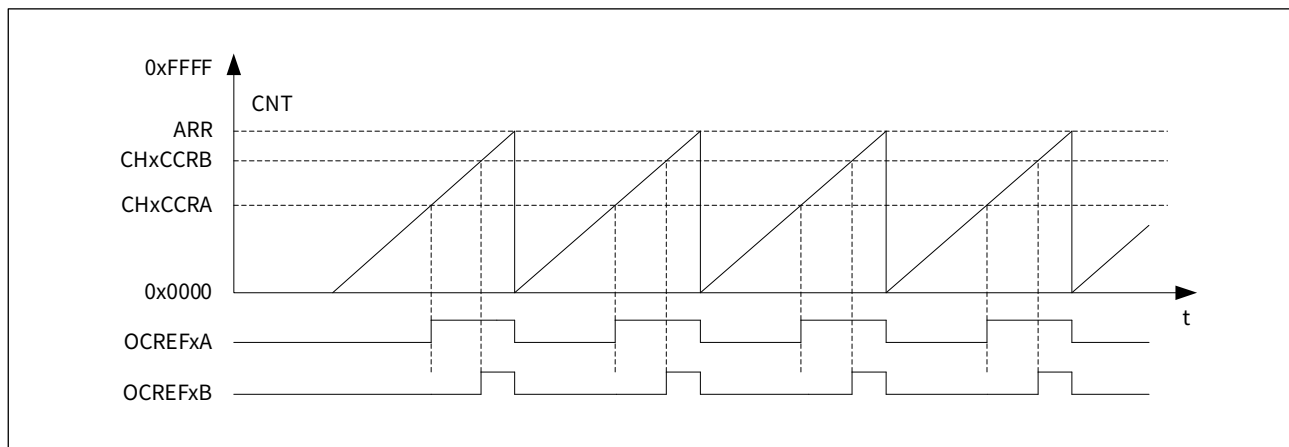
Table 16-8 PWM mode 1, 2 output state in different compare modes

Compare mode	Operating mode	Counting direction	PWM mode 1	PWM mode 2
Single-point	Edge-aligned mode, center-aligned mode	Upcounting	CNT < CHxCCRy, output high	CNT < CHxCCRy, output low
		Downcounting	CNT > CHxCCRy, output low	CNT > CHxCCRy, output high
Double-point	Edge-aligned mode	Upcounting	CHxCCRA < CNT ≤ CHxCCRB, output low	CHxCCRA ≤ CNT < CHxCCRB, output high
		Downcounting	CHxCCRA < CNT ≤ CHxCCRB, output high	CHxCCRA ≤ CNT < CHxCCRB, output low
	Center Aligned Mode	Upcounting	CNT < CHxCCRA, output high	CNT < CHxCCRA, output low
		Downcounting	CNT > CHxCCRB, output low	CNT > CHxCCRB, output high

The following are examples of independent PWM outputs of ATIM in different modes:



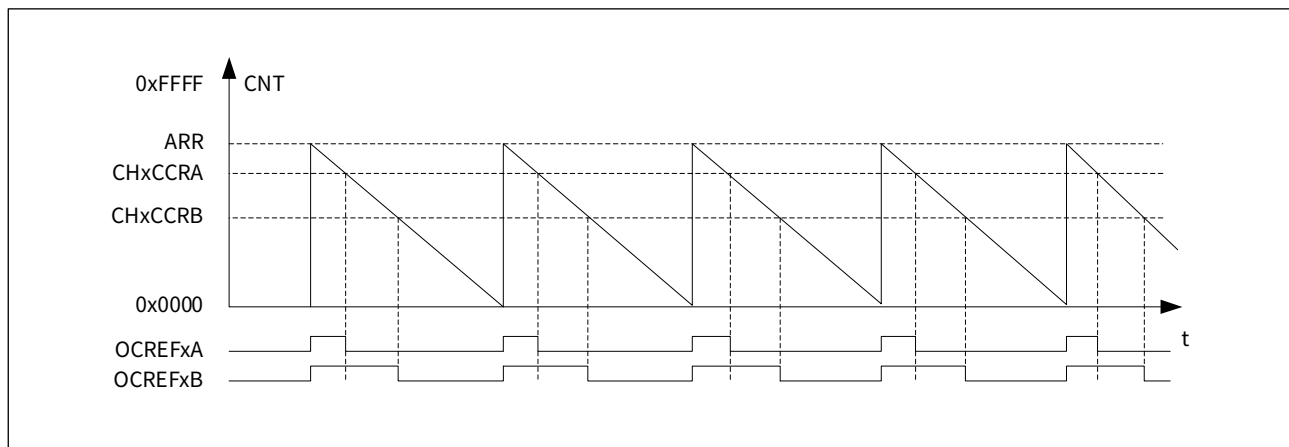
Figure 16-23 PWM mode 2, edge-aligned, upcounting, single-point comparison



The operation steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the register ATIM_CR.MODE to 0x2, the timer works in edge-aligned mode;
- Step 3: Set the register ATIM_CR.COMP to 0x0, set as independent PWM output;
- Step 4: Set the register ATIM_CR.DIR to 0x0, and the edge-aligned counting direction is upcounting;
- Step 5: Set ATIM_ARR according to the period of PWM;
- Step 6: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 7: Set compare registers ATIM_CHxCCRA, ATIM_CHxCCRB according to the PWM pulse width;
- Step 8: Set ATIM_FLTR.OCMxBFLTxB and ATIM_FLTR.OCMxAFLTxA to 0x7, select compare output mode as PWM mode 2;
- Step 9: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flag;
- Step 10: If necessary, set the relevant interrupt enable;
- Step 11: Set ATIM_FLTR.CCPxA and ATIM_FLTR.CCPxB to 0, select no inverting output;
- Step 12: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 13: Set the register ATIM_CR.EN to 0x01 to start the timer.

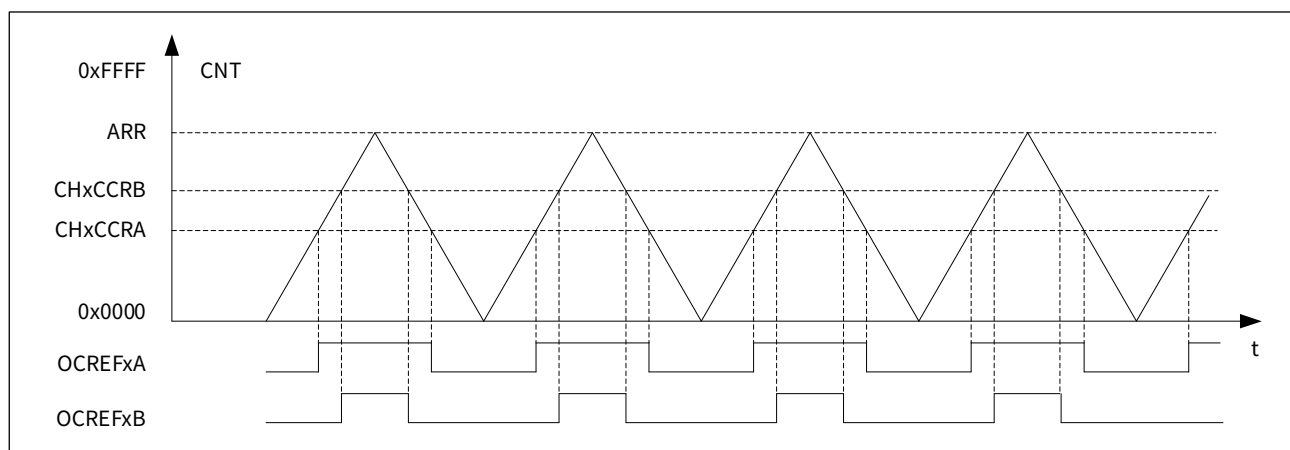
Figure 16-24 PWM mode 2, edge-aligned, downcounting, single-point comparison



The operation steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the register ATIM_CR.MODE to 0x2, the timer works in edge-aligned mode
- Step 3: Set the register ATIM_CR.COMP to 0x0, set as independent PWM output;
- Step 4: Set the register ATIM_CR.DIR to 0x1, and the edge-aligned counting direction is downcounting;
- Step 5: Set ATIM_ARR according to the period of PWM;
- Step 6: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 7: Set compare registers ATIM_CHxCCRA, ATIM_CHxCCRB according to the PWM pulse width;
- Step 8: Set ATIM_FLTR.OCMxBFLTxB and ATIM_FLTR.OCMxAFLTxA to 0x7, so that the compare output mode is PWM mode 2;
- Step 9: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flag;
- Step 10: If necessary, set the relevant interrupt enable;
- Step 11: Set ATIM_FLTR.CCPxA and ATIM_FLTR.CCPxB to 0, no inverting output is required;
- Step 12: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 13: Set the register ATIM_CR.EN to 0x01 to enable the timer.

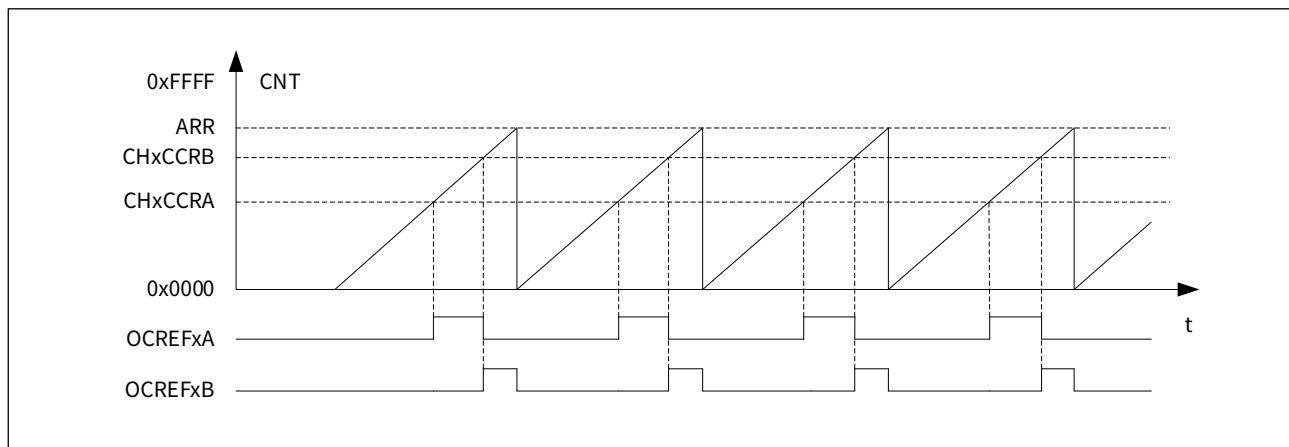
Figure 16-25 PWM mode 2, center Aligned, single-point comparison



The operation steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the register ATIM_CR.MODE to 0x3, the timer works in center-aligned mode;
- Step 3: Set register ATIM_CR.COMP to 0x0, set as independent PWM output;
- Step 4: Set ATIM_ARR according to the period of the PWM;
- Step 5: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 6: Set compare registers ATIM_CHxCCRA, ATIM_CHxCCRB according to PWM pulse width;
- Step 7: Set ATIM_FLTR.OCMxBFLTxB and ATIM_FLTR.OCMxAFLTxA to 0x7 to make the compare output mode PWM edge-aligned;
- Step 8: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flags;
- Step 9: Set related interrupt enable if needed;
- Step 10: Set ATIM_FLTR.CCPxA and ATIM_FLTR.CCPxB to 0, no inverting output required;
- Step 11: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 12: Set the register ATIM_CR.EN to 0x01 to enable the timer.

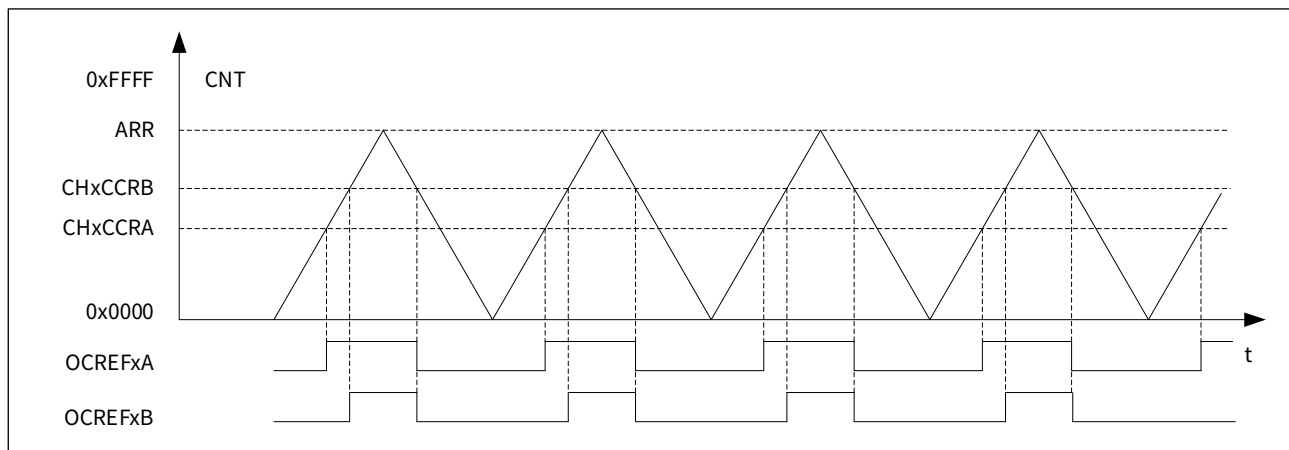
Figure 16-26 PWM mode 2, edge-aligned, two-point comparison



The operation steps are as follows:

- Step 1: Set the system control register SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the register ATIM_CR.MODE to 0x2, the timer works in edge-aligned mode;
- Step 3: Set register ATIM_CR.COMP to 0x0, set as independent PWM output;
- Step 4: Set the register ATIM_CR.DIR to 0x0, and the edge-aligned counting direction is upcounting;
- Step 5: Set ATIM_ARR according to the period of the PWM;
- Step 6: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 7: Set the compare registers ATIM_CHxCCRA, ATIM_CHxCCRB according to the PWM pulse width;
- Step 8: Set ATIM_FLTR.OCMxBFLTxB and ATIM_FLTR.OCMxAFLTxA to 0x7 to make the compare output mode PWM mode 2;
- Step 9: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flags;
- Step 10: Set related interrupt enable if needed;
- Step 11: Set ATIM_FLTR.CCPxA and ATIM_FLTR.CCPxB to 0, no inverting output required;
- Step 12: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 13: Set the register ATIM_CR.EN to 0x01 to enable the timer.

Figure 16-27 PWM mode 2, center-aligned, two-point comparison

**Caution:**

OCREFxA is output by two-point comparison, and OCREFxB is controlled by CHxCCRB for single-point comparison output.

The operation steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the register ATIM_CR.MODE to 0x3, the timer works in center-aligned mode;
- Step 3: Set the register ATIM_CR.COMP to 0x0, set as independent PWM output;
- Step 4: Set ATIM_ARR according to the period of PWM;
- Step 5: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 6: Set ATIM_CR.PWM2S to 0x0 to enable the two-point comparison function;
- Step 7: Set the comparison registers ATIM_CHxCCRA, ATIM_CHxCCRB according to the PWM pulse width;
- Step 8: Set ATIM_FLTR.OCMxBFLTxB and ATIM_FLTR.OCMxAFLTxA to 0x7, so that the compare output mode is PWM mode 2;
- Step 9: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flag;
- Step 10: If necessary, set the relevant interrupt enable;
- Step 11: Set ATIM_FLTR.CCPxA and ATIM_FLTR.CCPxB to 0, no inverting output is required;
- Step 12: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 13: Set the register ATIM_CR.EN to 0x01 to enable the timer.



16.3.3.5 Complementary PWM output and dead-time insertion

ATIM can output three complementary PWM signals, and can set dead-time.

Set the COMP bit field of the control register ATIM_CR to 1 to select the complementary PWM output mode, and compare the output channel CHxA and channel CHxB to generate a pair of complementary PWM. Set the OCMxAFLTxA bit field of the ATIM_FLTR register to 0x6 to select PWM mode 1, and to 0x7 to select PWM mode 2. Set the MOE bit field of the ATIM_DTR register to 1 to enable the PWM output.

Complementary PWM output mode, single-point comparison or two-point comparison can be selected through the PWM2S bit field of the control register ATIM_CR: use the comparison capture register ATIM_CHxCCRA to control the comparison output in single-point comparison; use the comparison capture register ATIM_CHxCCRA and ATIM_CHxCCRB to control the two-point comparison Compare output.

In complementary PWM output mode, channel A of channel CHx controls the output signal, and channel B compare capture register CHxCCRB no longer controls the CHxB output, but can still be used for internal control, such as triggering ADC or DMA.

Figure 16-28 Complementary PWM output waveform

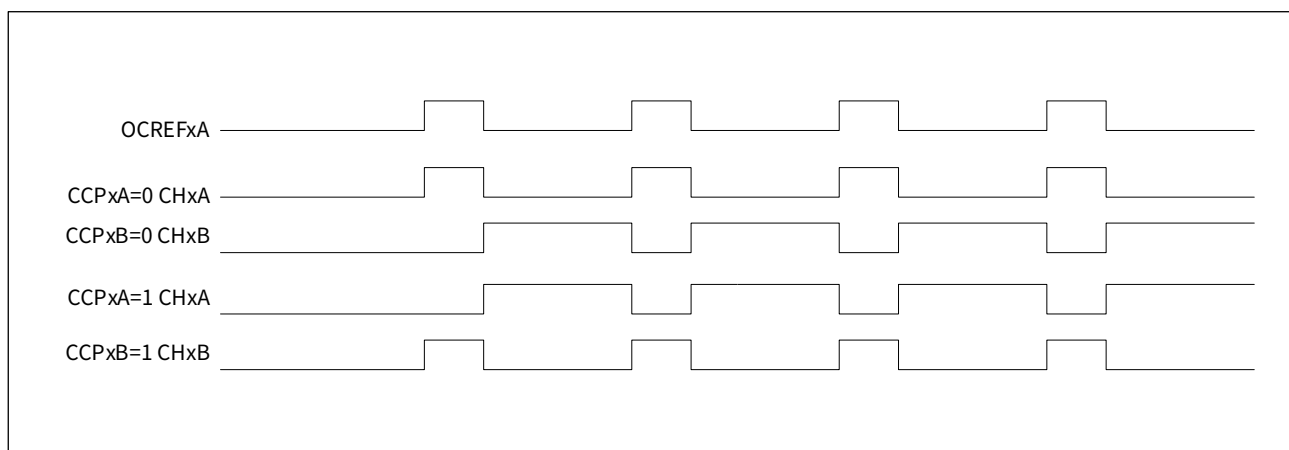
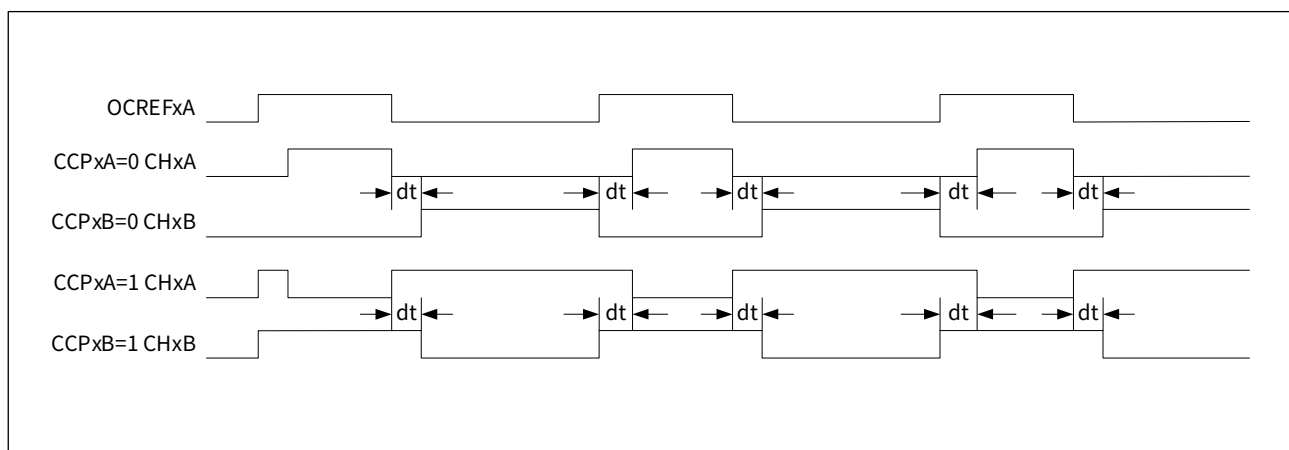


Figure 16-29 Complementary PWM output waveform with dead-time insertion



Set the DTEN bit field of the dead-time register ATIM_DTR to 1 to enable dead-time control.

The dead time of the three channels CHx is set uniformly and configured by the DTR bit field of the ATIM_DTR register, as shown in the following table:

Table 16-9 Dead-time settings of three channels CHx

ATIM_DTR.DTR	Step length	Dead-time (unit: T_{CLK})	When $T_{CLK} = 125\text{ ns}$, dead-time range
DTR[7] = 0	$1 T_{CLK}$	$DTR[6:0] + 2$	$0.25 \sim 16.125\text{ }\mu\text{s}$
DTR[7:6] = 10	$2 T_{CLK}$	$(DTR[5:0] + 64) \times 2 + 2$	$16.25 \sim 32\text{ }\mu\text{s}$
DTR[7:5] = 110	$8 T_{CLK}$	$(DTR[4:0] + 32) \times 8 + 2$	$32.5 \sim 63.25\text{ }\mu\text{s}$
DTR[7:5] = 111	$16 T_{CLK}$	$(DTR[4:0] + 32) \times 16 + 2$	$63.25 \sim 126.25\text{ }\mu\text{s}$

16.3.3.6 Brake function

Set the BKE bit field of the dead-time register ATIM_DTR to 1 to enable the brake function.

The brake signal is active at high level. When the brake signal is active, the compare output channel CHx will be immediately set to the output state set by the program. The specific output state is set by the BSKA and BSKB bit fields of the channel control register ATIM_CHxCR. The common brake control is BSKA and BAKB are high or low at the same time.

Brake trigger source

- Software brake, set the BG bit field of the control register ATIM_CR to 1 to trigger the software brake, and the BG bit is automatically cleared
- The compare output of the voltage comparator VC, the VCE bit field of the ATIM_DTR register is 1 to enable
- System abnormality, such as: abnormal clock, abnormal power supply, etc., the SAFEEN bit field of the ATIM_DTR register is 1 to enable
- External ATIM_BK pin input (GPIO function multiplexing setting), filter and set the brake input signal through the FLTBK bit field of the ATIM_FLTR register, and select the phase of the brake input signal in the BKP bit field of the ATIM_FLTR register

When the brake signal is valid, the brake interrupt flag ATIM_ISR.BIF will be set by hardware. If the brake interrupt is enabled (set ATIM_CR.BIE to 1), an interrupt request will be generated. Set ATIM_ICR.BIF to 0 to clear the flag.



16.3.3.7 Compare match interrupt

After the ATIM timer is started, the count register ATIM_CNT and the compare/capture register ATIM_CHxCCRy begin to compare, when the two values are equal, a compare match event will be generated.

When working in edge-aligned mode, regardless of whether the counting direction is up or down, when a compare match occurs, the capture/compare match flag bit ATIM_ISR.CxyF of the corresponding channel will be set by hardware, if interrupts are enabled (set ATIM_CHxCR.CIEy to 1), an interrupt request will be generated, set ATIM_ICR.CxyF to 0 to clear this flag.

When working in the center-aligned mode, the timing of the compare match interrupt of channel A and channel B of the compare channel is different:

- The channel A of compare channel is controlled by the CISA bit field of the control register ATIM_CR, and the timing of the compare match interrupt can be selected in the process of upcounting, downcounting or bidirectional counting. When the comparison matches, the capture/compare match flag bit ATIM_ISR.CxAF of the corresponding channel will be set by hardware. If the interrupt is enabled (set ATIM_CHxCR.CIEA to 1), an interrupt request will be generated, set ATIM_ICR.CxAF to 0 to clear the flag bit.
- The channel B of compare channel is controlled by the CISB bit field of the channel x control register ATIM_CHxCR, and the timing of the compare match interrupt can be selected in the process of upcounting, downcounting or bidirectional counting. When the comparison matches, the capture/compare match flag bit ATIM_ISR.CxBF of the corresponding channel will be set by hardware, if the interrupt is enabled (set ATIM_CHxCR.CIEB to 1), an interrupt request will be generated, set ATIM_ICR.CxBF to 0 to clear the flag bit. The compare match of channel B of the compare channel is controlled independently, which can trigger the ADC more flexibly. For details, see section [16.3.5 Trigger ADC](#).

Table 16-10 Compare match interrupt settings

Operating mode	Channel A/B	Counting direction	CISA/CISB bit fields	Whether to generate an interrupt on a compare match
Edge-aligned mode	Channel A/B	Down/up	-	Yes
Center-aligned mode	Channel A	Up	CISA=01 or 11	Yes
			CISA=10 or 00	No
		Down	CISA=10 or 11	Yes
			CISA=01 or 00	No
	ChannelB	Up	CISB=01 or 11	Yes
			CISB=10 or 00	No
		Down	CISB=10 or 11	Yes
			CISB=01 or 00	No

The example of interrupt generated by compare match is shown in the following figure:



Figure 16-30 Edge-aligned mode compare match interrupt

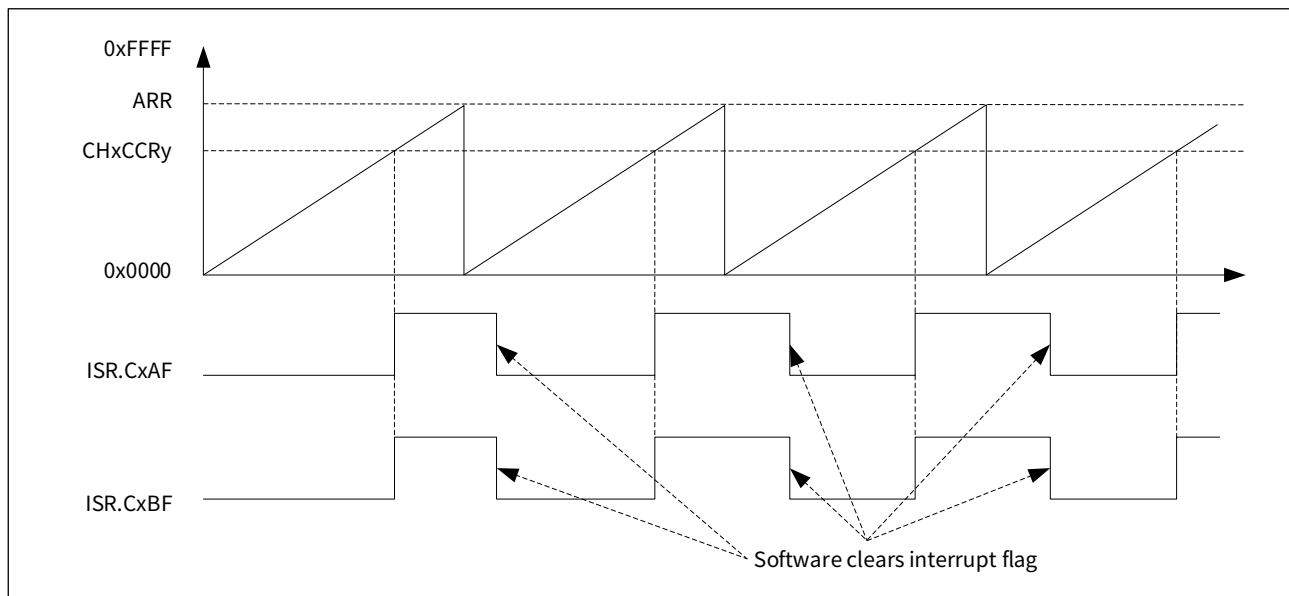
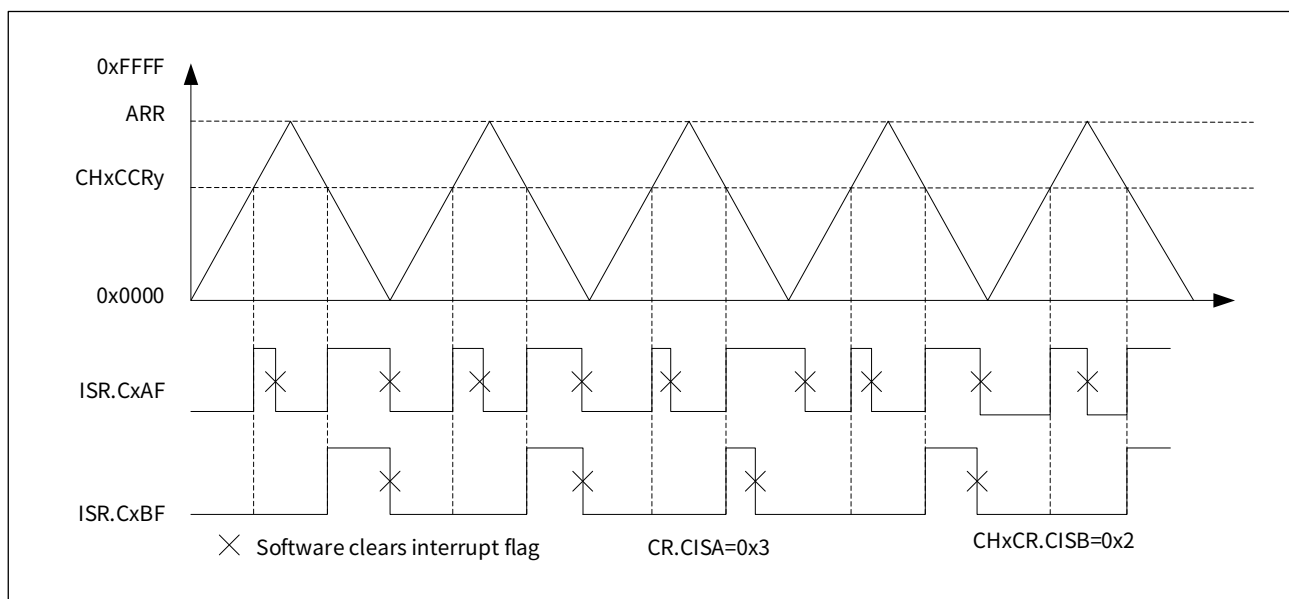


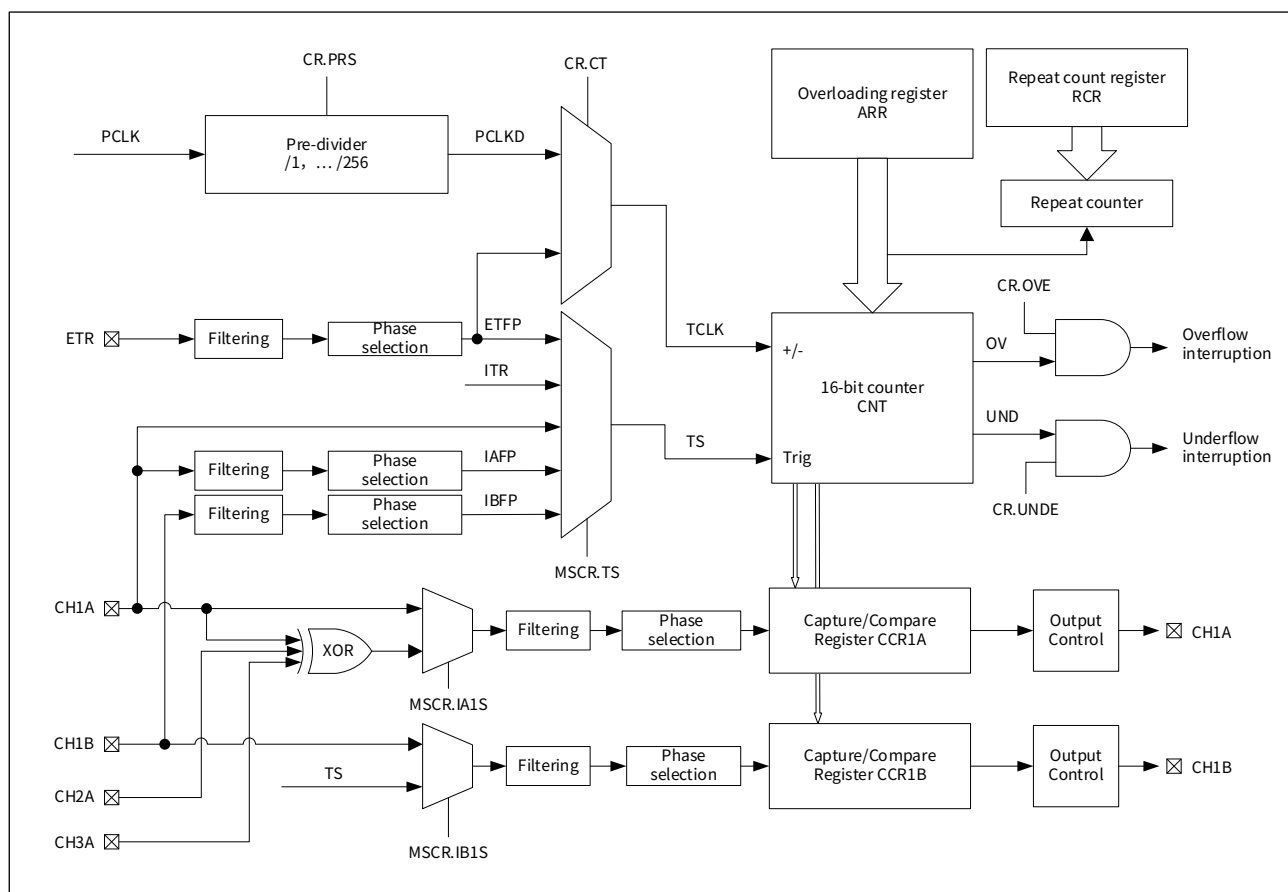
Figure 16-31 Center-aligned mode, channel A bidirectional compare match, channel B downcounting compare match



16.3.4 Quadrature encoding counting

When ATIM works in slave mode, it has the function of Quadrature encoding counting. It connects the external quadrature encoder through CH1A and CH1B. According to the jump sequence of the input signal, the counter can automatically count up or down. Its functional block diagram is shown in the following figure:

Figure 16-32 Quadrature encoding counting



The CH1A and CH1B input signals have filtering function, which are set by the OCM1AFLT1A and OCM1BFLT1B bit fields of the ATIM_FLTR register respectively; the configurable phase is controlled by the CCP1A and CCP1B bit fields of the ATIM_FLTR register respectively.

IAFP and IBFP are the internal signal names of CH1A and CH1B after filtering and phase selection, which are used as the input signal interface of the encoder. The phase relationship between IAFP and IBFP determines the counting direction, and also affects the direction bit field DIR of the control register ATIM_CR. .

The SMS bit fields of the master-slave mode control register ATIM_MSCR are 0x4, 0x5, and 0x6, which correspond to orthogonal encoding mode 1, mode 2, and mode 3 respectively. Quadrature encoding mode 1 uses the edge counting of CH1A; mode 2 uses the edge counting of CH1B; mode 3 uses the edge counting of CH1A and CH1B. The relationship between the counting direction and the encoder signal in the three modes of quadrature encoding is shown in the following table:

Table 16-11 Quadrature encoding mode counting direction

Mode	Signal level		IAFP		IBFP	
	IAFP	IBFP	Rising	Falling	Rising	Falling
Mode 1	High	-	Downcounting	Upcounting	No count	No count
	Low	-	Upcounting	Downcounting	No count	No count
Mode 2	-	High	No count	No count	Upcounting	Downcounting
	-	Low	No count	No count	Downcounting	Upcounting
Mode 3	High	High	Downcounting	Upcounting	Upcounting	Downcounting
	Low	Low	Upcounting	Downcounting	Downcounting	Upcounting

Caution:

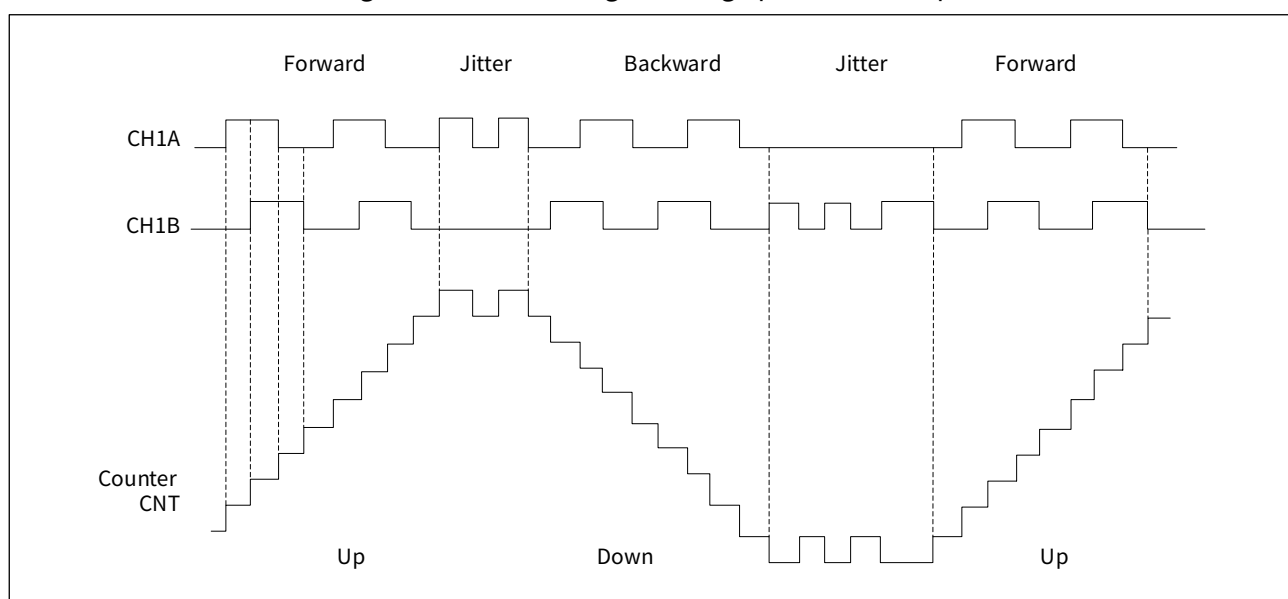
To ensure the correctness of counting direction and speed, the phase difference between CH1A and CH1B should be greater than one TCLK pulse width; the signal pulse width of CH1A or CH1B should be greater than two TCLK pulse widths.

The following figure is an example of encoding count operation, showing the generation and direction control of the count signal. (It also shows how to suppress input jitter when counting on both edges in center-aligned mode, which typically occurs when the encoder switches directions.)

The example configuration is as follows:

- CH1A is filtered and non-inverted into CH1CCRA
- CH1B is filtered and non-inverted into CH1CCRB
- Set the SMS bit field of the TIM_MSCR register to 0x6, select the quadrature encoding mode to 3, and count the rising and falling edges of CH1A and CH1B.
- Set ATIM_CR.EN to 0x01, start counter

Figure 16-33 Encoding counting operation example



16.3.5 Trigger ADC

Both ATIM edge-aligned and center-aligned modes support compare match events or update events to trigger the ADC. The ADC trigger function can be applied to motor FOC control.

Set the ADTE bit field of the trigger ADC control register ATIM_TRIG to 1, enable the ADC trigger global control, and allow the ADC to be triggered when a compare match or event update occurs.

Set ATIM_TRIG.UEVE to 1, and the ADC will be triggered synchronously when the update event occurs.

Set ATIM_TRIG.CMxyE to 1 to trigger the ADC when the channel CHxy compare match occurs. For the timing of the compare match, please refer to section [16.3.3.7 Compare match interrupt](#).

16.3.6 DMA function

Both edge-aligned and center-aligned modes of ATIM support capture/compare or timer overflow trigger DMA. Using the DMA function, data can be written to the timer from other locations, or read from the timer and written to other locations. For example, it can be applied to automatic transfer of data after data capture and changing the period or pulse width of PWM output.

When ATIM works in compare mode, the CCDS bit field of the master/slave mode control register ATIM_MSCR is 0, and the comparison match triggers DMA. The CCDS bit field is 1. DMA is not triggered by comparison matching, but by event update.

The compare/capture channels CH1~3 of ATIM allow the DMA function to be triggered when a capture or compare match occurs. The compare channel CH4 has no input port and can only trigger the DMA function when a compare match occurs.

To trigger DMA using capture/compare, you need to set the HARDSRC bit field of the DMA trigger source control register DMA_TRIG to 0x11 or 0x12. As shown in the following table:

Table 16-12 DMA trigger sources

HARDSRC bit fields	DMA trigger sources	DMA numbe
010001	CH1A, CH2A, CH3A, CH4 compare/capture flags, or event update flag	0x11
010010	CH1B, CH2B, CH3B compare/capture flags, or event update flag	0x12

The compare channels CH1A, CH2A, CH3A and CH4 share the DMA request source numbered 17, and the compare channels CH1B, CH2B and CH3B share the DMA request source numbered 18. For details, please refer to section [8.8.4 DMA_TRIGy channel y trigger source control register](#).



16.3.7 Slave mode

The slave mode of the ATIM timer means that the operation mode of the timer is controlled by the trigger signal. The SMS bit field of the master-slave mode control register ATIM_MSCR can set the different working states of the ATIM timer in the slave mode. As shown in the following table:

Table 16-13 Working status of slave mode

ATIM_MSCR.SMS	Slave mode function selection
000	Use internal clock
001	Reset function
010	Trigger mode
011	External clock mode
100	Quadrature encoding counting mode 1
101	Quadrature encoding counting mode 2
110	Quadrature encoding counting mode 3
111	Gated function

16.3.7.1 Use internal clock (master mode)

When the SMS bit field of the ATIM master-slave mode control register ATIM_MSCR is 0x0, the timer slave mode is disabled. The counting clock source is selected by the CT bit field of the control register ATIM_CR. Write 1 to the ATIM_CR.EN bit field, and the timer starts counting immediately.



16.3.7.2 Reset function (slave mode)

When the SMS bit field of the ATIM master-slave mode control register ATIM_MSCR is 0x1, the reset of the ATIM counter is controlled by the TS signal. When the TS signal is active, the ATIM counter CNT and the prescaler counter are initialized. If the URS bit field of the control register ATIM_CR is 0, an update event UEV is generated, the update event interrupt flag bit ATIM_ISR.UIF is set, and ATIM_ARR, ATIM_CHxCCRy are updated to its cache register at the same time.

The source of the TS signal is controlled by the TS bit of the master-slave mode control register ATIM_MSCR, as shown in the following table:

Table 16-14 TS signal sources

ATIM_MSCR.TS	TS signal source
000	ETR filtered phase-selected signal ETFP
001	Internal interconnect signal ITR
101	Input signal of port CH1A
110	Filtered and phase-selected signal IAFP at port CH1A
111	Filtered and phase-selected signal IBFP at port CH1B

The source of the ETR input signal can be the external ATIM_ETR pin or other on-chip peripherals, please refer to section [16.3.9 On-chip peripheral interconnect ETR](#). When ETR is selected as the TS signal source, the filter control can be performed through ATIM_FLTR.FLTET, and the ETR input phase can be selected through ATIM_FLTR.ETP.

The source of the internal interconnection signal ITR is the overflow signal of BTIM and GTIM, which can be selected by the timer ITR source configuration register SYSCTRL_TIMITR, see [Table 16-15 ATIM internal cascade ITR](#).

The external input ports CH1A and CH1B both have filtering and phase selection functions. CH1A and CH1B respectively use the OCM1AFLT1A and OCM1BFLT1B bit fields of the output control/input filtering register ATIM_FLTR for filtering control, and the CCP1A and CCP1B bit fields for phase control. The input CH1A and CH1B pins of ATIM need to be configured with multiplexing functions. For the supported pins, see [Table 16-3 ATIM compare/capture channel pins](#).



16.3.7.3 Trigger mode (slave mode)

The SMS bit field of the ATIM master-slave mode control register ATIM_MSCR is 0x2, which is configured as a trigger mode, and can be triggered by software or hardware to start the counter to start counting.

- Software trigger

Set the TG bit field of the control register ATIM_CR to 1, start the counter immediately, and the TG bit is automatically cleared.

- Hardware trigger

When the trigger signal TS is valid, the counter is started. For TS signal source and phase selection, please refer to section [16.3.7.2 Reset function \(slave mode\)](#).

When a trigger is generated, the trigger interrupt flag bit ATIM_ISR.TIF will be set by hardware. If the trigger interrupt enable bit ATIM_CR.TIE is set to 1, an interrupt request will be generated, and ATIM_ICR.TIF is set to 0 to clear the interrupt flag bit.

Caution:

If you use falling edge triggering, you need to select the trigger polarity first, and then select the trigger mode to avoid false triggering.

16.3.7.4 External clock mode (slave mode)

The SMS bit of the master-slave mode control register ATIM_MSCR is 0x3, and the ATIM counter counts on each valid edge of the TS signal. For TS signal source and phase selection, please refer to section [16.3.7.2 Reset function \(slave mode\)](#).

Caution:

In this mode, ATIM_CR.EN must be set to 1 to enable the timer.

16.3.7.5 Quadrature encoding mode (slave mode)

The SMS bits of the master-slave mode control register ATIM_MSCR are 0x4~0x6. The counter counts up or down according to the transition sequence of the channel CH1A and CH1B input signals. For details, please refer to section [16.3.4 Quadrature encoding counting](#).

16.3.7.6 Gated function (slave mode)

The SMS bit field of the master-slave mode control register ATIM_MSCR is 0x7, and the ATIM is configured in gated mode. When the gate control signal TS is valid and ATIM_CR.EN is 1, the counter starts counting; when the gate control signal TS is invalid or ATIM_CR.EN is 0, the counter counting is suspended.

For TS signal source and phase selection, please refer to section [16.3.7.2 Reset function \(slave mode\)](#).



16.3.8 Internal cascade ITR

All timers (ATIM, GTIM, BTIM) of CW32L083 can be used in cascade, and the overflow signal of the previous timer is used as the ITR input of the next timer.

The ITR source of ATIM is the overflow signal of BTIM and GTIM, which can be selected by the timer ITR source configuration register SYSCTRL_TIMITR, as shown in the following table:

Table 16-15 ATIM internal cascade ITR

SYSCTRL_TIMITR.ATIMITR	ITR signal sources of ATIM
000	Overflow signal of BTIM1
001	Overflow signal of BTIM2
010	Overflow signal of BTIM3
011	Overflow signal of GTIM1
100	Overflow signal of GTIM2
101	Overflow signal of GTIM3
110	Overflow signal of GTIM4

ATIM can also serve as an ITR source for BTIM and GTIM. Through the MMS bit field of the master-slave mode control register ATIM_MSCR, the master mode output of the ATIM can be selected and connected to the ITR input of other timers. As shown in the following figure:

Figure 16-34 ATIM internal cascade ITR

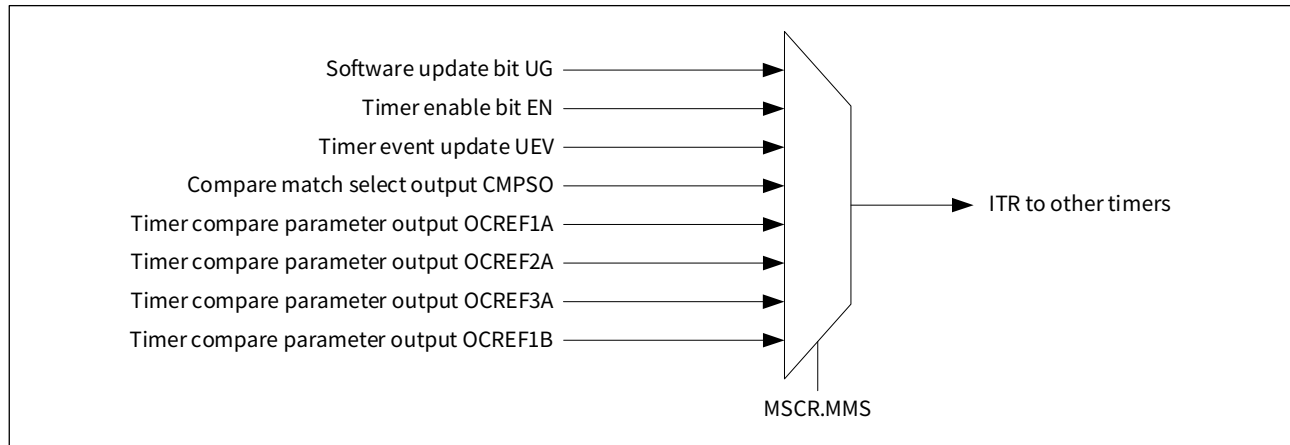


Table 16-16 ATIM master mode output selection

ATIM_MSCR.MMS	ATIM master mode output
000	Software update UG, write ATIM_CR.UG
001	Timer enable signal EN (ATIM_CR.EN)
010	Timer update event UEV
011	Compare match select output CMPSO
100	Timer channel CH1A compare reference output OCREF1A
101	Timer channel CH2A compare reference output OCREF2A
110	Timer channel CH3A compare reference output OCREF3A
111	Timer channel CH1B compare reference output OCREF1B

16.3.9 On-chip peripheral interconnect ETR

The source of the ETR signal of ATIM can be the ATIM_ETR pin or other on-chip peripherals, which can be selected through the advanced timer ETR source configuration register SYSCTRL_ATIMETR.

When SYSCTRL_ATIMETR.ATIMETR is 0x00, the ETR signal comes from the ATIM_ETR pin input; when ATIMETR is 0x01~0x07, the ETR signal comes from other on-chip peripherals to realize the interconnection between on-chip and peripherals, as shown in the following table:

Table 16-17 ETR sources of ATIM

SYSCTRL_ATIMETR.ATIMETR	ETR sources of ATIM
000	Configured by GPIOx_AFRH and GPIOx_AFRL
001	RXD signal of UART1
010	RXD signal of UART2
011	RXD signal of UART3
100	RXD signal of UART4
101	Compare output signal of VC1
110	Compare output signal of VC2
111	LVD output signal



16.4 Debugging support

ATIM supports stop or continue counting in debug mode, which is set by the ATIM bit field of the debug status timer control register `SYSCTRL_DEBUG`.

Set `SYSCTRL_DEBUG.ATIM` to 1, then suspend the counter count of ATIM in the debug state;

If `SYSCTRL_DEBUG.ATIM` is set to 0, the counter of ATIM continues to count in the debug state.



16.5 Programming examples

16.5.1 Input capture

The following example shows how to capture the counter value into the ATIM_CH1CCRA register on the rising edge of the CH1A input signal, the steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the MODE bit of the register ATIM_CR to 0x02, so that the counting mode of the ATIM is edge-aligned mode, so that the ATIM can work in the input capture mode;
- Step 3: Set the CSA bit of the register ATIM_CH1CR to 0x01, and configure CH1A to be the input capture mode;
- Step 4: Set the BKSA bit of the register ATIM_CH1CR to 0x01, and configure the CH1A rising edge capture;
- Step 5: According to the characteristics of the input signal, set the FLT1A bit of the ATIM_FLTR register, and configure the input filter to the required bandwidth;
- Step 6: Set the relevant bits of the ATIM_ICR register to 0, and clear the flag to prevent the previous setting from affecting the result of this operation;
- Step 7: According to the characteristics of the input signal, set the value of the ATIM_ARR register, and select the appropriate auto-reload value;
- Step 8: Set the EN bit of the ATIM_CR register to 0x01 to allow the capture of the counter value into the capture register;
- Step 9: If required, enable the relevant interrupt request by setting the CIEA bit in the ATIM_CH1CR register and enable the DMA request by setting the CDEA bit in the ATIM_CH1CR register.

16.5.2 PWM input

The following example shows how to measure the pulse width and period of the PWM signal input from the CH3B channel. The steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the MODE bit of the register ATIM_CR to 0x02, so that the counting mode of the ATIM is edge-aligned mode, so that the ATIM can work in the input capture mode;
- Step 3: Set the CSB bit of register ATIM_CH3CR to 0x01, and configure CH3B as input capture mode;
- Step 4: Set the BKSB bit of the register ATIM_CH3CR to 0x11, and configure CH3B rising/falling edge capture;
- Step 5: According to the characteristics of the input signal, set the FLT3B bit of the ATIM_FLTR register, and configure the input filter to the required bandwidth;
- Step 6: Set the relevant bits of the ATIM_ICR register to 0, and clear the flag to prevent the previous setting from affecting the result of this operation;
- Step 7: According to the characteristics of the input signal, set the value of the ATIM_ARR register, and select the appropriate auto-reload value;
- Step 8: Set the EN bit of the ATIM_CR register to 0x01 to allow the capture of the counter value into the capture register;
- Step 9: If required, enable the relevant interrupt request by setting the CIEA bit in the ATIM_CH3CR register;
- Step 10: Wait for the capture to occur three times, read the value captured in the ATIM_CH3CCRB register after each capture occurs, and clear the capture interrupt flag bit;
- Step 11: According to the value of the ATIM_CH3CCRB register read three times, it can be obtained that the period of PWM is the third value-first value, and the pulse width of PWM is the third value-first value or the second value- 1st value.



16.5.3 Output compare function

Configuration steps for output compare mode:

- Step 1: Select the counter clock (internal, external, prescaler);
- Step 2: Write the corresponding data into the ATIM_ARR and ATIM_CHxCCRy registers;
- Step 3: If an interrupt request is to be generated, set the CIEy bit in the ATIM_CHxCR register;
- Step 4: Select the output mode, if you need to flip the output, set ATIM_FLTR.OCMxy=0x4;
- Step 5: Set the CSy bit in the ATIM_CHxCR register to use the corresponding channel as a compare output;
- Step 6: Clear the relevant interrupt flag;
- Step 7: Set the CCPxy bit in the ATIM_FLTR register to select the desired output phase;
- Step 8: Set the EN bit in the ATIM_CR register to start the counter.

16.5.4 Complementary PWM output

The steps to set up a center-aligned complementary PWM output with dead-time are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the register ATIM_CR.MODE to 0x3, the timer works in center-aligned mode;
- Step 3: Set the register ATIM_CR.COMP to 0x01, and select the complementary PWM output;
- Step 4: Set the register ATIM_CR.PWM2S to 0x0 and use the two-point compare function;
- Step 5: Set ATIM_ARR according to the period of PWM;
- Step 6: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 7: Set the compare registers ATIM_CHxCCRA and ATIM_CHxCCRB according to the PWM pulse width;
- Step 8: Set ATIM_FLTR.OCMxBFLTxB and ATIM_FLTR.OCMxAFLTxA to 0x6 or 0x7 to make the compare output mode PWM mode 1 or PWM mode 2;
- Step 9: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flag;
- Step 10: If necessary, set the relevant interrupt enable;
- Step 11: Set ATIM_FLTR.CCPxA and ATIM_FLTR.CCPxB to 0, no inverting output is required;
- Step 12: Set ATIM_DTR.DTEN to 0x01 to enable dead-time insertion;
- Step 13: Set ATIM_DTR.DTR, and configure the inserted dead-time duration;
- Step 14: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 15: Set the register ATIM_CR.EN to 0x01 to enable the timer.



16.5.5 DMA function

The configuration steps for capturing DMA data transfer on the rising edge of CH1A are as follows:

- Step 1: Set the SYSCTRL_APBEN2.ATIM bit to 1 and open the ATIM module;
- Step 2: Set the SYSCTRL_AHBEN.DMA bit to 1 and open the DMA module;
- Step 3: Set DMA_CSRy.TRANS to 1 to make DMA work in BLOCK transfer mode;
- Step 4: Set the DMA data transfer bit width (DMA_CSRy.SIZE), the source address increment mode (DMA_CSRy.SRCINC) and the destination address increment mode (DMA_CSRy.DSTINC) of the DMA channel;
- Step 5: Set the DMA transfer data block size (DMA_CNTy.REPEAT, please keep it as 1) and the number of transfer data blocks (DMA_CNTy.CNT);
- Step 6: Set the source and destination addresses (DMA_SRCADDRy and DMA_DSTADDRy);
- Step 7: Set DMA_CSRy.EN to 1 to enable the corresponding DMA channel;
- Step 8: Set DMA_TRIGy.TYPE to 1, make DMA work in hardware trigger transmission mode, and set hardware trigger source DMA_TRIGy.HARDSRC to 0x11;
- Step 9: Set the MODE bit of the register ATIM_CR to 0x02, so that the counting mode of the ATIM is edge-aligned mode, so that the ATIM can work in the input capture mode;
- Step 10: Set the CSA bit of the register ATIM_CH1CR to 0x01, and configure CH1A to be the input capture mode;
- Step 11: Set the BKSA bit of the register ATIM_CH1CR to 0x01, and configure CH1A rising edge capture;
- Step 12: According to the characteristics of the input signal, set the FLT1A bit of the ATIM_FLTR register, and configure the input filter to the required bandwidth;
- Step 13: Set the relevant bits of the ATIM_ICR register to 0, and clear the flag to prevent the previous setting from affecting the result of this operation;
- Step 14: According to the characteristics of the input signal, set the value of the ATIM_ARR register, and select the appropriate auto-reload value;
- Step 15: Set the EN bit of the ATIM_CR register to 0x01 to allow the capture of the counter value into the capture register;
- Step 16: If required, enable the relevant interrupt request by setting the CIEA bit in the ATIM_CH1CR register;
- Step 17: Set the CDEA bit in the ATIM_CH1CR register to enable DMA requests.

Caution:

The source address is set to the address of the ATIM_CH1CCRA register, the source address is fixed, and the destination address is incremented automatically.



DMA data transfer changes the pulse width of the PWM output

- Step 1: Set DMA_CSRy.TRANS to 1 to make DMA work in BLOCK transfer mode;
- Step 2: Set the DMA data transfer bit width (DMA_CSRy.SIZE), the source address increment mode (DMA_CSRy.SRCINC) and the destination address increment mode (DMA_CSRy.DSTINC) of the DMA channel;
- Step 3: Set the DMA transfer data block size (DMA_CNTy.REPEAT, please keep it as 1) and the number of transfer data blocks (DMA_CNTy.CNT);
- Step 4: Set the source and destination addresses (DMA_SRCADDRy and DMA_DSTADDRy);
- Step 5: Set DMA_CSRy.EN to 1 to enable the corresponding DMA channel;
- Step 6: Set DMA_TRIGy.Type to 1, make DMA work in hardware trigger transmission mode, and set hardware trigger source DMA_TRIGy.HardSrc as hardware trigger source No.18;
- Step 7: Set the register ATIM_CR.MODE to 0x2, the timer works in edge-aligned mode;
- Step 8: Set the register ATIM_CR.DIR to 0x0, and the edge-aligned counting direction is upcounting;
- Step 9: Set ATIM_ARR according to the period of PWM;
- Step 10: Set the initial value of the counter ATIM_CNT (the initial value must be less than the value of ATIM_ARR);
- Step 11: Set the compare register ATIM_CHxCCRA according to the PWM pulse width;
- Step 12: Set ATIM_FLTR.OCMxA to 0x7, so that the compare output mode is PWM mode 2;
- Step 13: Set the relevant bits of the ATIM_ICR register and clear the relevant interrupt flag;
- Step 14: If necessary, set the relevant interrupt enable;
- Step 15: Set ATIM_FLTR.CCPxA to 0, no inverting output is required;
- Step 16: Set ATIM_DTR.MOE to 0x01 to enable PWM output;
- Step 17: Set the CDEA bit in the ATIM_CHxCR register to enable DMA requests;
- Step 18: Set the register ATIM_CR.EN to 0x01 to enable the timer.

Caution:

The destination address is the address of the ATIM_CHxCCRy register, the source address is incremented automatically, and the destination address is fixed.

16.5.6 Trigger mode

The following is an example of the counter starting to count up on the rising edge of the CH1B input:

- Step 1: Set ATIM_FLTR.FLT1B to 0x00, and configure the bandwidth of the input filter (in this example, no filtering is required);
- Step 2: Set ATIM_FLTR.CCP1B to 0, select polarity (rising edge);
- Step 3: Set the SMS bit of ATIM_MSQR to 0x2, and configure the timer as the trigger mode of slave mode;
- Step 4: Set the TS bit of ATIM_MSQR to 0x7, and select CH1B as the input trigger source.

Caution:

If you use falling edge triggering, you need to select the trigger polarity first, and then select the trigger mode to avoid false triggering.



16.5.7 Gated Mode

The following is an example of the counter counting up when the CH1A input is low:

- Step 1: Set ATIM_FLTR.FLT1A to 0x00, and configure the bandwidth of the input filter (in this example, no filtering is required);
- Step 2: Set ATIM_FLTR.CCP1A to 0x1, select polarity (low level);
- Step 3: Set the SMS bit of ATIM_MSCR to 0x7, and configure the timer to be the gated mode of the slave mode;
- Step 4: Set the TS bit of ATIM_MSCR to 0x6, and select CH1A as the input trigger source;
- Step 5: Set EN of ATIM_CR to 0x1 to enable counting. When the input level of CH1A is low, the counter starts to count the internal clock, and when the input level becomes high, the counter stops counting.

16.5.8 Internal cascade ITR

In this example, the enable bit EN of ATIM is used to trigger the start of BTIMx to realize the synchronous start of ATIM and BTIMx. The operation steps are as follows:

- Step 1: Set the SYSCTRL_APBEN2.BTIM bit to 1, and open the configuration clock of the BTIM1-3 module;

Caution:

BTIM1-3 share the SYSCTRL_APBEN2.BTIM bit.

- Step 2: Configure BTIMx_BCR.TRS to 1, and select the trigger source from the internal cascade signal;
- Step 3: Configure BTIMx_BCR.PSC and select the prescaler ratio;
- Step 4: Configure BTIMx_BCR.ONESHOT to select single or continuous counting mode. When configured as 0, it is continuous counting mode; when configured as 1, it is single counting;
- Step 5: If you want the trigger event to trigger an interrupt, configure BTIMx_IER.IT to 1;
- Step 6: If you want the ARR overflow event to trigger an interrupt, configure BTIMx_IER.OV to 1;
- Step 7: Configure the BTIMx_ARR register and select the BTIMx count overflow time;
- Step 8: Configure BTIMx_BCR.MODE to 0x10, select BTIMx to work in trigger start mode;
- Step 9: Set the system control register SYSCTRL_APBEN2.ATIM bit to 1, and open the ATIM module;
- Step 10: Configure ATIM_MSCR.MMS as 0x01, select ATIM main mode to output CTEN;
- Step 11: Set the register ATIM_CR.MODE to 0x2, the timer works in edge-aligned mode;
- Step 12: Set the register ATIM_CR.DIR to 0x0, and the edge-aligned counting direction is upcounting;
- Step 13: Set ATIM_ARR according to the period;
- Step 14: Set the register ATIM_CR.EN to 0x1, which will start ATIM and BTIMx synchronously.



16.6 List of registers

ATIM base address: ATIM_BASE = 0x4001 2C00

Table 16-18 List of ATIM registers

Register name	Register address	Register description
ATIM_ARR	ATIM_BASE + 0x00	Reload register
ATIM_CNT	ATIM_BASE + 0x04	Count register
ATIM_CR	ATIM_BASE + 0x0C	Control register
ATIM_ISR	ATIM_BASE + 0x10	Interrupt flag register
ATIM_ICR	ATIM_BASE + 0x14	Interrupt flag clear register
ATIM_MSCR	ATIM_BASE + 0x18	Master-slave mode control register
ATIM_FLTR	ATIM_BASE + 0x1C	Output control/Input filter register
ATIM_TRIG	ATIM_BASE + 0x20	Trigger ADC control register
ATIM_CH1CR	ATIM_BASE + 0x24	Channel 1 control register
ATIM_CH2CR	ATIM_BASE + 0x28	Channel 2 control register
ATIM_CH3CR	ATIM_BASE + 0x2C	Channel 3 control register
ATIM_CH4CR	ATIM_BASE + 0x58	Channel 4 control register
ATIM_DTR	ATIM_BASE + 0x30	Dead-time register
ATIM_RCR	ATIM_BASE + 0x34	Repeat count register
ATIM_CH1CCRA	ATIM_BASE + 0x3C	Channel 1 compare/capture register A
ATIM_CH1CCRB	ATIM_BASE + 0x40	Channel 1 compare/capture register B
ATIM_CH2CCRA	ATIM_BASE + 0x44	Channel 2 compare/capture register A
ATIM_CH2CCRB	ATIM_BASE + 0x48	Channel 2 compare/capture register B
ATIM_CH3CCRA	ATIM_BASE + 0x4C	Channel 3 compare/capture register A
ATIM_CH3CCRB	ATIM_BASE + 0x50	Channel 3 compare/capture register B
ATIM_CH4CCR	ATIM_BASE + 0x54	Channel 4 compare/capture register



16.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

16.7.1 ATIM_CR control register

Address offset: 0x0C Reset value: 0x0060 0008

Bit field	Name	Permission	Function description
31:30	RFU	-	Reserved bits, please keep the default value
29	UNDE	RW	Underflow interrupt enabled 0: Disabled 1: Enabled
28	OVE	RW	Overflow interrupt enabled 0: Disabled 1: Enabled
27	DIR	RW/RO	Counting direction, only writable in edge-aligned mode. Read only in other modes, write invalid 0: Upcounting 1: Downcounting Caution: DIR is automatically cleared to 0 when switching from other modes to center-aligned mode. Software event update and slave mode externally triggered reset mode DIR is automatically cleared.
26	BG	RW	Software brake, automatic reset Write 1 to generate software brake Write 0 invalid
25	UG	RW	Software update, auto reset Write 1 to generate a software update Write 0 invalid Caution: After software update, initialize the counter and update ATIM_ARR, ATIM_CHxCCRy to its cache register (cache enable), the prescaler counter will also be cleared.
24	TG	RW	Triggered by software, automatically cleared. It needs to be triggered in trigger mode (SMS=2) and MODE=2/3. Write 1 to generate software trigger Write 0 invalid
23	OCCE	RW	OCREF clear enabled 0: OCREF output is not affected by OCREF_CLR 1: OCREF_CLR high level signal can clear OCREF output



Bit field	Name	Permission	Function description
22:21	CISA	RW	In center-aligned mode, compare match interrupt settings for all A channels 00: No interrupt 01: Generate interrupt on match while counting up 10: Generate interrupt on match while counting down 11: Interrupt on match when up and down counting Caution: In center-aligned mode, the compare match interrupt of the B channel is set in the CISB bit field of the ATIM_CHxCR register
20	BIE	RW	Brake interrupt enabled 0: Disabled 1: Enabled
19	TIE	RW	Trigger interrupt enabled 0: Disabled 1: Enabled
18	RFU	-	Reserved bits, please keep the default value
17	URS	RW	Update source 0: Overflow/underflow/software update UG/slave mode reset 1: Overflow/underflow
16	OCCS	RW	OCREF clear source selection 0: Voltage comparator VC output, VC selection is set in VCx_CR1 register 1: The ETR port filters the phase-selected signal Caution: When OCCE is valid, the OCREF_CLR high level signal can clear the compare output signal of OCREF to zero (valid when OCMxyFLTxy>1), and continue to compare output after the next update event UEV.
15	RFU	-	Reserved bits, please keep the default value
14	ONESHOT	RW	Single trigger mode selection 0: Loop count 1: Timer stops after event update occurs
13:12	MODE	RW	Working mode 00: Reserved 01: Reserved 10: Edge-aligned mode 11: Center-aligned mode
11	RFU	-	Reserved bits, please keep the default value
10	UIE	RW	UIE update interrupt enabled 0: Disabled 1: Enabled
9:8	RFU	-	Reserved bits, please keep the default value



Bit field	Name	Permission	Function description
7	BUFEN	RW	Reload register cache enabled 0: The cache is invalid, and the period value is affected immediately after writing 1: The cache is enabled, and the period value will not be affected until the next event is updated after writing
6:4	PRS	RW	Internal clock PCLK frequency division selection 000: 1 001: 2 010: 4 011: 8 100: 16 101: 32 110: 64 111: 256
3	PWM2S	RW	OCREFA two-point compare selection (default is 1) 0: Two-point compare enabled, use CHxCCRA, CHxCCRB compare to control OCREFA output 1: Single-point compare enabled, use only CHxCCRA compare to control OCREFA output Caution: OCREFB is not affected, still use CHxCCRB to control OCREFB output
2	CT	RW	Count clock selection 0: Internal count clock PCLK 1: External count clock ETR
1	COMP	RW	PWM complementary output mode selection 0: Independent PWM output 1: Complementary PWM output
0	EN	RW	Timer enabled 0: Disabled 1: Enabled Caution: It can be enabled by external trigger, and this bit is automatically cleared when the ONESHOT mode ends.

16.7.2 ATIM_ARR reload register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	ARR	RW	Reload register/period register with cache function When the counter is not enabled or the cache is not enabled, the cache register can be updated immediately



16.7.3 ATIM_CNT count register

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CNT	RW	Reload timer count register

Caution:

When using the PWM compare output, the initialized CNT value needs to be smaller than the ARR value.

