QingKeV3 Microprocessor Manual

V1.6

Overview

The QingKe V3 series microprocessors are 32-bit general-purpose MCU microprocessors developed based on the standard RISC-V instruction set architecture. This series includes five models: V3A, V3B, V3C, V3F, and V3V.

- V3A: Support RV32IMAC standard instruction set extensions.
- V3B: Support RV32I[M]C[B] standard instruction sets and XW custom instruction set extensions; some chips do not support 'M' or 'B' instructions.
- V3C: Support the RV32IMCB standard instruction set and XW custom instruction set extensions.
- V3F: Support the RV32IMAFCB standard instruction set and XW custom instruction set extensions.
- V3V: Support the RV32IMACB_Zve64x_zvbb standard instruction set and XW custom instruction set extensions.

Additionally, this series of microprocessors incorporates several distinctive features, including Hardware Prologue/Epilogue (HPE), Vector Table Free (VTF), streamlined 1-/2-wire debugging interface, and “WFI” and “WFE” sleep modes.

Features

Features	Description
ISA	RV32I[M][A][F]C[B][V][XW]
Pipeline	3
FPU	V3F supports scalar floating-point operations
Branch prediction	Static branch prediction
Interrupt	Support a total of 256 interrupts including exceptions, and supports VTF
Automatic stack protection	Support up to level 2 automatic stack protection
Physical Memory Protection (PMP)	Supported
Low-power consumption mode	Support Sleep and Deep sleep modes, and support WFI and WFE sleep methods
Extended Instruction Set	Supported
Debug	1/2-wire SDI, standard RISC-V debug

Chapter 1 Overview

QingKe V3 series microprocessors include V3A, V3B, V3C, V3F, V3V, there are some differences between the series according to the application, the specific differences are detailed in Table 1-1.

Table 1-1 Overview of QingKe V3 microprocessor

Feature / Model	ISA	HPE number of levels	Interruptions nesting number of levels	VTF number of channels	Pipeline	Vector table mode	Extended Instruction (XW)	Number of memory protection areas
V3A	RV32IMAC	2	2	4	3	Instruction	×	×
V3B	RV32I[M]C[B]	2	2	4	3	Address/ Instruction	√	×
V3C	RV32IMCB	2	2	4	3	Address/ Instruction	√	4
V3F	RV32IMAFCB	2	2	4	3	Address/ Instruction	√	4
V3V	RV32IMACBV	2	2	4	3	Address/ Instruction	√	4

Note: OS task switching generally uses stack push, which are not limited in number of levels

1.1 Instruction Set

QingKe V3 series microprocessors follow the standard RISC-V Instruction Set Architecture (ISA). Detailed documentation of the standard can be found on the RISC-V International website. The RISC-V instruction set has a simple architecture and supports a modular design, allowing for flexible combinations based on different needs, and the V3 series supports the following instruction set extensions.

- RV32: 32-bit architecture, general-purpose register bit width of 32 bits
- I: Support integer operation, with 32 integer registers
- M: Support integer multiplication and division instructions
- A: Support atomic instructions, in which V3A simplifies the lr and sc instructions and executes them only as lw, sw, and the sc result return is always successful
- F: Support single-precision floating-point instructions
- C: Support 16-bit compression instruction
- B: Support for bit manipulation instructions
- V: Support the zve64x and zvbb instruction sets, with a 64-bit vector register width.
- XW: 16-bit compression instructions for self-extending byte and halfword operations

Note:

1: The subset of instructions supported by different models may be different, please refer to Table 1-1 for details;

2: In order to further improve the code density, extend the XW subset, add the following compression instructions c.lbu/c.lhu/c.sb/c.sh/c.lbusp/c.lhusp/c.sbsp/c.shsp, use of which needs to be based on the MRS compiler or the toolchain it provides;

3: With the exception of V3A, all other versions support memory copy instructions. For specific usage instructions, please refer to the library functions and use them in conjunction with the MRS compiler or the toolchain it provides.

1.2 Register Set

The RV32I has 32 register sets from x0-x31. In the RV32, each register is 32 bits. Table 1-2 below lists the registers of RV32I and their descriptions.

Table 1-2 RV32I general-purpose registers

Register	ABI Name	Description	Storer
x0	zero	Hardcoded 0	-
x1	ra	Return address	Caller
x2	sp	Stack pointer	Callee
x3	gp	Global pointer	-
x4	tp	Thread pointer	-
x5-7	t0-2	Temporary register	Caller
x8	s0/fp	Save register/frame pointer	Callee
x9	s1	Save register	Callee
x10-11	a0-1	Function parameters/return values	Caller
x12-17	a2-7	Function parameters	Caller
x18-27	s2-11	Save register	Callee
X28-31	t3-6	Temporary register	Caller

The Caller attribute in the above table means that the called procedure does not save the register value, and the Callee attribute means that the called procedure saves the register.

The V3F model kernel supports the F instruction set and has a total of 32 floating-point registers, F0-F31, which are used to store data required for single-precision floating-point instructions. Table 1-3 below lists the floating-point registers and their descriptions.

Table 1-3 RISC-V3F registers

Register	ABI Name	Description	Storer
f0-7	ft0-7	Floating point temporary register	Caller
f8-9	fs0-1	Floating point save register	Callee
f10-11	fa0-1	Floating point function parameter /return values	Caller
f12-17	fa2-7	Floating point function parameter	Caller
f18-27	fs2-11	Floating point save register	Callee
f28-31	ft8-11	Floating point temporary register	Caller

The Caller attribute in the above table means that the called process does not save the value of this register, and the Callee attribute means that the called process saves this register.

The V3V model kernel supports the V instruction set, featuring 32 vector register groups from V0 to V31. Each vector register has a 64-bit width and supports vector operations with 64-, 32-, 16-, and 8-bit widths.

Table 1-4 RISC-V3V registers

Register	ABI Name	Description	Storer
V0-V31	v0-v31	Vector register	Callee

Note: Vector registers support both standard ABI and variant ABI storage formats during invocation. For detailed ABI invocation specifications, refer to the *RISC-V ABIs Specification v1.1* and the *CSR.vcontrol* register configuration.

1.3 Privilege Mode

The standard RISC-V architecture includes 3 privileged modes: Machine mode, Supervisor mode, and User mode, as shown in Table 1-5 below. The machine mode is a mandatory mode, and the other modes are optional

modes. For details, you can refer to the RISC-V Privileged Architecture Standard document, which can be downloaded for free from the RISC-V International website.

Table 1-5 RISC-V architecture privilege mode

Code	Name	Abbreviations
0b00	User Mode	U
0b01	Supervisor Model	S
0b10	Reserved	Reserved
0b11	Machine mode	M

QingKe V3 series microprocessors support 2 of these privileged modes.

- Machine mode

Machine mode has the highest authority, the program in this mode can access all the Control and Status Register (CSR), but also can access all the physical address area. The power-up default is in machine mode, when the execution of mret (Machine mode return instruction) returns, according to the CSR register mstatus (Machine mode status register) in the MPP bit, if MPP = 0b00, then exit the Machine mode into the User mode, MPP = 0b11, then continue to retain the Machine mode.

- User mode

User mode has the lowest privilege, and only limited CSR registers can be accessed in this mode. When an exception or interrupt occurs, the microprocessor goes from User mode to Machine mode to handle exceptions and interrupts.

1.4 CSR Register

A series of CSR registers are defined in the RISC-V architecture to control and record the operating state of the microprocessor. These CSRs can be extended by 4096 registers using an internal dedicated 12-bit address coding space. And use the high two CSR[11:10] to define the read/write permission of this register, 0b00, 0b01, 0b10 for read/write allowed and 0b11 for read only. Use the two bits CSR[9:8] to define the lowest privilege level that can access this register, and the value corresponds to the privilege mode defined in Table 1-5. The CSR registers implemented in the QingKe V3 microprocessor are detailed in Chapter 8.

Chapter 2 Exception

Exception mechanism, which is a mechanism to intercept and handle "unusual operation events". QingKe V3 series microprocessors are equipped with an exception response system that can handle up to 256 exceptions, including interrupts. When an exception or interruption occurs, the microprocessor can quickly respond and handle the exception and interruption events.

2.1 Exception Types

The hardware behavior of the microprocessor is the same whether an exception or an interrupt occurs. The microprocessor suspends the current program, moves to the exception or interrupt handler, and returns to the previously suspended program when processing is complete. Broadly speaking, interrupts are also part of exceptions. Whether exactly the current occurrence is an interrupt or an exception can be viewed through the Machine mode exception cause register mcause. The mcause[31] is the interrupt field, which is used to indicate whether the cause of the exception is an interrupt or an exception. mcause[31]=1 means interrupt, mcause[31]=0 means exception. mcause[30:0] is the exception code, which is used to indicate the specific cause of the exception or the interrupt number, as shown in the following table.

Table 2-1 V3 microprocessor exception codes

Interrupt	Exception codes	Synchronous / Asynchronous	Reason for exception
1	0-1	-	Reserved
1	2	Precise asynchronous	NMI interrupts
1	3-11	-	Reserved
1	12	Precise asynchronous	SysTick interrupts
1	13	-	Reserved
1	14	Synchronous	Software interrupts
1	15	-	Reserved
1	16-255	Precise asynchronous	External interrupt 16-255
0	0	Synchronous	Instruction address misalignment
0	1	Synchronous	Fetch command access error
0	2	Synchronous	Illegal instructions
0	3	Synchronous	Breakpoints
0	4	Synchronous	Load instruction access address misalignment
0	5	Non- precision asynchronous	Load command access error
0	6	Synchronous	Store/AMO instruction access address misalignment
0	7	Non-precision asynchronous	Store/AMO command access error
0	8	Synchronous	Environment call in User mode
0	11	Synchronous	Environment call in Machine mode

'Synchronous' in the table means that an instruction can be located exactly where it is executed, such as an ebreak or ecall instruction, and each execution of that instruction will trigger an exception. 'Asynchronous' means that it is not possible to pinpoint an instruction, and the instruction PC value may be different each time an exception occurs. 'Precise asynchronous' means that after an exception occurs, it can precisely locate the boundary of an instruction, save all core state values at the time of the current exception, and resume the original instruction to continue executing the program after the exception is handled, such as an external interrupt. The 'non-precise asynchronous' refers to the inability to accurately locate the boundaries of a

particular instruction, may be an instruction is interrupted halfway through the execution of the state, the completion of the exception cannot be restored to the original normal operation of the program, such as memory access error. Access to memory takes time, the microprocessor access to memory is generally not always waiting for the end of the access, but to continue to execute the instruction, and then the access error exception, the microprocessor has already executed the subsequent instructions, cannot accurately locate or save the complete abnormal instruction before the register value.

2.2 Entering Exception

When the program is in the process of normal operation, if for some reason, triggered into an exception or interrupt. The hardware behavior of the microprocessor at this point can be summarized as follows.

(1) Suspend the current program flow and move to the execution of exception or interrupt handling functions. The entry base address and addressing mode of the exception or interrupt function are defined by the exception entry base address register mtvec. mtvec[31:2] defines the base address of the exception or interrupt function.

mtvec[1:0] defines the addressing mode of the handler function. when mtvec[0]=0, all exceptions and interrupts use a unified entry, i.e., when an exception or interrupt occurs, it turns to the mtvec[31:2] defines the base address to execute. When mtvec[0]=1, exceptions and interrupts use vector table mode, i.e., each exception and interrupt is numbered, and the address is offset according to interrupt number*4, and when an exception or interrupt occurs, it is shifted to the base address defined by mtvec[31:2] + interrupt number*4 Execution. The interrupt vector table holds an instruction to jump to the interrupt handler function, or it can be other instructions.

mtvec[1] defines whether an instruction or an address is stored in the entry address. When mtvec[1]=0, the exception entry address stores a jump instruction; when mtvec[1]=1, the exception entry address stores a jump address.

Note: The mtvec register must be 1K-address-aligned.

(2) Update CSR register

When an exception or interrupt is entered, the microprocessor automatically updates the relevant CSR registers, including the Machine mode exception cause register mcause, the Machine mode exception pointer register mepc, the Machine mode exception value register mtval, and the Machine mode status register mstatus.

- Update mcause

As mentioned before, after entering an exception or interrupt, its value reflects the current exception type or interrupt number, and the software can read this register value to check the cause of the exception or determine the source of the interrupt, as detailed in Table 2-1.

- Update mepc

The standard definition of the return address of the microprocessor after exiting an exception or interrupt is stored in mepc. So when an exception or interrupt occurs, the hardware automatically updates the mepc value to the current instruction PC value when the exception is encountered, or the next pre-executed instruction PC value before the interrupt. After the exception or interrupt is processed, the microprocessor uses its saved value as the return address to return to the location of the interrupt to continue execution.

However, it is worth noting that.

1. mepc is a readable and writable register, and the software can also modify the value for the purpose of

modifying the location of the PC pointer running after the return.

2. When an interrupt occurs, i.e., when the exception cause register mcause[31]=1, the value of mepc is updated to the PC value of the next unexecuted instruction at the time of the interrupt.

And when an exception occurs, the value of mepc is updated to the instruction PC value of the current exception when the exception cause register mcause[31]=0. Therefore, when the exception returns, if you use the value of mepc to return directly, you will try to execute the exception instruction again, and then it is possible to enter the exception repeatedly. For some exceptions, the value of mepc can be changed to the value of the next unexecuted instruction before returning. For example, if we cause an exception due to ecall/ebreak, after handling the exception, since ecall/ebreak (c.ebreak is 2 bytes) is a 4-byte instruction, we only need the software to modify the value of mepc to mepc+4 (c.ebreak is mepc+2) and then return.

- Update mtval

When exceptions and interrupts are entered, the hardware will automatically update the value of mtval, which is the value that caused the exception. The value is typically.

1. If an exception is caused by a memory access, the hardware will store the address of the memory access at the time of the exception into mtval.
2. If the exception is caused by an illegal instruction, the hardware will store the instruction code of the instruction into mtval.
3. If the exception is caused by a hardware breakpoint, the hardware will store the PC value at the breakpoint into mtval.
4. For other exceptions, the hardware sets the value of mtval to 0, such as ebreak, the exception caused by ecall instruction.
5. When entering the interrupt, the hardware sets the value of mtval to 0.

- Update mstatus

Upon entering exceptions and interrupts, the hardware updates certain bits in mstatus.

1. MPIE is updated to the MIE value before entering the exception or interrupt, and MPIE is used to restore the MIE after the exception and interrupt are over.
2. MPP is updated to the privileged mode before entering exceptions and interrupts, and after the exceptions and interrupts are over, MPP is used to restore the previous privileged mode.
3. QingKe V3 microprocessor supports interrupt nesting in Machine mode. After entering exceptions and interrupts, the MIE is updated to a new value based on information such as the current nesting depth and nesting enable.

(3) Update microprocessor privilege mode

When exceptions and interrupts occur, the privileged mode of the microprocessor is updated to Machine mode.

