Qualcomm uC extensions

Version 0.4.0, 2024-11-21

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Licensing and Acknowledgements

This document is in the Frozen state.

Change is extremely unlikely. A high threshold will be used, and a change will only occur because of some truly critical issue being identified during the public review cycle. Any other desired or needed changes can be the subject of a follow-on new extension.

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Versions

This specification documents version 0.4.0 of Xqci.

Version History

Version
0.1.0

State
development

Version
0.2.0

State
development

Changes
- Splits Xqci into sub-extensions based on instruction type
- Removed shXadd instructions in favor of generic shladd

Version
0.3.0

State
development

Changes
- Rename extension and sub extensions to match toolchain guidelines
- Rename mnemonics to match toolchain guidelines
- Ensure every instruction belongs to at least one sub extension

Implies
- Xqcia (0.1.0)
- Xqciac (0.1.0)
- Xqcibi (0.1.0)
- Xqcibm (0.1.0)
- Xqcicli (0.1.0)
- Xqcicm (0.1.0)
- Xqcics (0.1.0)
- Xqcicsr (0.1.0)
- Xqciint (0.1.0)
- Xqcilb (0.1.0)

- Xqcili (0.1.0)
- Xqcilia (0.1.0)
- Xqcilo (0.1.0)
- Xqcilsm (0.1.0)
- Xqcisls (0.1.0)

Version

0.4.0

State

frozen

Changes

- Add information about instruction formats of each instruction
- Fix description and functionality of qc.c.extu instruction
- Fix description and functionality of qc.shladd instruction

Implies

- Xqcia (0.2.0)
- Xqciac (0.2.0)
- Xqcibi (0.2.0)
- Xqcibm (0.2.0)
- Xqcicli (0.2.0)
- Xqcicm (0.2.0)
- Xqcics (0.2.0)
- Xqcicsr (0.2.0)
- Xqciint (0.2.0)
- Xqcilb (0.2.0)
- Xqcili (0.2.0)
- Xqcilia (0.2.0)
- Xqcilo (0.2.0)
- Xqcilsm (0.2.0)
- Xqcisls (0.2.0)

Requires

- Zca, version >= 1.0.0

Chapter 1. Extension description

The Xqci extension includes a set of instructions that improve RISC-V code density and performance in microontrollers. It fills several gaps:

Long immediates

This extension provides wide-immediate versions of loads, stores, branches, jumps, and several arithemtic operations.

Addressing modes

New indexed addressing modes are added for load and store instructions.

Load/store multiple

Xqci adds instructions that load multiple sequential values from memory into multiple registers. Analogous instructions for stores are also included.

Branch immediate instructions

The base RISC-V ISA provides conditional branches that compare two register values. Xqci adds conditional branch instructions that compare an immediate value to a register value, reducing a common code sequence into a single instruction.

Conditional instructions

Xqci includes a variety of conditional select instructions that pick one of two operand values based on the result of a condition and conditional move instructions that either move a value or retain a value in a destination register based on the result of a condition. Conditional select and conditional move instructions help reduce code size and avoid branches in common code sequences.

Extra bit manipulation instructions

Xqci expands upon the standard B extension by adding instructions for bit insertion/extraction, bit set/clear, sign and zero extension, and bit counting instructions.

Fast interrupt instructions

Xqci adds instructions to accelerate interrupt handling, including instructions to quickly enable/disable interrupts and instructions to automatically save an interrupt frame.

Saturating arithemtic

Xqci adds saturating arithmetic instructions to improve performance of fixed-point calculations.

Xqci adds 16, 32, and 48-bit instruction encodings. The 16 and 32-bit encodings are allocated in the custom opcode space so as not to conflict with standard RISC-V instructions. The 48-bit instructions follow the guidance for 48-bit instructions in the RISC-V standard, but are not allocated in reserved custom space since no such space has been defined by RISC-V International.

Extension-specific instruction formats

QC.EAI format used for 48-bit instructions that operate on 32-bit immediate argument.

Field	Start bit	Width	Description
opcode	0	7	Opcode field of 48-bit instructions is 0x1F
rd	7	5	Destination register
func3	12	3	Function field identifying instruction group
f1	15	1	Secondary function field
imm[31:0]	16	32	Immediate operand of 32 bits

QC.EI format used for 48-bit instructions that operate on 26-bit immediate argument, including loads.

Field	Start bit	Width	Description
opcode	0	7	Opcode field of 48-bit instructions is 0x1F
rd	7	5	Destination register
func3	12	3	Function field identifying instruction group
rs1	15	5	Register argument
imm[9:0]	20	10	Immediate operand of 26 bits, the 10 LSBs
func2	30	2	Secondary function field
imm[25:10]	32	16	Immediate operand of 26 bits, the 16 MSBs

QC.EB format used for 48-bit branch instructions that compare register with 16-bit immediate.

Field	Start bit	Width	Description
opcode	0	7	Opcode field of 48-bit instructions is 0x1F
imm[4:1,11]	7	5	Bits of immediate value of branch target
func3	12	3	Function field identifying instruction group
rs1	15	5	Register argument
func5	20	5	Secondary function field
imm[12,10:5]	25	7	Bits of immediate value of branch target
simm[15:0]	32	16	Immediate operand of 16 bits to compare with register

QC.EJ format used for 48-bit jump/call instructions with 32-bit immediate target address.

Field	Start bit	Width	Description
opcode	0	7	Opcode field of 48-bit instructions is 0x1F
imm[4:1,11]	7	5	Bits of immediate value of branch target
func3	12	3	Function field identifying instruction group
func2	15	2	Secondary function field
imm[15:13]	17	3	Bits of immediate value of branch target
func5	20	5	Secondary function field
imm[12,10:5]	25	7	Bits of immediate value of branch target
imm[31:16]	32	16	The 16 MSBs of immediate value of branch target

QC.ES format used for 48-bit store instructions with 26-bit immediate offset.

Field	Start bit	Width	Description
opcode	0	7	Opcode field of 48-bit instructions is 0x1F
imm[4:0]	7	5	Immediate operand of 26 bits offset, the 5 LSBs
func3	12	3	Function field identifying instruction group
rs1	15	5	Register argument used as base address
rs2	20	5	Register argument to be saved
imm[9:5]	25	5	Immediate operand of 26 bits offset, the 5 bits
func2	30	2	Secondary function field
imm[25:10]	32	16	Immediate operand of 26 bits offset, the 16 MSBs

1.1. Sub-extensions

Xqci defines the following #{implications.size} sub-extensions:

1.1.1. Xqcia (0.2.0)

The Xqcia extension includes eleven instructions to perform integer arithmetic.

1.1.2. Xqciac (0.2.0)

The Xqciac extension includes three instructions to accelerate common address calculations.

Xqciac requires:

- Zca, version >= 1.0.0

1.1.3. Xqcibi (0.2.0)

The Xqcibi extension includes twelve conditional branch instructions that use an immediate operand for a source.

All instructions in Xqcibi following the same relocation type as standard RISC-V branches in the base architecture (e.g., BEQ, BNE, etc.).

Xqcibi requires:

- Zca, version >= 1.0.0

1.1.4. Xqcibm (0.2.0)

The Xqcibm extension includes thirty eight instructions that perform bit manipulation, include insertion and extraction.

Xqcibm requires:

- Zca, version >= 1.0.0

1.1.5. Xqcicli (0.2.0)

The Xqcicli extension includes twelve instructions that conditionally load an immediate value.

1.1.6. Xqcicm (0.2.0)

The Xqcicm extension includes thirteen conditional move instructions.

Xqcicm requires:

- Zca, version >= 1.0.0

1.1.7. Xqcics (0.2.0)

The Xqcics extension includes eight conditional select instructions.

1.1.8. Xqcicsr (0.2.0)

The Xqcicsr extension contains two instructions to read/write CSR which index is in register and not immediate.

1.1.9. Xqciint (0.2.0)

The Xqciint extension includes eleven instructions to accelerate interrupt servicing by performing common actions during ISR prologue/epilogue.

Xqciint requires:

- Zca, version >= 1.0.0

1.1.10. Xqcilb (0.2.0)

The Xqcilb extension includes two 48-bit instructions to encode a long branch.

Xqcilb requires:

- Zca, version >= 1.0.0

1.1.11. Xqcili (0.2.0)

The Xqcili extension includes a two instructions that load large immediates than is available with the base RISC-V ISA.

1.1.12. Xqcilia (0.2.0)

The Xqcilia extension includes eight 48-bit instructions that perform arithmetic using large immediates.

Xqcilia requires:

- Zca, version >= 1.0.0

1.1.13. Xqcilo (0.2.0)

The Xqcilo extension includes eight 48-bit load/stores instructions that use an offset larger than can be found in the base RISC-V ISA.