16.7.4 ATIM_ISR interrupt flag register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:19	RFU	-	Reserved bits, please keep the default value
18	C4AF	RO	Channel CH4 compare match flag
17	UNDF	RO	Underflow interrupt flag
16	OVF	RO	Overflow interrupt flag
15	TIF	RO	Trigger interrupt flag
14	BIF	RO	Brake interruption flag
13	C3BE	RO	Channel CH3B capture data loss flag 0: No data loss 1: Data loss
12	C2BE	RO	Channel CH2B capture data loss flag 0: No data loss 1: Data loss
11	C1BE	RO	Channel CH1B capture data loss flag 0: No data loss 1: Data loss
10	C3AE	RO	Channel CH3A capture data loss flag 0: No data loss 1: Data loss
9	C2AE	RO	Channel CH2A capture data loss flag 0: No data loss 1: Data loss
8	C1AE	RO	Channel CH1A capture data loss flag 0: No data loss 1: Data loss



Bit field	Name	Permission	Function description
7	C3BF	RO	Capture/compare match flag occurred on channel CH3B 0: Not occur 1: Occur
6	C2BF	RO	Capture/compare match flag occurred on channel CH2B 0: Not occur 1: Occur
5	C1BF	RO	Capture/compare match flag occurred on channel CH1B 0: Not occur 1: Occur
4	C3AF	RO	Capture/compare match flag occurred on channel CH3A 0: Not occur 1: Occur
3	C2AF	RO	Capture/compare match flag occurred on channel CH2A 0: Not occur 1: Occur
2	C1AF	RO	Capture/compare match flag occurred on channel CH1A 0: Not occur 1: Occur
1	RFU	-	Reserved bits, please keep the default value
0	UIF	RO	Event update interrupt flag 0: Not occur 1: Occur



16.7.5 ATIM_ICR interrupt flag clear register

Address offset: 0x14 Reset value: 0x0007 FFFF

Bit field	Name	Permission	Function description
31:19	RFU	-	Reserved bits, please keep the default value
18	C4AF	R1W0	Channel CH4 compare match flag is cleared, write 0 to clear
17	UNDF	R1W0	Underflow interrupt flag is cleared, write 0 to clear
16	OVF	R1W0	Overflow interrupt flag is cleared, write 0 to clear
15	TIF	R1W0	Trigger interrupt flag to clear, write 0 to clear
14	BIF	R1W0	Brake interrupt flag is cleared, write 0 to clear
13	C3BE	R1W0	Channel CH3B capture data loss flag clear, write 0 to clear
12	C2BE	R1W0	Channel CH2B capture data loss flag clear, write 0 to clear
11	C1BE	R1W0	Channel CH1B capture data loss flag clear, write 0 to clear
10	C3AE	R1W0	Channel CH3A capture data loss flag clear, write 0 to clear
9	C2AE	R1W0	Channel CH2A capture data loss flag clear, write 0 to clear
8	C1AE	R1W0	Channel CH1A capture data loss flag clear, write 0 to clear
7	C3BF	R1W0	Channel CH3B capture/compare match flag clear, write 0 to clear
6	C2BF	R1W0	Channel CH2B capture/compare match flag clear, write 0 to clear
5	C1BF	R1W0	Channel CH1B capture/compare match flag clear, write 0 to clear
4	C3AF	R1W0	Channel CH3A capture/compare match flag clear, write 0 to clear
3	C2AF	R1W0	Channel CH2A capture/compare match flag clear, write 0 to clear
2	C1AF	R1W0	Channel CH1A capture/compare match flag clear, write 0 to clear
1	RFU	-	Reserved bits, please keep the default value
0	UIF	R1W0	Event update interrupt flag clear, write 0 to clear



16.7.6 ATIM_MSCR master-slave mode control register

Address offset: 0x18 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:13	RFU	-	Reserved bits, please keep the default value
12	IB1S	RW	CH1B input selection 0: CH1B 1: Internal trigger TS signal
11	IA1S	RW	CH1A input selection 0: CH1A 1: Exclusive OR of CH1A, CH2A, CH3A Caution: After setting to 1, any port change will cause the input to change
10:8	SMS	RW	Select from mode function 000: Use internal clock 001: Reset function 010: Trigger mode 011: External clock mode 100: Quadrature encoding counting mode 1 101: Quadrature encoding counting mode 2 110: Quadrature encoding counting mode 3 111: Gated function
7:5	TS	RW	Trigger selection 000: Filtered phase-selected signal ETRP at port ETR 001: Internal interconnect signal ITR 101: Edge signal of port CH1A 110: Filtered phase-selected signal IAFP for port CH1A 111: Filtered phase-selected signal IBFP for port CH1B
4	RFU	-	Reserved bits, please keep the default value
3	CCDS	RW	DMA trigger selection in compare mode 0: Compare match triggers DMA 1: Compare match does not trigger DMA, event updates trigger DMA instead of compare match Caution: Event update triggered DMA also requires the corresponding channel's DMA enable to be enabled(ATIM_CHxCR.CDEy).
2:0	MMS	RW	Master mode output selection for internal cascade connection to ITR of other timers 000: Software update UG, write CR.UG 001: Timer enable signal EN 010: Timer update event UEV 011: Compare match selects output CMPSO 100: Timer channel CH1A compare reference output OCREF1A 101: Timer channel CH2A compare reference output OCREF2A 110: Timer channel CH3A compare reference output OCREF3A 111: Timer channel CH1B compare reference output OCREF1B



16.7.7 ATIM_FLTR output control/input filter register

Address offset: 0x1C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31	ETP	RW	ETR input phase selection 0: In phase 1: Reverse input
30:28	FLTET	RW	ETR filter settings 0xx: Invalid filtering 100: PCLK 3 consecutive valid 101: PCLK /4 3 consecutive valid 110: PCLK /16 3 consecutive valid 111: PCLK /64 3 consecutive valid
27	BKP	RW	Brake BK input phase selection 0: in phase 1: reverse input
26:24	FLTBK	RW	Brake input filter settings 0xx: Invalid filtering 100: PCLK 3 consecutive valid 101: PCLK /4 3 consecutive valid 110: PCLK /16 3 consecutive valid 111: PCLK /64 3 consecutive valid
23	CCP3B	RW	Compare function: CH3B channel compare output phase control 0: Normal output 1: Reverse output
22:20	OCM3B FLT3B	RW	Compare function: CH3B channel compare control, refer to OCM1BFLT1B Capture function: CH3B input channel filter setting, refer to FLTBK
19	CCP3A	RW	Compare function: CH3A channel compare output phase control 0: Normal output 1: Reverse output
18:16	OCM3A FLT3A	RW	Compare function: CH3B channel compare control, refer to OCM1BFLT1B Capture function: CH3A input channel filter setting, refer to FLTBK
15	CCP2B	RW	Compare function: CH2B channel compare output phase control 0: Normal output 1: Reverse output
14: 12	OCM2B FLT2B	RW	Compare function: CH2B channel compare control, refer to OCM1BFLT1B Capture function: CH2B input channel filter setting, refer to FLTBK
11	CCP2A	RW	Compare function: CH2A channel compare output phase control 0: Normal output 1: Reverse output



Bit field	Name	Permission	Function description
10:8	OCM2A FLT2A	RW	Compare function: CH2A channel compare control, refer to OCM1BFLT1B Capture function: CH2A input channel filter setting, refer to FLTBK
7	CCP1B	RW	Compare function: CH1B channel compare output phase control 0: Normal output 1: Reverse output CH1B port input polarity control in slave mode: 0: Normal output 1: Reverse output
6:4	OCM1B FLT1B	RW	Compare function: CH1B channel compare control 000: Force output low 001: Force output high 010: Set to 0 on compare match 011: Set to 1 on compare match 100: Flip output on compare match 101: Output a high level for one count period on a compare match 110: PWM mode 1 Single-point comparison: CNT<CHxCCRy outputs high level when counting up; CNT>CHxCCRy outputs a low level when counting down. Two-point comparison : 1) CHxCCRA<CNT ≤ CHxCCRB outputs low level when edge-aligned upcounting; 2) CHxCCRA<CNT ≤ CHxCCRB outputs high level when edge-aligned downcounting; 3) CNT<CHxCCRA outputs high level when center-aligned upcounting, CNT>CHxCCRB outputs low level when center-aligned downcounting. 111: PWM mode 2 Single-point comparison: CNT<CHxCCRy outputs low level when counting up; CNT>CHxCCRy outputs a low level when counting down. Two-point comparison : 1) CHxCCRA ≤ CNT<CHxCCRB outputs high level when edge-aligned upcounting; 2) CHxCCRA ≤ CNT<CHxCCRB outputs low level when edge-aligned downcounting; 3) CNT<CHxCCRA outputs low level when center-aligned downcounting, CNT>CHxCCRB outputs high level when center-aligned upcounting. Capture function: CH1B input channel filter setting, refer to FLTBK



Bit field	Name	Permission	Function description
3	CCP1A	RW	Compare function: CH1A channel compare output phase control 0: Normal output 1: Reverse output CH1A port input polarity control in slave mode: 0: Normal input 1: Reverse input
2:0	OCM1A FLT1A	RW	Compare function: A channel compare control, refer to OCM1BFLT1B Capture function: CH1A input channel filter setting, refer to FLTBK

16.7.8 ATIM_TRIG trigger ADC control register

Address offset: 0x20 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	ADTE	RW	ADC trigger global control enabled 0: Disabled 1: Enabled
6	CM3BE	RW	Channel CH3B compare match trigger ADC enabled 0: Disabled 1: Enabled
5	CM2BE	RW	Channel CH2B compare match trigger ADC enabled 0: Disabled 1: Enabled
4	CM1BE	RW	Channel CH1B compare match trigger ADC enabled 0: Disabled 1: Enabled
3	CM3AE	RW	Channel CH3A compare match trigger ADC enabled 0: Disabled 1: Enabled
2	CM2AE	RW	Channel CH2A compare match trigger ADC enabled 0: Disabled 1: Enabled
1	CM1AE	RW	Channel CH1A compare match trigger ADC enabled 0: Disabled 1: Enabled
0	UEVE	RW	Event update triggers ADC enabled 0: Disabled 1: Enabled



16.7.9 ATIM_DTR dead-time register

Address offset: 0x30 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:15	RFU	-	Reserved bits, please keep the default value
14	VCE	RW	VC compare output brake enabled 0: Disabled 1: Enabled
13	SAFEEN	RW	Safety brake enabled (osc fail,brown down,lockup) 0: Disabled 1: Enabled
12	MOE	RW	Output compare enabled 0: Disabled 1: Enabled
11	AOE	RW	PWM output auto-enabled 0: Disabled 1: Enabled
10	BKE	RW	Brake enabled 0: Disabled 1: Enabled
9	DTEN	RW	Dead-time control enabled 0: Disabled 1: Enabled Caution: Disable dead-time control when independent PWM output is enabled.
8	RFU	-	Reserved bits, please keep the default value
7:0	DTR	RW	Dead-time register $DTR[7]=0 \quad T=DTR[6:0]+2 \quad 2 \sim 129 \quad \text{step}=1$ $DTR[7:6]=10 \quad T=\{DTR[5:0]+64\} \times 2 + 2 \quad 130 \sim 256 \quad \text{step}=2$ $DTR[7:5]=110 \quad T=\{DTR[4:0]+32\} \times 8 + 2 \quad 258 \sim 506 \quad \text{step}=8$ $DTR[7:5]=111 \quad T=\{DTR[4:0]+32\} \times 16 + 2 \quad 514 \sim 1010 \quad \text{step}=16$



16.7.10 ATIM_RCR repeat count register

Address offset: 0x34 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	UD	RW	Repeat count controlled underflow shielding 0: Repeat counter count when downcounting overflows 1: Downcounting overflow shielding
8	OV	RW	Repeat count control overflow shielding 0: Repeat counter count when upcounting overflows 1: Upcounting overflow shielding
7:0	RCR	RW	Repeat cycle count value Set the RCR+1 cycle to be updated by the overflow controlled by [9:8], and the internal RCR_CNT is decremented by 1 when the counter overflows or underflows. When the count reaches zero, the RCR_CNT reloads the RCR value and generates an event to update the UEV signal.

16.7.11 ATIM_CH1CR channel 1 control register

Address offset: 0x24 Reset value: 0x0000 3000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	CCGB	RW	The capture/compare B channel is triggered by software, and the hardware is automatically cleared. Only interrupt is generated in compare mode Generate an interrupt in capture mode and capture the value of the counter into the capture register
14	CCGA	RW	The capture/compare A channel is triggered by software, and the hardware is automatically cleared. Only interrupt is generated in compare mode Generate an interrupt in capture mode and capture the value of the counter into the capture register
13:12	CISB	RW	In center-aligned mode, the compare match interrupt setting of the B channel 00: No interrupt 01: Interrupt is generated on match when counting up 10: Interrupt is generated on match when counting down 11: Interrupt is generated on match when counting up and down Caution: in the center-aligned mode, the compare match interrupt of all A channels is set in the CISA bit field of the ATIM_CR register



Bit field	Name	Permission	Function description
11	CDEB	RW	B channel capture compare trigger DMA enabled 0: Disabled 1: Enabled
10	CDEA	RW	A channel capture compare trigger DMA enabled 0: Disabled 1: Enabled
9	CIEB	RW	B channel capture compare trigger interrupt enabled 0: Disabled 1: Enabled
8	CIEA	RW	A channel capture compare trigger interrupt enabled 0: Disabled 1: Enabled
7	BUFEB	RW	Compare function: compare capture register B cache enable control 0: Disabled 1: Enabled
6	BUFEA	RW	Compare function: compare capture register A cache enable control 0: Disabled 1: Enabled
5	CSB	RW	B channel capture/compare function selection 0: Compare mode 1: Capture mode
4	CSA	RW	A channel capture/compare function selection 0: Compare mode 1: Capture mode
3:2	BKSB	RW	Compare mode B channel compare function output brake level control 00: High resistance output 01: No effect on output 10: Force output low level 11: Force output high level Capture mode B channel capture enabled 00: Disabled 01: Rising edge capture enabled 10: Falling edge capture enabled 11: Rising/falling edge capture enabled
1:0	BKSA	RW	Compare mode A channel compare function output brake level control 00: High resistance output 01: No effect on output 10: Force output low level 11: Force output high level Capture mode A channel capture enable 00: Disabled 01: Rising edge capture enabled 10: Falling edge capture enabled 11: Rising/falling edge capture enabled



16.7.12 ATIM_CH2CR channel 2 control register

Address offset: 0x28 Reset value: 0x0000 3000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0			See ATIM_CH1CR for details

16.7.13 ATIM_CH3CR channel 3 control register

Address offset: 0x2C Reset value: 0x0000 3000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0			See ATIM_CH1CR

16.7.14 ATIM_CH4CR channel 4 control register

Address offset: 0x58 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	C4EN	RW	Channel compare enable
4:3	CIS	RW	In center-aligned mode, compare match interrupt setting of channel CH4 00: No interrupt 01: Interrupt on match when counting up 10: Interrupt on match when counting down 11: Interrupt on match when counting up and down
2	CDE	RW	Compare trigger DMA enabled 0: Disabled 1: Enabled
1	CIE	RW	Compare trigger interrupt enabled 0: Disabled 1: Enabled
0	BUFE	RW	Compare function: channel 4 compare capture register buffer enable control 0: Disabled 1: Enabled



16.7.15 ATIM_CH1CCRA channel 1 compare capture register A

Address offset: 0x3C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR1A	RW	Compare capture register, compare with cache function

16.7.16 ATIM_CH1CCRB channel 1 compare capture register B

Address offset: 0x40 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR1B	RW	Compare capture register, compare with cache function

16.7.17 ATIM_CH2CCRA channel 2 compare capture register A

Address offset: 0x44 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR2A	RW	Compare capture register, compare with cache function

16.7.18 ATIM_CH2CCRB channel 2 compare capture register B

Address offset: 0x48 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR2B	RW	Compare capture register, compare with cache function

16.7.19 ATIM_CH3CCRA channel 3 compare capture register A

Address offset: 0x4C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR3A	RW	Compare capture register, compare with cache function



16.7.20 ATIM_CH3CCRB channel 3 compare capture register B

Address offset: 0x50 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR3B	RW	Compare capture register, compare with cache function

16.7.21 ATIM_CH4CCR channel 4 compare capture register

Address offset: 0x54 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	CCR4	RW	Compare capture register, compare with cache function



17 Independent watchdog timer (IWDT)

17.1 Overview

The CW32L083 integrates an independent watchdog timer (IWDT) and uses a dedicated internal RC clock source RC10K to avoid external factors during operation. Once the IWDT is started, the user needs to reload the IWDT counter within the specified time interval, otherwise the counter overflow will trigger a reset or generate an interrupt signal. After the IWDT is started, the counting can be stopped. The IWDT can be selected to keep running or suspend counting during DeepSleep mode.

The specially set key-value register can lock the key registers of the IWDT to prevent the registers from being accidentally modified.

17.2 Main Features

- 12-bit down counter
- Independent internal low-speed RC oscillator
- Programmable clock prescale period
- Overflow can trigger interrupt or reset
- Register protection lock function
- Counting can be suspended in DeepSleep mode

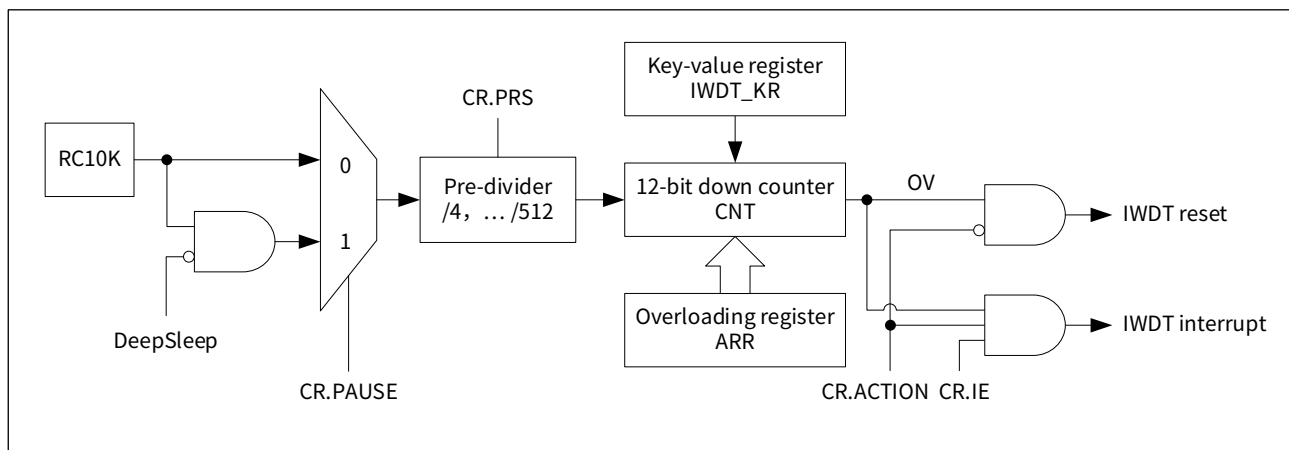


17.3 Functional description

17.3.1 Functional block diagram

The functional block diagram of IWDT is shown in the following figure:

Figure 17-1 IWDT functional block diagram



The IWDT is implemented by a 12-bit reloadable down-counter, and its counting clock source is the internal dedicated low-speed RC oscillator RC10K. The clock source RC10K signal can be prescaled by 4 to 512 through the PRS bit field of the control register IWDT_CR. When the IWDT counter overflows, it can optionally generate interrupt and reset signals.

17.3.2 Operating modes

To start the IWDT counter, you need to write 0xCCCC to the key value register IWDT_KR, and the counter starts to count down from 0xFFFF.

Before the counter reduces to 0, writing 0xAAAA to the IWDT_KR register will trigger a counter reload, loading the ARR register value into the counter. When the IWDT counter value is reduced to 0, an overflow event will be generated. The overflow event can trigger the MCU reset or generate the IWDT interrupt signal, and trigger the counter reload at the same time. The ACTION and IE bit fields of the control register IWDT_CR are used to control whether interrupts and resets are generated when the watchdog overflows, as shown in the following table:

Table 17-1 Operating modes

IWDT_CR.ACTION	IWDT_CR.IE	Action after IWDT overflows
0	X	Reset
1	1	No reset, only interrupt
1	0	No reset, no interrupt

When the MCU enters the DeepSleep mode, the IWDT can choose to suspend the IWDT counting, so as to achieve lower overall system power consumption: the PAUSE bit field of the control register IWDT_CR is 0, and the IWDT timer is kept running in the DeepSleep mode; when it is 1, the counting is suspended, the IWDT automatically resumes counting when the MCU exits the DeepSleep mode.

17.3.3 Window options

Write a value smaller than the reload register IWDT_ARR to the window register IWDT_WINR to make the IWDT work in the window watchdog mode. The default value of the IWDT_WINR register is 0x0FFF, that is, the window option is closed by default.

Modify the value of the IWDT_WINR register will trigger a reload operation to load the ARR register value into the counter.

When using the IWDT window function, the user should perform a reload operation before the counter value is less than or equal to the IWDT_WINR window value and decrements to 0 to avoid reset or watchdog timer overflow. A reload operation when the watchdog counter value is greater than the window value will trigger a system reset.

17.3.4 Register lock function

Through the key value register IWDT_KR of the IWDT, the important registers IWDT_CR, IWDT_ARR, and IWDT_WINR of the IWDT can be configured to be locked or unlocked. The registers cannot be modified in the locked state.

Write 0x5555 to the IWDT_KR register to unlock the IWDT_CR, IWDT_ARR, and IWDT_WINR registers; write any other value to the IWDT_KR register to enable lock protection.

After the CW32L083 is powered on, the IWDT_CR, IWDT_ARR, and IWDT_WINR registers are locked by default, and the user needs to unlock them before modifying them.

17.3.5 Start refresh and stop

Configure the IWDT_KR register to start, refresh and stop the IWDT:

- Write 0xCCCC to start IWDT
- Write 0xAAAA, reload the counter, that is, refresh the IWDT
- Write 0x5A5A, 0xA5A5 sequentially, stop IWDT

Caution:

The above operations will simultaneously activate the IWDT register lock protection.



17.3.6 Status register

The status register IWDT_SR indicates the current running status or register update status of the IWDT, as shown in the following table:

Table 17-2 IWDT status indication

IWDT_SR bit	Name	Description	1	0
4	RUN	Run flag	Running	Not running
3	OV	Overflow flag	Generate overflow	Not overflow
5	RELOAD	Counter reload flag	Reloading	Reload done
2	WINRF	WINR register update flag	Updating	Update completed
1	ARRF	ARR register update flag	Updating	Update completed
0	CRF	CR register update flag	Updating	Update completed

To ensure the correct operation of the IWDT register, after updating IWDT_WINR, IWDT_ARR, and IWDT_CR, the user needs to check whether the WINRF, ARRF, and CRF flags are 0 to confirm whether the operation is completed.

To ensure the reload operation of the IWDT, the user should check whether the RELOAD flag is 0 after the reload operation.



17.3.7 Timing duration setting

The counting clock source of the IWDT is the dedicated low-speed clock RC10K (the clock frequency is about 10KHz, please refer to the datasheet for details). By controlling the PRS bit field of the IWDT_CR register, the frequency of the clock source RC10K signal can be divided, as shown in the following table:

Table 17-3 IWDT prescaler divider table

IWDT_CR.PRS	Prescaler value
000	4
001	8
010	16
011	32
100	64
101	128
110	256
111	512

Watchdog timer duration calculation formula:

$$T = (4 \times 2^{\text{PRS}} / f) \times (\text{ARR} + 1)$$

Where, f is the frequency of the clock source RC10K, PRS is the prescaler divider, and ARR is the reload value.

Therefore, when the frequency of the clock source RC10K is 10000Hz, the longest and shortest timing ranges of the IWDT are:

$$\text{IWDT shortest timing} = (4 \times 2^0 / 10000) \times (0x000 + 1) \approx 400 \mu\text{s}$$

$$\text{IWDT longest timing} = (4 \times 2^7 / 10000) \times (0xFFFF + 1) \approx 209.7 \text{ s}$$

Example: When the frequency of the clock source RC10K is 10000Hz, set the prescale value to 64 and the reload value to 512, then:

$$\text{IWDT timing duration} = (4 \times 2^4 / 10000) \times (512 + 1) = 3.28 \text{ s}$$



17.4 Programming examples

17.4.1 Configure IWDT as independent watchdog

Step 1: Set SYSCTRL_APBEN1.IWDT to 1 to enable the configuration clock of IWDT;

Step 2: Write 0xCCCC to the IWDT_KR register to start the IWDT;

Caution:

The relevant registers can be modified only after the IWDT needs to be started.

Step 3: Write 0x5555 to the IWDT_KR register to release the lock function of the IWDT register;

Step 4: Configure IWDT_CR, configure the prescale value of watchdog count clock and RC10K oscillator, action after overflow, whether to automatically suspend in DeepSleep mode;

Step 5: Configure IWDT_ARR and configure the overflow period of the watchdog;

Step 6: Wait for IWDT_SR.ARRF and IWDT_SR.CRF to become 0, wait for the reload value and CR register update to complete;

Step 7: Write 0xAAAA to the IWDT_KR register to load the ARR into the IWDT counter.

17.4.2 Configure IWDT as window watchdog

Step 1: Set SYSCTRL_APBEN1.IWDT to 1 to enable the configuration clock of IWDT;

Step 2: Write 0xCCCC to the IWDT_KR register to start the IWDT;

Caution:

The relevant registers can be modified only after the IWDT needs to be started.

Step 3: Write 0x5555 to the IWDT_KR register to release the lock function of the IWDT register;

Step 4: Configure IWDT_CR, configure the prescale value of watchdog count clock and RC10K oscillator, action after overflow, whether to automatically suspend in DeepSleep mode;

Step 5: Configure IWDT_ARR, configure the reload value of the watchdog;

Step 6: Configure IWDT_WINR, configure the window size, Caution that IWDT_WINR must be less than the overloaded value of IWDT_ARR;

Step 7: Wait for IWDT_SR.ARRF, IWDT_SR.WINRF and IWDT_SR.CRF to become 0, wait for the reload value, window register and CR register update to complete;

Step 8: Write 0xAAAA to the IWDT_KR register to load the ARR into the IWDT counter.

17.4.3 Refresh IWDT (feed dog operation)

Step 1: Write 0xAAAA to the IWDT_KR register to load ARR into the counter;

Step 2: Wait for IWDT_SR.RELOAD to become 0, and wait for the reload operation to complete.



17.5 List of registers

IWDT base address: IWDT_BASE = 0x4000 3000

Table 17-4 List of IWDT registers

Register name	Register address	Register description
IWDT_KR	IWDT_BASE + 0x00	Key-value register
IWDT_CR	IWDT_BASE + 0x04	Control register
IWDT_ARR	IWDT_BASE + 0x08	Reload register
IWDT_SR	IWDT_BASE + 0x0C	Status register
IWDT_WINR	IWDT_BASE + 0x10	Window register
IWDT_CNT	IWDT_BASE + 0x24	Count value register



17.6 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

17.6.1 IWDT_KR key-value register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	KR	WO	Write 0xCCCC: start the IWDT counter Write 0xCCCC: start the IWDT counter Write 0x5A5A, 0xA5A5 in sequence: stop watchdog Write 0x5555: release the write protection of IWDT_ARR, IWDT_WINR, IWDT_CR Write to non-0x5555: enable write protection of IWDT_ARR, IWDT_WINR, IWDT_CR



17.6.2 IWDT_CR control register

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	PAUSE	RW	IWDT pause control in DeepSleep mode 0: IWDT continues to run in DeepSleep mode 1: IWDT auto-pause in DeepSleep mode
4	IE	RW	IWDT interrupt enable control 0: Watchdog interrupt disabled 1: Watchdog interrupt enabled
3	ACTION	RW	Action configuration after IWDT overflow 0: Reset after watchdog overflow 1: Interrupt after watchdog overflow
2:0	PRS	RW	Configure the divider ratio of the watchdog count clock to the RC10K oscillator 000: 4 frequency division 001: 8 frequency division 010: 16 frequency division 011: 32 frequency division 100: 64 frequency division 101: 128 frequency division 110: 256 frequency division 111: 512 frequency division

Caution:

This register can be modified only after writing 0x5555 to the IWDT_KR register; IWDT_CR can only be modified when IWDT_SR.CRF is 0.

17.6.3 IWDT_ARR reload register

Address offset: 0x08 Reset value: 0x0000 0FFF

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11:0	ARR	RW	IWDT reload value

Caution:

This register can be modified only after writing 0x5555 to the IWDT_KR register; This register can be modified only when IWDT_SR.ARRF is 0.



17.6.4 IWDT_CNT count value register

Address offset: 0x24 Reset value: 0x0000 0FFF

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11:0	CNT	RO	Count value register Caution: The count value can only be considered to be read if the value read twice in a row is the same

17.6.5 IWDT_WINR window register

Address offset: 0x10 Reset value: 0x0000 0FFF

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11:0	WINR	RW	Window comparator compare value



17.6.6 IWDT_SR status register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:6	RFU	-	Reserved bits, please keep the default value
5	RELOAD	RO	WDT counter reload flag 0: WDT counter has completed reload operation 1: WDT counter is reloading Caution: In window mode, you need to wait for the flag to become 0 after reloading
4	RUN	RO	WDT running flag 0: WDT is not running 1: WDT is running
3	OV	RW0	WDT overflow flag R0: WDT does not overflow R1: WDT overflow, write 0 to clear
2	WINRF	RO	WINR register update flag 0: WINR register update completed 1: WINR register is updating Caution: After writing the WINR register, you need to wait for this flag to become 0
1	ARRF	RO	ARR register update flag 0: ARR register update completed 1: ARR register is updating Caution: After writing the ARR register, you need to wait for this flag to become 0
0	CRF	RO	CR register update flag 0: CR register update completed 1: CR register is updating Caution: After writing the CR register, you need to wait for the flag to become 0



18 Window watchdog timer (WWDT)

18.1 Overview

The CW32L083 integrates a window watchdog timer (WWDT), the user needs to refresh within the set time window, otherwise it will trigger a system reset. WWDT is usually used to monitor the program execution flow with strict time requirements to prevent the abnormal execution of the application program caused by external interference or unknown conditions, resulting in system failure.

18.2 Main features

- 7-bit down counter
- PCLK clock driven, 8-level prescaler, maximum frequency division 524288
- Supports pre-overflow interrupt and count overflow, load count value error reset
- Can not be closed after opening, unless the system is reset

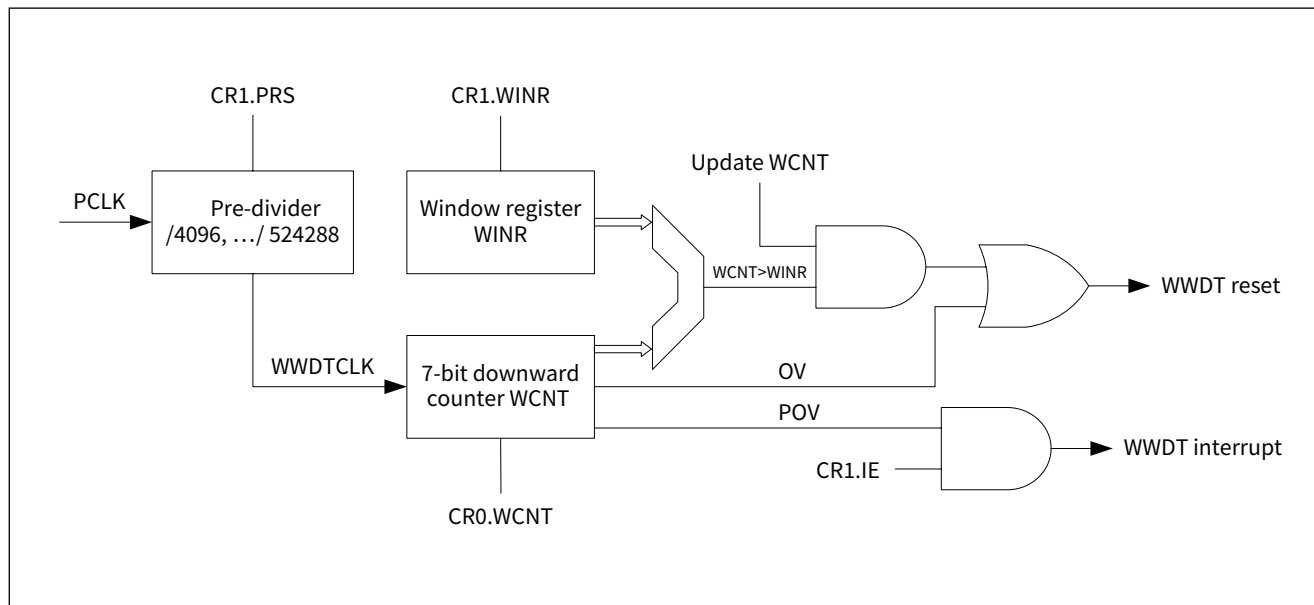


18.3 Functional description

18.3.1 Functional block diagram

The functional block diagram of WWDT is shown in the following figure:

Figure 18-1 WWDT functional block diagram



WWDT contains a 7-bit down counter. The counting clock source is the internal system clock PCLK. The clock source PCLK can be divided by the PRS bit field of the control register WWDT_CR1. After frequency division, the counting clock WWDTCCLK is used to drive the counter to count.

The WWDT will stop counting in DeepSleep mode, and resume normal work after the CPU is woken up.

18.3.2 Operating mode

After the system is reset, the window watchdog WWDT is in a closed state, and the EN bit field of the control register WWDT_CR0 is set to 1 to start the WWDT. Once the WWDT is opened, it cannot be closed unless a reset occurs.

Before starting the WWDT, the user must preset the watchdog overflow time and window time. Setting the value of WWDT_CR0.WCNT can update the initial value of the counter, and setting the value of WWDT_CR1.WINR can configure the window value of the watchdog. The window value must be less than the initial value of the watchdog counter. After starting the WWDT, the counter counts down from the initial value.

When the counter decrements to 0x40, the pre-overflow signal POV will be generated, and setting WWDT_CR1.IE to 1 will generate a pre-overflow interrupt.

When the counter decrements to 0x3F, an overflow signal OV will be generated, which can trigger a system reset.

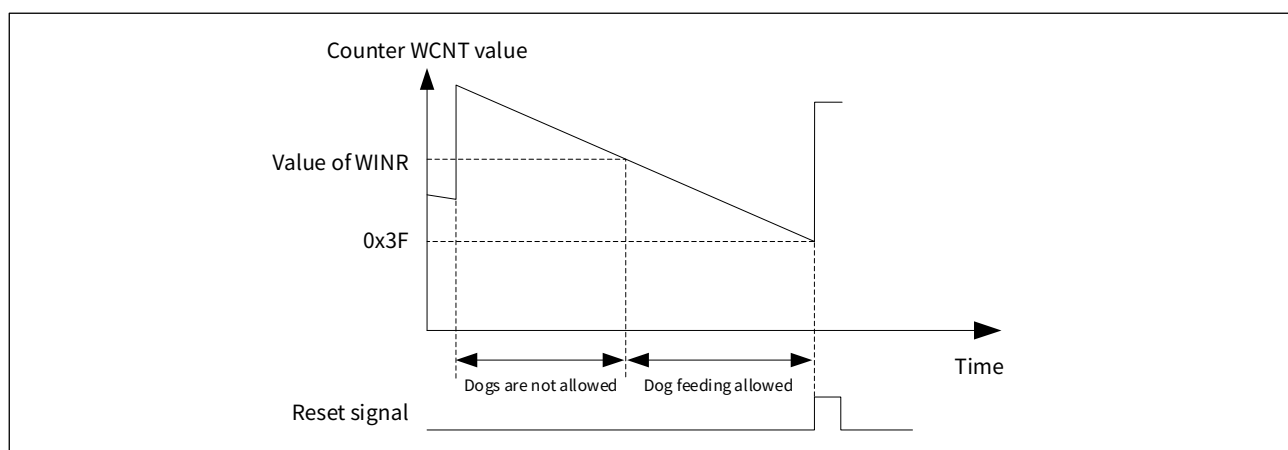
When the current count value WCNT is greater than the window value WINR, updating the watchdog counter will also trigger a system reset.

18.3.3 Refresh counter

When WWDT is running, the counter can be refreshed only when the count value is less than or equal to the window value and the count value is decremented to 0x3F, that is, the dog feeding operation, otherwise a system reset will occur.

Set the value of WWDT_CR1.WINR to configure the upper limit of the delay time window before reset, and the lower limit of the delay time window is fixed at 0x3F. The timing of feeding dog of the window watchdog is shown in the following figure:

Figure 18-2 Refresh (feed dog) timing of the window watchdog



18.3.4 Dog-feeding time

The calculation formula of the dog feeding time of the window watchdog:

Minimum time for dog-feeding:

$$T_{\text{WWDT_MIN}} = T_{\text{PCLK}} \times 4096 \times 2^{\text{PRS}} \times (\text{WCNT} - \text{WINR})$$

Maximum time for dog-feeding:

$$T_{\text{WWDT_MAX}} = T_{\text{PCLK}} \times 4096 \times 2^{\text{PRS}} \times (\text{WCNT} - 0x3F)$$

Where:

T_{PCLK} : PCLK clock period

PRS: Prescale factor

WCNT: Counter current count value

WINR: Watchdog window value

Example:

When the PCLK frequency is 24MHz, the prescaler factor PRS is set to 0x01, WCNT is set to 0x6F, and the window value WINR is set to 0x4F, then the dog-feeding time is as follows:

$$T_{\text{WWDT_MIN}} = 1 / 24\text{MHz} \times 4096 \times 2^1 \times (0x6F - 0x4F) \approx 10.922 \text{ ms}$$

$$T_{\text{WWDT_MAX}} = 1 / 24\text{MHz} \times 4096 \times 2^1 \times (0x6F - 0x3F) = 16.384 \text{ ms}$$

That is, the dog-feeding time cannot be earlier than 10.922ms at the earliest, otherwise an error in the loading count value will occur and the system will reset; the dog-feeding time cannot be later than 16.384ms at the latest, otherwise an underflow will occur and the system will reset. The time window size for properly dog-feeding is about 5ms.

18.3.5 Reset and interrupt

When the value of the counter WCNT is decremented to 0x40, the pre-overflow interrupt flag bit WWDT_SR.POV is set by hardware. If the IE bit field of the control register WWDT_CR1 is set to 1 (Caution: this bit cannot be cleared to 0 after being set to 1), a pre-overflow interrupt flag will be generated. Overflow interrupt request. The user can update the counter WCNT in the interrupt service routine to avoid the reset of the WWDT.

A system reset can be triggered when one of the following conditions is met:

1. The value of the counter WCNT is decremented to 0x3F;
2. When updating the counter WCNT, the current count value is greater than the window value;
3. Write a value less than or equal to 0x3F to WWDT_CR0.WCNT.



18.4 Programming examples

WWDT basic configuration process

Step 1: Set `SYSCTRL_APBEN1.WWDT` to 1, enable the configuration clock and working clock of WWDT;
Step 2: Configure the prescaler of the watchdog counter clock in the window through `WWDT_CR1.PRS`;
Step 3: Configure the compare value of the window watchdog count through `WWDT_CR1.WINR`;
Step 4: Configure the initial value of the counter through `WWDT_CR0.WCNT`;
Step 5: Configure `WWDT_CR1.IE` according to whether the pre-overflow interrupt needs to be enabled;
Step 6: Set `WWDT_CR0.EN` to 1 to start the window watchdog.

WWDT dog-feeding

When the value of the counter `WCNT` is decremented to less than or equal to `WWDT_CR1.WINR` and greater than 0x3F, rewrite the initial value of the counter to `WWDT_CR0.WCNT`.



18.5 List of registers

WWDT base address: WWDT_BASE = 0x4000 2C00

Table 18-1 List of WWDT registers

Register name	Register address	Register description
WWDT_CR0	WWDT_BASE + 0x00	Control register 0
WWDT_CR1	WWDT_BASE + 0x04	Control register 1
WWDT_SR	WWDT_BASE + 0x08	Status register



18.6 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

18.6.1 WWDT_CR0 control register 0

Address offset: 0x00 Reset value: 0x0000 007F

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	EN	RW1	WWDT enable control, cannot be disabled after enabling 0: WWDT disabled 1: WWDT enabled
6:0	WCNT	RW	Read: WWDT counter current count value Write: Update the current count value of the WWDT counter

18.6.2 WWDT_CR1 control register 1

Address offset: 0x04 Reset value: 0x0000 007F

Bit field	Name	Permission	Function description
31:11	RFU	-	Reserved bits, please keep the default value
10	IE	RW	WWDT pre-overflow interrupt enable control 0: Pre-overflow interrupt disabled 1: Pre-overflow interrupt enabled Caution: It cannot be cleared after being set to 1
9:7	PRS	RW	WWDT count clock prescale value 000: PCLK / 4096 001: PCLK / 8192 010: PCLK / 16384 011: PCLK / 32768 100: PCLK / 65536 101: PCLK / 131072 110: PCLK / 262144 111: PCLK / 524288
6:0	WINR	RW	Watchdog window value



18.6.3 WWDT_SR status register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:1	RFU	-	Reserved bits, please keep the default value
0	POV	RW	WWDT pre-overflow flag 0: No pre-overflow occurred in WWDT 1: WWDT pre-overflow has occurred, write 0 to clear the flag



19 Universal Asynchronous Receiver/Transmitter (UART)

19.1 Overview

CW32L083 integrates six universal asynchronous receiver/transmitter (UART), supports asynchronous full-duplex, synchronous half-duplex and single-wire half-duplex modes, supports hardware data flow control and multi-computer communication; programmable data frame structure can provide wide range of baud rate selection through wavelet baud rate generator.

The UART controller works in a dual clock domain, allowing data reception in DeepSleep mode, and the reception completion interrupt can wake the MCU back to Active mode.

19.2 Main features

- Supports dual clock domain drive
 - Configure clock PCLK
 - Transfer clock UCLK
- Programmable data frame structure
 - Data word length: 8/9 bits, LSB first
 - Parity bit: no parity/odd parity/even parity
 - Stop bit length: 1/1.5/2 bits
- 16-bit integer, 4-bit fractional baud rate generator
- Supports asynchronous full-duplex, synchronous half-duplex, single-wire half-duplex
- Supports hardware flow control RTS, CTS
- Supports Direct Memory Access (DMA)
- Supports multi-machine communication, automatic address recognition
- 6 interrupt sources with interrupt flags
- Error detection: parity error, frame structure error
- Send and receive data in low power mode, interrupt wake-up MCU



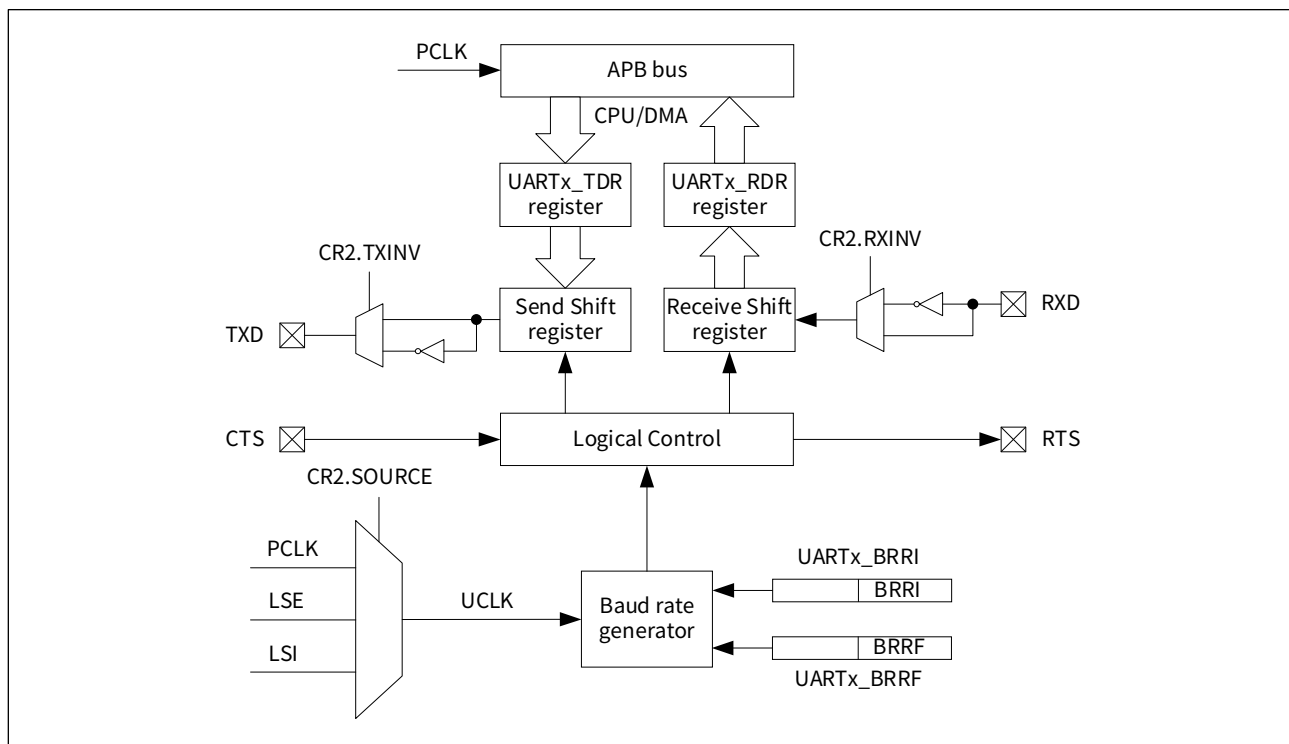
19.3 Functional description

19.3.1 Functional block diagram

The UART controller is mounted on the APB bus, and the clock domain PCLK is configured, which is fixed to the APB bus clock PCLK, which is used for register configuration logic work; transfer clock domain UCLK is used for data transceiver logic work, and its source can be selected from PCLK clock, external low-speed clock (LSE) and internal low-speed clock (LSI). The dual clock domain design facilitates baud rate setting and supports waking up the controller from DeepSleep mode.

The functional block diagram of the UART controller is shown in the following figure:

Figure 19-1 UART functional block diagram



The UART controller supports multiple operating modes. In different operating modes, each pin has different function and different pin configuration, as shown in the following table (where x = 1, 2, 3, 4, 5, 6):

Table 19-1 UART ports configuration

Operating mode	UART pins	Function	GPIO configuration
Asynchronous full duplex	UARTx_TXD	Data serial output	Digital, push-pull output/open-drain output, multiplexed
	UARTx_RXD	Data serial input	Digital, pull-up input, multiplexed
	UARTx_RTS ¹	Request to send	Digital, push-pull output/open-drain output, multiplexed
	UARTx_CTS ¹	Allow to send	Digital, pull-up input, multiplexed
Synchronous half duplex	UARTx_TXD	Clock signal output	Digital, push-pull output/open-drain output, multiplexed
	UARTx_RXD	Data transmitting and receiving	Digital, push-pull output/open-drain output, multiplexed
Single-wire half duplex	UARTx_TXD	Data transmitting and receiving	Digital, open-drain output, multiplexed (external pull-up required)
	UARTx_RXD	Do not use	Can be used as general IO

Caution 1:

Configuration is only required in hardware data flow control mode.



19.3.2 Synchronous mode

The UART supports the synchronous half-duplex working mode. In this mode, the UARTx_TXD pin outputs a synchronous shift clock signal, and the UARTx_RXD pin transmits and receives data. See [Table 19-1 UART ports configuration](#) for the specific configuration of the UARTx_TXD and UARTx_RXD pins.

The synchronous mode of the UART can communicate with the single-wire half-duplex mode of the SPI. At this time, the SPI must be configured in a fixed level mode: the clock polarity CPOL is 1, and the clock phase CPHA is 1.

Set the SYNC bit field of the control register UARTx_CR1 to 1 to make the UART work in synchronous half-duplex mode. At this time, the UART can only be used as a host, the data word length can only be 8 bits, and UARTx_CR2.SIGNAL and UARTx_CR2.ADDREN must be cleared.

19.3.2.1 Baud rate setting

In synchronous half-duplex mode, the baud rate calculation formula:

$$\text{BaudRate} = \text{UCLK} / 12$$

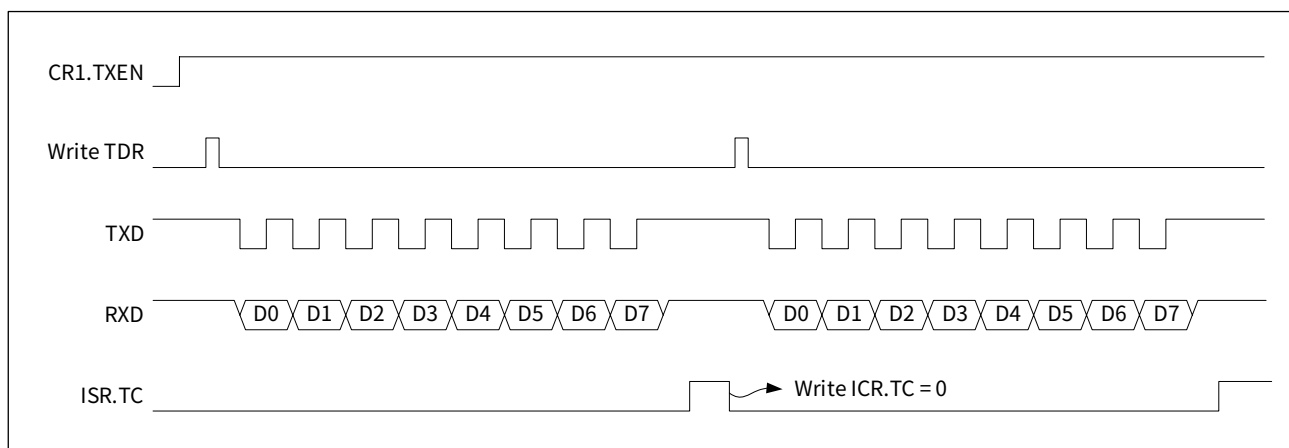
Where, UCLK is the transmission clock of the UART, and its source can be PCLK, LSE or LSI, which is selected by the SOURCE bit field of the control register UARTx_CR2.



19.3.2.2 Data transmission and reception

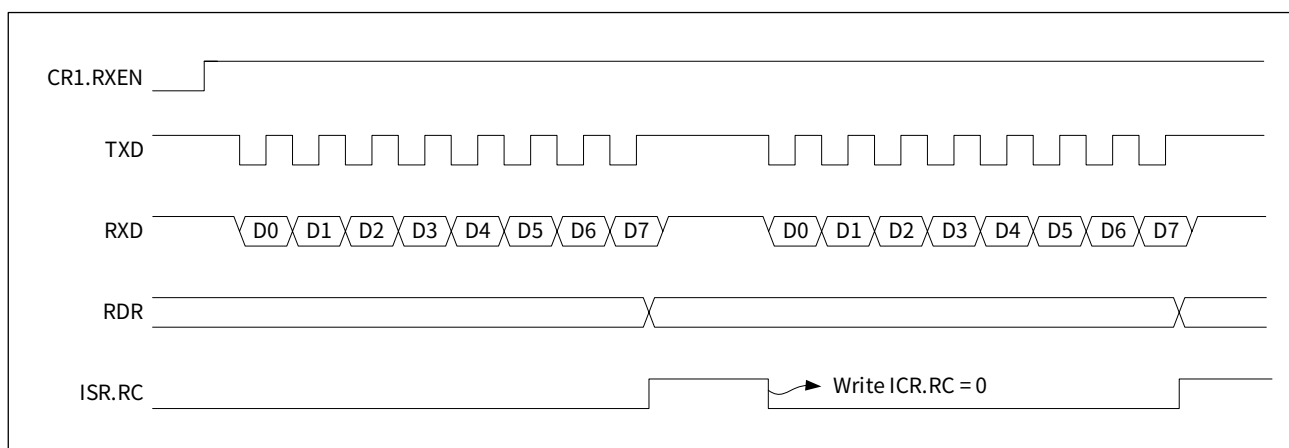
Set the UART transmitting enable bit `UARTx_CR1.TXEN` to 1 to make the UART work in the transmitting state. After writing the data to the `UARTx_TDR` register, the data will be serially output from the `UARTx_RXD` pin, and the `UARTx_TXD` pin will output a synchronous shift clock signal. When the data transmission is completed, the transmission completion interrupt flag `UARTx_ISR.TC` will be set by hardware.

Figure 19-2 Transmit timing in synchronous half-duplex mode (transmit two bytes of data)



Set the UART receiving enable bit `UARTx_CR1.RXEN` to 1 to make the UART work in the receiving state, the `UARTx_TXD` pin will output a synchronous shift clock signal, and the data will be serially input from the `UARTx_RXD` pin. After the data reception is completed, the reception completion interrupt flag `UARTx_ISR.RC` will be set by hardware, and the `UARTx_RDR` register can be read at this time. Before receiving the next byte, the `UARTx_ISR.RC` flag must be cleared to 0. After the `RC` flag is cleared, the next byte of data will be received immediately.

Figure 19-3 Receive timing in synchronous half-duplex mode (receive two bytes of data)



19.3.3 Asynchronous mode

19.3.3.1 Data frame format

In UART asynchronous communication, data is transmitted and received in the form of data frames, and a frame of data includes a start bit, a data field, an optional parity bit and a stop bit with a programmable width.

Start bit

The length of the start bit is fixed at 1 bit, and the judgment method of the start bit can be selected by falling edge or low level, which is selected by the START bit field of the control register UARTx_CR1. Generally, the falling edge is selected as the judgment method of the start bit. The low-level method to determine the start bit is mainly used in the low-power mode. Please refer to section [19.4 Low power mode](#).

Data field

The data word length can be set to 8 bits or 9 bits, and is automatically configured by the presence or absence of parity bits. When set to no parity, the data word length is 8 bits, and when it is set to have parity (including custom parity, even parity, odd parity), the data word length is automatically set to 9 bits. Please refer to [Table 19-2 Data frame structure](#).

Parity bit

The parity mode supports custom parity, even parity and odd parity, which is selected by the PARITY bit field of the control register UARTx_CR1.

Custom parity: The parity bit is determined by software writing to UARTx_TDR[8] and reading UARTx_RDR[8]. It is mainly used in multi-computer communication. Please refer to section [19.3.3.6 Multi-machine communicatio](#).

Odd parity: The parity bit makes the total number of "1"s in the data bits and parity bits in a frame of data an odd number.

Even parity: The parity bit makes the total number of "1" in the data bits and the parity bit in a frame of data an even number.

UARTx_CR1.PARITY is used to set the parity mode, and the corresponding relationship with the data frame is shown in the following table:

Table 19-2 Data frame structure

UARTx_CR1.PARITY	Checkout mode	Data frame
00	No parity	Start bit + 8-bit data + stop bit
01	Custom parity	Start bit + 8-bit data + custom parity bit + stop bit
10	Even parity	Start bit + 8-bit data + even parity bit + stop bit
11	Odd parity	Start bit + 8-bit data + odd parity bit + stop bit

Stop bit

The length of the stop bit can be configured as 1, 1.5 or 2 bits, which is configured through the STOP bit field of the control register UARTx_CR1.



19.3.3.2 Fractional baud rate generator

Generation of baud rate

The receive and transmit baud rates of the UART are the same, generated by the same baud rate generator.

The baud rate generator supports 4 sampling modes: 16 times sampling, 8 times sampling, 4 times sampling and dedicated sampling. The specific sampling mode is selected by the OVER bit field of the control register UARTx_CR1.

1. OVER = 00, set 16 times sampling, baud rate calculation formula:

$$\text{BaudRate} = \text{UCLK} / (16 \times \text{BRRI} + \text{BRRF})$$

UCLK is the transmission clock of UART, and its source can be PCLK, LSE or LSI. The specific source is selected by UARTx_CR2.SOURCE.

BRRI (UARTx_BRRI [15:0]) is the integer part of the baud rate counter and can be set in the range of 1 ~ 65535.

BRRF (UARTx_BRRF [3:0]) is the fractional part of the baud rate counter, and the settable range is 0 ~ 15.

Example 1:

When the frequency of the transmission clock UCLK is 24MHz, set BRRI=156 (ie UARTx_BRRI=0x9C), BRRF=4 (ie UARTx_BRRF=0x04), then:

$$\text{BaudRate} = 24000000 / (16 \times 156 + 4) = 9600 \text{ bps}$$

Example 2:

When the frequency of the transmission clock UCLK is 24MHz, it is required to configure BaudRate=115200bps, and calculate

$$16 \times \text{BRRI} + \text{BRRF} = 24000000 / 115200 = 208.33$$

then:

$$\text{BRRI} = 208.33 / 16 = 13.02, \text{ the nearest integer is: } 13 (0x0D)$$

$$\text{BRRF} = 0.02 \times 16 = 0.32, \text{ the nearest integer is: } 0 (0x00)$$

That is, you need to set UARTx_BRRI to 0x0D and UARTx_BRRF to 0x00

At this time, the actual baud rate BaudRate=115384.62bps, the error rate is 0.16%

2. OVER = 01, set 8 times sampling, baud rate calculation formula:

$$\text{BaudRate} = \text{UCLK} / (8 \times \text{BRRI})$$

3. OVER = 10, set 4 times sampling, baud rate calculation formula:

$$\text{BaudRate} = \text{UCLK} / (4 \times \text{BRRI})$$

4. OVER = 11, set dedicated sampling, baud rate calculation formula:

$$\text{BaudRate} = (256 \times \text{UCLK}) / \text{BRRI}$$

Caution:

Dedicated sampling is only suitable for UART communication at 2400bps, 4800bps or 9600bps baud rate when the transmission clock source is LSE or LSI.



Example 1:

The transmission clock UCLK selects LSE, the frequency is 32.768KHz, and the baud rate of 9600bps is required to be configured, then:

$$\text{BRRI} = 256 \times 32768 / 9600 = 873.81, \text{ the nearest integer is: } 874 \text{ (0x36A)}$$

That is, you need to set UARTx_BRRI to 0x36A

At this time, the actual baud rate BaudRate=9597.95bps, the error is 0.02%

Example of baud rate setting

Table 19-3 to Table 19-9 list the setting value of the baud rate count register and the baud rate error when the frequency of the common MCU is used.

Table 19-3 UCLK is 4MHz baud rate setting example (OVER=00)

Baud rate (bps)	BRRI	BRRF	Actual baud rate	Error rate
4800	52	1	4801.92	0.04%
9600	26	1	9592.33	-0.08%
14400	17	6	14388.49	-0.08%
19200	13	0	19230.77	0.16%
38400	6	8	38461.54	0.16%
56000	4	7	56338.03	0.60%
57600	4	5	57971.01	0.64%
115200	2	3	114285.71	-0.79%
256000	1	0	250000	-2.34%

Table 19-4 UCLK is 8MHz baud rate setting example (OVER=00)

Baud rate (bps)	BRRI	BRRF	Actual baud rate	Error rate
4800	104	3	4799.04	-0.02%
9600	52	1	9603.84	0.04%
14400	34	12	14388.49	-0.08%
19200	26	1	19184.65	-0.08%
38400	13	0	38461.54	0.16%
56000	8	15	55944.06	-0.10%
57600	8	11	57553.96	-0.08%
115200	4	5	115942.03	0.64%
500000	1	0	500000	0.00%



Table 19-5 UCLK is 16MHz baud rate setting example (OVER=00)

Baud rate (bps)	BRR1	BRRF	Actual baud rate	Error rate
4800	208	5	4800.48	0.01%
9600	104	3	9598.08	-0.02%
14400	69	7	14401.44	0.01%
19200	52	1	19207.68	0.04%
38400	26	1	38369.30	-0.08%
56000	17	14	55944.06	-0.10%
57600	17	6	57553.96	-0.08%
115200	8	11	115107.91	-0.08%
1000000	1	0	1000000	0.00%

Table 19-6 UCLK is 24MHz baud rate setting example (OVER=00)

Baud rate (bps)	BRR1	BRRF	Actual baud rate	Error rate
4800	312	8	4800.00	0.00%
9600	156	4	9600.00	0.00%
14400	104	3	14397.12	-0.02%
19200	78	2	19200.00	0.00%
38400	39	1	38400.00	0.00%
56000	26	13	55944.06	-0.10%
57600	26	1	57553.96	-0.08%
115200	13	0	115384.62	0.16%
1500000	1	0	1500000	0.00%



Table 19-7 UCLK is 32MHz baud rate setting example (OVER=00)

Baud rate (bps)	BRR1	BRRF	Actual baud rate	Error rate
4800	416	11	4799.76	0.00%
9600	208	5	9600.96	0.01%
14400	138	14	14401.44	0.01%
19200	104	3	19196.16	-0.02%
38400	52	1	38415.37	0.04%
56000	35	11	56042.03	0.08%
57600	34	12	57553.96	-0.08%
115200	17	6	115107.91	-0.08%
2000000	1	0	2000000	0.00%

Table 19-8 UCLK is 48MHz baud rate setting example (OVER=00)

Baud rate (bps)	BRR1	BRRF	Actual baud rate	Error rate
4800	625	0	4800.00	0.00%
9600	312	8	9600.00	0.00%
14400	208	5	14401.44	0.01%
19200	156	4	19200.00	0.00%
38400	78	2	38400.00	0.00%
56000	53	9	56009.33	0.02%
57600	52	1	57623.05	0.04%
115200	26	1	115107.91	-0.08%
3000000	1	0	3000000	0.00%

Table 19-9 UCLK is 32.768KHz baud rate setting example (OVER=11)

Baud rate (bps)	BRR1	Actual baud rate	Error rate
2400	3495	2400.17	0.01%
4800	1748	4798.97	-0.02%
9600	874	9597.95	-0.02%

Automatic baud rate detection

When the CW32L083 uses the UART as the slave for communication, it can automatically adapt to the baud rate of the UART master by means of automatic baud rate detection. The input capture source of the general-purpose timer (GTIM) can be configured as the RXD signal of the UART, or the gating signal of the GTIM can be configured as the RXD signal of the UART, and the baud rate of the UART can be measured by using related software algorithms to achieve the baud rate. Adaptive. Please refer to the relevant application Cautions for details.



19.3.3.3 Transmit control

Data transmission

Set UARTx_CR1.TXEN to 1 to enable transmit circuit. After writing the data to the UARTx_TDR register, the data will be transferred to the transmission shift register by hardware, and the transmission shift register will serially shift the data out from the lowest bit. For the register configuration of the specific transmission process, please refer to section [19.7 Programming examples](#).

Transmit interrupt

In the transmission control link, there are three flag bits UARTx_ISR.TXE, UARTx_ISR.TC and UARTx_ISR.TXBUSY, among which UARTx_ISR.TXE and UARTx_ISR.TC can generate interrupt requests.

When the data is transferred to the transmission shift register by hardware, the transmit buffer empty interrupt flag UARTx_ISR.TXE will be set by hardware, indicating that the UARTx_TDR register is empty, and new data to be sent is allowed to be written to the UARTx_TDR register. While writing data to the UARTx_TDR register, the UARTx_ISR.TXE flag will be automatically cleared. If there is still untransmitted data in the transmission shift register at this time, the newly written data will be temporarily stored in the UARTx_TDR register. After the current data transmission is completed, the data in the UARTx_TDR register will be transferred by hardware to the transmission shift register. continue to transmit in the register.

When the transmission of the data frame in the transmission shift register is completed, the transmission completion interrupt flag bit UARTx_ISR.TC will be set by hardware, indicating that a frame of data has been transmitted.

When the data frame in the transmission shift register is transmitted, if there is no data to be transmitted in the UARTx_TDR register (ie UARTx_ISR.TXE=1), the UART transmit busy flag UARTx_ISR.TXBUSY will be cleared by hardware, indicating that the data in the UARTx_TDR register and the transmission shift register has been transmitted.

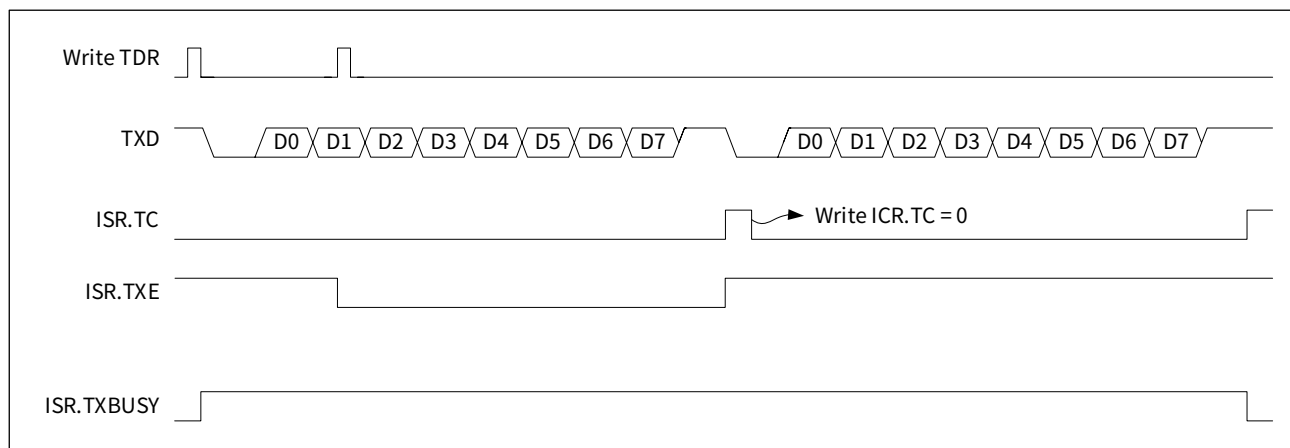
In user applications, before closing the UART, it is recommended to check whether the UARTx_ISR.TXBUSY flag has been cleared to ensure that all data has been transmitted to avoid data loss.

The UARTx_ISR.TXE flag bit and the UARTx_ISR.TC flag bit are generated by hardware, and both can generate interrupt requests, which are controlled by the interrupt enable bits UARTx_IER.TXE and UARTx_IER.TC respectively.

In the UART interrupt service routine, the interrupt source is determined by reading the UARTx_ISR.TXE and UARTx_ISR.TC flag bits. The corresponding flag bits should be cleared before exiting the interrupt service routine to avoid repeated entry into the interrupt service routine.

The timing diagram of the UART transmission control link is shown in the following figure:

Figure 19-4 Transmit control sequence in asynchronous working mode (transmitting two bytes of data)



19.3.3.4 Receive control

Data reception

Set UARTx_CR1.RXEN to 1 to enable the receive circuit. When the receiver detects the first falling edge of the start bit, the hardware will sample the port at 16 times the set baud rate, and at the same time, it will make a comprehensive judgement on the intermediate three sampling results of each bit, and finally form the receive data, which will be shifted into the receive shift register serially, and transferred to the UARTx_RDR register in parallel, and at this time, the data can be read out. For the register configuration of the specific receiving process, please refer to [19.7 Programming examples](#).

Receive interrupt

In the receiving control link, there are three flag bits UARTx_ISR.RC, UARTx_ISR.PE and UARTx_ISR.FE, and all can generate interrupt requests.

When the received data is transferred from the shift register to the UARTx_RDR register, the reception completion interrupt flag bit UARTx_ISR.RC will be set by hardware, indicating that the reception of a frame of data has been completed. In the user program, once the UARTx_ISR.RC flag is detected as 1, the UARTx_RDR register should be read as soon as possible, and the UARTx_ISR.RC flag should be cleared. If the UARTx_RDR register is not read in time, the newly received data will overwrite the data in the UARTx_RDR register, resulting in data loss.

When a data frame is received, the parity check will be performed automatically. If a parity check error is detected, the UARTx_ISR.PE flag will be set by hardware, indicating a parity check error.

When receiving a data frame, if the correct stop bit is not recognized within the expected time, it is determined that a frame structure error has occurred, and the UARTx_ISR.FE flag will be set by hardware.

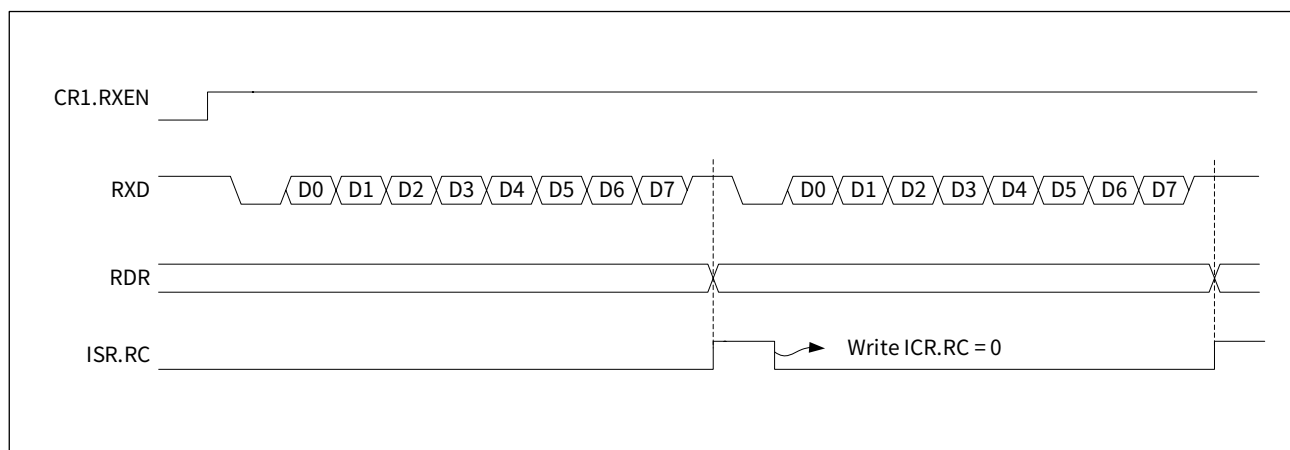
The UARTx_ISR.RC, UARTx_ISR.PE and UARTx_ISR.FE flag bits are generated by hardware and can generate interrupt requests, which are controlled by the interrupt enable bits UARTx_IER.RC, UARTx_IER.PE and UARTx_IER.FE respectively.

In the UART interrupt service routine, the interrupt source is determined by reading the UARTx_ISR.RC, UARTx_ISR.PE and UARTx_ISR.FE flag bits, and the corresponding flag bits should be cleared before exiting the interrupt service routine to avoid repeatedly entering the interrupt service routine.

In user applications, before closing the UART, it is recommended to check whether the UARTx_ISR.RC flag has been set to 1 to ensure that all data has been received to avoid data loss.

The timing diagram of the UART receiving control link is shown in the following figure:

Figure 19-5 Receive control timing in asynchronous working mode (receive two bytes of data)



19.3.3.5 Single-wire half-duplex mode

Set UARTx_CR2.SIGNAL to 1 to make the UART work in single-wire half-duplex mode. In this mode, the UARTx_TXD pin is used for data transmission and reception without occupying the UARTx_RXD pin (UARTx_RXD can be used as general IO). See [Table 19-1 UART ports configuration](#) for configuration.

After writing data to the UARTx_TDR register, the UARTx_TXD pin immediately enters the transmit state and the output UARTx_TDR data in the register. After the data transmission is complete, the UARTx_TXD pin returns to its normal receive state.

When no data is sent, the UARTx_TXD pin is in the receiving state. After the data is received, the reception completion flag UARTx_ISR.RC will be set by hardware. At this time, the UARTx_RDR register should be read as soon as possible, and the UARTx_ISR.RC flag should be cleared.

Caution:

Users should take appropriate application layer protection mechanisms to ensure that multiple masters do not send data to the bus at the same time.

19.3.3.6 Multi-machine communication

UART supports multi-machine communication mode. In this mode, there is one master and multiple slaves on the UART bus. Each slave has a unique slave address. During communication, the master will first send an address frame to address the slave. Only the slave with the matching address is activated and receives the data frame sent by the subsequent master.

Master transmits

In the multi-machine communication mode, the master needs to set UARTx_CR1.PARITY to 1, configure it as a custom check, and the frame data length is automatically set to 9 bits.

The highest bit of the UARTx_TDR register determines whether the master sends an address frame or a data frame. When UARTx_TDR[8] is 1, it means that the master sends an address frame. When UARTx_TDR[8] is 0, it means that the master sends a data frame.

Slave receives

In the multi-machine communication mode, the slave needs to set UARTx_CR1.PARITY to 1, configure it as a custom check, and set UARTx_CR2.ADDREN to 1 to enable the slave address recognition, and the slave hardware automatically detects the address sent by the host and the local machine. whether the address matches.

If the address matches, the slave will save the received address frame into the UARTx_RDR register, the UARTx_ISR.RC flag is set by hardware, and the UARTx_ISR.MATCH flag is set by hardware, and the slave receives the subsequent data frame sent by the master. During the communication process, the slave should pay attention to:

1. The application program queries UARTx_RDR[8] in the reception completion interrupt RC to determine whether it is an address frame or a data frame.
2. When the slave sends a data frame, it needs to set UARTx_TDR[8] to 0 to avoid being regarded as an address frame by other slaves.

If the addresses do not match, the slave will not receive the data frame sent by the master, nor will it generate a reception completion interrupt, and the set UARTx_ISR.MATCH flag will be cleared.



Slave address and address mask

The slave address is configured by the UARTx_ADDR register, and the slave address should be configured to be unique. The UARTx_MASK register is an address mask. The slave address bit corresponding to the bit '1' in UARTx_MASK[7:0] participates in the slave address matching operation, and the slave address bit corresponding to the bit '0' does not participate in the slave address matching operation.

When all bits in UARTx_MASK[7:0] are set to '1', that is, write 0xFF to the UARTx_MASK register, then all 8-bit address bits of the slave address participate in the slave address matching, and the master can uniquely identify the slave.

When some bits in UARTx_MASK[7:0] are set to '0', the corresponding slave address bits do not participate in slave address matching, so as to realize that multiple slaves respond to the same address frame sent by the master, that is, the master addresses multiple slaves at the same time.

Example 1:

Set the slave A: UARTx_ADDR = 0xA0, UARTx_MASK = 0xFE

Set the slave B: UARTx_ADDR = 0xA1, UARTx_MASK = 0xFE

Set the slave C: UARTx_ADDR = 0xA2, UARTx_MASK = 0xFC

Set the slave D: UARTx_ADDR = 0xA3, UARTx_MASK = 0xFC

Set the slave E: UARTx_ADDR = 0xA5, UARTx_MASK = 0xFF

When the master transmits a 0xA0 or 0xA1 address frame, it can address slave A, slave B, slave C, and slave D

When the master transmits 0xA2 or 0xA3 address frame, it can address slave C, slave D

When the master transmits a 0xA4 address frame, no slave is addressed

When the master transmits a 0xA5 address frame, it can address the slave E

Broadcast address

In multi-machine communication, the address 0xFF is defined as the broadcast address. When the master transmits the broadcast address frame, the slaves of all addresses are addressed.

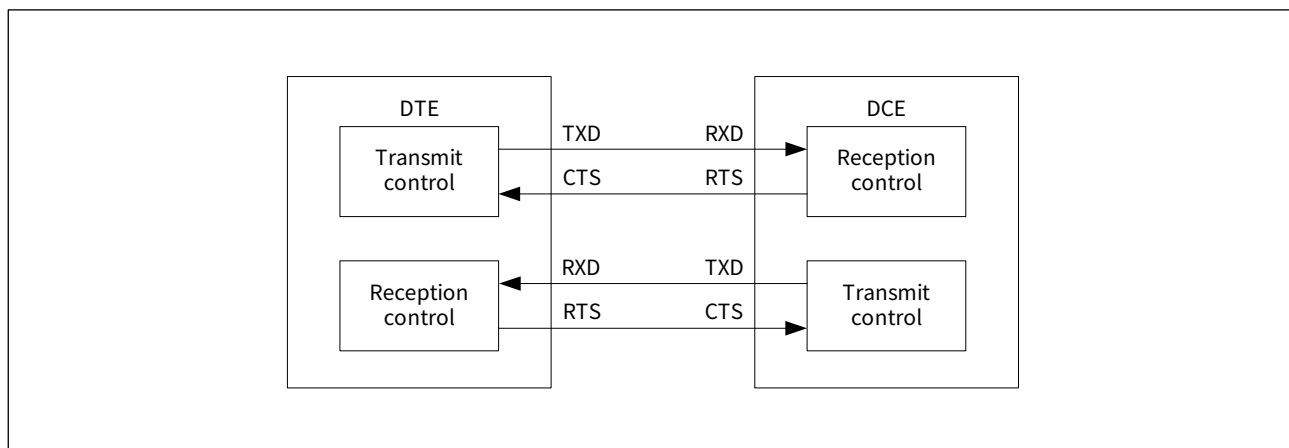


19.3.3.7 Hardware flow control

CW32L083 supports UART hardware flow control mode, that is, it supports request to transmit RTS and allow to transmit CTS, which is used to automatically control the transmission and reception of data.

In the data communication system, the schematic diagram of the communication hardware flow control between the data terminal equipment DTE and the data circuit terminating equipment DCE is shown in the following figure.