2.3 Exception Handling Functions

Upon entering an exception or interrupt, the microprocessor executes the program from the address and mode defined by the mtvec register. When using unified entry, the microprocessor enters the interrupt from the base address defined by mtvec[31:2]. At this time, the exception and interrupt handling function can determine whether the cause is an exception or interrupt based on the value of mcause[31], and the type and cause of the exception or the corresponding interrupt can be judged by the exception code and handled accordingly.

When using the base address + interrupt number *4 for offset, the hardware automatically jumps to the vector table to get the entry address of the exception or interrupt function based on the interrupt number.

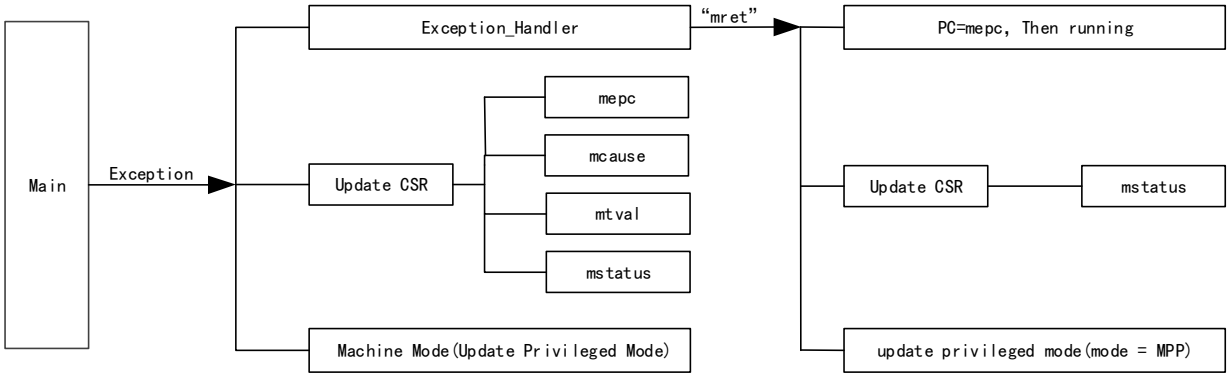
2.4 Exception Exit

After the exception or interrupt handler is completed, it is necessary to exit from the service program. After entering exceptions and interrupts, the microprocessor enters Machine mode from User mode, and the processing of exceptions and interrupts is also completed in Machine mode. When it is necessary to exit exceptions and interrupts, it is necessary to use the mret instruction to return. At this time, the microprocessor hardware will automatically perform the following operations.

- The PC pointer is restored to the value of CSR register mepc, i.e., execution starts at the instruction address saved by mepc. It is necessary to pay attention to the offset operation of mepc after the exception handling is completed.
- Update CSR register mstatus, MIE is restored to MPIE, and MPP is used to restore the privileged mode of the previous microprocessor.

The entire exception response process can be described by the following Figure 2-1.

Figure 2-1 Exception response process diagram



Chapter 3 PFIC and Interrupt Control

QingKe V3 microprocessor is designed with a Programmable Fast Interrupt Controller (PFIC) that can manage up to 256 interrupts including exceptions.

The first 16 of V3A, V3B, V3C, V3V are fixed as internal interrupts of the microprocessor, and the rest are external interrupts, i.e. the maximum number of external interrupts can be extended to 240. Its main features are as follows.

- 240 external interrupts, each interrupt request has independent trigger and mask control bits, with dedicated status bits
- Programmable multi-level interrupt nesting, maximum nesting depth 2 levels
- Vector Table Free (VTF) interrupt response mechanism, 4-channel programmable direct access to interrupt vector addresses

Among them, the first 32 of V3F are fixed as microprocessor internal interrupts, and the rest are external interrupts, i.e., it supports the expansion of a maximum of 224 external interrupts. Its main features are as follows:

- 224 external interrupts, each interrupt request has independent trigger and mask control bits, with dedicated status bits
- Programmable multi-level interrupt nesting, maximum nesting depth 2 levels
- Special fast interrupt in/out mechanism, hardware automatic stacking and recovery, maximum HPE depth of 2 levels
- Vector Table Free (VTF) interrupt response mechanism, 4-channel programmable direct access to interrupt vector addresses

Note: The maximum nesting depth and HPE depth supported by interrupt controllers vary for different microprocessor models, which can be found in Table 1-1.

The vector table of V3A, V3B, V3C, V3V interrupts and exceptions is shown in Table 3-1 below.

Table 3-1 V3A, V3B, V3C, V3V Exception and interrupt vector table

Number	Priority	Type	Name	Description
0	-	-	-	-
1	-	-	-	-
2	-5	Fixed	NMI	Non-maskable interrupt
3	-4	Fixed	EXC	Exception interrupt
4	-	-	-	-
5	-3	Fixed	ECALL-M	Machine mode callback interrupt
6-7	-	-	-	-
8	-2	Fixed	ECALL-U	User mode callback interrupt
9	-1	Fixed	BREAKPOINT	Breakpoint callback interrupt
10-11	-	-	-	-
12	0	Programmable	SysTick	System timer interrupt
13	-	-	-	-
14	1	Programmable	SW	Software interrupt
15	-	-	-	-
16-255	2-241	Programmable	External Interrupt	External interrupt 16-255

Note: ECALL-M, ECALL-U, BREAKPOINT are all different types of exception EXC, which are independent

in V3B/C for ease of use, and the above 3 entry addresses are shared with EXC in V3A.

The vector table of V3F interrupts and exceptions is shown in Table 3-2 below.

Table 3-2 V3F Exception and interrupt vector table

Number	Priority	Type	Name	Description
0	-6	Fixed	RESET	Reset interrupt
1	-	-	-	-
2	-5	Fixed	NMI	Non-maskable interrupt
3	-4	Fixed	HardFault	Exception interrupt
4	-	-	-	-
5	-3	Fixed	Ecall-M	Machine mode callback interrupt
6-7	-	-	-	-
8	-2	Fixed	Ecall-U	User mode callback interrupt
9	-1	Fixed	BreakPoint	Breakpoint callback interrupt
10-11	-	-	-	-
12	0	Programmable	SysTick0	System timer interrupt 0
13	1	Programmable	SysTick1	System timer interrupt 1
14	2	Programmable	SW	Software interrupt
15	-	-	-	-
16	3	Programmable	IPC_CH0	Inter-core communication interrupt 0
17	4	Programmable	IPC_CH1	Inter-core communication interrupt 1
18	5	Programmable	IPC_CH2	Inter-core communication interrupt 2
19	6	Programmable	IPC_CH3	Inter-core communication interrupt 3
20-27	-	-	-	-
28	7	Programmable	HSEM	Hardware semaphore interrupt
29-31	-	-	-	-
32-255	8-224	Programmable	External Interrupt	External interrupt 32-255

3.1 PFIC Register Set

Table 3-3 PFIC Registers

Name	Access address	Access	Description	Reset value
PFIC_ISRx	0xE000E000 -0xE000E01C	RO	Interrupt enable status register x	0x00000000
PFIC_IPRx	0xE000E020 -0xE000E03C	RO	Interrupt pending status register x	0x00000000
PFIC_ITHRESDR	0xE000E040	RW	Interrupt priority threshold configuration register	0x00000000
PFIC_VTFBADDRR	0xE000E044	RW	VTF base address register *Note: Valid only for V3A*	0x00000000
PFIC_CFGR	0xE000E048	RW	Interrupt configuration register *Note: Valid only for V3A/F/V*	0x00000000

PFIC_GISR	0xE000E04C	RO	Interrupt global status register	0x00000002
PFIC_VTFIDR	0xE000E050	RW	VTF interrupt ID configuration register *Note: Valid only for V3B/C/F/V.*	0x00000000
PFIC_VTFADDRRx	0xE000E060 -0xE000E06C	RW	VTF x offset address register	0x00000000
PFIC_IENRx	0xE000E100 -0xE000E11C	WO	Interrupt enable setting register x	0x00000000
PFIC_IRERx	0xE000E180 -0xE000E19C	WO	Interrupt enable clear register x	0x00000000
PFIC_IPSRx	0xE000E200 -0xE000E21C	WO	Interrupt pending setting register x	0x00000000
PFIC_IPRRx	0xE000E280 -0xE000E29C	WO	Interrupt pending clear register x	0x00000000
PFIC_IACTRx	0xE000E300 -0xE000E31C	RO	Interrupt activation status register x	0x00000000
PFIC_IPRIORx	0xE000E400 -0xE000E43C	RW	Interrupt priority configuration register	0x00000000
PFIC_CSTAR0	0xE000E780	RO	Core status register 0	0x00000000
PFIC_EENR	0xE000EC80	RW	Event Enable Register *Note: Supported by some chips, see chip manual for specific implementation.*	0xFFFFFFFF
PFIC_EPR	0xE000EC84	RO/RW1Z	Event pending register *Note: Supported by some chips, see chip manual for specific implementation.*	0x00000000
PFIC_EWUPR	0xE000EC88	RO	Event wake-up Register *Note: Supported by some chips, see chip manual for specific implementation.*	0x00000000
PFIC_SCTLR	0xE000ED10	RW	System control register	0x00000000

Note: 1. NMI, EXC, ECALL-M, ECALL-U, BREAKPOINT are always enabled by default.

2. ECALL-M, ECALL-U, and BREAKPOINT are a case of EXC.

3. NMI, EXC, ECALL-M, ECALL-U, BREAKPOINT support interrupt pending clear and setting operation, but not interrupt enable clear and setting operation.

Each register is described as follows:

Interrupt enable status and interrupt pending status registers (PFIC_ISR<0-7>/PFIC_IPR<0-7>)

Name	Access address	Access	Description	Reset value
PFIC_ISR0	0xE000E000	RO	Interrupt 0-31 enable status register, a total of 32 status bits [n], indicating #n interrupt enable status	For V3A: 0x0000000C For V3B/C/F: 0x0000032C

			Note: NMI and EXC are enabled by default	
PFIC_ISR1	0xE000E004	RO	Interrupt 32-63 enable status register, total 32 status bits	0x00000000
…	…	…	…	…
PFIC_ISR7	0xE000E01C	RO	Interrupt 224-255 enable status register, total 32 status bits	0x00000000
PFIC_IPR0	0xE000E020	RO	Interrupt 0-31 pending status register, a total of 32 status bits [n], indicating the pending status of interrupt #n	0x00000000
PFIC_IPR1	0xE000E024	RO	Interrupt 32-63 pending status registers, 32 status bits in total	0x00000000
…	…	…	…	…
PFIC_IPR7	0xE000E03C	RO	Interrupt 224-255 pending status register, 32 status bits in total	0x00000000

2 sets of registers are used to enable and de-enable the corresponding interrupts.

Interrupt enable setting and clear registers (PFIC_IENR<0-7>/PFIC_IRER<0-7>)

Name	Access address	Access	Description	Reset value
PFIC_IENR0	0xE000E100	WO	Interrupt 0-31 enable setting register, a total of 32 setting bits [n], for interrupt #n enable setting *Note: NMI and EXC are enabled by default*	0x00000000
PFIC_IENR1	0xE000E104	WO	Interrupt 32-63 enable setting register, total 32 setting bits	0x00000000
…	…	…	…	…
PFIC_IENR7	0xE000E11C	WO	Interrupt 224-255 enable setting register, total 32 setting bits	0x00000000
-	-	-	-	-
PFIC_IRER0	0xE000E180	WO	Interrupt 0-31 enable clear register, a total of 32 clear bits [n], for interrupt #n enable clear *Note: NMI and EXC cannot be operated*	0x00000000
PFIC_IRER1	0xE000E184	WO	Interrupt 32-63 enable clear register, total 32 clear bits	0x00000000
…	…	…	…	…
PFIC_IRER7	0xE000E19C	WO	Interrupt 224-255 enable clear register, total 32 clear bits	0x00000000

2 sets of registers are used to enable and de-enable the corresponding interrupts.

Note: When using registers to mask any interrupt or using CSR registers to mask global interrupts, add a 'fence.i' instruction to synchronize between core control state and interrupt enable state.

Interrupt pending setting and clear registers (PFIC_IPSR<0-7>/PFIC_IPRR<0-7>)

Name	Access address	Access	Description	Reset value
PFIC_IPSR0	0xE000E200	WO	Interrupt 0-31 pending setting register, 32 setting bits [n], for interrupt #n pending setting	0x00000000
PFIC_IPSR1	0xE000E204	WO	Interrupt 32-63 pending setup register, total 32 setup bits	0x00000000
…	…	…	…	…
PFIC_IPSR7	0xE000E21C	WO	Interrupt 224-255 pending setting register, 32 setting bits in total	0x00000000
-	-	-	-	-
PFIC_IPRR0	0xE000E280	WO	Interrupt 0-31 pending clear register, a total of 32 clear bits [n], for interrupt #n pending clear	0x00000000
PFIC_IPRR1	0xE000E284	WO	Interrupt 32-63 pending clear register, total 32 clear bits	0x00000000
…	…	…	…	…
PFIC_IPRR7	0xE000E29C	WO	Interrupt 224-255 pending clear register, total 32 clear bits	0x00000000

When the microprocessor enables an interrupt, it can be set directly through the interrupt pending register to trigger into the interrupt. Use the interrupt pending clear register to clear the pending trigger.

Interrupt activation status register (PFIC_IACTR<0-7>)

Name	Access address	Access	Description	Reset value
PFIC_IACTR0	0xE000E300	RO	Interrupt 0-31 activates the status register with 32 status bits [n], indicating that interrupt #n is being executed	0x00000000
PFIC_IACTR1	0xE000E304	RO	Interrupt 32-63 activation status registers, 32 status bits in total	0x00000000
…	…	…	…	…
PFIC_IACTR7	0xE000E31C	RO	Interrupt 224-255 activation status register, total 32 status bits	0x00000000

Each interrupt has an active status bit that is set up when the interrupt is entered and cleared by hardware when mret returns.