Xqcilo requires:

- Zca, version >= 1.0.0

1.1.14. Xqcilsm (0.2.0)

The Xqcilsm extension includes six instructions that transfer multiple values between registers and memory.

1.1.15. Xqcisls (0.2.0)

The Xqcisls extension includes five load and three store instructions with a scaled index addressing mode.

Chapter 2. Instruction summary

The following 134 instructions are added by this extension:

RV32	RV64	Mnemonic	Instruction
✓		`qc.addsat rd, rs1, rs2`	Saturating signed addition
✓		`qc.addusat rd, rs1, rs2`	Saturating unsigned addition
✓		`qc.beqi rs1, imm, offset`	Branch on equal (Immediate)
✓		`qc.bgei rs1, imm, offset`	Branch on greater than or equal (immediate)
✓		`qc.bgeui rs1, imm, offset`	Branch on greater than or equal unsigned (immediate)
✓		`qc.blti rs1, imm, offset`	Branch on less than (immediate)
✓		`qc.bltui rs1, imm, offset`	Branch on less than unsigned (immediate)
✓		`qc.bnei rs1, imm, offset`	Branch on not equal (immediate)
✓		`qc.brev32 rd, rs1`	Reverse bit order
✓		`qc.c.bexti rd, shamt`	Single-Bit extract (Immediate)
✓		`qc.c.bseti rd, shamt`	Single-Bit set (Immediate)
✓		`qc.c.clrint rs1`	Clear interrupt (Register)
✓		`qc.c.di`	Disable interrupts
✓		`qc.c.dir rd`	Disable interrupts (Register)
✓		`qc.c.ei`	Enable interrupts
✓		`qc.c.eir rs1`	Restore interrupts (Register)
✓		`qc.c.extu rd, width`	Extract bits unsigned
✓		`qc.c.mienter.nest`	Machine mode interrupt enter
✓		`qc.c.mienter`	Machine mode interrupt enter
✓		`qc.c.mileaveret`	Machine mode interrupt exit
✓		`qc.c.muladdi rd, rs1, uimm`	Multiply and accumulate (Immediate)
✓		`qc.c.mveqz rd, rs1`	Conditional Move if equal to zero
✓		`qc.c.setint rs1`	Set interrupt (Register)
✓		`qc.clo rd, rs1`	Count leading ones
✓		`qc.clrinti imm`	Clear interrupt (Immediate)
✓		`qc.compress2 rd, rs1`	Bit compression (every 2nd bit)
✓		`qc.compress3 rd, rs1`	Bit compression (every 3rd bit)

✓		qc.csrrwr rd, rs1, rs2	Atomic Read/Write CSR (Register)
✓		qc.csrrwri rd, imm, rs2	Atomic Read/Write CSR (Register) Immediate
✓		qc.cto rd, rs1	Count trailing ones
✓		qc.e.addai rd, imm	Add immediate
✓		qc.e.addi rd, rs1, imm	Add immediate
✓		qc.e.andai rd, imm	And immediate
✓		qc.e.andi rd, rs1, imm	Add immediate
✓		qc.e.beqi rs1, imm, offset	Branch on equal (immediate)
✓		qc.e.bgei rs1, imm, offset	Branch on greater than or equal (immediate)
✓		qc.e.bgeui rs1, imm, offset	Branch on greater than or equal unsigned (immediate)
✓		qc.e.blti rs1, imm, offset	Branch on less than (immediate)
✓		qc.e.bltui rs1, imm, offset	Branch on less than unsigned (immediate)
✓		qc.e.bnei rs1, imm, offset	Branch on not equal (immediate)
✓		qc.e.j imm	Jump
✓		qc.e.jal imm	Jump and link
✓		qc.e.lb rd, imm(rs1)	Load byte
✓		qc.e.lbu rd, imm(rs1)	Load byte unsigned
✓		qc.e.lh rd, imm(rs1)	Load halfword
✓		qc.e.lhu rd, imm(rs1)	Load halfword unsigned
✓		qc.e.li rd, imm	Load immediate large
✓		qc.e.lw rd, imm(rs1)	Load word
✓		qc.e.orai rd, imm	Or immediate
✓		qc.e.ori rd, rs1, imm	Or immediate
✓		qc.e.sb rs2, imm(rs1)	Store byte
✓		qc.e.sh rs2, imm(rs1)	Store halfword
✓		qc.e.sw rs2, imm(rs1)	Store word
✓		qc.e.xorai rd, imm	Exclusive Or immediate
✓		qc.e.xori rd, rs1, imm	Exclusive Or immediate
✓		qc.expand2 rd, rs1	Bit expansion (every 2nd bit)
✓		qc.expand3 rd, rs1	Bit expansion (every 3rd bit)

✓		`qc.ext rd, rs1, width, shamt`	Extract bits signed
✓		`qc.extd rd, rs1, width, shamt`	Extract bits from pair signed (Immediate)
✓		`qc.extdpr rd, rs1, rs2`	Extract bits from pair signed, packed descriptor (Register)
✓		`qc.extdprh rd, rs1, rs2`	Extract bits from pair signed, packed descriptor high part (Register)
✓		`qc.extdr rd, rs1, rs2`	Extract bits from pair signed (Register)
✓		`qc.extdu rd, rs1, width, shamt`	Extract bits from pair unsigned (Immediate)
✓		`qc.extdupr rd, rs1, rs2`	Extract bits from pair unsigned, packed descriptor (Register)
✓		`qc.extduprh rd, rs1, rs2`	Extract bits from pair unsigned, packed descriptor high part (Register)
✓		`qc.extdur rd, rs1, rs2`	Extract bits from pair unsigned (Register)
✓		`qc.extu rd, rs1, width, shamt`	Extract bits unsigned
✓		`qc.insb rd, rs1, width, shamt`	Insert bits (Register)
✓		`qc.insbh rd, rs1, width, shamt`	Insert bits in 64-bit higher part (Register)
✓		`qc.insbhr rd, rs1, rs2`	Insert bits in 64-bit higher part (Register)
✓		`qc.insbi rd, imm, width, shamt`	Insert bits (Immediate)
✓		`qc.insbpr rd, rs1, rs2`	Insert bits, packed descriptor (Register)
✓		`qc.insbprh rd, rs1, rs2`	Insert bits, packed descriptor high part (Register)
✓		`qc.insbr rd, rs1, rs2`	Insert bits (Register)
✓		`qc.insbri rd, rs1, imm`	Insert bits (Immediate)
✓		`qc.li rd, imm`	Load immediate large
✓		`qc.lieq rd, rs1, rs2, simm`	Conditional load immediate if equal (Register)
✓		`qc.lieqi rd, rs1, imm, simm`	Conditional load immediate if equal (Immediate)
✓		`qc.lige rd, rs1, rs2, simm`	Conditional load immediate if great or equal than (Register)
✓		`qc.ligei rd, rs1, imm, simm`	Conditional load immediate if great or equal than (Immediate)

✓		qc.ligeu rd, rs1, rs2, simm	Conditional load immediate if great or equal than unsigned (Register)
✓		qc.ligeui rd, rs1, imm, simm	Conditional load immediate if great or equal than unsigned (Immediate)
✓		qc.lilt rd, rs1, rs2, simm	Conditional load immediate if less than (Register)
✓		qc.lilti rd, rs1, imm, simm	Conditional load immediate if less than (Immediate)
✓		qc.liltu rd, rs1, rs2, simm	Conditional load immediate if less than unsigned (Register)
✓		qc.liltui rd, rs1, imm, simm	Conditional load immediate if less than unsigned (Immediate)
✓		qc.line rd, rs1, rs2, simm	Conditional load immediate if not equal (Register)
✓		qc.linei rd, rs1, imm, simm	Conditional load immediate if not equal (Immediate)
✓		qc.lrb rd, rs1, rs2, shamt	Load indexed byte
✓		qc.lrbu rd, rs1, rs2, shamt	Load indexed unsigned byte
✓		qc.lrh rd, rs1, rs2, shamt	Load indexed halfword
✓		qc.lrhu rd, rs1, rs2, shamt	Load indexed unsigned halfword
✓		qc.lrw rd, rs1, rs2, shamt	Load indexed word
✓		qc.lwm rd, rs2, imm(rs1)	Load word multiple
✓		qc.lwmi rd, length, imm(rs1)	Load word multiple (Immediate)
✓		qc.muladdi rd, rs1, imm	Multiply and accumulate (Immediate)
✓		qc.mveq rd, rs1, rs2, rs3	Conditional move if equal (Register)
✓		qc.mveqi rd, rs1, imm, rs3	Conditional move if equal (Immediate)
✓		qc.mvge rd, rs1, rs2, rs3	Conditional move if great or equal than (Register)
✓		qc.mvgei rd, rs1, imm, rs3	Conditional move if great or equal than (Immediate)
✓		qc.mvgeu rd, rs1, rs2, rs3	Conditional move if great or equal than unsigned (Register)
✓		qc.mvgeui rd, rs1, imm, rs3	Conditional move if great or equal than unsigned (Immediate)
✓		qc.mvlt rd, rs1, rs2, rs3	Conditional move if less than (Register)
✓		qc.mvlti rd, rs1, imm, rs3	Conditional move if less than (Immediate)
✓		qc.mvltu rd, rs1, rs2, rs3	Conditional move if less than unsigned (Register)