Figure 19-6 Schematic diagram of hardware flow control



Request to transmit RTS

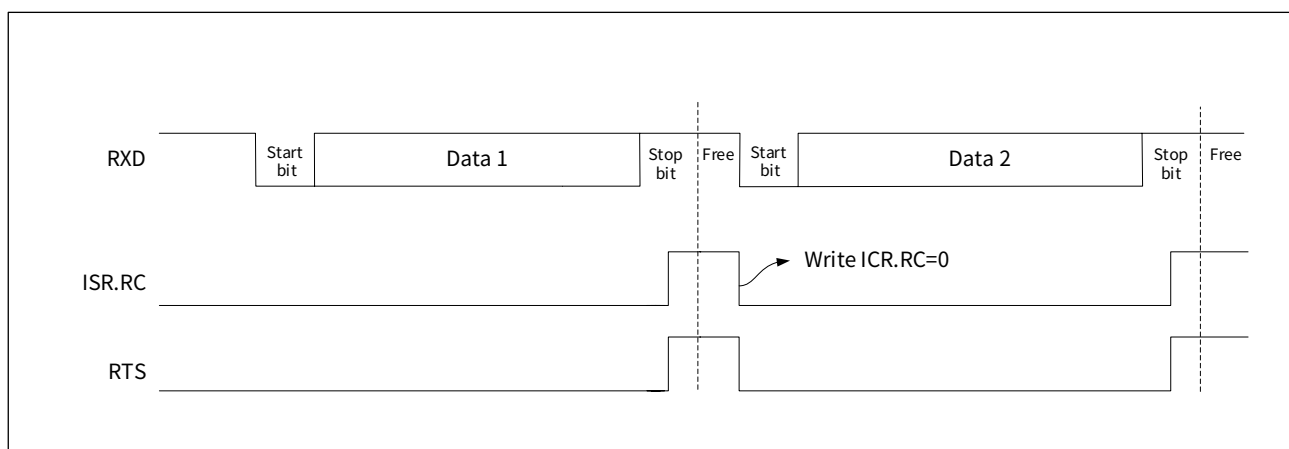
Set `UARTx_CR2.RTSN` to 1 to enable RTS flow control, RTS means request to transmit, and low level is active.

When the receiver is ready to receive new data (ie `UARTx_ISR.RC=0`), the RTS pin will output a low level, requesting the transmitting terminal to transmit a frame of data.

When the receiving terminal receives a frame of data (ie `UARTx_ISR.RC=1`), the RTS pin will output a high level to notify the transmitting terminal to suspend transmitting.

In the user application, after reading the data in the `UARTx_RDR` register, if you want to continue to receive the next frame of data, the software must clear the `UARTx_ISR.RC` flag bit. At this time, the RTS pin will output a low level, requesting the transmitting terminal to transmit the next frame of data.

Figure 19-7 RTS flow control sequence



Allow transmitting CTS

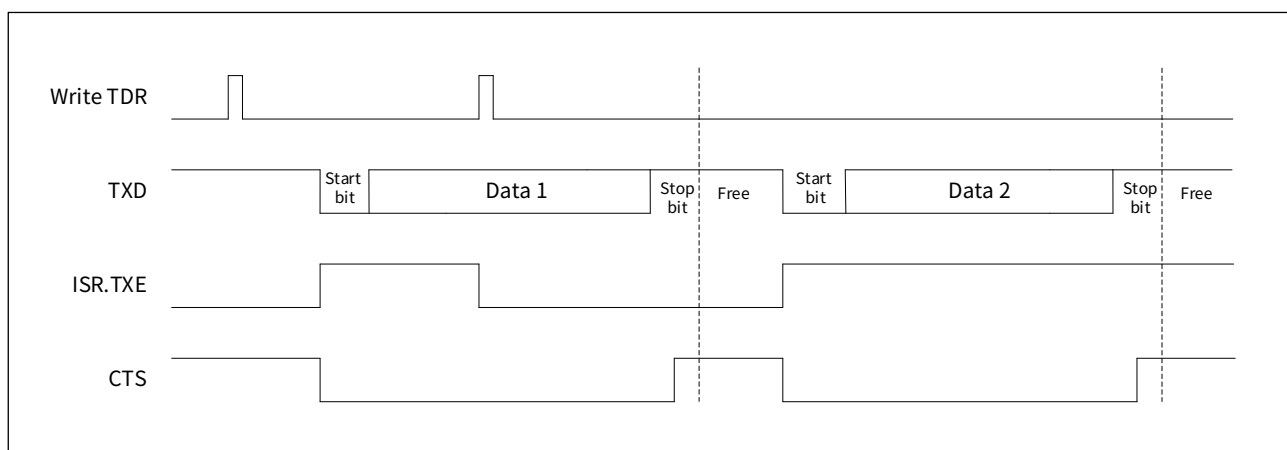
Set UARTx_CR.CTSSEN to 1 to enable CTS flow control, CTS means transmission is allowed, and low level is active.

When the transmitting terminal detects that the CTS signal is low, if there is data to be sent (ie UARTx_ISR.TXE=0), and there is no data currently being transmitted, this frame of data will be transmitted.

When the transmitting terminal detects that the CTS signal is at a high level, if there is ongoing data transmission, the current transmission will continue, and the transmission will be stopped after the current transmission is completed.

In the CTS flow control process, the CTS signal level flag bit UARTx_ISR.CTSLV indicates the current level state of the CTS pin; the CTS signal change flag bit UARTx_ISR.CTS indicates whether the CTS signal has changed, when the CTS signal changes, The UARTx_ISR.CTS flag will be set by hardware. When the CTS interrupt is enabled (that is, set UARTx_IER.CTS to 1), an interrupt will be generated. Write UARTx_ICR.CTS to 0 to clear the interrupt flag.

Figure 19-8 CTS flow control sequence



19.4 Low power mode

The UART controller works in a dual clock domain, supports normal data transmission and reception in DeepSleep mode, and wakes up the MCU back to Active mode through a reception completion interrupt.

If the source of the transmission clock UCLK is set as the low-speed clock, when the system enters the DeepSleep mode, the high-speed clock will stop, the low-speed clock will keep running, and the UART can still transmit and receive data normally (the baud rate only supports 2400bps, 4800bps and 9600bps).

To use the UART wake-up function in DeepSleep mode, you need to enable the UART reception completion interrupt (that is, set UARTx_IER.RC to 1) before entering DeepSleep mode. When data reception is completed, the reception completion interrupt will wake up the MCU and return to Active mode.

If the source of the transmission clock UCLK is set as the high-speed clock, when the system enters the DeepSleep mode, the high-speed clock will stop running and the UART will not receive data. At this time, the MCU can still be woken up through the GPIO interrupt to receive data in DeepSleep mode. The reference configuration steps are as follows:

Step 1: Enable the GPIO falling edge interrupt of the corresponding pin of UARTx_RXD;

Step 2: Set UARTx_CR1.START to 1, and select the RXD signal start bit determination method to be low level;

Step 3: Enable UART reception (that is, set UARTx_CR1.RXEN to 1);

Step 4: Enter DeepSleep mode;

Step 5: Wait for the master to transmit data, generate a GPIO falling edge interrupt, and wake up the MCU;

Step 6: Closed the GPIO interrupt function of the corresponding pin to RXD and wait for the completion of RXD reception.

For more information on the optimized design of low power mode entry and wake-up, please refer to chapter [3 Power Control \(PWR\) and Power Consumption](#).



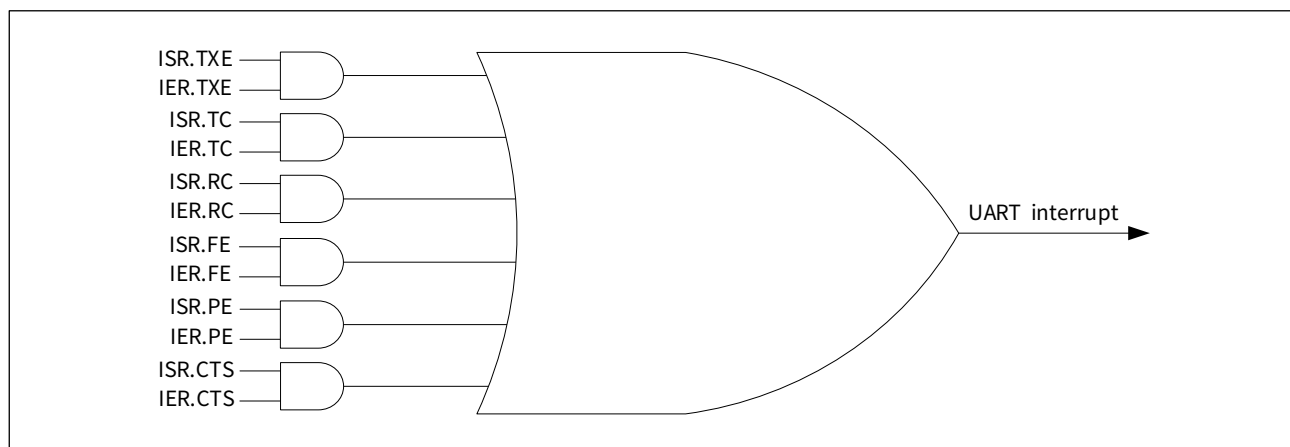
19.5 UART interrupts

The UART controller supports 6 interrupt sources. When the UART interrupt trigger event occurs, the interrupt flag bit will be set by hardware. If the corresponding interrupt enable control bit is set, an interrupt request will be generated.

A UART module of CW32L083 uses a same system UART interrupt. Whether the UART interrupt generates interrupt jump is controlled by the corresponding bit of the interrupt enable setting register NVIC_ISER of the Nested Vectored Interrupt Controller (NVIC).

The schematic diagram of the system UART interrupt is shown in the following figure:

Figure 19-9 Schematic diagram of UART interrupt structure



In the user's UART interrupt service routine, the relevant UART interrupt flag bit should be queried for corresponding processing. Before exiting the interrupt service routine, the interrupt flag bit should be cleared to avoid repeatedly entering the interrupt routine.

The flag bits, interrupt enable bits, interrupt flag clear bits and clear methods of each interrupt source of the UART are shown in the following table:

Table 19-10 UART interrupt control

Interrupt event	Interrupt flag bit	Interrupt enable bit	Flag clear method
Transmit buffer empty	ISR.TXE	IER.TXE	Write UARTx_TDR register
Complete transmitting	ISR.TC	IER.TC	Write 0 to ICR.TC
Complete receiving	ISR.RC	IER.RC	Write 0 to ICR.RC
Frame structure error	ISR.FE	IER.FE	Write 0 to ICR.FE
Parity error	ISR.PE	IER.PE	Write 0 to ICR.PE
CTS signal changes	ISR.CTS	IER.CTS	Write 0 to ICR.CTS

19.6 Direct Memory Access (DMA)

The UART controller supports the DMA transfer function, allowing high-speed data transfer between the UART transceiver data registers and memory without CPU intervention. DMA requests can be triggered by software or hardware, and the DMA requests for transmitting TXD and receiving RXD are generated separately.

DMA transmits

Set UARTx_CR2.DMATX to 1 to enable DMA transmit. When the UARTx_TDR register is empty, the DMA will be triggered to transfer a frame of data from the specified storage area to the UARTx_TDR register, until all the data configured in the DMA controller is transferred.

For the specific register configuration process of DMA transmission, please refer to chapter [8 Direct memory access \(DMA\)](#) and section [19.7 Programming examples](#).

When the DMA transfer is completed, the corresponding DMA channel y transfer completion flag bit DMA_ISR.TCy will be set by hardware. If the interrupt is enabled (that is, set DMA_CSRy.TCIE to 1), an interrupt request will be generated.

In user application, before closing the UART, it is recommended to check whether the UARTx_ISR.TXBUSY flag has been cleared to ensure that all data has been sent to avoid disrupting the last transmission process.

DMA receives

Set UARTx_CR2.DMARX to 1 to enable DMA reception. When a frame of data is received (that is, the UARTx_RDR register is not empty), the DMA will be triggered to transfer the data from the UARTx_RDR register to the specified storage area, until all the data configured in the DMA controller is transferred.

For the specific register configuration process of DMA reception, please refer to chapter [8 Direct memory access \(DMA\)](#) and section [19.7 Programming examples](#).

When the DMA transfer is completed, the corresponding DMA channel y transfer completion flag bit DMA_ISR.TCy will be set by hardware. If the interrupt is enabled (that is, set DMA_CSRy.TCIE to 1), an interrupt request will be generated.



19.7 Programming examples

19.7.1 Asynchronous full-duplex programming examples

19.7.1.1 Transmit data in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable the GPIO clock and UART configuration clock corresponding to the UART pin;
- Step 2: Configure the UARTx_TXD pin to the push-pull multiplexed output mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR1.SYNC to 0, and configure UARTx to be asynchronous full-duplex communication mode;
- Step 4: Configure the data frame;
1. Start bit determination method: configure UARTx_CR1.START
 2. Parity bit: configure UARTx_CR1.PARITY
 3. Stop bit: configure UARTx_CR1.STOP
- Step 5: Configure UARTx_CR2.SOURCE and select the transmission clock source;
- Step 6: Configure UARTx_CR1.OVER and select sampling mode;
- Step 7: Configure the UARTx_BRRI and UARTx_BRRF registers and configure the baud rate. For details, please refer to section [19.3.3.2 Fractional baud rate generator](#);
- Step 8: Set UARTx_CR1.TXEN to 1 to enable transmit;
- Step 9: Set UARTx_ICR.TC to 0, clear the transmit completion flag;
- Step 10: Write a frame of data to be transmitted into the UARTx_TDR register;
- Step 11: Query and wait for the UARTx_ISR.TC flag to be set to 1 to confirm that one frame of data is transmitted;
- Step 12: Repeat steps 9 ~ 12 to transmit the next frame of data.



19.7.1.2 Receive data in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable the GPIO clock and UART configuration clock corresponding to the UART pin;
- Step 2: Configure the RXD pin as the pull-up input multiplexed mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR1.SYNC to 0, and configure UARTx to be asynchronous full-duplex communication mode;
- Step 4: Configure the data frame;
1. Start bit determination method: configure UARTx_CR1.START
 2. Parity bit: configure UARTx_CR1.PARITY
 3. Stop bit: configure UARTx_CR1.STOP
- Step 5: Configure UARTx_CR2.SOURCE and select the transmission clock source;
- Step 6: Configure UARTx_CR1.OVER and select sampling mode;
- Step 7: Configure the UARTx_BRRI and UARTx_BRRF registers and configure the baud rate. For details, please refer to section [19.3.3.2 Fractional baud rate generator](#);
- Step 8: Write 0x00 to the UARTx_ICR register to clear all flags;
- Step 9: Set UARTx_CR1.RXEN to 1 to enable receive;
- Step 10: Query and wait for the UARTx_ISR.RC flag to be set to 1 to confirm that one frame of data has been received;
- Step 11: Query the error flags UARTx_ISR.PE and UARTx_ISR.FE to confirm whether the data is valid. If the data is invalid, perform error processing. If the data is valid, read the UARTx_RDR register and save the data;
- Step 12: Set UARTx_ICR.RC to 0, clear the reception completion flag;
- Step 13: Repeat steps 10 ~ 13 to receive the next frame of data.



19.7.1.3 Transmit data in interrupt mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable GPIO clock and UART configuration clock corresponding to UART pins;
- Step 2: Configure the TXD pin to the push-pull multiplexed output mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR1.SYNC to 0, and configure UARTx to be asynchronous full-duplex communication mode;
- Step 4: Configure the data frame;
1. Start bit determination method: configure UARTx_CR1.START
 2. Parity bit: configure UARTx_CR1.PARITY
 3. Stop bit: configure UARTx_CR1.STOP
- Step 5: Configure UARTx_CR2.SOURCE and select the transmission clock source;
- Step 6: Configure UARTx_CR1.OVER and select sampling mode;
- Step 7: Configure the UARTx_BRRI and UARTx_BRRF registers and configure the baud rate. For details, For details, please refer to section [19.3.3.2 Fractional baud rate generator](#);
- Step 8: Configure the NVIC controller, see chapter [5 Interrupt](#);
- Step 9: Set UARTx_IER.TXE to 1 to enable transmit buffer empty interrupt;
- Step 10: Set UARTx_CR1.TXEN to 1 to enable transmit;
- Step 11: Write a frame of data to be transmitted into the UARTx_TDR register;
- Step 12: The data starts to transmit, the transmit buffer is empty, and the interrupt service function is entered: query and judge the UARTx_ISR.TXE flag bit, if the flag bit is 1, write a new frame of data to the UARTx_TDR register;
- Step 13: Query and wait for the UARTx_ISR.TXBUSY flag to be cleared and turn off the UART.



19.7.1.4 Receive data in interrupt mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable the GPIO clock and UART configuration clock corresponding to the UART pin;
- Step 2: Configure the RXD pin as the pull-up input multiplexed mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR1.SYNC to 0, and configure UARTx to be asynchronous full-duplex communication mode;
- Step 4: Configure the data frame;
1. Start bit determination method: configure UARTx_CR1.START
 2. Parity bit: configure UARTx_CR1.PARITY
 3. Stop bit: configure UARTx_CR1.STOP
- Step 5: Configure UARTx_CR2.SOURCE and select the transmission clock source;
- Step 6: Configure UARTx_CR1.OVER and select sampling mode;
- Step 7: Configure the UARTx_BRRI and UARTx_BRRF registers and configure the baud rate. For details, please refer to section [19.3.3.2 Fractional baud rate generator](#);
- Step 8: Configure the NVIC controller, see chapter [5 Interrupt](#);
- Step 9: Set UARTx_IER.RC to 1 to enable receive completion interrupt;
- Step 10: Set UARTx_CR1.RXEN to 1 to enable receive;
- Step 11: Wait for the completion of receiving a frame of data, and enter the interrupt service function: query the UARTx_ISR.PE and UARTx_ISR.FE flag bits to confirm whether the data is valid, if invalid, perform error handling; if valid, query and judge the UARTx_ISR.RC flag bit, If the flag bit is 1, read the UARTx_RDR register and save the data, and clear the flag bit.



19.7.1.5 DMA transmits data

The following is an example of DMA channel 1 transmit data for UART1 (UART1_TXD pin is PA08). In this application example, set the transfer clock UCLK to 24MHz, the baud rate to 115200bps, and the DMA data transmission amount to 100. The DMA transmission is started by hardware triggering, and the data in an 8-bit array defined in the SRAM area is transferred to the UART1_TDR register .

The specific configuration process is as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOA to 1, SYSCTRL_APBEN2.UART1 to 1, SYSCTRL_AHBEN.DMA to 1, enable the configuration clock and working clock of GPIOA, UART1 and DMA respectively;

Step 2: Configure the UART1_TXD pin (ie PA08) to push-pull multiplexed output mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set UART1_CR1.SYNC to 0, and configure UART1 to be asynchronous full-duplex communication mode;

Step 4: Configure the data frame;

1. Start bit determination method: set UART1_CR1.START to 0, the falling edge of RXD signal
2. Parity bit: set UART1_CR1.PARITY to 0, no parity
3. Stop bit: configure UART1_CR1.STOP as 0, 1-bit length of stop bit

Step 5: Set UART1_CR2.SOURCE to 0, select the transmission clock source as PCLK=24MHz;

Step 6: Set UART1_CR1.OVER to 0, select 16 times sampling mode;

Step 7: Set UART1_BRR1.BRR1 to 0x0D, UART1_BRRF.BRRF to 0x00, configure baud rate to 115200bps;

Step 8: Set UART1_CR1.TXEN to 1 to enable transmission;

Step 9: Define a variable uint8_t SendBuff[100], and assign it;

Step 10: Write 0x00 to UART1_ICR to clear all flag bits of UART1;

Step 11: Set DMA_ICR.TC1 and DMA_ICR.TE1 to 0, clear all interrupt flags of DMA channel 1;

Step 12: Set DMA_SRCADDR1= (uint32_t) SendBuff, the source address is SendBuff;

Step 13: Set DMA_DSTADDR1= (uint32_t) &UART1_TDR, the destination address is the UART1_TDR register;

Step 14: Set DMA_CSR1.SRCINC to 1, the source address is incremented automatically;

Step 15: Set DMA_CSR1.DSTINC to 0, the destination address is fixed;

Step 16: Write 0x10064 to DMA_CNT1, and the data transmission amount is 100;

Step 17: Set DMA_CSR1.SIZE to 0, and the transmission data bit width to 8 bits;

Step 18: Set DMA_CSR1.TRANS to 1, block transmission (BLOCK);

Step 19: Set DMA_TRIG1.Type to 1, hardware trigger mode;

Step 20: Set DMA_TRIG1. HardSrc to 0x01, trigger DMA transmission when UART1_TDR register is empty;

Step 21: Set DMA_CSR1.EN to 1 to enable DMA channel 1 transmit;

Step 22: Set UART1_CR2.DMATX to 1, and enable the DMA hardware handshake logic of UART1 TXD;

Step 23: Query and wait for DMA_ISR.TC1 to become 1 to confirm that the DMA transmission is completed;

Step 24: Set UART1_CR2.DMATX to 0, and turn off the DMA hardware handshake logic of UART1 TXD;

Step 25: Query and wait for UART1_ISR.TXBUSY to become 0, confirm that the data has been transmitted through UART1;

Step 26: Repeat steps 9 ~ 26 if new data is to be transferred.



19.7.1.6 DMA receives data

The following is an example of DMA channel 2 receive data for UART1 (UART1_RXD pin is PA09). In this application example, the transmission clock UCLK is set to 24MHz, the baud rate is 115200bps, and the DMA data transmission amount is 100. The DMA transmission is started by hardware triggering, and the data in the UART1_RDR register is transferred to an 8-bit array in the SRAM area. .

The specific configuration process is as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOA to 1, SYSCTRL_APBEN2.UART1 to 1, SYSCTRL_AHBEN.DMA to 1, enable the configuration clock and working clock of GPIOA, UART1 and DMA respectively;

Step 2: Configure the UART1_RXD pin (that is, PA09) as the pull-up multiplexing input mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set UART1_CR1.SYNC to 0, and configure UART1 to be asynchronous full-duplex communication mode;

Step 4: Configure the data frame;

1. Start bit determination method: set UART1_CR1.START to 0, the falling edge of RXD signal
2. Parity bit: set UART1_CR1.PARITY to 0, no parity
3. Stop bit: configure UART1_CR1.STOP as 0, 1-bit length of stop bit

Step 5: Set UART1_CR2.SOURCE to 0, select the transmission clock source as PCLK=24MHz;

Step 6: Set UART1_CR1.OVER to 0, select 16 times sampling mode;

Step 7: Set UART1_BRR1.BRR1 to 0x0D, UART1_BRRF.BRRF to 0x00, configure baud rate to 115200bps;

Step 8: Set UART1_CR1.RXEN to 1 to enable reception;

Step 9: Define a variable `uint8_t RecvBuff[100]`;

Step 10: Write 0x00 to UART1_ICR to clear all flag bits of UART1;

Step 11: Set DMA_ICR.TC2 and DMA_ICR.TE2 to 0, clear all interrupt flags of DMA channel 2;

Step 12: Set DMA_SRCADDR2= (`uint32_t`) &UART1_RDR, the source address is the UART1_RDR register;

Step 13: Set DMA_DSTADDR2=(`uint32_t`) RecvBuff, the destination address is RecvBuff;

Step 14: Set DMA_CSR2.SRCINC to 0, the source address is fixed;

Step 15: Set DMA_CSR2.DSTINC to 1, and the destination address is incremented automatically;

Step 16: Write 0x10064 to DMA_CNT2, and the data transmission amount is 100;

Step 17: Set DMA_CSR2.SIZE to 0, and the transmission data bit width to 8 bits;

Step 18: Set DMA_CSR2.TRANS to 1, block transmission (BLOCK);

Step 19: Set DMA_TRIG2.Type to 1, hardware trigger mode;

Step 20: Set DMA_TRIG2. HardSrc to 0x00, trigger DMA transmission when UART1_RDR register is not empty;

Step 21: Set DMA_CSR2.EN to 1 to enable DMA channel 2 transmit;

Step 22: Set UART1_CR2.DMARX to 1, and enable the DMA hardware handshake logic of UART1 RXD;

Step 23: Query and wait for DMA_ISR.TC2 to become 1 to confirm that the DMA transfer is completed;

Step 24: Set UART1_CR2.DMARX to 0, and disable the DMA hardware handshake logic of UART1 RXD;

Step 25: Repeat steps 10 ~ 25 if new data is to be transferred.



19.7.2 Synchronous half-duplex programming examples

19.7.2.1 Transmit data in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable GPIO clock and UART configuration clock;
- Step 2: Configure the UARTx_TXD and UARTx_RXD pins as push-pull multiplexed output mode, and configure the slave chip select pin NCS as push-pull output mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR1.SYNC to 1, and configure UARTx to be synchronous half-duplex communication mode;
- Step 4: Configure UARTx_CR2.SOURCE, select the transmission clock source, and configure the baud rate. For details, please refer to chapter [19.3.2 Synchronous mode](#);
- Step 5: Pull down the NCS signal and select a slave;
- Step 6: Set UARTx_CR1.TXEN to 1 to enable transmit;
- Step 7: Set UARTx_ICR.TC to 0, and clear the transmission completion flag;
- Step 8: Write the 8-bit data to be transmitted to the UARTx_TDR register;
- Step 9: Query and wait for the UARTx_ISR.TC flag bit to be set to 1 to confirm that the data transmission is completed;
- Step 10: Repeat steps 7 ~ 10 to transmit the next frame of data;
- Step 11: Pull up the NCS signal to end the communication.

19.7.2.2 Receive data in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable GPIO clock and UART configuration clock;
- Step 2: Configure the UARTx_TXD and UARTx_RXD pins as push-pull multiplexed output mode, and configure the slave chip select pin NCS as push-pull output mode. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR1.SYNC to 1, and configure UARTx to be synchronous half-duplex communication mode;
- Step 4: Configure UARTx_CR2.SOURCE, select the transmission clock source, and configure the baud rate. For details, please refer to section [19.3.2 Synchronous mode](#);
- Step 5: Pull down the NCS signal and select a slave;
- Step 6: Write 0x00 to UARTx_ICR to clear all flags;
- Step 7: Set UARTx_CR1.RXEN to 1 to enable reception;
- Step 8: Query and wait for the UARTx_ISR.RC flag to be set to 1 to confirm that the data reception is completed;
- Step 9: Read the UARTx_RDR register and save the data;
- Step 10: Set UARTx_ICR.RC to 0, clear the reception completion flag;
- Step 11: Repeat steps 8 ~ 11 to receive the next 8-bit data;
- Step 12: Pull up the NCS signal to end the communication.



19.7.3 Single-wire half-duplex programming examples

19.7.3.1 Transmit data in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable the GPIO clock and UART configuration clock corresponding to the UART pin;
- Step 2: Configure the UARTx_TXD pin to open-drain multiplexed output mode, and connect an external pull-up resistor. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR2.SIGNAL to 1, and configure UARTx to be single-wire half-duplex communication mode;
- Step 4: Configure the data frame;
1. Start bit determination method: configure UARTx_CR1.START
 2. Parity bit: configure UARTx_CR1.PARITY
 3. Stop bit: configure UARTx_CR1.STOP
- Step 5: Configure UARTx_CR2.SOURCE and select the transmission clock source;
- Step 6: Configure UARTx_CR1.OVER and select sampling mode;
- Step 7: Configure the UARTx_BRR1 and UARTx_BRRF registers and configure the baud rate. For details, please refer to section [19.3.3.2 Fractional baud rate generator](#);
- Step 8: Set UARTx_CR1.TXEN to 1 and UARTx_CR1.RXEN to 1 to enable transmit and receive;
- Step 9: Set UARTx_ICR.TC to 0, and clear the transmission completion flag;
- Step 10: Write a frame of data to be transmitted into the UARTx_TDR register;
- Step 11: Query and wait for the UARTx_ISR.TC flag bit to be set to 1 to confirm that the data transmission is completed;
- Step 12: Repeat steps 9 ~ 12 to transmit the next frame of data.



19.7.3.2 Receive data in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.UARTx to 1, enable the GPIO clock and UART configuration clock corresponding to the UART pin;
- Step 2: Configure the UARTx_TXD pin to open-drain multiplexed output mode, and connect an external pull-up resistor. For the specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set UARTx_CR2.SIGNAL to 1, and configure UARTx to be single-wire half-duplex communication mode;
- Step 4: Configure the data frame;
1. Start bit determination method: configure UARTx_CR1.START
 2. Parity bit: configure UARTx_CR1.PARITY
 3. Stop bit: configure UARTx_CR1.STOP
- Step 5: Configure UARTx_CR2.SOURCE and select the transmission clock source;
- Step 6: Configure UARTx_CR1.OVER and select sampling mode;
- Step 7: Configure the UARTx_BRRI and UARTx_BRRF registers and configure the baud rate. For details, please refer to section [19.3.3.2 Fractional baud rate generator](#);
- Step 8: Write 0x00 to UARTx_ICR to clear all flags;
- Step 9: Set UARTx_CR1.TXEN to 1 and UARTx_CR1.RXEN to 1 to enable transmit and receive;
- Step 10: Query and wait for the UARTx_ISR.RC flag to be set to 1 to confirm that one frame of data has been received;
- Step 11: Query the error flags UARTx_ISR.PE and UARTx_ISR.FE to confirm whether the data is valid. If the data is invalid, perform error processing. If the data is valid, read the UARTx_RDR register and save the data;
- Step 12: Set UARTx_ICR.RC to 0, clear the reception completion flag;
- Step 13: Repeat steps 10 ~ 13 to receive the next frame of data.



19.8 List of registers

UART1 base address: UART1_BASE = 0x4001 3800

UART2 base address: UART2_BASE = 0x4000 4400

UART3 base address: UART3_BASE = 0x4000 4800

UART4 base address: UART4_BASE = 0x4000 4C00

UART5 base address: UART5_BASE = 0x4000 5000

UART6 base address: UART6_BASE = 0x4001 1400

Table 19-11 List of UART registers

Register name	Register address	Register description
UARTx_CR1	UARTx_BASE + 0x00	Control register 1
UARTx_CR2	UARTx_BASE + 0x04	Control register 2
UARTx_IER	UARTx_BASE + 0x08	Interrupt enable register
UARTx_BRRI	UARTx_BASE + 0x0C	Baud rate counter integer part register
UARTx_BRRF	UARTx_BASE + 0x10	Baud rate counter fractional part register
UARTx_ISR	UARTx_BASE + 0x1C	Interrupt flag register
UARTx_ICR	UARTx_BASE + 0x20	Interrupt flag clear register
UARTx_RDR	UARTx_BASE + 0x24	Receive data register
UARTx_TDR	UARTx_BASE + 0x28	Transmit data register
UARTx_ADDR	UARTx_BASE + 0x30	Slave address register
UARTx_MASK	UARTx_BASE + 0x34	Slave address mask register



19.9 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

19.9.1 UARTx_CR1 control register 1

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:11	RFU	-	Reserved bits, please keep the default value
10:9	OVER	RW	Sampling mode settings 00: 16 times sampling, Baud = $UCLK/(BRR1 \times 16 + BRRF)$ 01: 8 times sampling, Baud = $UCLK/(BRR1 \times 8)$ 10: 4 times sampling, Baud = $UCLK/(BRR1 \times 4)$ 11: dedicated sampling, Baud = $UCLK \times 256 / BRR1$ Caution 1: Dedicated sampling is only suitable for 2400, 4800, 9600 communication when the transmission clock is LSI/LSE Caution 2: When BRRF is a non-zero value, 16 times sampling is automatically adopted
8	START	RW	RXD signal START bit determination mode settings 0: RXD signal falling edge 1: RXD signal low level
7	RFU	-	Reserved bits, please keep the default value
6	SYNC	RW	Transmission sync-async mode settings 0: Working in asynchronous mode 1: Working in synchronous mode
5:4	STOP	RW	Stop bit length settings 00: 1 bit 01: 1.5 bit 10: 2 bit 11: Reserved Caution: STOP bit must be cleared in synchronous mode
3:2	PARITY	RW	Check digit settings 00: No parity 01: Custom check 10: Even parity 11: Odd parity Caution 1: When there is no parity check, the data word length is 8 bits; when there is a check bit, the data word length is 9 bits; Caution 2: In the multi-computer communication mode, both the master and the slave are configured as custom check.
1	RXEN	RW	Receive circuit enable control 0: Disabled 1: Enabled
0	TXEN	RW	Transmit circuit enable control 0: Disabled 1: Enabled



19.9.2 UARTx_CR2 control register 2

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9:8	SOURCE	RW	UART transmission clock source configuration 00: UCLK is from PCLK 01: UCLK is from PCLK 10: UCLK is from LSE 11: UCLK is from LSI
7	DMATX	RW	DMA transmit data enable control 0: Disabled 1: Enabled
6	DMARX	RW	DMA receive data enable control 0: Disabled 1: Enabled
5	TXINV	RW	TXD pin outputs signal inversion control 0: The TXD pin outputs the non-inverting signal 1: The TXD pin outputs the inverted signal
4	RXINV	RW	RXD pin inputs signal inversion control 0: The RXD pin signal is directly transmitted to the receiving circuit 1: The RXD pin signal is inverted and transmitted to the receiving circuit
3	RTSEN	RW	RTS hardware signal enable control 0: Disabled 1: Enabled
2	CTSEN	RW	CTS hardware signal enable control 0: Disabled 1: Enabled
1	SIGNAL	RW	Single bus mode enable control 0: Disabled, transmit data through TXD port and receive data through RXD port 1: Enabled, transmit and receive data through the TXD port
0	ADDREN	RW	Slave address recognition enable control 0: Disabled 1: Enabled



19.9.3 UARTx_BRR1 baud rate counter integer part register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	BRR1	RW	Baud rate counter integer part

19.9.4 UARTx_BRRF baud rate counter fractional register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:4	RFU	-	Reserved bits, please keep the default value
3:0	BRRF	RW	Baud rate counter fractional part

19.9.5 UARTx_TDR transmit data register

Address offset: 0x28 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:9	RFU	-	Reserved bits, please keep the default value
8:0	TDR	WO	Data to be transmitted Caution: When UARTX_CR1.PARITY is set to a custom verification, the TXD pin will send UARTx_TDR[8]

19.9.6 UARTx_RDR receive data register

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:9	RFU	-	Reserved bits, please keep the default value
8:0	RDR	RO	Received data Caution: When UARTx_CR1.PARITY is set to a custom verification, the receiving circuit will receive UARTx_TDR[8]



19.9.7 UARTx_IER interrupt enable register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	CTS	RW	CTS signal change interrupt enable control 0: Disabled 1: Enabled
5	RFU	-	Reserved bits, please keep the default value
4	PE	RW	Parity check error interrupt enable control 0: Disabled 1: Enabled
3	FE	RW	Frame structure error interrupt enable control 0: Disabled 1: Enabled
2	RC	RW	Receive completion interrupt enable control 0: Disabled 1: Enabled
1	TC	RW	Transmit completion interrupt enable control 0: Disabled 1: Enabled
0	TXE	RW	Transmit buffer empty interrupt enable control 0: Disabled 1: Enabled



19.9.8 UARTx_ISR interrupt flag register

Address offset: 0x1C Reset value: 0x0000 0001

Bit field	Name	Permission	Function description
31:9	RFU	-	Reserved bits, please keep the default value
8	TXBUSY	RO	TXD transmitting status 0: TDR register and transmit shift register are empty 1: TDR register or transmit shift register is not empty
7	CTSLV	RO	CTS signal level status 0: CTS signal is low level 1: CTS signal is high level
6	CTS	RO	CTS signal change interrupt flag 0: No CTS level change detected 1: CTS level change has been detected
5	MATCH	RO	Slave address match flag 0: No match address was detected. 1: The match address has been detected
4	PE	RO	Parity check error interrupt flag 0: No parity check error was detected 1: Parity check error has been detected
3	FE	RO	Frame structure error interrupt flag 0: No frame structure error was detected 1: The frame structure error has been detected
2	RC	RO	Receive completion interrupt flag 0: The reception of a frame of data has not been completed 1: The reception of a frame of data has been completed
1	TC	RO	Transmit completion interrupt flag The transmit shift register is set by hardware when the transmission of a frame of data is completed. 0: The transmission of a frame of data has not been completed 1: The transmission of a frame of data has been completed
0	TXE	RO	Transmit buffer empty flag 0: There is data in the transmit buffer 1: No data in transmit buffer Caution: Write the uartx_tdr register will clear the flag bit



19.9.9 UARTx_ICR interrupt flag clear register

Address offset: 0x20 Reset value: 0x0000 00FF

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	CTS	R1W0	Clear control of CTS signal change interrupt flag W0: CTS signal change interrupt flag cleared W1: No function
5	RFU	-	Reserved bits, please keep the default value
4	PE	R1W0	Clear control of parity check error interrupt flag W0: Parity check error interrupt flag cleared W1: No function
3	FE	R1W0	Clear control of frame error interrupt flag W0: Frame structure error interrupt flag cleared W1: No function
2	RC	R1W0	Clear control of receiving completion interrupt flag W0: Receive completion interrupt flag cleared W1: No function
1	TC	R1W0	Clear control of transmitting completion interrupt flag W0: Transmit completion interrupt flag cleared W1: No function
0	RFU	-	Reserved bits, please keep the default value

19.9.10 UARTx_ADDR slave address register

Address offset: 0x30 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	ADDR	RW	Slave address register

19.9.11 UARTx_MASK slave address mask register

Address offset: 0x34 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	MASK	RW	Slave address mask register



20 Serial peripheral interface (SPI)

20.1 Overview

Serial peripheral interface (SPI) is a synchronous serial data communication interface, which is often used for synchronous serial communication between MCU and external devices. CW32L083 integrates 2 serial peripheral SPI interfaces, supports bidirectional full-duplex, single-wire half-duplex and simplex communication modes, can configure MCU as master or slave, supports multi-master communication mode, supports direct memory access (DMA).

20.2 Main features

- Supports master mode, slave mode
- Supports full-duplex, single-wire half-duplex, simplex
- Selectable 4 to 16 bit data frame width
- Supports sending and receiving data LSB or MSB first
- Programmable clock polarity and clock phase
- Communication rates up to $PCLK/4$ in master mode
- Communication rates up to $PCLK/4$ in slave mode
- Supports multi-computer communication mode
- 8 interrupt sources with flag bits
- Supports direct memory access (DMA)

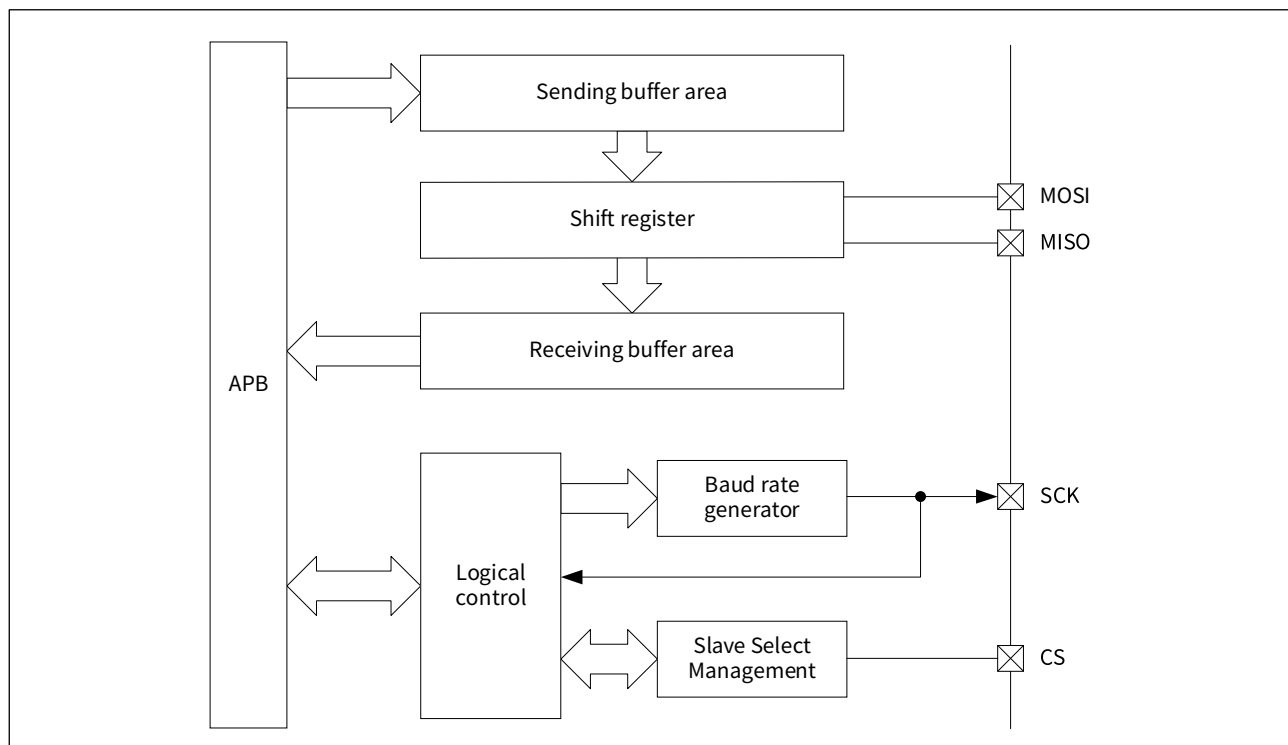


20.3 Functional description

20.3.1 Functional block diagram

The functional block diagram of the SPI controller is shown in the following figure:

Figure 20-1 SPI functional block diagram



SPI is generally connected to external devices through 4 pins:

- MOSI
Master output/slave input, used for data transmission in master mode and data reception in slave mode;
- MISO
Master input/slave output, used for data reception in master mode and data transmission in slave mode;
- SCK
Synchronous serial clock, master clock output and slave clock input, transmit or receive master synchronous clock;
- CS
Slave selection is also used for bus conflict detection in multi-computer communication. Refer to section [20.3.3 Slave select pin CS](#).

CW32L083 supports the user to flexibly select GPIO as the SPI communication pin, which is realized by multiplexing the AFR function, please refer to the pin definitions in the Datasheet.

SPI supports a variety of operating modes. In different operating modes, each pin has different functions. The pin configuration is shown in the following table (where x=1,2):

Table 20-1 SPI ports configuration

SPI pins	Mode configuration	Function	GPIO configuration
SPIx_SCK	Master	Serial clock output	Digital, push-pull output, multiplexed
	Slave	Serial clock input	Digital, floating input, multiplexed
SPIx_MOSI	Full duplex/master	Master data output	Digital, push-pull output, multiplexed
	Full duplex/slave	Slave data input	Digital, floating input, multiplexed
	Single-wire half-duplex/ master	Master data transmitting and receiving	Digital, push-pull output, multiplexed
	Single-wire half-duplex/ slave	Do not use	Can be used as general purpose I/O
	Simplex single transmitting/master	Master data output	Digital, push-pull output, multiplexed
	Simplex single transmitting/slave	Do not use	Can be used as general purpose I/O
	Simplex single receiving/ master	Do not use	Can be used as general purpose I/O
	Simplex single receiving/ slave	Slave data input	Digital, floating input, multiplexed
SPIx_MISO	Full duplex/master	Master data input	Digital, floating input, multiplexed
	Full duplex/slave	Slave data output	Digital, push-pull output, multiplexed
	Single-wire half-duplex/ master	Do not use	Can be used as general purpose I/O
	Single-wire half-duplex/ slave	Slave data transmission and reception	Digital, push-pull output, multiplexed
	Simplex single transmitting/master	Do not use	Can be used as general purpose I/O
	Simplex single transmitting/slave	Slave data output	Digital, push-pull output, multiplexed
	Simplex single receiving/ master	Master data output	Digital, push-pull output, multiplexed
	Simplex single receiving/ slave	Do not use	Can be used as general purpose I/O
SPIx_CS	Master (SSM=0)	Slave select input	Digital, floating input, multiplexed
	Master (SSM=1)	Slave select output	Digital, push-pull output, multiplexed
	Slave (SSM=0)	Slave select input	Digital, floating input, multiplexed
	Slave (SSM=1)	Do not use	Can be used as general purpose I/O

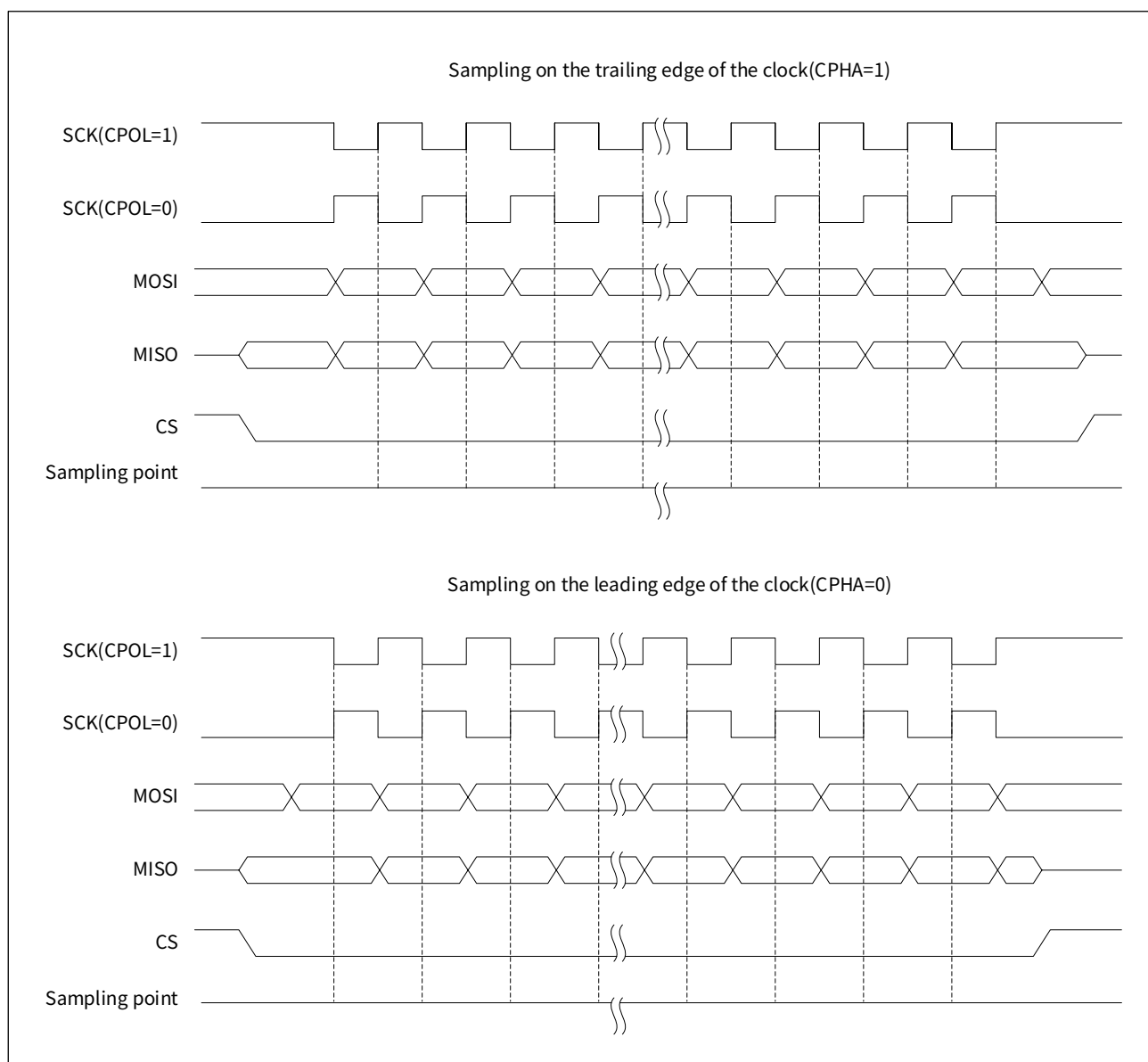


20.3.2 Communication timing and data format

Communication timing

The following figure shows the communication timing of SPI. The CS, SCK, and MOSI signals are all controlled by the master, and the MISO signal is the slave response signal. The slave selects the CS signal from high level to low level, which is the start signal of SPI communication. When the slave detects the start signal, it starts to communicate with the master. In each SCK clock cycle, the MOSI and MISO signal lines transmit one bit of data. CS changes from low level to high, which is the stop signal of communication, indicating the end of this communication.

Figure 20-2 SPI communication timing



Data frame format

The data frame width is configured by the WIDTH bit field of the control register SPIx_CR1, which can be set to any data bit width from 4 to 16 bits.

The size of the data is configured by the LSBF bit field of the control register SPIx_CR1, and the most significant bit first (MSB) or the least significant bit first (LSB) can be selected.

Clock frequency

The synchronous serial clock SCK signal is controlled and generated by the SPI host, and its clock source is PCLK. The frequency division factor is set by configuring the BR bit field of the control register SPIx_CR1, and the frequency division can be selected from 2 to 128. For SPI slaves, configuring SPIx_CR1.BR has no effect.

Clock polarity, clock phase

Clock polarity CPOL refers to the level state of the SCK serial clock line when the device is in an idle state without data transmission. Configure through the CPOL bit field of the control register SPIx_CR1: set SPIx_CR1.CPOL to 0, and the SCK clock line is low when it is idle; set SPIx_CR1.CPOL to 1, and the SCK clock line is high when it is idle.

The clock phase CPHA refers to the sampling and shifting moment of the data. Configure through the CPHA of the control register SPIx_CR1: set SPIx_CR1.CPHA to 0, sample on the front edge of SCK (the clock edge when SCK changes from idle state to non-idle state), and the trailing edge (SCK changes from non-idle state to idle state). Clock edge) shift; set SPIx_CR1.CPHA to 1, shift on the leading edge of SCK, and sample on the trailing edge.

According to the different configurations of clock polarity CPOL and clock phase CPHA, SPI can set 4 level modes. The master and slave need to be configured to the same level mode to ensure normal communication.

Table 20-2 SPI level mode

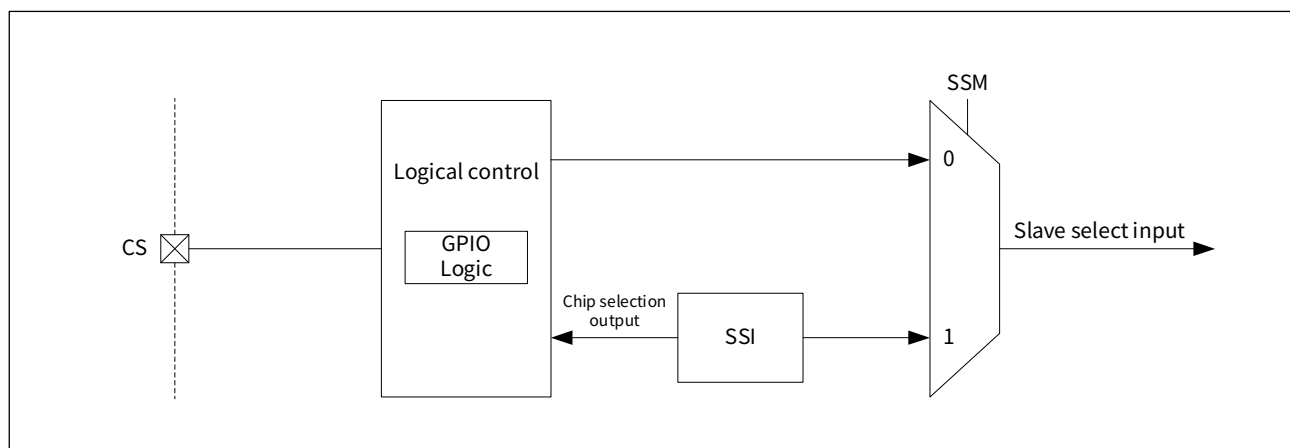
CPOL	CPHA	SCK clock when idle	Sampling time
0	0	Low level	Front edge
0	1	Low level	Back edge
1	0	High level	Front edge
1	1	High level	Back edge



20.3.3 Slave select pin CS

The following figure shows a schematic diagram of the configuration management of slave select pin CS. In master mode, CS can be selected as input or output. When used as input, it is used to detect bus conflicts in multi-master mode, and when used as output, it is used to generate slave chip select signals. In slave mode, CS acts as a device chip select input.

Figure 20-3 Slave select pin management



In master and slave mode, the slave select CS is managed by the SSM bit field of the control register SPIx_CR1.

CS pin in master mode

Set SPIx_CR1.SSM to 0, and CS is configured as an input to detect whether there is a bus conflict in the multi-computer communication system (Caution that the master needs to select the slave to communicate through other GPIOs at this time), please refer to section [20.3.7 Multi-machine communication](#).

Setting SPIx_CR1.SSM to 1, the slave select pin CS is configured as an output for generating the slave select signal. The CS pin output level is determined by the SSI bit field of the slave select register SPIx_SSI: set SPIx_SSI.SSI to 1, CS outputs a high level; set SPIx_SSI.SSI to 0, CS outputs a low level.

CS pin in slave mode

Set SPIx_CR1.SSM to 0 to use CS signal as device select. The CS level determines whether this unit is selected: when CS is low level, this unit is selected; when CS is high level, this unit is deselected.

Set SPIx_CR1.SSM to 1, do not use CS as the device selection, the slave select is determined by the SSI bit field value of the SPIx_SSI register. Set SPIx_SSI.SSI to 0, this machine is selected; set SPIx_SSI.SSI to 1, this machine is unchecked. In this configuration, the user program sets whether the machine is selected by software, and the CS pin can be used as a common IO.

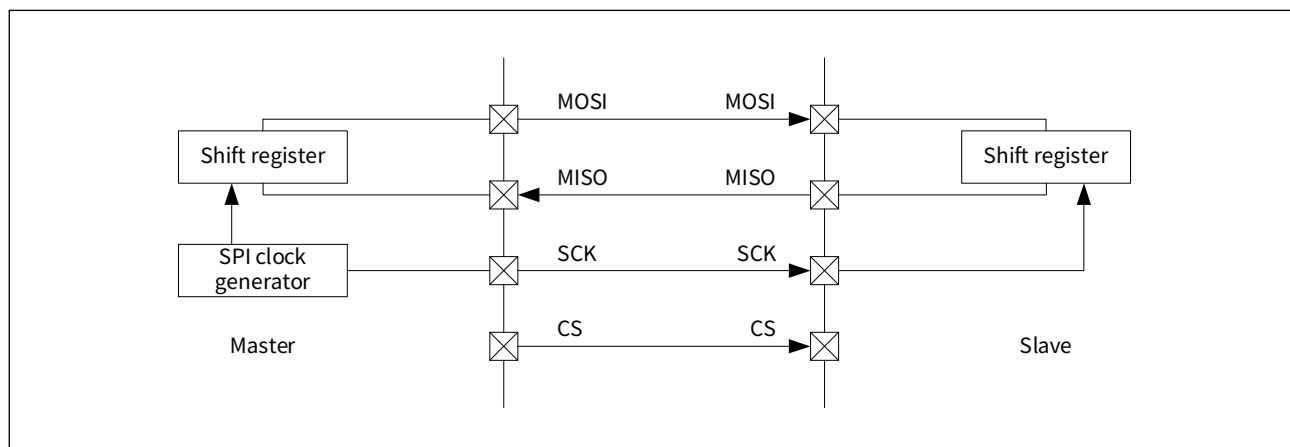
20.3.4 Full-duplex mode

SPI supports full-duplex communication mode. In this mode, the shift registers of the master and slave are connected through two unidirectional data lines, MOSI and MISO, and two lines of data are simultaneously performed under the control of the SCK clock signal provided by the host. transmission.

Set the MODE bit field of the control register SPIx_CR1 to 0x0 to make the SPI work in full-duplex communication mode.

A typical application block diagram of full-duplex mode is shown in the following figure:

Figure 20-4 Full-duplex communication mode



Master transmits and receives

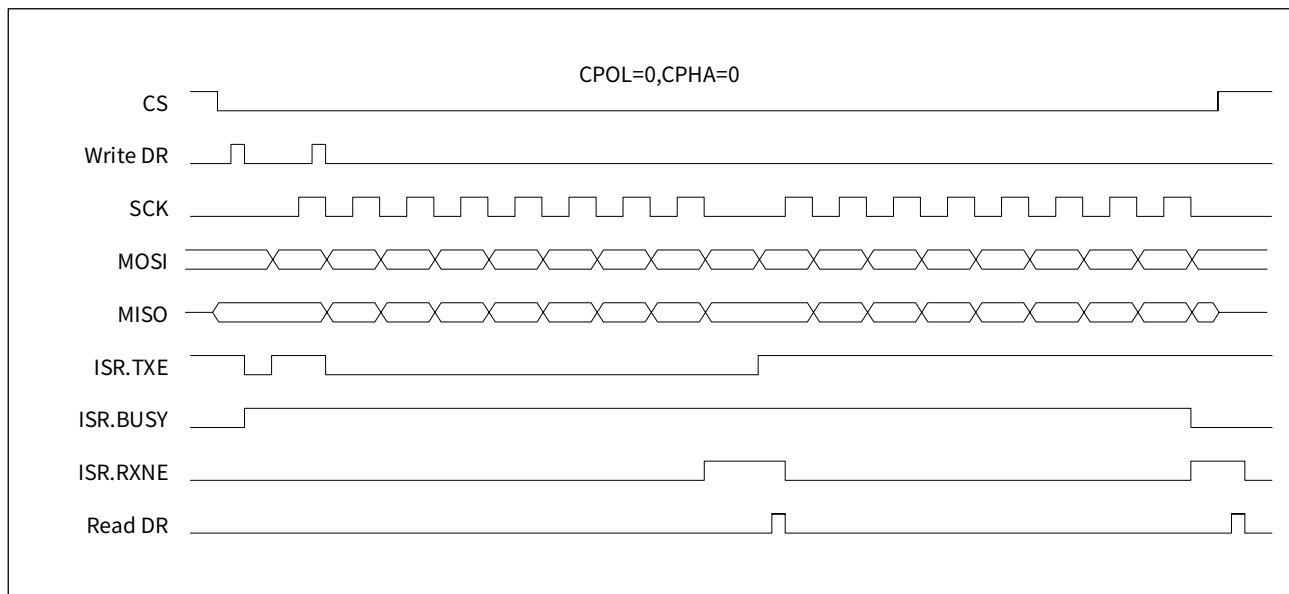
Set SPIx_CR1.MSTR to 1, SPI works in master mode.

The master sets SPIx_SSI.SSI to 0, and the slave selects the CS pin to output a low level as the communication start signal.

When the transmit buffer is empty, that is, the SPIx_ISR.TXE flag is 1, write a frame of data to be sent into the SPIx_DR register, the data is output from the MOSI pin under the control of the synchronous shift clock signal, and the MISO pin is simultaneously pin data is received into the shift register. At the end of transmitting a data frame, the non-empty flag bit SPIx_ISR.RXNE of the receive buffer is set to 1 by hardware, indicating that a frame of data has been received, and the SPIx_DR register can be read at this time.

Set SPIx_SSI.SSI to 1, and the slave select pin CS outputs a high level to end this communication.

Figure 20-5 Master transmit and receive timing in full-duplex mode (two bytes)



Slave transmits and receives

Set SPIx_CR1.MSTR to 0, SPI works in slave mode.

Before the slave select CS signal is pulled low, the slave needs to set SPIx_ICR.FLUSH to 0 to clear the transmit buffer and shift register, and write the first frame data to be transmitted into the SPIx_DR register.

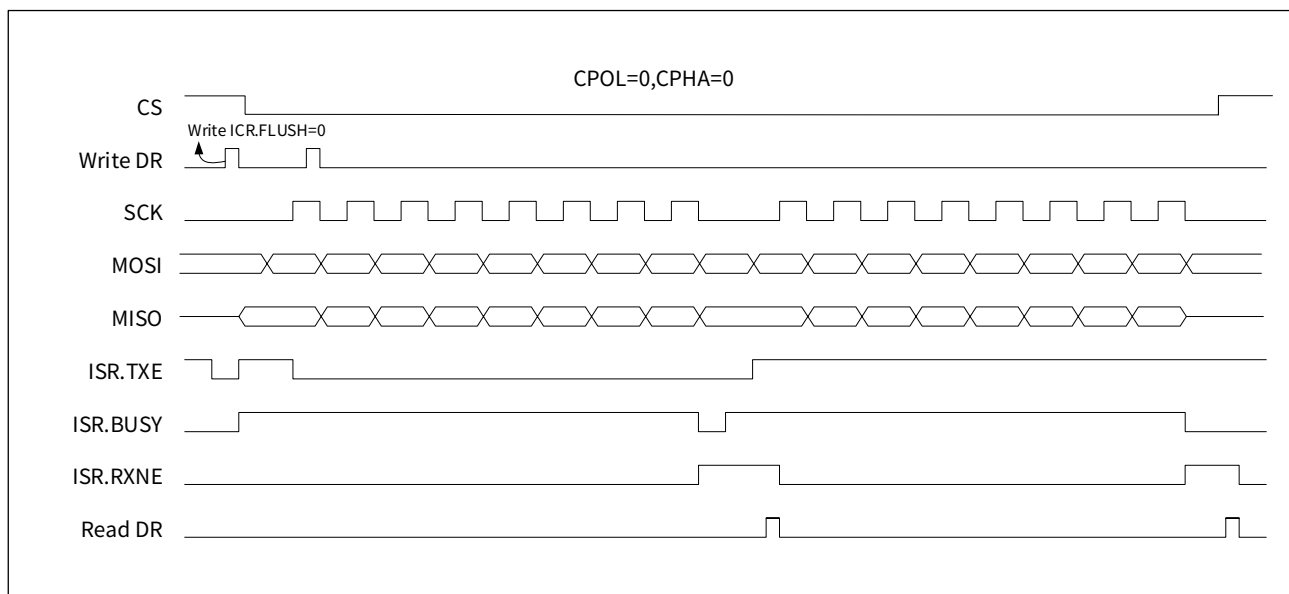
When the CS signal is pulled low, the written data will be output from the MISO pin under the control of the master's synchronous shift clock signal, and at the same time receive the data from the MOSI pin to the shift register.

If it is continuous communication of multiple data frames, the user should continuously query the SPIx_ISR.TXE flag bit. Once the flag is 1, immediately write the data to be transmitted into the SPIx_DR register to avoid data leakage.

When the receive buffer is not empty, that is, the SPIx_ISR.RXNE flag is 1, indicating that a frame of data has been received, and the SPIx_DR register can be read at this time.

This communication ends when it is detected that the CS pin changes to a high level.

Figure 20-6 Slave transmit and receive timing in full-duplex mode (two bytes)



20.3.5 Single-wire half-duplex mode

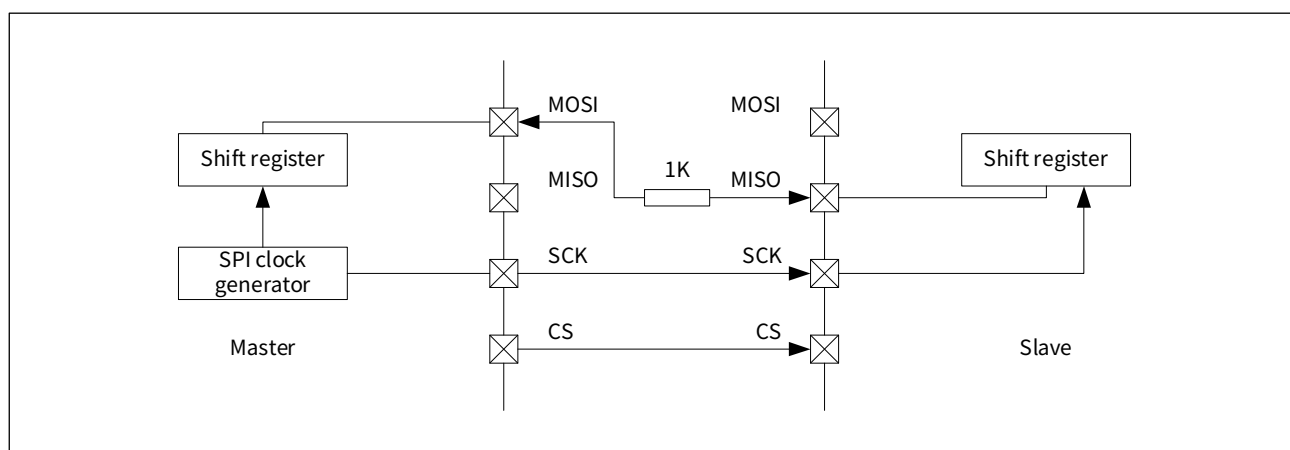
SPI supports single-wire half-duplex communication mode. In this mode, the master and slave communicate data through a bidirectional data line. The master uses MOSI, the slave uses MISO, and other unused SPI signal lines can be used by other functions.

Set the MODE bit field of the control register SPIx_CR1 to 0x3 to make the SPI work in single-wire half-duplex mode.

The HDOE bit field of the control register SPIx_CR2 selects the transmitting and receiving direction. When HDOE is 0, it is only received, and when HDOE is 1, it is only transmitted.

A typical application block diagram of single-wire half-duplex mode is shown in the following figure:

Figure 20-7 Single-wire half-duplex mode



During single-wire half-duplex communication, since the communication directions of the master and the slave cannot be guaranteed to switch synchronously, there may be a driving conflict and cause device damage. It is recommended to connect a resistor in series on the data line between the master and the slave to limit the current. .

When the SPI is used as a slave, the single-wire half-duplex mode can be used to communicate with a standard UART transceiver in synchronous mode. At this time, the SPI must be configured as a fixed level mode: the clock polarity CPOL is 1, and the clock phase is CPHA. is 1.

Master transmits

Set SPIx_CR1.MSTR to 1, SPI works in master mode; set SPIx_CR2.HDOE to 1, the master only transmits data.

The master sets SPIx_SSI.SSI to 0, and outputs a low level on the slave selection pin CS as a communication start signal.

When the transmit buffer is empty, that is, the SPIx_ISR.TXE flag bit is 1, a frame of data to be transmitted is written into the SPIx_DR register, and the data is output from the MOSI pin under the control of the synchronous shift clock signal.

After writing the last frame of data, you must wait for the transmit buffer to be empty, that is, the SPIx_ISR.TXE flag becomes 1, and the SPIx_ISR.BUSY flag becomes 0 to ensure that the data is transmitted. Then set SPIx_SSI.SSI to 1, select the CS pin to output a high level in the slave, and end this communication.

Master receives

Set SPIx_CR1.MSTR to 1, SPI works in master mode; set SPIx_CR2.HDOE to 0, the master only receives data.

The master sets SPIx_SSI.SSI to 0, and the slave selects the CS pin to output a low level as the communication start signal.

When the transmit buffer is empty, that is, the SPIx_ISR.TXE flag is 1, write a frame of dummy data to the SPIx_DR register to start the transmission.

When the receive buffer is not empty, that is, the SPIx_ISR.RXNE flag is 1, indicating that a frame of data has been received, and the SPIx_DR register can be read at this time.

If you want to receive multiple frames of data, repeat the above steps to write to SPIx_DR and read the received data from SPIx_DR.

When all data frames are received, set SPIx_SSI.SSI to 1, select the CS pin to output a high level in the slave, and end this communication.

Slave transmits

Set SPIx_CR1.MSTR to 0, SPI works in slave mode; set SPIx_CR2.HDOE to 1, the slave only transmits data.

Before the slave select CS signal is pulled low, the slave needs to set SPIx_ICR.FLUSH to 0 to clear the transmit buffer and shift register, and write the first frame data to be transmitted into the SPIx_DR register.

When the CS signal is pulled low, the written data will be output from the MISO pin under the control of the master's synchronous shift clock signal.

If it is continuous communication of multiple data frames, the user should continuously query the SPIx_ISR.TXE flag bit. Once the flag is 1, immediately write the data to be transmitted into the SPIx_DR register to avoid data leakage.

This communication ends when it is detected that the CS pin changes to a high level.

Slave receives

Set SPIx_CR1.MSTR to 0, SPI works in slave mode; set SPIx_CR2.HDOE to 0, the slave only receives data.

When the CS pin is detected to go low, the slave starts to communicate with the master.

When the receive buffer is not empty, that is, the SPIx_ISR.RXNE flag becomes 1, indicating that a frame of data has been received, and the SPIx_DR register can be read at this time.

This communication ends when it is detected that the CS pin changes to a high level.



20.3.6 Simplex mode

SPI supports simplex communication mode, and the master and slave communicate with single transmitting or single receiving through a unidirectional data line.

The master uses the MOSI signal line for single transmitting communication, and the MISO signal line for single receiving communication; the slave uses the MOSI signal line for single receiving communication, and the MISO signal line for single transmitting communication, and the unused signal line can be used for other functions.

Set the MODE bit field of the control register SPIx_CR1 to 0x1, and the SPI works in the simplex single transmitting communication mode; set the MODE bit field to 0x2, and the SPI works in the simplex single receiving communication mode.

Caution:

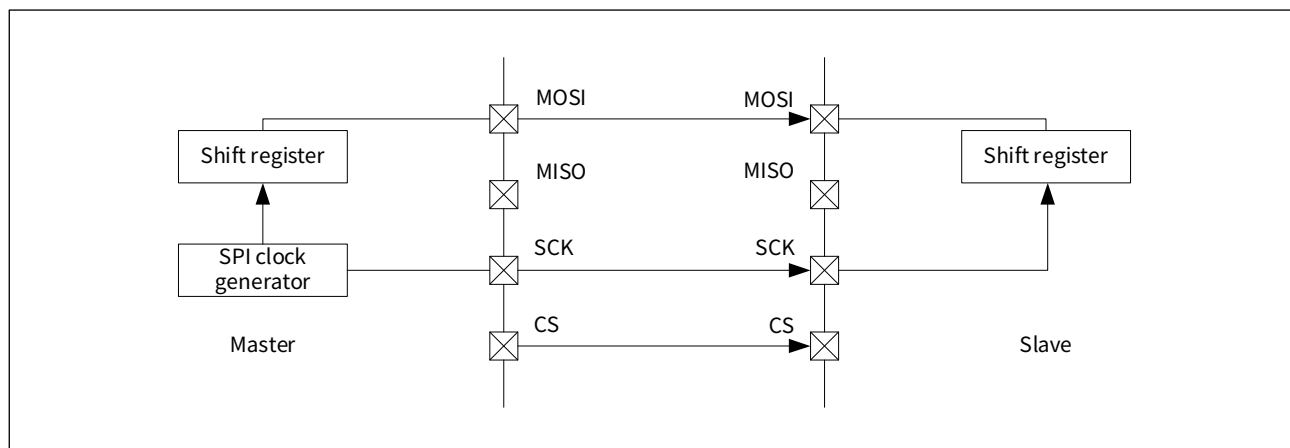
In simplex single receiving mode, all events related to the receive stream on the transmitter side, such as the receive buffer overflow error flag bit SPIx_ISR.OV, must be ignored.



20.3.6.1 Master single transmitting/slave single receiving

In the application scenario of single transmitting by the master and single receiving of the slave, the master and the slave use a MOSI data line to communicate. The application block diagram is shown in the following figure:

Figure 20-8 Master single transmitting, slave single receiving mode



Master single transmitting

Set SPIx_CR1.MODE to 0x1, SPI works in simplex single transmitting communication mode; set SPIx_CR1.MSTR to 1, SPI works in master mode.

Set SPIx_SSI.SSI to 0, and select the CS pin to output a low level in the slave as the communication start signal.

When the transmit buffer is empty, that is, the SPIx_ISR.TXE flag bit is 1, a frame of data to be sent is written into the SPIx_DR register, and the data is output from the MOSI pin under the control of the synchronous shift clock signal.

After writing the last frame of data, you must wait for transmit buffer empty flag SPIx_ISR.TXE to become 1, and the SPI bus busy flag SPIx_ISR.BUSY to become 0 to ensure that the data is transmitted. Then set SPIx_SSI.SSI to 1, so that the slave selects the CS pin to output a high level, and ends this communication.

Slave single receiving

Set SPIx_CR1.MODE to 0x2, SPI works in simplex single receiving communication mode; set SPIx_CR1.MSTR to 0, SPI works in slave mode.

When the CS pin is detected to go low, the slave starts to communicate with the master.