Interrupt priority and priority threshold registers (PFIC_IPRIOR<0-7>/PFIC_ITHRESDR)

Name	Access address	Access	Description	Reset value
PFIC_IPRIOR0	0xE000E400	RW	Interrupt 0 priority configuration. V3A/V3V: [7:4]: Priority control bits If the configuration is not nested,	0x00

			no preemption bit If nesting is configured, bit7 is the preempted bit. [3:0]: Reserved, fixed to 0 V3B: [7:6]: Priority control bits If configuration is not nested, no preemptive bits If configured nested, all bits are preempted, but up to two levels of interrupts are allowed to occur [5:0]: Reserved, fixed to 0 V3C/V3F: [7:5]: Priority control bits If configuration is not nested, no preemptive bits If configured nested, all bits are preempted, but up to two levels of interrupts are allowed to occur [4:0]: Reserved, fixed to 0 *Note: The smaller the priority value, the higher the priority. If the same preemption priority interrupt hangs at the same time, the interrupt with the higher priority will be executed first.*	
PFIC_IPRIOR1	0xE000E401	RW	Interrupt 1 priority setting, same function as PFIC_IPRIOR0	0x00
PFIC_IPRIOR2	0xE000E402	RW	Interrupt 2 priority setting, same function as PFIC_IPRIOR0	
…	…	…	…	…
PFIC_IPRIOR254	0xE000E4FE	RW	Interrupt 254 priority setting, same function as PFIC_IPRIOR0	0x00
PFIC_IPRIOR255	0xE000E4FF	RW	Interrupt 255 priority setting, same function as PFIC_IPRIOR0	0x00
-	-	-	-	-
PFIC_ITHRESDR	0xE000E040	RW	Interrupt priority threshold setting V3A/V3V: [31:8]: Reserved, fixed to 0 [7:4]: Priority threshold [3:0]: Reserved, fixed to 0 V3B:	0x00

			[31:8]: Reserved, fixed to 0 [7:6]: Priority threshold [5:0]: Reserved, fixed to 0 V3C/V3F: [31:8]: Reserved, fixed to 0 [7:5]: Priority threshold [4:0]: Reserved, fixed to 0 *Note: For interrupts with priority value ⩾ threshold, the interrupt service function is not executed when a hang occurs, and when this register is 0, it means the threshold register is invalid.*	

Note: The number of interrupt nesting levels and preemptive priority bit width, preemptive priority bit width configuration may be different, use need to refer to the specific chip manual.

Interrupt configuration register (PFIC_CFGR)

Name	Access address	Access	Description	Reset value
PFIC_CFGR	0xE000E048	RW	Interrupt configuration register	0x00000000

For V3A, its bits are defined as:

Bit	Name	Access	Description	Reset value
[31:16]	KEYCODE	WO	Corresponding to different target control bits, the corresponding security access identification data needs to be written simultaneously in order to be modified, and the readout data is fixed to 0. KEY1 = 0xFA05; KEY2 = 0xBCAF; KEY3 = 0xBEEF。	0
[15:8]	Reserved	RO	Reserved	0
7	SYSRESET	WO	System reset (simultaneous writing to KEY3). Auto clear 0. Writing 1 is valid, writing 0 is invalid.	0
6	PFICRESET	WO	PFIC module reset. Auto clear 0. Writing 1 is valid, writing 0 is invalid.	0
5	EXCRESET	WO	Exception interrupt pending clear (simultaneous writing to KEY2) Writing 1 is valid, writing 0 is invalid.	0
4	EXCSET	WO	Exception interrupt pending setting (simultaneous writing to KEY2) Writing 1 is valid, writing 0 is invalid.	0
3	NMIRESET	WO	NMI interrupt pending clear (simultaneous writing to KEY2)	0

			Writing 1 is valid, writing 0 is invalid.	
2	NMISET	WO	NMI interrupt pending setting (Simultaneous writing to KEY2) Writing 1 is valid, writing 0 is invalid.	0
1	NESTCTRL	RW	Interrupt nesting enable control. 1: off; 0: on (synchronous writing to KEY1)	0
0	HWSTKCTRL	RW	HPE enable control 1: off; 0: on (synchronous writing to KEY1)	0

For V3F/V3V, its bits are defined as:

Name	Access address	Access	Description	Reset value
[31:0]	SYSRST	WO	System reset when 0xBEEF0080 is written, other values are invalid.	0

Interrupt global status register (PFIC_GISR)

Name	Access address	Access	Description	Reset value
PFIC_GISR	0xE000E04C	RO	Interrupt global status register	0x00000000

The definitions are as follows:

Bit	Name	Access	Description	Reset value
[31:16]	Reserved	RO	Reserved	0
[15:14]	EXSTATE	RO	Core status register, used to get the operational status of the core: 00: Running; 01: Light sleep; 10: Deep sleep; 11: Deep sleep (locked). *Note: This bit is only valid for V3B/C/F/V.*	0
13	LOCKSTA	RO	Whether the processor is currently in a locked state: 1: Locked state; 0: Non-locked state. *Note: This bit is only valid for the V3B/C/F/V.*	0
12	DBGMODE	RO	Whether the processor is currently in debug state: 1: Debug state; 0: Non-debug state. *Note: This bit is only valid for the V3B/C/F/V.*	0
11	GLOBLIE	RO	Global interrupt enable: 1: Enable interrupt; 0: Disable interrupt. *Note: This bit is only valid for the V3B/C/F/V.*	
10	Reserved	RO	Reserved	0
9	GPENDSTA	RO	Whether an interrupt is currently pending. 1: Yes; 0: No.	0
8	GACTSTA	RO	Whether an interrupt is currently being executed.	0

			1: Yes; 0: No.	
[7:0]	NESTSTA	RO	Current interrupt nesting status. 0x03: in level 2 interrupt. 0x01: in level 1 interrupt. 0x00: no interrupts occur. Other: Impossible situation.	0

VTF ID base address and offset address registers (PFIC_VTFBADDRR/PFIC_VTFADDRR<0-3>)

Name	Access address	Access	Description	Reset value
PFIC_VTFBADDRR	0xE000E044	RW	[31:28]: High 4 bits of the target address of VTF [27:0]: Reserved *This register is valid only for V3A.*	0x00000000
PFIC_VTFIDR	0xE000E050	RW	[31:24]: Number of VTF 3 [23:16]: Number of VTF 2 [15:8]: Number of VTF 1 [7:0]: Number of VTF 0 *This register is valid only for V3B/C/F/V.*	0x00000000
-	-	-	-	-
PFIC_VTFADDRR0	0xE000E060	RW	V3A: [31:24]: VTF 0 interrupt number [23:0]: the low 24 bits of the VTF target address, of which the low 20 bits are configured to be valid and [23:20] is fixed to 0. V3B/C/F/V: [31:1]: VTF 0 address, 2-byte aligned [0]: 1: Enable VTF 0 channel 0: Disable	For V3A: 0x00000000 For V3B/C/*F/V*: 0xXXXXXXXX
PFIC_VTFADDRR1	0xE000E064	RW	V3A: [31:24]: VTF 1 interrupt number [23:0]: The low 24 bits of the VTF target address, of which the low 20 bits are configured to be valid and [23:20] is fixed to 0. V3B/C/F/V:	For V3A: 0x00000000 For V3B/C/F/V: 0xXXXXXXXX

			[31:1]: VTF 1 address, 2-byte aligned [0]: 1: Enable VTF 1 channel 0: Disable	
PFIC_VTFADDRR2	0xE000E068	RW	V3A: [31:24]: VTF 2 interrupt number [23:0]: the low 24 bits of the VTF target address, of which the low 20 bits are configured to be valid and [23:20] is fixed to 0. V3B/C/F/V: [31:1]: VTF 2 address, 2-byte aligned [0]: 1: Enable VTF 2 channel 0: Disable	For V3A: 0x00000000 For V3B/C/F/V: 0xXXXXXXXX
PFIC_VTFADDRR3	0xE000E06C	RW	V3A: [31:24]: VTF 3 interrupt number [23:0]: the low 24 bits of the VTF target address, of which the low 20 bits are configured to be valid and [23:20] is fixed to 0. V3B/C/F/V: [31:1]: VTF 3 address, 2-byte aligned [0]: 1: Enable VTF 3 channel 0: Disable	For V3A: 0x00000000 For V3B/C/F/V: 0xXXXXXXXX

Core status register (PFIC_CSTAR0)

Name	Access address	Access	Description	Reset value
PFIC_CSTAR0	0xE000E780	RO	Core status register 0	0x00000000

The definitions are as follows:

Name	Access address	Access	Description	Reset value
[31:16]	Reserved	RO	Reserved	0
[15:14]	CPU_ex_state_0	RO	Core C0 status register, used to get the running status of core C0:	0

			00: Running; 01: Light sleep; 10: Deep sleep; 11: Deep sleep (locked).	
13	CPU_lock_up_0	RO	Core C0 locked state register, used to query whether core C0 is in locked state: 1: Locked; 0: Non-locked.	0
12	CPU_dbg_mode_0	RO	Kernel C0 debug mode register, used to query whether core C0 is in debug mode: 1: Core is in debug mode; 0: Core is in non-debug mode.	0
11	CPU_globl_ie_0	RO	Core C0 global interrupt enable register, used to query whether the core C0 global interrupt is enabled or not: 1: Core global interrupt enable is on; 0: Core global interrupt enable is off.	0
10	Reserved	RO	Reserved	0
9	CPU_irq_pend_0	RO	Core C0 interrupt pending flag register, used to query whether there are unprocessed interrupts in core C0: 1: There are unprocessed interrupts in the core; 0: There are no unprocessed interrupts in the core.	0
8	CPU_irq_active_0	RO	Core C0 interrupt active flag register, used to query whether core C0 is processing interrupts 1: Core is processing interrupts; 0: Core is not processing interrupts.	0
[7:0]	CPU_nest_sta_0	RO	Core C0 interrupt nested status register, used to query the nested status of kernel C0 interrupts. Same as the INEST_CTLR register nest_sta bit of the CSR register.	0

Event enable register (PFIC_EENR)

Name	Access address	Access	Description	Reset value
PFIC_EENR	0xE000EC80	RW	Event enable register	0x00000000

Supported by some chips; for specific implementation details, refer to the chip manual. The bit definitions are as follows:

Name	Access address	Access	Description	Reset value
[31:0]	EVENTEN	RW	31#-0# event wakeup enable: 1: Allow the corresponding event to wake up the kernel during sleep; 0: Block the corresponding event and do not allow waking up the kernel when this event occurs. Up to 32 event sources are supported, of which 0-7 is level triggered (high active) and 8-31 is pulse triggered: 0#: Core pause request; 1#: Core interrupt request; 7#-2#: Reserved; 8#: Core entry interrupt; 9#: Core exit interrupt; 10#: A new interrupt is pending; (For shared interrupts, it is not distinguished whether the interrupt is routed to the local core.) 11#: Core sends event; (Local core sends events) 12#: Core receive events;(Other core sends events) 13#: The system receives events;(system-configured events such as GPIO rollover events…) 31#-14#: Reserved.	0xFFFFFFFF

Event pending register (PFIC_EPR)

Name	Access address	Access	Description	Reset value
PFIC_EPR	0xE000EC84	RW	Event pending register	0x00000000

Supported by some chips; for specific implementation details, refer to the chip manual. The bit definitions are as follows:

Name	Access address	Access	Description	Reset value
[31:8]	EVENT_PEND	RW1Z	31#-8# Event pending status, write 1 to clear: 1: The corresponding event occurs without being processed; 0: The corresponding event does not occur.	0
[7:0]	EVENT_PEND	RO	7#-0# Event pending status, not clearable: 1: The corresponding event occurred without being processed; 0: The corresponding event did not occur.	0

Event wakeup register (PFIC_EWUPR)

Name	Access address	Access	Description	Reset value
PFIC_EWUPR	0xE000EC88	RO	Event wakeup register	0x00000000

Supported by some chips; for specific implementation details, refer to the chip manual. The bit definitions are as follows:

Name	Access address	Access	Description	Reset value
[31:0]	EVENT_WUP	RO	31#-0# event wake-up registers: 1: The corresponding event wakes up the core from sleep; 0: The corresponding event is not the event that wakes up the core this time.	0

System control register (PFIC_SCTLR)

Name	Access address	Access	Description	Reset value
PFIC_SCTLR	0xE000ED10	RW	System control register	0x00000000

Each of them is defined as follows.

Bit	Name	Access	Description	Reset value
31	SYSRESET	WO	System reset, auto clear 0. Write 1 is valid, write 0 is invalid. *Note: This bit is only valid for V3B/C/F/V*	0
[30:24]	Reserved	RO	Reserved	0
[23:16]	HART_ID	RO	Core ID register, used to get the core ID of the core reading this register: 1: this core is C1; 0: this core is C0. *Note: This bit is only valid for V3F.*	0
[15:6]	Reserved	RO	Reserved	0
5	SETEVENT	WO	Set the event to wake up the WFE case.	0
4	SEVONPEND	RW	When an event occurs or interrupts a pending state, the system can be woken up from after the WFE instruction, or if the WFE instruction is not executed, the system will be woken up immediately after the next execution of the instruction. 1: Enabled events and all interrupts (Including unenabled interrupts) can wake up the system. 0: Only enabled events and enabled interrupts can wake up the system.	0
3	WFITOWFE	RW	Execute the WFI command as if it were	0

			a WFE. 1: Treat the subsequent WFI instruction as a WFE instruction. 0: No effect.	
2	SLEEPDEEP	RW	Low power mode of the control system. 1: deepsleep 0: sleep	0
1	SLEEPONEXIT	RW	System status after control leaves the interrupt service program. 1: The system enters low-power mode. 0: The system enters the main program.	0
0	Reserved	RO	Reserved	0

3.2 Interrupt-related CSR Registers

In addition, the following CSR registers also have a significant impact on the processing of interrupts.

Interrupt system control register (intsyscr)

This register is not valid for V3A only:

Name	CSR Address	Access	Description	Reset value
intsyscr	0x804	URW	Interrupt system control register	0x0000E002

The definitions are as follows:

Bit	Name	Access	Description	Reset value
31	LOCK	URO	0: This register can be read and written in user mode; 1: This register can only be read and written in machine mode. *Note: This configuration bit is valid from version 1.0 onwards.*	0
[30:6]	Reserved	URO	Reserved	0x380
5	GIHWSTKNEN	URW1	Global interrupt and hardware stack shutdown are enabled. *Note: This bit is often used in real-time operating systems. When the context is switched during an interrupt, setting this bit can turn off the global interrupt and push the hardware stack. When the context switch is completed and the interrupt returns, the hardware will automatically clear this bit.*	0
4	Reserved	URO	Reserved	0
[3:2]	PMTCFG	URW	Configuration of priority preemption bits: 00: The number of preemption bits is 0; 01: The number of preemption bits is 1; 10: The number of preemption bits is 2;	0

			11: The number of preemption bits is 3; *Note: This configuration bit is valid after 1.0.*	
1	INESTEN	URW	The interrupt nesting function is enabled, and the fixed value is 1: 0: Disable; 1: Enable. *Note: 1. The actual nesting level is controlled by NEST_LVL in CSR 0xBC1;* *2. Only versions after 1.0 can be written.*	1
0	HWSTKEN	URW	Hardware stack enable: 0: Hardware stack pressing function is disabled; 1: Hardware stack pressing function is enabled.	0

Machine mode exception base address register (mtvec)

Name	CSR Address	Access	Description	Reset value
mtvec	0x305	MRW	Exception base address register	0x00000000

The definitions are as follows:

Bit	Name	Access	Description	Reset value
[31:2]	BASEADDR	MRW	Interrupt vector table base address, where bits [9:2] are fixed to 0.	0
1	MODE1	MRW	Interrupt vector table recognition mode: 0: Identify by jump instruction, with limited scope, and support non-jump instruction; 1: Identify by absolute address, support full range, but must jump. *Note: This bit is only valid for V3B/C/F/V.*	0
0	MODE0	MRW	Interrupt or exception entry address mode selection. 0: Use of the uniform entry address. 1: Address offset based on interrupt number *4.	0

For MCUs with V3 series microprocessors, MODE0 is configured to be 1 by default in the startup file, and the entries for exceptions or interrupts are offset according to the interrupt number *4. Note that the V3A microprocessor stores a jump instruction at the vector table, while the V3B/C/F/V microprocessor can be either a jump instruction or use the absolute address of the interrupt function, which is configured as an absolute address in the default startup file.