✓		qc.mvltui rd, rs1, imm, rs3	Conditional move if less than unsigned (Immediate)
✓		qc.mvne rd, rs1, rs2, rs3	Conditional move if not equal (Register)
✓		qc.mvnei rd, rs1, imm, rs3	Conditional move if not equal (Immediate)
✓		qc.norm rd, rs1	Signed Normalization
✓		qc.normeu rd, rs1	Unsigned Even Normalization
✓		qc.normu rd, rs1	Unsigned Normalization
✓		qc.selecteqi rd, imm, rs2, rs3	Select load immediate or register if equal (Immediate)
✓		qc.selectieq rd, rs1, rs2, simm2	Select load immediate or register if equal (Register)
✓		qc.selectieqi rd, imm, rs2, simm2	Select load immediate or register if equal (Immediate)
✓		qc.selectiieq rd, rs1, simm1, simm2	Select load immediate if equal (Register)
✓		qc.selectiine rd, rs1, simm1, simm2	Select load immediate if not equal (Register)
✓		qc.selectine rd, rs1, rs2, simm2	Select load immediate or register if not equal (Register)
✓		qc.selectinei rd, imm, rs2, simm2	Select load immediate or register if not equal (Immediate)
✓		qc.selectnei rd, imm, rs2, rs3	Select load immediate or register if not equal (Immediate)
✓		qc.setinti imm	Set interrupt (Immediate)
✓		qc.setwm rs3, rs2, imm(rs1)	Set word multiple (Register)
✓		qc.setwmi rs3, length, imm(rs1)	Set word multiple (Immediate)
✓		qc.shladd rs1, rs2, shamt	Shift left and add (immediate)
✓		qc.slasat rd, rs1, rs2	Saturating arithmetic left shift
✓		qc.sllsat rd, rs1, rs2	Saturating logical left shift
✓		qc.srb rs3, rs1, rs2, shamt	Store indexed byte
✓		qc.srh rs3, rs1, rs2, shamt	Store indexed halfword
✓		qc.srw rs3, rs1, rs2, shamt	Store indexed word

✓		qc.subsat rd, rs1, rs2	Saturating signed subtraction
✓		qc.subusat rd, rs1, rs2	Saturating unsigned subtraction
✓		qc.swm rs3, rs2, imm(rs1)	Store word multiple
✓		qc.swmi rs3, length, imm(rs1)	Store word multiple (immediate)
✓		qc.wrap rd, rs1, rs2	Wraparound (Register)
✓		qc.wrapi rd, rs1, imm	Wraparound (Immediate)

2.1. Instructions by sub-extension

Mnemonic	Xqcia	Xqciac	Xqcibi	Xqcibm	Xqcicli	Xqcicm	Xqcics	Xqicsr	Xqciint	Xqcilb	Xqcili	Xqcilia	Xqcilo	Xqcilsm	Xqcisls
qc.addsat	✓														
qc.addusat	✓														
qc.beqi			✓												
qc.bgei			✓												
qc.bgeui			✓												
qc.blti			✓												
qc.bltui			✓												
qc.bnei			✓												
qc.brev32				✓											
qc.c.bexti				✓											
qc.c.bseti				✓											
qc.c.clrint									✓						
qc.c.di									✓						
qc.c.dir									✓						
qc.c.ei									✓						
qc.c.eir									✓						
qc.c.extu				✓											
qc.c.mienter.nest									✓						
qc.c.mienter									✓						

Mnemonic	Xqcia	Xqciac	Xqcibi	Xqcibm	Xqcicli	Xqcicm	Xqcics	Xqcicsr	Xqciint	Xqcilb	Xqcili	Xqcilia	Xqcilo	Xqcilsm	Xqcisls
qc.c.mileaveret									✓						
qc.c.muladdi		✓													
qc.c.mveqz						✓									
qc.c.setint									✓						
qc.clo				✓											
qc.clrinti									✓						
qc.compress2				✓											
qc.compress3				✓											
qc.csrrwr								✓							
qc.csrrwri								✓							
qc.cto				✓											
qc.e.addai												✓			
qc.e.addi												✓			
qc.e.andai												✓			
qc.e.andi												✓			
qc.e.beqi			✓												
qc.e.bgei			✓												
qc.e.bgeui			✓												
qc.e.blti			✓												
qc.e.bltui			✓												
qc.e.bnei			✓												
qc.e.j										✓					
qc.e.jal										✓					
qc.e.lb													✓		
qc.e.lbu													✓		

Mnemonic	Xqcia	Xqciac	Xqcibi	Xqcibm	Xqcicli	Xqcicm	Xqcics	Xqcicsr	Xqciint	Xqcilb	Xqcili	Xqcilia	Xqcilo	Xqcilsm	Xqcisls
qc.e.lh													✓		
qc.e.lhu													✓		
qc.e.li											✓				
qc.e.lw													✓		
qc.e.orai												✓			
qc.e.ori												✓			
qc.e.sb													✓		
qc.e.sh													✓		
qc.e.sw													✓		
qc.e.xorai												✓			
qc.e.xori												✓			
qc.expand2				✓											
qc.expand3				✓											
qc.ext				✓											
qc.extd				✓											
qc.extdpr				✓											
qc.extdprh				✓											
qc.extdr				✓											
qc.extdu				✓											
qc.extdupr				✓											
qc.extduprh				✓											
qc.extdur				✓											
qc.extu				✓											
qc.insb				✓											
qc.insbh				✓											
qc.insbhr				✓											
qc.insbi				✓											

Mnemonic	Xqcia	Xqciac	Xqcibi	Xqcibm	Xqcicli	Xqcicm	Xqcics	Xqcicsr	Xqciint	Xqcilb	Xqcili	Xqcilia	Xqcilo	Xqcilsm	Xqcisls
qc.insbpr				✓											
qc.insbprh				✓											
qc.insbr				✓											
qc.insbri				✓											
qc.li											✓				
qc.lieq					✓										
qc.lieqi					✓										
qc.lige					✓										
qc.ligei					✓										
qc.ligeu					✓										
qc.ligeui					✓										
qc.lilt					✓										
qc.lilti					✓										
qc.liltu					✓										
qc.liltui					✓										
qc.line					✓										
qc.linei					✓										
qc.lrb															✓
qc.lrbu															✓
qc.lrh															✓
qc.lrhu															✓
qc.lrw															✓
qc.lwm														✓	
qc.lwmi														✓	
qc.muladdi		✓													
qc.mveq						✓									
qc.mveqi						✓									
qc.mvge						✓									

Mnemonic	Xqcia	Xqciac	Xqcibi	Xqcibm	Xqcicli	Xqcicm	Xqcics	Xqicsr	Xqciint	Xqcilb	Xqcili	Xqcilia	Xqcilo	Xqcilsm	Xqcisls
qc.mvgei						✓									
qc.mvgeu						✓									
qc.mvgeui						✓									
qc.mvlt						✓									
qc.mvlti						✓									
qc.mvltu						✓									
qc.mvltui						✓									
qc.mvne						✓									
qc.mvnei						✓									
qc.norm	✓														
qc.normeu	✓														
qc.normu	✓														
qc.selecteqi							✓								
qc.selecteq							✓								
qc.selecteqi							✓								
qc.selectieq							✓								
qc.selectine							✓								
qc.selectne							✓								
qc.selectnei							✓								
qc.selectnei							✓								
qc.setinti									✓						
qc.setwm														✓	
qc.setwmi														✓	

Mnemonic	Xqcia	Xqciac	Xqcibi	Xqcibm	Xqcicli	Xqcicm	Xqcics	Xqcicsr	Xqciint	Xqcilb	Xqcili	Xqcilia	Xqcilo	Xqcilsm	Xqcisls
qc.shladd		✓													
qc.slasat	✓														
qc.sllsat	✓														
qc.srb															✓
qc.srh															✓
qc.srw															✓
qc.subsat	✓														
qc.subusat	✓														
qc.swm														✓	
qc.swmi														✓	
qc.wrap	✓														
qc.wrapi	✓														

Chapter 3. CSR summary

The following 17 are added by this extension.