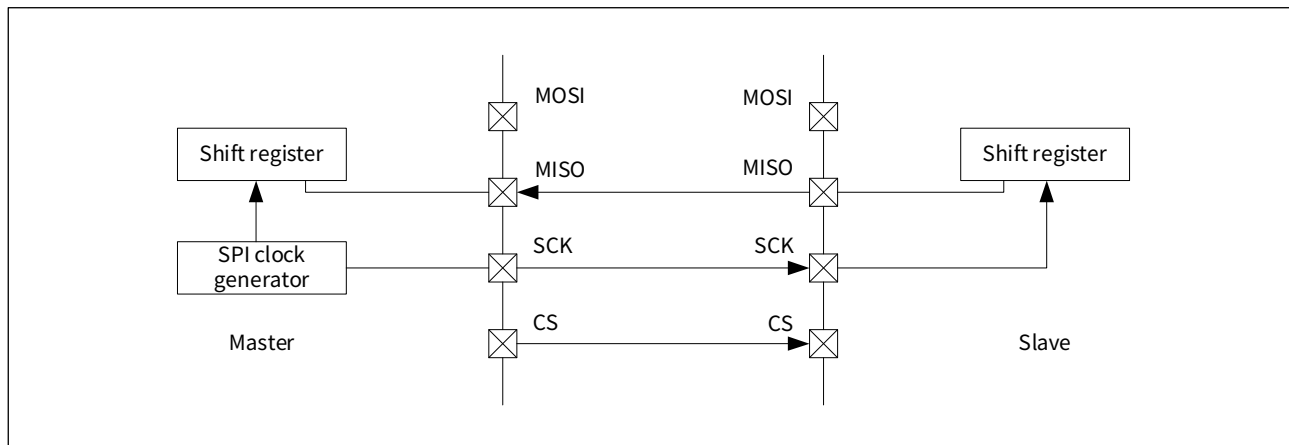
When the receive buffer is not empty, that is, the SPIx_ISR.RXNE flag is 1, indicating that a frame of data has been received, and the SPIx_DR register can be read at this time.

This communication ends when it is detected that the CS pin changes to a high level.

20.3.6.2 Master single receiving/slave single transmitting

In the application scenario of the master single receiving and the slave single transmitting, the master and the slave use a MISO data line to communicate. The application block diagram is shown in the following figure:

Figure 20-9 Master single receiving, slave single transmitting mode



Master single receiving

Set SPIx_CR1.MODE to 0x2, SPI works in simplex single receiving communication mode; set SPIx_CR1.MSTR to 1, SPI works in master mode.

Set SPIx_SSI.SSI to 0, and select the CS pin to output a low level in the slave as the communication start signal.

When the transmit buffer is empty, that is, the SPIx_ISR.TXE flag is 1, write a frame of dummy data to the SPIx_DR register to start the transmission.

When the receive buffer is not empty, that is, the SPIx_ISR.RXNE flag is 1, indicating that a frame of data has been received, and the SPIx_DR register can be read at this time.

If you want to receive multiple frames of data, repeat the above steps to write to SPIx_DR and read the received data from SPIx_DR.

When all data frames are received, set SPIx_SSI.SSI to 1, and the slave selects the CS pin to output a high level to end this communication.

Slave single transmitting

Set SPIx_CR1.MODE to 0x1, SPI works in simplex single transmitting communication mode; set SPIx_CR1.MSTR to 0, SPI works in slave mode.

Before the slave selection signal CS is pulled low, the slave needs to set SPIx_ICR.FLUSH to 0 to clear the transmit buffer and shift register, and write the first frame data to be transmitted into the SPIx_DR register.

When the CS signal is pulled low, the written data is output from the MISO pin under the control of the master's synchronous shift clock signal.

If it is continuous communication of multiple data frames, the user should continuously query the SPIx_ISR.TXE flag bit. Once the flag is 1, immediately write the data to be transmitted into the SPIx_DR register to avoid data leakage.

This communication ends when it is detected that the CS pin changes to a high level.

20.3.7 Multi-machine communication

SPI supports multi-machine communication mode. In this mode, the slave select CS pin of the master should be configured as an input and connected to the bus application signal of other masters to detect whether there is a conflict on the SPI bus.

If the slave select CS pin of a master is pulled to a low level, it means that another master is occupying the bus, the master will generate a mode error (please refer to section [20.3.9 Error flags](#)), the master SPI will be disabled, and the SPI will be disabled. Avoid SPI bus conflicts.

If the slave of a master selects the CS pin to detect a high level, it means that the SPI bus is idle. At this time, if the master wants to communicate with the slave, it must first apply for a signal on the bus to output a low level to other masters. CS signal, get SPI bus control, and then select a slave to start communication.

[Figure 20-10 Multi-machine communication system](#) shows a typical multi-machine communication system. Taking the communication between master A and slave 1 as an example, the operation process is as follows:

Step 1: Master A detects the CS pin until a high level occurs;

Step 2: GPIO0 of master A outputs a low level to obtain bus control, and master B is disabled;

Step 3: GPIO1 of master A outputs low level, and slave 1 is selected;

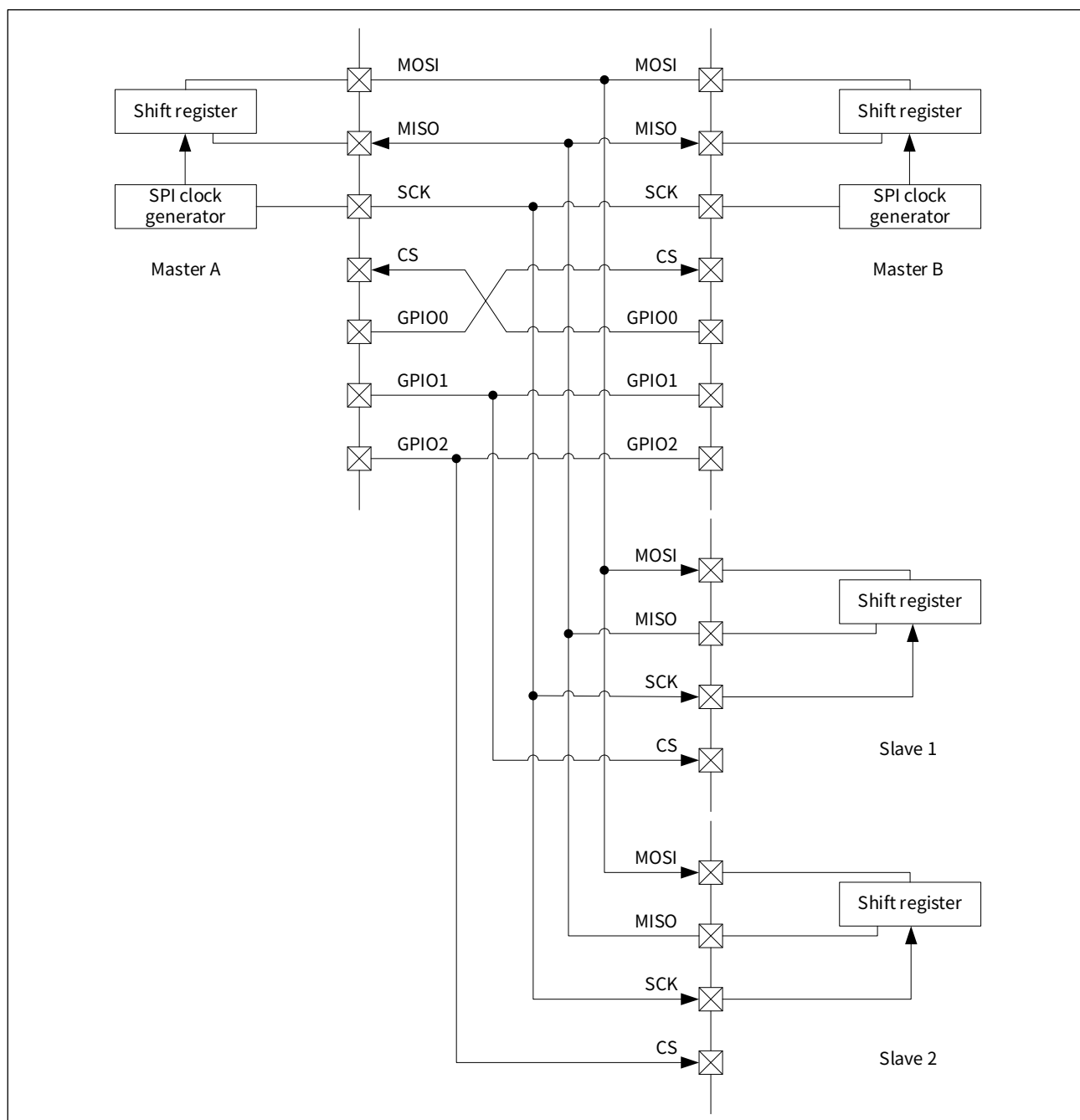
Step 4: The master A communicates with the slave 1;

Step 5: GPIO1 of master A outputs a high level, releasing slave 1;

Step 6: GPIO0 of master A outputs a high level, releasing the SPI bus.



Figure 20-10 Multi-machine communication system



In order to ensure the communication reliability in the multi-machine communication mode, the MIS0HD bit field of the slave control register SPIx_CR1 should be set to 1. When the slave is selected, the MISO pin is CMOS output; when it is not selected, the MISO pin is high resistance output.

20.3.8 Status flags

There are 6 status flags in the SPI controller to indicate the general working status of the SPI.

Transmit buffer empty flag (SPIx_ISR.TXE)

When the transmit data is transferred from the SPIx_DR register to the shift register, the SPIx_ISR.TXE flag will be set by hardware, indicating that the transmit buffer is empty, and new data to be transmitted is allowed to be written to the SPIx_DR register. While writing data to the SPIx_DR register, the SPIx_ISR.TXE flag will be automatically cleared.

Receive buffer not empty flag (SPIx_ISR.RXNE)

When the received data is transferred from the shift register to the SPIx_DR register, the SPIx_ISR.RXNE flag will be set by hardware, indicating that the reception of a frame of data has been completed. At this time, the SPIx_DR register can be read, and the SPIx_ISR will be cleared while reading the SPIx_DR register. RXNE flag bit.

Users can also manually clear the SPIx_ISR.RXNE flag by software.

Bus busy flag bit (SPIx_ISR.BUSY)

The SPIx_ISR.BUSY flag bit, set and cleared by hardware, is used to indicate the current SPI communication status.

When preparing or performing data transmission (there is data in the transmit buffer or data in the shift register), the BUSY flag will be set by hardware, indicating that the SPI interface is in a busy state;

When there is no data transmission (no data in the send buffer and no data in the shift register), the BUSY flag is automatically cleared by hardware, indicating that the SPI interface is in an idle state.

Slave select signal status (SPIx_ISR.SSLVL)

The SPIx_ISR.SSLVL status bit, set and cleared by hardware, indicates the level status of the slave select input signal.

SPIx_ISR.SSLVL is 0, the slave select CS input is low, and the slave is selected; SPIx_ISR.SSLVL is 1, the slave select CS input is high, and the slave is not selected.

Slave select input rising edge flag (SPIx_ISR.SSR)

The SPIx_ISR.SSR flag bit is used to indicate whether the slave select CS input signal has a rising edge.

SPIx_ISR.SSR is 0, indicating that the slave select CS input has no rising edge; SPIx_ISR.SSR is 1, indicating that the slave select input has a rising edge.

Slave select input falling edge flag (SPIx_ISR.SSF)

The SPIx_ISR.SSF flag bit is used to indicate whether the slave select CS input signal has a falling edge.

SPIx_ISR.SSF is 0, indicating that the slave select CS input has no falling edge; SPIx_ISR.SSF is 1, indicating that the slave select CS input has a falling edge.



20.3.9 Error flags

There are 4 error flags in the SPI controller to indicate whether an error has occurred in the SPI.

Mode error flag (SPIx_ISR.MODF)

SPIx_ISR.MODF flag bit, used to detect bus conflict in SPI multi-machine communication mode.

When the SPI works in master mode and the slave select CS pin is configured as an input, if the CS pin input is low, a mode error will occur, and the SPIx_ISR.MODF flag is set by hardware, indicating that other SPI masters are occupying the bus at this time.

After a mode error occurs, SPIx_CR1.EN is cleared and the SPI is forced to shut down.

Setting SPIx_ICR.MODF to 0 can clear the SPIx_ISR.MODF flag. After clearing, the user needs to reconfigure the SPI controller.

After a mode error occurs, if the SPI controller is re-enabled, the SPI can still perform normal data transmission, but the SPIx_ISR.MODF flag will remain set until cleared by user software.

Slave select error flag in slave mode (SPIx_ISR.SSERR)

When the SPI is working in slave mode and a valid data transfer is in progress, if the slave select CS input is pulled high, a slave select error will occur, and the SPIx_ISR.SSERR flag will be set by hardware.

The occurrence of a slave select error will cause an error in the current data transmission, and the slave will enter the unselected state.

After a slave select error occurs, if the slave select CS input is pulled low again, the SPI can still perform normal data transmission, but the SPIx_ISR.SSERR flag will remain set until cleared by user software.

Receive buffer overflow error flag (SPIx_ISR.OV)

When the master or slave does not clear the SPIx_ISR.RXNE flag after receiving a frame of data, that is, neither read the SPIx_DR register nor clear the SPIx_ICR.RXNE to 0 by software, and then when a new frame of data is received, a receive buffer overflow error will occur, and the SPIx_ISR.OV flag is set by hardware.

After a receive buffer overflow error occurs, the newly received data will overwrite the original data in the buffer.

After a receive buffer overflow error occurs, the SPI can still perform normal data transmission, but the SPIx_ISR.OV flag will remain set until cleared by user software.

Transmit buffer underflow error flag in slave mode (SPIx_ISR.UD)

When the SPI works in slave mode, if the transmit buffer is empty and the transmission of a new frame has already started, a transmit buffer underflow error will occur, and the SPIx_ISR.UD flag will be set by hardware, indicating that the slave did not send the data in time. The SPIx_DR register writes data and misses transmitting data to the host.

After the transmit buffer underflow error occurs, the SPI can still perform normal data transmission, but the SPIx_ISR.UD flag will remain set until cleared by user software.

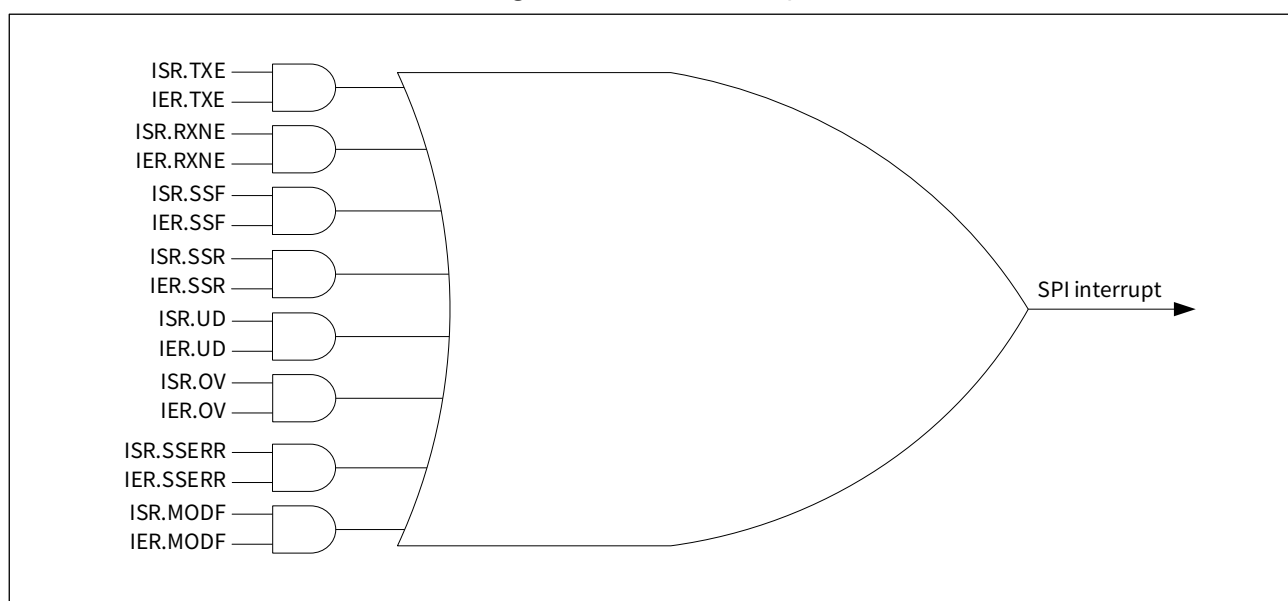


20.4 SPI interrupts

The SPI controller supports 8 interrupt sources. When the SPI interrupt trigger event occurs, the interrupt flag bit will be set by hardware. If the corresponding interrupt enable control bit is set, an interrupt request will be generated.

An SPI module of CW32L083 uses a same system SPI interrupt, whether the SPI interrupt generates an interrupt jump is controlled by the corresponding bit of the interrupt enable setting register NVIC_ISER. The schematic diagram of the system SPI interrupt is shown in the following figure:

Figure 20-11 SPI interrupts



In the user's SPI interrupt service routine, the relevant SPI interrupt flag bit should be queried for corresponding processing. Before exiting the interrupt service routine, the interrupt flag bit should be cleared to avoid repeatedly entering the interrupt routine.

The flag bit, interrupt enable bit, interrupt flag clear bit and clear method of each interrupt source of SPI are shown in the following table:

Table 20-3 SPI interrupt control

Interrupt event	Interrupt flag bit	Interrupt enable bit	Flag clear method
Transmit buffer empty	ISR.TXE	IER.TXE	Write SPIx_DR register
Receive buffer not empty	ISR.RXNE	IER.RXNE	Read SPIx_DR register, or write 0 to ICR.RXNE
Falling edge appears on the slave select input	ISR.SSF	IER.SSF	Write 0 to ICR.SSF
Rising edge appears on the slave select input	ISR.SSR	IER.SSR	Write 0 to ICR.SSR
Transmit buffer underflow in slave mode	ISR.UD	IER.UD	Write 0 to ICR.UD
Receive buffer overflow	ISR.OV	IER.OV	Write 0 to ICR.OV
Slave select error in slave mode	ISR.SSERR	IER.SSERR	Write 0 to ICR.SSERR
Mode error	ISR.MODF	IER.MODF	Write 0 to ICR.MODF

20.5 Direct memory access (DMA)

The SPI controller supports the DMA transfer function to realize high-speed data transfer between the SPI data register and the memory without CPU intervention. DMA requests can be triggered by software or hardware, and DMA requests for transmit and receive are generated separately.

DMA transmission

Set SPIx_CR1.DMATX to 1 to enable SPI to send DMA transfer requests.

When the send buffer is empty, a DMA request is generated, triggering the DMA to transfer a frame of data from the specified storage area to the SPIx_DR register, until all the data configured in the DMA controller is transferred.

For the specific register configuration process of DMA transmission, please refer to chapter [8 Direct memory access \(DMA\)](#) and section [20.6 Programming examples](#).

When the DMA transmission is completed, the corresponding DMA channel y transfer completion flag DMA_ISR.TCy will be set by hardware. If the interrupt is enabled (that is, set DMA_CSRy.TCIE to 1), an interrupt request will be generated.

In the user application, before closing the SPI, it is recommended to check whether the SPIx_ISR.BUSY flag has been cleared to ensure that all data has been sent through the SPI to avoid damaging the last transmitted data.

DMA reception

Set SPIx_CR1.DMARX to 1 to enable SPI to receive DMA transfer requests.

When the receive buffer is not empty, a DMA request is generated, triggering the DMA to transfer data from the SPIx_DR register to the specified storage area, until all the data configured in the DMA controller is transferred.

For the specific register configuration process of DMA reception, please refer to chapter [8 Direct memory access \(DMA\)](#) and section [20.6 Programming examples](#).

When the DMA transmission is completed, the corresponding DMA channel y transfer completion flag DMA_ISR.TCy will be set by hardware. If the interrupt is enabled (that is, set DMA_CSRy.TCIE to 1), an interrupt request will be generated.



20.6 Programming examples

20.6.1 Full duplex/master mode

20.6.1.1 Transmit and receive in query mode

- Step 1: Set `SYSCTRL_AHBEN.GPIOx` to 1, `SYSCTRL_APBENx.SPIx` to 1, and enable the GPIO clock and SPI working clock corresponding to the SPI pin;
- Step 2: Configure the `SPIx_SCK`, `SPIx_MOSI` and `SPIx_CS` pins as push-pull multiplexed output mode, and configure the `SPIx_MISO` pin as floating input and multiplexed mode. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set `SPIx_CR1.MODE` to 0x0, and configure SPIx to be bidirectional full-duplex communication mode;
- Step 4: Set `SPIx_CR1.MSTR` to 1, and configure SPIx to master mode;
- Step 5: Configure `SPIx_CR1.WIDTH` and set the width of each frame of data;
- Step 6: Configure `SPIx_CR1.LSBF` and set the data bit sending and receiving sequence;
- Step 7: Configure `SPIx_CR1.CPOL` and set the clock polarity;
- Step 8: Configure `SPIx_CR1.CPHA` and set the clock phase;
- Step 9: Set `SPIx_CR1.SSM` to 1, and determine the slave select output value through the SSI register;
- Step 10: Configure `SPIx_CR1.BR` and set the SCK baud rate;
- Step 11: Set `SPIx_CR1.EN` to 1 to enable the SPIx controller;
- Step 12: Set `SPIx_SSI.SSI` to 0, communication starts;
- Step 13: Query and wait for the `SPIx_ISR.TXE` flag to be set to 1, and confirm that the transmit buffer is empty;
- Step 14: Write a frame of data to be transmitted into the `SPIx_DR` register;
- Step 15: Query and wait for the `SPIx_ISR.RXNE` flag to be set to 1 to confirm that one frame of data has been received;
- Step 16: Read the `SPIx_DR` register and save the data;
- Step 17: Repeat steps 13~17 to send and receive the next frame of data until all data is transmitted and received;
- Step 18: Set `SPIx_SSI.SSI` to 1, communication ends.



20.6.1.2 Transmit and receive in interrupt mode

- Step 1: Set `SYSCTRL_AHBEN.GPIOx` to 1, `SYSCTRL_APBENx.SPIx` to 1, and enable the GPIO clock and SPI working clock corresponding to the SPI pin;
- Step 2: Configure the `SPIx_SCK`, `SPIx_MOSI` and `SPIx_CS` pins as push-pull multiplexed output mode, and configure the `SPIx_MISO` pin as floating input and multiplexed mode. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set `SPIx_CR1.MODE` to 0x0, and configure SPIx to be bidirectional full-duplex communication mode;
- Step 4: Set `SPIx_CR1.MSTR` to 1, and configure SPIx to master mode;
- Step 5: Configure `SPIx_CR1.WIDTH` and set the width of each frame of data;
- Step 6: Configure `SPIx_CR1.LSBF` and set the data bit sending and receiving sequence;
- Step 7: Configure `SPIx_CR1.CPOL` and set the clock polarity;
- Step 8: Configure `SPIx_CR1.CPHA` and set the clock phase;
- Step 9: Set `SPIx_CR1.SSM` to 1, and determine the slave selection output value through the SSI register;
- Step 10: Configure `SPIx_CR1.BR` and set the SCK baud rate;
- Step 11: Set `SPIx_CR1.EN` to 1 to enable the SPIx controller;
- Step 12: Write 0x00 to `SPIx_ICR` to clear all flags;
- Step 13: Configure the NVIC controller, please refer to chapter [5 Interrupt](#);
- Step 14: Set `SPIx_SSI.SSI` to 0, communication starts;
- Step 15: Set `SPIx_IER.RXNE` to 1 to enable receive buffer non-empty interrupt;
- Step 16: Set `SPIx_IER.TXE` to 1 to enable transmit buffer empty interrupt;
- Step 17: Enter the interrupt service function: query and judge the `SPIx_ISR.TXE` flag bit, if the flag bit is 1, write a frame of data to be transmitted into the `SPIx_DR` register; query and judge the `SPIx_ISR.RXNE` flag bit, if the flag bit is 1, then read the `SPIx_DR` register and save the data;
- Step 18: Set `SPIx_SSI.SSI` to 1, communication ends.



20.6.1.3 Transmit and receive in DMA mode

The following is a programming example of SPI1 (SPI1_CS pin is PA04, SPI1_SCK pin is PA05, SPI1_MISO pin is PA06, SPI1_MOSI pin is PA07) working in master mode, transmitting full-duplex mode data through DMA channel 1 and receiving full-duplex mode data through DMA channel 2.

In this application example, the PCLK is set to 24MHz, the baud rate is 6M bps, and the DMA data transmission amount is 100. The DMA transmission is started by hardware triggering, and the data in an 8-bit array SendBuff defined in the SRAM area is transferred to the transmit buffer. area, transfer the data in the receive buffer to an 8-bit array RecvBuff and save it.

Step 1: Set SYSCTRL_AHBEN.GPIOA to 1, SYSCTRL_APBEN2.SPI1 to 1, SYSCTRL_AHBEN.DMA to 1, enable the configuration clock and working clock of GPIOA, SPI1 and DMA respectively;

Step 2: Configure the PA04, PA05 and PA07 pins as push-pull multiplexed output mode, and configure the PA06 pin as floating input and multiplexed mode. For specific register configuration steps. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set SPI1_CR1.MODE to 0x0, and configure SPI1 to be bidirectional full-duplex communication mode;

Step 4: Set SPI1_CR1.MSTR to 1, and configure SPI1 to master mode;

Step 5: Set SPI1_CR1.WIDTH to 0x7 and the data width to 8bit;

Step 6: Set SPI1_CR1.LSBF to 0, the most significant bit is transmitted and received first;

Step 7: Set SPI1_CR1.CPOL to 1, high level when the clock is idle;

Step 8: Set SPI1_CR1.CPHA to 0, sample the front edge and shift the back edge;

Step 9: Set SPI1_CR1.SSM to 1, and determine the slave select output value through the SSI register;

Step 10: Set SPI1_CR1.BR to 0x1 and baud rate to 6M bps;

Step 11: Set SPI1_CR1.EN to 1 to enable the SPI1 controller;

Step 12: Define a variable uint8_t SendBuff [100], and assign a value to store the data to be transmitted;

Step 13: Define a variable uint8_t RecvBuff [100] to store the data to be received;

Step 14: Write 0x00 to SPI1_ICR to clear all flag bits of SPI1;

Step 15: Set DMA_ICR.TC1, DMA_ICR.TE1, DMA_ICR.TC2, DMA_ICR.TE2 to 0, clear all interrupt flags of DMA channel 1 and DMA channel 2;

Step 16: Set DMA_SRCADDR1= (uint32_t) SendBuff, the source address is SendBuff;

Step 17: Set DMA_DSTADDR1= (uint32_t) &SPI1_DR, the destination address is the SPI1_DR register;

Step 18: Set DMA_CSR1.SRCINC to 1, the source address is incremented automatically;

Step 19: Set DMA_CSR1.DSTINC to 0, the destination address is fixed;

Step 20: Write 0x10064 to DMA_CNT1, and the data transmission amount is 100;

Step 21: Set DMA_CSR1.SIZE to 0, and the transmission data bit width to 8bit;

Step 22: Set DMA_CSR1.TRANS to 1, block transmission (BLOCK);

Step 23: Set DMA_TRIG1.Type to 1, hardware trigger mode;

Step 24: Set DMA_TRIG1. HardSrc to 0x7, trigger DMA transmission when SPI1 transmit buffer is empty;

Step 25: Set DMA_SRCADDR2= (uint32_t) &SPI1_DR, the source address is the SPI1_DR register;

Step 26: Set DMA_DSTADDR2=(uint32_t) RecvBuff, the destination address is RecvBuff;

Step 27: Set DMA_CSR2.SRCINC to 0, the source address is fixed;

Step 28: Set DMA_CS2.DSTINC to 1, the destination address is incremented automatically;

Step 29: Write 0x10064 to DMA_CNT2, and the data transmission amount is 100;

Step 30: Set DMA_CSR2.SIZE to 0, and the transmission data bit width to 8bit;



- Step 31: Set DMA_CSR2.TRANS to 1, block transmission (BLOCK);
- Step 32: Set DMA_TRIG2.Type to 1, hardware trigger mode;
- Step 33: Set DMA_TRIG2.HardSrc to 0x6, trigger DMA transmission when SPI1 receive buffer is not empty;
- Step 34: Set SPI1_SSI.SSI to 0, communication starts;
- Step 35: Set DMA_CSR1.EN to 1 to enable DMA channel 1 transfer;
- Step 36: Set DMA_CSR2.EN to 1 to enable DMA channel 2 transfer;
- Step 37: Set SPI1_CR1.DMATX to 1, and turn on the hardware handshake logic of SPI1 DMA transmission;
- Step 38: Set SPI1_CR1.DMATX to 1, and turn on the hardware handshake logic of SPI1 DMA reception;
- Step 39: Query and wait for DMA_ISR.TC1 to become 1, and confirm that the transmission of DMA channel 1 is completed;
- Step 40: Query and wait for DMA_ISR.TC2 to become 1, and confirm that the transmission of DMA channel 2 is completed;
- Step 41: Set SPI1_CR1.DMATX to 0, and turn off the hardware handshake logic of SPI1 DMA transmission;
- Step 42: Set SPI1_CR1.DMATX to 0, and turn off the hardware handshake logic of SPI1 DMA reception;
- Step 43: Query and wait for SPI1_ISR.BUSY to become 0 to ensure that the SPI1 bus is idle;
- Step 44: Set SPI1_SSI.SSI to 1, communication ends;
- Step 45: Repeat steps 14~45 if new data is to be transferred.



20.6.2 Single-wire half-duplex/master mode

20.6.2.1 Transmit in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.SPIx to 1, and enable the GPIO clock and SPI working clock corresponding to the SPI pin;
- Step 2: Configure the SPIx_SCK, SPIx_MOSI and SPIx_CS pins as push-pull multiplexed output mode. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set SPIx_CR1.MODE to 0x3, and configure SPIx to be single-wire half-duplex communication mode;
- Step 4: Set SPIx_CR1.MSTR to 1, and configure SPIx to master mode;
- Step 5: Configure SPIx_CR1.WIDTH and set the width of each frame of data;
- Step 6: Configure SPIx_CR1.LSBF and set the data bit transmitting and receiving sequence;
- Step 7: Configure SPIx_CR1.CPOL and set the clock polarity;
- Step 8: Configure SPIx_CR1.CPHA and set the clock phase;
- Step 9: Set SPIx_CR1.SSM to 1, and determine the slave select output value through the SSI register;
- Step 10: Configure SPIx_CR1.BR and set the SCK baud rate;
- Step 11: Set SPIx_CR1.EN to 1 to enable the SPIx controller;
- Step 12: Set SPIx_SSI.SSI to 0, communication starts;
- Step 13: Set SPIx_CR2.HDOE to 1, only transmit;
- Step 14: Query and wait for the SPIx_ISR.TXE flag to be set to 1, and confirm that the transmit buffer is empty;
- Step 15: Write a frame of data to be transmitted into the SPIx_DR register;
- Step 16: If there is still data to be transmitted, repeat steps 14-16 to transmit the next frame of data;
- Step 17: Query and wait for the SPIx_ISR.TXE flag bit to be 1, and the last frame of data starts to be transmitted;
- Step 18: Query and wait for the SPIx_ISR.BUSY flag to become 0, and the SPIx bus is idle;
- Step 19: Set SPIx_SSI.SSI to 1, communication ends.



20.6.2.2 Receive in query mode

- Step 1: Set `SYSCTRL_AHBEN.GPIOx` to 1, `SYSCTRL_APBENx.SPIx` to 1, and enable the GPIO clock and SPI working clock corresponding to the SPI pin;
- Step 2: Configure the `SPIx_SCK`, `SPIx_MOSI` and `SPIx_CS` pins as push-pull multiplexed output mode. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set `SPIx_CR1.MODE` to 11, and configure SPIx to be single-wire half-duplex communication mode;
- Step 4: Set `SPIx_CR1.MSTR` to 1, and configure SPIx to master mode;
- Step 5: Configure `SPIx_CR1.WIDTH` and set the width of each frame of data;
- Step 6: Configure `SPIx_CR1.LSBF` and set the data bit transmitting and receiving sequence;
- Step 7: Configure `SPIx_CR1.CPOL` and set the clock polarity;
- Step 8: Configure `SPIx_CR1.CPHA` and set the clock phase;
- Step 9: Set `SPIx_CR1.SSM` to 1, and determine the slave select output value through the SSI register;
- Step 10: Configure `SPIx_CR1.BR` and set the SCK baud rate;;
- Step 11: Set `SPIx_CR1.EN` to 1 to enable the SPIx controller;
- Step 12: Set `SPIx_SSI.SSI` to 0, communication starts;
- Step 13: Set `SPIx_CR2.HDOE` to 0, only receive;
- Step 14: Query and wait for the `SPIx_ISR.TXE` flag to be set to 1, and confirm that the transmit buffer is empty;
- Step 15: Write a frame of dummy data into the `SPIx_DR` register;
- Step 16: Query and wait for the `SPIx_ISR.RXNE` flag to be set to 1 to confirm that one frame of data has been received;
- Step 17: Read the `SPIx_DR` register and save the data;
- Step 18: Repeat steps 14-18 to receive the next frame of data until all data is received;
- Step 19: Set `SPIx_SSI.SSI` to 1, communication ends.



20.6.3 Simplex mode/master mode

20.6.3.1 Transmit in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.SPIx to 1, and enable the GPIO clock and SPI working clock corresponding to the SPI pin;
- Step 2: Configure the SPIx_SCK, SPIx_MOSI and SPIx_CS pins as push-pull multiplexed output mode. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set SPIx_CR1.MODE to 01, and configure SPIx as simplex single-transmit communication mode;
- Step 4: Set SPIx_CR1.MSTR to 1, and configure SPIx to master mode;
- Step 5: Configure SPIx_CR1.WIDTH and set the width of each frame of data;
- Step 6: Configure SPIx_CR1.LSBF and set the data bit transmitting and receiving sequence;
- Step 7: Configure SPIx_CR1.CPOL and set the clock polarity;
- Step 8: Configure SPIx_CR1.CPHA and set the clock phase;
- Step 9: Set SPIx_CR1.SSM to 1, and determine the slave select output value through the SSI register;
- Step 10: Configure SPIx_CR1.BR and set the SCK baud rate;
- Step 11: Set SPIx_CR1.EN to 1 to enable the SPIx controller;
- Step 12: Set SPIx_SSI.SSI to 0, communication starts;
- Step 13: Query and wait for the SPIx_ISR.TXE flag to be set to 1, and confirm that the transmit buffer is empty;
- Step 14: Write a frame of data to be transmitted into the SPIx_DR register;
- Step 15: If there is still data to be transmitted, repeat steps 13-15 to transmit the next frame of data;
- Step 16: Query and wait for the SPIx_ISR.TXE flag bit to be 1, and the last frame of data starts to be transmitted;
- Step 17: Query and wait for the SPIx_ISR.BUSY flag to become 0, and the SPIx bus is idle;
- Step 18: Set SPIx_SSI.SSI to 1, communication ends.



20.6.3.2 Receive in query mode

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBENx.SPIx to 1, and enable the GPIO clock and SPI working clock corresponding to the SPI pin;
- Step 2: Configure the SPIx_SCK and SPIx_CS pins as push-pull multiplexing output mode, and configure the SPIx_MISO pin as floating input and multiplexing mode. For specific register configuration steps, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set SPIx_CR1.MODE to 10, and configure SPIx as simplex single receiving communication mode;
- Step 4: Set SPIx_CR1.MSTR to 1, and configure SPIx to master mode;
- Step 5: Configure SPIx_CR1.WIDTH and set the width of each frame of data;
- Step 6: Configure SPIx_CR1.LSBF and set the data bit transmitting and receiving sequence;
- Step 7: Configure SPIx_CR1.CPOL and set the clock polarity;
- Step 8: Configure SPIx_CR1.CPHA and set the clock phase;
- Step 9: Set SPIx_CR1.SSM to 1, and determine the slave select output value through the SSI register;
- Step 10: Configure SPIx_CR1.BR and set the SCK baud rate;
- Step 11: Set SPIx_CR1.EN to 1 to enable the SPIx controller;
- Step 12: Set SPIx_SSI.SSI to 0, communication starts;
- Step 13: Query and wait for the SPIx_ISR.TXE flag to be set to 1, and confirm that the transmit buffer is empty;
- Step 14: Write a frame of dummy data into the SPIx_DR register;
- Step 15: Query and wait for the SPIx_ISR.RXNE flag to be set to 1 to confirm that one frame of data has been received;
- Step 16: Read the SPIx_DR register and save the data;
- Step 17: Repeat steps 13-17 to receive the next frame of data until all data is received;
- Step 18: Set SPIx_SSI.SSI to 1, communication ends.



20.7 List of registers

SPI1 base address: SPI1_BASE = 0x4001 3000

SPI2 base address: SPI2_BASE = 0x4000 3800

Table 20-4 List of SPI registers

Register name	Register address	Register description
SPIx_CR1	SPIx_BASE + 0x00	Control register 1
SPIx_CR2	SPIx_BASE + 0x08	Control register 2
SPIx_SSI	SPIx_BASE + 0x0C	Slave select register
SPIx_IER	SPIx_BASE + 0x04	Interrupt enable register
SPIx_ISR	SPIx_BASE + 0x10	Interrupt flag register
SPIx_ICR	SPIx_BASE + 0x14	Interrupt flag clear register
SPIx_DR	SPIx_BASE + 0x18	Data register



20.8 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

20.8.1 SPIx_CR1 control register 1

Address offset: 0x00 Reset value: 0x0000 1C04

Bit field	Name	Permission	Function description
31:19	RFU	-	Reserved bits, please keep the default value
18	MISOHD	RW	Slave MISO output configuration 0: MISO is always output for COMS 1: When the slave is selected, MISO is COMS output, and when it is not selected, it is high resistance output
17	DMATX	RW	DMA transmit data enable control 0: Disabled 1: Enabled
16	DMARX	RW	DMA receive data enable control 0: Disabled 1: Enabled
15:14	MODE	RW	Communication mode configuration 00: bidirectional full duplex 01: simplex single transmitting 10: simplex single receiving 11: single-wire half-duplex
13:10	WIDTH	RW	The width of each frame of data is WIDTH+1, for example 0011: 4bit 0100: 5bit ... 1110: 15bit 1111: 16bit
9	SSM	RW	Slave select configuration (Master mode) 0: The SPI_CS pin is in input mode, and the low level of the pin can select the machine 1: The SPI_CS pin is in output mode, and the output level comes from SSI Slave select configuration (slave mode) 0: SPI_CS pin level determines whether the machine is selected 1: The value of the SSI register determines whether the machine is selected



Bit field	Name	Permission	Function description
8	SMP	RW	Master mode delayed sampling 0: In the traditional way of SPI, the data received by the master is sampled according to the settings of CPOL and CPHA 1: Delayed sampling method, the sampling time is delayed by half SCK cycle compared with the traditional method
7	LSBF	RW	Data frame high and low sequence selection 0: Most significant bit MSB is sent and received first 1: Least significant bit MSB is sent and received first
6	EN	RW	Enable control 0: SPI module disabled 1: SPI module enabled
5:3	BR	RW	Master mode SCK baud rate configuration 000: PCLK/2 001: PCLK/4 010: PCLK/8 011: PCLK/16 100: PCLK/32 101: PCLK/64 110: PCLK/128 111: Reserved
2	MSTR	RW	Work mode configuration 0: slave mode 1: master mode
1	CPOL	RW	Serial clock polarity configuration 0: Low level in standby 1: High level in standby
0	CPHA	RW	Serial clock phase configuration 0: Leading edge sampling/trailing edge shift 1: Leading edge shift/trailing edge sampling



20.8.2 SPIx_CR2 control register 2

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:1	RFU	-	Reserved bits, please keep the default value
0	HDOE	RW	When single-wire half-duplex, data transmission/reception status control 0: Only received 1: Only transmitted Caution: Only valid for single-wire half-duplex communication

20.8.3 SPIx_SSI slave select register

Address offset: 0x0C Reset value: 0x0000 0001

Bit field	Name	Permission	Function description																			
31:1	RFU	-	Reserved bits, please keep the default value																			
0	SSI	RW	Slave select, valid when SPIx_CR1.SSM is 1 <table border="1"> <thead> <tr> <th>SSM</th><th>MSTR</th><th>SSI</th><th>Description</th></tr> </thead> <tbody> <tr> <td>0</td><td>-</td><td>-</td><td>Invalid</td></tr> <tr> <td rowspan="4">1</td><td rowspan="2">0(slave)</td><td>0</td><td>Set the machine to selected state</td></tr> <tr> <td>1</td><td>Set this machine to unselected state</td></tr> <tr> <td rowspan="2">1(master)</td><td>0</td><td>SPIx_CS pins output low</td></tr> <tr> <td>1</td><td>SPIx_CS pins output high</td></tr> </tbody> </table>	SSM	MSTR	SSI	Description	0	-	-	Invalid	1	0(slave)	0	Set the machine to selected state	1	Set this machine to unselected state	1(master)	0	SPIx_CS pins output low	1	SPIx_CS pins output high
SSM	MSTR	SSI	Description																			
0	-	-	Invalid																			
1	0(slave)	0	Set the machine to selected state																			
		1	Set this machine to unselected state																			
	1(master)	0	SPIx_CS pins output low																			
		1	SPIx_CS pins output high																			



20.8.4 SPIx_IER interrupt enable register

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	MODF	RW	Mode error interrupt enable control 0: Disabled 1: Enabled
6	SSERR	RW	Slave select error interrupt enable control in slave mode 0: Disabled 1: Enabled
5	OV	RW	Receive buffer overflow error interrupt enable control 0: Disabled 1: Enabled
4	UD	RW	Transmit buffer underflow error interrupt enable control in slave mode 0: Disabled 1: Enabled
3	SSR	RW	Slave select input rising edge interrupt enable control 0: Disabled 1: Enabled
2	SSF	RW	Slave select input falling edge interrupt enable control 0: Disabled 1: Enabled
1	RXNE	RW	Receive buffer non-empty interrupt enable control 0: Disabled 1: Enabled
0	TXE	RW	Transmit buffer empty interrupt enable control 0: Disabled 1: Enabled



20.8.5 SPIx_ISR interrupt flag register

Address offset: 0x10 Reset value: 0x0000 0001

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	SSLVL	RO	Slave select signal state 0: Slave select signal is low level 1: Slave select signal is high level
8	BUSY	RO	Bus busy flag 0: Bus idle 1: Bus busy
7	MODF	RO	Mode error flag 0: Normal 1: Error Caution: In master mode, the slave select input is low to trigger MODF
6	SSERR	RO	Slave select error flag in slave mode 0: Normal 1: Error
5	OV	RO	Receive buffer overflow error flag bit 0: Normal 1: Error
4	UD	RO	Transmit buffer underflow error flag in slave mode 0: Normal 1: Error
3	SSR	RO	Slave select input rising edge flag bit 0: No rising edge occurred 1: Rising edge has occurred
2	SSF	RO	Slave select input falling edge flag bit 0: No falling edge occurred 1: Falling edge occurred
1	RXNE	RO	Receive buffer not empty flag bit 0: Receive buffer is empty 1: Receive buffer is not empty Caution: This flag can be cleared by reading the DR register or writing 0 to ICR.RXNE
0	TXE	RO	Send buffer empty flag bit 0: Send buffer is not empty 1: Send buffer is empty



20.8.6 SPIx_ICR interrupt flag clear register

Address offset: 0x14 Reset value: 0x0000 00FF

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	MODF	R1W0	Mode error flag cleared W0: Mode error flag cleared W1: No function
6	SSERR	R1W0	Slave select error flag cleared in slave mode W0: Slave select error flag in slave mode cleared W1: No function
5	OV	R1W0	Receive buffer overflow error flag cleared W0: Receive buffer overflow error flag cleared W1: No function
4	UD	R1W0	Transmit buffer underflow error flag cleared in slave mode W0: Transmit buffer underflow error flag in slave mode cleared W1: No function
3	SSR	R1W0	Slave select input rising edge flag cleared W0: Slave select input rising edge flag cleared W1: No function
2	SSF	R1W0	Slave select input falling edge flag cleared W0: Slave select input falling edge flag cleared W1: No function
1	RXNE	R1W0	Receive buffer not empty flag cleared W0: Receive buffer not empty flag cleared W1: No function
0	FLUSH	R1W0	Clear transmit buffer and shift register W0: The transmit buffer and shift register (ISR.TXE is set to 1 after clearing) cleared W1: No function

20.8.7 SPIx_DR data register

Address offset: 0x18 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	DR	RW	Write data to be transmitted Read as received data



21 I2C interface

21.1 Overview

CW32L083 integrates two I2C controllers, which can serially transmit the data to be transmitted to the I2C bus according to the I2C specification according to the set transmission rate (standard, fast, high-speed), and detect the state during the communication process. Bus collision and arbitration handling in multi-master communication is also supported.

21.2 Main features

- Supports master transmit/receive and slave transmit/receive four working modes
- Supports clock stretching (clock synchronization) and multi-master communication conflict arbitration
- Supports standard (100Kbps)/fast (400Kbps)/high speed (1Mbps) three working rates
- Supports 7bit addressing function
- Supports 3 slave addresses
- Supports broadcast address
- Supports input signal noise filtering function
- Supports interrupt status query function



21.3 Protocol description

The I2C bus uses two signal lines (the data line SDA and the clock line SCL) to transfer data between devices. SCL is a unidirectional clock line, which is fixedly driven by the master. SDA is a bidirectional data line, which is driven by the transmitting and receiving terminals in time sharing during data transmission.

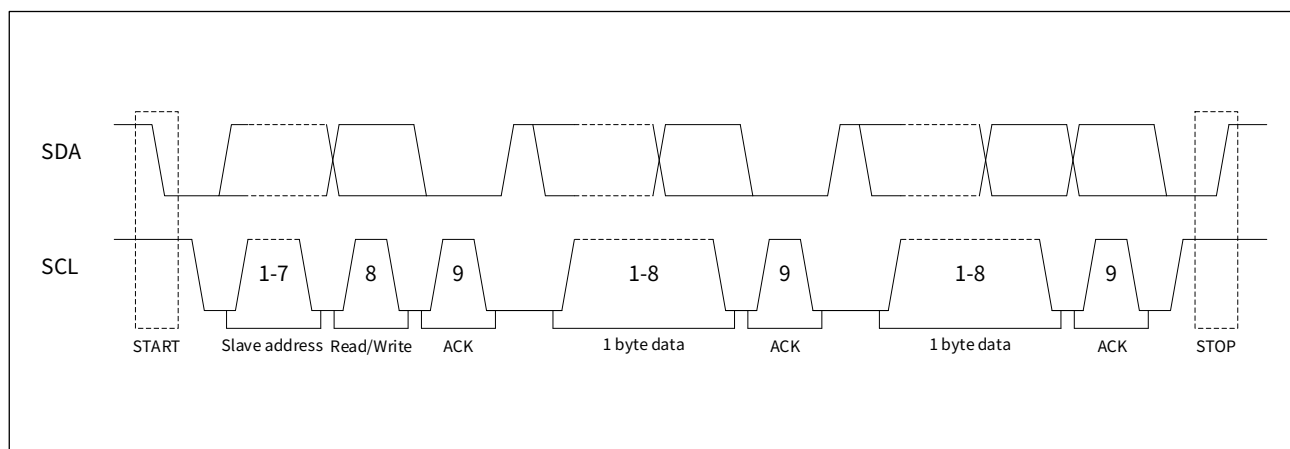
Multiple devices can be connected to the I2C bus. All devices are in an idle state when they are not transmitting data (the slave receiving mode is not addressed). Any device can send a START signal as a master to start data transmission. The bus is occupied until the STOP signal appears on the bus.

I2C communication adopts the master-slave structure, and the communication is initiated and terminated by the master. The master initiates communication by transmitting the START signal, then transmits a total of 8 bits of SLA+W/R data (where SLA is the 7-bit slave address, and W/R is the read-write bit), and releases the SDA bus at the ninth SCL clock, the corresponding slave occupies the SDA bus at the ninth SCL clock and outputs an ACK response signal to complete the slave addressing. After that, the transmitter and receiver of data communication are determined according to the W/R bit of the first byte transmitted by the master. For each byte of data transmitted by the transmitter, the receiver must respond with an ACK response signal. After the data transmission is completed, the master transmits a STOP signal to end the communication.

21.3.1 Protocol frame format

The standard I2C transmission protocol frame consists of four parts: start signal (START) or repeated start signal (Repeated START), slave address and read and write bits, data transmission, and stop signal (STOP). As shown in the following figure:

Figure 21-1 I2C protocol frame



- Start signal (START)

When the bus is in an idle state (SCL and SDA lines are high at the same time), a falling edge signal from high to low appears on the SDA line, which is defined as a start signal. After the master transmits a start signal to the bus, data transmission starts and the bus is occupied.

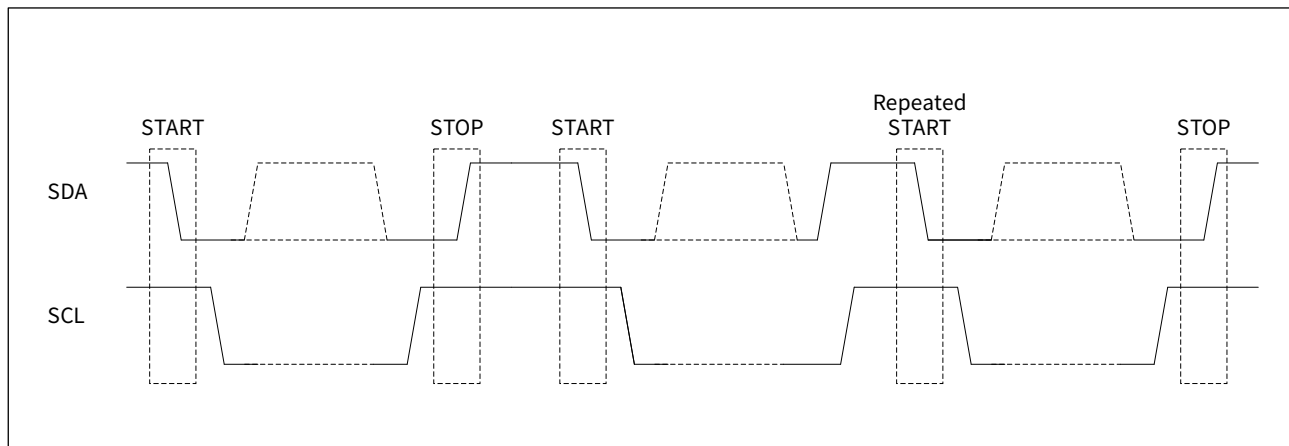
- Repeated start signal (Repeated START)

When a start signal does not appear before a stop signal, a new start signal appears, and the new start signal is defined as a repeated start signal. Before the master transmits the stop signal, the SDA bus is always in the occupied state, and other masters cannot occupy the bus.

- Stop signal (STOP)

When the SCL line is high, a rising edge signal from low to high appears on the SDA line, which is defined as a stop signal. The master transmits a stop signal to the bus to end the data transfer and releases the bus.

Figure 21-2 Start and stop signals



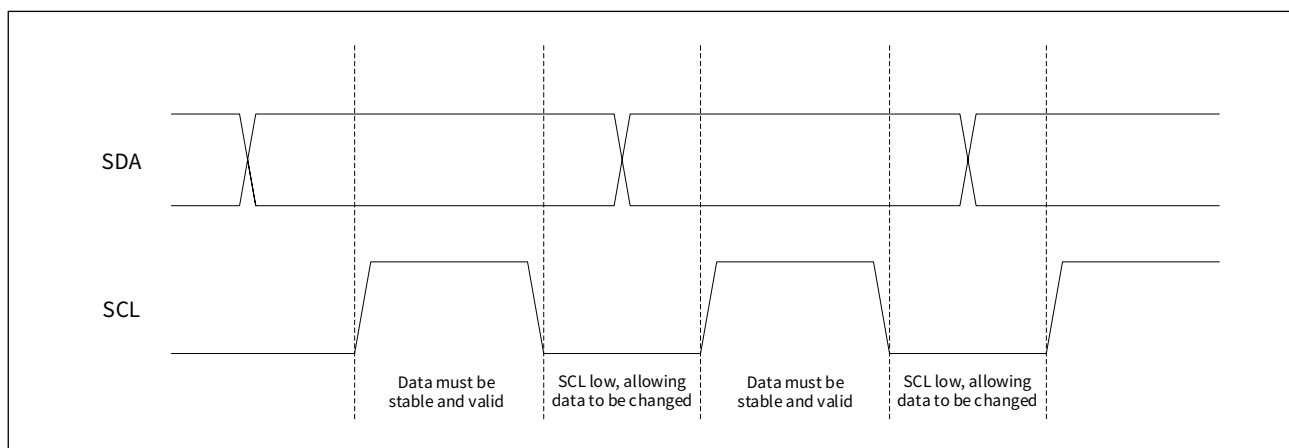
- Slave address and read/write bit

When the start signal is generated, the master starts to transmit the first byte of data: 7 bit slave address + read and write bits. The read and write bits (1: read; 0: write) control the direction of data transfer on the bus. The addressed slave occupies the SDA bus during the 9th SCL clock cycle and acknowledges the ACK by asserting SDA low.

- Data transmission

The master outputs the serial clock signal on the SCL line, and the master and slave devices transmit data through the SDA line. During data transmission, 1 SCL clock pulse transmits 1 data bit (the most significant bit MSB is first), and the data on the SDA line changes only when SCL is low, and each transmitted 1 byte is followed by an acknowledge bit. As shown in the following figure:

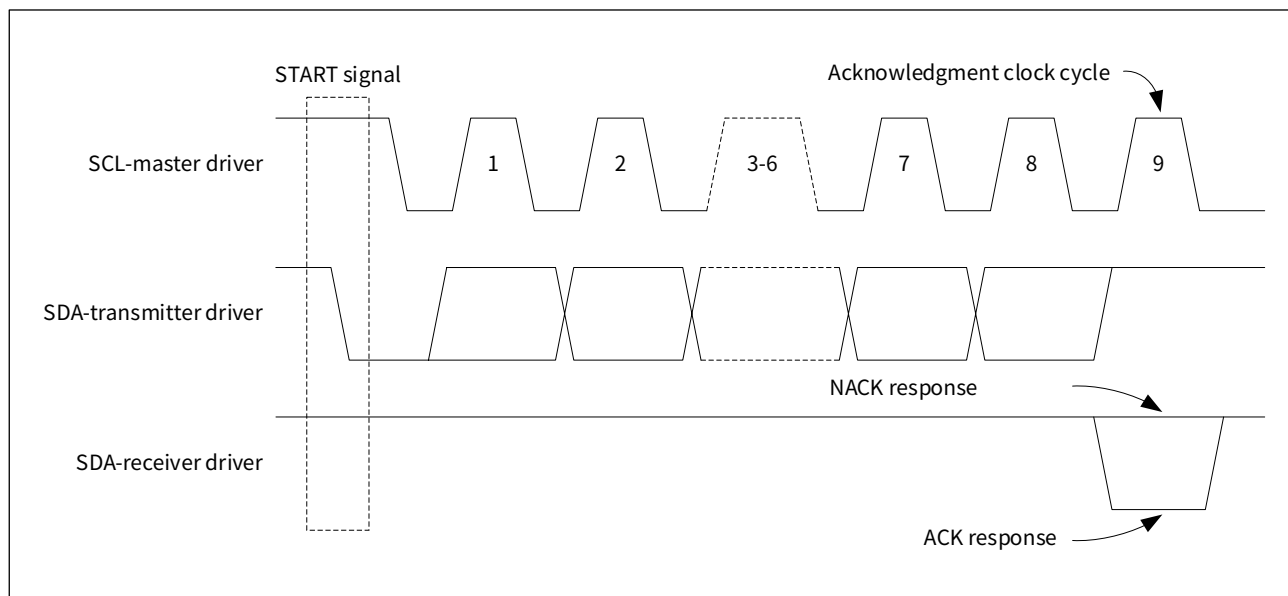
Figure 21-3 Data transmission



21.3.2 Transmission response

When transmitting data on the bus, the transmitter gives up the control of SDA in the 9th SCL clock cycle after transmitting 1 byte of data, and the receiver must reply a response bit in the 9th SCL clock cycle: the reception is successful, Send ACK response, receive exception send NACK response.

Figure 21-4 Transmission response



21.3.3 Conflict detection and arbitration

In a multi-master communication system, each node on the bus has a slave address. Each node can be accessed by other nodes as a slave node, and can also be used as a master node to send control bytes and transmit data to other nodes. A bus collision occurs when two or more nodes send a start signal to the bus at the same time and start transmitting data. The I2C controller has a built-in arbiter that can detect and arbitrate I2C bus conflicts to ensure the reliability and integrity of data communication.

- Conflict detection principle

In the physical realization, the SDA and SCL pins have the same circuit structure, and the output drive of the pin is connected with the input buffer. The output structure is an open-drain field effect transistor, and the input structure is an inverter with high input impedance. Based on this structure:

1. Since SDA and SCL are open-drain structures, the "wire-and" logic of the signal is realized by means of an external pull-up resistor;
2. The device reads data while writing data to the bus, which can be used to detect bus conflicts and realize "clock synchronization" and "bus arbitration".

According to the "wire-and" logic, if two masters send logic 1 or logic 0 at the same time, neither of the two masters can detect the conflict, and it needs to wait until the next bit of data is transmitted before continuing to detect the conflict; if one of the two hosts sends a logic 1, When a logic 0 is transmitted, the bus is logic 0 at this time, the master transmitting logic 1 detects a conflict, and the master transmitting logic 0 does not detect a conflict.

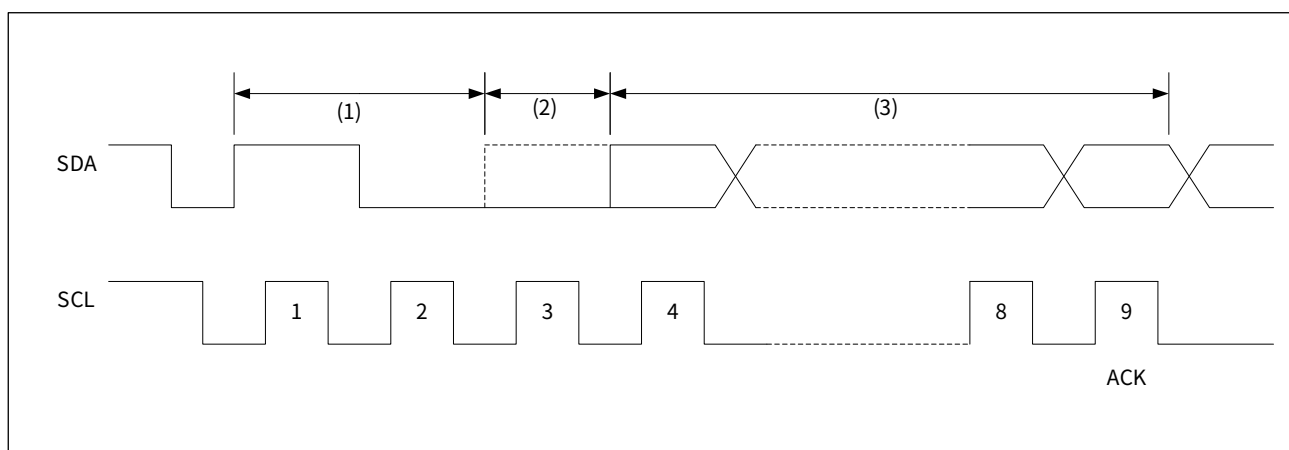
- Conflict arbitration principles

When the master detects a bus conflict, the master loses arbitration, exits the master transmit mode, enters the unaddressed slave mode, releases the SDA data line, and returns to the address detection state, and then enters the state according to the received SLA+W/R corresponding slave mode (SLA address match enters addressed slave mode, SLA address mismatch enters unaddressed slave mode). The master that loses arbitration will still send the SCL serial clock until the end of the current byte transfer.

When the master does not detect a bus conflict, the master wins the arbitration and continues to dominate the data transfer until the communication is complete.

The following figure is a schematic diagram of transmitting conflict and arbitration between master A and master B on an I2C bus (assuming that the transmitting clocks of the two masters A and B are synchronized):

Figure 21-5 Conflict detection and arbitration



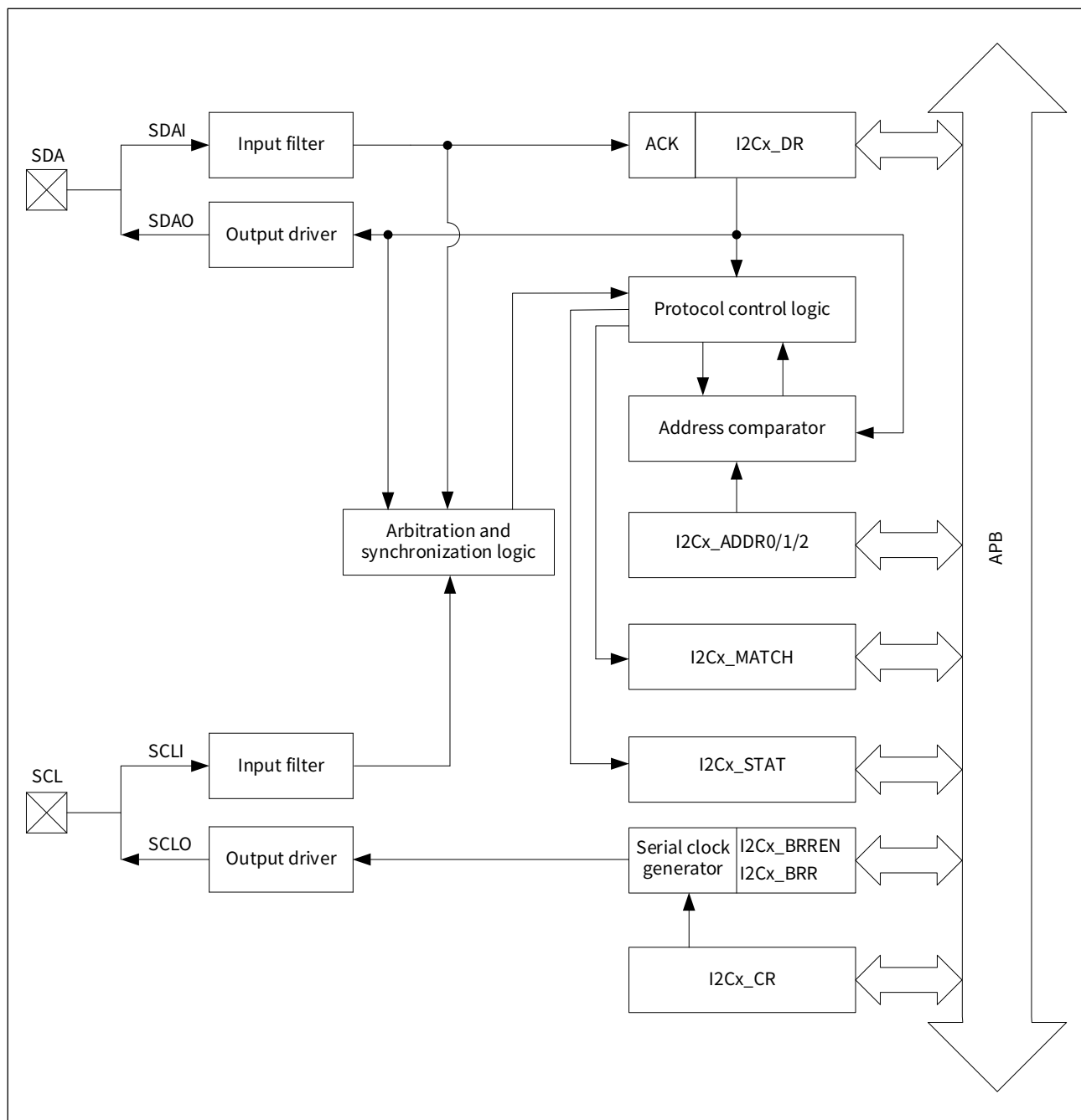
1. In stage (1), both master A and master B transmit logic 1 and logic 0 successively. Since the data is the same and synchronous, neither host will detect a bus conflict.
2. In stage (2), master A transmits a logic 1, master B transmits a logic 0, and the data on the SDA bus is a logic 0. The A host controller detects a data error and exits the transmission competition, that is, the arbitration is lost, and the A master enters the unaddressed slave receiver mode. Host B does not detect a bus conflict, wins the arbitration, and continues this data transfer.
3. In phase (3), the A master is in unaddressed slave receive mode, but still generates SCL clock pulses until the end of the current byte transfer. After that, the A host I2C controller no longer transmits the clock signal. Since the B master wins the arbitration, both SCL and SDA are dominated by the B master to control the transfer.

21.4 Functional description

21.4.1 Functional block diagram

The I2C module mainly includes clock generator, input filter, address comparator, protocol control logic, arbitration and synchronization logic, and related registers. Its functional block diagram is shown in the following figure:

Figure 21-6 I2C functional block diagram



CW32L083 supports users to flexibly select GPIO as I2C communication pin, as shown in the following table:

Table 21-1 I2C pin selection

	I2C1	I2C2
SCL	PA09/PA14/PB06/PB08/PB10/PD06/PF01/PF06	PA01/PA04/PA11/PA13/PB00/PB10/ PB13/PC00/PD00/PD03/PE00/PE03/PF06
SDA	PA10/PA13/PB07/PB09/PB11/PC09/PD07/PF00/PF07	PA02/PA05/PA12/PA14/PB01/PB11/ PB14/PC01/PD01/PD04/PE01/PE04/PF07

21.4.2 Serial clock generator

The serial clock generator is used to generate the baud rate clock SCL for I2C communication. The serial clock generator uses PCLK as the input clock, counts through an 8-bit counter, and outputs the I2C clock signal with the required baud rate.

SCL clock frequency calculation formula:

$$f_{SCL} = f_{PCLK} / 8 / (BRR + 1)$$

Where, BRR is configured through the baud rate counter configuration register I2Cx_BRR, and the effective range of BRR is 1~255.

The counter count of the serial clock generator is enabled by the EN bit field of the I2Cx_BRREN register. EN is 1 to enable and 0 to prohibit. When the master is used, EN should be set to 1, and this bit has no effect when the slave is used.

The corresponding relationship between the combination of PCLK and BRR and the SCL clock frequency is shown in the following table:

Table 21-2 I2C transfer rate and configuration example

f _{SCL} (kHz) f _{PCLK} (kHz)	I2Cx_BRR						
	1	2	3	4	5	6	7
1000	62	41	31	25	20	17	15
2000	125	83	62	50	41	35	31
4000	250	166	125	100	83	71	62
6000	375	250	187	150	124	107	93
8000	500	333	250	200	166	142	125
10000	625	416	312	250	208	178	156
12000	750	500	375	300	250	214	187
14000	875	583	437	350	291	250	218
16000	1000	666	500	400	333	285	250



21.4.3 Input filter

The input filter can filter the SDA and SCL input signals, and the spike signal less than 1 PCLK cycle will be filtered out.

The input filter can be configured in two modes: simple filter mode and advanced filter mode. Simple filtering has faster communication rate; advanced mode has higher anti-jamming performance. The filtering mode is configured through the FLT bit field of the I2C control register I2Cx_CR. Setting I2Cx_CR.FLT to 1 is the simple filtering mode, and setting I2Cx_CR.FLT to 0 is the advanced filtering mode.

As a master, if the value of BRR is less than or equal to 9, I2Cx_CR.FLT should be set to 1; if the value of BRR is greater than 9, then I2Cx_CR.FLT should be set to 0.

As a slave, if the frequency ratio of PCLK to SCL is less than or equal to 40, then I2Cx_CR.FLT should be set to 1; if the frequency ratio of PCLK to SCL is greater than 40, then I2Cx_CR.FLT should be set to 0.

21.4.4 Address comparator

Each device on the I2C bus has a slave address, and each slave address is different. The master addresses the slave according to the slave address, and the slave automatically detects whether the 7bit addressing address transmitted by the master matches the local address through the address comparator to determine whether to communicate with the master.

The I2C controller supports 3 programmable slave addresses, and the specific address information is configured through the slave address registers I2Cx_ADDR0/I2Cx_ADDR1/I2Cx_ADDR2.

The address comparator of the slave machine compares the received 7-bit addressing address with the three slave addresses and the broadcast address (0x00). If it matches any one of the 4 addresses, it is considered that the address matches, and the I2C interrupt flag bit I2Cx_CR.SI will be set to 1, and an interrupt request will be generated. The application program can obtain the successfully matched address serial number by querying the slave address matching register I2Cx_MATCH.

If the address matches I2Cx_ADDR0/1/2, the slave enters the corresponding addressed slave receive mode (receives SLA+W) or addressed slave transmit mode (receives SLA+R); if the address matches to If the broadcast address is 0x00 (SLA+W is received), the slave enters the broadcast receiving mode.



21.4.5 Arbitration and synchronization logic

21.4.5.1 SCL synchronization

I2C supports clock synchronization (clock stretching) function, the time of SCL clock low level is determined by the device with the longest SCL clock low level width, and the SCL clock high level time is determined by the device with the shortest clock high level width.

If the slave wants the master to reduce the transmission speed, it can keep I2Cx_CR.SI 1 after receiving the data and responding to ACK, and the slave I2C controller will keep SCL low to notify the master. When the master is ready for the next byte data transfer (transmit or receive), it detects that the level of SCL is pulled low, and waits until the slave completes the operation and clears I2Cx_CR.SI to 0, and the slave controller releases the pull of SCL. Low control, the master continues to transmit the next byte of data after detecting that SCL is high.

21.4.5.2 SDA arbitration

I2C supports SDA conflict detection and arbitration, which can ensure that the data on the I2C bus is not destroyed when multiple masters attempt to control the I2C bus.

When each master transmits data, it will simultaneously compare whether the data on the bus is consistent with the data transmitted by itself. If they are inconsistent, it is considered that a bus conflict is detected, and the transmitting competition will be withdrawn, that is, the arbitration will be lost. A master that loses arbitration will immediately switch to an unaddressed slave state to ensure that it can be addressed by a master that succeeds in arbitration. A master that loses arbitration continues to output the SCL serial clock until the current byte transfer is complete.

SDA arbitration generally occurs when the master transmits SLA+W/R data. If two masters transmit data to a slave at the same time, that is, the slave addresses transmitted by the two masters are the same, the arbitration will continue in the second byte.



21.4.6 Response control

The receiver of the I2C data transmission must give an ACK or NACK response to the transmitter in the 9th SCL clock cycle of each byte. The receiver obtains the current state of the receiver through the response bit: responding with an ACK response means that the receiver has received it correctly. This byte of data can continue to receive the next byte of data; responding to NACK generally indicates that the receiver no longer receives any data.

Whether the receiver sends ACK or NACK is controlled by the AA bit field of the receiver's I2C control register I2Cx_CR. When I2Cx_CR.AA is set to 1, the I2C module will respond with an ACK response every time it receives 1 byte of data. When I2Cx_CR.AA is set to 0, the I2C module will respond with a NACK response every time it receives 1 byte of data.

In the process of receiving data by the master, the master as the initiator of communication, controls the number of bytes transmitted and received. The master (receiver) responds to the NACK response to the slave (transmitter) after receiving the last byte of data, and the slave receives the NACK. After the slave receives the NACK response, it will switch to unaddressed slave receive mode and release the SDA bus so that the master can transmit a STOP signal or a Repeated START signal.

In the process of transmitting data from the slave, if its own I2Cx_CR.AA response control bit is cleared by the application program, the slave will switch itself to the unaddressed slave receiving mode after transmitting the last 1 byte of valid data, and release the SDA bus, the master will get 0xFF when reading data from the bus. At this time, the master should be able to judge that the slave is in an unresponsive state, and send a STOP signal or a Repeated START signal.

In the process of receiving data from the slave, if it responds to NACK to the master (transmitter), it means that the slave (receiver) actively ends the communication, no longer receives the data transmits by the master, and switches itself to the unaddressed slave to receive mode, and release the SDA bus, at this time the master should send a STOP signal or a Repeated START signal.

21.4.7 I2C interrupts

The SI bit field of the I2C control register I2Cx_CR is the interrupt flag bit. When the value of the STAT bit field of the I2C status register I2Cx_STAT changes (except for 0xF8), the I2Cx_CR.SI flag will be set and an interrupt request will be generated.

In the user I2C interrupt service routine, you should query the STAT bit field value of the I2C status register I2Cx_STAT to obtain the status of the I2C bus to determine the cause of the interrupt. Set I2Cx_CR.SI to 0 to clear this flag.



21.4.8 Operating modes

The I2C controller supports 4 operating modes: master transmit mode, master receive mode, slave transmit mode, and slave receive mode. In addition, the broadcast receive mode is also supported, and its working method is similar to that of the slave receive mode.

21.4.8.1 Master transmit mode

In master transmit mode, the master actively transmits multiple bytes to the slave.

The SCL serial clock is controlled by the master, so it is necessary to set the I2Cx_BRR register according to the transmission baud rate and set the EN bit field of the I2Cx_BRREN register to 1, and then start the transmission.

The master sets I2Cx_CR.STA to 1, and informs the controller to transmit a START signal. After the controller receives the notification, it detects whether the bus is free. When the bus is free, the master controller transmits a START signal to the bus. If the transmission is successful, the status code I2Cx_STAT becomes 0x08, and the interrupt flag bit I2Cx_CR.SI is set to 1.

After the master transmits the START signal, software needs to set I2Cx_CR.STA to 0, and then write the slave address and write flag bit (SLA+W) to the I2C data register I2Cx_DR; clear the I2Cx_CR.SI bit, the master controller SLA+W will be transmitted to the I2C bus; when the master transmits SLA+W and receives the ACK response signal from the slave, the status code I2Cx_STAT becomes 0x18, and the interrupt flag bit I2Cx_CR.SI is set to 1.