Microprocessor configuration register (corecfgr)

This register is invalid for V3A:

Name	CSR Address	Access	Description	Reset value
corecfgr	0xBC0	MRW	Microprocessor configuration register	V3B/C:0x00000001 V3F:0x12370000

The definitions are as follows:

Bit	Name	Access	Description	Reset value
[31:28]	FADD_CLKDIV	MRW	Floating-point plus instruction division factor, default value is 1, that is, floating-point plus instruction frequency is the dominant frequency of 2 division. *Note: This bit is valid only for V3F.*	0x1
[27:24]	FMUL_CLKDIV	MRW	Floating-point multiply instruction division factor, default value is 2, that is, floating-point multiply instruction frequency is the dominant frequency of 3 division. *Note: This bit is valid only for V3F.*	0x2
[23:20]	FMAC_CLKDIV	MRW	Floating-point multiply plus instruction division factor, default value is 3, that is, floating-point multiply plus instruction frequency is the dominant frequency of 4 division. *Note: This bit is valid only for V3F.*	0x3
[19:16]	FDIV_CLKDIV	MRW	Floating-point division instruction division factor, default value is 7, that is, floating-point division instruction frequency is the dominant frequency of 8 division. *Note: This bit is valid only for V3F.*	0x7
7	CSTA_FAULT_IE	MRW	Core status error interrupt enable: 0: On status error, no NMI interrupt is generated; 1: On status error, NMI interrupt is generated.	0
6	INT_FENCE	MRW	FENCE mask interrupt enable: 0: Do not clear the interrupt request when executing the fence instruction; 1: Clear the interrupt request when executing the fence instruction.	0
5	IE_REMAP_EN	MRW	MIE register mapping enable: 0: CSR address 0x800 is a read-only register and the return value is the value of MSTATUS; 1: Bits 3 and 7 of CSR address 0x800 are	0

			mapped to bit MIE of the MSTATUS register and bit MPIE of the MSTATUS register, respectively.	
4	Reserved	MRO	Reserved	0
3	ROM_LOOP_ACC	MRW	ROM area instruction loop acceleration enable: 0: Turn off the cyclic acceleration function in ROM area; 1: Continuous instructions with loop body within 128 bytes will be fully accelerated, while those with loop body within 256 bytes will be partially accelerated. *Note: This bit is not valid for V3A/V3F.*	0
2	ROM_JUMP_ACC	MRW	ROM area instruction jump acceleration enabled: 0: Disable ROM area instruction jump acceleration; 1: Enable instruction jump acceleration in ROM area. *Note: This bit is not valid for V3A/V3F.*	0
[1:0]	FETCH_MODE	MRW	Fetching mode: 00: Prefetch is off. The instruction prefetch function is turned off to avoid invalid instruction fetching operation, and there is at most one valid instruction on the CPU pipeline. This mode has the lowest power consumption, and its performance drops by about 2 ~ 3 times. 01: Prefetch Mode 1. When the instruction prefetch function is turned on, the CPU will continue to access the instruction memory until the number of instructions to be executed in the internal instruction buffer exceeds a certain number, or the instruction buffer is full, and instruction fetching will be suspended; (Failure of CPU prediction will lead to redundant fetch operation, and in some cases, the execution unit will introduce 0 ~ 2 cycles of bubbles, and the performance of most programs will not decrease obviously); Others: Reserved.	0x1

Floating-point arithmetic instructions are multi-cycle instructions, for different types of floating-point instructions, the maximum running frequency constraints check each chip manual. Depending on the processor's operating frequency, the user needs to configure the floating-point arithmetic crossover coefficients so that the frequency after crossover is not higher than the maximum operating frequency shown in the table

above.

fxxx_- freq(max) ≥ Core main frequency / fxxx_- clkdiv

Interrupt nested control register (inestcr)

This register is invalid only for V3A:

Name	CSR Address	Access	Description	Reset value
inestcr	0xBC1	MRW	Interrupt nested control register	0x00000000

The definitions are as follows:

Bit	Name	Access	Description	Reset value
31	Reserved	MRO	Reserved	0
30	NEST_OV	MRW	Interrupt/exception nested overflow flag bit, write 1 to clear: 0: Interrupt did not overflow; 1: Interrupt overflow flag. *Note: Interrupt overflow will only occur when executing secondary interrupt service function to generate instruction exception or NMI interrupt. At this time, the exception and NMI interrupt enter normally, but the CPU stack overflows, so you cannot exit from this exception and NMI interrupt.*	0
[29:12]	Reserved	MRO	Reserved	0
[11:8]	NEST_STA	MRO	Nested status flag bit: 0000: No interrupt; 0001: Level 1 interrupt; 0011: level 2 interrupt (1-level nesting); 0111: Level 3 interrupt (overflow); 1111: Level 4 interrupt (overflow).	0
[7:2]	Reserved	MRO	Reserved	0
[1:0]	NEST_LVL	MRW	Nesting level: 00: Nesting is prohibited and the nesting function is turned off; 01: First-level nesting, which turns on the nesting function; Other: Invalid. *Note: Write 10 or 11 to this field, and the field will be set to 01. When write 11 to this field, read this register to get the highest nesting level of the chip.*	0

User mode global interrupt enable register (gintenr)

This register is invalid only for V3A:

Name	CSR Address	Access	Description	Reset value

gintenr	0x800	URW	Global interrupt enable register	0x00000000

This register is used to control the enable and mask of global interrupt. The enable and mask of global interrupt in machine mode can be controlled by the MIE and MPIE bits in mstatus, but this register cannot be operated in user mode. The global interrupt enable register gintenr is the mapping of MIE and MPIE in mstatus, and can be used to set and clear MIE and MPIE by operating gintenr in user mode. Each of them is defined as:

Bit	Name	Access	Description	Reset value
31	SD	RO	Used to mark whether a floating-point instruction is in a dirty state. *Note: This bit applies to V3F only.*	0
[30:15]	Reserved	URO	Reserved	0
[14:13]	FS	RO	Floating-point instruction set state that allows single-precision floating-point instructions (F) to execute when the value is not zero: 00: OFF; 01: Initial; 10: Clean; 11: Dirty. *Note: This bit applies to V3F only.*	0
[12:11]	MPP	URO	Enter privileged mode before interruption.	0
[10:8]	Reserved	URO	Reserved	0
7	MPIE	URW	When 0xBC0(CSR)bit5 is enabled, this bit can be read and written in user mode.	0
[6:4]	Reserved	URO	Reserved	0
3	MIE	URW	When 0xBC0(CSR)bit5 is enabled, this bit can be read and written in user mode.	0
[2:0]	Reserved	URO	Reserved	0

3.3 Interrupt Nesting

In conjunction with the interrupt configuration register PFIC_CFGR and the interrupt priority register PFIC_IPRIOR, nesting of interrupts can be allowed to occur. Enable nesting in the interrupt configuration register (Nesting is turned on by default for V3 series microprocessors) and configure the priority of the corresponding interrupt. The smaller the priority value, the higher the priority. The smaller the value of the preemption bit, the higher the preemption priority. If there are interrupts hanging at the same time under the same preemption priority, the microprocessor responds to the interrupt with the lower priority value (higher priority) first.

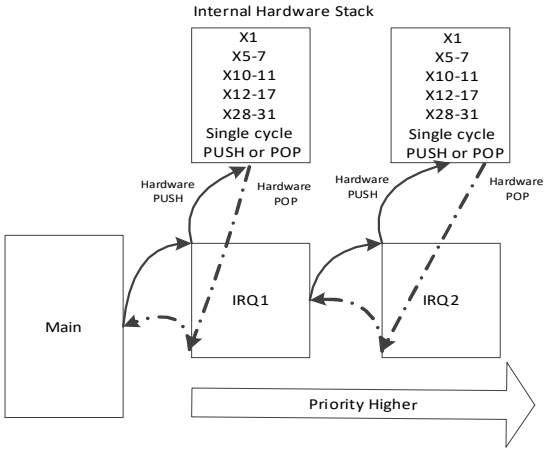
3.4 Hardware Prologue/Epilogue (HPE)

When an exception or interrupt occurs, the microprocessor stops the current program flow and shifts to the execution of the exception or interrupt handling function, the site of the current program flow needs to be saved. After the exception or interrupt returns, it is necessary to restore the site and continue the execution of the stopped program flow. For V3 series microprocessors, the "site" here refers to all the Caller Saved registers in Table 1-2.

The V3 series microprocessors support hardware single-cycle automatic saving of 16 of the integer Caller Saved registers to an internal stack area that is not visible to the user. When an exception or interrupt returns, the hardware single cycle automatically restores the data from the internal stack area to the 16 integer registers. HPE supports nesting up to 2 levels deep.

A schematic of the microprocessor pressure stack is shown in the following figure.

Figure 3-1 Schematic diagram of pressure stack



Note: 1. Interrupt functions using the HPE need to be compiled using MRS or its provided toolchain and the interrupt function needs to be declared with __attribute__((interrupt("WCH-Interrupt-fast"))).

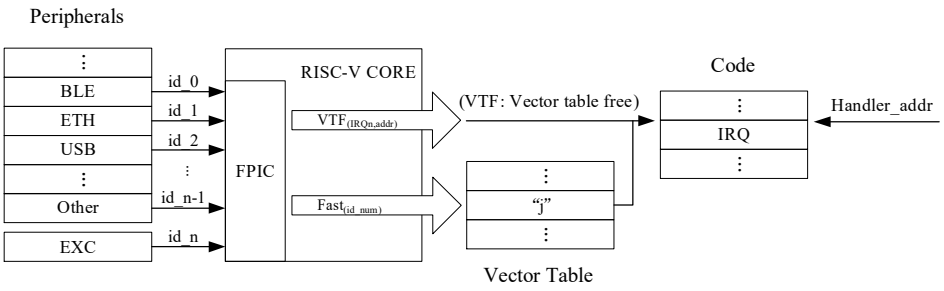
2. The interrupt function using stack push is declared by __attribute__((interrupt())).

3.5 Vector Table Free (VTF)

The Programmable Fast Interrupt Controller (PFIC) provides 4 VTF channels, i.e., direct access to the interrupt function entry without going through the interrupt vector table lookup process.

The VTF channel can be enabled by writing its interrupt number, interrupt service function base address and offset address into the corresponding PFIC controller register while configuring an interrupt function normally. The PFIC response process for fast and table-free interrupts is shown in Figure 3-2 below.

Figure 3-2 Schematic diagram of programmable fast interrupt controller



Chapter 4 Physical Memory Protection (PMP)

In order to improve the security of the system, the physical memory protection (PMP) module is designed according to RISC-V architecture standard for the QingKe V3 series microprocessors. Access rights management of up to 4 physical region is supported. Permissions include read (R), write (W) and execute (X) attributes, and the length of the protected area can be set to 4 bytes at least. PMP module always takes effect in user mode, but it can take effect optionally by locking (L) attribute in machine mode.

If the access violates the current permission limit, it will trigger an abnormal interrupt. The PMP module includes four groups of 8-bit configuration registers (One group of 32-bit) and four groups of address registers, all of which need to be accessed in machine mode by CSR instruction.

Note: The number of protected areas supported by PMP in different models of microprocessors may be different, and the number supported by pmpcfg and pmpaddr registers is also different. See Table 1-1 for details.

4.1 PMP Register Set

The list of CSR registers supported by PMP module of V3 microprocessor is shown in Table 4-1 below.

Table 4-1 PMP module register set

Name	CSR address	Access	Description	Reset value
pmpcfg0	0x3A0	MRW	PMP configuration register 0	0x00000000
pmpaddr0	0x3B0	MRW	PMP address register 0	0xXXXXXXXX
pmpaddr1	0x3B1	MRW	PMP address register 1	0xXXXXXXXX
pmpaddr2	0x3B2	MRW	PMP address register 2	0xXXXXXXXX
pmpaddr3	0x3B3	MRW	PMP address register 3	0xXXXXXXXX

4.2 pmp<i>cfg Register

pmpcfg is the configuration register of PMP unit, and each register contains four 8-bit pmpcfg fields, corresponding to the configuration of four regions, and pmpcfg represents the configuration value of region i. Its format is shown in the following table 4-2.

Table 4-2 pmpcfg0 register

31 24	23 16	15 8	7 0	
pmp3cfg	pmp2cfg	pmp1cfg	pmp0cfg	pmpcfg0

pmpcfg is used to configure area i, and its bit definition is described in the following table 4-3.

Table 4-3 pmp<i>cfg register

Bit	Name	Description
7	L	Locking is enabled and can be unlocked in machine mode. 0: Not locked; 1: Lock the relevant register.
[6:5]	-	Reserved
[4:3]	A	Address alignment and protection area range selection. 00: OFF (PMP off) 01: TOR (Top alignment protection) 10: NA4 (Fixed four-byte protection) 11: NAPOT ($2^{(G+2)}$ Byte protection, G≥1)

2	X	Executable attribute. 0: No execute permission; 1: Execute permission.
1	W	Writeable attribute. 0: No write permission 1: Write permission.
0	R	Readable attribute 0: No read permission 1: Read permission.

4.3 pmpaddr<i> Register

The pmpaddr register is used to configure the address of area I. The standard definition is under RV32 architecture, which is the encoding of the upper 32 bits of a 34-bit physical address, and its format is shown in the following table 4-4. The whole physical address space of V3 microprocessor is 4G, so the upper two bits of this register are not used.

Table 4-4 pmpaddr<i> register

31	0
address[33:2]	

When NAPOT is selected, the low bit of the address register is also used to indicate the size of the current protection area, as shown in the following table, where 'y' is a bit of the register.

Table 4-5 Relationship table between PMP configuration and address register and protected area

pmpaddr	pmpcfg.A	Matching base address and size
yyyy…yyyy	NA4	With 'yy…yyyy00' as the base address, the 4-byte area is protected.
yyyy…yyy0	NAPOT	With 'yy…yyy000' as the base address, the 8-byte area is protected.
yyyy…yy01	NAPOT	With 'yy…yy0000' as the base address, the 16-byte area is protected.
yyyy…y011	NAPOT	With 'yy…y00000' as the base address, the 32-byte area is protected.
…	…	…
yyy01…111	NAPOT	With 'y0…000000' as the base address, the 2^{31}-byte area is protected.
yy011…111	NAPOT	Protect the entire 2^{32}-byte area.