RV32	RV64	CSR	Name
✓		qc_flags	Flags register (Condition Code Register + co-processor flags)
✓		qc_mclicie0	IRQ Enable 0
✓		qc_mclicie1	IRQ Enable 1
✓		qc_mclicie2	IRQ Enable 2
✓		qc_mclicie3	IRQ Enable 3
✓		qc_mclicie4	IRQ Enable 4
✓		qc_mclicie5	IRQ Enable 5
✓		qc_mclicie6	IRQ Enable 6
✓		qc_mclicie7	IRQ Enable 7
✓		qc_mclicip0	IRQ Pending 0
✓		qc_mclicip1	IRQ Pending 1
✓		qc_mclicip2	IRQ Pending 2
✓		qc_mclicip3	IRQ Pending 3
✓		qc_mclicip4	IRQ Pending 4
✓		qc_mclicip5	IRQ Pending 5
✓		qc_mclicip6	IRQ Pending 6
✓		qc_mclicip7	IRQ Pending 7

Chapter 4. Csrs (in alphabetical order)

4.1. qc_flags

Flags register (Condition Code Register + co-processor flags)

Condition Code Register with condition codes, plus a co-processor flags (*e.g.*, to support floating point)

4.1.1. Attributes

CSR Address	0x803
Length	32-bit-bit
Privilege Mode	M

4.1.2. Format

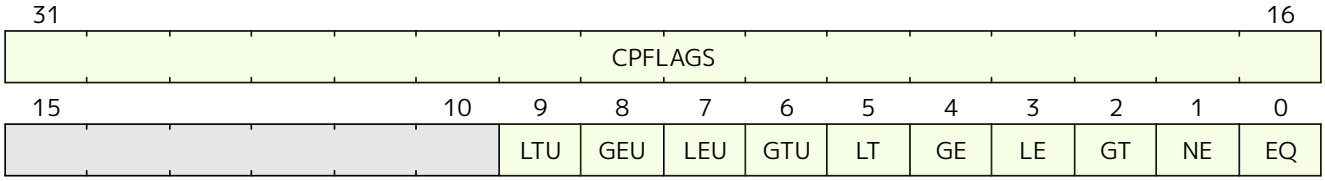


Figure 1. qc_flags format

4.1.3. Field Summary

Name	Location	Type	Reset Value
CPFLAGS	31:16	RW-H	0
LTU	9	RW-H	0
GEU	8	RW-H	0
LEU	7	RW-H	0
GTU	6	RW-H	0
LT	5	RW-H	0
GE	4	RW-H	0
LE	3	RW-H	0
GT	2	RW-H	0
NE	1	RW-H	0
EQ	0	RW-H	0

4.1.4. Fields

CPFLAGS

Location

31:16

Description

Co-Processor FLAGS: comprocessor-dependednt context (used to support floating point, for example)

Type

RW-H

Reset value

0

LTU

Location

9

Description

Less Then (Unsigned) flag

Type

RW-H

Reset value

0

GEU

Location

8

Description

Greater or Equal (Unsigned) flag

Type

RW-H

Reset value

0

LEU

Location
7

Description
Less or Equal (Unsigned) flag

Type
RW-H

Reset value
0

GTU

Location
6

Description
Greater Then (Unsigned) flag

Type
RW-H

Reset value
0

LT

Location
5

Description
Less Then flag

Type
RW-H

Reset value
0

GE

Location
4

Description
Greater or Equal flag

Type
RW-H

Reset value
0

LE

Location
3

Description
Less or Equal flag

Type
RW-H

Reset value
0

GT

Location
2

Description
Greater Than flag

Type
RW-H

Reset value
0

NE

Location

1

Description

Not Equal flag

Type

RW-H

Reset value

0

EQ

Location

0

Description

EQual flag

Type

RW-H

Reset value

0

4.2. qc_mclicie0

IRQ Enable 0

Enable bits for IRQs 0-31

4.2.1. Attributes

CSR Address	0x7f0
Length	32-bit-bit
Privilege Mode	M

4.2.2. Format

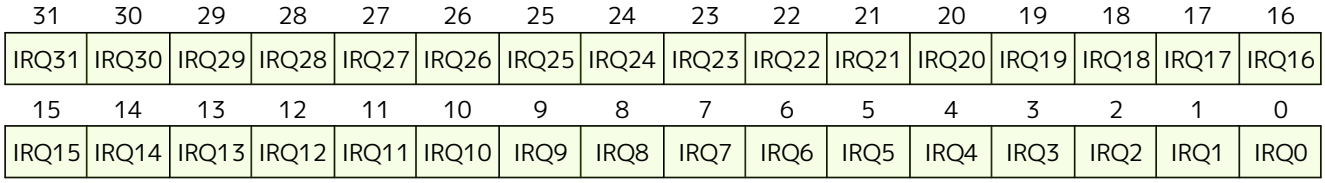


Figure 2. qc_mclicie0 format

4.2.3. Field Summary

Name	Location	Type	Reset Value
IRQ0	0	RW	0
IRQ1	1	RW	0
IRQ2	2	RW	0
IRQ3	3	RW	0
IRQ4	4	RW	0
IRQ5	5	RW	0
IRQ6	6	RW	0
IRQ7	7	RW	0
IRQ8	8	RW	0
IRQ9	9	RW	0
IRQ10	10	RW	0
IRQ11	11	RW	0
IRQ12	12	RW	0
IRQ13	13	RW	0

Name	Location	Type	Reset Value
IRQ14	14	RW	0
IRQ15	15	RW	0
IRQ16	16	RW	0
IRQ17	17	RW	0
IRQ18	18	RW	0
IRQ19	19	RW	0
IRQ20	20	RW	0
IRQ21	21	RW	0
IRQ22	22	RW	0
IRQ23	23	RW	0
IRQ24	24	RW	0
IRQ25	25	RW	0
IRQ26	26	RW	0
IRQ27	27	RW	0
IRQ28	28	RW	0
IRQ29	29	RW	0
IRQ30	30	RW	0
IRQ31	31	RW	0