After that, the master transmits multiple bytes of user-defined data and detects the ACK response signal according to the needs of the application. The transmitting process of each byte is similar to that of sending SLA+W data frames.

In the process of transmitting data, if the master receives a NACK response signal, it indicates that the slave no longer receives the data sent by the host (I2Cx_CR.AA of the slave is cleared), the master should send a STOP signal to end the data transfer, or send Repeated START repeats the start signal to start a new round of transmission.

When the master completes transmitting all the data, set I2Cx_CR.STO to 1 to notify the controller that the data has been transmitted and the STOP signal is to be transmitted. Clear the I2Cx_CR.SI bit, and the master controller will transmit a STOP signal to the I2C bus to complete this data transfer and release the bus.

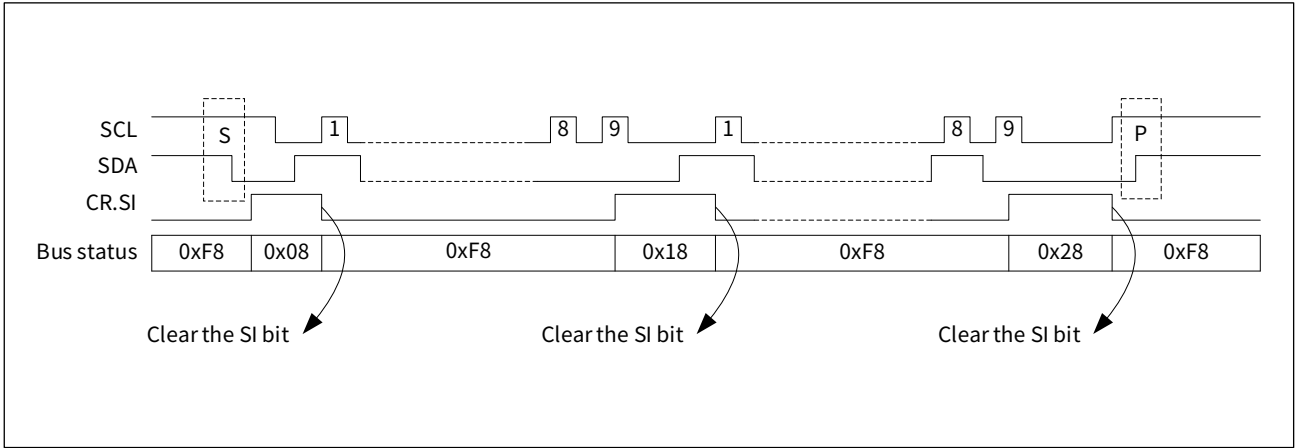
When the master has finished transmitting all the data, it can also not transmit the STOP signal, but directly transmit the Repeated START signal, and continue to occupy the bus for a new round of data transmission.

When the master loses arbitration due to a bus conflict, it enters the unaddressed slave receive mode (status code I2Cx_STAT=0x38).

The state synchronization diagram in the master transmit mode is shown in the following figure:



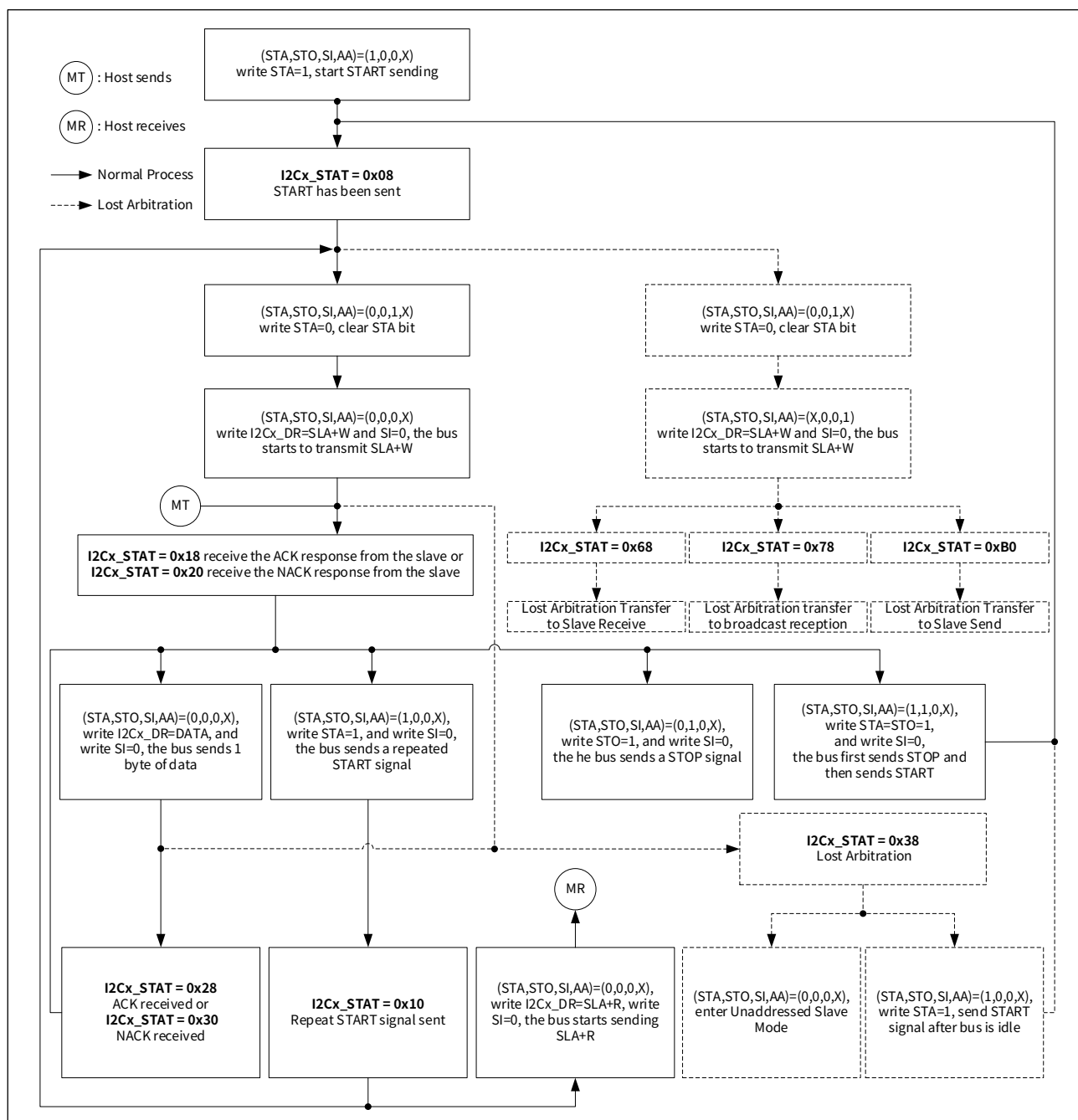
Figure 21-7 The status synchronization diagram of master transmit mode



The data transmission flow chart and status register values in the master transmit mode are shown in the following figure:



Figure 21-8 Master transmit mode flow and register status



21.4.8.2 Master receive mode

The master receive mode is used to receive multiple data transmitted by the slave, and the master will respond with an ACK response signal every time it receives 1 byte of data.

The SCL serial clock is controlled and generated by the master, so it is necessary to set the I2Cx_BRR register of the master according to the transmission baud rate and set the EN bit field of the I2Cx_BRREN register to 1, and then start the transmission.

The master sets I2Cx_CR.STA to 1, and informs the controller to send a START signal. After the controller receives the notification, it detects whether the bus is free. When the bus is free, the master controller sends a START signal to the bus. If the transmission is successful, the status code I2Cx_STAT becomes 0x08, and the interrupt flag bit I2Cx_CR.SI is set to 1.

After the master sends the START signal, the software needs to set I2Cx_CR.STA to 0, and then write the slave address and read flag bit (SLA+R) to the I2C data register I2Cx_DR; clear the I2Cx_CR.SI flag bit, the master controls the controller will send SLA+R to the I2C bus; when the master sends SLA+R and receives the ACK response signal from the slave, the status code I2Cx_STAT becomes 0x40, and the interrupt flag bit I2Cx_CR.SI is set to 1.

After that, the master sets I2Cx_CR.AA to 1, clears the I2Cx_CR.SI bit, and starts to receive the data transmitted by the slave. After receiving 1 byte of data, it will reply an ACK response signal. During the master receiving process, it should be cautioned that:

1. In order to ensure that the I2Cx_CR.SI interrupt signal can be correctly generated after receiving 1 byte of data, it is necessary to clear the I2Cx_CR.SI bit in time after receiving 1 byte of data.
2. Before receiving the last byte, I2Cx_CR.AA needs to be cleared, that is, the master does not generate an ACK response signal when receiving the last byte, so as to notify the slave to stop data transmission.

In the process of receiving data by the master, if the slave no longer transmits the data required by the master for some reason (the I2Cx_CR.AA of the slave is cleared), the master will receive all 1 signals later. At this time, the master needs to be in the application layer. Judgment is made on the data, and it is determined that the slave is in an unresponsive state. It should send a STOP signal to end the current transmission, or send a Repeated START signal to start a new round of transmission.

When the master completes receiving all the data, set I2Cx_CR.STO to 1 to notify the controller that the data has been received and to send a STOP signal. Clear the I2Cx_CR.SI bit, and the master controller sends a STOP signal to the I2C bus to complete the data transfer and release the bus.

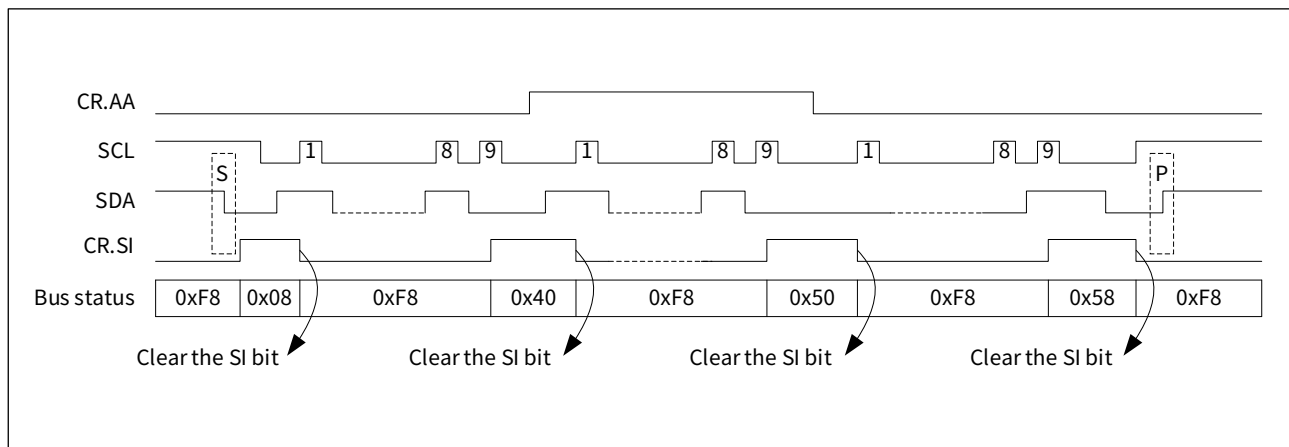
When the master has finished receiving all the data, it can also not send the STOP signal, but directly send the Repeated START signal, and continue to occupy the bus for a new round of data transmission.

When the master loses arbitration due to a bus conflict, it enters the unaddressed slave receive mode (status code I2Cx_STAT=0x38).

The state synchronization diagram in the master receive mode is shown in the following figure:

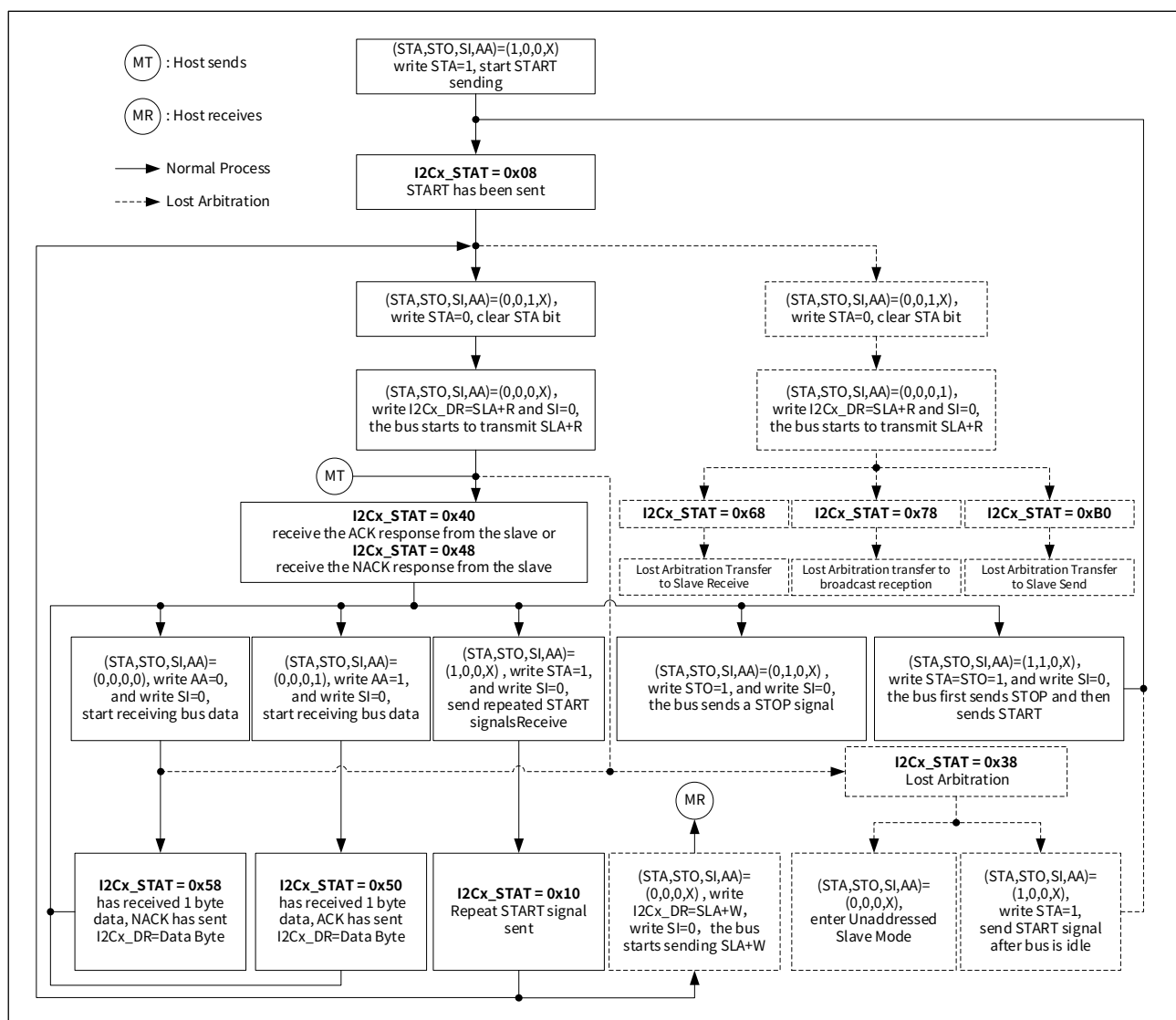


Figure 21-9 The status synchronization diagram of master receive mode



The data reception flow chart and status register value in the master receive mode are shown in the following figure:

Figure 21-10 Master receive mode flow and register status



21.4.8.3 Slave receive mode

In slave receive mode, the slave receives the data transmitted by the master.

Before transmission, the slave needs to set the slave address: write the slave address to any one of the three slave address registers I2Cx_ADDR0, I2Cx_ADDR1, I2Cx_ADDR2; set I2Cx_CR.AA to 1 to respond to the master's addressing; I2Cx_BRR The set value of the register is invalid, so it is not necessary to set it.

After completing the above initialization work, the slave machine enters the idle state (the slave receiving mode is not addressed), waiting to be addressed by the write signal (SLA+W) sent by the master. After the slave receives SLA+W, if the address matches I2Cx_ADDR0/1/2, the slave responds with ACK and enters the addressed slave receiving mode, the status code I2Cx_STAT becomes 0x60, and the interrupt flag bit I2Cx_CR.SI Also set to 1. The I2Cx_CR.SI bit must be cleared at this time in order to receive data from the master from the bus.

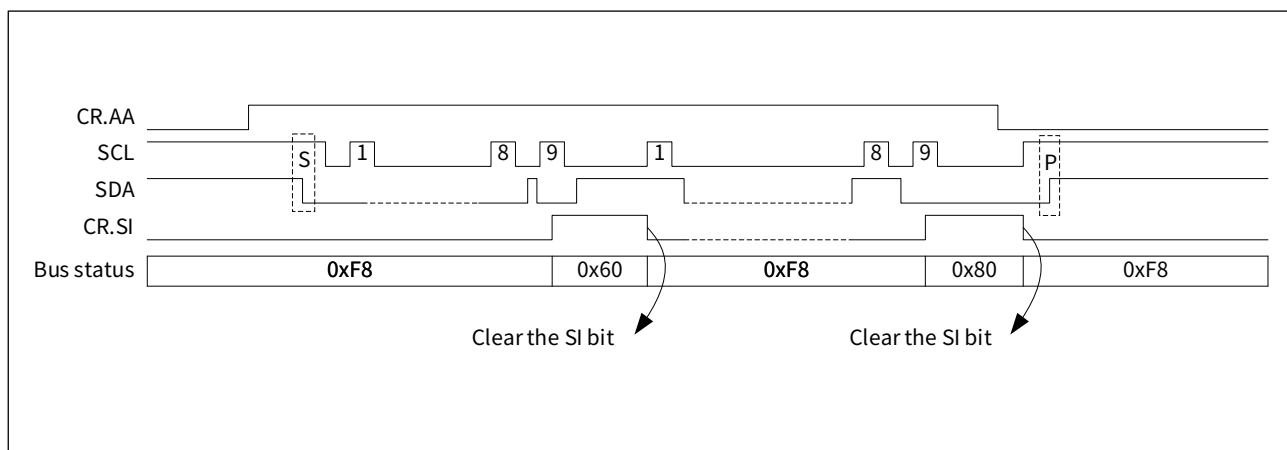
Every time the slave receives 1 byte of data, it must respond with an ACK response. After the application reads the byte of data, it must clear the I2Cx_CR.SI bit to prepare for receiving the next byte of data.

In the process of receiving data from the slave, if I2Cx_CR.AA is cleared, the slave will return a NACK signal when it receives the next byte, and the state of the slave will also switch to the unaddressed slave receiving mode, ending with the master. communication, no more data is received, and the I2Cx_DR register holds the previously received data. It can be seen from this feature that the slave application can actively switch the slave from the addressed slave receive mode to the unaddressed slave receive mode by setting I2Cx_CR.AA to 0.

When the master loses arbitration due to bus conflict in the SLA+ read and write stage, it will enter the unaddressed slave receiving mode, and then if it receives SLA+W that matches the local address and responds with ACK (status code I2Cx_STAT=0x68), it will enter addressed slave receive mode.

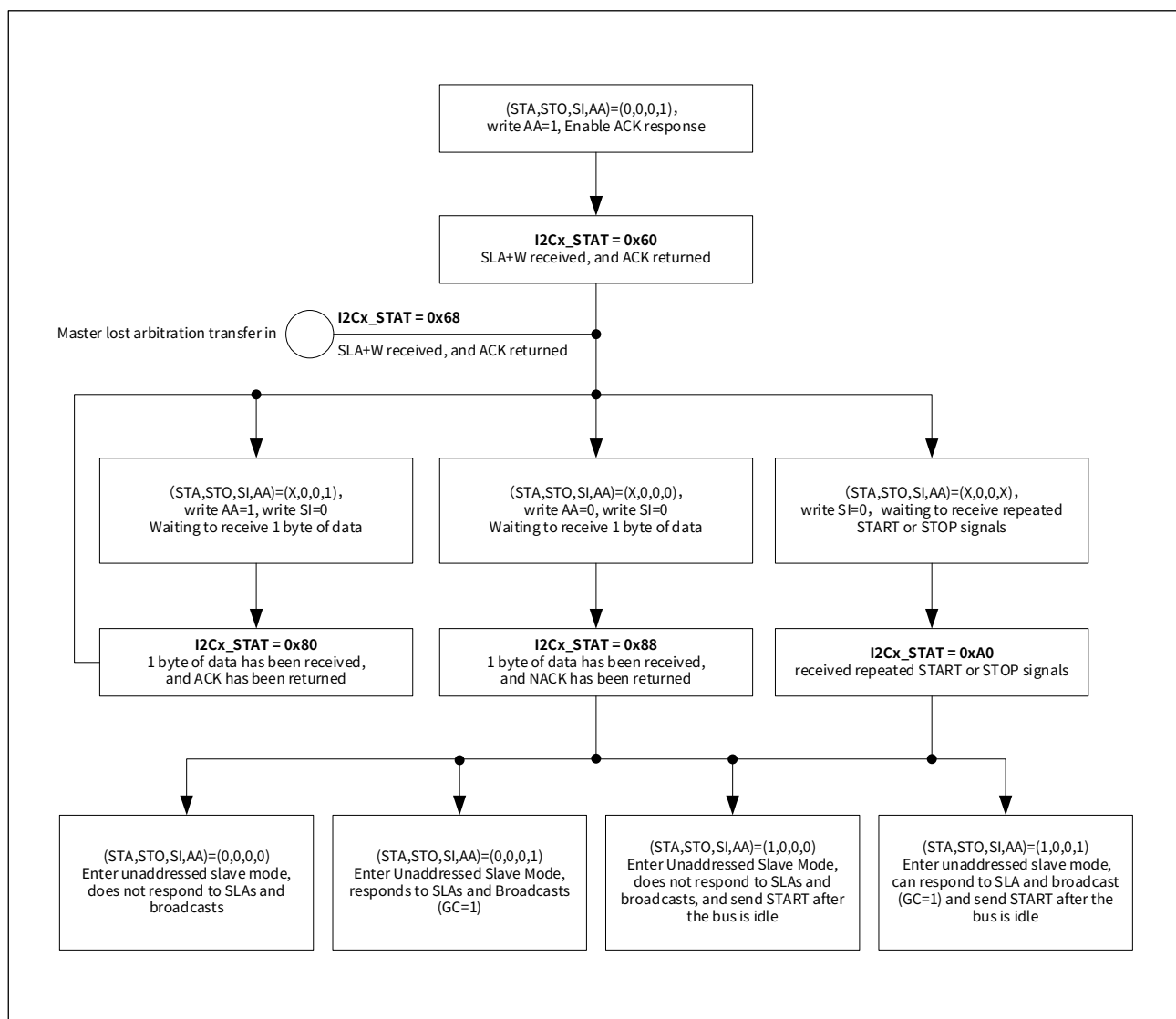
The state synchronization diagram in slave receive mode is shown in the following figure:

Figure 21-11 The status synchronization diagram of slave receive mode



The data receive flow chart and status register value in slave receive mode are shown in the following figure:

Figure 21-12 Slave receive mode flow and register status



21.4.8.4 Slave transmit mode

In slave transmit mode, data is transmitted from the slave to the master.

Before transmission, the slave needs to set the slave address: write the slave address to any one of the three slave address registers I2Cx_ADDR0, I2Cx_ADDR1, I2Cx_ADDR2; set I2Cx_CR.AA to 1 to respond to the master's addressing; I2Cx_BRR The set value of the register is invalid, so it is not necessary to set it.

After completing the above initialization work, the slave machine enters the idle state (the slave receive mode is not addressed), waiting to be addressed by the read signal (SLA+R) transmitted by the master. After the slave receives SLA+R, if the address matches I2Cx_ADDR0/1/2, the slave responds with ACK and enters the addressed slave transmit mode, the status code I2Cx_STAT becomes 0xA8, and the interrupt flag bit I2Cx_CR.SI Also set to 1. At this time, the data to be transmitted should be written into the I2Cx_DR register in time, and the I2Cx_CR.SI bit should be cleared, waiting for 1 byte of data to be transmitted, and ACK confirmation after each byte of data is transmitted until all data is transmitted.

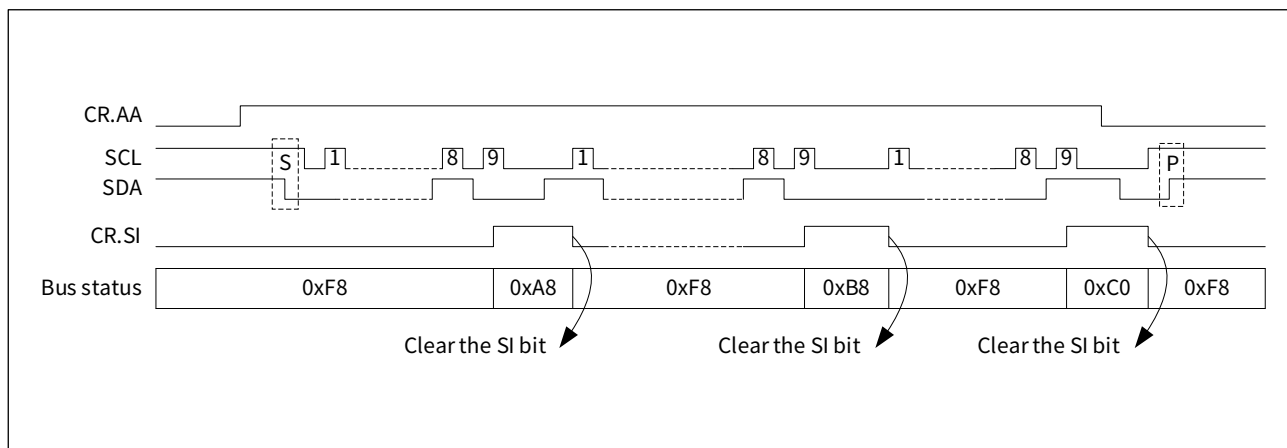
If the slave receives a NACK response during transmission, the slave no longer transmits data and enters the unaddressed slave receive mode.

If the slave actively sets I2Cx_CR.AA to 0 during the transmission process, the slave switches itself to the unaddressed slave receive mode after transmitting the last 1 byte of valid data, after which the master will get 0xFF when reading data from the bus.

When the master loses arbitration due to bus conflict in the SLA+ read and write stage, it will enter the unaddressed slave receive mode, and then if it receives SLA+R that matches the local address and responds with ACK (status code I2Cx_STAT=0xB0), it will enter addressed slave transmit mode.

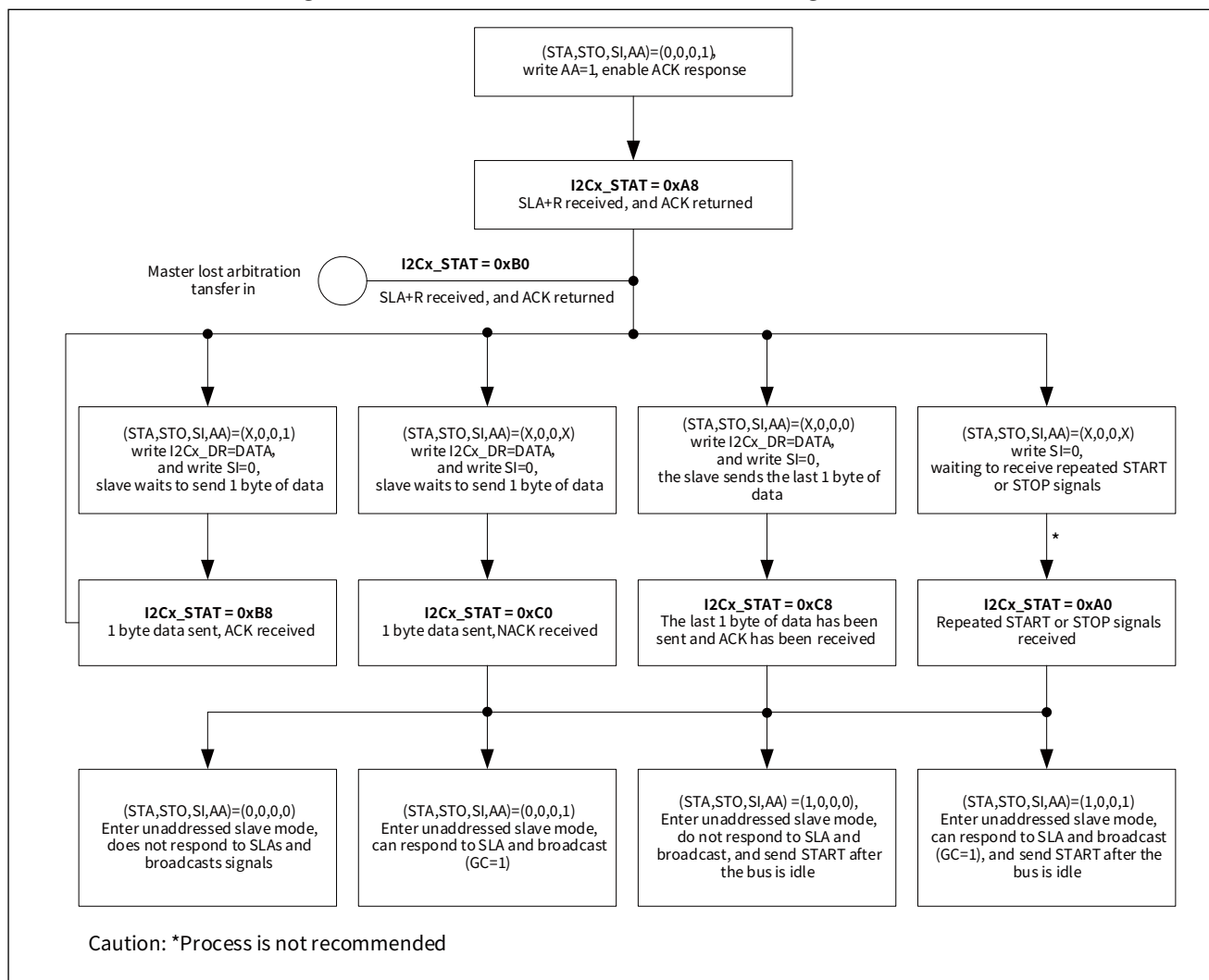
The state synchronization diagram in slave transmit mode is shown in the following figure:

Figure 21-13 The status synchronization diagram of slave transmit mode



The data transmission flow chart and status register value in slave transmit mode are shown in the following figure:

Figure 21-14 Slave transmit mode flow and register status



21.4.8.5 Broadcast receive mode

The broadcast receive mode is a special slave receive mode. When the slave is in an idle state (the slave receive mode is not addressed), the broadcast receive mode is entered when the SLA+W transmitted by the master is received, and the SLA is broadcast address 0x00. In this mode, the data reception process is the same as the slave receive mode, but the I2C bus status code is different.

To receive the broadcast information transmitted by the master, the slave needs to set I2Cx_CR.AA to 1 and I2Cx_ADDR0.GC to 1 to respond to the master's broadcast addressing and broadcast data; the three slave address registers I2Cx_ADDR0/1/2 do not need to be set; The value of I2Cx_BRR is invalid and does not need to be set.

After completing the above initialization work, the slave machine enters the idle state (the slave receive mode is not addressed), waiting to be addressed by the write signal (SLA+W) transmitted by the master. When the slave receives SLA+W, if the address matches the broadcast address 0x00, the slave responds with an ACK response and enters the broadcast receive mode, the status code I2Cx_STAT becomes 0x70, and the interrupt flag bit I2Cx_CR.SI is set to 1 at the same time. At this time, the I2Cx_CR.SI bit must be cleared in time to receive the data transmitted by the master from the bus.

Every time the slave receives 1 byte of data, it must respond with an ACK response. After the application reads the byte of data, it must clear the I2Cx_CR.SI bit to prepare for receiving the next byte of data.

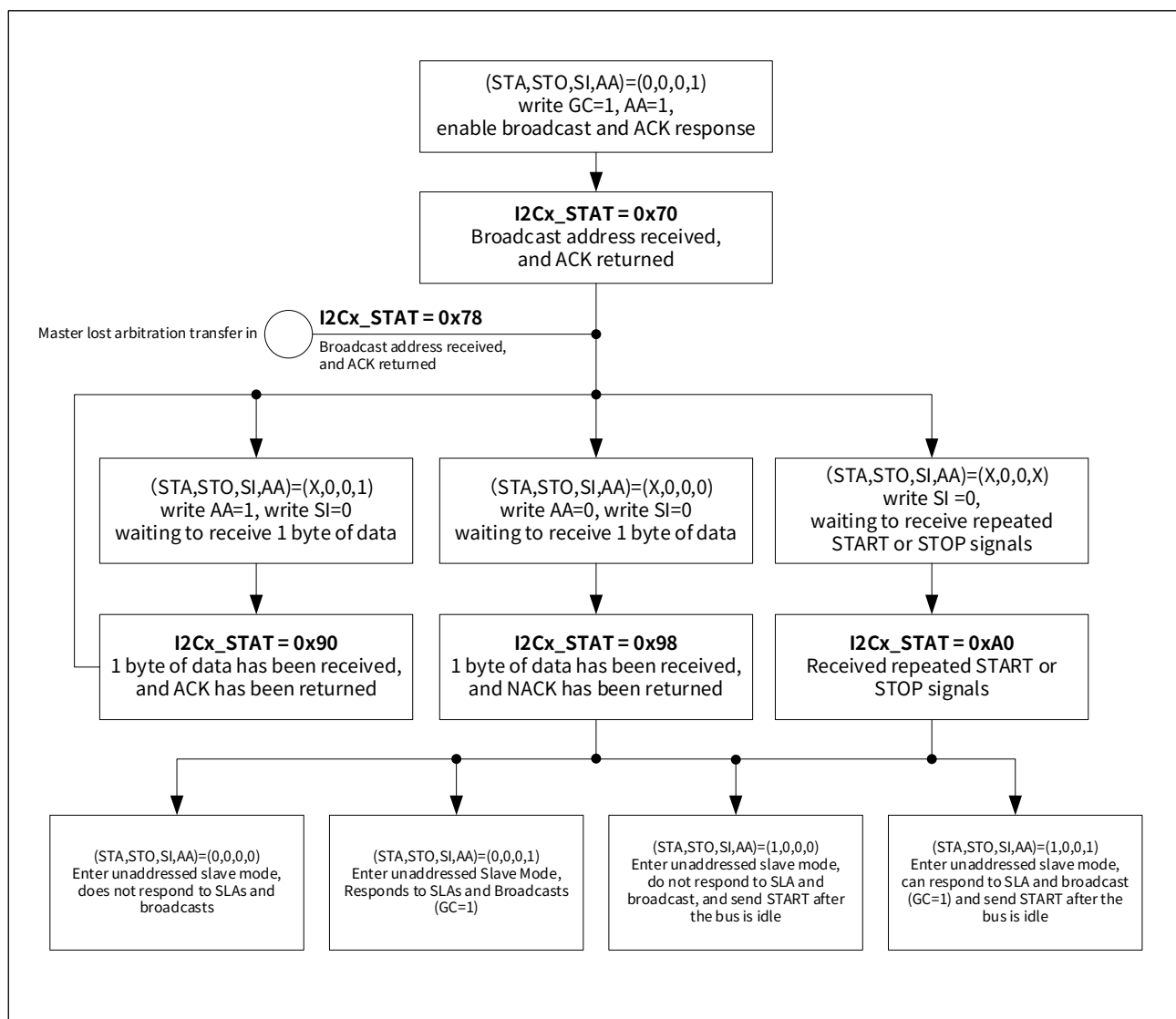
In the process of receiving data from the slave, if I2Cx_CR.AA is cleared, the slave will return the NACK signal when it receives the next byte, and the state of the slave will also switch to the unaddressed slave receive mode, ending communication with the master, no more data is received, and the I2Cx_DR register holds the previously received data. It can be seen from this feature that the slave application can actively switch from the addressed broadcast reception mode to the unaddressed slave receive mode by setting I2Cx_CR.AA to 0.

When the master loses arbitration due to bus conflict in the SLA+ read and write stage, it will enter the unaddressed slave receive mode, and then if it receives SLA+W that conforms to the broadcast address and responds with ACK (status code I2Cx_STAT=0x78), it will enter the addressed broadcast receive mode.

The data reception flow chart and status register value in broadcast receive mode are shown in the following figure:



Figure 21-15 Broadcast receive mode flow and register status



21.4.9 Multi-master communication

In some applications, there are two or more masters accessing the slave at the same time on one I2C bus, and it is possible to transmit data at the same time. At this time, there will be data conflicts on the SDA bus.

The I2C of the CW32L083 can perform data conflict detection and arbitration on the SDA bus to achieve multi-master applications. If two masters transmit data at the same time, the master that detects the conflict will lose arbitration and enter the unaddressed slave mode, and the master that has not detected the conflict will win the arbitration and continue to dominate the data communication flow.

21.4.10 I2C status codes

The I2C bus status is identified by the I2C status register I2Cx_STAT, with a total of 26 normal receiving or transmitting statuses, and 2 special statuses (0xF8: no information available on the I2C bus; 0x00: bus error).

Whether I2C is in master transmit, master receive, slave receive, slave transmit or broadcast receive mode, when the content of the status register I2Cx_STAT changes, I2Cx_CR.SI will be set and an I2C interrupt will be generated.

The I2C status codes are shown in the following table:

Table 21-3 I2C status codes

Operating mode	Status code	Meaning
Master transmit mode	08H	Start signal has been transmitted
	10H	Repeated start signal has been transmitted
	18H	SLA+W has been transmitted, ACK has been received
	20H	SLA+W has been transmitted, NACK has been received
	28H	Data in I2Cx_DR has been transmitted, ACK has been received
	30H	Data in I2Cx_DR has been transmitted, NACK has been received
	38H	The master loses arbitration during sending SLA+W phase or during transmitting data phase
Master receive mode	08H	Start signal has been transmitted
	10H	Repeated start signal has been transmitted
	38H	Host loses arbitration during transmitting SLA+R phase or responding to NACK phase
	40H	SLA+R has been transmitted, ACK has been received
	48H	SLA+R has been transmitted, NACK has been received
	50H	Data bytes have been received, ACK has been returned
	58H	Data bytes have been received, NACK has been returned

Operating mode	Status code	Meaning
Slave receive mode	60H	Its own SLA+W has been received, ACK has been returned
	68H	When the master loses arbitration in the SLA+read-write phase, its own SLA+W has been received, and ACK has been returned
	80H	The previous addressing used its own slave address, the data byte has been received, and ACK has been returned
	88H	The previous addressing used its own slave address, the data byte has been received, and NACK has been returned
	A0H	STOP or Repeated START condition is received while the addressed slave is waiting to receive data
Slave transmit mode	A8H	Its own SLA+R has been received, ACK has been returned
	B0H	When the master loses arbitration in the SLA+read-write phase, its own SLA+R has been received, and ACK has been returned
	B8H	Data bytes have been transmitted, ACK has been received
	C0H	Data bytes have been transmitted, NACK has been received
	C8H	Slave last data byte has been transmitted and ACK has been received
Broadcast receive mode	70H	The broadcast address (0x00) has been received, ACK has been returned
	78H	When the master loses arbitration in the SLA + read and write phase, the broadcast address has been received, and ACK has been returned
	90H	The previous addressing used the broadcast address, the data byte has been received, and the ACK has been returned
	98H	The previous addressing used the broadcast address, the data byte has been received, and NACK has been returned
	A0H	STOP or Repeated START condition is received while the addressed slave is waiting to receive data
Others	F8H	No relevant status information available, I2Cx_CR.SI=0
	00H	A bus error occurred during the transfer, or external interference caused the I2C to enter an undefined state

The special status code F8H indicates that there is no useful information at the current moment, and the current bus status cannot be determined, because I2Cx_CR.SI has not been set, and no interrupt is generated. This condition occurs before other states and the I2C module has started to perform a serial transfer.

The special status code 00H indicates that there is a bus error during the I2C serial transmission, such as the START or STOP signal appears in the wrong position of the data frame (including the address byte, data byte or response bit in the serial transmission process) or when external interference affects the internal I2C module signal, etc. When a bus error occurs, the I2Cx_CR.SI flag is immediately set, and the device is immediately switched to unaddressed slave receive mode, releasing SDA and SCL, and clearing the I2Cx_DR register.



When it is detected that the STAT of the I2C bus is a bus error (status code is 00H), since the I2C bus is continuously enabled, and the error has not been cleared for the I2C module, SI will continue to remain 1, that is, SI cannot be cleared.

Bus error clearing method:

1. Transmit a STOP signal to the bus: set the STO bit and clear the SI bit (due to the current bus error state, the controller does not actually transmit the STOP signal to the bus), the STO bit will be automatically cleared by hardware, releasing the bus to normal idle state.
2. If the SI bit cannot be cleared by setting the STO bit, it means that the timing has been disrupted. It is necessary to set I2Cx_CR.EN to 0 and 1 in turn, that is, shut down and restart the I2C module, and then set SI to 0 to clear the SI bit.

In each operating mode, the I2C bus state transition diagram is shown in the following figure. Caution that when transitioning between the two normal states, when the action is not completed (such as in the process of transmitting SLA), that is, before entering a new state, the status code will appear a short-term transition state, 0xF8. The user does not care, and no interruption is generated.

Figure 21-16 The status transition diagram of master transmit/receive mode

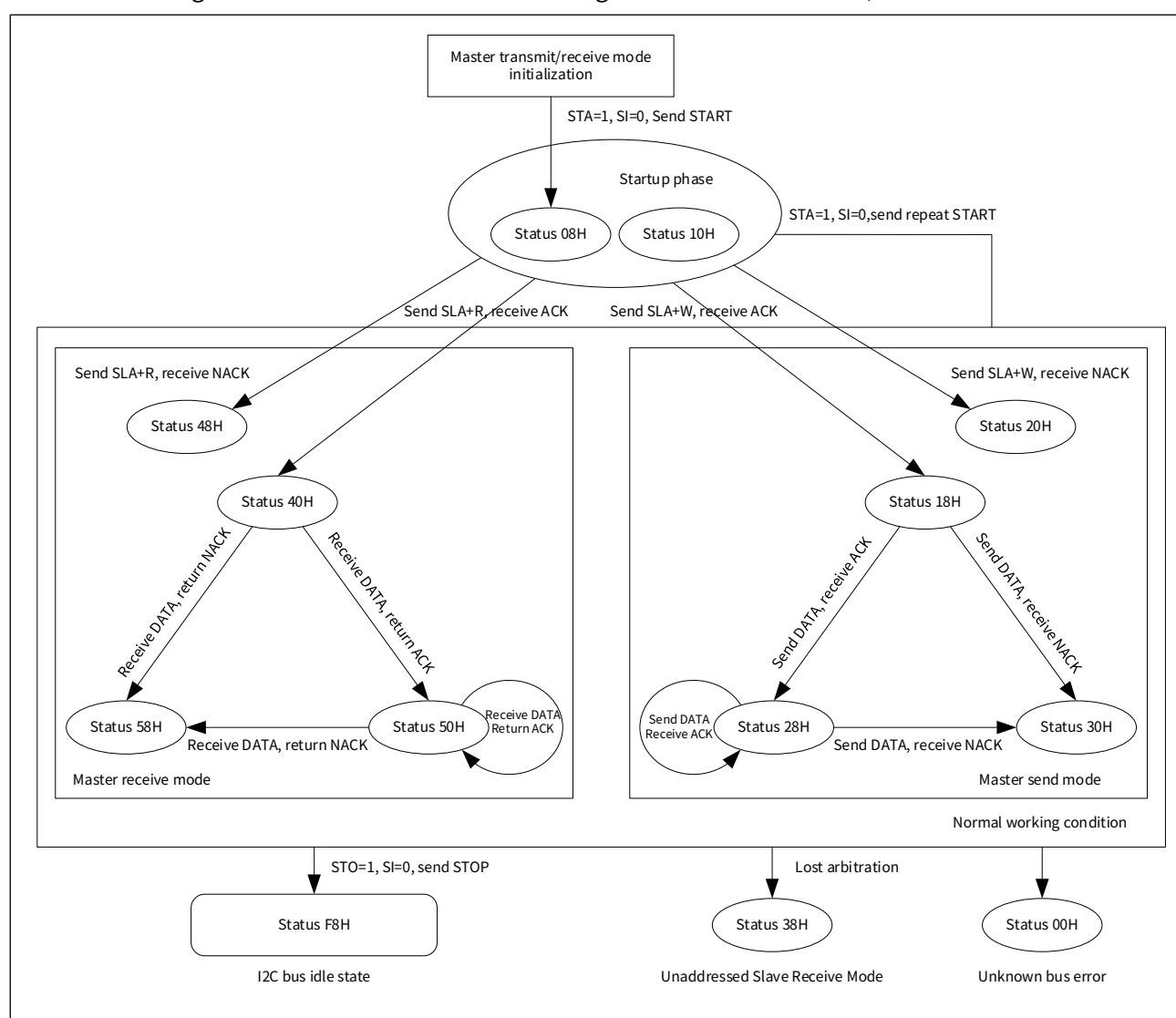


Figure 21-17 The status transition diagram of slave transmit/receive mode

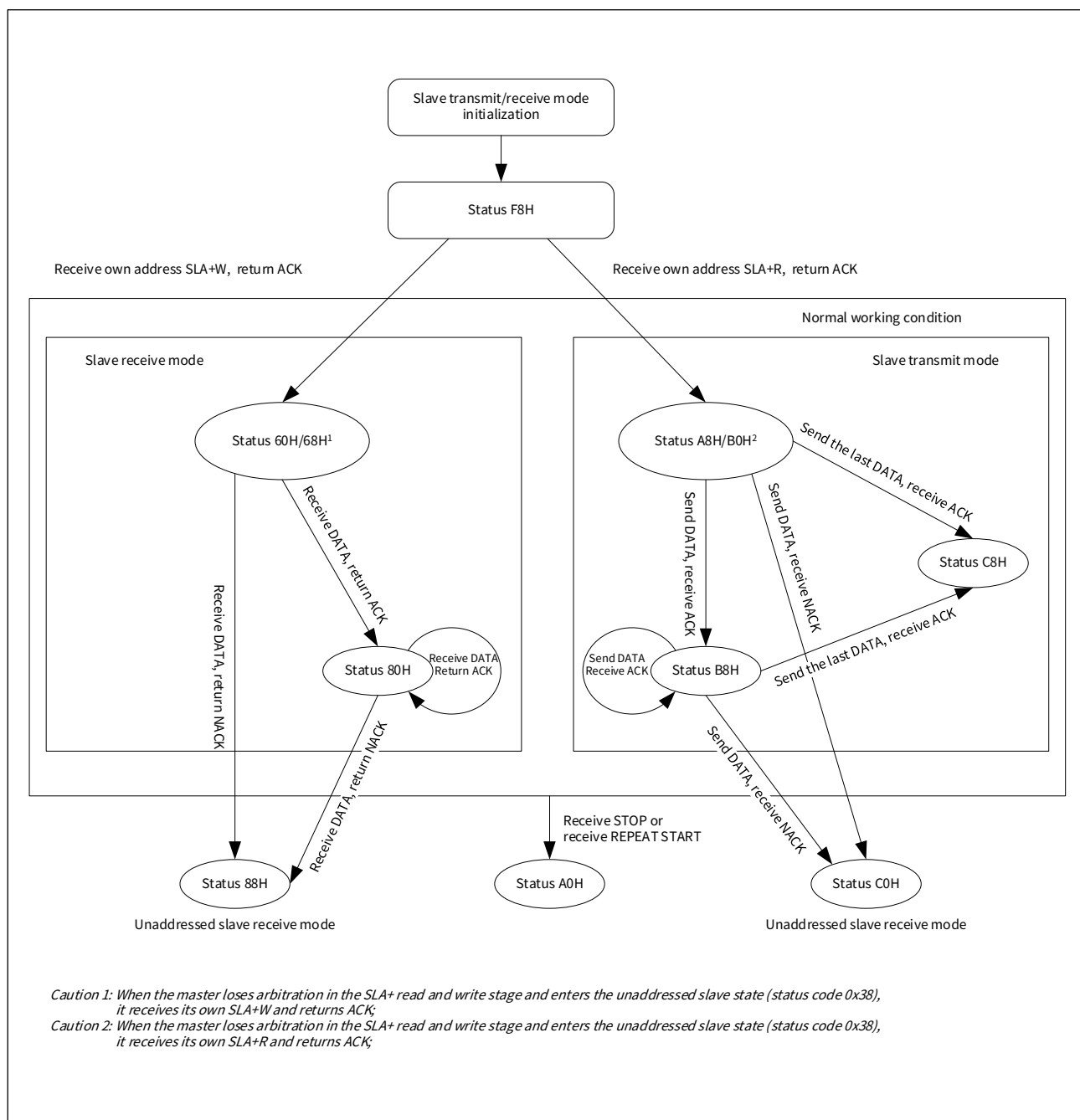
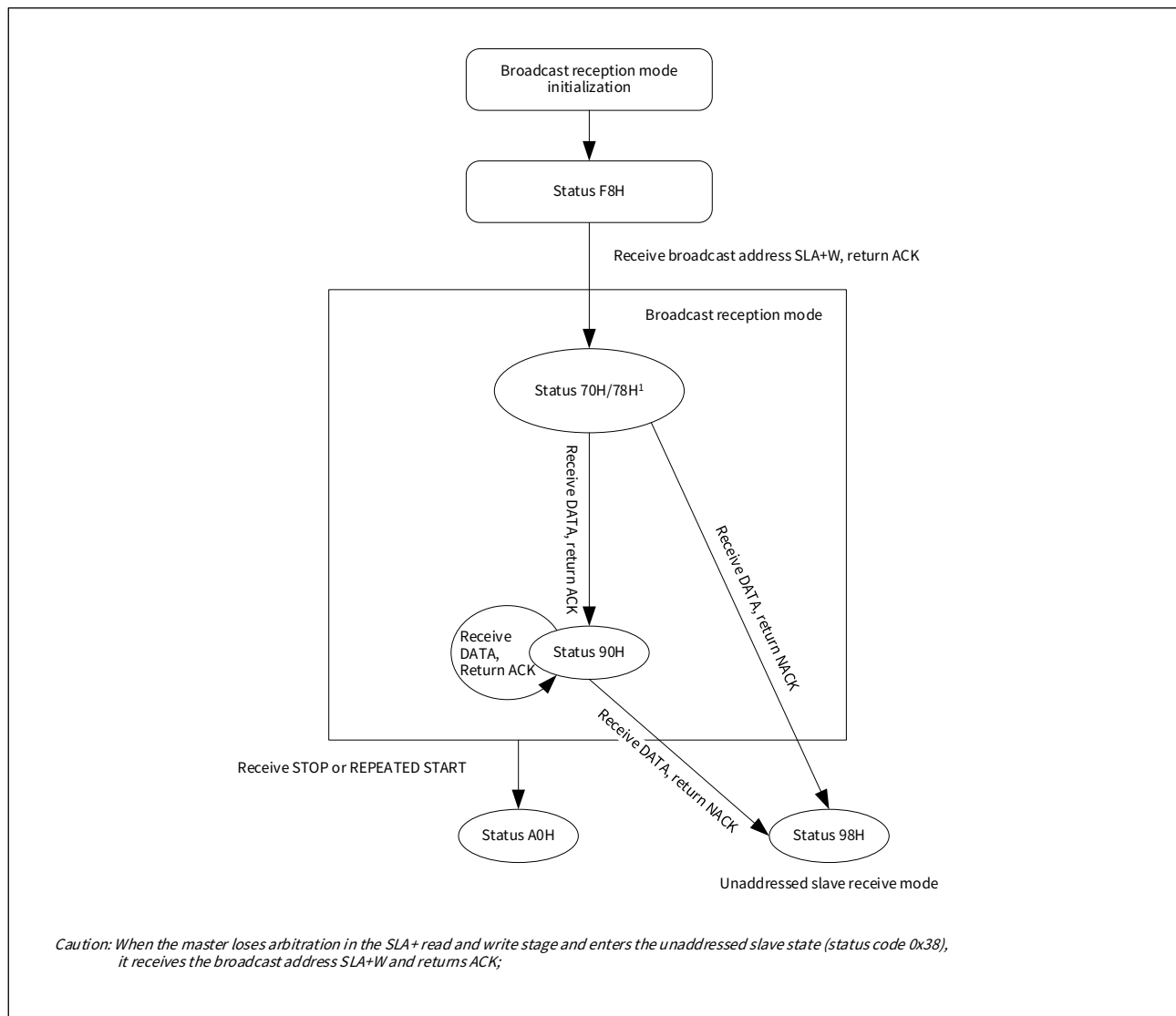


Figure 21-18 The status transition diagram of broadcast receive mode



21.5 Programming examples

21.5.1 Master transmits example

- Step 1: According to the relevant description of the pin digital multiplexed function in the GPIO chapter, map SCL and SDA to the required pins, and configure the SCL and SDA pins as open-drain output mode;
- Step 2: Set `SYSCTRL_APBEN1.I2Cx` to 1 to enable the I2Cx module clock;
- Step 3: Write 0 and 1 to `SYSCTRL_APBRS1.I2Cx` in turn to reset the I2Cx module;
- Step 4: Configure `I2Cx_BRR` to make the clock rate of SCL meet the application requirements;
- Step 5: Set `I2Cx_BRREN` to 1 to enable the SCL clock generator;
- Step 6: Set `I2Cx_CR.EN` to 1 to enable the I2C module;
- Step 7: Set `I2Cx_CR.STA` to 1, the bus tries to transmit a START signal;
- Step 8: Wait for `I2Cx_CR.SI` to become 1, START signal has been transmitted to the bus;
- Step 9: Query `I2Cx_STAT`, if the register value is 0x08 or 0x10, continue to the next step, otherwise, perform error processing;
- Step 10: Write `SLA+W` to `I2Cx_DR`, set `I2Cx_CR.STA` to 0, set `I2Cx_CR.SI` to 0, and transmit `SLA+W`;
- Step 11: Wait for `I2Cx_CR.SI` to become 1, `SLA+W` has been transmitted to the bus;
- Step 12: Query `I2Cx_STAT`, if the register value is 0x18, continue to the next step, otherwise, perform error processing;
- Step 13: Write the data to be transmitted to `I2Cx_DR`, set `I2Cx_CR.SI` to 0, and transmit the data;
- Step 14: Wait for `I2Cx_CR.SI` to become 1, the data has been transmitted to the bus;
- Step 15: Query `I2Cx_STAT`, if the register value is 0x28, continue to the next step, otherwise, perform error processing;
- Step 16: If the data to be transmitted is not completed, then jump to step 13 and continue to execute;
- Step 17: Set `I2Cx_CR.STO` to 1, set `I2Cx_CR.SI` to 0, transmit STOP signal, and end this data transfer.



21.5.2 Master receives example

- Step 1: According to the relevant description of the pin digital multiplexed function in the GPIO chapter, map SCL and SDA to the required pins, and configure the SCL and SDA pins as open-drain output mode;
- Step 2: Set `SYSCTRL_APBEN1.I2Cx` to 1 to enable the I2Cx module clock;
- Step 3: Write 0 and 1 to `SYSCTRL_APBRS1.I2Cx` in turn to reset the I2Cx module;
- Step 4: Configure `I2Cx_BRR` to make the clock rate of SCL meet the application requirements;
- Step 5: Set `I2Cx_BRREN` to 1 to enable the SCL clock generator;
- Step 6: Set `I2Cx_CR.EN` to 1 to enable the I2C module;
- Step 7: Set `I2Cx_CR.STA` to 1, the bus tries to transmit a START signal;
- Step 8: Wait for `I2Cx_CR.SI` to become 1, START signal has been transmitted to the bus;
- Step 9: Query `I2Cx_STAT`, if the register value is 0x08 or 0x10, continue to the next step, otherwise, perform error processing;
- Step 10: Write `SLA+W` to `I2Cx_DR`, set `I2Cx_CR.STA` to 0, set `I2Cx_CR.SI` to 0, and transmit `SLA+R`;
- Step 11: Wait for `I2Cx_CR.SI` to become 1, `SLA+R` has been transmitted to the bus;
- Step 12: Query `I2Cx_STAT`, if the register value is 0x40 (ACK has been received), continue to the next step, otherwise, perform error processing;
- Step 13: Set `I2Cx_CR.AA` to 1, enable the response flag;
- Step 14: Set `I2Cx_CR.SI` to 0, waiting to receive 1 byte of data (the master transmits the clock, and the slave transmits data under the action of the clock);
- Step 15: Wait for `I2Cx_CR.SI` to become 1 (the host has completed the 1-byte data reception and has responded to the ACK signal), and read the received data from `I2Cx_DR`;
- Step 16: Query `I2Cx_STAT`, if the register value is 0x50 or 0x58, continue to the next step, otherwise, perform error processing;
- Step 17: If the data to be received is only missing the last byte, set `I2Cx_CR.AA` to 0, and enable the non-response flag;
- Step 18: If the data to be received is not completed, then jump to step 14 and continue to execute;
- Step 19: Set `I2Cx_CR.STO` to 1, set `I2Cx_CR.SI` to 0, transmit STOP signal, and end this data transfer.



21.5.3 Slave receives example

- Step 1: According to the relevant description of the pin digital multiplexed function in the GPIO chapter, map SCL and SDA to the required pins, and configure the SCL and SDA pins as open-drain output mode;
- Step 2: Set `SYSCTRL_APBEN1.I2Cx` to 1 to enable the I2Cx module clock;
- Step 3: Write 0 and 1 to `SYSCTRL_APBRS1.I2Cx` in turn to reset the I2Cx module;
- Step 4: Set `I2Cx_CR.EN` to 1 to enable the I2C module;
- Step 5: Configure `I2Cx_ADDR0` as the slave address;
- Step 6: Set `I2Cx_CR.AA` to 1, enable the response flag;
- Step 7: Wait for `I2Cx_CR.SI` to become 1 and be addressed by `SLA+W`;
- Step 8: Query `I2Cx_STAT`, if the register value is 0x60, continue to the next step, otherwise, perform error processing;
- Step 9: Set `I2Cx_CR.SI` to 0, wait for the master to transmit data, and respond to the ACK signal;
- Step 10: Wait for `I2Cx_CR.SI` to become 1, and read the received data from `I2Cx_DR`;
- Step 11: Query `I2Cx_STAT`, if the register value is 0x80, continue to the next step, otherwise, perform error processing;
- Step 12: If the data to be received is not completed, then jump to step 9 and continue to execute;
- Step 13: Set `I2Cx_CR.AA` to 0, set `I2Cx_CR.SI` to 0, the slave switches to the unaddressed slave receive mode, and does not respond to master addressing.

21.5.4 Slave transmits example

- Step 1: According to the relevant description of the pin digital multiplexed function in the GPIO chapter, map SCL and SDA to the required pins, and configure the SCL and SDA pins as open-drain output mode;
- Step 2: Set `SYSCTRL_APBEN1.I2Cx` to 1 to enable the I2Cx module clock;
- Step 3: Write 0 and 1 to `SYSCTRL_APBRS1.I2Cx` in turn to reset the I2Cx module;
- Step 4: Set `I2Cx_CR.EN` to 1 to enable the I2C module;
- Step 5: Configure `I2Cx_ADDR0` as the slave address;
- Step 6: Set `I2Cx_CR.AA` to 1, enable the response flag;
- Step 7: Wait for `I2Cx_CR.SI` to become 1 and be addressed by `SLA+R`;
- Step 8: Query `I2Cx_STAT`, if the value of this register is 0xA8, continue to the next step, otherwise, perform error processing;
- Step 9: Write the data to be transmitted to `I2Cx_DR`, set `I2Cx_CR.SI` to 0, and prepare to transmit data;
- Step 10: Wait for `I2Cx_CR.SI` to become 1, indicating that the data has been transmitted to the bus and received an ACK or NACK response;
- Step 11: Query `I2Cx_STAT`, if the value of this register is 0xB8, continue to the next step, otherwise, perform error processing;
- Step 12: If the data to be transmitted is not completed, then jump to step 9 to continue execution;
- Step 13: Set `I2Cx_CR.AA` to 0, set `I2Cx_CR.SI` to 0, the slave switches to the unaddressed slave receive mode, and does not respond to master addressing.



21.6 List of registers

I2C1 base address: I2C1_BASE = 0x4000 5400

I2C2 base address: I2C2_BASE = 0x4000 5800

Table 21-4 List of I2C registers

Register name	Register address	Register description
I2Cx_BRREN	I2Cx_BASE + 0x00	Baud rate counter enable register
I2Cx_BRR	I2Cx_BASE + 0x04	Baud rate counter configuration register
I2Cx_CR	I2Cx_BASE + 0x08	Control register
I2Cx_DR	I2Cx_BASE + 0x0C	Data register
I2Cx_ADDR0	I2Cx_BASE + 0x10	Slave address 0 register
I2Cx_STAT	I2Cx_BASE + 0x14	Status register
I2Cx_ADDR1	I2Cx_BASE + 0x20	Slave address 1 register
I2Cx_ADDR2	I2Cx_BASE + 0x24	Slave address 2 register
I2Cx_MATCH	I2Cx_BASE + 0x28	Slave address match flag register



21.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

21.7.1 I2Cx_BRREN baud rate counter enable register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:1	RFU	-	Reserved bits, please keep the default value
0	EN	RW	I2C bus SCL baud rate counter enable control 0: Disabled 1: Enabled Caution: EN should be enabled when the master, this bit does not affect the slave

21.7.2 I2Cx_BRR baud rate counter configuration register

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	BRR	RW	I2C bus SCL baud rate configuration $f_{SCL} = f_{PCLK} / 8 / (BRR+1)$, where $BRR > 0$



21.7.3 I2Cx_CR control register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	EN	RW	Module enable control 0: Disabled 1: Enabled
5	STA	RW	Bus Status Control W0: Clear STA W1: Send START signal to the bus Caution 1: After setting STA to 1, if the bus is idle, send the START signal, if the bus is busy, wait for the I2C to stop, and then send the START signal. Caution 2: If the device is already in master mode and has sent one or more bytes, and then set STA at this time, the I2C bus will generate a Repeated START signal. Caution 3: STA can be set at any time, including slave mode. However, the hardware will not automatically clear 0 after the completion of the START or repeat START signal transmission, and the user needs to manually clear STA.
4	STO	RW	Bus Status Control W0: No function W1: Send STOP signal to bus Caution 1: The hardware will automatically clear STO to 0 after the completion of the STOP signal transmission. Caution 2: If STA and STO are set at the same time in master mode, the I2C bus sends START immediately after sending STOP. In slave mode, it is forbidden to set STA and STO at the same time to avoid sending illegal I2C frames. Caution 3: STO is also set to 1 when an error state occurs on the bus (STAT status word is 00H), but the I2C bus will not send a STOP signal in this case.



Bit field	Name	Permission	Function description
3	SI	RW	<p>I2C interrupt flags</p> <p>R0: No I2C interrupt occurred</p> <p>R1: I2C interrupt has occurred</p> <p>W0: Clear the I2C interrupt flag and cause the status machine to execute the next action</p> <p>W1: No function</p> <p>Caution 1: If one of the 26 states of I2C occurs, the hardware will set this bit (except F8H) to 1. At this time, the software confirms the current status of the bus through the I2Cx_STAT register value.</p> <p>Caution 2: SI needs to be cleared by software.</p> <p>Caution 3: Before SI is cleared to 0, the SCL low level period is extended and the transmission is suspended. This status is very useful for the slave to process the received data, which can ensure that the previous data is accurately processed before the next data is received.</p> <p>Caution 4: Before software clears SI, software should prepare appropriate register settings. After SI is cleared, the I2C bus will perform the corresponding operation according to the register settings.</p>
2	AA	RW	<p>Response control</p> <p>0: Transmit NACK in response phase</p> <p>1: Transmit ACK in response phase</p> <p>Caution 1: For the addressed slave, if no ACK response bit is returned in slave receive mode or no ACK response bit is received in slave transmit mode, the slave will switch to unaddressed slave receive mode, cannot receive data until its AA is set and re-addressed by the master.</p> <p>Caution 2: Special case: in slave transmit mode, before the slave transmits the last byte to the master, clear AA. After transmitting the last byte, the slave will switch to the unaddressed slave mode and be disconnected from the master, the status register I2Cx_STAT is C8H. If the master reads data from the bus again, it will get 0xFF.</p>
1	RFU	-	Reserved bits, please keep the default value
0	FLT	RW	<p>I2C filter parameter configuration</p> <p>0: Advanced filtering, higher anti-interference performance</p> <p>1: Simple filtering, faster communication rate</p> <p>Caution: See section 21.4.3 Input filter.</p>



21.7.4 I2Cx_DR data register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	DR	RW	Data register In transmit mode, write the transmitted data In receive mode, read the received data

21.7.5 I2Cx_STAT status register

Address offset: 0x14 Reset value: 0x0000 00F8

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:0	STAT	RO	I2C status register, see section 21.4.10 I2C status codes for the specific definition of status value; when STAT = F8H, it means that there is no relevant status information available, and SI will remain at 0. For the other 26 states, SI will be set to 1 and an interrupt request will be generated.

21.7.6 I2Cx_ADDR0 slave address 0 register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:1	ADDR0	RW	Slave mode address 0 Caution 1: The master mode is invalid. Caution 2: The master needs to address the slave, and the address information must be the same as this address through the first byte value address information after START or Repeated START. If AA is 1, the slave responds to the master and becomes the addressed slave, otherwise the master broadcast addressing information will be ignored. Caution 3: I2Cx_ADDR0[7:1] cannot be written as all 0, because 0x00 is reserved for broadcast addressing.
0	GC	RW	Broadcast address response enabled 0: Disabled 1: Enabled Caution 1: The master mode is invalid. Caution 2: After enabling GC, if AA is set to 1, the broadcast receive mode is enabled, and if AA is cleared to 0, the broadcast addressing information on the bus is ignored.



21.7.7 I2Cx_ADDR1 slave address 1 register

Address offset: 0x20 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:1	ADDR1	RW	Slave mode address 1 Caution: The master mode is invalid.
0	RFU	-	Reserved bits, please keep the default value

21.7.8 I2Cx_ADDR2 slave address 2 register

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7:1	ADDR2	RW	Slave mode address 2 Caution: The master mode is invalid.
0	RFU	-	Reserved bits, please keep the default value



21.7.9 I2Cx_MATCH slave address match register

Address offset: 0x28 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:3	RFU	-	Reserved bits, please keep the default value
2	ADDR2	RO	I2C slave mode address 2 match flag bit 0: The device address received from the bus is not the same as ADDR2 1: The device address received from the bus is the same as ADDR2
1	ADDR1	RO	I2C slave mode address 1 match flag bit 0: The device address received from the bus is not the same as ADDR1 1: The device address received from the bus is the same as ADDR1
0	ADDR0	RO	I2C slave mode address 0 match flag bit 0: The device address received from the bus is not the same as ADDR0 1: The device address received from the bus is the same as ADDR0

Caution:*The address match flag bit will be cleared in the following three cases:*

- When the module is reset;
- When START/STOP is transmitted.



22 Infrared modulation transmitter (IR)

22.1 Overview

The CW32L083 integrates an infrared modulation transmitter (IR), which can be used in conjunction with UART through two general-purpose timers or one general-purpose timer, which can easily implement various standard PWM or PPM encoding methods, and can also realize infrared modulation transmission of UART data.

22.2 Main features

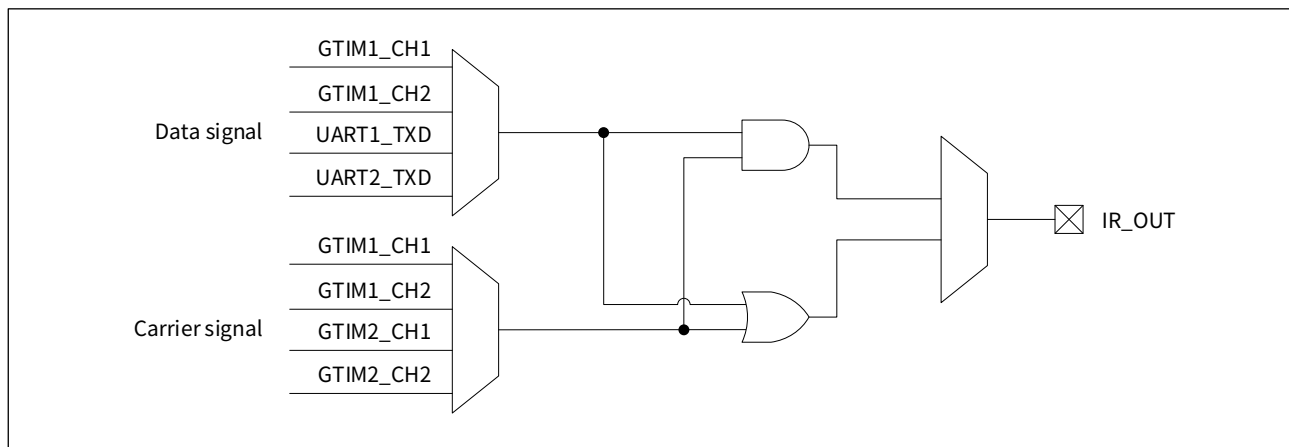
- Supports SIR of IrDA standard 1.0
- Maximum data rate 115.2kbps
- Can adapt to high and low level infrared emission tube



22.3 Functional description

When the infrared modulation transmitter is implemented, a general timer channel is used to generate a square wave signal with a fixed frequency, and another general timer or UART is used to generate modulation data. After 'AND' or 'OR' operation of the two, it is converted from IR_OUT pin output, for specific IR_OUT pins, please refer to the pin definitions in the data sheet. The schematic diagram of internal connection of IR is shown in the following figure:

Figure 22-1 Schematic diagram of internal connection of IR



The IR infrared modulation control register SYSCTRL_IRMOD is used to select the source of the carrier signal and the data signal, as well as the 'AND' or 'OR' operation of the two. The choice of 'AND' and 'OR' is determined by the drive level of the user's hardware infrared emitter.

The carrier signal frequency can be set by the user, the most common carrier frequency is 38KHz.

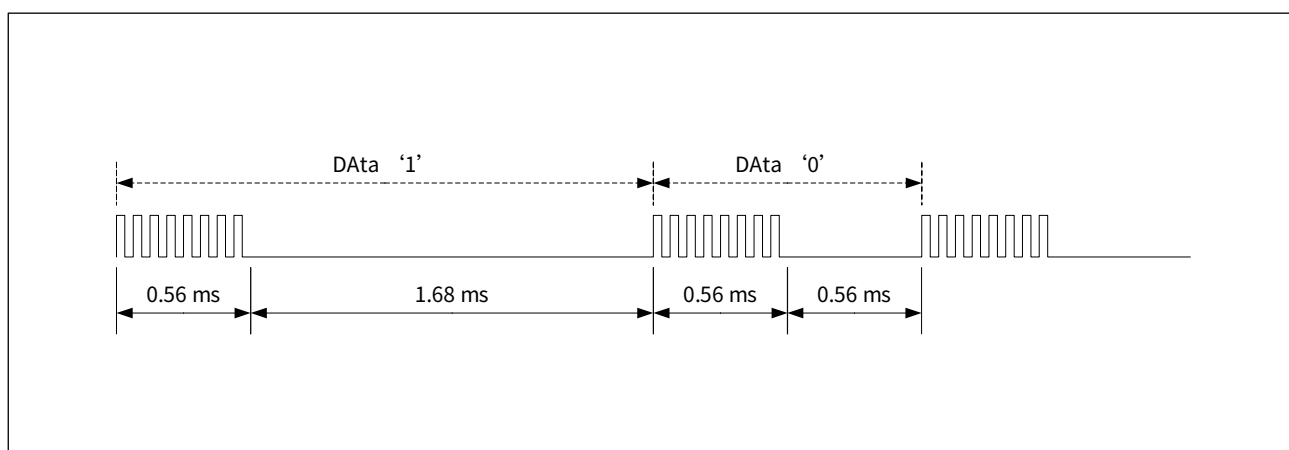
In order to reduce the transmission power consumption, the duty cycle of the carrier is generally set to about 20%, and the timer that generates the carrier can use the PWM mode, please refer to chapter [15 General-purpose timer \(GTIM\)](#). In order to increase the transmission distance, the duty cycle can be appropriately increased. In the IrDA standard 1.0, in order to achieve a fast IR communication rate, the width of the pulse is specified as 3/16 of a bit period or a fixed 1.63 μ s, and the minimum cannot be lower than 1.41 μ s.

22.3.1 Infrared modulation mode

There are two common IR infrared encoding methods, pulse width modulation PWM and pulse position modulation PPM.