4.4 Protection Mechanism

X/W/R in pmpcfg is used to set the protection authority of area I, and violation of relevant authority will cause corresponding exception:

(1) When trying to fetch instructions in the PMP area without execution authority, it will cause an instruction fetch access error exception (mcause=1).

(2) When trying to write data in the PMP area without write permission, it will cause an error exception (mcause=7) in the store instruction access.

(3) When trying to read data in the PMP area without read permission, it will cause an abnormal memory access error (mcause=5) for the load instruction.

A in pmpcfg is used to set the protection range and address alignment of region i, and to protect the memory

of A_ADDR ≤ region<i><B_ADDR (both A_ADDR and B_ADDR are required to be aligned in 4 bytes):

(1) If B _ ADDR–A_ADDR = = 2^2, NA4 mode is adopted;

(2) If B _ ADDR - A_ADDR = = $2^{(G+2)}$, G≥1, and a _ addr is $2^{(G+2)}$, the NAPOT method is adopted;

(3) Otherwise, the TOR mode is adopted.

Table 4-6 PMP address matching methods

A value	Name	Description
0b00	OFF	No area to protect
0b01	TOR	Top Aligned Area Protection. Under pmp<i>cfg, $pmpaddr_{i-1}$≤ region<i> <$pmpaddr_i$; $pmpaddr_{i-1}$ = A_ADDR >> 2; $pmpaddr_i$ = B_ADDR >> 2. *Note: If area 0 of PMP is configured as TOR mode (i=0), the lower boundary of the protection area is 0 address, i.e. 0 ≤ addr < pmpaddr0, all within the matching range.*
0b10	NA4	Fixed 4-byte area protection. pmp<i>cfg under pmpaddri as the starting address of the 4-byte pmpaddri = A_ADDR>>2.
0b11	NAPOT	Protect the $2^{(G+2)}$ region with G ≥ 1, when A_ADDR is $2^{(G+2)}$ aligned. pmpaddri = ((A_ADDR|($2^{(G+2)}$-1)) &~(1<<G+1))>>2.

The L bit in pmp<i>cfg is used to lock the PMP entry. After locking, the configuration register pmp<i>cfg and the address register pmpaddr<i> will not be able to be modified. If A in pmp<i>cfg is set to TOR mode, pmpaddr<i-1> will also not be modified. when L is set, the X/W/R permissions defined in pmp<i>cfg are also valid for machine mode, and when L is cleared, X/W/R is only valid for user mode, and L is cleared only after system reset.

QingKe V3 series microprocessors support protection of multiple zones. When the same operation matches multiple zones at the same time, the zone with the smaller number is matched first.

Chapter 5 System Timer (SysTick)

QingKe V3 series microprocessor is designed with a 32-bit or 64-bit counter (SysTick) inside. Its clock source is the system clock or its divide-by-8 frequency; the V3A core in the CH32V103 chip only supports divide-by-8. It can provide time base, timing and measuring time for real-time operating system. Different types of registers involved in the timer have different mapping addresses, as shown in the following tables 5-1 and 5-2.

Table 5-1 V3A SysTick register list

Name	Access address	Description	Reset value
STK_CTLR	0xE000F000	System counter control register	0x00000000
STK_CNTL	0xE000F004	System counter low register	0xXXXXXXXX
STK_CNTH	0xE000F008	System counter high register *Note: Only valid for V3A.*	0xXXXXXXXX
STK_CMPLR	0xE000F00C	System count comparison value low register	0xXXXXXXXX
STK_CMPHR	0xE000F010	System count comparison value high register *Note: Only valid for V3A.*	0xXXXXXXXX
STK_SR	0xE000F014	System counter status register	0x00000000

Table 5-2 V3B/V3C/V3F/V3V SysTick register list

Name	Access address	Description	Reset value
STK_CTLR	0xE000F000	System counter control register	0x00000000
STK_SR	0xE000F004	System counter status register	0x00000000
STK_CNTL	0xE000F008	Low register of system counter	0xXXXXXXXX
STK_CMPLR	0xE000F010	Count comparison value low register	0xXXXXXXXX

Each register is described in detail as follows.

System counter control register (STK_CTLR)

This register applies to V3A/B/C/F/V:

Bit	Name	Access	Description	Reset value
[31:7]	Reserved	RO	Reserved	0
6	CID	RW	Counter assignment core register, which is used to configure the counter to generate interrupt requests to the specified core, and is automatically updated to the core ID of the operation when the counter enable is configured to be valid. *Note: See specific chip for details.*	0
5	INIT	RW1	Counter Initial Value Update: 1: Updates to 0 during upward counting; updates to the comparison value during downward counting. 0: Invalid. *Note: Does not apply to V3A.*	0
4	MODE	RW	Counting mode:	0

			1: Count down; 0: Count up. *Note: Invalid for V3A.*	
3	STRE	RW	Automatic reload count enable bit: 1: Count from 0 again after counting up to the comparison value, and count from the comparison value again after counting down to 0; 0: Continue counting up/down. *Note: Invalid for V3A.*	0
2	STCLK	RW	Counter clock source selection bit: 1: HCLK as time base; 0: HCLK/8 as time base.	0
1	STIE	RW	Counter interrupt enable control bits: 1: Enable counter interrupt; 0: Disable counter interrupt.	0
0	STE	RW	System counter enable control bit. 1: Enable system counter STK; 0: Disable the system counter STK and the counter stops counting.	0

System counter status register (STK_SR)

This register applies to V3B/C/F/V:

Bit	Name	Access	Description	Reset value
31	SWIE	RW	Software interrupt trigger enable (SW): 1: Trigger software interrupt; 0: Turn off the trigger. *Note: This bit must be cleared after entering the software interrupt, otherwise it will always trigger.*	0
[30:1]	Reserved	RO	Reserved	0
0	STK_ISR0	RW	Systick interrupt flags: 1: There is an unprocessed interrupt request for the timer; 0: There is no interrupt request for the timer.	0

Note: Multi-channel system counters may be implemented in different models of chips. For specific interrupt flag width, please refer to chip manual.

This register applies to V3A:

Bit	Name	Access	Description	Reset value
[31:2]	Reserved	RO	Reserved	0
1	STK_ISR0	RW	Systick interrupt flag: 1: An unprocessed interrupt request exists for the timer; 0: No interrupt request exists for the timer. *Note: This bit is not applicable to the CH32V103 chip.*	0

0	SWIE	RW	Software interrupt trigger enable (SWI): 1: Trigger software interrupt; 0: Turn off trigger. *Note: This bit must be cleared to 0 after entering the software interrupt, otherwise it will be triggered all the time.*	0

System counter low register (STK_CNTL)

This register applies to V3A/B/C/F/V:

Bit	Name	Access	Description	Reset value
[31:0]	CNTL	RW	The current counter count value is 32 bits lower. For V3A, this register can be read as 8-bit /16-bit /32-bit, but can only be written as 8-bit, and other models are not limited. *Note: CH32V103 only supports upward counting.*	0xXXXXXXXX

Note: Register STK_CNTL and register STK_CNTH in V3A together constitute a 64-bit system counter.

System counter high register (STK_CNTH)

This register applies to V3A:

Bit	Name	Access	Description	Reset value
[31:0]	CNTH	RW	The current counter count value is 32 bits higher. This register can be read by 8-bit/16-bit/32-bit, but can only be written by 8-bit. *Note: Only valid for V3A. CH32V103 only supports upward counting.*	0xXXXXXXXX

Note: Register STK_CNTL and register STK_CNTH in V3A together constitute a 64-bit system counter.

System count comparison value low register (STK_CMPLR)

This register applies to V3A/B/C/F/V:

Bit	Name	Access	Description	Reset value
[31:0]	CMPL	RW	Set the counter comparison value 32 bits lower. The STK interrupt will be triggered when the count up CMP register value is equal to the CNT counter value or when the count down CNT counter value is zero. For V3A, this register can be read as 8-bit /16-bit /32-bit, but can only be written as 8-bit, and other models are not limited.	0xXXXXXXXX

Note: The register STK_CMPLR and the register STK_CMPHR in V3A together constitute the 64-bit counter comparison value.

System count comparison value high register (STK_CMPHR)

This register applies to V3A:

Bit	Name	Access	Description	Reset value
[31:0]	CMPH	RW	Set the counter comparison value 32 bits higher.	0xXXXXX

			The STK interrupt will be triggered when the count up CMP register value is equal to the CNT counter value or when the count down CNT counter value is zero. This register can be read by 8-bit/16-bit/32-bit, but can only be written by 8-bit. *Note: Only valid for V3A.*	XXX

Note: The register STK_CMPLR and the register STK_CMPHR in V3A together constitute the 64-bit counter comparison value.

Chapter 6 Processor Low-power Settings

QingKe V3 series microprocessors support sleep state via WFI (Wait For Interrupt) instruction to achieve low static power consumption. Together with PFIC's system control register (PFIC_SCTLR), various Sleep modes and WFE instructions can be implemented.

6.1 Enter Sleep

QingKe V3 series microprocessors can go to sleep in two ways, Wait for Interrupt (WFI) and Wait For Event (WFE). The WFI method means that the microprocessor goes to sleep, waits for an interrupt to wake up, and then wakes up to the corresponding interrupt to execute. The WFE method means that the microprocessor goes to sleep, waits for an event to wake up, and wakes up to continue executing the previously stopped program flow.

The standard RISC-V supports WFI instruction, and the WFI command can be executed directly to enter sleep by WFI method. For the WFE method, the WFITOWFE bit in the system control register PFIC_SCTLR is used to control the subsequent WFI commands as WFE processing to achieve the WFE method to enter sleep.

The depth of sleep is controlled according to the SLEEPDEEP bit in PFIC_SCTLR.

- If the SLEEPDEEP in PFIC_SCTLR register is cleared to zero, the microprocessor enters Sleep mode and the internal unit clock is allowed to be turned off except for SysTick and part of the wake-up logic.
- If SLEEPDEEP in the PFIC_SCTLR register is set, the microprocessor enters Deep sleep mode and all cell clocks are allowed to be turned off.

When the microprocessor is in Debug mode, it is not possible to enter any kind of Sleep mode.

6.2 Sleep Wakeup

QingKe V3 series microprocessors can be woken up after sleep due to WFI and WFE in the following ways.

- After the WFI method goes to sleep, it can be awakened by

(1) The microprocessor can be woken up by the interrupt source responded by the interrupt controller. After waking up, the microprocessor executes the interrupt function first.

(2) Enter Sleep mode, debug request can make the microprocessor wake up and enter deep sleep, debug request cannot wake up the microprocessor.

- After the WFE method goes to sleep, the microprocessor can be woken up by the following.

(1) Internal or external events, when there is no need to configure the interrupt controller, wake up and continue to execute the program.

(2) If the SEVONPEND bit in PFIC_SCTLR is configured, the interrupt controller does not enable the interrupt, but when a new interrupt pending signal is generated (the previously generated pending signal does not take effect), it can also make the microprocessor wake up, and the corresponding interrupt pending flag needs to be cleared manually after waking up.

(3) Enter Sleep mode debug request can make the microprocessor wake up and enter deep sleep, debug request cannot wake up the microprocessor.

In addition, the state of the microprocessor after wake-up can be controlled by configuring the SLEEPONEXIT bit in PFIC_SCTLR.

- SLEEPONEXIT is set and the last level interrupt return instruction (mret) will trigger the WFI mode sleep.

- SLEEPONEXIT is cleared with no effect.

Various MCU products equipped with V3 series microprocessors can adopt different sleep modes, turn off different peripherals and clocks, implement different power management policies and wake-up methods according to different configurations of PFIC_SCTLR, and realize various low-power modes.

Chapter 7 Debug Support

QingKe V3 series microprocessors include a hardware debug module that supports complex debugging operations. When the microprocessor is suspended, the debug module can access the microprocessor's GPRs, CSRs, Memory, external devices, etc. through abstract commands, program buffer deployment instructions, etc. The debug module can suspend and resume the microprocessor's operation.

The debug module follows the RISC-V External Debug Support Version0.13.2 specification, detailed documentation can be downloaded from RISC-V International website.

7.1 Debug Module

The debug module inside the microprocessor, capable of performing debug operations issued by the debug host, includes.

- Access to registers through the debug interface
- Reset, suspend and resume the microprocessor through the debug interface
- Read and write memory, instruction registers and external devices through the debug interface
- Deploy multiple arbitrary instructions through the debug interface
- Set software breakpoints through the debug interface
- Set hardware breakpoints through the debug interface
- Support abstract command auto-execution
- Support single-step debugging

Note: V3A does not support hardware breakpoints, V3B hardware breakpoints support instruction address matching, and V3C, V3F hardware breakpoints support instruction address and data address matching.

The internal registers of the debugging module use a 7-bit address code, and the following registers are implemented inside QingKe V3 series microprocessors.

Table 7-1 Debug module register List

Name	Access address	Description
data0	0x04	Data register 0, can be used for temporary storage of data
data1	0x05	Data register 1, can be used for temporary storage of data
dmcontrol	0x10	Debug module control register
dmstatus	0x11	Debug module status register
hartinfo	0x12	Microprocessor status register
abstractcs	0x16	Abstract command status register
command	0x17	Abstract command register
abstractauto	0x18	Abstract command auto-execution
progbuf0-7	0x20-0x27	Instruction cache registers 0-7
haltsum0	0x40	Pause status register
capabi	0x7c	Debugger interface register
config	0x7d	Debugger configuration register
config_pre	0x7e	Debugger pre-configuration registers

The debug host can control the microprocessor's suspend, resume, reset, etc. by configuring the dmcontrol register. The RISC-V standard defines three types of abstract commands: access register, fast access, and

access memory. QingKe V3A microprocessor only supports register access, other models support register and memory access, but not fast access. Access to registers (GPRs, CSRs) and continuous access to memory can be realized by abstract commands.

The debug module implements 8 instruction cache registers progbuf0-7, and the debug host can cache multiple instructions (which can be compressed instructions) to the buffer, and can choose to continue executing the instructions in the instruction cache registers after executing the abstract command, or execute the cached instructions directly. Note that the last instruction in the progbufs needs to be an "ebreak" or "c.ebreak" instruction. Access to storage, peripherals, etc. is also possible through abstract commands and instructions cached in the progbufs.

Each register is described in detail as follows.

Data register 0 (data0)

Bit	Name	Access	Description	Reset Value
[31:0]	data0	RW	Data register 0, used for temporary storage of data	0

Data register 1 (data1)

Bit	Name	Access	Description	Reset Value
[31:0]	data1	RW	Data register 1, used for temporary storage of data	0

Debug module control register (dmcontrol)

This register controls the pause, reset, and resume of the microprocessor. Debug host write data to the corresponding field to achieve pause (haltreq), reset (ndmreset), resume (resumereq).