4.2.4. Fields

IRQ0

Location

0

Description

IRQ0 enabled

Type

RW

Reset value

0

IRQ1

Location
1

Description
IRQ1 enabled

Type
RW

Reset value
0

IRQ2

Location
2

Description
IRQ2 enabled

Type
RW

Reset value
0

IRQ3

Location
3

Description
IRQ3 enabled

Type
RW

Reset value
0

IRQ4

Location
4

Description
IRQ4 enabled

Type
RW

Reset value
0

IRQ5

Location
5

Description
IRQ5 enabled

Type
RW

Reset value
0

IRQ6

Location
6

Description
IRQ6 enabled

Type
RW

Reset value
0

IRQ7

Location
7

Description
IRQ7 enabled

Type
RW

Reset value
0

IRQ8

Location
8

Description
IRQ8 enabled

Type
RW

Reset value
0

IRQ9

Location
9

Description
IRQ9 enabled

Type
RW

Reset value
0

IRQ10

Location
10

Description
IRQ10 enabled

Type
RW

Reset value
0

IRQ11

Location
11

Description
IRQ11 enabled

Type
RW

Reset value
0

IRQ12

Location
12

Description
IRQ12 enabled

Type
RW

Reset value
0

IRQ13

Location
13

Description
IRQ13 enabled

Type
RW

Reset value
0

IRQ14

Location
14

Description
IRQ14 enabled

Type
RW

Reset value
0

IRQ15

Location
15

Description
IRQ15 enabled

Type
RW

Reset value
0

IRQ16

Location
16

Description
IRQ16 enabled

Type
RW

Reset value
0

IRQ17

Location
17

Description
IRQ17 enabled

Type
RW

Reset value
0

IRQ18

Location
18

Description
IRQ18 enabled

Type
RW

Reset value
0

IRQ19

Location
19

Description
IRQ19 enabled

Type
RW

Reset value
0

IRQ20

Location
20

Description
IRQ20 enabled

Type
RW

Reset value
0

IRQ21

Location
21

Description
IRQ21 enabled

Type
RW

Reset value
0

IRQ22

Location
22

Description
IRQ22 enabled

Type
RW

Reset value
0

IRQ23

Location
23

Description
IRQ23 enabled

Type
RW

Reset value
0

IRQ24

Location
24

Description
IRQ24 enabled

Type
RW

Reset value
0

IRQ25

Location
25

Description
IRQ25 enabled

Type
RW

Reset value
0

IRQ26

Location
26

Description
IRQ26 enabled

Type
RW

Reset value
0

IRQ27

Location
27

Description
IRQ27 enabled

Type
RW

Reset value
0

IRQ28

Location
28

Description
IRQ28 enabled

Type
RW

Reset value
0

IRQ29

Location
29

Description
IRQ29 enabled

Type
RW

Reset value
0

IRQ30

Location
30

Description
IRQ30 enabled

Type
RW

Reset value
0

IRQ31

Location

31

Description

IRQ31 enabled

Type

RW

Reset value

0

4.3. qc_mclicie1

IRQ Enable 1

Enable bits for IRQs 32-63

4.3.1. Attributes

CSR Address	0x7f1
Length	32-bit-bit
Privilege Mode	M

4.3.2. Format

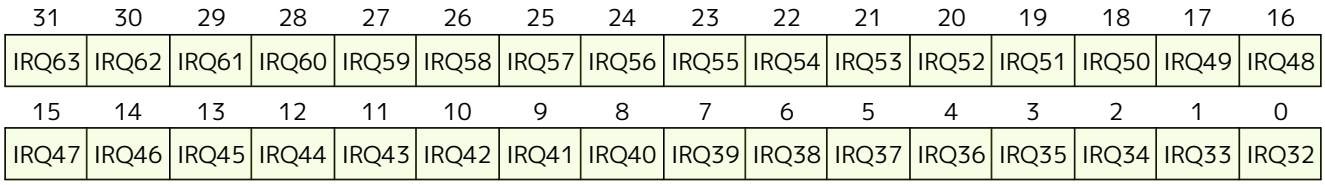


Figure 3. qc_mclicie1 format

4.3.3. Field Summary

Name	Location	Type	Reset Value
IRQ32	0	RW	0
IRQ33	1	RW	0
IRQ34	2	RW	0
IRQ35	3	RW	0
IRQ36	4	RW	0
IRQ37	5	RW	0
IRQ38	6	RW	0
IRQ39	7	RW	0
IRQ40	8	RW	0
IRQ41	9	RW	0
IRQ42	10	RW	0
IRQ43	11	RW	0
IRQ44	12	RW	0
IRQ45	13	RW	0

Name	Location	Type	Reset Value
IRQ46	14	RW	0
IRQ47	15	RW	0
IRQ48	16	RW	0
IRQ49	17	RW	0
IRQ50	18	RW	0
IRQ51	19	RW	0
IRQ52	20	RW	0
IRQ53	21	RW	0
IRQ54	22	RW	0
IRQ55	23	RW	0
IRQ56	24	RW	0
IRQ57	25	RW	0
IRQ58	26	RW	0
IRQ59	27	RW	0
IRQ60	28	RW	0
IRQ61	29	RW	0
IRQ62	30	RW	0
IRQ63	31	RW	0

4.3.4. Fields

IRQ32

Location

0

Description

IRQ32 enabled

Type

RW

Reset value

0

IRQ33

Location
1

Description
IRQ33 enabled

Type
RW

Reset value
0

IRQ34

Location
2

Description
IRQ34 enabled

Type
RW

Reset value
0

IRQ35

Location
3

Description
IRQ35 enabled

Type
RW

Reset value
0

IRQ36

Location
4

Description
IRQ36 enabled

Type
RW

Reset value
0

IRQ37

Location
5

Description
IRQ37 enabled

Type
RW

Reset value
0

IRQ38

Location
6

Description
IRQ38 enabled

Type
RW

Reset value
0

IRQ39

Location
7

Description
IRQ39 enabled

Type
RW

Reset value
0

IRQ40

Location
8

Description
IRQ40 enabled

Type
RW

Reset value
0

IRQ41

Location
9

Description
IRQ41 enabled

Type
RW

Reset value
0

IRQ42

Location
10

Description
IRQ42 enabled

Type
RW

Reset value
0

IRQ43

Location
11

Description
IRQ43 enabled

Type
RW

Reset value
0

IRQ44

Location
12

Description
IRQ44 enabled

Type
RW

Reset value
0

IRQ45

Location
13

Description
IRQ45 enabled

Type
RW

Reset value
0

IRQ46

Location
14

Description
IRQ46 enabled

Type
RW

Reset value
0

IRQ47

Location
15

Description
IRQ47 enabled

Type
RW

Reset value
0

IRQ48

Location
16

Description
IRQ48 enabled

Type
RW

Reset value
0

IRQ49

Location
17

Description
IRQ49 enabled

Type
RW

Reset value
0

IRQ50

Location
18

Description
IRQ50 enabled

Type
RW

Reset value
0

IRQ51

Location
19

Description
IRQ51 enabled

Type
RW

Reset value
0

IRQ52

Location
20

Description
IRQ52 enabled

Type
RW

Reset value
0

IRQ53

Location
21

Description
IRQ53 enabled

Type
RW

Reset value
0

IRQ54

Location
22

Description
IRQ54 enabled

Type
RW

Reset value
0

IRQ55

Location
23

Description
IRQ55 enabled

Type
RW

Reset value
0

IRQ56

Location
24

Description
IRQ56 enabled

Type
RW

Reset value
0

IRQ57

Location
25

Description
IRQ57 enabled

Type
RW

Reset value
0

IRQ58

Location
26

Description
IRQ58 enabled

Type
RW

Reset value
0

IRQ59

Location
27

Description
IRQ59 enabled

Type
RW

Reset value
0

IRQ60

Location
28

Description
IRQ60 enabled

Type
RW

Reset value
0

IRQ61

Location
29

Description
IRQ61 enabled

Type
RW

Reset value
0

IRQ62

Location
30

Description
IRQ62 enabled

Type
RW

Reset value
0

IRQ63

Location

31

Description

IRQ63 enabled

Type

RW

Reset value

0

4.4. qc_mclicie2

IRQ Enable 2

Enable bits for IRQs 64-95

4.4.1. Attributes

CSR Address	0x7f2
Length	32-bit-bit
Privilege Mode	M

4.4.2. Format

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IRQ95	IRQ94	IRQ93	IRQ92	IRQ91	IRQ90	IRQ89	IRQ88	IRQ87	IRQ86	IRQ85	IRQ84	IRQ83	IRQ82	IRQ81	IRQ80
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IRQ79	IRQ78	IRQ77	IRQ76	IRQ75	IRQ74	IRQ73	IRQ72	IRQ71	IRQ70	IRQ69	IRQ68	IRQ67	IRQ66	IRQ65	IRQ64

Figure 4. qc_mclicie2 format

4.4.3. Field Summary

Name	Location	Type	Reset Value
IRQ64	0	RW	0
IRQ65	1	RW	0
IRQ66	2	RW	0
IRQ67	3	RW	0
IRQ68	4	RW	0
IRQ69	5	RW	0
IRQ70	6	RW	0
IRQ71	7	RW	0
IRQ72	8	RW	0
IRQ73	9	RW	0
IRQ74	10	RW	0
IRQ75	11	RW	0
IRQ76	12	RW	0
IRQ77	13	RW	0

Name	Location	Type	Reset Value
IRQ78	14	RW	0
IRQ79	15	RW	0
IRQ80	16	RW	0
IRQ81	17	RW	0
IRQ82	18	RW	0
IRQ83	19	RW	0
IRQ84	20	RW	0
IRQ85	21	RW	0
IRQ86	22	RW	0
IRQ87	23	RW	0
IRQ88	24	RW	0
IRQ89	25	RW	0
IRQ90	26	RW	0
IRQ91	27	RW	0
IRQ92	28	RW	0
IRQ93	29	RW	0
IRQ94	30	RW	0
IRQ95	31	RW	0