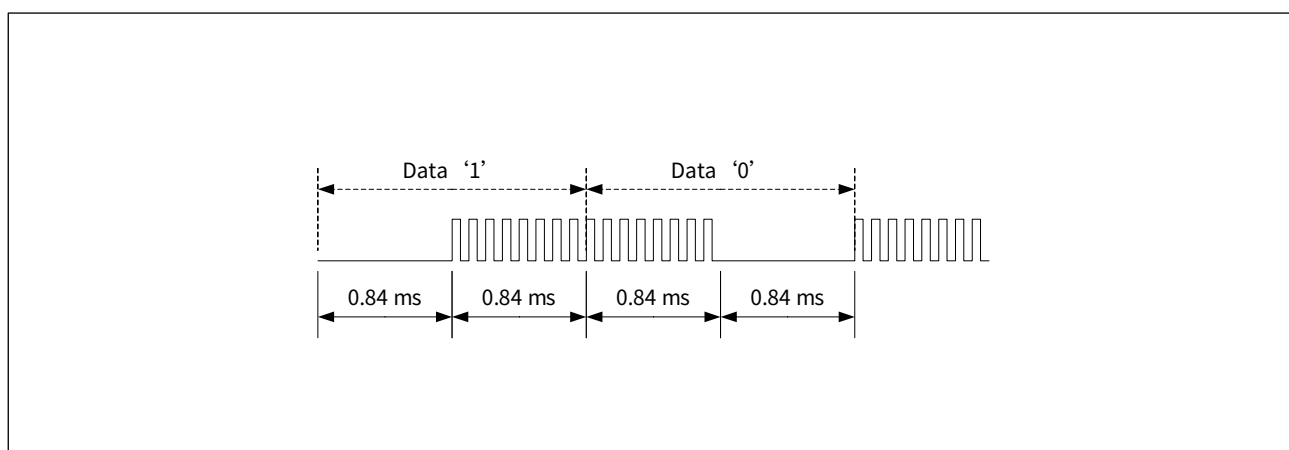
PWM pulse width modulation to represent '0' and '1' with the duty cycle of the transmitted infrared carrier. For example, UPD6121, the carrier transmits 0.56ms, and does not transmit 0.56ms, which means '0'; the carrier transmits 0.56ms, and does not transmit 1.68ms, which means '1'. The reference diagram is shown in the following figure:

Figure 22-2 PWM modulation mode



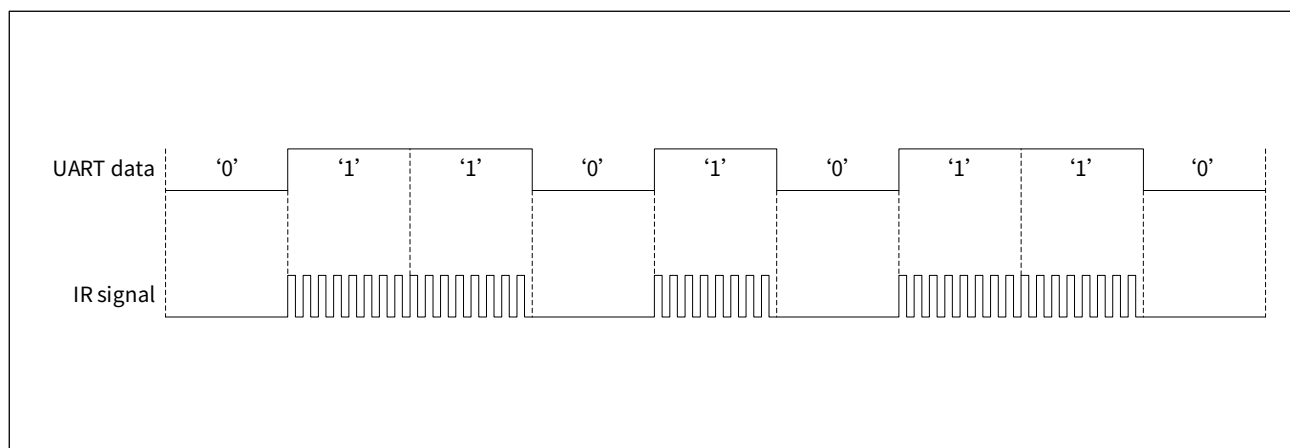
PPM pulse position modulation to represent '0' and '1' with the position of the transmitted carrier. It is '0' from transmitting carrier to not transmitting carrier, and '1' from never transmitting carrier to transmitting carrier. For example, SAA3010, the carrier transmits 0.84ms, and does not transmit 0.84ms, which means '0'; does not transmit 0.84ms, and the carrier transmits 0.84ms, means '1'. The reference diagram is shown in the following figure:

Figure 22-3 PPM modulation mode



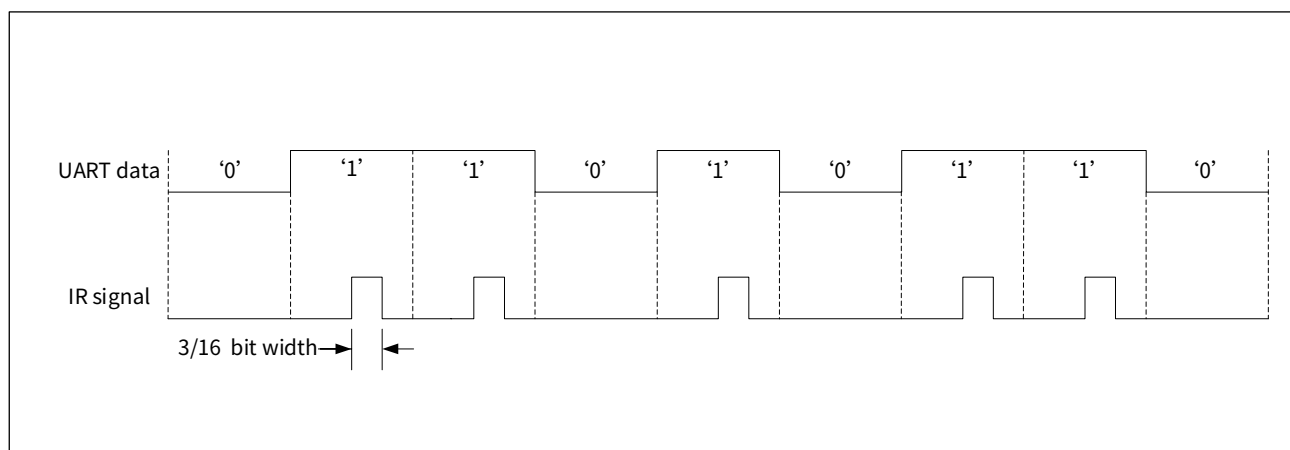
UART modulation is a relatively simple infrared modulation method, which directly performs 'AND' or 'OR' operation on serial data and carrier signal. When the UART serial baud rate is lower than the carrier frequency, the reference schematic diagram is shown in the following figure:

Figure 22-4 UART modulation mode



When the UART serial baud rate is higher than the carrier frequency, the carrier pulse width should be set to 3/16 of the bit width, and the carrier frequency should be kept consistent with the serial frequency. For example, when the UART baud rate is set to 115.2Kbps, the carrier frequency is also set to 115.2KHz, and the width of the carrier pulse is $1.63\mu\text{s}$ ($3/16 \times 1/115200\text{Hz} = 1.63\mu\text{s}$). The reference schematic diagram is shown in the following figure:

Figure 22-5 High-speed UART modulation mode



For the convenience of debugging, usually a standard data frame also includes boot code, end bit, retransmission code, etc. Please refer to the relevant data manual by yourself.

22.3.2 Infrared modulation initialization configuration

The initialization process of a complete IR infrared modulation transmitter should include the configuration of timer, UART, and GPIO. The reference steps are as follows:

- Step 1: Set the SYSCtrl_APBEN1 and SYSCtrl_APBEN2 registers to enable the timer and UART peripheral clock to be selected;
- Step 2: Set the allowed bits of the GPIO clock corresponding to the IR_OUT pin in the SYSCtrl_AHBEN register.
- Step 3: Configure the timer selected as the carrier, set the carrier frequency, duty cycle (common frequency 38KHz, 1/3 duty cycle), and set the timer working mode (PWM output is recommended);
- Step 4: Configure the timer or UART selected as data, set the bit width, and UART working mode (no need to define output pins);
- Step 5: Write '0x5A5Axxxx' to the GPIOx_LCKR register to unlock the GPIO pin selected as the IR_OUT output port;
- Step 6: Set GPIOx_ANALOG as IR_OUT output port as digital mode, set GPIOx_DIR as output, and set appropriate GPIOx_OPENDRAIN, GPIOx_PUPDR and GPIOx_PDR;
- Step 7: Start the timer and UART as carrier and data;
- Step 8: Set the MOD bit field of the IR infrared modulation control register SYSCtrl_IRMOD, and set the infrared modulation mode configuration;
- Step 9: Set the GPIOx_AFRH of the IR_OUT output port to IR_OUT, and enable the IR multiplexing function.

22.3.3 Infrared reception

CW32L083 does not have an IR receiving demodulation module inside. In IR receiving applications, it is necessary to use an integrated infrared receiving head with demodulation function. With the capture function of GTIM (UART mode can directly use the RXD pin input), it can be easily realized IR receiving function.



22.4 SYSCTRL_IRMOD infrared modulation control register

Address: 0x4001 0000 + 0x74 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:4	RFU	-	Reserved bits, please keep the default value
3:0	MOD	RW	Infrared modulation mode configuration 0000: GTIM1_CH1 & GTIM2_CH1 0001: GTIM1_CH1 & GTIM2_CH2 0010: GTIM1_CH2 & GTIM2_CH1 0011: GTIM1_CH2 & GTIM2_CH2 0100: GTIM1_CH1 GTIM2_CH1 0101: GTIM1_CH1 GTIM2_CH2 0110: GTIM1_CH2 GTIM2_CH1 0111: GTIM1_CH2 GTIM2_CH2 1000: UART1_TXD & GTIM1_CH1 1001: UART1_TXD GTIM1_CH1 1010: UART1_TXD & GTIM1_CH2 1011: UART1_TXD GTIM1_CH2 1100: UART2_TXD & GTIM2_CH1 1101: UART2_TXD GTIM2_CH1 1110: UART2_TXD & GTIM2_CH2 1111: UART2_TXD GTIM2_CH2



23 Analog-to-digital converter (ADC)

23.1 Overview

CW32L083 integrates a successive approximation analog-to-digital converter (SAR ADC) with a 12-bit precision and a maximum conversion speed of 1M SPS, which can convert up to 16 analog signals into digital signals. The vast majority of signals in the real world are analog, such as light, electricity, sound, image signals, etc., which must be converted into digital signals by ADC before they can be digitally processed by MCU.

23.2 Main features

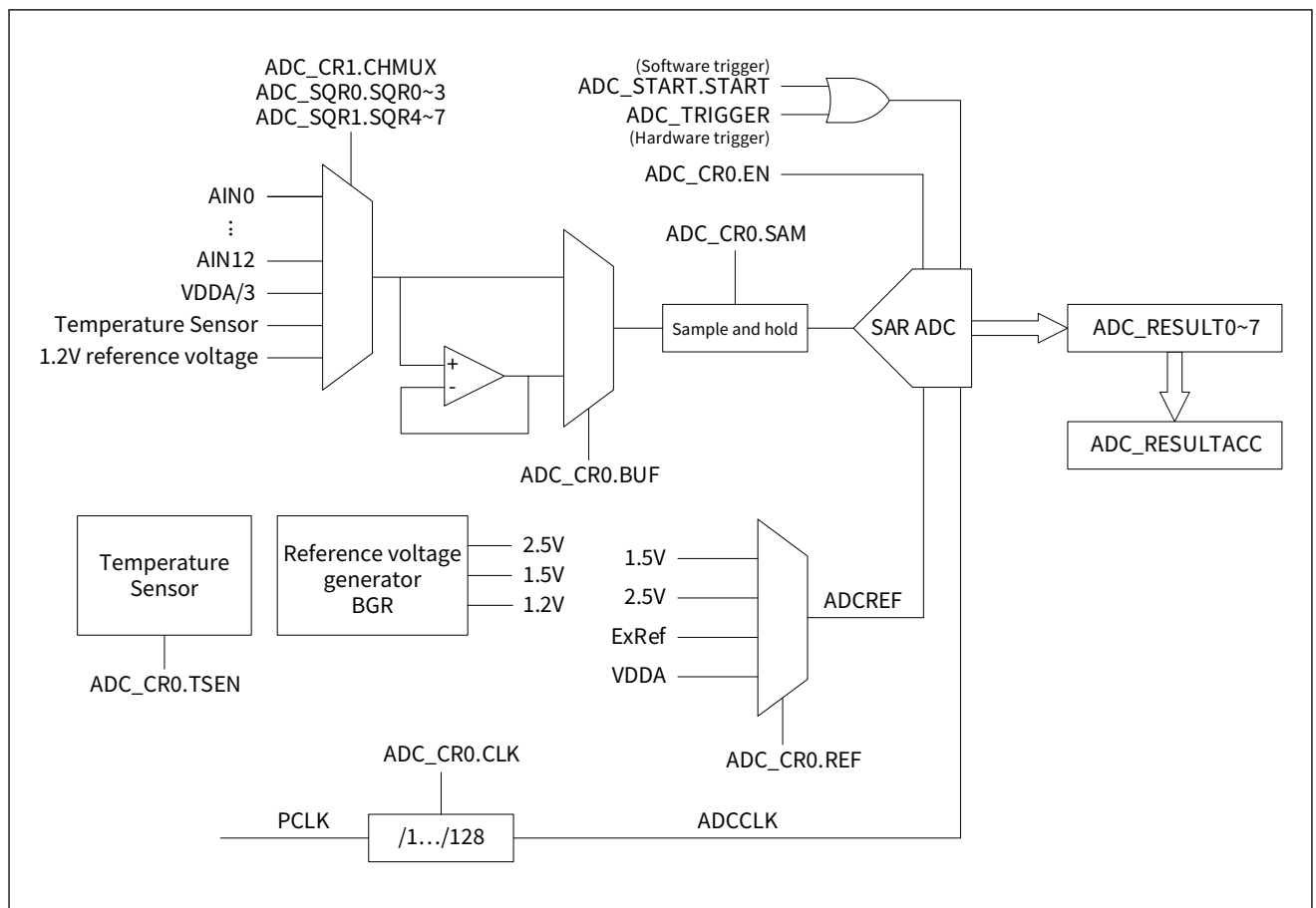
- 12-bit precision
- Programmable conversion speed, up to 1M SPS
- 16 channels of input conversion
 - 13 external pin inputs
 - Built-in temperature sensor
 - Built-in BGR 1.2V reference
 - 1/3 VDDA supply voltage
- 4-channel reference voltage source (Vref)
 - VDDA supply voltage
 - ExRef (PB00) pin voltage
 - Built-in 1.5V reference voltage
 - Built-in 2.5V reference voltage
- Sampling voltage input range: $0 \sim V_{ref}$
- Multiple conversion modes, all support conversion accumulation function
 - Single conversion
 - Multiple conversions
 - Continuous conversion
 - Sequence scan conversion
 - Sequence discontinuous conversion
- Supports single channel and sequence channel selection, and supports up to 8 sequences at the same time
- Supports input channel voltage threshold monitoring
- Built-in signal follower to convert high impedance input signals
- Supports on-chip peripherals to automatically trigger ADC conversion
- Support ADC conversion to complete triggering DMA



23.3 Functional block diagram

The ADC functional block diagram is shown in the following figure:

Figure 23-1 ADC functional block diagram

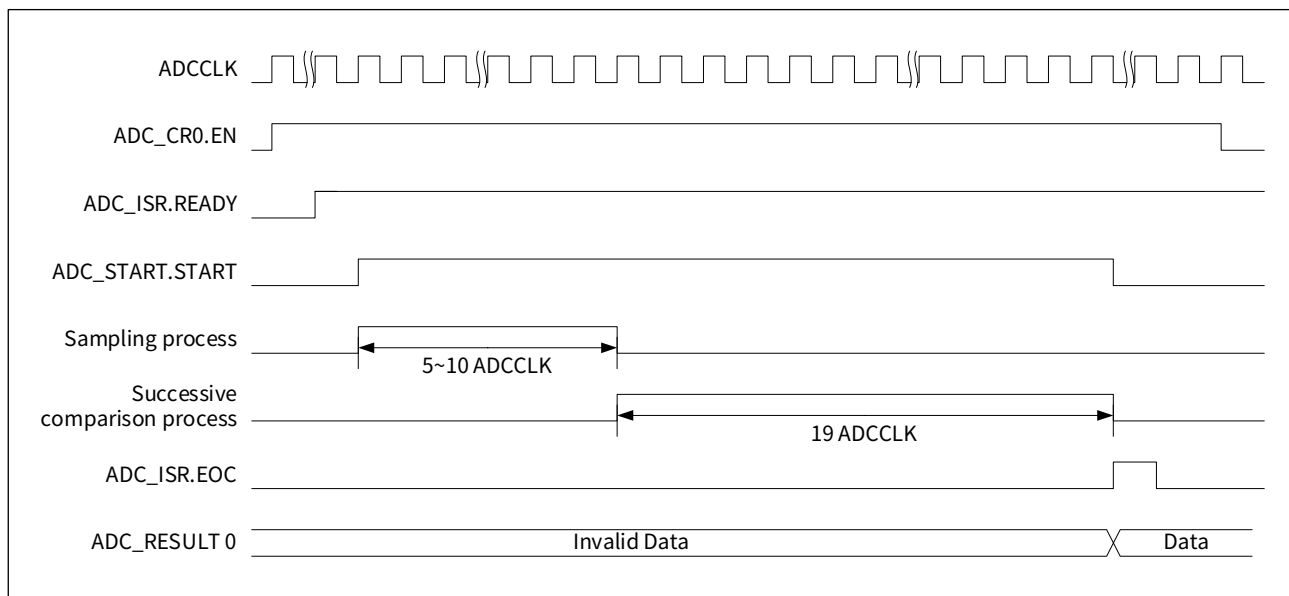


23.4 Conversion timing, conversion speed, conversion accuracy, and conversion results

23.4.1 Conversion timing

The conversion timing of the ADC is shown in the following figure:

Figure 23-2 ADC conversion timing diagram



Write 1 to the EN bit field of the ADC control register ADC_CR0 to enable the ADC module.

About 40μs after ADC_CR0.EN changes from 0 to 1, the ADC_ISR.READY flag is set to 1, indicating that the initialization of the analog circuit is completed, and the ADC conversion can be started.

Write 1 to the START bit field of the ADC start register ADC_START to start the ADC conversion, and the hardware will automatically clear it after the conversion is completed.

The ADC working clock ADCCLK is obtained by dividing the system clock PCLK by the prescaler. The CLK bit field of the control register ADC_CR0 can be selected to divide the frequency from 1 to 128, as shown in the following table:

Table 23-1 ADC clock configuration table

ADC_CR0.CLK	ADCCLK
000	PCLK
001	PCLK/2
010	PCLK/4
011	PCLK/8
100	PCLK/16
101	PCLK/32
110	PCLK/64
111	PCLK/128

A complete ADC conversion requires 24~29 ADCCLK clock cycles, including sampling phase and successive comparison phase:

1. Sampling phase: 5~10 ADCCLK clock cycles are required. The sampling period is configured by the SAM bit field of the control register ADC_CR0, as shown in the following table:

Table 23-2 ADC sampling period selection table

ADC_CR0.SAM	ADC sampling period (ADCCLK number)
00	5
01	6
10	8
11	10

The length of the ADC sampling period is determined by the user's sampling speed requirements and the electrical characteristics of the sampling signal. The user should select an appropriate sampling period to achieve the best conversion effect.

2. Successive comparison phase: 19 ADCCLK clock cycles are required.

After the ADC conversion is completed, the conversion completion flag ADC_ISR.EOC will be set to 1 by hardware, and the ADC conversion result is stored in the corresponding ADC conversion result register ADC_RESULTy (y=0,1,2,3,4,5,6,7), the user can set ADC_ICR.EOC to 0 to clear this flag.

23.4.2 Conversion speed

The ADC conversion speed is closely related to the ADC reference voltage and VDDA supply voltage, and the maximum conversion speed under various conditions is shown in the following table:

Table 23-3 ADC conversion speed and voltage comparison table

ADC reference voltage	VDDA voltage	Maximum conversion speed	Maximum ADCCLK frequency
Internal 1.5V	1.8V ~ 2V	100K SPS	2MHz
Internal 1.5V	2V ~ 5.5V	200K SPS	4MHz
Internal 2.5V	2.8V ~ 5.5V	200K SPS	4MHz
VDDA/ExRef	1.65V ~ 1.8V	25K SPS	500kHz
VDDA/ExRef	1.8V ~ 2V	100K SPS	2MHz
VDDA/ExRef	2V ~ 2.4V	200K SPS	4MHz
VDDA/ExRef	2.4V ~ 2.7V	500K SPS	12MHz
VDDA/ExRef	2.7V ~ 5.5V	1M SPS	24MHz

The corresponding relationship between the conversion speed of the ADC and the working clock ADCCLK is as follows:

$$\text{ADC conversion speed} = f_{\text{ADCCLK}} / N_T$$

Where, f_{ADCCLK} is the clock frequency of ADCCLK, and N_T is ADCCLK number required for one ADC conversion.



23.4.3 Conversion accuracy

When the ADC external input signal driving capability is insufficient, or the ADC input comes from the chip (built-in temperature sensor voltage, built-in 1.2V reference voltage or 1/3 VDDA voltage), the built-in signal follower of the ADC module must be enabled, and a single channel must be used. Single conversion mode. The built-in signal follower is controlled by the BUF bit field of the control register ADC_CR0. Set BUF to 1 to enable the follower; set BUF to 0 to disable the follower.

When multi-channel ADC conversion is selected, and the signal driving capability of some of the channels is weak, in order to avoid the interference of the input channel with weak ADC driving capability, the signal follower must be enabled, and the ADC conversion speed must be no higher than 200K SPS.

To further improve the ADC conversion accuracy, the user can use the ADC conversion accumulation function to sample the same channel multiple times, and use the arithmetic mean of the accumulated results as the final measurement value. For details, please refer to section [23.6 Accumulation conversion function](#).

23.4.4 Conversion results

After the ADC conversion is completed, the 12-bit ADC conversion result is stored in the corresponding conversion result register ADC_RESULTy.

When the ADC works in single-channel conversion mode, the conversion result is stored in the ADC_RESULT0 register.

When the ADC works in the sequence conversion mode, the conversion result of the conversion sequence SQRY (y=0,1,2,3,4,5,6,7) is stored in the corresponding ADC_RESULTy (y=0,1,2,3,4,5,6,7) register.

The conversion result register ADC_RESULTy is 16 bits wide, and the user can choose left-aligned or right-aligned, which is determined by the ALIGN bit field of the control register ADC_CR1:

- The ALIGN bit is 0, select right alignment, the effective value is stored in the lower 12 bits (bit 11:0) of the ADC_RESULTy register, and the higher bits (bit 15:12) are automatically filled with 0;
- When the ALIGN bit is 1, the left alignment is selected, and the effective value is stored in the higher 12 bits (bit 15:4) of the ADC_RESULTy register, and the lower bits (bit 3:0) are automatically filled with 0.



23.5 Operating modes

The MODE bit field of the ADC control register ADC_CR0 configures the ADC operating mode, as shown in the following table:

Table 23-4 ADC operating mode configuration

ADC_CR0.MODE	ADC operating mode
000	Single channel single conversion mode
001	Single channel multiple conversion mode, see CR2.CNT for conversion times
010	Single channel continuous conversion mode
011	Sequence continuous conversion mode
100	Sequence scan conversion mode
101	Sequence multiple conversion mode, see CR2.CNT for conversion times.
110	Sequence intermittent conversion mode

The ADC conversion can be started by writing 1 to the START bit field of the ADC start register ADC_START; it can also be triggered by other peripherals, see section [23.8 External trigger source](#).



23.5.1 Single channel single conversion mode (MODE=0)

After the ADC is started, a conversion is performed on a specified channel.

The ADC has 16 channels that can be selected, which is determined by the CHMUX bit field of the control register ADC_CR1, as shown in the following table. Among them, AIN0~AIN12 are external pin inputs, and the analog function of the corresponding GPIO must be enabled before use (GPIOx_ANALOG.PINy = 1).

Table 23-5 Single channel configuration

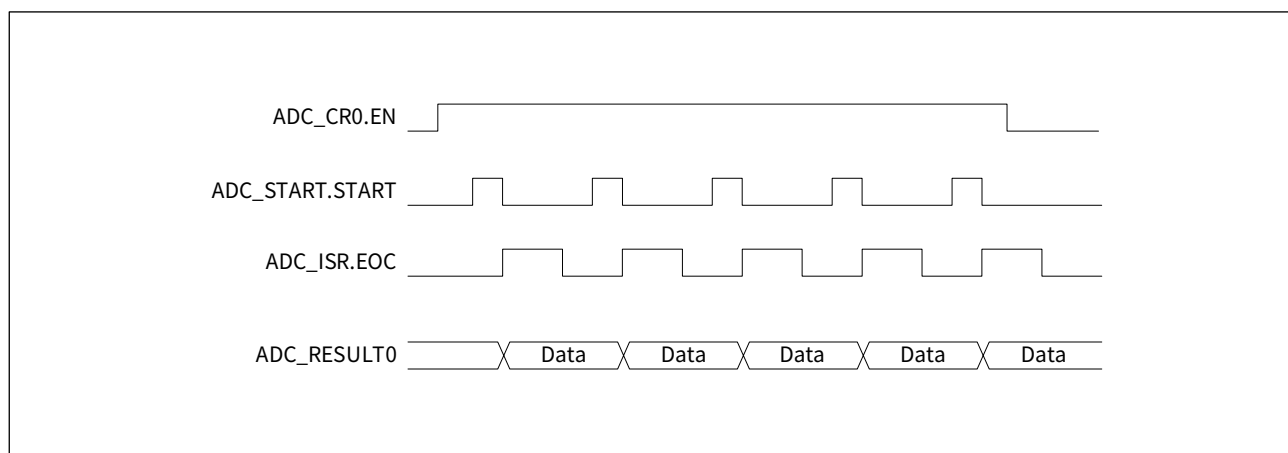
ADC_CR1.CHMUX	Channel selection	GPIO
0000	AIN0	PA00
0001	AIN1	PA01
0010	AIN2	PA02
0011	AIN3	PA03
0100	AIN4	PA04
0101	AIN5	PA05
0110	AIN6	PA06
0111	AIN7	PA07
1000	AIN8	PC04
1001	AIN9	PC05
1010	AIN10	PB00
1011	AIN11	PB01
1100	AIN12	PB02
1101	VDDA/3	-
1110	TS built-in temperature sensor	-
1111	1.2V core voltage reference source	-

In the single channel single conversion mode, after the ADC conversion is completed, the conversion completion flag ADC_ISR.EOC will be automatically set to 1 by the hardware, the conversion result is stored in the ADC_RESULT0 register, and the START bit of the ADC start register ADC_START is automatically cleared to 0, and the ADC conversion stop.

The timing of single channel single conversion mode is shown in the following figure:



Figure 23-3 Single channel single conversion timing diagram



The single conversion of the ADC single channel to the external analog input signal is started through the START bit. The reference operation flow is as follows:

- Step 1: Set `SYSCTRL_AHBEN.GPIOx` to 1 and `SYSCTRL_APBEN2.ADC` to 1 to enable the GPIO clock and ADC working clock corresponding to the ADC channel;
- Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set `ADC_CR0.EN` to 1 to enable the ADC module;
- Step 4: Query and wait for the `ADC_ISR.READY` bit to become 1, and wait for the ADC module to start up;
- Step 5: Set `ADC_CR0.MODE` to 0, select single channel single conversion mode;
- Step 6: Configure `ADC_CR0.REF` and select the reference voltage source of ADC;

Caution:

If an external reference voltage pin is selected, this pin must be configured as an analog function first.

- Step 7: Configure `ADC_CR0.SAM` and `ADC_CR0.CLK`, set ADC sampling speed and clock selection;
- Step 8: Configure `ADC_CR1.CHMUX` and select the channel to be converted;
- Step 9: Set `ADC_START.START` to 1 to start ADC conversion;
- Step 10: Wait for `ADC_ISR.EOC` to become 1, and read the ADC conversion result in the `ADC_RESULT0` register;
- Step 11: If it is necessary to convert other channels, repeat steps 8 to 10;
- Step 12: Set `ADC_CR0.EN` to 0 to turn off the ADC module.

Start a single conversion of the ADC single channel to the external analog input signal through an external trigger, and use the ADC conversion completion interrupt to read the conversion result. The reference operation flow is as follows:

Step 1: Set `SYSCTRL_AHBEN.GPIOx` to 1 and `SYSCTRL_APBEN2.ADC` to 1 to enable the GPIO clock and ADC working clock corresponding to the ADC channel;

Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set `ADC_CR0.EN` to 1 to enable the ADC module;

Step 4: Query and wait for the `ADC_ISR.READY` bit to become 1, and wait for the ADC module to start up;

Step 5: Set `ADC_CR0.MODE` to 0, select single channel single conversion mode;

Step 6: Configure `ADC_CR0.REF` and select the reference voltage of ADC;

Caution:

If an external reference voltage pin is selected, this pin must be configured as an analog function first.

Step 7: Configure `ADC_CR0.SAM` and `ADC_CR0.CLK`, set ADC sampling speed and clock selection;

Step 8: Set `ADC_IER.EOC` to 1 to enable ADC conversion complete interrupt;

Step 9: Enable ADC interrupt in NVIC interrupt vector table;

Step 10: Set `ADC_ICR` to 0x00, clear ADC interrupt flag;

Step 11: Configure the external trigger register `ADC_TRIGGER` and select the external trigger source;

Step 12: Configure `ADC_CR1.CHMUX` and select the channel to be converted;

Step 13: Wait for the ADC to be triggered to start. When the ADC conversion is completed, the `ADC_ISR.EOC` flag is set to 1 by hardware, and the MCU responds to the ADC interrupt and enters the ADC interrupt service routine. The user reads the ADC conversion result in the `ADC_RESULT0` register; when exiting the service routine, the `ADC_ISR.EOC` flag should be cleared first.;

Step 14: If it is necessary to convert other channels, repeat steps 11 to 13;

Step 15: Set `ADC_CR0.EN` to 0 to turn off the ADC module.



23.5.2 Single channel multiple conversion mode (MODE=1)

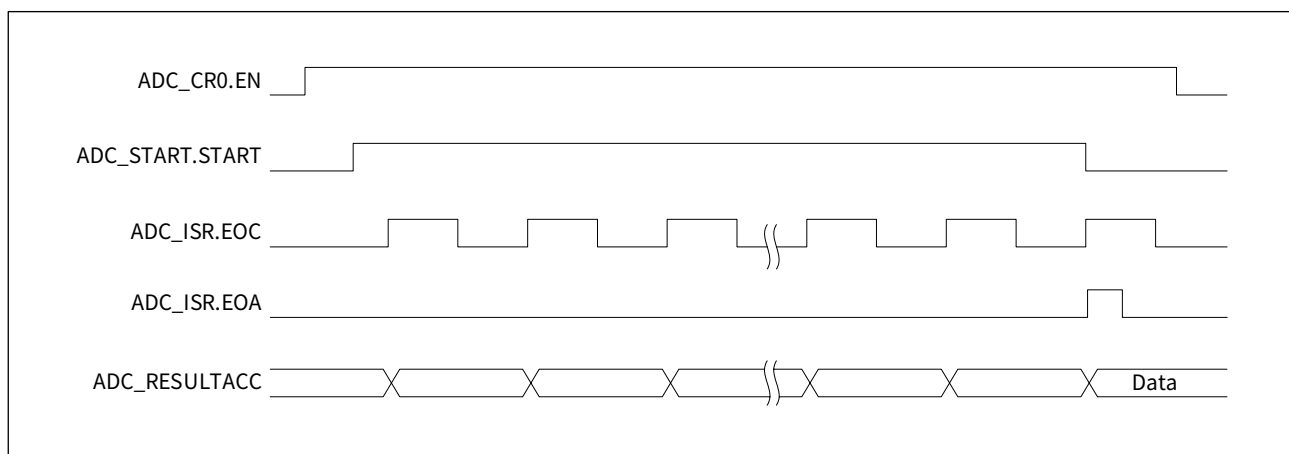
After the ADC is started, it performs multiple conversions for a specified channel. The number of conversions is determined by the ADC_CR2.CNT bit field value. The default number of conversion is 1.

In multiple conversion mode, the accumulation conversions function must be enabled, that is, setting ADC_CR2.ACCRST to 1 clears the ADC_RESULTACC register, while setting ADC_CR2.ACCEN to 1 enables the automatic accumulation function of ADC conversion results.

After each ADC conversion is completed, the ADC_ISR.EOC flag is automatically set to 1, the conversion result is stored in the ADC_RESULT0 register, and the conversion result is automatically accumulated, and the accumulated value is stored in the ADC_RESULTACC register. If the set ADC conversion times are not reached, the ADC will continue to convert; when the set ADC conversion times are reached, the multiple conversion completion flag ADC_ISR.EOA is automatically set to 1, and the ADC_START.START bit is automatically cleared to 0, the ADC conversion stops.

The timing of single channel multiple conversion mode is shown in the following figure:

Figure 23-4 Single channel multiple conversion timing diagram



The ADC single channel multiple conversion are started through the START bit. The reference operation flow is as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;

Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

Step 4: Set ADC_CR0.EN to 1 to enable the ADC module;

Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;

Step 6: Set ADC_CR0.MODE to 1 and select single channel multiple conversions mode;

Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;

Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;

Step 9: Configure ADC_CR1.CHMUX and select the channel to be converted;

Step 10: Configure ADC_CR2.CNT and set the conversion times;

Step 11: Set ADC_CR2.ACCRST and ADC_CR2.ACCEN to 1 to enable the conversion result accumulation function;

Step 12: Set ADC_IER.EOA to 1 to enable multiple conversion completion interrupts;

Step 13: Enable ADC interrupt in NVIC interrupt vector table;

Step 14: Set ADC_ICR.EOA to 0, clear the EOA interrupt flag;

Step 15: Set ADC_START.START to 1 to start ADC conversion;

Step 16: Query and wait for ADC_ISR.EOA to become 1, indicating that multiple conversions are completed, ADC_START.START bit is automatically cleared to 0, and ADC conversion stops. At this time, the user can read the ADC_RESULTACC register to obtain the accumulated value of the ADC conversion result, and divide it by the conversion times to obtain the ADC conversion result;

Step 17: If you need to convert other channels, repeat steps 9 to 16;

Step 18: Set ADC_CR0.EN to 0 to turn off the ADC module.



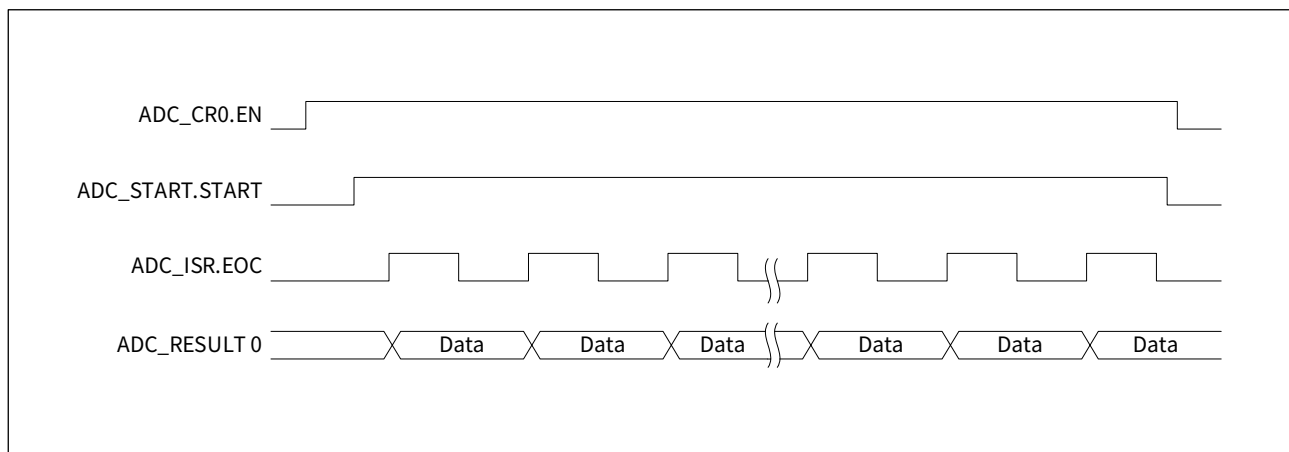
23.5.3 Single channel continuous conversion mode (MODE=2)

In this mode, whether the ADC is started by the software START bit or the external trigger, once the ADC is started, it will continue to convert a specified channel until the ADC_START.START bit is cleared to 0, and the conversion will not be stopped.

After each ADC conversion is completed, the ADC_ISR.EOC flag is automatically set to 1, and the conversion result is stored in the ADC_RESULT0 register. The user should read the conversion result in ADC_RESULT0 in time to avoid conversion result overflow. User writes 0 to ADC_START.START bit to stop conversion.

The timing of single channel continuous conversion mode is shown in the following figure:

Figure 23-5 Single channel continuous conversion timing diagram



The ADC single channel continuous conversion is started through the START bit, and the reference operation flow is as follows:

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;
- Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

- Step 4: Set ADC_CR0.EN to 1 to enable ADC module;
- Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;
- Step 6: Set ADC_CR0.MODE to 2, select single channel continuous conversion mode;
- Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;
- Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;
- Step 9: Configure ADC_CR1.CHMUX and select the channel to be converted;
- Step 10: Set ADC_START.START to 1 to start ADC conversion;
- Step 11: Query and wait for ADC_ISR.EOC to become 1, and continuously read the ADC_RESULT0 register to obtain the ADC conversion result;
- Step 12: Set ADC_START.START to 0 to stop ADC conversion;
- Step 13: If you need to convert other channels, repeat steps 9 to 13;
- Step 14: Set ADC_CR0.EN to 0 to turn off the ADC module.



23.5.4 Sequence continuous conversion mode (MODE=3)

Sequence continuous conversion mode is similar to single channel continuous conversion mode, except that the sequence continuous conversion mode can alternately convert up to 8 sequence channels instead of a single channel, and each sequence SQRy can select one of 16 conversion channels, which is configured by the SQRy bit field of the sequence configuration register ADC_SQR0 and ADC_SQR1. The sequence configuration to be converted is determined by the ENS bit field of the ADC sequence configuration register ADC_SQR0, as shown in the following table:

Table 23-6 Sequence configuration to be converted

ADC_SQR.ENS	The sequence configuration to be converted
000	Only SQR0 is converted
001	Convert SQR0, SQR1
010	Convert SQR0, SQR1, SQR2
011	Convert SQR0, SQR1, SQR2, SQR3
100	Convert SQR0, SQR1, SQR2, SQR3, SQR4
101	Convert SQR0, SQR1, SQR2, SQR3, SQR4, SQR5
110	Convert SQR0, SQR1, SQR2, SQR3, SQR4, SQR5, SQR6
111	Convert SQR0, SQR1, SQR2, SQR3, SQR4, SQR5, SQR6, SQR7

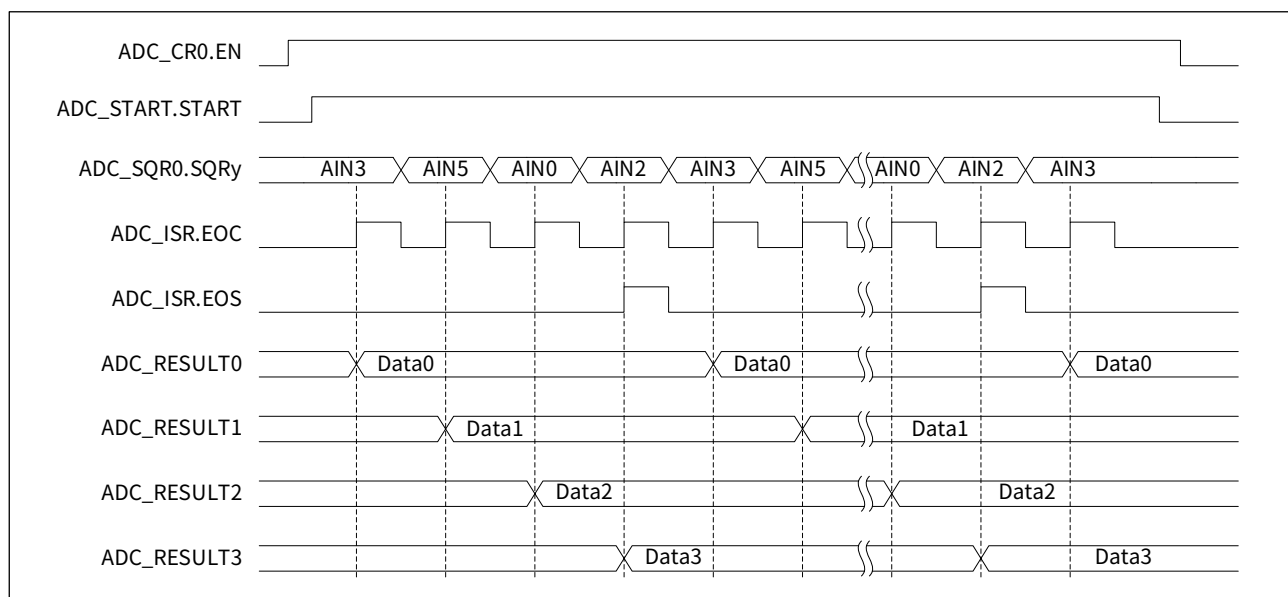
In this mode, whether the ADC is started through the software START bit or an external trigger, once the ADC is started, it will continue to convert the selected conversion sequence until the ADC_START.START bit is cleared to 0, and the conversion will not stop.

After each ADC conversion is completed, the ADC_ISR.EOC flag is automatically set to 1, and the conversion result is stored in the conversion result registers ADC_RESULT0~ADC_RESULT7 with the same sequence number as the sequence SQR0~SQR7. When all conversions of the selected conversion sequence are completed, the sequence conversion completion flag ADC_ISR.EOS is set to 1. The user should read the conversion result in time to avoid overflow of the conversion result. User clears ADC_START.START bit to 0 to stop conversion.

Taking the sequence conversion SQR0~SQR3 as an example, the sequence of the sequence continuous conversion mode is shown in the following figure:



Figure 23-6 Sequence continuous conversion timing diagram



The ADC sequence continuous conversion is started by the START bit, and the reference operation flow is as follows:

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;
- Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

- Step 4: Set ADC_CR0.EN to 1 to enable ADC module;
- Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;
- Step 6: Set ADC_CR0.MODE to 3, select sequential continuous conversion mode;
- Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;
- Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;
- Step 9: Configure ADC_SQR0.ENS, select the sequence to be converted, as shown in [Figure 23-6](#), set ADC_SQR0.ENS to 3, and the conversion sequence to be SQR0~SQR3;
- Step 10: Configure ADC_SQR0.SQR0, select the channel to be converted for the sequence SQR0 to be converted, as shown in [Figure 23-6](#), set ADC_SQR0.SQR0 to 3, and the channel to be converted for the sequence SQR0 to AIN3;
- Step 11: Configure ADC_SQR0.SQR1, select the channel to be converted for the sequence SQR1 to be converted, as shown in [Figure 23-6](#), set ADC_SQR0.SQR1 to 5, and the channel to be converted for the sequence SQR1 to AIN5;
- Step 12: Configure ADC_SQR0.SQR2, select the channel to be converted of the sequence SQR2 to be converted, as shown in [Figure 23-6](#), set ADC_SQR0.SQR2 to 0, and the channel to be converted of the sequence SQR2 to AIN0;



- Step 13: Configure ADC_SQR0.SQR3, select the channel to be converted of the sequence SQR3 to be converted, as shown in [Figure 23-6](#), set ADC_SQR0.SQR3 to 2, and the channel to be converted of the sequence SQR3 to AIN2;
- Step 14: Set ADC_ICR to 0, clear ADC interrupt flag;
- Step 15: Set ADC_START.START to 1 to start ADC conversion;
- Step 16: Query and wait for ADC_ISR.EOS to become 1, and read the ADC_RESULT0~ADC_RESULT3 registers in sequence to obtain the ADC conversion results of each channel. When ADC_ISR.EOS is 1, it means that a sequence conversion of 4 channels is completed;
- Step 17: Set ADC_START.START to 0 to stop ADC conversion;
- Step 18: If you need to convert other channels, repeat steps 9 to 18;
- Step 19: Set ADC_CR0.EN to 0 to turn off the ADC module.



23.5.5 Sequence scan conversion mode (MODE=4)

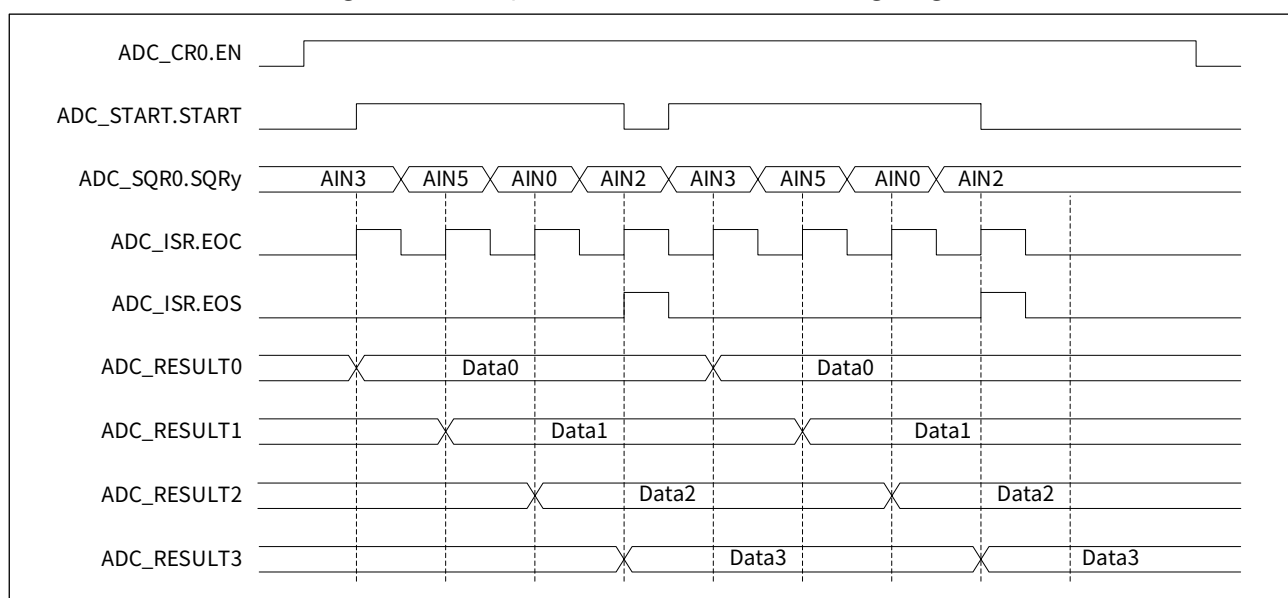
The difference between the sequence scan conversion mode and the sequence continuous conversion is that the sequence scan conversion mode only completes the conversion of the selected sequence once.

In this mode, whether the ADC is started through the software START bit or an external trigger, starting the ADC once will convert all the selected conversion sequences once.

After each ADC conversion is completed, the ADC_ISR.EOC flag is automatically set to 1, and the conversion result is stored in the conversion result registers ADC_RESULT0~ADC_RESULT7 with the same serial number as the sequence SQR0~SQR7. When all conversions of the selected conversion sequence are completed, the ADC_ISR.EOS flag becomes 1, the ADC_START.START bit is automatically cleared to 0, and the ADC stops converting.

Taking the sequence conversion SQR0~SQR3 as an example, the sequence of the sequence continuous conversion mode is shown in the following figure:

Figure 23-7 Sequence scan conversion timing diagram



The ADC sequence scan conversion is started by the START bit, and the reference operation flow is as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;

Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

Step 4: Set ADC_CR0.EN to 1 to enable ADC module;

Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;

Step 6: Set ADC_CR0.MODE to 4, select sequence scan conversion mode;

Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;

Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;

Step 9: Configure ADC_SQR0.ENS, select the sequence to be converted, as shown in [Figure 23-7](#), set ADC_SQR0.ENS to 3, and the conversion sequence to be SQR0~SQR3;

Step 10: Configure ADC_SQR0.SQR0, select the channel to be converted for the sequence SQR0 to be converted, as shown in [Figure 23-7](#), set ADC_SQR0.SQR0 to 3, and the channel to be converted for the sequence SQR0 to AIN3;

Step 11: Configure ADC_SQR0.SQR1, select the channel to be converted for the sequence SQR1 to be converted, as shown in [Figure 23-7](#), set ADC_SQR0.SQR1 to 5, and the channel to be converted for the sequence SQR1 to AIN5;

Step 12: Configure ADC_SQR0.SQR2, select the channel to be converted of the sequence SQR2 to be converted, as shown in [Figure 23-7](#), set ADC_SQR0.SQR2 to 0, and the channel to be converted of the sequence SQR2 to AIN0;

Step 13: Configure ADC_SQR0.SQR3, select the channel to be converted for the sequence SQR3 to be converted, as shown in [Figure 23-7](#), set ADC_SQR0.SQR3 to 2, and the channel to be converted for the sequence SQR3 to AIN2;

Step 14: Set ADC_ICR to 0, clear ADC interrupt flag;

Step 15: Set ADC_START.START to 1 to start ADC conversion;

Step 16: Wait for ADC_ISR.EOS to become 1, and read the ADC_RESULT0~ADC_RESULT3 registers in sequence to obtain the ADC conversion result of the corresponding channel. When ADC_ISR.EOS becomes 1, it means that a sequence conversion of 4 channels is completed, the ADC_START.START bit is automatically cleared to 0, and the ADC conversion stops;

Step 17: If you need to convert other channels, repeat steps 9 to 17;

Step 18: Set ADC_CR0.EN to 0 to turn off the ADC module.



23.5.6 Sequence multiple conversion mode (MODE=5)

The difference between the sequence multiple conversion mode and the sequence scan conversion mode is that the sequence scan conversion mode only completes the conversion of the selected sequence once, while the sequence multiple conversion mode is continuously converted multiple times. The sequence conversion times are determined by the ADC_CR2.CNT bit field. value, the default conversion times is 1.

In multiple conversion mode, the accumulation conversion function must be enabled, that is, set ADC_CR2.ACCRST to 1 to clear the ADC_RESULTACC register. At the same time, set ADC_CR2.ACCEN to 1 to enable the automatic accumulation function of ADC conversion results.

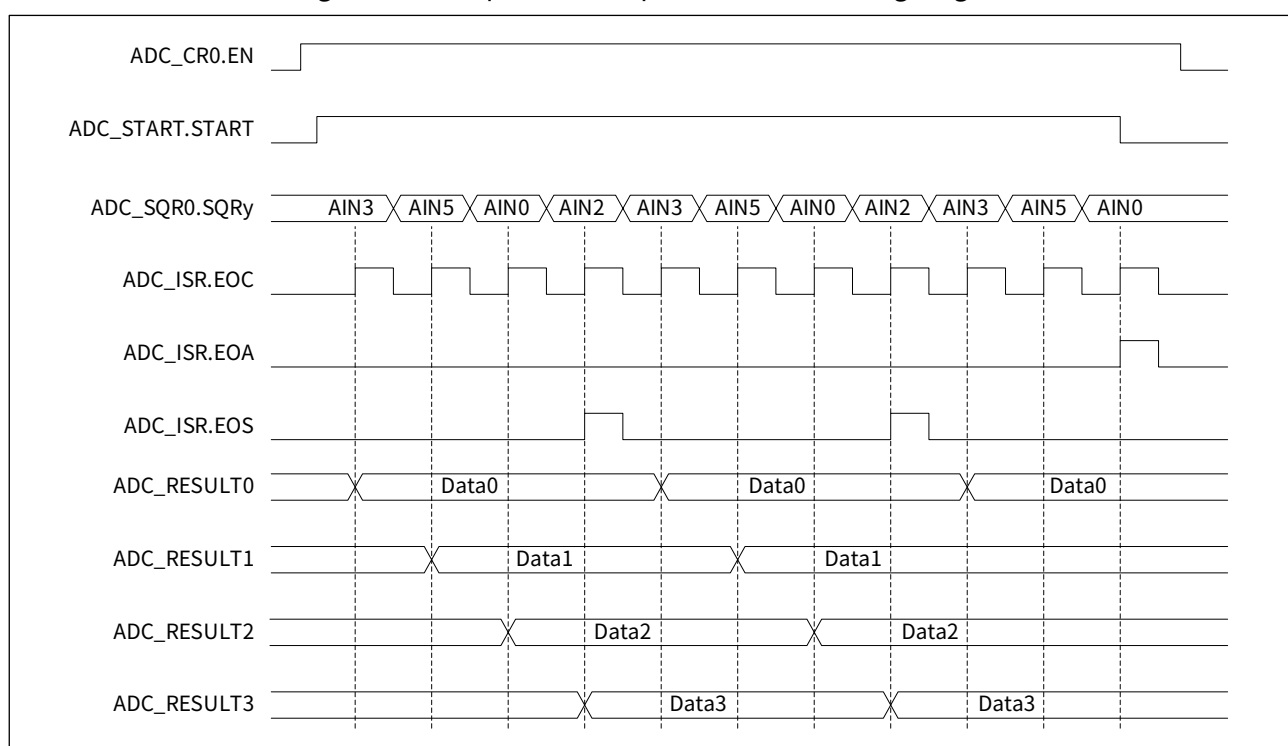
In this mode, whether the ADC is started by the software START bit or an external trigger, once the ADC is started, the selected conversion sequence will continue to be converted in turn, and the conversion will not stop until the sequence conversion times of the ADC_CR2.CNT bit value is reached.

After each ADC conversion is completed, the ADC_ISR.EOC flag is automatically set to 1, and the conversion result is stored in the conversion result registers ADC_RESULT0~ADC_RESULT3 with the same serial number as the sequence SQR0~SQR3. At the same time, the conversion result is automatically accumulated, and the accumulated value is stored in the ADC_RESULTACC register. When all the conversions of the selected conversion sequence are completed, the ADC_ISR.EOS flag becomes 1. If the sequence conversion times set by the ADC_CR2.CNT bit field value is not reached, the conversion will continue. The user should read the conversion result in time to avoid overflow of the conversion result.

When the number of sequence conversions reaches the ADC_CR2.CNT bit value, the ADC_ISR.EOA flag bit is set to 1, the ADC_START.START bit is automatically cleared to 0, and the ADC conversion stops.

Taking the sequence conversion SQR0~SQR3 as an example, the sequence of the sequence multiple conversion mode is shown in the following figure, where ADC_CR2.CNT is 10, and the number of conversions is 11.

Figure 23-8 Sequence multiple conversion timing diagram



The ADC sequence multiple conversions are started through the START bit, and the reference operation flow is as follows:

Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;

Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

Step 4: Set ADC_CR0.EN to 1 to enable ADC module;

Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;

Step 6: Set ADC_CR0.MODE to 5, select sequence multiple conversion mode;

Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;

Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;

Step 9: Configure ADC_SQR0.ENS, select the sequence to be converted, as shown in [Figure 23-8](#), set ADC_SQR0.ENS to 3, and the conversion sequence to be SQR0~SQR3;

Step 10: Configure ADC_SQR0.SQR0, select the channel to be converted of the sequence SQR0 to be converted, as shown in [Figure 23-8](#), set ADC_SQR0.SQR0 to 3, and the channel to be converted of SQR0 to AIN3;

Step 11: Configure ADC_SQR0.SQR1, select the channel to be converted of the sequence SQR1 to be converted, as shown in [Figure 23-8](#), set ADC_SQR0.SQR1 to 5, and the channel to be converted of SQR1 to AIN5;

Step 12: Configure ADC_SQR0.SQR2, select the channel to be converted of the sequence SQR2 to be converted, as shown in [Figure 23-8](#), set ADC_SQR0.SQR2 to 0, and the channel to be converted of SQR2 to AIN0;

Step 13: Configure ADC_SQR0.SQR3, select the channel to be converted of the sequence SQR3 to be converted, as shown in [Figure 23-8](#), set ADC_SQR0.SQR3 to 2, and the channel to be converted of SQR3 to AIN2;

Step 14: Configure ADC_CR2.CNT, as shown in [Figure 23-8](#), set ADC_CR2.CNT to 10, then the number of conversions is 11;

Step 15: Set ADC_CR2.ACCRST and ADC_CR2.ACCEN to 1 to enable the conversion result accumulation function;

Step 16: Set ADC_ICR to 0, clear ADC interrupt flag;

Step 17: Set ADC_START.START to 1 to start ADC conversion;

Step 18: Wait for ADC_ISR.EOS to become 1 in a loop, and continuously read the ADC_RESULT0~ADC_RESULT3 registers in turn to obtain the ADC conversion result of the corresponding channel. When ADC_ISR.EOS is 1, it means that a sequence conversion of 4 channels is completed;

Step 19: Wait for ADC_ISR.EOA to become 1 in a loop, and continuously read ADC_RESULT0~ADC_RESULT3 registers in turn to obtain ADC conversion results. When ADC_ISR.EOA is 1, it means that multiple conversions are completed, the ADC_START.START bit is automatically cleared to 0, and the ADC conversion stops;

Step 20: If you need to convert other channels, repeat steps 9 to 19;

Step 21: Set ADC_CR0.EN to 0 to turn off the ADC module.



23.5.7 Sequence intermittent conversion mode (MODE=6)

In sequence intermittent conversion mode, each time the ADC is turned on, only the current sequence is converted, not all sequences selected.

In this mode, the ADC can be started via the software START bit, or an external trigger can be selected to start.

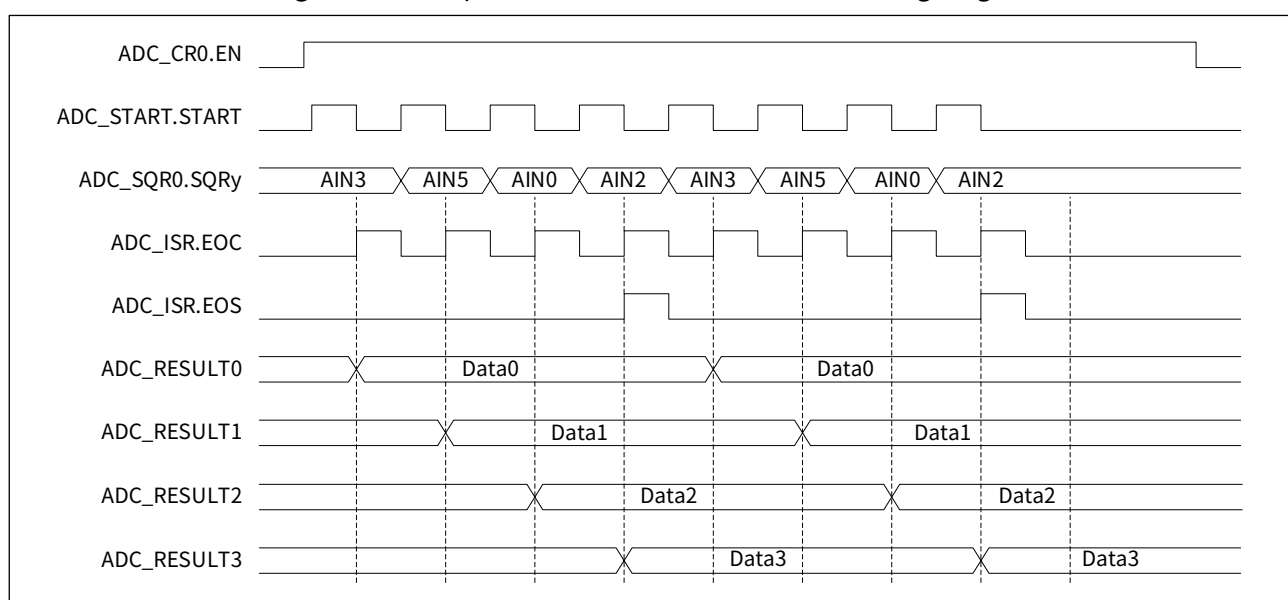
Each time the ADC is started, an ADC conversion is performed for the specified channel in the current ADC conversion sequence SQRy (y=0~7). The ADC conversion is completed, the ADC_ISR.EOC flag is automatically set to 1, and the conversion result is stored in the corresponding ADC_RESULTy (y=0~7). At the same time, the ADC_START.START bit is automatically cleared to 0, and the ADC conversion is completed. Waiting for the ADC conversion to start again.

When the ADC is restarted next time, the channel to be converted is automatically switched to the designated channel of the next conversion sequence SQR(y+1), and the ADC conversion is performed again. If the currently completed conversion sequence is SQR7, the next sequence to be converted is automatically reset to SQR0.

The ADC_ISR.EOS flag becomes 1 when all channels of the conversion sequence SQRy are converted.

Taking the sequence conversion SQR0~SQR3 as an example, the sequence of the sequence intermittent conversion mode is shown in the following figure:

Figure 23-9 Sequence intermittent conversion timing diagram



The ADC sequence intermittent conversion is started by the START bit, and the reference operation flow is as follows:

- Step 1: Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;
- Step 2: Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);
- Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

- Step 4: Set ADC_CR0.EN to 1 to enable ADC module;



- Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;
- Step 6: Set ADC_CR0.MODE to 6, and select sequence intermittent conversion mode;
- Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;
- Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;
- Step 9: Configure ADC_SQR0.ENS, select the sequence to be converted, as shown in [Figure 23-9](#), set ADC_SQR0.ENS to 3, and the conversion sequence to be SQR0~SQR3;
- Step 10: Configure ADC_SQR0.SQR0, select the channel to be converted of the sequence SQR0 to be converted, as shown in [Figure 23-9](#), set ADC_SQR0.SQR0 to 3, and the channel to be converted of the sequence SQR0 to AIN3;
- Step 11: Configure ADC_SQR0.SQR1, select the channel to be converted of the sequence SQR1 to be converted, as shown in [Figure 23-9](#), set ADC_SQR0.SQR1 to 5, and the channel to be converted of the sequence SQR1 to AIN5;
- Step 12: Configure ADC_SQR0.SQR2, select the channel to be converted of the sequence SQR2 to be converted, as shown in [Figure 23-9](#), set ADC_SQR0.SQR2 to 0, and the channel to be converted of the sequence SQR2 to AIN0;
- Step 13: Configure ADC_SQR0.SQR3, select the channel to be converted of the sequence SQR3 to be converted, as shown in [Figure 23-9](#), set ADC_SQR0.SQR3 to 2, and the channel to be converted of the sequence SQR3 to AIN2;
- Step 14: Set ADC_ICR to 0, clear ADC interrupt flag;
- Step 15: Set ADC_START.START to 1 to start ADC conversion;
- Step 16: Wait for ADC_ISR.EOC to become 1, and choose to read the ADC_RESULT0 register to obtain the ADC conversion result of the channel specified by the conversion sequence SQR0;
- Step 17: Set ADC_START.START to 1 to start ADC conversion again;
- Step 18: Wait for ADC_ISR.EOC to become 1, and choose to read the ADC_RESULT1 register to obtain the ADC conversion result of the channel specified by the conversion sequence SQR1;
- Step 19: Set ADC_START.START to 1 to start ADC conversion again;
- Step 20: Wait for ADC_ISR.EOC to become 1, and choose to read the ADC_RESULT2 register to obtain the ADC conversion result of the channel specified by the conversion sequence SQR2;
- Step 21: Set ADC_START.START to 1 and start ADC conversion again;
- Step 22: Wait for ADC_ISR.EOC to become 1, and choose to read the ADC_RESULT3 register to get the ADC conversion result for the channel specified by conversion sequence SQR3. When ADC_ISR.EOS is 1, it means that a sequence conversion of 4 channels is completed;
- Step 23: Repeat steps 15 to 22 to continue ADC conversion; if you need to convert other channels, repeat steps 8 to 22;
- Step 24: Set ADC_CR0.EN to 0 to turn off the ADC module.



23.6 Accumulation conversion function

The accumulation conversion function can be performed in any working mode of the ADC. And in the multiple conversion mode, the cumulative conversion function must be enabled.

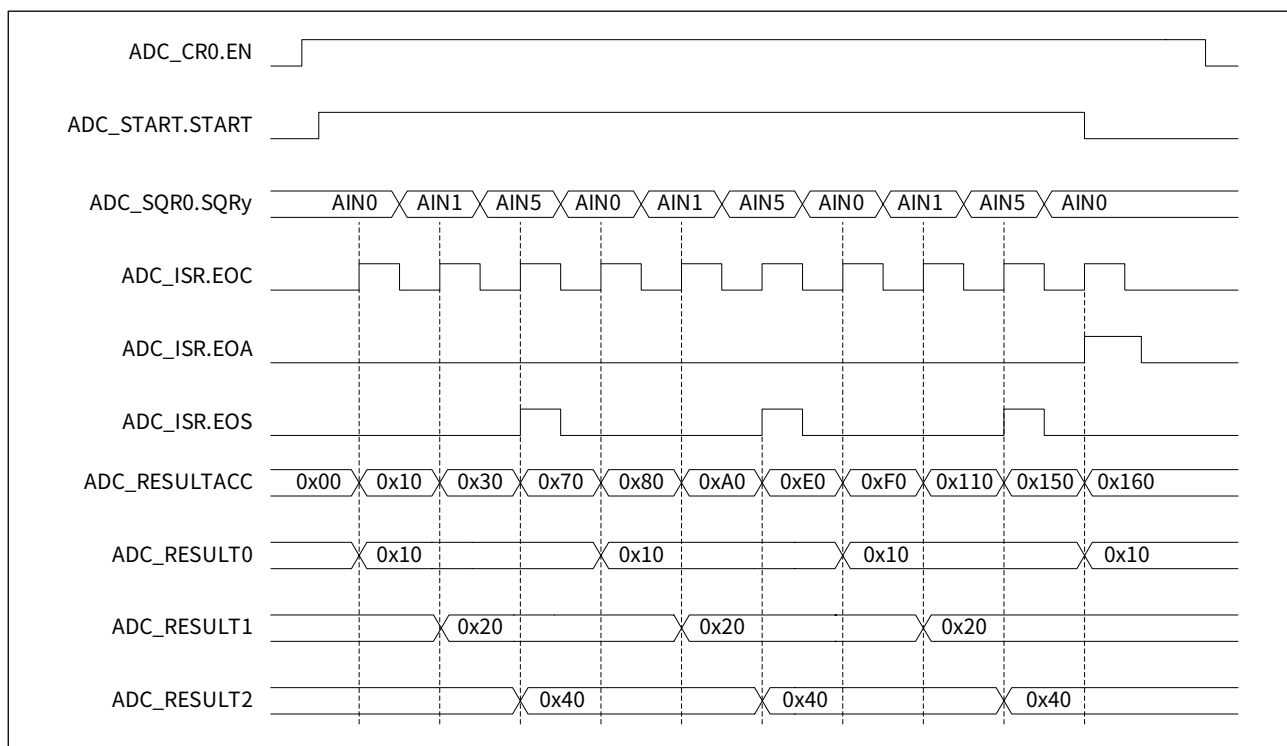
Set ADC_CR2.ACCEN to 1 to enable the automatic accumulation function of ADC conversion results. Each time the ADC completes a channel conversion, it automatically accumulates the conversion results, and the accumulated value is stored in the ADC_RESULTACC register.

Before using the accumulation function, the ADC_RESULTACC register must be cleared first. Setting ADC_CR2.ACCRST to 1 can clear the ADC_RESULTACC register to 0.

Figure 23-10 Accumulation conversion timing diagram demonstrates the process of 10 consecutive conversion accumulations for the three channels of AIN0, AIN1, and AIN5. It is assumed that the ADC conversion results of AIN0, AIN1, and AIN5 are 0x010, 0x020, and 0x040 in sequence.

Set ADC_START.START to 1 to start the ADC, and the state machine inside the ADC will convert AIN0, AIN1, and AIN5 in turn, and the ADC conversion will not stop until the total number of conversions reaches 10. Each time a conversion completes, the ADC_RESULTACC register automatically accumulates the conversion result.

Figure 23-10 Accumulation conversion timing diagram



The ADC sequence is started for multiple conversions through the START bit, and the conversion results are accumulated. The operation flow is as follows:

- Step 1:** Set SYSCTRL_AHBEN.GPIOx to 1, SYSCTRL_APBEN2.ADC to 1, enable the GPIO clock corresponding to the ADC channel, the GPIO clock corresponding to the external reference voltage pin, and the ADC working clock;
- Step 2:** Set the GPIO pin corresponding to the ADC channel to the analog function. For the specific register configuration, please refer to chapter 9 *General-purpose input/output (GPIO)*;

Step 3: Set the GPIO pin corresponding to the external reference voltage to the analog function. For the specific register configuration, please refer to chapter [9 General-purpose input/output \(GPIO\)](#);

Caution:

If the ADC reference voltage does not select the external reference voltage pin, skip this step.

Step 4: Set ADC_CR0.EN to 1 to enable ADC module;

Step 5: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;

Step 6: Set ADC_CR0.MODE to 5, select sequence multiple conversion mode;

Step 7: Configure ADC_CR0.REF and select the reference voltage of ADC;

Step 8: Configure ADC_CR0.SAM and ADC_CR0.CLK, set ADC sampling speed and clock selection;

Step 9: Configure ADC_CR2.CNT, as shown in [Figure 23-10](#), set ADC_CR2.CNT to 9, then the number of conversions is 10;

Step 10: Set ADC_CR2.ACCEN to 1 to enable the automatic accumulation control of ADC conversion results;

Step 11: Set ADC_CR2.ACCRST to 1, and the ADC conversion result accumulation register ADC_RESULTACC is cleared to 0;

Step 12: Configure ADC_SQR0.ENS, select the sequence to be converted, as shown in [Figure 23-10](#), set ADC_SQR0.ENS to 2, and the conversion sequence to be SQR0~SQR2;

Step 13: Configure ADC_SQR0.SQR0, select the channel to be converted for the sequence SQR0 to be converted, as shown in [Figure 23-10](#), set ADC_SQR0.SQR0 to 0, and the channel to be converted for the sequence SQR0 to AIN0;

Step 14: Configure ADC_SQR0.SQR1, select the channel to be converted for the sequence SQR1 to be converted, as shown in [Figure 23-10](#), set ADC_SQR0.SQR1 to 1, and the channel to be converted for the sequence SQR1 to AIN1;

Step 15: Configure ADC_SQR0.SQR2, select the channel to be converted of the sequence SQR2 to be converted, as shown in [Figure 23-10](#), set ADC_SQR0.SQR2 to 5, and the channel to be converted of the sequence SQR2 to AIN5;

Step 16: Set ADC_IER.EOA to 1 to enable multiple conversion completion interrupts;

Step 17: Set ADC_ICR.EOA to 0, clear ADC_ISR.EOA interrupt flag;

Step 18: Set ADC_ICR to 0, clear ADC interrupt flag;

Step 19: Set ADC_START.START to 1 to start ADC conversion;

Step 20: Wait for ADC_ISR.EOC to become 1 in a loop, and continuously read the ADC_RESULTACC register to obtain the accumulated value of ADC conversion result. When ADC_ISR.EOS is 1, it means that a sequence conversion of 3 channels is completed.

Step 21: Wait for ADC_ISR.EOA to become 1, while reading the ADC_RESULTACC register continuously. When ADC_ISR.EOA is 1, it means that multiple conversions are completed, the ADC_START.START bit is automatically cleared to 0, and the ADC conversion stops. In this example, when AIN0 completes the 4th ADC conversion, the ADC conversion stops;

Step 22: Set ADC_CR0.EN to 0 to turn off the ADC module.



23.7 Auto-off mode

The user can enable the ADC auto-off function by setting ADC_START.AUTOSTOP to 1. When the specified ADC conversion is completed, the ADC_CR0.EN bit is automatically cleared to 0, and the ADC function is disabled. If the ADC conversion needs to continue, ADC_CR0.EN must be reset to 1 to enable the ADC module.

If the single channel single conversion mode is used, when the conversion is completed, the ADC enable is automatically turned off.

If the sequence scan conversion mode is used, when all sequence conversions are completed, the ADC enable is automatically turned off.

If the multiple conversion mode (single channel multiple conversion mode or sequence multiple conversion mode) is used, when the set number of conversions is reached, the ADC conversion stops and the ADC enable is automatically turned off.

If the continuous conversion mode (single channel continuous conversion mode or sequence continuous conversion mode) is used, the ADC enable will not be automatically turned off after the conversion is completed. Setting ADC_START.START to 0 will turn off continuous conversion and automatically turn off ADC enable.

When using sequence intermittent conversion mode, when all selected channels are converted, the ADC enable is automatically turned off.