Bit	Name	Access	Description	Reset Value
31	haltreq	WO	Pause the selected microprocessor, controlled by hartsel. 0: Clear the pause request 1: Send a pause request	0
30	resumereq	W1	Restore the selected microprocessor, controlled by hartsel. 0: Invalid 1: Restore the current microprocessor *Note: Write 1 is valid and the hardware is cleared after the microprocessor is recovered*	0
29	Reserved	RO	Reserved	0
28	ackhavereset	W1	0: Invalid 1: Clear the haverest status bit of the microprocessor	0
[27:18]	Reserved	RO	Reserved	0
[17:16]	hartsel	RW	Microprocessor selection register, fixed value 0. *Note: Valid only for V3F.*	0
[15:2]	Reserve	RO	Reserve	0
1	ndmreset	RW	0: Clear reset 1: Reset the entire system other than the debug module	0

0	dmactive	RW	0: Reset debug module 1: Debug module works properly	0

Debug module status register (dmstatus)

This register is used to indicate the status of the debug module and is a read-only register with the following description of each bit.

Bit	Name	Access	Description	Reset Value
[31:23]	Reserved	RO	Reserved	0
22	impebreak	RO	Fixed value, a value of 1 means that an ebreak instruction is implied after progbuf.	V3A:0 V3B/C/F:1
[21:20]	Reserved	RO	Reserved	0
19	allhavereset	RO	0: Invalid 1: Microprocessor reset	0
18	anyhavereset	RO	0: Invalid 1: Microprocessor reset	0
17	allresumeack	RO	0: Invalid 1: Microprocessor has resumed	0
16	anyresumeack	RO	0: Invalid 1: Microprocessor has resumed	0
15	allnoexit	RO	The selected microprocessor does not exist and is controlled by hartsel 0: No microprocessor is present; 1: Microprocessor is present/optional. *Note: Valid for V3F only.*	0
14	anynoexit	RO	The selected microprocessor does not exist and is controlled by hartsel 0: No microprocessor is present; 1: Microprocessor is present/optional. *Note: Valid for V3F only.*	0
13	allavail	RO	0: Invalid 1: Microprocessor is not available	0
12	anyavail	RO	0: Invalid 1: Microprocessor is not available	0
11	allrunning	RO	0: Invalid 1: Microprocessor is running	0
10	anyrunning	RO	0: Invalid 1: Microprocessor is running	0
9	allhalted	RO	0: Invalid 1: Microprocessor is in suspension	0
8	anyhalted	RO	0: Invalid 1: Microprocessor is in suspension	0
7	authenticated	RO	0: Authentication is required before using the debug module 1: The debugging module has been certified	0x1
[6:4]	Reserved	RO	Reserved	0

[3:0]	version	RO	Debugging system support architecture version 0010: V0.13	0x2

Microprocessor status register (hartinfo)

This register is used to provide information about the microprocessor to the debug host and is a read-only register with each bit described as follows.

Bit	Name	Access	Description	Reset Value
[31:24]	Reserved	RO	Reserved	0
[23:20]	nscratch	RO	Number of dscratch registers supported	0x3
[19:17]	Reserved	RO	Reserved	0
16	dataaccess	RO	0: Data register is mapped to CSR address 1: Data register is mapped to memory address	0x1
[15:12]	datasize	RO	Number of data registers	0x2
[11:0]	dataaddr	RO	The offset address of the data register data0, whose base address is 0xe0000000, is subject to specific reading.	0xXXX

Abstract command control and status registers (abstractcs)

This register is used to indicate the execution of the abstract command. The debug host can read this register to know whether the last abstract command is executed or not, and can check whether an error is generated during the execution of the abstract command and the type of the error, which is described in detail as follows.

Bit	Name	Access	Description	Reset Value
[31:29]	Reserved	RO	Reserved	0
[28:24]	progbufsize	RO	Indicates the number of program buffer program cache registers	0x8
[23:13]	Reserved	RO	Reserved	0
12	busy	RO	0: No abstract command is executing 1: There are abstract commands being executed *Note: After execution, the hardware is cleared.*	0
11	Reserved	RO	Reserved	0
[10:8]	cmder	RW	Abstract command error type 000: No error 001: Abstract command execution to write to command, abstractcs, abstractauto registers or read and write to data and progbuf registers 010: Does not support current abstract command 011: Execution of abstract command with exception 100: The microprocessor is not suspended or unavailable and cannot execute abstract commands 101: Bus error 110: Parity bit error during communication 111: Other errors *Note: Set the corresponding bit to 1 to clear the value.*	0
[7:4]	Reserved	RO	Reserved	0

[3:0]	datacount	RO	Number of data registers	0x2

Abstract command register(command)

Debugging host can access GPRs, CSRs registers and memory by writing different configuration values into the abstract command register.

When accessing the registers, the command register bits are defined as follows.

Bit	Name	Access	Description	Reset Value
[31:24]	cmdtype	WO	Abstract command type 0: Access register; 1: Quick access (not supported); 2: Access to memory.	0
23	Reserved	WO	Reserved	0
[22:20]	aarsize	WO	Access register data bit width 000: 8-bit 001: 16-bit 010: 32-bit 011: 64-bit (not supported) 100: 128-bit (not supported) *Note: When accessing floating-point registers FPRs, only 32-bit access is supported.*	0
19	aarpostincrement	WO	0: No effect 1: Automatically increase the value of regno after accessing the register	0
18	postexec	WO	0: No effect 1：Execute the abstract command and then execute the command in progbuf	0
17	transfer	WO	0: Do not execute the operation specified by write 1: Execute the manipulation specified by write	0
16	write	WO	0: Copy data from the specified register to data0 1: Copy data from data0 register to the specified register	0
[15:0]	regno	WO	Specify access registers 0x0000-0x0fff are CSRs 0x1000-0x101f are GPRs 0x1020-0x103f are FPRs	0

When accessing the memory of, the bits in the command register are defined as follows:

Bit	Name	Access	Description	Reset Value
[31:24]	cmdtype	WO	Abstract command type 0: Access register; 1: Fast access (not supported); 2: Access memory.	0
23	aamvirtual	WO	0: Access physical address; 1: Access virtual address.	0
[22:20]	aamsize	WO	Access memory data bit width	0

			000: 8-bit; 001: 16-bit; 010: 32-bit; 011: 64-bit (not supported); 100: 128-bit (not supported);	
19	aampostincrement	WO	0: No influence; 1: After accessing the memory successfully, increase the address stored in the data1 register by the number of bytes corresponding to the bit width configured by aamsize. Aamsize=0, accessed by byte, data1 plus 1. Aamsize=1, accessed by half-word, data1 plus 2. aamsize=2, accessed by word, data1 plus 4.	0
18	postexec	WO	0: No influence; 1: Execute the command in progbuf after executing the abstract command.	0
17	Reserve	RO	Reserved	0
16	write	WO	0: Read data from the address specified by data1 to data0 1: Write data in data0 to the address specified by data1.	0
[15:14]	target-specific	WO	Definition of reading and writing mode Write: 00, 01: Write directly to the memory; 10: After the data in data0 is OR with the data bits in the memory, the result is written into the memory (Only word access is supported). 11: After the data in data0 is AND with the data bits in the memory, the result is written into the memory (Only word access is supported). Read: 00, 01, 10, 11: Read directly from memory.	0
[13:0]	Reserve	RO	Reserved	0

Abstract command automatic execution register (abstractauto)

This register is used to configure the debugging module. When reading and writing progbufx and datax of the debugging module, the abstract command can be executed again. The description of this register is as follows:

Bit	Name	Access	Description	Reset Value
[31:16]	autoexecprogbuf	RW	If a bit is set, the corresponding reading and writing of progbufx will cause the abstract command in the command register to be executed again. *Note: V3 series is designed with 8 progbufs, corresponding to bits [23:16].*	0
[15:12]	Reserve	RO	Reserved	0

[11:0]	autoexecdata	RW	If a bit is set to 1, the corresponding reading and writing of the datax register will cause the abstract command in the Command register to be executed again. *Note: V3 series is designed with two data registers, corresponding to bits [1:0].*	0

Instruction cache register (progbufx)

This register is used to store arbitrary instructions and deploy corresponding operations, including eight. The V3A type core does not implicitly contain the "ebreak" instruction after progbuf, and the V3B/C/F type core implicitly contains the "ebreak" instruction after progbuf.

Bit	Name	Access	Description	Reset Value
[31:0]	progbuf	RW	Instruction encoding for cache operations, which may include compression instructions	0

Pause status register (haltsum0)

This register is used to indicate whether the microprocessor is suspended or not. Each bit indicates the suspended status of a microprocessor, and when there is only one core, only the lowest bit of this register is used to indicate it.

Bit	Name	Access	Description	Reset Value
[31:1]	Reserved	RO	Reserved	0
0	haltsum0	RO	haltsum0 V3F core suspend state 0: Microprocessor operates normally 1: Microprocessor stop	0

Debug interface register (capabi)

This register is used to obtain information such as protocol and frequency supported by debugging.

Bit	Name	Access	Description	Reset Value
[31:28]	swd_version	RO	1-wire interface version information	1
[27:24]	twd_version	RO	2-wire interface version information	1
[23:18]	SWD_FREQ	RO	1-wire interface sampling clock frequency, 25MHz	25
[17:16]	dmi_info	RO	Debugger support 1/2-wire communication information 00: Dual line only 01: Single line only 11: Single/dual line support	0x3
15	SWD&TWD	RO	Flag bit for both single/two-wire communication support 0: Only single or two-wire communication is supported 1: Both single/two-wire communication is supported	1
[14:11]	Reserved	RO	Reserved	0
10	output_cap	RO	Debugger allows data output	1

[9:0]	Reserved	RO	Reserved	0

Debug interface configuration register (config)

This register is used to configure the debugger 1/2-wire mode, output enable, communication rate and other information. This register does not support direct writing. It is necessary to write the value to the config_pre register first, and then write the configuration password and configuration bit mask to this register. After this register value is written and takes effect.

Bit	Name	Access	Description	Reset Value
[31:16]	config_key	WO	Write configuration password register, write operation takes effect when 0x5aa5 is written	0
15	swdmd	RW	1/2-wire selection register, write 1 to synchronize swdmd_pre register value 1: 2-wire communication; 0: 1-wire communication.	1
[14:11]	Reserved	RO	Reserved	0
10	outen	RW	Debugger output enable, set 1 to allow output data, write 1 to synchronize outen_pre register value 0: Output mask; 1: Output enable.	0
[9:2]	Reserved	RO	Reserved	0
[1:0]	psc1x	RW	Synchronized psc1x_pre register value when writing 11b to the 1-wire communication code element rate selection register 00: 1-wire code element base frequency is 8M; 01: 1-wire code element base frequency is 4M; 10: 1-wire code element base frequency is 25M; 11: 1-wire code element base frequency is 12.5M.	1

Note: 10b and 11b of psc1x bits are unit symbol rates configured differently in different chips and are related to capabi.SWD_FREQ values. See the specific chip manual for details.

Debug interface pre-configuration register (config_pre)

This register is used to pre-configure the debugger single/two-wire mode, output enable, communication rate and other information. When the configuration password is written to this register, the write operation takes effect. The config_pre register and config register need to be configured continuously, and other registers cannot be operated during this period.

Bit	Name	Access	Description	Reset Value
[31:16]	config_key	WO	Write the configuration password register, write 0x5aa5 when the write operation takes effect, after the configuration password is correct, read this register to read 0x5aa5 that the pre-configuration register is written successfully, allowing to write the configuration register, otherwise read this register value is 0, cannot configure the config register.	0
15	swdmd_pre	RW	1/2-wire pre-select register	1

[14:11]	Reserved	RO	Reserved	0
10	outen_pre	RW	Debugger output pre-enable	0
[9:2]	Reserved	RO	Reserved	0
[1:0]	psc1x_pre	RW	1-wire communication symbol rate preselection register	1

In addition to the above-mentioned registers of the debug module, the debug function also involves some CSR registers, mainly the debug control and status register dcsr and the debug instruction pointer dpc, which are described in detail as follows.

Debug control and status register (dcsr)

Bit	Name	Access	Description	Reset Value
[31:28]	xdebugver	DRO	0000: External debugging is not supported 0100: Support standard external debugging 1111: External debugging is supported, but does not meet the specification	0x4
[27:16]	Reserved	DRO	Reserved	0
15	ebreakm	DRW	0: The ebreak command in machine mode behaves as described in the privilege file 1: The ebreak command in machine mode can enter debug mode	0
[14:13]	Reserved	DRO	Reserved	0
12	ebreaku	DRW	0: The ebreak command in user mode behaves as described in the privilege file 1: The ebreak command in user mode can enter debug mode	0
11	stepie	DRW	0: Interrupts are disabled under single-step debugging 1: Enable interrupts under single-step debugging	0
10	Reserved	DRO	Reserved	0
9	stoptime	DRW	0: System timer running in Debug mode 1: System timer stop in Debug mode	0
[8:6]	cause	DRO	Reasons for entering debugging 001: Entering debugging in the form of ebreak command (priority 3) 010: Entering debugging in the form of trigger module (priority 4, the highest) 011: Entering debugging in the form of pause request (priority 1) 100: debugging in the form of single-step debugging (priority 0, the lowest) 101: enter debug mode directly after microprocessor reset (priority 2) Others: Reserved	0
[5:4]	Reserved	DRO	Reserved	0
3	nmi_pend	DRO	Non-maskable interrupt pending status	0

			Note: Valid only for V3F.	
2	step	DRW	0: Turn off single-step debugging 1: Enable single-step debugging	0
[1:0]	prv	DRW	Privilege mode 00: User mode 01: Supervisor mode (not supported) 10: Reserved 11: Machine mode *Note: Record the privileged mode when entering debug mode, the debugger can modify this value to modify the privileged mode when exiting debug*	0

Debug mode program pointer (dpc)

This register is used to store the address of the next instruction to be executed after the microprocessor enters debug mode, and its value is updated with different rules depending on the reason for entering debug. dpc register is described in detail as follows.

Bit	Name	Access	Description	Reset Value
[31:0]	dpc	DRW	Instruction address	0

The rules for updating the registers are shown in the following table.

Enter the debugging method	dpc Update rules
ebreak	Address of the Ebreak instruction
single step	Instruction address of the next instruction of the current instruction
trigger module	Temporarily not supported
halt request	Address of the next instruction to be executed when entering Debug

7.2 Debug Interface

Different from the standard JTAG interface defined by RISC-V, QingKe V3 series microprocessor adopts 1-wire/2-wire serial debug interface and follows WCH debug interface protocol. The debug interface is responsible for the communication between the debug host and the debug module, and realizes the read/write operation of the debug host to the debug module registers. WCH designed WCH_Link and open source its schematic and program binary files, which can be used for debugging all microprocessors of RISC-V architecture.

Refer to WCH Debug Protocol Manual for specific debug interface protocols.