4.4.4. Fields

IRQ64

Location

0

Description

IRQ64 enabled

Type

RW

Reset value

0

IRQ65

Location
1

Description
IRQ65 enabled

Type
RW

Reset value
0

IRQ66

Location
2

Description
IRQ66 enabled

Type
RW

Reset value
0

IRQ67

Location
3

Description
IRQ67 enabled

Type
RW

Reset value
0

IRQ68

Location
4

Description
IRQ68 enabled

Type
RW

Reset value
0

IRQ69

Location
5

Description
IRQ69 enabled

Type
RW

Reset value
0

IRQ70

Location
6

Description
IRQ70 enabled

Type
RW

Reset value
0

IRQ71

Location
7

Description
IRQ71 enabled

Type
RW

Reset value
0

IRQ72

Location
8

Description
IRQ72 enabled

Type
RW

Reset value
0

IRQ73

Location
9

Description
IRQ73 enabled

Type
RW

Reset value
0

IRQ74

Location
10

Description
IRQ74 enabled

Type
RW

Reset value
0

IRQ75

Location
11

Description
IRQ75 enabled

Type
RW

Reset value
0

IRQ76

Location
12

Description
IRQ76 enabled

Type
RW

Reset value
0

IRQ77

Location
13

Description
IRQ77 enabled

Type
RW

Reset value
0

IRQ78

Location
14

Description
IRQ78 enabled

Type
RW

Reset value
0

IRQ79

Location
15

Description
IRQ79 enabled

Type
RW

Reset value
0

IRQ80

Location
16

Description
IRQ80 enabled

Type
RW

Reset value
0

IRQ81

Location
17

Description
IRQ81 enabled

Type
RW

Reset value
0

IRQ82

Location
18

Description
IRQ82 enabled

Type
RW

Reset value
0

IRQ83

Location
19

Description
IRQ83 enabled

Type
RW

Reset value
0

IRQ84

Location
20

Description
IRQ84 enabled

Type
RW

Reset value
0

IRQ85

Location
21

Description
IRQ85 enabled

Type
RW

Reset value
0

IRQ86

Location
22

Description
IRQ86 enabled

Type
RW

Reset value
0

IRQ87

Location
23

Description
IRQ87 enabled

Type
RW

Reset value
0

IRQ88

Location
24

Description
IRQ88 enabled

Type
RW

Reset value
0

IRQ89

Location
25

Description
IRQ89 enabled

Type
RW

Reset value
0

IRQ90

Location
26

Description
IRQ90 enabled

Type
RW

Reset value
0

IRQ91

Location
27

Description
IRQ91 enabled

Type
RW

Reset value
0

IRQ92

Location
28

Description
IRQ92 enabled

Type
RW

Reset value
0

IRQ93

Location
29

Description
IRQ93 enabled

Type
RW

Reset value
0

IRQ94

Location
30

Description
IRQ94 enabled

Type
RW

Reset value
0

IRQ95

Location

31

Description

IRQ95 enabled

Type

RW

Reset value

0

4.5. qc_mclicie3

IRQ Enable 3

Enable bits for IRQs 96-127

4.5.1. Attributes

CSR Address	0x7f3
Length	32-bit-bit
Privilege Mode	M

4.5.2. Format

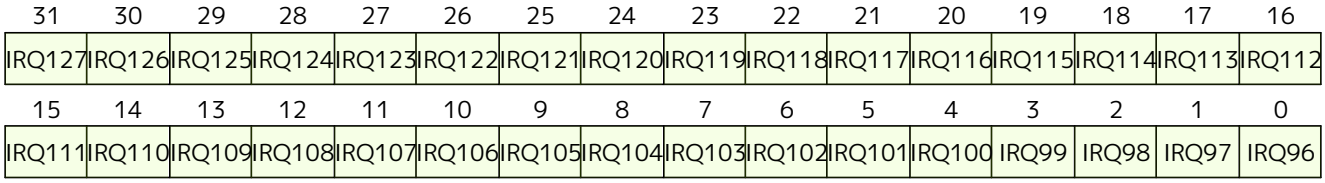


Figure 5. qc_mclicie3 format

4.5.3. Field Summary

Name	Location	Type	Reset Value
IRQ96	0	RW	0
IRQ97	1	RW	0
IRQ98	2	RW	0
IRQ99	3	RW	0
IRQ100	4	RW	0
IRQ101	5	RW	0
IRQ102	6	RW	0
IRQ103	7	RW	0
IRQ104	8	RW	0
IRQ105	9	RW	0
IRQ106	10	RW	0
IRQ107	11	RW	0
IRQ108	12	RW	0
IRQ109	13	RW	0

Name	Location	Type	Reset Value
IRQ110	14	RW	0
IRQ111	15	RW	0
IRQ112	16	RW	0
IRQ113	17	RW	0
IRQ114	18	RW	0
IRQ115	19	RW	0
IRQ116	20	RW	0
IRQ117	21	RW	0
IRQ118	22	RW	0
IRQ119	23	RW	0
IRQ120	24	RW	0
IRQ121	25	RW	0
IRQ122	26	RW	0
IRQ123	27	RW	0
IRQ124	28	RW	0
IRQ125	29	RW	0
IRQ126	30	RW	0
IRQ127	31	RW	0

4.5.4. Fields

IRQ96

Location

0

Description

IRQ96 enabled

Type

RW

Reset value

0

IRQ97

Location
1

Description
IRQ97 enabled

Type
RW

Reset value
0

IRQ98

Location
2

Description
IRQ98 enabled

Type
RW

Reset value
0

IRQ99

Location
3

Description
IRQ99 enabled

Type
RW

Reset value
0

IRQ100

Location
4

Description
IRQ100 enabled

Type
RW

Reset value
0

IRQ101

Location
5

Description
IRQ101 enabled

Type
RW

Reset value
0

IRQ102

Location
6

Description
IRQ102 enabled

Type
RW

Reset value
0

IRQ103

Location
7

Description
IRQ103 enabled

Type
RW

Reset value
0

IRQ104

Location
8

Description
IRQ104 enabled

Type
RW

Reset value
0

IRQ105

Location
9

Description
IRQ105 enabled

Type
RW

Reset value
0

IRQ106

Location
10

Description
IRQ106 enabled

Type
RW

Reset value
0

IRQ107

Location
11

Description
IRQ107 enabled

Type
RW

Reset value
0

IRQ108

Location
12

Description
IRQ108 enabled

Type
RW

Reset value
0

IRQ109

Location
13

Description
IRQ109 enabled

Type
RW

Reset value
0

IRQ110

Location
14

Description
IRQ110 enabled

Type
RW

Reset value
0

IRQ111

Location
15

Description
IRQ111 enabled

Type
RW

Reset value
0

IRQ112

Location
16

Description
IRQ112 enabled

Type
RW

Reset value
0

IRQ113

Location
17

Description
IRQ113 enabled

Type
RW

Reset value
0

IRQ114

Location
18

Description
IRQ114 enabled

Type
RW

Reset value
0

IRQ115

Location
19

Description
IRQ115 enabled

Type
RW

Reset value
0

IRQ116

Location
20

Description
IRQ116 enabled

Type
RW

Reset value
0

IRQ117

Location
21

Description
IRQ117 enabled

Type
RW

Reset value
0

IRQ118

Location
22

Description
IRQ118 enabled

Type
RW

Reset value
0

IRQ119

Location
23

Description
IRQ119 enabled

Type
RW

Reset value
0

IRQ120

Location
24

Description
IRQ120 enabled

Type
RW

Reset value
0

IRQ121

Location
25

Description
IRQ121 enabled

Type
RW

Reset value
0

IRQ122

Location
26

Description
IRQ122 enabled

Type
RW

Reset value
0

IRQ123

Location
27

Description
IRQ123 enabled

Type
RW

Reset value
0

IRQ124

Location
28

Description
IRQ124 enabled

Type
RW

Reset value
0

IRQ125

Location
29

Description
IRQ125 enabled

Type
RW

Reset value
0

IRQ126

Location
30

Description
IRQ126 enabled

Type
RW

Reset value
0

IRQ127

Location

31

Description

IRQ127 enabled

Type

RW

Reset value

0

4.6. qc_mclicie4

IRQ Enable 4

Enable bits for IRQs 128-159

4.6.1. Attributes

CSR Address	0x7f4
Length	32-bit-bit
Privilege Mode	M

4.6.2. Format

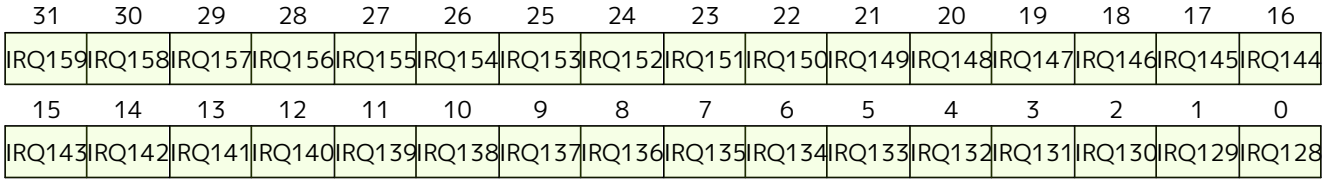


Figure 6. qc_mclicie4 format

4.6.3. Field Summary

Name	Location	Type	Reset Value
IRQ128	0	RW	0
IRQ129	1	RW	0
IRQ130	2	RW	0
IRQ131	3	RW	0
IRQ132	4	RW	0
IRQ133	5	RW	0
IRQ134	6	RW	0
IRQ135	7	RW	0
IRQ136	8	RW	0
IRQ137	9	RW	0
IRQ138	10	RW	0
IRQ139	11	RW	0
IRQ140	12	RW	0
IRQ141	13	RW	0

Name	Location	Type	Reset Value
IRQ142	14	RW	0
IRQ143	15	RW	0
IRQ144	16	RW	0
IRQ145	17	RW	0
IRQ146	18	RW	0
IRQ147	19	RW	0
IRQ148	20	RW	0
IRQ149	21	RW	0
IRQ150	22	RW	0
IRQ151	23	RW	0
IRQ152	24	RW	0
IRQ153	25	RW	0
IRQ154	26	RW	0
IRQ155	27	RW	0
IRQ156	28	RW	0
IRQ157	29	RW	0
IRQ158	30	RW	0
IRQ159	31	RW	0