23.8 External trigger source

ADC conversion can be started either by software (that is, setting ADC_START.START to 1) or by external trigger. The trigger source is selected by the external trigger register ADC_TRIGGER. There are 25 ways to trigger the ADC, as shown in the following table:

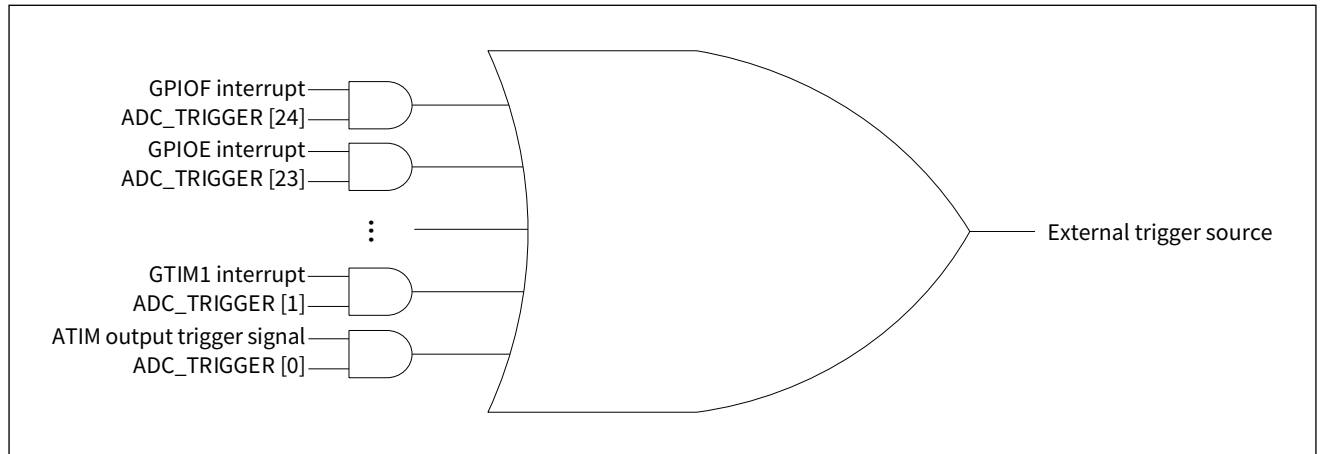
Table 23-7 ADC conversion external trigger source

ADC_TRIGGER bit field	Bit field name	Functional description
24	GPIOF	GPIOF interrupt triggers ADC to start
23	GPIOE	GPIOE interrupt triggers ADC to start
22	GIOD	GIOD interrupt triggers ADC to start
21	GPIOC	GPIOC interrupt triggers ADC to start
20	GPIOB	GPIOB interrupt triggers ADC to start
19	GPIOA	GPIOA interrupt triggers ADC to start
18	UART6	UART6 interrupt triggers ADC to start
17	UART5	UART5 interrupt triggers ADC to start
16	UART4	UART4 interrupt triggers ADC to start
15	DMA	DMA interrupt triggers ADC to start
14	I2C2	I2C2 interrupt triggers ADC to start
13	I2C1	I2C1 interrupt triggers ADC to start
12	SPI2	SPI2 interrupt triggers ADC to start
11	SPI1	SPI1 interrupt triggers ADC to start
10	UART3	UART3 interrupt triggers ADC to start
9	UART2	UART2 interrupt triggers ADC to start
8	UART1	UART1 interrupt triggers ADC to start
7	BTIM3	BTIM3 interrupt triggers ADC to start
6	BTIM2	BTIM2 interrupt triggers ADC to start
5	BTIM1	BTIM1 interrupt triggers ADC to start
4	GTIM4	GTIM4 interrupt triggers ADC to start
3	GTIM3	GTIM3 interrupt triggers ADC to start
2	GTIM2	GTIM2 interrupt triggers ADC to start
1	GTIM1	GTIM1 interrupt triggers ADC to start
0	ATIM	The trigger signal output by ATIM triggers the ADC to start

The schematic diagram of the external trigger source for ADC conversion is shown in the following figure:



Figure 23-11 Schematic diagram of external trigger source for ADC conversion



23.9 Analog watchdog

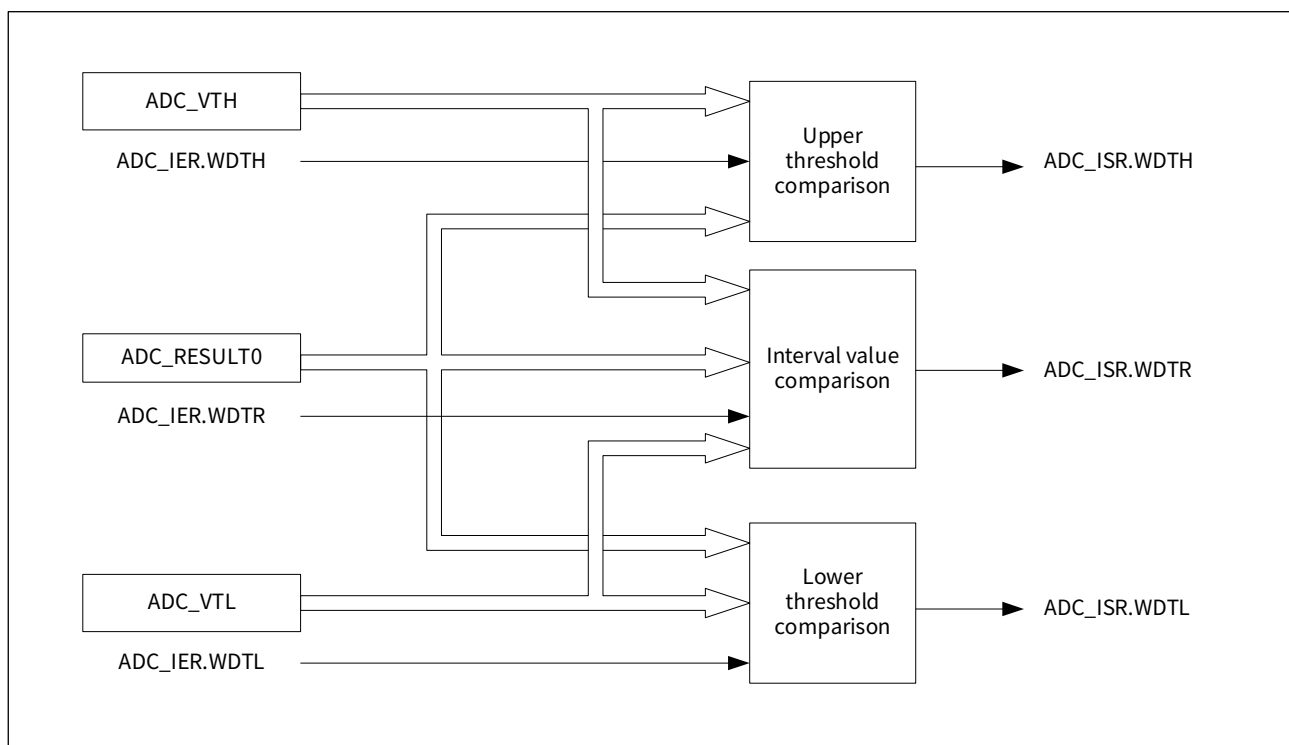
The analog watchdog function supports the comparison of the ADC conversion result with the threshold set by the user, supports the comparison of upper threshold, lower threshold, and interval value, and sets the comparison threshold through the threshold registers ADC_VTH and ADC_VTL.

Set the WDTALL bit field of the control register ADC_CR1 to 1 to enable the analog watchdog, and enable the analog watchdog function of the specified channel through the WDTCH bit field of the ADC_CR1 register.

The analog watchdog function is often used for automatic monitoring of analog quantities. If the corresponding bit fields (WDTR, WDTCH, WDTL) of the interrupt enable register ADC_IER are set, an interrupt request will be generated when the ADC conversion result meets the user's expectation.

A schematic diagram of the threshold comparison of the analog watchdog is shown in the following figure:

Figure 23-12 Schematic diagram of ADC threshold comparison



Upper threshold comparison: When the conversion result is within the interval $[ADC_VTH, 4095]$, the ADC_ISR.WDTH flag bit is set to 1.

Lower threshold comparison: When the conversion result is in the $[0, ADC_VTL)$ interval, the ADC_ISR.WDTL flag is set to 1.

Interval value comparison: When the conversion result is in the interval $[ADC_VTL, ADC_VTH)$, the ADC_ISR.WDTR flag is set to 1.

23.10 Temperature sensor

CW32L083 has a built-in temperature sensor module. The output voltage of the sensor changes with temperature. Set the sampling channel of the ADC module as an internal temperature sensor, and the current ambient temperature can be calculated through the ADC measurement results.

The temperature sensor is off by default. By setting the TSEN bit field of the control register ADC_CR0 to 1, the temperature sensor is enabled.

The formula for calculating the ambient temperature is as follows:

$$\text{Ambient temperature} = T_0 \times 0.5 + 0.0924 \times V_{\text{ref}} \times (\text{AdcValue} - \text{Trim})$$

Where:

V_{ref} is the reference voltage of the current ADC module, which is 1.5V or 2.5V.

T_0 is the 8-bit initial calibration temperature value, which is recorded in the FLASH memory of the chip. Its address is 0x0001 0A09, and the unit is 0.5 degrees Celsius. The read value needs to be divided by 2 to be the actual temperature.

AdcValue is the ADC conversion result of the ADC module measuring the output voltage of the temperature sensor, and the value range is 0 ~ 4095.

Trim is a 16-bit calibration value, which needs to be read from the FLASH memory of the chip during calculation, and its storage address is shown in the following table:

Table 23-8 ADC calibration value address

ADC reference voltage	Calibration value storage address	Calibration value accuracy
Internal 1.5V	0x0010 0A0A - 0x0010 0A0B	$\pm 3^\circ\text{C}$
Internal 2.5V	0x0010 0A0C - 0x0010 0A0D	$\pm 3^\circ\text{C}$

A calculation example is as follows:

Condition 1: $V_{\text{ref}}=1.5$, AdcValue = 0x8CB, Trim = 0x883, $T_0 = 0x32$

Temperature 1: $0x32 \times 0.5 + 0.0924 \times 1.5 \times (0x8CB - 0x883) = 35^\circ\text{C}$

Condition 2: $V_{\text{ref}} = 2.5$, AdcValue = 0x599, Trim = 0x516, $T_0 = 0x32$

Temperature 2: $0x32 \times 0.5 + 0.0924 \times 2.5 \times (0x599 - 0x516) = 55.3^\circ\text{C}$

The reference operation flow for measuring the ambient temperature through the ADC is as follows:



- Step 1: Set SYSCTRL_APBEN2.ADC to 1, enable ADC configuration clock and working clock;
- Step 2: Set ADC_CR0.EN to 1 to enable the ADC module;
- Step 3: Query and wait for the ADC_ISR.READY bit to become 1, and wait for the ADC module to start up;
- Step 4: Set ADC_CR0.MODE to 0, select single channel single conversion mode;
- Step 5: Configure ADC_CR0.REF, select ADC reference voltage as internal 1.5V or internal 2.5V;
- Step 6: Configure ADC_CR0.SAM and ADC_CR0.CLK, and set the conversion speed of ADC;
- Step 7: Set ADC_CR0.TSEN to 1 to enable the temperature sensor;
- Step 8: Set ADC_CR1.CHMUX to 0x0E, and select the channel to be converted as the voltage output of the temperature sensor;
- Step 9: Set ADC_CR0.BUF to 1 to enable the built-in follower;
- Step 10: Set ADC_ICR.EOC to 0, clear ADC_ISR.EOC flag;
- Step 11: Set ADC_START.START to 1 to start ADC conversion;
- Step 12: Wait for ADC_ISR.EOC to become 1, and read the ADC_RESULT0 register to get the ADC conversion result;
- Step 13: Set ADC_CR0.EN to 0 and turn off the ADC module;
- Step 14: Read T_0 and Trim, and calculate the current ambient temperature according to the formula.



23.11 ADC interrupts

ADC interrupt request, as shown in the following table:

Table 23-9 ADC interrupt sources and interrupt flags

Interrupt source	Interrupt flag bit	Interrupt enable	Flag clear
Conversion result overflow	ADC_ISR.OVW	ADC_IER.OVW is set to 1	ADC_ICR.OVW is cleared to 0
Conversion result \geq ADC_VTL, and $<$ ADC_VTH	ADC_ISR.WDTR	ADC_IER.WDTR is set to 1	ADC_ICR.WDTR is cleared to 0
Conversion result \geq ADC_VTH	ADC_ISR.WDTH	ADC_IER.WDTH is set to 1	ADC_ICR.WDTH is cleared to 0
Conversion result $<$ ADC_VTL	ADC_ISR.WDTL	ADC_IER.WDTL is set to 1	ADC_ICR.WDTL is cleared to 0
ADC completes multiple conversions	ADC_ISR.EOA	ADC_IER.EOA is set to 1	ADC_ICR.EOA is cleared to 0
ADC sequence conversion completed	ADC_ISR.EOS	ADC_IER.EOS is set to 1	ADC_ICR.EOS is cleared to 0
ADC conversion completed	ADC_ISR.EOC	ADC_IER.EOC is set to 1	ADC_ICR.EOC is cleared to 0



23.12 List of registers

ADC base address: ADC_BASE = 0x4001 2400

Table 23-10 List of ADC registers

Register name	Register address	Register description
ADC_CR0	ADC_BASE + 0x00	ADC control register 0
ADC_CR1	ADC_BASE + 0x04	ADC control register 1
ADC_START	ADC_BASE + 0x08	ADC startup register
ADC_CR2	ADC_BASE + 0x10	ADC control register2
ADC_VTH	ADC_BASE + 0x14	ADC high threshold register
ADC_VTL	ADC_BASE + 0x18	ADC low threshold register
ADC_TRIGGER	ADC_BASE + 0x1C	ADC external trigger register
ADC_RESULT0	ADC_BASE + 0x20	ADC conversion result 0 register
ADC_RESULT1	ADC_BASE + 0x24	ADC conversion result 1 register
ADC_RESULT2	ADC_BASE + 0x28	ADC conversion result 2 register
ADC_RESULT3	ADC_BASE + 0x2C	ADC conversion result 3 register
ADC_RESULT4	ADC_BASE + 0x30	ADC conversion result 4 register
ADC_RESULT5	ADC_BASE + 0x34	ADC conversion result 5 register
ADC_RESULT6	ADC_BASE + 0x38	ADC conversion result 6 register
ADC_RESULT7	ADC_BASE + 0x3C	ADC conversion result 7 register
ADC_RESULTACC	ADC_BASE + 0x40	ADC conversion result accumulation value register
ADC_IER	ADC_BASE + 0x44	ADC interrupt enable register
ADC_ICR	ADC_BASE + 0x48	ADC interrupt flag clear register
ADC_ISR	ADC_BASE + 0x4C	ADC interrupt flag register
ADC_SQR0	ADC_BASE + 0x50	ADC sequence configuration register 0
ADC_SQR1	ADC_BASE + 0x54	ADC sequence configuration register 1



23.13 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

23.13.1 ADC_CR0 control register 0

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:14	BIAS	RW	Please keep the default value
13	BUF	RW	Built-in follower enable control 0: Turn off the follower, the external input signal is directly connected to the ADC 1: Turn on the follower, the external input signal is connected to the ADC after passing through the follower Caution 1: When this function is enabled, the maximum conversion speed is 200K SPS Caution 2: The following conditions must enable this function: The output impedance of the signal to be converted is relatively high; the signal to be converted is VDDA/3, the output voltage of the built-in temperature sensor, and the output voltage of the internal reference 1.2V.
12:11	SAM	RW	ADC sampling cycle selection 00: 5 ADCCLK clock cycles 01: 6 ADCCLK clock cycles 10: 8 ADCCLK clock cycles 11: 10 ADCCLK clock cycles
10:8	CLK	RW	ADC working clock configuration 000: PCLK

Bit field	Name	Permission	Function description
3:1	MODE	RW	ADC operating mode configuration 000: Single channel single conversion mode 001: Single channel multiple conversion mode, see CR2.CNT for the number of conversions 010: Single channel continuous conversion mode 011: Sequence continuous conversion mode 100: Sequence scan conversion mode 101: Sequence multiple conversion mode, see CR2.CNT for the number of conversions 110: Sequence intermittent conversion mode
0	EN	RW	ADC enable control 0: ADC disabled 1: ADC enabled Caution: After enabling ADC, you should wait for ISR.READY to become 1 before performing ADC conversion.



23.13.2 ADC_CR1 control register 1

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15	DMASOCEN	RW	One conversion completes DMA trigger signal enable control 0: No function 1: ADC triggers DMA every time conversion is complete
14	DMASOFEN	RW	Sequence conversion complete DMA trigger signal enable control 0: No function 1: Trigger DMA when ADC sequence conversion is complete
13	WDTALL	RW	All channels analog watchdog enable control 0: Analog watchdog disabled 1: Analog watchdog enabled
12	RFU	-	Reserved bits, please keep the default value
11:8	WDTCH	RW	Single channel analog watchdog enable configuration 0000: AIN0 1000: AIN8 0001: AIN1 1001: AIN9 0010: AIN2 1010: AIN10 0011: AIN3 1011: AIN11 0100: AIN4 1100: AIN12 0101: AIN5 1101: VDDA/3 0110: AIN6 1110: TS built-in temperature sensor 0111: AIN7 1111: 1.2V core voltage reference source
7	RFU	-	Reserved bits, please keep the default value
6	ALIGN	RW	ADC conversion result alignment 0: Right justified, the conversion result is stored in [11:0] 1: Left justified, conversion result is stored in [15:4]
5	DISCARD	RW	Single channel ADC conversion result saving strategy configuration 0: Overwrite old data that has not been read, keep new data 1: Discard the newly converted data, keep the unread old data
4	RFU	-	Reserved bits, please keep the default value
3:0	CHMUX	RW	Single channel conversion mode to be converted channel configuration 0000: AIN0 1000: AIN8 0001: AIN1 1001: AIN9 0010: AIN2 1010: AIN10 0011: AIN3 1011: AIN11 0100: AIN4 1100: AIN12 0101: AIN5 1101: VDDA/3 0110: AIN6 1110: TS built-in temperature sensor 0111: AIN7 1111: 1.2V core voltage reference source



23.13.3 ADC_CR2 control register 2

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	ACCRST	R0W1	The accumulated value register is cleared to 0 0: No function 1: The conversion result accumulation value register ADC_RESULTACC is cleared to 0
8	ACCEN	RW	Conversion result accumulation enabled 0: Accumulation function disabled 1: Accumulation function enabled
7:0	CNT	RW	Configuration of the number of conversions in multiple conversion mode The number of conversions is CNT+1

23.13.4 ADC_SQR0 sequence configuration register 0

Address offset: 0x50 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:19	RFU	-	Reserved bits, please keep the default value
18:16	ENS	RW	Sequence configuration to convert 000: Convert SQR0 100: Convert SQR0-SQR4 001: Convert SQR0-SQR1 101: Convert SQR0-SQR5 010: Convert SQR0-SQR2 110: Convert SQR0-SQR6 011: Convert SQR0-SQR3 111: Convert SQR0-SQR7
15:12	SQR3	RW	Sequence 3 channel configuration to be converted See SQR0 for details
11:8	SQR2	RW	Sequence 2 channel configuration to be converted See SQR0 for details
7:4	SQR1	RW	Sequence 1 channel configuration to be converted See SQR0 for details
3:0	SQR0	RW	Sequence 0 Channel configuration to be converted 0000: AIN0 1000: AIN8 0001: AIN1 1001: AIN9 0010: AIN2 1010: AIN10 0011: AIN3 1011: AIN11 0100: AIN4 1100: AIN12 0101: AIN5 1101: VDDA/3 0110: AIN6 1110: TS built-in temperature sensor 0111: AIN7 1111: 1.2V core voltage reference source



23.13.5 ADC_SQR1 sequence configuration register 1

Address offset: 0x54 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:12	SQR7	RW	Sequence 7 channel configuration to be converted See SQR4 for details
11:8	SQR6	RW	Sequence 6 channel configuration to be converted See SQR4 for details
7:4	SQR5	RW	Sequence 5 channel configuration to be converted See SQR4 for details
3:0	SQR4	RW	Sequence 4 Channel configuration to be converted 0000: AIN0 1000: AIN8 0001: AIN1 1001: AIN9 0010: AIN2 1010: AIN10 0011: AIN3 1011: AIN11 0100: AIN4 1100: AIN12 0101: AIN5 1101: VDDA/3 0110: AIN6 1110: TS built-in temperature sensor 0111: AIN7 1111: 1.2V core voltage reference source

23.13.6 ADC_VTH high threshold register

Address offset: 0x14 Reset value: 0x0000 0FFF

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11:0	VTH	RW	Analog watchdog detects high threshold

23.13.7 ADC_VTL low threshold register

Address offset: 0x18 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:12	RFU	-	Reserved bits, please keep the default value
11:0	VTL	RW	Analog watchdog detects low threshold



23.13.8 ADC_TRIGGER external trigger register

Address offset: 0x1C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:25	RFU	-	Reserved bits, please keep the default value
24	GPIOF	RW	GPIOF interrupt triggers ADC startup 0: Disable 1: Enable
23	GPIOE	RW	GPIOE interrupt triggers ADC startup 0: Disable 1: Enable
22	GPIOD	RW	GPIOD interrupt triggers ADC startup 0: Disable 1: Enable
21	GPIOC	RW	GPIOC interrupt triggers ADC startup 0: Disable 1: Enable
20	GPIOB	RW	GPIOB interrupt triggers ADC startup 0: Disable 1: Enable
19	GPIOA	RW	GPIOA interrupt triggers ADC startup 0: Disable 1: Enable
18	UART6	RW	UART6 interrupt triggers ADC to start 0: Disable 1: Enable
17	UART5	RW	UART5 interrupt triggers ADC to start 0: Disable 1: Enable
16	UART4	RW	UART4 interrupt triggers ADC to start 0: Disable 1: Enable
15	DMA	RW	DMA interrupt triggers ADC to start 0: Disable 1: Enable
14	I2C2	RW	I2C2 interrupt triggers ADC to start 0: Disable 1: Enable
13	I2C1	RW	I2C1 interrupt triggers ADC to start 0: Disable 1: Enable



Bit field	Name	Permission	Function description
12	SPI2	RW	SPI2 interrupt triggers ADC to start 0: Disable 1: Enable
11	SPI1	RW	SPI1 interrupt triggers ADC to start 0: Disable 1: Enable
10	UART3	RW	UART3 interrupt triggers ADC to start 0: Disable 1: Enable
9	UART2	RW	UART2 interrupt triggers ADC to start 0: Disable 1: Enable
8	UART1	RW	UART1 interrupt triggers ADC to start 0: Disable 1: Enable
7	BTIM3	RW	BTIM3 interrupt triggers ADC to start 0: Disable 1: Enable
6	BTIM2	RW	BTIM2 interrupt triggers ADC to start 0: Disable 1: Enable
5	BTIM1	RW	BTIM1 interrupt triggers ADC to start 0: Disable 1: Enable
4	GTIM4	RW	GTIM4 interrupt triggers ADC to start 0: Disable 1: Enable
3	GTIM3	RW	GTIM3 interrupt triggers ADC to start 0: Disable 1: Enable
2	GTIM2	RW	GTIM2 interrupt triggers ADC to start 0: Disable 1: Enable
1	GTIM1	RW	GTIM1 interrupt triggers ADC to start 0: Disable 1: Enable
0	ATIM	RW	The trigger signal output by ATIM triggers the ADC to start 0: Disable 1: Enable



23.13.9 ADC_START start register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:2	RFU	-	Reserved bits, please keep the default value
1	AUTOSTOP	RW	ADC auto disable configuration 0: Continue to keep CR0.EN at 1 after the conversion is completed 1: Automatically set CR0.EN to 0 after the conversion is completed
0	START	RW	ADC start conversion control 0: Stop ADC conversion 1: Start ADC conversion

23.13.10 ADC_IER interrupt enable register

Address offset: 0x44 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	OVW	RW	Conversion result overflow interrupt enable control 0: Disabled 1: Enabled
5	WDTR	RW	Analog watchdog interval interrupt enable control 0: Disabled 1: Enabled
4	WDTH	RW	Analog watchdog upper threshold interrupt enable control 0: Disabled 1: Enabled
3	WDTL	RW	Analog watchdog lower threshold interrupt enable control 0: Disabled 1: Enabled
2	EOA	RW	Multiple conversion complete interrupt enable control 0: Disabled 1: Enabled
1	EOS	RW	Sequence conversion complete interrupt enable control 0: Disabled 1: enable
0	EOC	RW	Conversion complete interrupt enable control 0: Disabled 1: Enabled



23.13.11 ADC_ISR interrupt flag register

Address offset: 0x4C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	READY	RO	Analog circuit initialization complete flag 0: Initialization not completed 1: Initialization has been completed, and ADC conversion can be started
6	OVW	RO	Conversion result overflow flag 0: The event did not occur 1: A new conversion is completed before the data in the result register has been read
5	WDTR	RO	Analog watchdog interval flag 0: The conversion result is outside the range of [ADC_VTL, ADC_VTH) 1: The conversion result is in the range of [ADC_VTL, ADC_VTH)
4	WDTH	RO	Analog watchdog upper threshold flag 0: The conversion result is outside the range of [ADC_VTH, 4096) 1: The conversion result is in the interval [ADC_VTH, 4096)
3	WDTL	RO	Analog watchdog lower threshold flag 0: The conversion result is outside the range [0, ADC_VTL) 1: The conversion result is in the interval [0, ADC_VTL)
2	EOA	RO	Multiple conversion complete flag 0: Multiple conversions are not completed 1: Multiple conversions completed
1	EOS	RO	Sequence conversion complete flag 0: Sequence conversion not completed 1: Sequence conversion completed
0	EOC	RO	Conversion complete flag 0: One ADC conversion is not completed 1: One ADC conversion has been completed



23.13.12 ADC_ICR interrupt flag clear register

Address offset: 0x48 Reset value: 0x0000 007F

Bit field	Name	Permission	Function description
31:7	RFU	-	Reserved bits, please keep the default value
6	OVW	R1W0	The conversion result overflow flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function
5	WDTR	R1W0	Analog watchdog interval flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function
4	WDTH	R1W0	Analog watchdog upper threshold flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function
3	WDTL	R1W0	Analog watchdog lower threshold flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function
2	EOA	R1W0	Multiple conversion completion flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function
1	EOS	R1W0	Sequence conversion complete flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function
0	EOC	R1W0	Conversion complet flag is cleared to 0 control W0: The corresponding flag in the ISR register cleared W1: No function

23.13.13 ADC_RESULT0 conversion result 0 register

Address offset: 0x20 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 0 register



23.13.14 ADC_RESULT1 conversion result 1 register

Address offset: 0x24 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 1 register

23.13.15 ADC_RESULT2 conversion result 2 register

Address offset: 0x28 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 2 register

23.13.16 ADC_RESULT3 conversion result 3 register

Address offset: 0x2C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 3 register

23.13.17 ADC_RESULT4 conversion result 4 register

Address offset: 0x30 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 4 register

23.13.18 ADC_RESULT5 conversion result 5 register

Address offset: 0x34 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 5 register



23.13.19 ADC_RESULT6 conversion result 6 register

Address offset: 0x38 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result6 register

23.13.20 ADC_RESULT7 conversion result 7 register

Address offset: 0x3C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:0	RESULT	RO	ADC conversion result 7 register

23.13.21 ADC_RESULTACC conversion result accumulated value register

Address offset: 0x40 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:24	RFU	-	Reserved bits, please keep the default value
23:0	RESULT	RO	ADC conversion result accumulated value register



24 Analog voltage comparator (VC)

24.1 Overview

CW32L083 integrates two analog voltage comparators (VC), which are used to compare two analog input voltages, and output the comparison results from the pins. The positive terminal input of the voltage comparator supports up to 8 external analog inputs, and the negative terminal supports not only 8 external analog inputs, but also internal voltage reference, internal resistance voltage divider, internal temperature sensor and other voltage references. The comparison result output has filtering function, hysteresis window function, and polarity selection. Support compare interrupt, which can be used to wake up MCU in low power mode.

24.2 Main features

- Dual-channel analog voltage comparators VC1, VC2
- Internal 64-step resistor divider
- Up to 8 external analog signal inputs
- 4 on-chip analog input signals
 - Built-in resistor divider output voltage
 - Built-in temperature sensor output voltage
 - Built-in 1.2V reference voltage
 - ADC reference voltage
- Selectable output polarity
- Supports hysteresis window compare function
- Programmable filters and filter time
- 3 interrupt trigger modes, which can be used in combination
 - High level trigger
 - Rising edge trigger
 - Falling edge trigger
- Supports running in low power mode, interrupt wake-up MCU

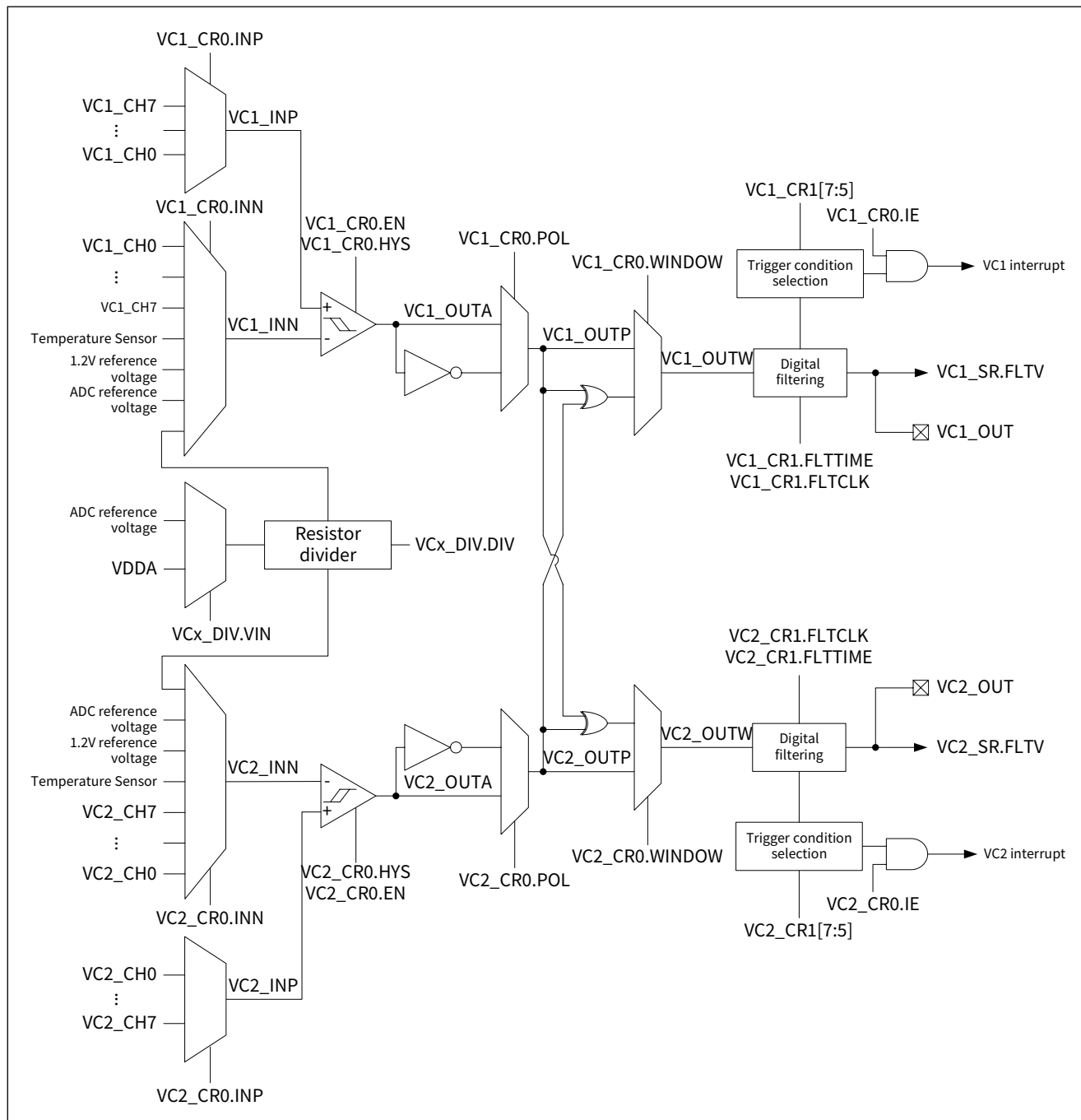


24.3 Functional description

24.3.1 Functional block diagram

The functional block diagram of the analog voltage comparator (VC) is shown in the following figure:

Figure 24-1 VC functional block diagram



The input selection of the positive and negative terminals of VC1 and VC2 is selected by the INP and INN bit fields of the control register VCx_CR0, as shown in the following table:

Table 24-1 VC positive and negative input signal configuration

VCx_CR0.INP	VCx positive terminal input signal	VCx_CR0.INN	VCx negative terminal input signal
0000	VCx_CH0	0000	VCx_CH0
0001	VCx_CH1	0001	VCx_CH1
0010	VCx_CH2	0010	VCx_CH2
0011	VCx_CH3	0011	VCx_CH3
0100	VCx_CH4	0100	VCx_CH4
0101	VCx_CH5	0101	VCx_CH5
0110	VCx_CH6	0110	VCx_CH6
0111	VCx_CH7	0111	VCx_CH7
-	-	1000	Built-in resistor divider output voltage
-	-	1001	Reference voltage configured by ADC module Caution: ADC_CR0.EN should be enabled
-	-	1010	Built-in 1.2V reference voltage
-	-	1011	Built-in temperature sensor output voltage Caution: ADC_CR0.TSEN should be enabled

The built-in resistor divider configuration is controlled by three bit fields in the VCx_DIV register¹:

- EN bit field, enable resistor divider
- VIN bit field, select the input voltage of the voltage divider
 - VIN is 0, select VDDA
 - VIN is 1, select the reference voltage configured by the ADC module (Caution that the ADC must be enabled first)
- DIV bit field, voltage divider proportional coefficient, valid range is 0~63, select the output voltage of the voltage divider, the calculation formula is as follows:

$$\text{Voltage divider output voltage} = \text{input voltage} \times (1 + \text{DIV}) / 64$$

Caution 1:

VC1_DIV and VC2_DIV point to the same entity register, and VC1 and VC2 share the resistor divider circuit.

When selecting the built-in 1.2V reference voltage or the ADC module reference voltage as the negative input of the comparator, it is necessary to enable the BGR module inside the chip. The startup time of the internal BGR is about 20μs, the VC voltage comparator needs to wait for the internal BGR to stabilize before it can work normally.



24.3.2 I/O pins

The analog voltage comparator supports 8 external analog signal inputs, and the user must configure the corresponding GPIO port as an analog function (GPIOx_ANALOG.PINy = 1).

The analog voltage comparator supports outputting the comparison result from the pin. The user must configure the corresponding GPIO port as a digital output and select the function multiplexing.

The I/O pins supported by VC1 and VC2 are shown in the following table:

Table 24-2 VC I/O pins configuration

VC1 I/O	GPIO	Configuration	VC2 I/O	GPIO	Configuration
VC1_CH0	PA00	Analog	VC2_CH0	PB00	Analog
VC1_CH1	PA01	Analog	VC2_CH1	PB01	Analog
VC1_CH2	PA02	Analog	VC2_CH2	PB02	Analog
VC1_CH3	PA03	Analog	VC2_CH3	PB10	Analog
VC1_CH4	PA04	Analog	VC2_CH4	PA08	Analog
VC1_CH5	PA05	Analog	VC2_CH5	PA09	Analog
VC1_CH6	PA06	Analog	VC2_CH6	PA10	Analog
VC1_CH7	PA07	Analog	VC2_CH7	PA11	Analog
VC1_OUT	PA06	Digital output (AFR=3)	VC2_OUT	PA07	Digital output (AFR=3)
	PA00	Digital output (AFR=4)		PA02	Digital output (AFR=4)
	PA11	Digital output (AFR=4)		PA12	Digital output (AFR=4)
	PD03	Digital output (AFR=4)		PD04	Digital output (AFR=4)
	PC10	Digital output (AFR=5)		PC11	Digital output (AFR=5)

24.3.3 Latency/Response Time

Set the EN bit field of the control register VCx_CR0 to 1 to enable the VC module.

The time from when VC is enabled or the input voltage at the positive and negative ends of VC changes to the time when the voltage comparator outputs the correct comparison result is defined as the delay/response time of the comparator. The delay/response time is configured by the RESP bit field of the control register VCx_CR0. The response time value is adjustable from 200ns to 20μs in four gears, and the shorter the response time, the greater the power consumption of the VC module.



24.3.4 Polarity selection

The polarity of the output signals of the voltage comparators VC1 and VC2 is set by the POL bit field of the control register VCx_CR0:

- POL is 1, the polarity of VCx_OUTP signal is opposite to that of VCx_OUTA signal, that is, when the positive terminal is greater than the negative terminal, VCx outputs a low level
- POL is 0, and the VCx_OUTP signal has the same polarity as the VCx_OUTA signal, that is, when the positive terminal is greater than the negative terminal, VCx outputs a high level

24.3.5 Digital filter

The built-in digital filter of the voltage comparator is used to digitally filter the output signal of the voltage comparator. It is controlled by the FLTEN bit field of the control register VCx_CR1. FLTEN is 1 to enable digital filter, and FLTEN is 0 to disable digital filter. Users can use the filtering function to filter system noise, such as high current noise when the motor is stopped, to avoid system malfunction caused by the noise output of the comparator.

The clock for the digital filter is selected by the FLTCLK bit field in the control register VCx_CR1:

- FLTCLK is 1, use PCLK as filter clock
- FLTCLK is 0, the built-in RC oscillator clock is used as the filter clock, and its frequency is about 150KHz

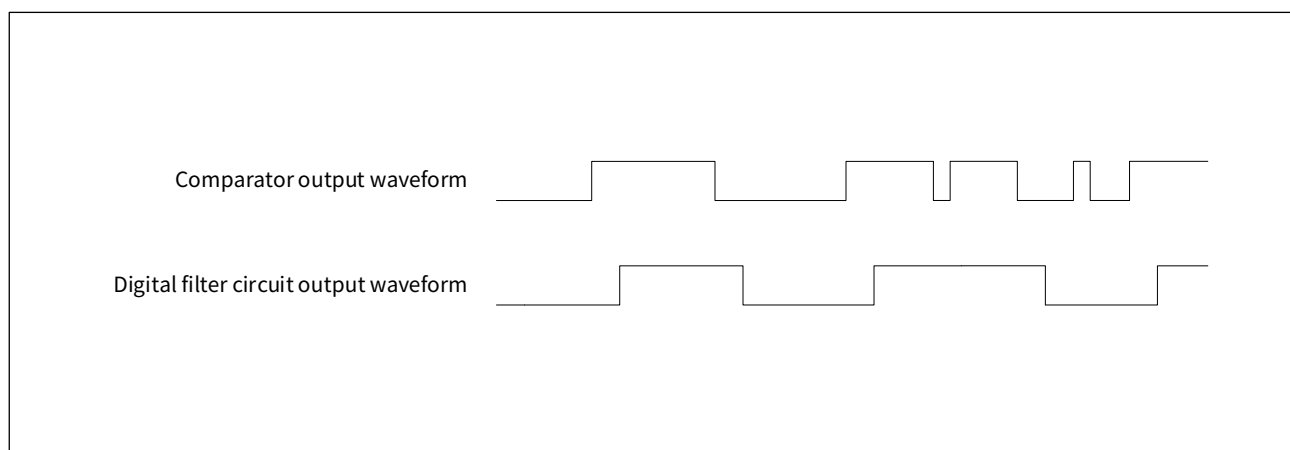
The filter width of the digital filter is selected by the FLTIME bit field of the control register VCx_CR1, and the signal whose width is less than a certain clock cycle is filtered out. There are 8 filter widths to choose from.

The digitally filtered output level of the voltage comparator can be read out through the FLTV bit field of the status register VCx_SR.

When the user sets the VCx_OUT pin as a digital output and selects the multiplexing function of the VC comparison output, the VCx_OUT pin will output the digitally filtered output level of the voltage comparator.

The filter response waveform of VC is shown in the following figure:

Figure 24-2 VC filter response time



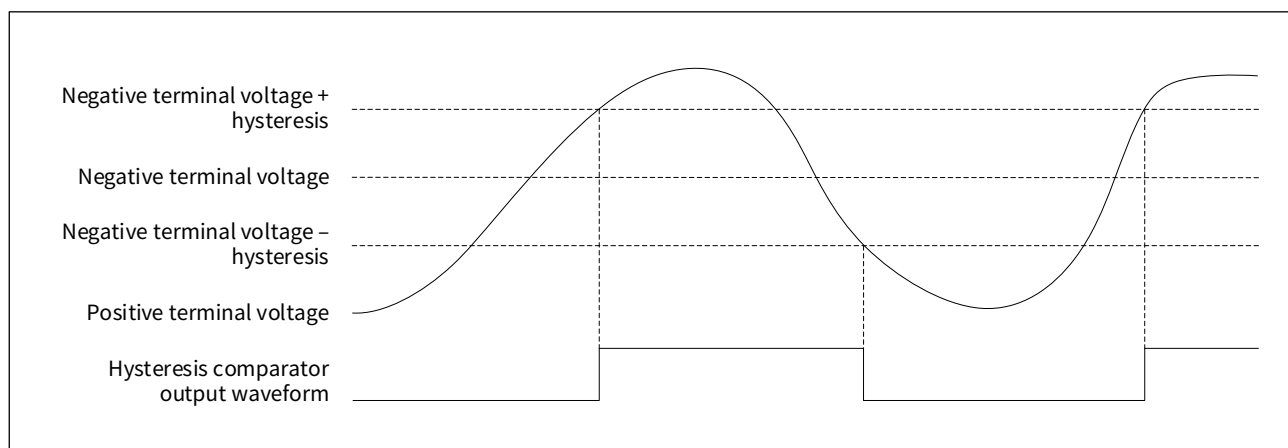
The output of the voltage comparator can be used as the BK brake input or OCREF_CLR input of the advanced timer (ATIM), which is controlled by the ATIMBK and ATIMCLR bit fields of the control register VCx_CR1 respectively. For the detailed introduction of BK and OCREF_CLR, please refer to chapter [16 Advanced-control timer \(ATIM\)](#). This function is usually used in motor protection applications, please refer to the relevant application Cautions for details.

24.3.6 Hysteresis function

The analog voltage comparator supports the hysteresis function. After the hysteresis function is used, the output result of the comparator will not be reversed immediately with the change of the input signal, but will reverse only after the offset value of the two input signals is higher or lower than the hysteresis threshold voltage.

The waveform diagram of VC hysteresis function is shown in the following figure:

Figure 24-3 VC hysteresis function



The hysteresis function can effectively enhance the anti-interference ability of the chip, and avoid unnecessary frequent flipping of the output end of the comparator due to the small amplitude jitter of the input signal.

The hysteresis threshold voltage is determined by the HYS bit field of the control register VCx_CR0, as shown in the following table:

Table 24-3 VC hysteresis threshold voltage

VCx_CR0.HYS	Hysteresis window configuration
00	No hysteresis
01	Hysteresis window about 10mV
10	Hysteresis window about 20mV
11	Hysteresis window about 30mV

24.3.7 Window compare function

The analog voltage comparator supports the window compare function, which can output the comparison results of VC1 and VC2 after XOR operation, which is enabled by the WINDOW bit field of the control register VCx_CR0.

When WINDOW is 1, the VCx_OUTW signal is the XOR value of the VC1_OUTP signal and the VC2_OUTP signal;

When WINDOW is 0, the VCx_OUTW signal is at the same level as the VCx_OUTP signal.

24.3.8 BLANK window function

While keeping the VCx module working, if you want to temporarily stop the voltage comparison function, or in some application systems (such as motor control), the short-term reasonable fluctuation of the monitored signal may cause unnecessary reverse of output levels of voltage comparator, the voltage comparator of this chip has added the BLANK window function, that is, when the specified external trigger condition starts the BLANK window, no voltage comparison is performed within the set BLANK window, and the output level of the voltage comparator remains current. level status. After the BLANK window period, the voltage comparator resumes normal operation.

The BLANK window duration is configured by the BLANKFLT bit field of the control register VCx_CR1. The window duration is

$$(2^{(\text{BLANKFLT}+2)} \sim 2^{(\text{BLANKFLT}+2)} + 2) \text{ PCLK cycles}$$

As shown in the following table:

Table 24-4 BLANK window duration configuration

VCx_CR1.BLANKFLT	The number of PCLK clocks in the BLANK window
000	4 ~ 6
001	8 ~ 10
010	16 ~ 18
011	32 ~ 34
100	64 ~ 66
101	128 ~ 130
110	256 ~ 258
111	512 ~ 514

The trigger start condition of the BLANK window is configured by the BLANKCH1B, BLANKCH2B, and BLANKCH3B bit fields of the control register VCx_CR1, and the BLANK window is triggered by the rising edge of CH1B, CH2B, and CH3B of ATIM respectively.



24.4 VC interrupts

The voltage comparator of CW32L083 supports working in low power consumption mode, and the comparison interrupt can wake up the chip from low power consumption mode.

Set the IE bit field of the control register VCx_CR0 to 1 to enable the VCx interrupt. When an interrupt occurs, the interrupt flag bit INTF of the status register VCx_SR will be set to 1 by hardware. The user can write 0 to the INTF bit to clear the interrupt flag.

Set the HIGHIE, RISEIE, FALLIE bit fields of the control register VCx_CR1 to select different interrupt triggering methods:

- HIGHIE is 1, VCx_OUT output signal high level triggers interrupt
- RISEIE is 1, the rising edge of VCx_OUT output signal triggers interrupt
- FALLIE is 1, the falling edge of VCx_OUT output signal triggers interrupt

24.5 Programming examples

In this example, the digital filtering function is used, and the compare interrupt is configured as follows:

Step 1: Configure VCx_DIV.EN to 1, enable the voltage divider;

Step 2: Configure VCx_DIV.DIV and set the voltage division coefficient;

Step 3: Configure VCx_CR0.INP and select the voltage source to be monitored at the positive terminal;

Step 4: Configure VCx_CR0.INN and select the voltage source to be monitored at the negative terminal;

Step 5: Configure VCx_CR1.FLTTIME and select the filter time;

Step 6: Configure VCx_CR1.FLTCLK, select filter clock;

Step 7: Configure VCx_CR1.FLTEN to 1 to enable VCx filter;

Step 8: Set the HIGHIE, RISEIE, and FALLIE of the VCx_CR1 register to 1, and select the interrupt trigger mode;

Step 9: Set VCx_CR0.IE to 1 to enable VCx interrupt;

Step 10: Set VCx_CR0.EN to 1 to enable VCx;

Step 11: Wait for the VCx_SR.READY flag to become 1;

Step 12: In the initialization routine of the VC module and the interrupt service routine of the VC module, write 0 to the INTF bit of the VCx_SR register, clear the interrupt flag, and enable the generation of the VCx interrupt.



24.6 List of registers

VC1 base address: VC1_BASE = 0x4001 2A00

VC2 base address: VC2_BASE = 0x4001 2A10

Table 24-5 List of VC registers

Register name	Register address	Register description
VCx_DIV	VCx_BASE + 0x00	Resistor divider control register ¹
VCx_CR0	VCx_BASE + 0x04	Control register 0
VCx_CR1	VCx_BASE + 0x08	Control register 1
VCx_SR	VCx_BASE + 0x0C	Status register

Caution 1:

VC1_DIV and VC2_DIV point to the same entity register, and VC1 and VC2 share the resistor divider circuit.



24.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

24.7.1 VCx_DIV resistor divider control register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	VIN	RW	Resistor divider circuit input voltage setting 0: VDDA 1: The reference voltage configured by the ADC module (the ADC needs to be enabled)
6	EN	RW	Resistor divider circuit enable control 0: Disabled 1: Enabled
5:0	DIV	RW	Resistor divider circuit output voltage configuration Output voltage = input voltage $\times (1 + \text{DIV}) / 64$

Caution:

VC1_DIV and VC2_DIV point to the same entity register, and VC1 and VC2 share the resistor divider circuit.



24.7.2 VCx_CR0 control register 0

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:12	INN	RW	VCx negative terminal input signal configuration 0000: VCx_CH0 0001: VCx_CH1 0010: VCx_CH2 0011: VCx_CH3 0100: VCx_CH4 0101: VCx_CH5 0110: VCx_CH6 0111: VCx_CH7 1000: Built-in voltage divider output voltage 1001: The reference voltage configured by the ADC module (Caution: ADC_CR0.EN needs to be enabled) 1010: Built-in 1.2V reference voltage 1011: Built-in temperature sensor output voltage (Caution: ADC_CR0.TSEN needs to be enabled) Caution: To configure the ADC_CR0 register, you need to enable the ADC peripheral clock first
11:8	INP	RW	VCx positive terminal input signal configuration 0000: VCx_CH0 0001: VCx_CH1 0010: VCx_CH2 0011: VCx_CH3 0100: VCx_CH4 0101: VCx_CH5 0110: VCx_CH6 0111: VCx_CH7
7	WINDOW	RW	Window compare function configuration 0: Window function disabled, VCx_OUTW signal equals VCx_OUTP signal 1: Window function enabled, VCx_OUTW signal equals to the XOR of VC1_OUTP and VC2_OUTP
6	POL	RW	VCx output signal polarity settings 0: When the positive terminal is greater than the negative terminal, VCx outputs a high level 1: When the positive terminal is greater than the negative terminal, VCx outputs a low level
5	IE	RW	Interrupt enable configuration 0: Disabled 1: Enabled



Bit field	Name	Permission	Function description
4:3	HYS	RW	VCx hysteresis window configuration 00: No hysteresis 01: Hysteresis window about 10mV 10: Hysteresis window about 20mV 11: Hysteresis window about 30mV
2:1	RESP	RW	VCx response speed configuration 00: Ultra-low speed 01: Low speed 10: Medium speed 11: High speed Caution: The faster the response speed, the greater the power consumption.
0	EN	RW	VCx enable control 0: Disabled 1: Enabled Caution: After enabling VCx, wait for the VCx_SR.READY flag bit to become 1.



24.7.3 VCx_CR1 control register 1

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:16	RFU	-	Reserved bits, please keep the default value
15:13	BLANKFLT	RW	BLANK window duration configuration: ($2^{(\text{BLANKFLT}+2)} \sim 2^{(\text{BLANKFLT}+2)+2}$) PCLK cycles Caution: Any rising edge of CH1B, CH2B, and CH3B of ATIM will trigger the start of the BLANK window. During the duration of the BLANK window, no voltage comparison will be performed.
12	BLANKCH3B	RW	ATIM's CH3B rising edge triggers VCx to start BLANK window configuration 0: Disabled 1: Enabled
11	BLANKCH2B	RW	ATIM's CH2B rising edge triggers VCx to start BLANK window configuration 0: Disabled 1: Enabled
10	BLANKCH1B	RW	ATIM's CH1B rising edge triggers VCx to start BLANK window configuration 0: Disabled 1: Enabled
9	ATIMBK	RW	ATIM's BK brake signal connectivity configuration 0: No function 1: VCx output connected to BK brake signal of ATIM
8	ATIMCLR	RW	ATIM's OCREF_CLR signal connectivity configuration 0: No function 1: VCx output connected to OCREF_CLR signal of ATIM
7	HIGHIE	RW	VCx output signal high level trigger interrupt enabled 0: Disabled 1: Enabled
6	RISEIE	RW	VCx output signal rising edge trigger interrupt enabled 0: disable 1: Enabled
5	FALLIE	RW	VCx output signal falling edge trigger interrupt enabled 0: Disabled 1: Enabled
4	FLTCLK	RW	Digital filter module filter clock settings 0: Built-in RC oscillator clock, its frequency is about 150KHz 1: PCLK



Bit field	Name	Permission	Function description
3:1	FLTTIME	RW	Digital filter module filter time configuration 000: Filter out signals with width less than 1 clock cycle 001: Filter out signals with width less than 3 clock cycle 010: Filter out signals with width less than 7 clock cycles 011: Filter out signals with width less than 15 clock cycles 100: Filter out signals with width less than 63 clock cycles 101: Filter out signals with width less than 255 clock cycles 110: Filter out signals with width less than 1023 clock cycles 111: Filter out signals with width less than 4095 clock cycles
0	FLTEN	RW	Digital filter module enable configuration 0: Disabled 1: Enabled

24.7.4 VCx_SR status register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:3	RFU	-	Reserved bits, please keep the default value
2	READY	RO	VCx status flag, by reading this bit to determine whether VCx has been stable 0: Not yet stable, cannot be used 1: Already stable and ready to use
1	FLTV	RO	Level value of digital filter output 0: Digital filter output low level 1: Digital filter output high level
0	INTF	RW0	Interrupt flag R0: No VC interrupt occurred R1: VC interrupt has occurred W0: VC interrupt flag cleared W1: No function



25 Low voltage detector (LVD)

25.1 Overview

Low voltage detector (LVD) is used to monitor VDDA power supply voltage or external pin input voltage. When the comparison result between the monitored voltage and the LVD threshold meets the trigger condition, an LVD interrupt or reset signal will be generated, which is usually used to handle some urgent tasks.

The interrupt and reset flags generated by the LVD can only be cleared by software; only after the interrupt or reset flag is cleared and the trigger condition is reached again, the LVD can generate an interrupt or reset signal again.

25.2 Main features

- 4-channel monitoring voltage source: VDDA power supply voltage, PA00, PB00, PB11 pin input
- 16-step threshold voltage, range 1.8V~3.3V
- 3 trigger conditions, which can be used in combination
 - Level triggered: voltage below threshold
 - Falling edge trigger: the falling edge when the voltage falls below the threshold
 - Falling edge trigger: the falling edge when the voltage falls below the threshold
- Can trigger to generate interrupt or reset signal, both cannot be generated at the same time
- 8th order filter configurable
- Hysteresis function supported
- Supports running in low power mode, interrupt wake-up MCU

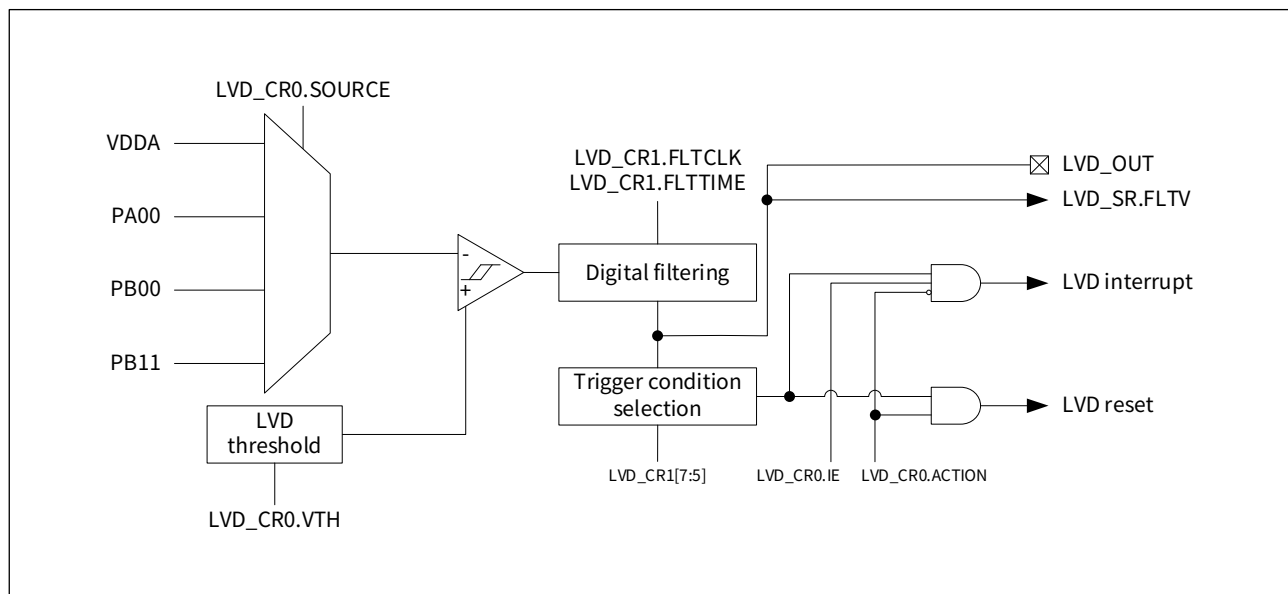


25.3 Functional description

25.3.1 Functional block diagram

The functional block diagram of the Low voltage detector (LVD) is shown in the following figure:

Figure 25-1 LVD functional block diagram



The LVD can monitor the VDDA power supply voltage, as well as the external pin input voltage (PA00, PB00, PB11), which is selected by the SOURCE bit field of the control register LVD_CR0. When using external analog signal input, the user must configure the corresponding GPIO port as analog function (GPIOx_ANALOG.PINy = 1).

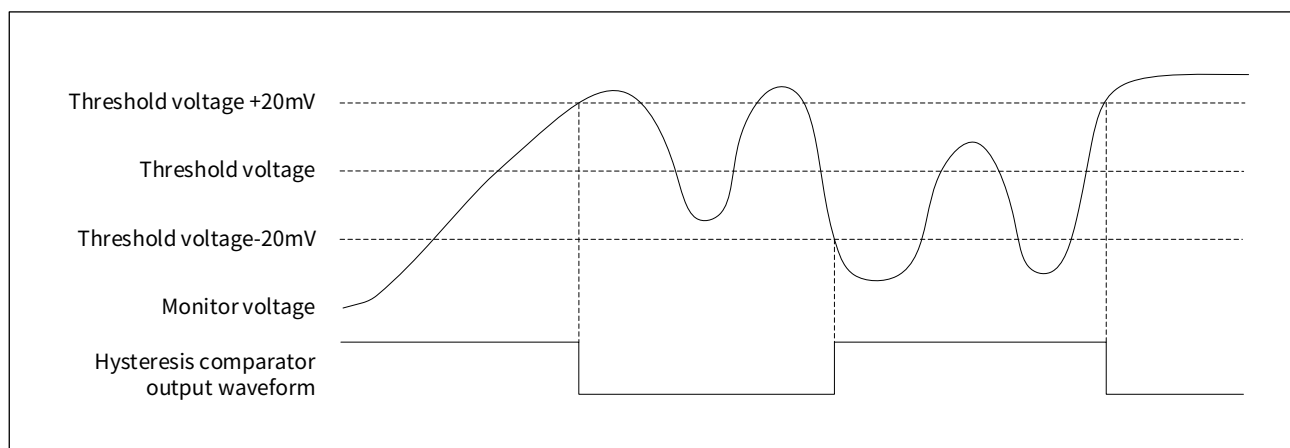
The LVD output result can be output from the PA01, PA08, PC12, PE02 or PF02 pin, the user must configure the corresponding GPIO port as a digital output, and select function multiplexing at the same time.

25.3.2 Hysteresis function

The built-in voltage comparator of the LVD has a hysteresis function, which can avoid frequent flipping of the output result of the voltage comparator when the monitored voltage of the LVD is near the threshold voltage, and enhance the anti-interference ability of the system.

The comparator output signal toggles only when the monitored voltage is 20mV above or below the threshold voltage. The specific waveform is shown in the following figure:

Figure 25-2 LVD hysteretic response



The threshold voltage of LVD is determined by the VTH bit value of the control register LVD_CR0, and the effective value is 0 ~ 15, as shown in the following table:

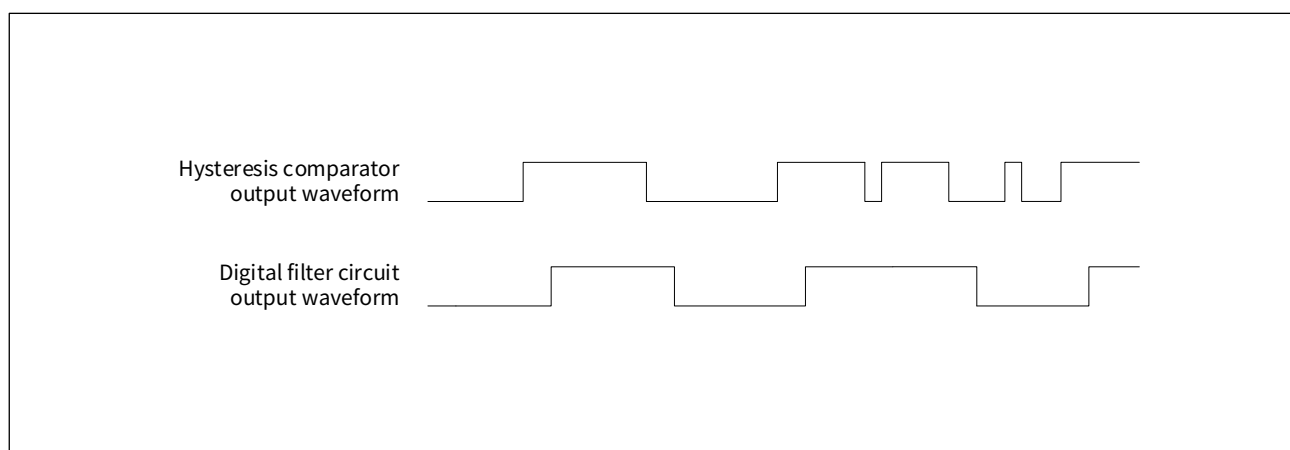
Table 25-1 LVD threshold voltage

LVD_CR0.VTH	Threshold voltage (unit: V)	LVD_CR0.VTH	Threshold voltage (unit: V)
0000	1.8	1000	2.6
0001	1.9	1001	2.7
0010	2.0	1010	2.8
0011	2.1	1011	2.9
0100	2.2	1100	3.0
0101	2.3	1101	3.1
0110	2.4	1110	3.2
0111	2.5	1111	3.3

25.3.3 Digital filter

In order to enhance the robustness of the system, the LVD supports the digital filtering function, which can digitally filter the output result signal of the LVD voltage comparison, and the signal smaller than the filtering width is filtered out without triggering an interrupt or reset. The specific waveform is shown in the following figure:

Figure 25-3 LVD filter output



Set the FLTEN bit field of the control register LVD_CR1 to 1 to enable the digital filter module;

The FLTCLK bit field of the control register LVD_CR1 is used to select the clock for digital filter:

- FLTCLK bit is 1, select HSIOSC as filter clock
- FLTCLK bit is 0, and the built-in RC oscillator clock is selected as the filter clock, and its frequency is about 150KHz

The FLTTIME bit field of the control register LVD_CR1 is used to select the number of clocks for digital filter, as shown in the following table:

Table 25-2 Number of LVD digital filter clocks

LVD_CR1.FLTTIME	Number of filter clocks
000	1
001	3
010	7
011	15
100	63
101	255
110	1023
111	4095

From the FLTV bit field of the LVD status register LVD_SR, the signal level after LVD digital filter can be read out; When the function of GPIO is multiplexed as LVD_OUT, the digitally filtered signal can be output from GPIO to facilitate observation and measurement.



25.4 LVD interrupts

LVD supports working in low power mode, and interrupt output can wake up the chip from low power mode.

When the comparison result of the monitored voltage and the LVD threshold meets the trigger condition, an interrupt or reset signal can be generated. Whether to generate an interrupt or a reset signal is controlled by the ACTION bit field of the control register LVD_CR0:

- ACTION is 1, LVD triggers to generate reset
- ACTION is 0, LVD triggers an interrupt

Set the IE bit field of the control register LVD_CR0 to 1 to enable the LVD interrupt. When the trigger condition is met, an LVD interrupt will be generated. The interrupt flag bit LVD_SR.INTF will be set to 1 by hardware. The user can write 0 to the INTF bit to clear the interrupt flag.

Set the LEVEL, FALL, and RISE bit fields of the control register LVD_CR1 to select different interrupt or reset trigger methods. The three can be used in combination:

- LEVEL is 1, when the monitored voltage is lower than the threshold, an interrupt is triggered or a reset is generated
- FALL is 1, the falling edge of the monitored voltage falling below the threshold triggers an interrupt or generates a reset
- RISE is 1, the rising edge of the monitored voltage rises above the threshold to trigger an interrupt or generate a reset



25.5 Programming examples

25.5.1 Brown-out reset programming example

In this example, the MCU is reset when the monitored voltage falls below the threshold voltage, using digital filtering.

The configuration method is as follows:

Step 1: Configure LVD_CR0.SOURCE and select the voltage source to be monitored;

Step 2: Configure LVD_CR0.VTH and set the threshold voltage;

Step 3: Configure LVD_CR1.FLTTIME and select LVD filter time;

Step 4: Configure LVD_CR1.FLTCLK and select the filter clock;

Step 5: Configure LVD_CR1.FLTEN to enable LVD filter;

Step 6: Set LVD_CR1.LEVEL to 1, and select to trigger LVD action when the monitored voltage is lower than the threshold;

Step 7: Set LVD_CR0.ACTION to 1, and select LVD trigger action as system reset;

Step 8: Set LVD_CR0.EN to 1 to enable LVD.

25.5.2 Interrupt programming example

In this example, an interrupt is generated when the monitored voltage is above or below a threshold voltage, using digital filtering.

The configuration method is as follows:

Step 1: Configure LVD_CR0.SOURCE and select the voltage source to be monitored;

Step 2: Configure LVD_CR0.VTH and select the threshold voltage;

Step 3: Configure LVD_CR1.FLTTIME and select LVD filter time;

Step 4: Configure LVD_CR1.FLTCLK and select the filter clock;

Step 5: Configure LVD_CR1.FLTEN to enable LVD filter;

Step 6: Set both LVD_CR1.RISE and FALL to 1, and select rising and falling edge triggers;

Step 7: Set LVD_CR0.ACTION to 0, and select LVD trigger action as interrupt;

Step 8: Set LVD_CR0.IE to 1 to enable LVD interrupt;

Step 9: Enable the LVD interrupt in the NVIC interrupt vector table;

Step 10: Set LVD_CR0.EN to 1 to enable LVD;

Step 11: In the LVD initialization routine and the LVD interrupt service routine, write 0 to the LVD_SR.INTF bit to clear the interrupt flag and allow a new LVD interrupt to be generated.



25.6 List of registers

LVD base address: LVD_BASE = 0x4001 2A80

Table 25-3 List of LVD registers

Register name	Register address	Register description
LVD_CR0	LVD_BASE + 0x00	Control register 0
LVD_CR1	LVD_BASE + 0x04	Control register 1
LVD_SR	LVD_BASE + 0x08	Status register



25.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

25.7.1 LVD_CR0 control register 0

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:10	RFU	-	Reserved bits, please keep the default value
9	IE	RW	Interrupt enable control 0: LVD interrupt disabled 1: LVD interrupt enable
8	RFU	-	Reserved bits, please keep the default value
7:4	VTH	RW	Threshold voltage selection 0000: 1.8V 1000: 2.6V 0001: 1.9V 1001: 2.7V 0010: 2.0V 1010: 2.8V 0011: 2.1V 1011: 2.9V 0100: 2.2V 1100: 3.0V 0101: 2.3V 1101: 3.1V 0110: 2.4V 1110: 3.2V 0111: 2.5V 1111: 3.3V
3:2	SOURCE	RW	Monitor source configuration 00: VDDA supply voltage 01: PA00 port input voltage 10: PB00 port input voltage 11: PB11 port input voltage
1	ACTION	RW	Trigger action configuration 0: NVIC interrupts 1: System resets
0	EN	RW	Enable control 0: LVD disabled 1: LVD enabled



25.7.2 LVD_CR1 control register 1

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:8	RFU	-	Reserved bits, please keep the default value
7	LEVEL	RW	Triggered when the monitored voltage falls below the threshold level (that is, the LVD output signal is triggered by a high level) 0: Disabled 1: Enabled
6	FALL	RW	Trigger on falling edge of monitored voltage falling below threshold (that is, the rising edge of the LVD output signal is triggered) 0: Disabled 1: Enabled
5	RISE	RW	Triggered on rising edge when the monitored voltage rises back above the threshold (that is, the falling edge of the LVD output signal is triggered) 0: Disabled 1: Enabled
4	FLTCLK	RW	Digital filter module filter clock settings 0: Built-in RC oscillator clock, its frequency is about 150KHz 1: HSIOSC
3:1	FLTTIME	RW	Digital filter module filter time configuration 000: Filter out signals with width less than 1 clock cycle 001: Filter out signals with width less than 3 clock cycle 010: Filter out signals with width less than 5 clock cycle 011: Filter out signals with width less than 15 clock cycle 100: Filter out signals with width less than 63 clock cycle 101: Filter out signals with width less than 255 clock cycle 110: Filter out signals with width less than 1023 clock cycle 111: Filter out signals with width less than 4095 clock cycle
0	FLTEN	RW	Digital filter module enable configuration 0: Disabled 1: Enabled



25.7.3 LVD_SR status register

Address offset: 0x08 Reset value: 0x0000 0000

Bit field	Name	Permission	Function description
31:2	RFU	-	Reserved bits, please keep the default value
1	FLTV	RO	Level value of digital filter output 0: Digital filter output low level 1: Digital filter output high level
0	INTF	RW0	Interrupt flags R0: LVD interrupt did not occur R1: LVD interrupt has occurred W0: LVD interrupt flag cleared W1: No function



26 True random number generator (TRNG)

26.1 Overview

The True Random Number Generator (TRNG) uses an internal analog random source to generate 64-bit true random numbers through a specific configuration mode.

26.2 Main features

- 64-bit true random number
- 3 kinds of True Random Number Generation Configurations
- Can be disabled to reduce power consumption

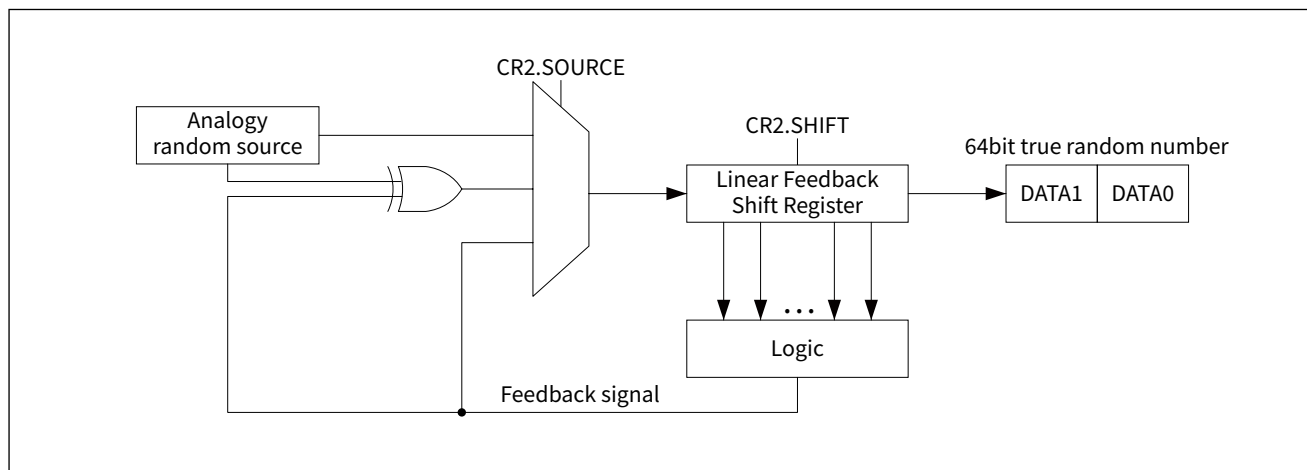


26.3 Function description

26.3.1 Functional block diagram

The core components of TRNG are an internal analog random source and a linear feedback shift register. Its functional block diagram is shown in the following figure:

Figure 26-1 TRNG functional block diagram



26.3.2 Way of working

Set TRNG_CR1.EN to 1 to enable the analog random source circuit, set TRNG_CR1.START to 1 to start a TRNG operation, and the hardware will generate 64-bit true random numbers according to the true random number generation method configured by the TRNG_CR2 register.

After the TRNG operation is completed, the START bit is automatically cleared. At this time, the data registers TRNG_DATA0 and TRNG_DATA1 can be read to obtain a 64-bit true random number. It is recommended that after generating a true random number, set TRNG_CR1.EN to 0 to turn off the analog random source circuit to save power consumption.

26.4 Programming example

Step 1: Set SYSCTRL_AHBEN.TRNG to 1 to enable the configuration clock and working clock of the TRNG module;

Step 2: Set TRNG_CR1.EN to 1 to enable the analog random source;

Step 3: Configure TRNG_CR2.SOURCE to select the input signal of the linear feedback shift register;

1. Set TRNG_CR2.SOURCE to 00: Linear feedback signal
2. Set TRNG_CR2.SOURCE to 01: simulate the signal output by the random source
3. Set TRNG_CR2.SOURCE to 10: the signal output by the analog random source is XORed with the linear feedback signal

Step 4: Configure TRNG_CR2.SHIFT to select the shift times of the linear feedback shift register;

Step 5: Set TRNG_CR1.START to 1, start the TRNG operation, and generate a true random number;

Step 6: The query waits for TRNG_CR1.START to be cleared to confirm that the TRNG operation is completed;

Step 7: Read the TRNG_DATA0 and TRNG_DATA1 registers to get 64bit true random numbers;

Step 8: Set TRNG_CR1.EN to 0, disable analog random source, save power.