Chapter 8 CSR Register List

The RISC-V architecture defines a number of Control and Status Registers (CSRs) for controlling and recording the operating status of the microprocessor. Some of the CSRs have been introduced in the previous section, and this chapter will detail the CSR registers implemented in the QingKe V3 series microprocessors.

8.1 CSR Register List

Table 8-1 List of Microprocessor CSR Registers

Type	Name	CSR Address	Access	Description
RISC-V Standard CSR	mvendorid	0xF11	MRO	Chip Manufacturer ID Register
	marchid	0xF12	MRO	Architecture number register
	mimpid	0xF13	MRO	Hardware implementation numbering register
	mhartid	0xF14	MRO	Core ID register
	mstatus	0x300	MRW	Status register
	misa	0x301	MRW	Hardware instruction set register
	mtvec	0x305	MRW	Exception base address register
	mscratch	0x340	MRW	Machine mode scratch register
	mepc	0x341	MRW	Exception program pointer register
	mcause	0x342	MRW	Exception cause register
	mtval	0x343	MRW	Exception value register
	pmpcfg<i>	0x3A0+i	MRW	PMP configuration register
	pmpaddr<i>	0x3B0+i	MRW	PMP address register
	tselect	0x7A0	MRW	Debug trigger selection register
	tdata1	0x7A1	MRW	Debug trigger data register 1
	tdata2	0x7A2	MRW	Debug trigger data register 2
	tinfo	0x7A4	MRO	Trigger information register
	dcsr	0x7B0	DRW	Debug control and status registers
	dpc	0x7B1	DRW	Debug mode program pointer register
	dscratch0	0x7B2	DRW	Debug mode scratch register 0
	dscratch1	0x7B3	DRW	Debug mode scratch register 1
	dbgmcu_0	0x7C0	MRW	Debug Register 0
	fflags	0x001	RW	Floating point accumulation exception flag register
	frm	0x002	RW	Floating point rounding mode register
	fcsr	0x003	RW	Floating point control and status register
Vendor defined CSR	gintenr	0x800	URW	Global interrupt enable register
	intsyscr	0x804	URW	Interrupt system control register
	corecfgr	0xBC0	MRW	Microprocessor configuration register
	inestcr	0xBC1	MRW	Interrupt nested control register

Table 8-2 List of RISC-V3V Microprocessor CSR Registers

Type	Name	CSR Address	Access	Description
RISC-V3V CSR	vxsat	0x009	URW	Fixed-point saturation status register
	vxrm	0x00A	URW	Fixed-point rounding register
	vcsr	0x00F	URW	Vector control and status register
	mcount_inhibit	0x320	MRW	Counter mask register
	mcycle	0xB00	MRW	Machine cycle counter register
	minstret	0xB02	MRW	Machine instruction counter register
	ucycle	0xC00	RO	User mode cycle counter register
	uinstret	0xC02	RO	User mode instruction counter register

	vl	0xC20	URO	Element body length register
	vtype	0xC21	URO	Vector data type register
	vlenb	0xC22	URO	Vector register byte length register
	vcontrol	0x805	URW	Custom vector control register
	vppaddr	0x806	URW	Custom vector register stack base address register
	vcause	0x808	URO	Custom vector exception source register
	vtval	0x809	URO	Custom vector exception trap information register

8.2 RISC-V Standard CSR Registers

Chip Vendor ID Register (mvendorid)

Bit	Name	Access	Description	Reset Value
[31:0]	mvendorid	MRO	Chip Manufacturer ID, fixed value 0. *Note: Valid for V3F only.*	0

Architecture number register (marchid)

This register is a read-only register to indicate the current microprocessor hardware architecture number, which is mainly composed of vendor code, architecture code, series code, and version code. Each of them is defined as follows.

Bit	Name	Access	Description	Reset Value
31	Reserved	MRO	Reserved	1
[30:26]	Vender0	MRO	Manufacturer code 0 Fixed to the letter "W" code	0x17
[25:21]	Vender1	MRO	Manufacturer code1 Fixed to the letter "C" code	0x03
[20:16]	Vender2	MRO	Manufacturer code 2 Fixed to the letter "H" code	0x08
15	Reserved	MRO	Reserved	1
[14:10]	Arch	MRO	Architecture code RISC-V architecture is fixed to the letter "V" code	0x16
[9:5]	Serial	MRO	Series code QingKe V3 series, fixed to the number "3"	0x03
[4:0]	Version	MRO	Version code Can be the version "A", "B", "C" and other letters of the code	x

The manufacturer number and version number are alphabetic, and the series number is numeric. The coding table of letters is shown in the following table.

Table 8-3 Alphabetic Mapping Table

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Among them, QingKe V3A microprocessor, the register reads back to 0.

Hardware implementation numbering register (mimpid)

This register is mainly composed of vendor codes, each of which is defined as follows.

Bit	Name	Access	Description	Reset Value
31	Reserved	MRO	Reserved	1
[30:26]	Vender0	MRO	Manufacturer code 0 Fixed to the letter "W" code	0x17
[25:21]	Vender1	MRO	Manufacturer code1 Fixed to the letter "C" code	0x03
[20:16]	Vender2	MRO	Manufacturer code 2 Fixed to the letter "H" code	0x08
15	Reserved	MRO	Reserved	1
[14:8]	Reserved	MRO	Reserved	0
[7:0]	Minor	MRO	Subversion number	0xX

This register is readable in any machine implementation, and in the QingKe V3A series processor, this register reads back to zero.

Core ID register (mhartid)

Bit	Name	Access	Description	Reset Value
[31:0]	mhartid	MRO	Core ID, indicating the core ID number of this core in the chip architecture. *Note: Valid only for V3F.*	0

Machine mode status register (mstatus)

Some fields of this register have already been described above; the bit definitions are as follows:

Bit	Name	Access	Description	Reset Value
31	SD	MRO	Used to mark whether a floating-point instruction is in a dirty state. *Note: Valid only for V3F.*	0
[30:15]	Reserved	MRO	Reserved	0
[14:13]	FS	MRW	Floating-point instruction set state that allows single-precision floating-point instructions(F) to execute when the value is not zero: 00: OFF; 01: Initial; 10: Clean; 11: Dirty. *Note: Valid only for V3F.*	0
[12:11]	MPP	MRW	Privileged mode before entering interrupt	0
[10:9]	VS	MRW	Vector instruction set state, value other than 0 allows vector instruction (V) execution: 00: OFF; 01: Initial; 10: Clean; 11: Dirty.	0
8	Reserved	MRO	Reserved	0

7	MPIE	MRW	Interrupt enable state before entering interrupt	0
[6:4]	Reserved	MRO	Reserved	0
3	MIE	MRW	Machine mode interrupt enable	0
[2:0]	Reserved	MRO	Reserved	0

The MPP field is used to save the privileged mode before entering the exception or interrupt, and is used to restore the privileged mode after exiting the exception or interrupt. MIE is the global interrupt enable bit, and when entering the exception or interrupt, the value of MPIE is updated to the value of MIE, and it should be noted that in the QingKe V3 series microprocessors, The MIE will not be updated to 0 until the last level of nested interrupts to ensure that the interrupt nesting in Machine mode continues to be executed. When an exception or interrupt is exited, the microprocessor reverts to the Machine mode saved by MPP and the MIE is restored to the MPIE value.

QingKe V3 microprocessor supports Machine mode and User mode, if you need to make the microprocessor only work in Machine mode, you can set the MPP to 0x3 in the initialization of the boot file, that is, after returning, it will always remain in Machine mode.

Hardware instruction set register (misa)

This register is used to indicate the architecture of the microprocessor and the supported instruction set extensions, each of which is described as follows.

Bit	Name	Access	Description	Reset Value
[31:30]	MXL	MRO	Machine word length 01:32 10:64 11:128	0x1
[29:26]	Reserved	MRO	Reserved	0
[25:0]	Extensions	MRO	Instruction set extensions	x

The MXL is used to indicate the word length of the microprocessor, QingKe V3 are 32-bit microprocessors, the domain is fixed to 1. Extensions are used to indicate that the microprocessor supports extended instruction set details, each indicates a class of extensions, its detailed description is shown in the following table.

Table 8-4 Instruction Set Extension Details

Bit	Name	Description
0	A	Atomic extension
1	B	Tentatively reserved for Bit-Manipulation extension
2	C	Compressed extension
3	D	Double-precision floating-point extension
4	E	RV32E base ISA
5	F	Single-precision floating-point extension
6	G	Additional standard extensions present
7	H	Hypervisor extension
8	I	RV32I/64I/128I base ISA
9	J	Tentatively reserved for Dynamically Translated Languages extension
10	K	Reserved
11	L	Tentatively reserved for Decimal Floating-Point extension

12	M	Integer Multiply/Divide extension
13	N	User-level interrupts supported
14	O	Reserved
15	P	Tentatively reserved for Packed-SIMD extension
16	Q	Quad-precision floating-point extension
17	R	Reserved
18	S	Supervisor mode implemented
19	T	Tentatively reserved for Transactional Memory extension
20	U	User mode implemented
21	V	Tentatively reserved for Vector extension
22	W	Reserved
23	X	Non-standard extensions present
24	Y	Reserved
25	Z	Reserved

For example, for QingKe V3A microprocessor, the register value is 0x40101105, which means that the supported instruction set architecture is RV32IMAC, and it has User mode implementation.

Machine mode exception base address register (mtvec)

This register is used to store the base address of the exception or interrupt handler and the lower two bits are used to configure the mode and identification method of the vector table as described in Section 3.2.

Machine mode scratch register (mscratch)

Bit	Name	Access	Description	Reset Value
[31:0]	mscratch	MRW	Data storage	0

This register is a 32-bit readable and writable register in machine mode for temporary data storage. For example, when entering an exception or interrupt handler, the user stack pointer SP is stored in this register and the interrupt stack pointer is assigned to the SP register. After exiting the exception or interrupt, restore the value of user stack pointer SP from mscratch. That is, the interrupt stack and user stack can be isolated.

Machine mode exception program pointer register (mepc)

Bit	Name	Access	Description	Reset Value
[31:0]	mepc	MRW	Exception procedure pointer	0

This register is used to save the program pointer when entering an exception or interrupt. It is used to save the instruction PC pointer before entering an exception when an exception or interrupt is generated, and mepc is used as the return address when the exception or interrupt is handled and used for exception or interrupt return. However, it is important to note that.

- When an exception occurs, mepc is updated to the PC value of the instruction currently generating the exception.
- When an interrupt occurs, mepc is updated to the PC value of the next instruction.

When you need to return an exception after processing the exception, you should pay attention to modifying the value of the mepc, and more details can be found in Chapter 2 Exceptions.

Machine mode exception cause register (mcause)

Bit	Name	Access	Description	Reset Value
31	Interrupt	MRW	Interrupt indication field	0

			0: Exception 1: Interruption	
[30:0]	Exception Code	MRW	Exception codes, see Table 2-1 for details	0

This register is mainly used to store the cause of the exception or the interrupt number of the interrupt. Its highest bit is the Interrupt field, which is used to indicate whether the current occurrence is an exception or an interrupt. The lower bit is the exception code, which is used to indicate the specific cause. Its details can be found in Chapter 2 Exceptions.

Machine mode exception value register (mtval)

Bit	Name	Access	Description	Reset Value
[31:0]	mtval	MRW	Exception value	0

This register is used to hold the value that caused the exception when an exception occurs. For details such as the value and time of its storage, please refer to Chapter 2 Exceptions.

PMP configuration register (pmpcfg<i>)

This register is mainly used to configure the physical memory protection unit, and every 8 bits of this register are used to configure the protection of an area. Please refer to Chapter 4 for the detailed definition.

PMP address register (pmpaddr<i>)

This register is mainly used for the address configuration of the physical memory protection unit, which encodes the upper 32 bits of a 34-bit physical address. Please refer to Chapter 4 for the specific configuration method.

Debug trigger select register (tselect)

It is only valid for microprocessors that support hardware breakpoints, and supports 4-channel breakpoints at most, and its lower 2 bits are valid. When configuring each channel breakpoint, you need to select the corresponding channel through this register before configuration.

Bit	Name	Access	Description	Reset Value
[31:2]	Reserved	MRO	Reserved	0
[1:0]	TSELECT	MRW	The breakpoint channel selection register is configured, that is, after the corresponding channel is selected, the tdata1 and tdata2 registers can be operated to configure breakpoint information.	X

Debug trigger data register 2(tdata2)

It is only valid for microprocessors that support hardware breakpoints, and is used to save the matching value of the trigger.

Bit	Name	Access	Description	Reset Value
[31:0]	TDATA2	MRW	Used to save matching values.	X

Trigger information register (tinfo)

Bit	Name	Access	Description	Reset Value
[31:0]	tinfo	MRO	The trigger information register corresponds to the type value of the TDATA1 register, and the	0x4

			type value is 2, and the second bit of tinfo is set to 1.	

Note: This register is only valid for V3F.

Debug control and status register (dcsr)

This register is used to control and record the running state of the debugging mode. Refer to Section 7.1 for details.

Debug mode program pointer register (dpc)

This register is used to store the address of the next instruction to be executed after the microprocessor enters the debugging mode, and its value is different according to the reasons for entering the debugging mode, and the updating rules are also different. Refer to Section 7.1 for detailed description.

Debug trigger data register 1 (tdata1)

Valid only for microprocessors that support hardware breakpoints, microprocessors that support only instruction address and data address breakpoints, where bit TYPE in the tdata1 register has a fixed value of 2 and the other bits meet the definition of mcontrol in the debug standard.

Bit	Name	Access	Description	Reset Value
[31:28]	TYPE	MRO	Breakpoint type definition, mcontrol type.	0x2
27	DMODE	MRO	0: Both machine mode and debug mode can modify the relevant register of the trigger; 1: Debug mode only can modify the relevant register of the trigger.	1
[26:21]	MASKMAX	MRO	When MATCH=1, the maximum exponential power range allowed for matching, i.e., the maximum allowed matching range of 2^{31} bytes.	0x1F
[20:13]	Reserved	MRO	Reserved	0
12	ACTION	MRW	Processing mode when setting breakpoints: 0: Enter breakpoint callback interrupt upon triggering; 1: Enter debug mode upon triggering.	0
[11:8]	Reserved	MRO	Reserved	0
7	MATCH	MRW	Matching strategy configuration: 0: Matches when the trigger value equals TDATA2; 1: Matches when the trigger value matches the high M bits of TDATA2, where M = 31 – N, and N is the index of the first zero in TDATA2 (starting from the least significant bit).	0
6	M	MRW	Trigger enable in M mode: 0: Disable trigger in M mode; 1: Enable trigger in M mode.	0
[5:4]	Reserved	MRO	Reserved	0
3	U	MRW	Trigger enable in U mode: 0: Disable trigger in U mode;	0

			1: Enable trigger in U mode.	
2	EXECUTE	MRW	Instruction read address trigger enable: 0: Disabled; 1: Enabled.	0
1	STORE	MRW	Data write address trigger enable: 0: Disabled; 1: Enabled.	0
0	LOAD	MRW	Data read address trigger enable: 0: Disabled; 1: Enabled.	0

Debug mode scratch register (dscratch0-1)

This group of registers is used for temporary storage of data in Debug mode.