4.6.4. Fields

IRQ128

Location

0

Description

IRQ128 enabled

Type

RW

Reset value

0

IRQ129

Location
1

Description
IRQ129 enabled

Type
RW

Reset value
0

IRQ130

Location
2

Description
IRQ130 enabled

Type
RW

Reset value
0

IRQ131

Location
3

Description
IRQ131 enabled

Type
RW

Reset value
0

IRQ132

Location
4

Description
IRQ132 enabled

Type
RW

Reset value
0

IRQ133

Location
5

Description
IRQ133 enabled

Type
RW

Reset value
0

IRQ134

Location
6

Description
IRQ134 enabled

Type
RW

Reset value
0

IRQ135

Location
7

Description
IRQ135 enabled

Type
RW

Reset value
0

IRQ136

Location
8

Description
IRQ136 enabled

Type
RW

Reset value
0

IRQ137

Location
9

Description
IRQ137 enabled

Type
RW

Reset value
0

IRQ138

Location
10

Description
IRQ138 enabled

Type
RW

Reset value
0

IRQ139

Location
11

Description
IRQ139 enabled

Type
RW

Reset value
0

IRQ140

Location
12

Description
IRQ140 enabled

Type
RW

Reset value
0

IRQ141

Location
13

Description
IRQ141 enabled

Type
RW

Reset value
0

IRQ142

Location
14

Description
IRQ142 enabled

Type
RW

Reset value
0

IRQ143

Location
15

Description
IRQ143 enabled

Type
RW

Reset value
0

IRQ144

Location
16

Description
IRQ144 enabled

Type
RW

Reset value
0

IRQ145

Location
17

Description
IRQ145 enabled

Type
RW

Reset value
0

IRQ146

Location
18

Description
IRQ146 enabled

Type
RW

Reset value
0

IRQ147

Location
19

Description
IRQ147 enabled

Type
RW

Reset value
0

IRQ148

Location
20

Description
IRQ148 enabled

Type
RW

Reset value
0

IRQ149

Location
21

Description
IRQ149 enabled

Type
RW

Reset value
0

IRQ150

Location
22

Description
IRQ150 enabled

Type
RW

Reset value
0

IRQ151

Location
23

Description
IRQ151 enabled

Type
RW

Reset value
0

IRQ152

Location
24

Description
IRQ152 enabled

Type
RW

Reset value
0

IRQ153

Location
25

Description
IRQ153 enabled

Type
RW

Reset value
0

IRQ154

Location
26

Description
IRQ154 enabled

Type
RW

Reset value
0

IRQ155

Location
27

Description
IRQ155 enabled

Type
RW

Reset value
0

IRQ156

Location
28

Description
IRQ156 enabled

Type
RW

Reset value
0

IRQ157

Location
29

Description
IRQ157 enabled

Type
RW

Reset value
0

IRQ158

Location
30

Description
IRQ158 enabled

Type
RW

Reset value
0

IRQ159

Location

31

Description

IRQ159 enabled

Type

RW

Reset value

0

4.7. qc_mclicie5

IRQ Enable 5

Enable bits for IRQs 160-191

4.7.1. Attributes

CSR Address	0x7f5
Length	32-bit-bit
Privilege Mode	M

4.7.2. Format

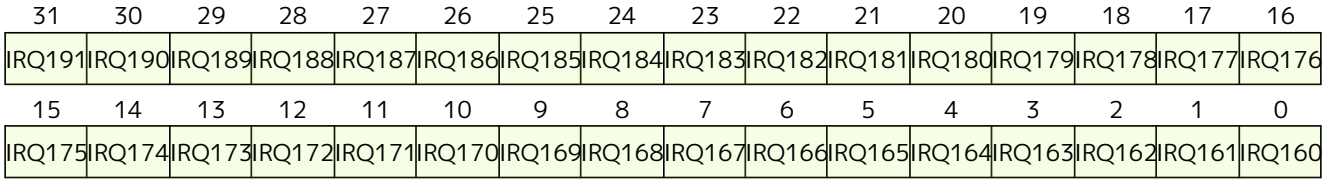


Figure 7. qc_mclicie5 format

4.7.3. Field Summary

Name	Location	Type	Reset Value
IRQ160	0	RW	0
IRQ161	1	RW	0
IRQ162	2	RW	0
IRQ163	3	RW	0
IRQ164	4	RW	0
IRQ165	5	RW	0
IRQ166	6	RW	0
IRQ167	7	RW	0
IRQ168	8	RW	0
IRQ169	9	RW	0
IRQ170	10	RW	0
IRQ171	11	RW	0
IRQ172	12	RW	0
IRQ173	13	RW	0

Name	Location	Type	Reset Value
IRQ174	14	RW	0
IRQ175	15	RW	0
IRQ176	16	RW	0
IRQ177	17	RW	0
IRQ178	18	RW	0
IRQ179	19	RW	0
IRQ180	20	RW	0
IRQ181	21	RW	0
IRQ182	22	RW	0
IRQ183	23	RW	0
IRQ184	24	RW	0
IRQ185	25	RW	0
IRQ186	26	RW	0
IRQ187	27	RW	0
IRQ188	28	RW	0
IRQ189	29	RW	0
IRQ190	30	RW	0
IRQ191	31	RW	0

4.7.4. Fields

IRQ160

Location

0

Description

IRQ160 enabled

Type

RW

Reset value

0

IRQ161

Location
1

Description
IRQ161 enabled

Type
RW

Reset value
0

IRQ162

Location
2

Description
IRQ162 enabled

Type
RW

Reset value
0

IRQ163

Location
3

Description
IRQ163 enabled

Type
RW

Reset value
0

IRQ164

Location
4

Description
IRQ164 enabled

Type
RW

Reset value
0

IRQ165

Location
5

Description
IRQ165 enabled

Type
RW

Reset value
0

IRQ166

Location
6

Description
IRQ166 enabled

Type
RW

Reset value
0

IRQ167

Location
7

Description
IRQ167 enabled

Type
RW

Reset value
0

IRQ168

Location
8

Description
IRQ168 enabled

Type
RW

Reset value
0

IRQ169

Location
9

Description
IRQ169 enabled

Type
RW

Reset value
0

IRQ170

Location
10

Description
IRQ170 enabled

Type
RW

Reset value
0

IRQ171

Location
11

Description
IRQ171 enabled

Type
RW

Reset value
0

IRQ172

Location
12

Description
IRQ172 enabled

Type
RW

Reset value
0

IRQ173

Location
13

Description
IRQ173 enabled

Type
RW

Reset value
0

IRQ174

Location
14

Description
IRQ174 enabled

Type
RW

Reset value
0

IRQ175

Location
15

Description
IRQ175 enabled

Type
RW

Reset value
0

IRQ176

Location
16

Description
IRQ176 enabled

Type
RW

Reset value
0

IRQ177

Location
17

Description
IRQ177 enabled

Type
RW

Reset value
0

IRQ178

Location
18

Description
IRQ178 enabled

Type
RW

Reset value
0

IRQ179

Location
19

Description
IRQ179 enabled

Type
RW

Reset value
0

IRQ180

Location
20

Description
IRQ180 enabled

Type
RW

Reset value
0

IRQ181

Location
21

Description
IRQ181 enabled

Type
RW

Reset value
0

IRQ182

Location
22

Description
IRQ182 enabled

Type
RW

Reset value
0

IRQ183

Location
23

Description
IRQ183 enabled

Type
RW

Reset value
0

IRQ184

Location
24

Description
IRQ184 enabled

Type
RW

Reset value
0

IRQ185

Location
25

Description
IRQ185 enabled

Type
RW

Reset value
0

IRQ186

Location
26

Description
IRQ186 enabled

Type
RW

Reset value
0

IRQ187

Location
27

Description
IRQ187 enabled

Type
RW

Reset value
0

IRQ188

Location
28

Description
IRQ188 enabled

Type
RW

Reset value
0

IRQ189

Location
29

Description
IRQ189 enabled

Type
RW

Reset value
0

IRQ190

Location
30

Description
IRQ190 enabled

Type
RW

Reset value
0

IRQ191

Location

31

Description

IRQ191 enabled

Type

RW

Reset value

0

4.8. qc_mclicie6

IRQ Enable 6

Enable bits for IRQs 192-223

4.8.1. Attributes

CSR Address	0x7f6
Length	32-bit-bit
Privilege Mode	M

4.8.2. Format

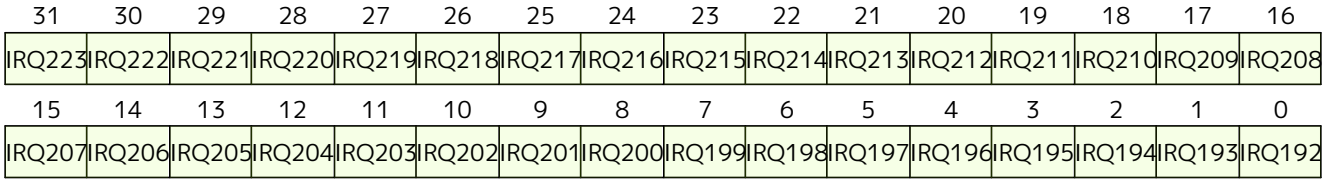


Figure 8. qc_mclicie6 format

4.8.3. Field Summary

Name	Location	Type	Reset Value
IRQ192	0	RW	0
IRQ193	1	RW	0
IRQ194	2	RW	0
IRQ195	3	RW	0
IRQ196	4	RW	0
IRQ197	5	RW	0
IRQ198	6	RW	0
IRQ199	7	RW	0
IRQ200	8	RW	0
IRQ201	9	RW	0
IRQ202	10	RW	0
IRQ203	11	RW	0
IRQ204	12	RW	0
IRQ205	13	RW	0