26.5 List of registers

TRNG base address: TRNG_BASE = 0x4002 5000

Table 26-1 List of TRNG registers

Register name	Register address	Register description
TRNG_CR1	TRNG_BASE + 0x00	Control register 1
TRNG_CR2	TRNG_BASE + 0x04	Control register 2
TRNG_DATA0	TRNG_BASE + 0x0C	Data register 0
TRNG_DATA1	TRNG_BASE + 0x10	Data register 1



26.6 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

26.6.1 TRNG_CR1 Control register 1

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:2	RFU	-	Reserved bits, please keep the default value
1	START	RW	TRNG operation control W1: Start TRNG operation R0: TRNG operation completed R1: TRNG is running
0	EN	RW	Analog Random Source Enable Control 0: Disable 1: Enable

26.6.2 TRNG_CR2 Control register 2

Address offset: 0x04 Reset value: 0x0000 0010

Bit field	Name	Permission	Functional description
31:5	RFU	-	Reserved bits, please keep the default value
4:2	SHIFT	RW	Linear Feedback Shift Register Shift Times Configuration 001: Shift 8 times 010: Shift 16 times 011: Shift 32 times 100: Shift 64 times 101: Shift 128 times 110: Shift 256 times
1:0	SOURCE	RW	Linear Feedback Shift Register Input Signal Configuration 00: Linear feedback signal 01: Simulate the signal output by the random source 10: The signal output by the analog random source is XORed with the linear feedback signal

26.6.3 TRNG_DATA0 Data register 0

Address offset: 0x0C Reset value: 0x-----

Bit field	Name	Permission	Functional description
31:0	DATA0	RO	The random number output by TRNG, bit31~bit0



26.6.4 TRNG_DATA1 Data register 1

Address offset: 0x10 Reset value: 0x---- ----

Bit field	Name	Permission	Functional description
31:0	DATA1	RO	The random number output by TRNG, bit63~bit32



27 LCD controller (LCD)

27.1 Overview

CW32L083 integrates a liquid crystal controller, which is used for digital control and driving of monochrome passive liquid crystal display (LCD). It has up to 8 common terminals (COM) and 56 segment terminals (SEG). 224 (4×56), 324 (6×54) or 416 (8×52) LCD picture elements can be driven.

27.2 Main features

- Highly flexible frame rate control
- Supports Static, 1/2, 1/3, 1/4, 1/6 and 1/8 Duty Cycles
- Support 1/2, 1/3 offset
- 16-level contrast adjustment
- 3 kinds of bias voltage generation modes: internal resistor divider, external resistor divider, and external capacitor divider
- Internal Resistor Divider Adjustable by Software
- Built-in charge pump circuit
- Support frame interrupt
- Support DMA transfer
- Support LCD flicker function, flicker frequency can be configured
- Unused LCD segments and common pins can be configured as digital or analog functions

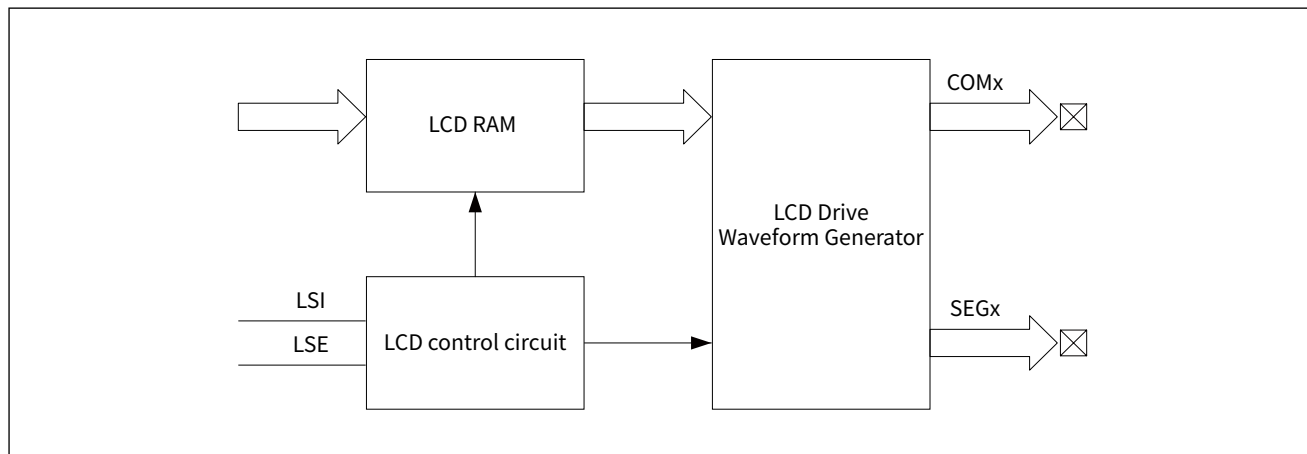


27.3 Function description

27.3.1 Functional block diagram

The LCD functional block diagram is shown in the following figure:

Figure 27-1 LCD functional block diagram



27.3.2 Clock

The working clock source of the LCD controller can be selected from the internal low-speed clock LSI or the external low-speed clock LSE, which is selected by the CLKCS bit field of the control register LCD_CR1. When the LSI or LSE clock frequency is typically 32kHz, the LCD scan frequency can be selected as 128Hz, 256Hz, 512Hz or 64Hz through the LCDFS bit field of the LCD_CR1 register.

The time to apply the scanning voltage to all the common terminals (COM) once is called one frame, and how many frames can be refreshed per unit time is called the frame rate of the LCD, namely:

$$\text{LCD frame rate} = \text{LCD scanning frequency} \times \text{Duty}$$

Caution 1:

Generally, in order to achieve a good display effect, when more COM ports are used, the higher the scanning frequency of the LCD should be selected.

Caution 2:

For the relationship between Duty and COM, see [27.3.4 LCD drive waveform](#).

27.3.3 LCD Bias Voltage

The Bias voltage of the LCD can be generated in three ways: internal resistor divider, external resistor divider, and external capacitor divider. Bias voltage can be configured as 1/3bias or 1/2bias through the BIAS bit field of the LCD_CR0 register.

Caution:

When using an external circuit to generate the voltage divider, the BIAS bit field configuration must match the external circuit. When the drive waveform is static, the BIAS bit field should be set to 0.

Internal resistor divider

In this mode, the Bias voltage is generated by the internal circuit of the chip, and the pins VLCD1~VLCD4 can be used as the SEG output or GPIO port of the LCD. The driving ability of this mode is weak, and different power consumption modes can be selected through the INRS bit field of the LCD_CR0 register, as shown in the following table:

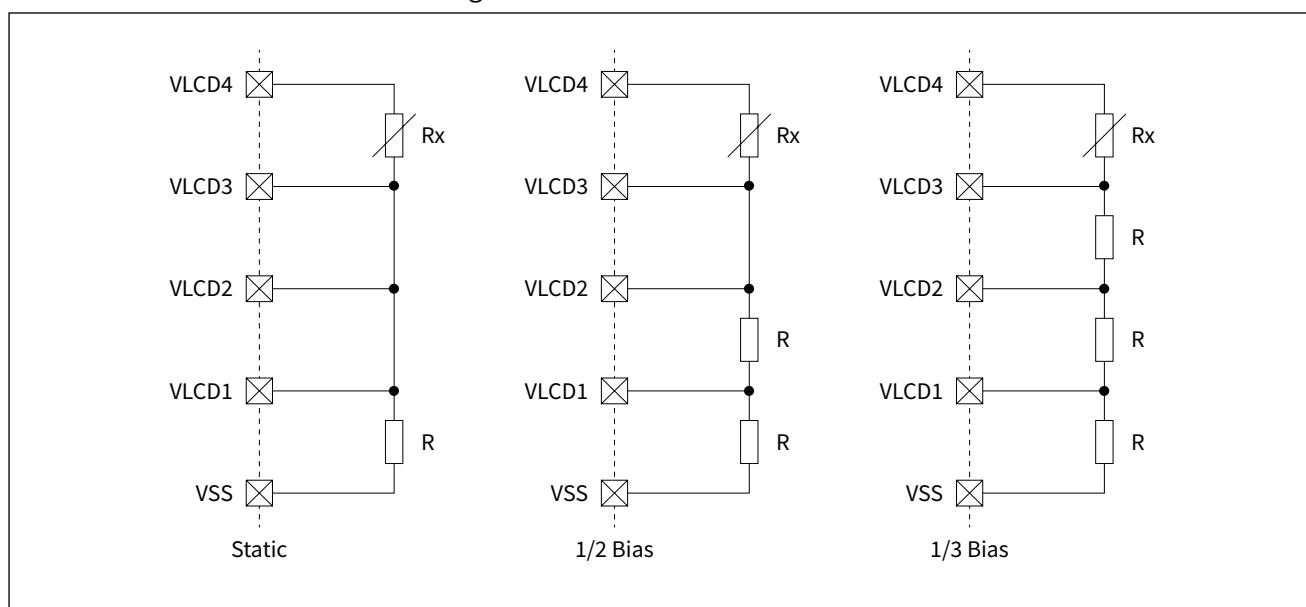
Table 27-1 Internal resistor divider power consumption

LCD_CR0.INRS	Power consumption
111	Maximum
001	Middle
010	Small
100	Minimum

External resistor divider

When the INRS bit field of the LCD_CR0 register is set to '000', the Bias voltage is generated by an external circuit. The circuit for voltage dividing by an external resistor is shown in the following figure:

Figure 27-2 External Resistor Mode



Caution 1:

Rx is an adjustable resistor, used to adjust the LCD display contrast.

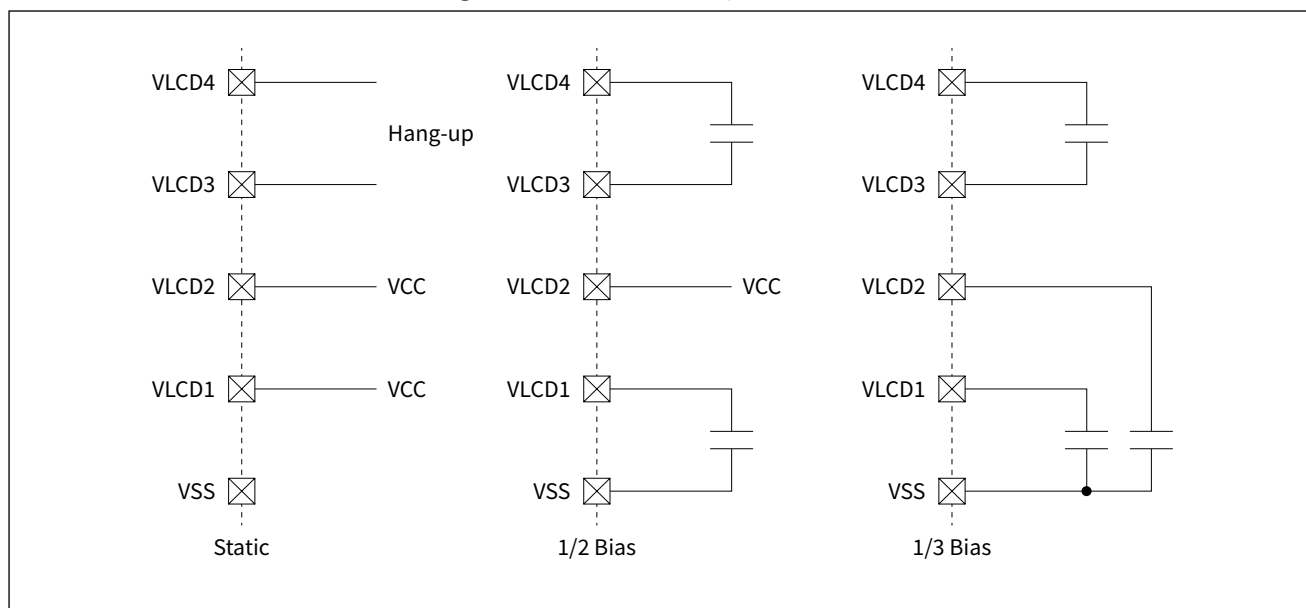
Caution 2:

Select the appropriate resistor R value according to the LCD screen used.

External capacitor divider

When the INRS bit field of the LCD_CR0 register is set to '000', the Bias voltage is generated by an external circuit. The circuit for dividing the voltage by an external capacitor is shown in the following figure:

Figure 27-3 External Capacitor Mode



When using the external capacitor voltage divider mode, the ability to drive the LCD screen is strong, and a 100nF capacitor is recommended. At the same time, it is necessary to enable the charge pump mode by setting the BUMP bit of the LCD_CR0 register to 1, and set the CPCLK bit field of the LCD_CR0 register to select the appropriate charge pump operating frequency. If the external capacitor divider mode is not used, the BUMP bit in the LCD_CR0 register must be set to 0 to turn off the charge pump.

27.3.4 LCD drive waveform

LCD is an element that uses the optical properties and physical structure of liquid crystal molecules to display. Liquid crystal molecules are driven by AC voltage. A long-term DC voltage applied to both ends of the liquid crystal molecules will affect the electrochemical properties of the liquid crystal molecules, causing blurred display, shortened life, and irreversible damage. Therefore, the LCD controller needs to generate AC waveforms at the SEG end and the COM end to drive the display of the LCD.

The LCD controller of CW32L083 provides up to 8 COM ports. According to the actual LCD screen, the DUTY bit field of the LCD_CR0 register can be configured to match the COM port with the LCD screen. The relationship between the DUTY bit field configuration and the COM port is shown in the following table:

Table 27-2 Relationship between DUTY configuration and COM port

LCD_CR0.DUTY	Duty	Usable COM ports
000	Static	COM0
001	1/2	COM0~COM1
010	1/3	COM0~COM2
011	1/4	COM0~COM3
100	Reserved	-
101	1/6	COM0~COM5
110	Reserved	-
111	1/8	COM0~COM7

In order to achieve the ideal display effect, in general, there is a certain relationship between Bias and COM. The more COMs, the shorter the corresponding strobe time of each COM, and to achieve the same display brightness and contrast, Bias needs to be added big. The suggested combinations are shown in the table below:

Table 27-3 Relationship between DUTY configuration and Bias

	1/2 Duty	1/3 Duty	1/4 Duty	1/6 Duty	1/8 Duty
1/2 Bias	Recommend	Recommend	Not recommended	Not recommended	Not recommended
1/3 Bias	Not recommended	Not recommended	Recommend	Recommend	Recommend

The driving waveforms in each mode are as follows:



Figure 27-4 Static drive waveform

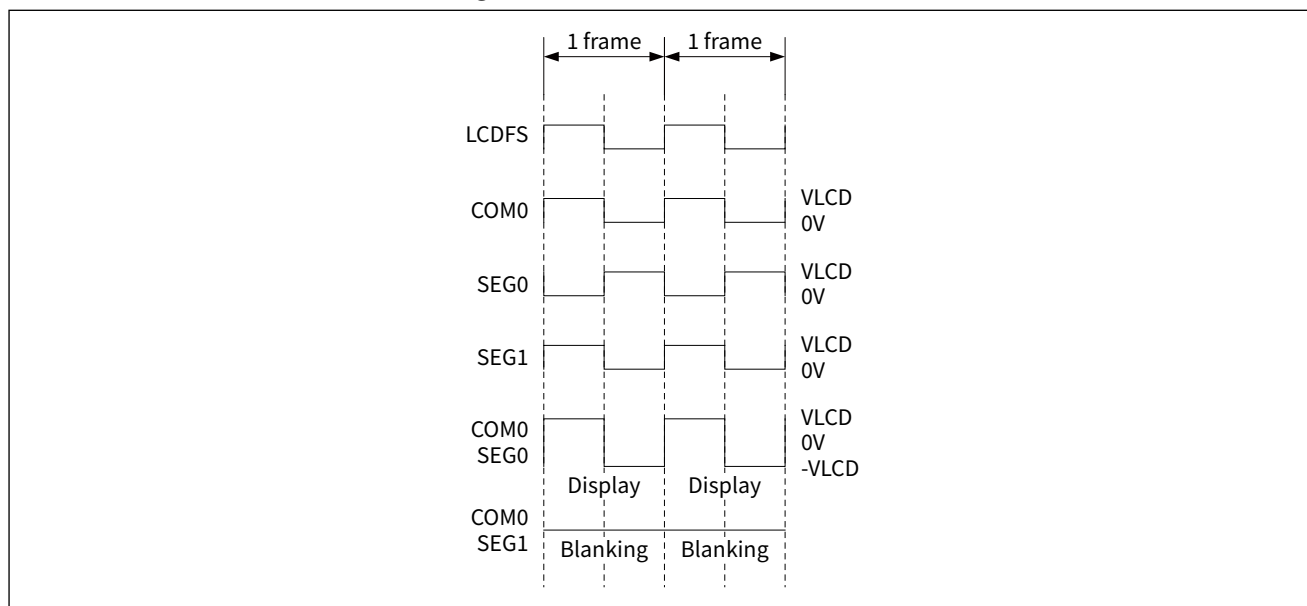


Figure 27-5 1/2 Duty 1/2 Bias driving waveform

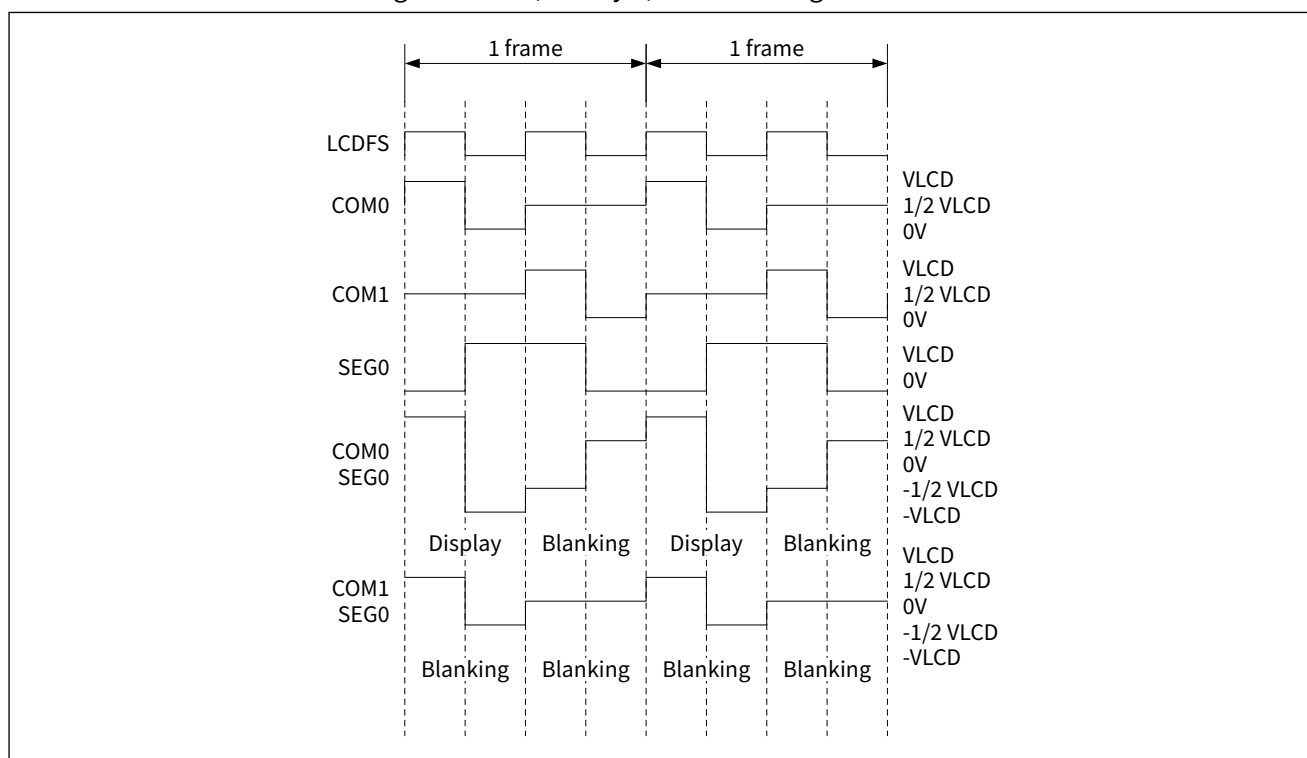


Figure 27-6 1/3 Duty 1/2 Bias driving waveform

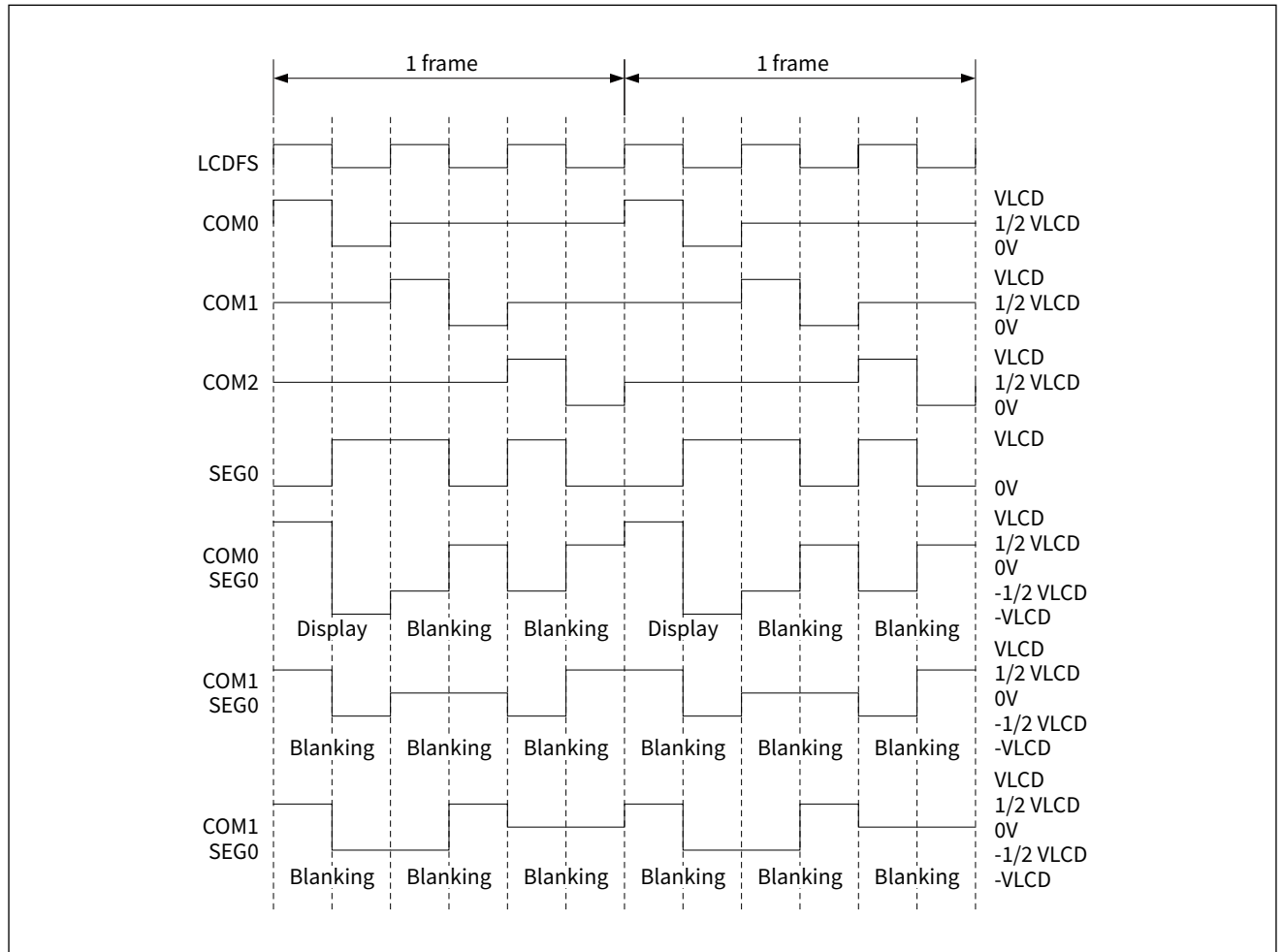


Figure 27-7 1/4 Duty 1/3 Bias driving waveform

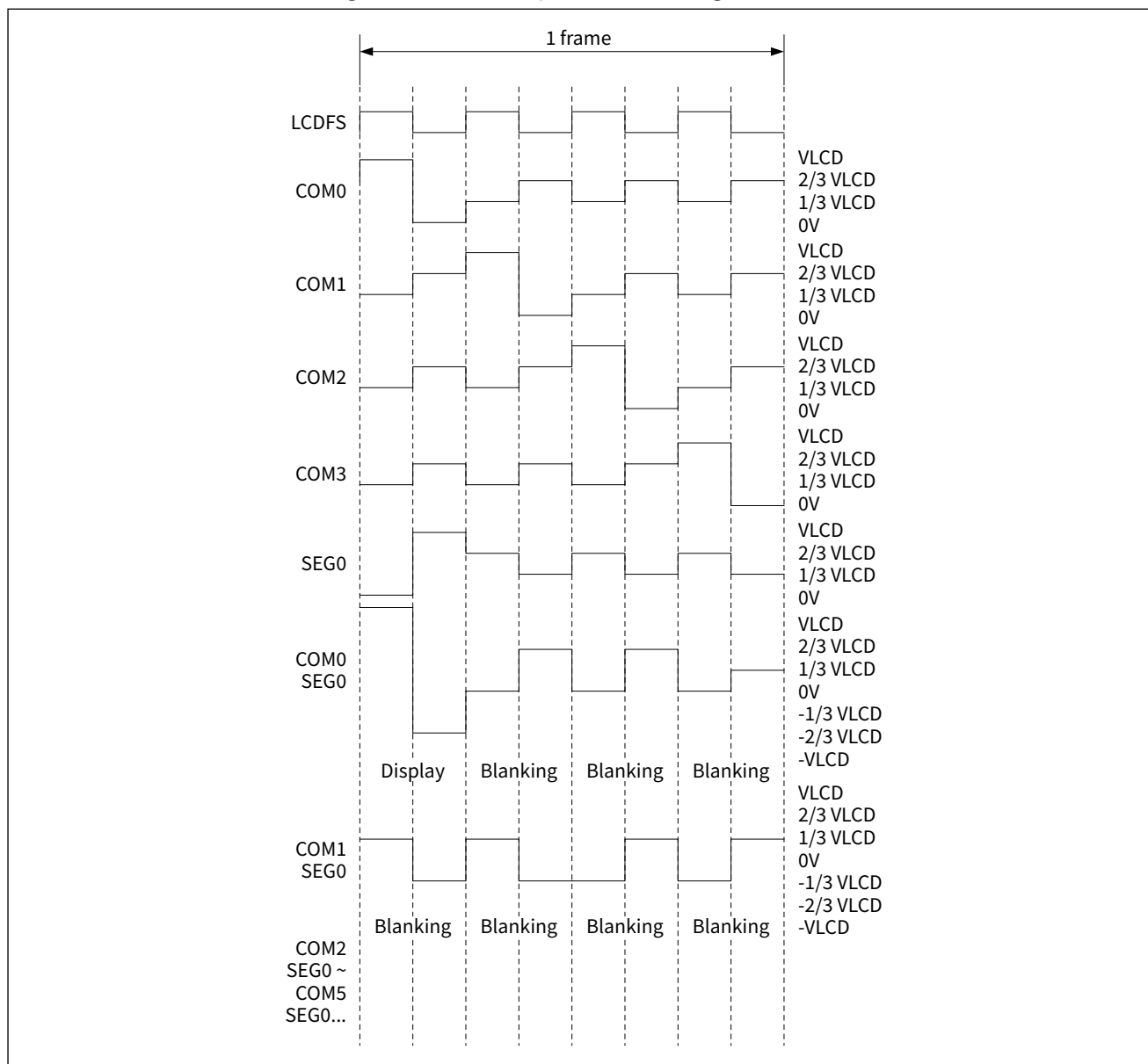
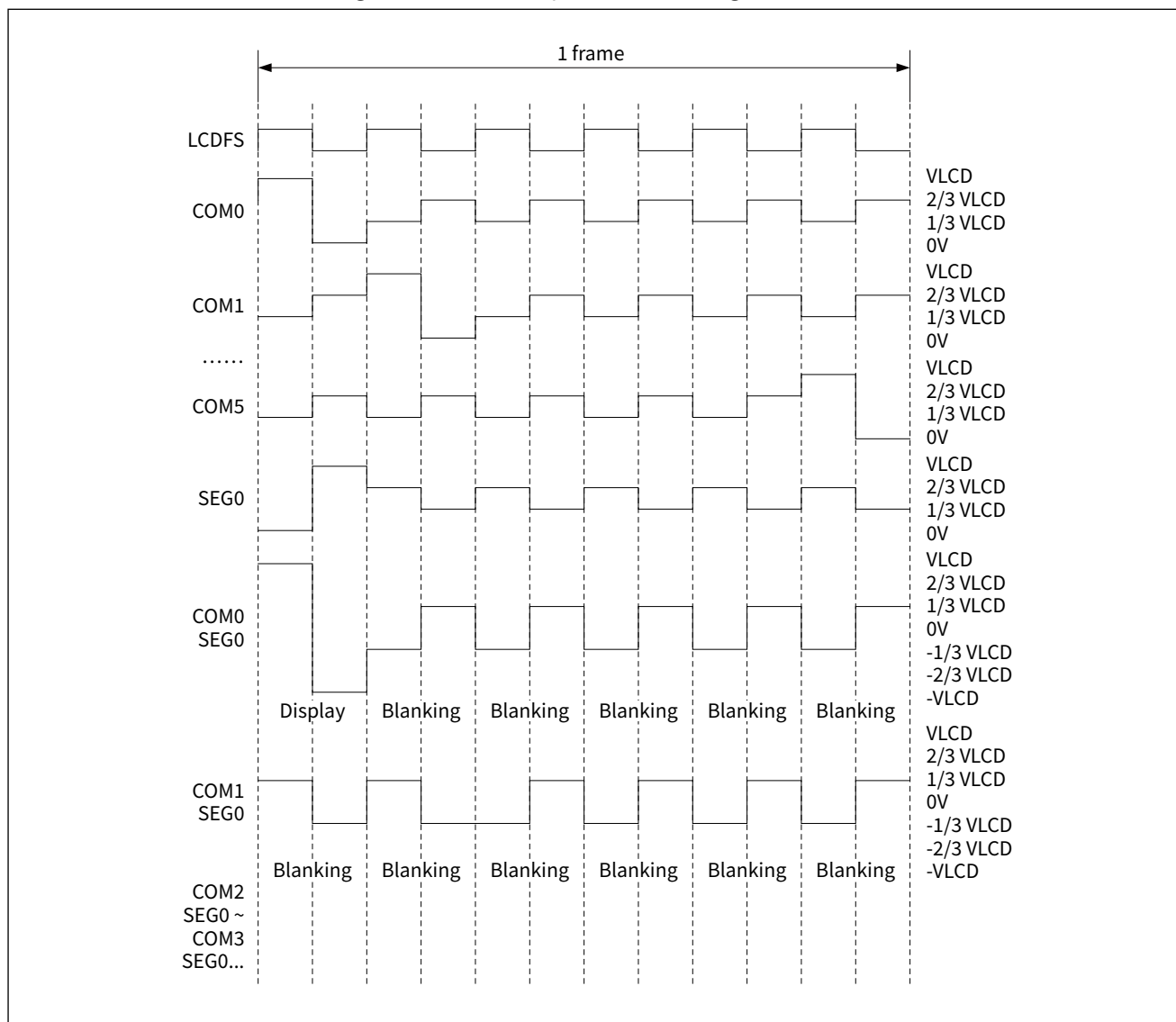


Figure 27-8 1/6 Duty 1/3 Bias driving waveform



27.3.5 Configuration of output pins

- COM0~COM3

Sometimes when driving the LCD screen, it is not necessary to use too many COM ports. You can enable the COM ports that need to be used by configuring the COMY bit field of the LCD_PINEN2 register, as shown in the following table:

Table 27-4 COM0 ~ COM3 port configuration

	Bit	Port	Function description
LCD_PINEN2.COMY	27	COM3	0: COM output is closed, other functions such as IO, analog input and output can be used 1: COM output enable
	26	COM2	
	25	COM1	
	24	COM0	

- COM4~COM7

COM4 ~ COM7 are shared with SEG28 ~ SEG31. When using COM4 ~ COM7, you need to configure the SEG/COM bit field of the LCD_PINEN1 register to enable the port to be used, and you need to configure LCD_CR0.DUTY to match it. The corresponding relationship is shown in the following table:

Table 27-5 COM4 ~ COM7 port configuration

	Bit	Port	Function description
LCD_PINEN1.SEG/COM	31	SEG31/COM4	0: SEG/COM output is closed, other functions such as IO, analog input and output can be used 1: SEG/COM output enable
	30	SEG30/COM5	
	29	SEG29/COM6	
	28	SEG28/COM7	

- VLCD1~VLCD4

VLCD1~VLCD4 and SEG24~SEG27 are shared, configure the MUX bit of LCD_PINEN2 register to 0, the SEG24~SEG27 ports are used as IO or analog input and output ports. When the MUX bit of the LCD_PINEN2 register is configured to be 1, the SEG24~SEG27 ports are used as LCD driver ports. When the Bias voltage source of the LCD is configured as an external circuit, the SEG24~SEG27 ports are used as VLCD1~VLCD4 ports. When the Bias voltage source of the LCD is configured as an internal circuit, the SEG/VBIAS bit field of the LCD_PINEN1 register can control SEG24~SEG27 as the LCD output function or other functions.

The corresponding relationship is shown in the following table:

Table 27-6 SEG24~SEG27 port configuration

	Bit	Port	Function description
LCD_PINEN1.SEG/VBIAS	27	SEG27/VLCD4	0: SEG/VLCD output is closed, other functions such as IO, analog input and output can be used 1: SEG/VLCD output enable
	26	SEG26/VLCD3	
	25	SEG25/VLCD2	
	24	SEG24/VLCD1	



- SEG0~SEG23

Whether the ports SEG0~SEG23 are used as the output function of the LCD or other functions is determined by the SEGX bit field of the LCD_PINEN1 register, and the corresponding relationship is shown in the following table:

Table 27-7 SEG0~SEG23 port configuration

	Bit	Port	Function description
LCD_PINEN1.SEGX	23	SEG23	0: SEG output is closed, other functions such as IO, analog input and output can be used 1: SEG output enable
	
	1	SEG1	
	0	SEG0	

- SEG32~SEG55

Whether the ports SEG32~SEG55 are used as the output function of the LCD or other functions is determined by the SEGX bit field of the LCD_PINEN2 register, and the corresponding relationship is shown in the following table:

Table 27-8 SEG32~SEG55 port configuration

	Bit	Port	Function description
LCD_PINEN2.SEGX	23	SEG55	0: SEG output is closed, other functions such as IO, analog input and output can be used 1: SEG output enable
	
	1	SEG33	
	0	SEG32	



27.3.6 Memory map

Register	SEG segment	COM segment							
LCD_RAM13	SEG55	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG54	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG53	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG52	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM12	SEG51	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG50	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG49	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG48	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM11	SEG47	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG46	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG45	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG44	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0



Register	SEG segment	COM segment							
LCD_RAM10	SEG43	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG42	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG41	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM9	SEG39	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG38	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG37	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM8	SEG35	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG34	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG33	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM8	SEG32	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0



Register	SEG segment	COM segment							
LCD_RAM7	SEG31	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG30	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG29	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM6	SEG27	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG26	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG25	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM5	SEG23	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG22	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG21	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM5	SEG20	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0



Register	SEG segment	COM segment							
LCD_RAM4	SEG19	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG18	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG17	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM3	SEG15	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG14	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG13	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM2	SEG11	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG10	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG9	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM1	SEG8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0



Register	SEG segment	COM segment							
LCD_RAM1	SEG7	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG6	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG5	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG4	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
LCD_RAM0	SEG3	Bit31	Bit30	Bit29	Bit28	Bit27	Bit26	Bit25	Bit24
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG2	Bit23	Bit22	Bit21	Bit20	Bit19	Bit18	Bit17	Bit16
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG1	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0
	SEG0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0



27.3.7 Splash screen

By setting the BLINKEN bit field of the control register LCD_CR1 to 1, the splash screen function of the LCD can be turned on. By setting the value of the BLINKCNT bit field of the LCD_CR1 register, the content on the LCD display can be displayed and blanked at different frequencies to achieve the effect of flashing the screen.

The calculation method of LCD flicker frequency is as follows:

$$\text{LCD flicker frequency} = \text{LCD frame rate} / (\text{BLINKCNT} + 1)$$



27.4 LCD interrupt

The LCD controller can generate an interrupt signal every time a frame is refreshed, or can generate an interrupt signal after refreshing multiple frames continuously. The interrupt interval is determined by the setting of the BLINKCNT bit field of the LCD_CR1 register. The calculation formula is as follows:

$$\text{LCD Interrupt interval} = (\text{BLINKCNT} + 1) \times (1 / \text{LCD frame rate})$$

Caution:

LCD frame rate = LCD scan frequency × Duty (see [27.3.2 Clock](#))

Set LCD_CR1.IE to 1 to enable LCD interrupt. After the LCD controller generates an interrupt signal, the LCD_CR1.INTF flag will be set by hardware. Setting LCD_INTCLR.INTF to 0 can clear this flag.

27.5 Direct memory access (DMA)

The LCD controller can trigger the DMA function through hardware. When the DMAEN bit field of the control register LCD_CR1 is set to 1, the LCD interrupt signal will trigger the DMA. Through the DMA function, the data in the ROM or RAM can be conveniently and automatically transferred to the display RAM of the LCD, for example, to realize the function of refreshing the screen.



27.6 List of registers

LCD base address: LCD_BASE = 0x4000 2400

Table 27-9 Table LCD Register List

Register name	Register address	Register description
LCD_CR0	LCD_BASE + 0x00	LCD control register 0
LCD_CR1	LCD_BASE + 0x04	LCD control register 1
LCD_INTCLR	LCD_BASE + 0x08	LCD interrupt clear register
LCD_PINEN1	LCD_BASE + 0x0C	LCD Output Configuration Register1
LCD_PINEN2	LCD_BASE + 0x10	LCD Output Configuration Register2
LCD_RAM0	LCD_BASE + 0x40	LCD RAM0
LCD_RAM1	LCD_BASE + 0x44	LCD RAM1
LCD_RAM2	LCD_BASE + 0x48	LCD RAM2
LCD_RAM3	LCD_BASE + 0x4C	LCD RAM3
LCD_RAM4	LCD_BASE + 0x50	LCD RAM4
LCD_RAM5	LCD_BASE + 0x54	LCD RAM5
LCD_RAM6	LCD_BASE + 0x58	LCD RAM6
LCD_RAM7	LCD_BASE + 0x5C	LCD RAM7
LCD_RAM8	LCD_BASE + 0x60	LCD RAM8
LCD_RAM9	LCD_BASE + 0x64	LCD RAM9
LCD_RAM10	LCD_BASE + 0x68	LCD RAM10
LCD_RAM11	LCD_BASE + 0x6C	LCD RAM11
LCD_RAM12	LCD_BASE + 0x70	LCD RAM12
LCD_RAM13	LCD_BASE + 0x74	LCD RAM13



27.7 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

27.7.1 LCD_CR0 control register 0

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:16	RFU	-	Reserved bits, please keep the default value
15:12	CONTRAST	RW	<p>LCD contrast adjustment</p> <p>When 0x0, the LCD waveform amplitude is the largest and the contrast ratio is the largest;</p> <p>.....</p> <p>When 0xF, the LCD waveform amplitude is the smallest and the contrast is the smallest.</p> <p>Caution 1: The CONTRAST value is valid only when the Bias voltage source selects the internal resistor divider;</p> <p>Caution 2: The larger the CONTRAST value, the smaller the LCD waveform amplitude and the smaller the contrast.</p>
11:9	INRS	RW	<p>LCD Bias Voltage source selection</p> <p>000: External resistor/capacitor mode requires external circuit coordination</p> <p>001: Internal resistor divider, power consumption 4</p> <p>010: Internal resistor divider, power consumption 2</p> <p>011: Reserved</p> <p>100: Internal resistor divider, low power consumption mode, power consumption 1, minimum power consumption</p> <p>101: Reserved</p> <p>110: Reserved</p> <p>111: Internal resistor divider, high power consumption mode, power consumption 7, maximum power consumption</p>



Bit field	Name	Permission	Functional description																														
8:6	DUTY	RW	LCD duty configure 000: Static 001: 1/2 duty 010: 1/3 duty 011: 1/4 duty 100: Reserved 101: 1/6 duty 110: Reserved 111: 1/8 duty																														
			<table><tr><th>Duty</th><th>PAD</th><th>FUNCTION</th></tr><tr><td rowspan="4">1/4 duty</td><td>COM4SEG31PAD</td><td>SEG31</td></tr><tr><td>COM5SEG30PAD</td><td>SEG30</td></tr><tr><td>COM6SEG29PAD</td><td>SEG29</td></tr><tr><td>COM7SEG28PAD</td><td>SEG28</td></tr><tr><td rowspan="4">1/6 duty</td><td>COM4SEG31PAD</td><td>COM4</td></tr><tr><td>COM5SEG30PAD</td><td>COM5</td></tr><tr><td>COM6SEG29PAD</td><td>SEG29</td></tr><tr><td>COM7SEG28PAD</td><td>SEG28</td></tr><tr><td rowspan="4">1/8 duty</td><td>COM4SEG31PAD</td><td>COM4</td></tr><tr><td>COM5SEG30PAD</td><td>COM5</td></tr><tr><td>COM6SEG29PAD</td><td>COM6</td></tr><tr><td>COM7SEG28PAD</td><td>COM7</td></tr></table>	Duty	PAD	FUNCTION	1/4 duty	COM4SEG31PAD	SEG31	COM5SEG30PAD	SEG30	COM6SEG29PAD	SEG29	COM7SEG28PAD	SEG28	1/6 duty	COM4SEG31PAD	COM4	COM5SEG30PAD	COM5	COM6SEG29PAD	SEG29	COM7SEG28PAD	SEG28	1/8 duty	COM4SEG31PAD	COM4	COM5SEG30PAD	COM5	COM6SEG29PAD	COM6	COM7SEG28PAD	COM7
			Duty	PAD	FUNCTION																												
			1/4 duty	COM4SEG31PAD	SEG31																												
				COM5SEG30PAD	SEG30																												
				COM6SEG29PAD	SEG29																												
				COM7SEG28PAD	SEG28																												
			1/6 duty	COM4SEG31PAD	COM4																												
				COM5SEG30PAD	COM5																												
				COM6SEG29PAD	SEG29																												
				COM7SEG28PAD	SEG28																												
			1/8 duty	COM4SEG31PAD	COM4																												
				COM5SEG30PAD	COM5																												
				COM6SEG29PAD	COM6																												
				COM7SEG28PAD	COM7																												
			5	RFU	-	Reserved bits, please keep the default value																											
4	BIAS	RW	LCD Bias configure 0: 1/3 bias 1: 1/2 bias																														
3	BUMP	RW	Charge Pump Mode Selection 0: Disable 1: Enable Caution: It needs to be enabled when external capacitor mode is selected.																														
2:1	CPCLK	RW	Voltage Pump Clock Frequency Selection 00: 2kHz 01: 4kHz 10: 8kHz 11: 16kHz																														
0	EN	RW	LCD enable control 0: Disable 1: Enable																														



27.7.2 LCD_CR1 control register 1

Address offset: 0x04 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:13	RFU	-	Reserved bits, please keep the default value
12	INTF	RO	Interrupt flag 0: Without interruption 1: Interrupt
11	IE	RW	Interrupt enables 0: Disable 1: Enable
10	DMAEN	RW	DMA hardware trigger enable 0: Disable LCD interrupt triggering DMA 1: Enable LCD interrupt triggering DMA
9:8	LCDFS	RW	LCD scan frequency selection 00: 128Hz 01: 256Hz 10: 512Hz 11: 64Hz Caution: LCD frame frequency = LCD scan frequency × Duty
7	CLKCS	RW	LCD clock source selection 0: LSI 1: LSE
6	BLINKEN	RW	LCD splash screen configuration 0: Disable 1: Enable
5:0	BLINKCNT	RW	Splash screen frequency and LCD interrupt interval settings LCD flicker frequency = LCD frame frequency / (BLINKCNT + 1) LCD Interrupt Interval = (BLINKCNT + 1) × (1/LCD Frame Frequency)

27.7.3 LCD_INTCLR interrupt clear register

Address offset: 0x08 Reset value: 0x0000 1000

Bit field	Name	Permission	Functional description
31:13	RFU	-	Reserved bits, please keep the default value
12	INTF	RW0	Interrupt flag is cleared, write 0 to clear, write 1 is invalid
11:0	RFU	-	Reserved bits, please keep the default value



27.7.4 LCD_PINEN1 LCD output configuration register

Address offset: 0x0C Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:28	SEG/COM	RW	SEG/COM output control bit 0: SEG/COM output is closed, other functions can be used, such as IO, analog input and output 1: SEG/COM output enable, corresponding to SEG 28 ~ SEG 31 and COM7 ~ COM4 Caution: SEG/COM pin function selection is determined by LCD_CR0.DUTY
27:24	SEG/VBIAS	RW	SEG/VBIAS output control 0: SEG/VBIAS output is closed, other functions can be used, such as IO, analog input and output 1: SEG/VBIAS output enable, corresponding to SEG24 ~ SEG27 Caution: Selecting SEG/VBIAS output requires MUX to be enabled
23:0	SEGx	RW	SEGx output control bit 0: SEG output is closed, other functions can be used, such as IO, analog input and output 1: SEG output enable, corresponding to SEG0 ~ SEG23

27.7.5 LCD_PINEN2 LCD output configuration register

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:29	RFU	-	Reserved bits, please keep the default value
28	MUX	RW	SEG27 ~ SEG24 Port function selection, see selection table for details 0: VBIAS/SEG output is closed, other functions can be used, such as IO, analog input and output 1: Select VBIAS bias/SEG output
27:24	COMy	RW	COMy output control bit 0: COM output is closed, other functions can be used, such as IO, analog input and output 1: COM output enable, corresponding to COM0 ~ COM3
23:0	SEGx	RW	SEGx output control bit 0: SEG output is closed, other functions can be used, such as IO, analog input and output 1: SEG output enable, corresponding to SEG32 ~ SEG55



27.7.6 LCD_RAM 0 ~ 13

Address offset: 0x40~0x74 Reset value: 0x---- ----

Bit field	Name	Permission	Functional description
31:0	Dy y = 0 ~ 31	RW	LCD dot output, display reference LCD display mode 0: Corresponding SEG and COM cross points are not lighting 1: Corresponding SEG, COM cross lighting



28 Advanced Encryption Standard Module (AES)

28.1 Overview

The Advanced Encryption Standard Module (AES) can be used to encrypt and decrypt data through the AES algorithm. AES supports 128-bit block processing and supports key lengths of 128, 192 or 256 bits. AES hardware supports Electronic Code Book (ECB), and other linking algorithms need to be implemented by software.

28.2 Main features

- Encrypt/Decrypt using AES algorithm
- 128-bit data block processing
- 128-bit, 192-bit, 256-bit key length
- Support electronic codebook (ECB)



28.3 Programming example

28.3.1 Encryption Mode Programming Example

Step 1: Set SYSCTRL_AHBEN.AES to 1 to enable the configuration clock and working clock of the AES module;
Step 2: Set AES_CR.MODE to 0, configure AES as encryption mode;
Step 3: Configure AES_CR.KEYSIZE, select the key length;
Step 4: Write the encryption key into the key register AES_KEY according to the key length configured in step 3;
Step 5: Write the 128-bit AES plaintext data to be encrypted into the data register AES_DATA;
Step 6: Set AES_CR.START to 1 to start AES encryption operation;
Step 7: The query waits for AES_CR.START to be cleared to confirm that the AES operation is completed;
Step 8: Read the data register AES_DATA to get 128-bit ciphertext;
Step 9: Repeat steps 5 to 8 to encrypt more data.

28.3.2 Decryption Mode Programming Example

Step 1: Set SYSCTRL_AHBEN.AES to 1 to enable the configuration clock and working clock of the AES module;
Step 2: Set AES_CR.MODE to 1, configure AES as encryption mode;
Step 3: Configure AES_CR.KEYSIZE, select the key length;
Step 4: Write the decryption key into the key register AES_KEY according to the key length configured in step 3;
Step 5: Write the 128-bit AES ciphertext data to be decrypted into the data register AES_DATA;
Step 6: Set AES_CR.START to 1 to start the AES decryption operation;
Step 7: The query waits for AES_CR.START to be cleared to confirm that the AES operation is completed;
Step 8: Read the data register AES_DATA to get 128-bit plaintext;
Step 9: Repeat steps 5 to 8 to decrypt more data.



28.4 List of register

AES base address: AES_BASE = 0x4002 6000

Table 28-1 List of AES register

Register name	Register address	Register description
AES_CR	AES_BASE + 0x00	Control register
AES_DATA0	AES_BASE + 0x10	Data register 0
AES_DATA1	AES_BASE + 0x14	Data register 1
AES_DATA2	AES_BASE + 0x18	Data register 2
AES_DATA3	AES_BASE + 0x1C	Data register 3
AES_KEY0	AES_BASE + 0x20	Key register 0
AES_KEY1	AES_BASE + 0x24	Key register 1
AES_KEY2	AES_BASE + 0x28	Key register 2
AES_KEY3	AES_BASE + 0x2C	Key register 3
AES_KEY4	AES_BASE + 0x30	Key register 4
AES_KEY5	AES_BASE + 0x34	Key register 5
AES_KEY6	AES_BASE + 0x38	Key register 6
AES_KEY7	AES_BASE + 0x3C	Key register 7

Caution 1:

AES peripheral does not support DMA access



28.5 Register descriptions

See section [1 Documentation conventions](#) for abbreviations used in register descriptions.

28.5.1 AES_CR control register

Address offset: 0x00 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:5	RFU	-	Reserved bits, please keep the default value
4:3	KEYSIZE	RW	AES key length configuration 00: The key length is 128 bits 01: The key length is 192 bits 10: The key length is 256 bits 11: The key length is 128 bits
2	RFU	-	Reserved bits, please keep the default value
1	MODE	RW	AES working mode configuration 0: Encryption mode 1: Decryption mode
0	START	RW	AES start operation control W1: Start AES operation R0: AES operation completed R1: AES is running

28.5.2 AES_DATA0 data register 0

Address offset: 0x10 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:0	DATA0	RW	AES plaintext or ciphertext, bit31 ~ bit0

28.5.3 AES_DATA1 data register 1

Address offset: 0x14 Reset value: 0x0000 0000

Bit field	Name	Permission	Functional description
31:0	DATA1	RW	AES plaintext or ciphertext, bit63 ~ bit32



28.5.4 AES_DATA2 data register 2

Address offset: 0x18 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	DATA2	RW	AES plaintext or ciphertext, bit95 ~ bit64

28.5.5 AES_DATA3 data register 3

Address offset: 0x1C Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	DATA3	RW	AES plaintext or ciphertext, bit127 ~ bit96

28.5.6 AES_KEY0 key register 0

Address offset: 0x20 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY0	WO	AES KEY, bit31 ~ bit0

28.5.7 AES_KEY1 key register 1

Address offset: 0x24 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY1	WO	AES KEY, bit63 ~ bit32

28.5.8 AES_KEY2 key register 2

Address offset: 0x28 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY2	WO	AES KEY, bit95 ~ bit64

28.5.9 AES_KEY3 key register 3

Address offset: 0x2C Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY3	WO	AES KEY, bit127 ~ bit96



28.5.10 AES_KEY4 key register 4

Address offset: 0x30 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY4	WO	AES KEY, bit159 ~ bit128

28.5.11 AES_KEY5 key register 5

Address offset: 0x34 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY5	WO	AES KEY, bit191 ~ bit160

28.5.12 AES_KEY6 key register 6

Address offset: 0x38 Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY6	WO	AES KEY, bit223 ~ bit192

28.5.13 AES_KEY7 key register 7

Address offset: 0x3C Reset value: 0x00000000

Bit field	Name	Permission	Functional description
31:0	KEY7	WO	bit255 ~ bit224



29 Debug interface (DBG)

29.1 Overview

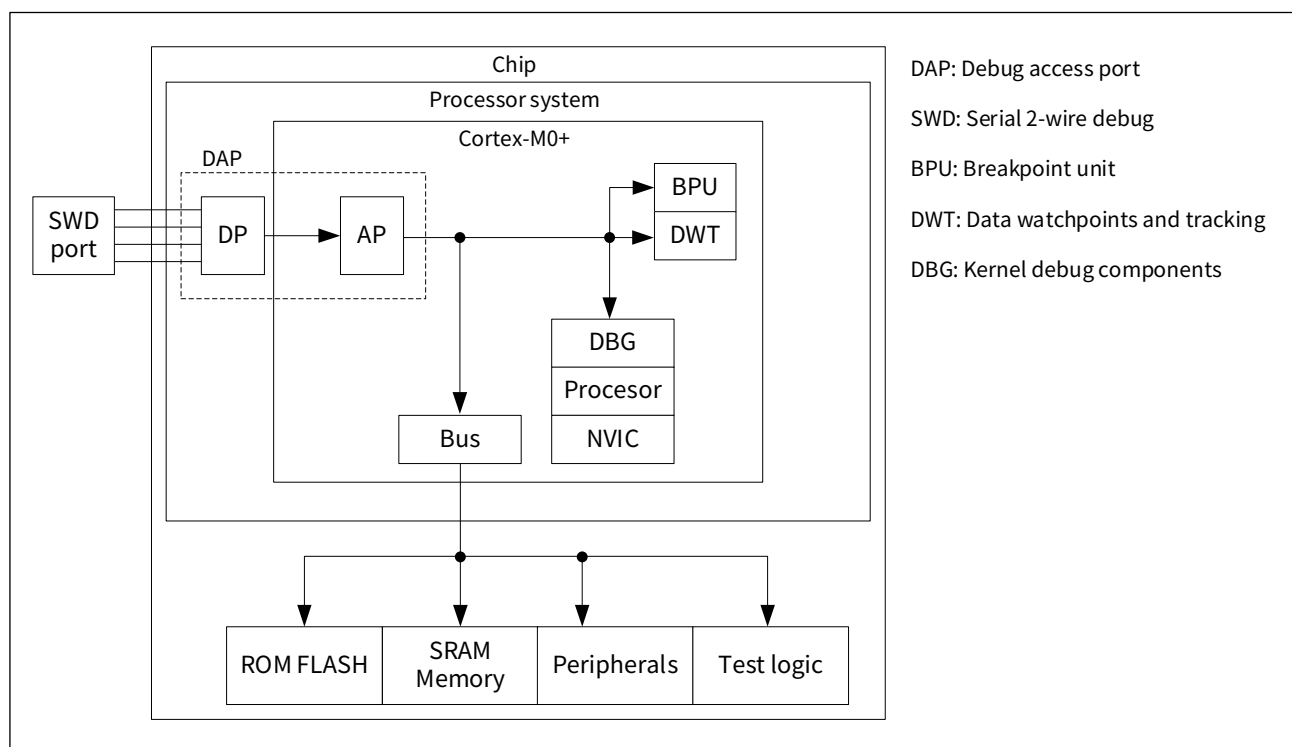
The core of CW32L083 is ARM® Cortex®-M0+, the core has built-in DAP hardware debug module, and supports SWD mode debugging. The hardware debug module can be suspended when fetching instructions (instruction breakpoints) or accessing data (data breakpoints), and the program stops running. query; and the core and peripherals can be restored, and program execution continues.

When using the debugging simulation tool to connect to the CW32L083 through the SWD interface, enter the debugging mode, and perform debugging operations through the DAP hardware debugging module in the chip core.

29.2 Serial wire debug port SWD

Use the SWD interface of the CW special debugger or the general debugging simulation tool to connect with the DAP debugging module inside the target chip, and carry out data exchange through the packet transmission protocol to realize the debugging operation. The SWD mode is a 2-wire serial communication, including a clock line SWCLK and a bidirectional data line SWDIO. As shown in the following figure:

Figure 29-1 SWD functional block diagram



The pin assignment of the SWD interface of the CW32L083 series is shown in the following table. The PA13/PA14 pin is the SWD function by default when the chip leaves the factory.

Table 29-1 SWD pin assignment

SWD port name	Pin function	Pin assignment
SWCLK	Serial clock input	PA14
SWDIO	Serial data input and output	PA13

The PA13/PA14 pins can be configured as SWD function or GPIO/ISP function, and the function configuration is performed by the SWDIO bit field of the system control register SYSCTRL_CR2. When SWDIO is 0, the PA13/PA14 pin is configured as SWD function; when SWDIO is 1, it is configured as GPIO/ISP function.

It is generally recommended to use a 100KΩ pull-up resistor for the SWD pin. When the PA13/PA14 of the CW32L083 is used as the SWD function, there is a built-in pull-up resistor with a resistance value between 50KΩ ~ 200KΩ. Users can add a pull-up resistor externally to improve the anti-interference performance.

The PA13/PA14 pin of the CW32L083 series is the SWD function by default. If the user has set the encryption level, it is necessary to judge whether the SWD function is supported according to the set level. The configuration and function of the SWD pin are shown in the following table:

Table 29-2 SWD pin function

Encryption level	SYSCTRL_CR2.SWDIO	PA13/PA14 function
Level0/1 encryption	0 (default)	SWD function
	1	GPIO/ISP function
Level2 encryption	0 (default)	NA, no function
	1	GPIO/ISP function
Level3 encryption	0 (default)	NA, no function
	1	GPIO function

Cautions :

1. The encryption level can be set through the ISP communication method. For details, please refer to the ISP communication protocol document;
2. After the chip is powered on, both SWDIO and SWCLK are internal pull-ups by default, and users do not need to connect external pull-up resistors;
3. When the chip encryption level is set to 2, the SWD function is disabled and can only be programmed by ISP;
4. When the chip encryption level is set to 3, the SWD function and the ISP function are disabled, and the chip cannot be programmed with new programs again.



29.3 Debug communication protocol

The debugger and the DAP debug module of the target chip communicate through the SWD packet transmission protocol. The packet transmission protocol is a 2-wire synchronous serial protocol, using the SWCLK clock signal and the SWDIO data signal:

- SWCLK is a one-way clock signal, which is output by the debugger to the target chip
- SWDIO is a bidirectional data signal, which is driven by the debugger and the target chip bidirectionally time-sharing

The protocol defines the conversion time of the transceiver and the transceiver with a length of one SWCLK cycle. During the conversion time of the transceiver and the target chip, neither the debugger nor the target chip drives SWDIO, and SWDIO is pulled up to a high level by a pull-up resistor.

When transmitting data on the SWDIO signal line, follow the principle that the lowest LSB is transmitted first, and the highest MSB is transmitted last.

Through the packet transfer protocol, the debugger can read and write access to the DP register and AP register in the DAP debug module of the target chip, hereinafter referred to as SW-DP and SW-AP.

29.3.1 Transmission protocol format

The DAP debug module includes the DP debug port register and the AP access port register. The communication between the debugger and the DAP debug module of the target chip is actually the read and write operations on the DP register and the AP register.

The transmission communication frame usually contains three fields:

- Package request
The length is 8-bit, the debugger to the target chip;
- Response
The length is 3-bit; the target chip to the debugger;
- Data transmission
The length is 33-bit, the target chip to the debugger or the debugger to the target chip, optional field.

The function definition of each request package is as follows:

Table 29-3 Definition of packet request bits

Bit	Name	Description
0	Start up	Must be 1
1	APnDP	0: DP access; 1: AP access
2	RnW	0: Write request; 1: Read request
3:4	A[3:2]	Address field of DP or AP register, bit3 is A2, bit4 is A3
5	Parity check	Bit parity bit of the previous 5-bit
6	Stop	0
7	Reside	Not driven by the host. Target chip reads as 1 due to pull-up



The request packet is always followed by the conversion time of the transceiver (default 1bit). At this time, neither the master nor the target drives SWDIO.

The response bits transmitted by the target are defined as follows:

Table 29-4 Definition of target transmit response bits

Bit	Name	Description
0:2	ACK	001: FAULT (bit0:0, bit1:0, bit2:1) 010: WAIT (bit0:0, bit1:1, bit2:0) 100: OK (bit0:1, bit1:0, bit2:0)

After the ACK response is the conversion time of the transceiver (default 1bit), at this time, neither the master nor the target will drive SWDIO.

Data transmitted by the debugger or target chip, the bits are defined as follows:

Table 29-5 Definition of data transmission bits

Bit	Name	Description
0:31	WDATA or RDATA	Write or read data
32	Parity check	Bit parity bit of 32-bit data

The data transmission phase is not necessary, and data transmission occurs only in the following two cases:

- The response received after the data read or write request is the OK response
- The ORUNDETECT flag bit of the DP-CTRL/STAT register is set to 1. At this time, no matter what kind of response (including WAIT and FAULT) is received, data transmission is required

29.3.2 SW-DP state machine

There is an ID CODE register inside SW-DP with a fixed value of 0x0BB11477 (Cortex®-M0+ identification code of ARM company). Before using the SWD packet protocol to read and write the target register, the ID number must be read to activate the SW-DP logic of the target chip, otherwise the SW-DP state machine of the target chip will not work.

The operation sequence is as follows:

Step 1: After power-on reset or after the SWDIO line is at a high level for more than 50 cycles, the SW-DP state machine enters the reset state;

Step 2: After entering the reset state, keep the SWDIO line at a low level for at least 2 cycles, and the SW-DP state machine enters the idle state;

Step 3: After entering the idle state, perform read access to the ID CODE register of DP-SW;

Caution:

If this operation is not performed, the target board will send a FAULT response in the subsequent packet communication response phase.

Step 4: Read and write access to the registers to be accessed according to the packet protocol.



29.3.3 Read and write access for SW-DP and SW-AP

- Write access for SW-DP/SW-DP

After the debugger receives the ACK, the data must be transmitted immediately after the conversion time of 1 clock cycle.

- Read access for SW-DP

- When the target chip is ready to transmit data, it transmits an OK response, and then transmits data immediately;
- When the target chip DAP is not ready for data transmission, it transmits a WAIT response to end the communication;
- When the DAP status of the target chip is wrong, a FAULT response is transmitted to end the communication.

- Read access for SW-AP

The read access to the AP is registered, that is, the read AP operation cannot return the required result, but the result of the read operation cannot be returned until the next AP operation. If the next access to be performed is not an AP read access operation, the DP-RDBUFF register must be read to obtain the result of this read operation.

- The READOK flag in the DP-CTRL/STAT register of the M0 core's debug control/status register is updated every time a SW-AP read access or DP-RDBUFF read request is made to indicate whether the AP read access is successful.
- SW-DP has write buffers (for SW-DP or SW-AP writes) that can accept the next write operation while the read and write operations are not complete. If the SW-DP's write buffer is full, the chip SW-DP logic will reply with a WAIT response to notify the host to suspend the operation. The exception is special operations such as IDCODE read, DP-CTRL/STAT read or ABORT write operations, which are also accepted when the write buffer is full.
- Since SWCLK and HCLK are not synchronous clocks and belong to the asynchronous clock domain, two additional SWCLK cycles are required after the write operation (after the parity bit of the data transmission) to ensure that the write operation takes effect. The SWDIO line should be driven low (idle state) while the master is driving these 2 SWCLK cycles. This is especially important when writing power-on request operations to the DP-CTRL/STAT registers, otherwise the next operation (one that is valid after the core is powered on) will be executed immediately and will fail.



29.3.4 SW-DP register

When APnDP is 0, access the DP register, which is addressed by A[3:2]. When the address is the same, the meaning of the register may be different due to different read and write operations, as shown in the following table:

Table 29-6 List and definition of DP registers

A[3:2]	Read/write	R register name	Register content description
00	Read	IDCODE	Fixed at 0x0BB1 1477 (to identify SW-DP), ARM Cortex [®] -M0+ identification code
	Write	ABORT	See Table 29-7 Definition of DP ABORT register bits
01	Read/write	DP-CTRL/STAT (SELECT.CTRLSEL = 0)	Mainly used for: 1. Request system or debug power-on; 2. Configure transfer operation for AP access; 3. Control comparison and verification operations; 4. Read some status flags (overflow and power-up acknowledgment)
		WIRE CONTROL (SELECT.CTRLSEL = 1)	Used to configure the physical serial port protocol (such as the duration of transition times, etc.)
10	Read	READ RESEND	Allow recovery of read data from corrupted debug transfers without repeating the original AP transfer.
	Write	SELECT	Used to select the current access AP port and the 4-word register BANK in the AP port. See Table 29-8 DP SELECT register
11	Read/write	READ BUFFER	Since an AP access has been issued, this read buffer is useful (providing the result of reading this AP request when executing the next AP transaction). This read buffer captures the data in the AP, displayed as the result of the previous read, without starting a new operation.

Table 29-7 Definition of DP ABORT register bits

Bit	Name	Description
31:5	RESERVE	
4	ORUNERRCLR	Write 1 to clear the STICKYORUN error flag
3	WDATAERR	Write 1 to clear the WDATAERR error flag
2	STICKYERR	Write 1 to clear the STICKYERR error flag
1	STICKYCMP	Write 1 to clear the STICKYCMP flag
0	DAPABORT	Write 1 to generate the DAP ABORT signal and abandon the current access operation; when the target chip responds to the WAIT response, this operation must be performed to abort this operation.



Table 29-8 DP SELECT register

Bit	Name	Description
31:24	APSEL	Select the current AP port, fixed as b00000000
23:8	RESERVE	
7:4	APBANKSEL	Select the active 4-word register BANK on the current AP
3:1	RESERVE	
0	CTRLSEL	DP port register selection: The default is 0 after reset, select the CTRL/STAT register; Set to 1 to select the WCR register (Wire Control Register)

29.3.5 SW-AP register

When APnDP is 1, access the AP register. Since there are many SW-AP registers, it is necessary to combine A[3:2] and the APBANKSEL bit field value of the SW-DP selection register SELECT to uniquely address the SW-AP register.

This article will not go into details about SW-AP one by one, but only introduces a common IDR public register (address 0xFC), as shown in the following table:

Table 29-9 AP IDR public register

Bit	Definition
31:28	AP designed version Rrevision.
27:24	AP designer identification code, this chip is fixed to 0x04.
23:17	AP designer identification code, this chip is fixed to 0x3B.
16:13	AP type. For example, the memory access port type identification code is b1000, and the undefined type access port type identification code is b0000.
12:8	Reserved
7:0	AP ID. Such as MEM-AP or JTAG-AP and so on.



29.4 Kernel debugging

The core can be debugged by manipulating the core debug registers, and the debugger accesses these registers through DAP debugging.

The kernel debug registers mainly include 4 registers, as shown in the following table:

Table 29-10 Kernel debug registers

Register	Description
DHCSR	Debug suspend control and status register, 32-bit, control processor suspend, single step and restart actions
DCRSR	Debug kernel register selector register, 17-bit, controls reading and writing of kernel registers during suspend
DCRDR	Debug kernel register data register, 32-bit, data transfer register for reading and writing kernel registers during pause
DEMCR	Debug exception monitoring control register, 32-bit, used to enable data watchpoint unit and vector capture feature, using vector capture, the debugger can suspend the processor when the processor is reset or a hardware error occurs

These registers can only be reset by a power-on reset. See 《Cortex®-M0+ Technical Reference Manual》 for more details.

29.5 Breakpoint unit BPU

The Cortex®-M0+ BPU breakpoint unit provides four breakpoint registers to implement the PC pointer-based breakpoint function.

For more information on the identification registers and access types of the BPU CoreSight component, see 《ARMv6-M Architecture Reference Manual》 and the ARM® CoreSight Component Technical Reference Manual.

29.6 Data observation points and tracking DWT

Cortex®-M0+ DWT provides two observation point register sets. Realize the following functions:

- Set data watchpoints:
Data or peripheral addresses can be marked as watch variables, and access to this address will generate a debug event and suspend program execution.
- Optional DWT program counter sampling register (DWT_PCSR) feature in ARMv6-M. Allows the debugger to periodically sample the PC pointer, providing a rough analysis without stopping the processor.

See 《ARMv6-M Architecture Reference Manual》 for more information.



29.7 Debug components DBG

The debugger implements clock control support for peripherals such as timers, watchdogs, and RTCs during breakpoints through the debug components DBG. Through the setting of the debug state timer control register SYSCTRL_DEBUG, you can control the timer, watchdog timer, RTC, etc. to run normally or pause during the breakpoint in the debug state, as shown in the following table:

Table 29-11 Debug status timer control register SYSCTRL_DEBUG

Bit	Name	Vaule	Counter function configuration during breakpoints in debug state
11	LPTIM	1	In the debug state, the LPTIM counter is suspended from counting
		0	In the debug state, the LPTIM counter counts normally
10	WWDT	1	In debug state, the WWDT counter pauses counting
		0	In debug state, the WWDT counter counts normally
9	IWDT	1	In debug state, the IWDT counter pauses counting
		0	In debug state, the IWDT counter counts normally
8	RTC	1	In debug state, the RTC counter pauses counting
		0	In debug state, the RTC counter counts normally
6	AUTOTRIM	1	In debug state, the AUTOTRIM counter pauses counting
		0	In debug state, the AUTOTRIM counter counts normally
5	BTIM123	1	In debug state, the BTIM1, BTIM 2, BTIM 3 counters pause counting
		0	In debug state, the BTIM1, BTIM 2, BTIM 3 counters count normally
4	GTIM4	1	In debug state, the GTIM4 counter pauses counting
		0	In debug state, the GTIM4 counter counts normally
3	GTIM3	1	In debug state, the GTIM3 counter pauses counting
		0	In debug state, the GTIM3 counter counts normally
2	GTIM2	1	In debug state, the GTIM2 counter pauses counting
		0	In debug state, the GTIM2 counter counts normally
1	GTIM1	1	In debug state, the GTIM1 counter pauses counting
		0	In debug state, the GTIM1 counter counts normally
0	ATIM	1	In debug state, the ATIM counter pauses counting
		0	In debug state, the ATIM counter counts normally

For example, when the timer outputs PWM for motor control, the timer cannot be stopped, otherwise the motor will be damaged. For another example, the watchdog timer should stop counting during the breakpoint to prevent an undesired reset of the system.



29.8 Cautions

CW32L083 needs to use HCLK for debugging connection during debugging. It is not allowed to turn off HCLK during the debugging session. Therefore, executing WFI in the debugging environment will turn off the kernel HCLK, causing the debugging function to fail.

If the target chip has entered the DeepSleep mode, the DAP hardware debugging module does not work at this time, the debugger cannot connect with the DAP hardware debugging module of the target chip, and the debugging function cannot be realized.

The user must ensure that the chip is in Active mode or Sleep mode to use the debugger for debugging.

Therefore, it is recommended that users complete all functional debugging of the device in non-DeepSleep mode before merging the relevant code of deep sleep, and then debug the code related to deep sleep.



30 Digital signature

30.1 Overview

The digital signature is mainly used to store information such as the unique identification (UID) of the chip, product model, FLASH capacity, SRAM capacity, and the number of pins in the chip package, which can be read by SWD or CPU. The digital signature-related information is programmed at the factory, and user firmware or external devices can verify the legitimacy of the chip by reading the digital signature.

30.2 Product Unique Identification (UID) register (80bit)

The UID register stores the unique identifier of the chip, and its address is 0x0010 0A10 - 0x0010 0A19, a total of 80 bits. The UID is written during chip production and cannot be modified by the user. UID registers support reading in single-byte/half-word/full-word, etc., and then concatenated using custom algorithms.

Typical application scenarios of unique identifiers:

- Used as device serial number
- Device legitimacy verification to prevent piracy

When the device is produced, the user uses the private key to encrypt the UID, and stores the calculation result in the main FLASH memory or OTP memory. If the result is compared with the previously stored calculation result, it is considered that the device is legal, otherwise the program will not start, which can effectively prevent the user's device from being illegally copied (piracy).

- Used as a security key

Combined with UID and private algorithm, users can perform security verification before users program FLASH to improve the security of the code in FLASH.

- Activate the secure boot process, etc.

30.3 Product model register

The product model register stores the ASCII code of the product model, and its address is 0x0010 0A24 - 0x0010 0A39, with a total of 22 bytes. When the product model is less than 22 bytes, it is filled with 0x00.

For example, the model of the chip is CW32L083VCT6-LQFP100, the corresponding data stored (starting from the low address) is: 0x43 0x57 0x33 0x32 0x4C 0x30 0x38 0x33 0x56 0x43 0x54 0x36 0x2D 0x4C 0x51 0x46 0x50 0x31 0x30 0x30 0x00 0x00.

Caution:

If there are letters in the product model, the letters need to be capitalized.

30.4 FLASH capacity register

The FLASH capacity register stores the capacity of the built-in FLASH memory of the chip, and its address is 0x0010 0A3C - 0x0010 0A3F, a total of 4 bytes.

The FLASH capacity size read from the FLASH capacity register is in bytes, such as 0x0001 0000 for 64KB, and 0x0000 8000 for 32KB.



30.5 SRAM capacity register

The SRAM capacity register stores the capacity of the built-in SRAM memory in the chip, and its address is 0x0010 0A40 - 0x0010 0A43, a total of 4 bytes.

The SRAM capacity size read from the SRAM capacity register is in bytes, such as 0x0001 0000 for 64KB, and 0x0000 4000 for 16KB.

30.6 Pin number register

The pin number register stores the chip pin number, its address is 0x0010 0A3A - 0x0010 0A3B, a total of 2 bytes. For example, 0x0020 represents 32Pin, and 0x0030 represents 48Pin.



31 Revision history

Table 31-1 Document revision history

Date	Revision	Changes
October 10, 2022	Rev 1.0	Initial release.