Bit	Name	Access	Description	Reset Value
[31:0]	dscratch	DRW	Debug mode data scratch value	0

Debug register 0 (dbgmcu_0)

Bit	Name	Access	Description	Reset Value
[31:8]	dbg_mode_stop	MRW	The registration module stops working when entering the debugging mode: 1. The registered peripheral stops working when the core enters the debugging mode; 0: The registered peripheral works normally when the core enters debugging mode.	0
[7:0]	dbg_link_stop	MRW	The registered module stops working when you enter the connected debugger: 1: The registered peripheral stops working when you connect the debugger; 0: The registered peripheral works normally when you connect the debugger.	0

Floating-point accumulation exception flag register (fflags)

Bit	Name	Access	Description	Reset Value
[31:5]	Reserved	RO	Reserved	0
[4:0]	FFlags	RW	Accumulated exception flag, used to indicate exceptions that have occurred on floating point arithmetic instructions since the last reset (reset or software clear). name / bit / description NV / 4 / Illegal operation DZ / 3 / Divide by zero OF / 2 / Overflow up UF / 1 / Overflow down	0

			NX | 0 | Imprecise	

Note: This register is valid only for V3F.

Floating-point rounding mode register (frm)

Bit	Name	Access	Description	Reset Value
[31:3]	Reserved	RO	Reserved	0
[2:0]	Frm	RW	Floating-point operation rounding mode register: 000: Round to the nearest value (round to the even direction when it is in the middle value); 001: Round to zero; 010: Round down; 011: Round up; 100: Rounding to the nearest value (rounding to the maximum magnitude when it is in the middle value); 101, 110: Reserved; 111: Dynamic rounding: select the rounding mode according to the configuration value of FRM bit in the instruction.	0

Note: This register is valid only for V3F.

Floating-point control and status register (fcsr)

Bit	Name	Access	Description	Reset Value
[31:8]	Reserved	RO	Reserved	0
[7:5]	Frm	RW	Floating-point operation rounding mode register.	0
[4:0]	FFlags	RW	Cumulative anomaly flag.	0

Note: This register is valid only for V3F.

Fixed-point saturation status register (vxsat)

Bit	Name	Access	Description	Reset Value
[31:1]	Reserved	URW	Reserved	0
0	VXSAT	URW	Fixed-point saturation state register, which	0

			is set to 1 when the result of fixed-point operation must be output as a saturated value.	

Note: This register is valid only for V3V.

Fixed-point rounding register (vxrm)

Bit	Name	Access	Description	Reset Value
[31:2]	Reserved	URW	Reserved	0
[1:0]	VXRM	URW	Fixed-point rounding register for controlling rounding modes in fixed-point operations: 00: Round toward nearest value (rounding toward positive for intermediate values); 01: Round toward nearest value (rounding toward even for intermediate values); 10: Round down; 11: Round toward odd.	0

Note: This register is valid only for V3V.

Vector control and status register (vcsr)

Bit	Name	Access	Description	Reset Value
[31:3]	Reserved	URW	Reserved	0
[2:1]	VXRM	URW	Fixed-point rounding register for controlling rounding modes in fixed-point operations: 00: Round toward nearest value (rounding toward positive for intermediate values); 01: Round toward nearest value (rounding toward even for intermediate values); 10: Round down; 11: Round toward odd.	0
0	VXSAT	URW	Fixed-point saturation state register, which is set to 1 when the result of fixed-point operation must be output as a saturated value.	0

Note: This register is valid only for V3V.

Counter mask register (mcount_inhibit)

Bit	Name	Access	Description	Reset Value
[31:3]	Reserved	MRO	Reserved	0
2	IR	MRW	Instruction counter mask register: 1: Masks the instruction counter; minstret and unstret stop counting; 0: Does not mask the instruction counter; minstret and unstret count normally.	0

1	Reserved	MRO	Reserved	0
0	CY	MRW	Cycle counter mask register: 1: Masks the cycle counter; mcycle and ucycle stop counting; 0: Does not mask the cycle counter; mcycle and ucycle count normally.	0

Note: This register is valid only for V3V.

Machine cycle counter register (mcycle)

Bit	Name	Access	Description	Reset Value
[31:0]	MCYLE	MRW	Machine cycle counter, used to count the clock cycles of machine operation. Counting occurs when the CY bit in the mcount_inhibit register is set to 0. Counting is disabled when the counter is stopped in debug mode.	0

Note: This register is valid only for V3V.

Machine instruction counter register (minstret)

Bit	Name	Access	Description	Reset Value
[31:0]	MINSTRET	MRW	Instruction count register, used to count the number of instructions correctly executed and completed by the machine. Counting occurs when the IR bit in the mcount_inhibit register is set to 0. Counting is disabled when the counter is stopped in debug mode.	0

Note: This register is valid only for V3V.

User mode cycle counter register (ucycle)

Bit	Name	Access	Description	Reset Value
[31:0]	UCYLE	RO	User Mode Cycle Counter, used to count the clock cycles of machine operation. Counting occurs when the CY bit in the mcount_inhibit register is set to 0. Counting is disabled when the counter is stopped in debug mode.	0

Note: 1. User-mode cycle counter; functions identically to the mcycle register and is used to read the number of machine cycles in user mode.

2. This register is only valid for V3V.

User mode instruction counter register (uinstret)

Bit	Name	Access	Description	Reset Value
[31:0]	uinstret	RO	Instruction count register, used to count the number of instructions correctly executed and completed by the machine. Counting occurs when the IR bit in the MCOUNT_INHIBIT register is set to 0. Counting is disabled when the counter is	0

			stopped in debug mode.	

Note: 1. User Mode Instruction Counter, with functionality identical to the minstret register, is used to read the number of instructions correctly executed by the machine in user mode.

2. This register is only valid for V3V.

Element body length register (vl)

Bit	Name	Access	Description	Reset Value
[31:7]	Reserved	URW	Reserved	0
[6:0]	VL	URO	Vector Length Register, used to store the element length employed in operations. The register value can only be modified by the vset instruction. Assignment rules are detailed in the *RISC-V "V" vector Extension 1.0 manual*.	0

Note: This register is valid only for V3V.

Vector data type register (vtype)

Bit	Name	Access	Description	Reset Value
[31:6]	Reserved	URW	Reserved	0
[5:3]	VSEW	URO	Vector width register, which is used to select the widths of vectors and elements. Only the VSET instruction can be configured: 000: 8bit; 001: 16bit; 010: 32bit; 011: 64bit; 1xx: Reserved. Note: configuring eew to 64bit requires enabling the relevant configuration of vcontrol.	0
[2:0]	VLMUL	URO	Vector group allocation register, used to select grouping information for vector operations, configurable only via the VSET instruction: 000: 1; 001: 2; 010: 4; 011: 8; 100: Reserved; 101: 1/8; 110: 1/4; 111: 1/2.	0

Note: This register is valid only for V3V.

Vector register byte length register (vlenb)

Bit	Name	Access	Description	Reset Value
[31:0]	VLENB	URO	Vector register group byte length register, this kernel vector register has a length of 64bit and a byte length of 8, with a fixed value.	0x8

Note: This register is valid only for V3V.

Custom vector control register (vcontrol)

Bit	Name	Access	Description	Reset Value
31	VEC_ILL	URW1C	Vector instruction exception flag, which is set when the vector instruction generates an exception. When NMI_EN register is enabled, the vector exception will enter NMI exception.	0
[30:24]	Reserved	URO	Reserved	0
[23:22]	NEST_INT_PTR	URO	Interrupt nesting depth: 00: No interrupt; 01: Level 1 interrupt nesting; 10: Level 2 interrupt nesting; 11: Level 3 interrupt nesting.	0
[21:20]	VEC_INT_PTR	URW	Vector pipeline interrupt nesting depth: 00: No interrupt; 01: Level 1 interrupt nesting; 10: Level 2 interrupt nesting; 11: Level 3 interrupt nesting. When vector instructions are not used in the interrupt service routine, the vector pipeline interrupt nesting depth retains its previous value.	0
[19:16]	VEC_REG_STATE	URW	Vector register status register, comprising 4 bits corresponding to a maximum vector register status depth of four levels. A value of 1 indicates that the vector register status at the corresponding interrupt depth is in a dirty state, meaning a vector instruction has been executed, resulting in a change to the vector register value.	0
[15:10]	Reserved	URO	Reserved	0
9	VEC_ILL_INFO	URW	Vector exception information save enabled. When set, the VCAUSE and VTVAL registers will store vector exception information.	1
8	Reserved	URO	Reserved, cannot write 0.	1

[7:4]	Reserved	URO	Reserved.	0
3	LSU_WAX_ON	URW	Force write sequence enabled, forces write operations to execute in order of instruction.	1
2	LSU_RAW_ON	URW	Force read sequence enabled, forces read operations to be executed in order of instruction.	1
1	VEC_HW_PP_ABI	URW	Vector register hardware stack protection ABI configuration registers: 1: Call-variant ABI, hardware stack protection for registers V0 and V8-V23; 0: Standard ABI call, hardware stack protection for registers V0-V31. Note: For ABI calls, refer to the RISC-V ABIS SPECIFICATION V1.1.	0
0	VEC_HW_PP_EN	URW	Vector register hardware stack protection enable: 1: Enable vector stack protection; 0: Disable vector stack protection.	0

Note: This register is valid only for V3V.

Custom vector register stack base address register (vppaddr)

Bit	Name	Access	Description	Reset Value
[31:0]	VPPADDR	URW	Vector register stack protection memory address register used to configure the vector register stack protection address. The lower 10 bits are fixed at 0. Memory is 1KB-aligned.	0x20000000

Note: This register is valid only for V3V.

Custom vector exception source register (vcause)

Bit	Name	Access	Description	Reset Value
[31:0]	VCAUSE	URO	Vector exception cause register When VEC_ILL_INFO is enabled, this register stores the cause of vector exceptions. Note: Debug mode causes loss of exception cause information and cannot be used in debug mode.	0

Note: This register is valid only for V3V.

custom vector exception trap information register (vtval)

Bit	Name	Access	Description	Reset Value
[31:0]	VTVAL	URO	Vector instruction self-trap information register	0

			When VEC_ILL_INFO is enabled, this register stores the PC value at the time of the vector exception. Note: Debug mode causes loss of exception cause information and cannot be used in debug mode.	

Note: This register is valid only for V3V.

8.3 User-defined CSR Register

User mode global interrupt enable register (gintenr)

This register is used to control the enable and mask of global interrupt. The enable and mask of global interrupt in machine mode can be controlled by the MIE and MPIE bits in mstatus, but this register cannot be operated in user mode. While the global interrupt enable register gintenr is the mapping of MIE and MPIE in mstatus. In user mode, gintenr can be used to set and clear MIE and MPIE, as described in Section 3.2 for details.

Note: Global interrupts do not include unmasked interrupts NMI and exceptions.

Interrupt system control register (intsyscr)

This register is mainly used to configure interrupt nesting depth, hardware stack pressing and other related functions, as described in Section 3.2 for details.

Microprocessor configuration register (corecfgr)

This register is used to control whether the NMI interrupt is allowed after the interrupt overflows, and whether the interrupt request is cleared when the fence instruction is executed. Please refer to Section 3.2 for the specific definition.

Interrupt nested control register (inestcr)

This register is used to indicate the interrupt nesting state and whether it overflows or not, and to control the maximum nesting level. Please refer to Section 3.2 for the specific definition.

Chapter 9 V3 Series Core Model and Subversion Description

V3B, V3C and V3F versions are mainly used in V3 processors, of which V3C version is the most used.

	V3A	V3B	V3C	V3F
AMO	√	×	×	√
MRS (Shift multiplication custom instruction)	×	√	×	×
Interrupt priority register width	4	2	3	3
PMP	√	×	√	√
LSU_TRIGGER	×	×	√	√

MIMPID is a csr register for recording sub-version information:

mimpid[7:0]=1; CH32M030, CH585 only.

mimpid[7:0]=2; Support software reset (i.e., Interrupt Module FPIC_CFGR register)

Software interrupt (Add STK_CTLR[31] as software interrupt flag bit, same function as STK_SR[31]);

Support interrupt nested enable and mask;

Support preemption priority bit width configuration;

mimpid[7:0]=3; new custom delay instruction;

Support zicond instruction.

Chapter 10 Appendix 1 Delay Instructions

Custom delay instructions are precise delay commands that incur a single instruction overhead. They can delay specified matching instructions with clock-cycle precision, eliminating uncertainties caused by instruction jumps during timer operations or delays. These instructions automatically match instruction codes, configure delay cycles, and apply clock division factors, offering flexible usage. They provide significant advantages in applications requiring precise control, process management, and low-overhead delays.

Delay instruction coding format

Bit	Name	Description
[31:20]	imm	Delay immediate number, depending on configuration, can indicate the number of clock cycles delayed or divided.
[19:15]	rs1	Match rs1 register code.
[14:12]	func3	001b。
[11：9]	match	Matching instruction types; instructions matching types cannot execute while delay persists 000: Reserved; 001: Matches load instructions; 010: Matches store instructions; 011: Matches load/store instructions; 100: Matches delay instructions; 101: Reserved; 110: Matches all instructions (pipeline stalls); 111: Matches instructions with specified func3 and opcode (matching values configured by CSR register).
8	div	Count using the main frequency clock or the divided frequency clock 1: Count using the divided frequency cycle (division factor configured by the CSR register); 0: Count using the main frequency cycle.
7	sel	Number of delay options: 1: rs1+rs2; 0: rs1 + imm.
[6:0]	func7	0001011b.

Note: Read/write instructions using the SP register as the base address are not subject to matching load/store instructions (match=001/010/011).

Delay instruction control register (U_NONS_DLY_0)

CSR address: 0x8C0

Bit	Name	Access	Description	Reset Value
[31:24]	dly_mask	URW	Matching instruction parameter mask when dly instruction match=111.	x
[23:16]	dly_data	URW	The {func, opcode} matched when the dly instruction has match=111.	x

15	CPU_dly_busy_sta	URO	The flag that that core is in a delay state.	0
14	dly_tout	RW1Z	Timeout information, there is no matching instruction request within the delay range.	0
13	dly_ie	URW	Delay interrupt request. If timeout occurs after enabling, a software interrupt request will be generated.	0
12	dly_priv	URW	1: Both machine mode and user mode are permitted to match. 0: Delay operations executed in user mode do not match instructions in machine mode.	0
[11:10]	Reserved	URO	Reserved	0
[9:0]	dly_freq	URW	Delay counting frequency division coefficient configuration, if configured as the main frequency clock frequency, can realize the us unit delay.	x