Name	Location	Type	Reset Value
IRQ206	14	RW	0
IRQ207	15	RW	0
IRQ208	16	RW	0
IRQ209	17	RW	0
IRQ210	18	RW	0
IRQ211	19	RW	0
IRQ212	20	RW	0
IRQ213	21	RW	0
IRQ214	22	RW	0
IRQ215	23	RW	0
IRQ216	24	RW	0
IRQ217	25	RW	0
IRQ218	26	RW	0
IRQ219	27	RW	0
IRQ220	28	RW	0
IRQ221	29	RW	0
IRQ222	30	RW	0
IRQ223	31	RW	0

4.8.4. Fields

IRQ192

Location

0

Description

IRQ192 enabled

Type

RW

Reset value

0

IRQ193

Location
1

Description
IRQ193 enabled

Type
RW

Reset value
0

IRQ194

Location
2

Description
IRQ194 enabled

Type
RW

Reset value
0

IRQ195

Location
3

Description
IRQ195 enabled

Type
RW

Reset value
0

IRQ196

Location
4

Description
IRQ196 enabled

Type
RW

Reset value
0

IRQ197

Location
5

Description
IRQ197 enabled

Type
RW

Reset value
0

IRQ198

Location
6

Description
IRQ198 enabled

Type
RW

Reset value
0

IRQ199

Location
7

Description
IRQ199 enabled

Type
RW

Reset value
0

IRQ200

Location
8

Description
IRQ200 enabled

Type
RW

Reset value
0

IRQ201

Location
9

Description
IRQ201 enabled

Type
RW

Reset value
0

IRQ202

Location
10

Description
IRQ202 enabled

Type
RW

Reset value
0

IRQ203

Location
11

Description
IRQ203 enabled

Type
RW

Reset value
0

IRQ204

Location
12

Description
IRQ204 enabled

Type
RW

Reset value
0

IRQ205

Location
13

Description
IRQ205 enabled

Type
RW

Reset value
0

IRQ206

Location
14

Description
IRQ206 enabled

Type
RW

Reset value
0

IRQ207

Location
15

Description
IRQ207 enabled

Type
RW

Reset value
0

IRQ208

Location
16

Description
IRQ208 enabled

Type
RW

Reset value
0

IRQ209

Location
17

Description
IRQ209 enabled

Type
RW

Reset value
0

IRQ210

Location
18

Description
IRQ210 enabled

Type
RW

Reset value
0

IRQ211

Location
19

Description
IRQ211 enabled

Type
RW

Reset value
0

IRQ212

Location
20

Description
IRQ212 enabled

Type
RW

Reset value
0

IRQ213

Location
21

Description
IRQ213 enabled

Type
RW

Reset value
0

IRQ214

Location
22

Description
IRQ214 enabled

Type
RW

Reset value
0

IRQ215

Location
23

Description
IRQ215 enabled

Type
RW

Reset value
0

IRQ216

Location
24

Description
IRQ216 enabled

Type
RW

Reset value
0

IRQ217

Location
25

Description
IRQ217 enabled

Type
RW

Reset value
0

IRQ218

Location
26

Description
IRQ218 enabled

Type
RW

Reset value
0

IRQ219

Location
27

Description
IRQ219 enabled

Type
RW

Reset value
0

IRQ220

Location
28

Description
IRQ220 enabled

Type
RW

Reset value
0

IRQ221

Location
29

Description
IRQ221 enabled

Type
RW

Reset value
0

IRQ222

Location
30

Description
IRQ222 enabled

Type
RW

Reset value
0

IRQ223

Location

31

Description

IRQ223 enabled

Type

RW

Reset value

0

4.9. qc_mclicie7

IRQ Enable 7

Enable bits for IRQs 224-255

4.9.1. Attributes

CSR Address	0x7f7
Length	32-bit-bit
Privilege Mode	M

4.9.2. Format

Figure 9. qc_mclicie7 format

4.9.3. Field Summary

Name	Location	Type	Reset Value
IRQ224	0	RW	0
IRQ225	1	RW	0
IRQ226	2	RW	0
IRQ227	3	RW	0
IRQ228	4	RW	0
IRQ229	5	RW	0
IRQ230	6	RW	0
IRQ231	7	RW	0
IRQ232	8	RW	0
IRQ233	9	RW	0
IRQ234	10	RW	0
IRQ235	11	RW	0
IRQ236	12	RW	0
IRQ237	13	RW	0

Name	Location	Type	Reset Value
IRQ238	14	RW	0
IRQ239	15	RW	0
IRQ240	16	RW	0
IRQ241	17	RW	0
IRQ242	18	RW	0
IRQ243	19	RW	0
IRQ244	20	RW	0
IRQ245	21	RW	0
IRQ246	22	RW	0
IRQ247	23	RW	0
IRQ248	24	RW	0
IRQ249	25	RW	0
IRQ250	26	RW	0
IRQ251	27	RW	0
IRQ252	28	RW	0
IRQ253	29	RW	0
IRQ254	30	RW	0
IRQ255	31	RW	0

4.9.4. Fields

IRQ224

Location

0

Description

IRQ224 enabled

Type

RW

Reset value

0

IRQ225

Location
1

Description
IRQ225 enabled

Type
RW

Reset value
0

IRQ226

Location
2

Description
IRQ226 enabled

Type
RW

Reset value
0

IRQ227

Location
3

Description
IRQ227 enabled

Type
RW

Reset value
0

IRQ228

Location
4

Description
IRQ228 enabled

Type
RW

Reset value
0

IRQ229

Location
5

Description
IRQ229 enabled

Type
RW

Reset value
0

IRQ230

Location
6

Description
IRQ230 enabled

Type
RW

Reset value
0

IRQ231

Location
7

Description
IRQ231 enabled

Type
RW

Reset value
0

IRQ232

Location
8

Description
IRQ232 enabled

Type
RW

Reset value
0

IRQ233

Location
9

Description
IRQ233 enabled

Type
RW

Reset value
0

IRQ234

Location
10

Description
IRQ234 enabled

Type
RW

Reset value
0

IRQ235

Location
11

Description
IRQ235 enabled

Type
RW

Reset value
0

IRQ236

Location
12

Description
IRQ236 enabled

Type
RW

Reset value
0

IRQ237

Location
13

Description
IRQ237 enabled

Type
RW

Reset value
0

IRQ238

Location
14

Description
IRQ238 enabled

Type
RW

Reset value
0

IRQ239

Location
15

Description
IRQ239 enabled

Type
RW

Reset value
0

IRQ240

Location
16

Description
IRQ240 enabled

Type
RW

Reset value
0

IRQ241

Location
17

Description
IRQ241 enabled

Type
RW

Reset value
0

IRQ242

Location
18

Description
IRQ242 enabled

Type
RW

Reset value
0

IRQ243

Location
19

Description
IRQ243 enabled

Type
RW

Reset value
0

IRQ244

Location
20

Description
IRQ244 enabled

Type
RW

Reset value
0

IRQ245

Location
21

Description
IRQ245 enabled

Type
RW

Reset value
0

IRQ246

Location
22

Description
IRQ246 enabled

Type
RW

Reset value
0

IRQ247

Location
23

Description
IRQ247 enabled

Type
RW

Reset value
0

IRQ248

Location
24

Description
IRQ248 enabled

Type
RW

Reset value
0

IRQ249

Location
25

Description
IRQ249 enabled

Type
RW

Reset value
0

IRQ250

Location
26

Description
IRQ250 enabled

Type
RW

Reset value
0

IRQ251

Location
27

Description
IRQ251 enabled

Type
RW

Reset value
0

IRQ252

Location
28

Description
IRQ252 enabled

Type
RW

Reset value
0

IRQ253

Location
29

Description
IRQ253 enabled

Type
RW

Reset value
0

IRQ254

Location
30

Description
IRQ254 enabled

Type
RW

Reset value
0

IRQ255

Location

31

Description

IRQ255 enabled

Type

RW

Reset value

0

4.10. qc_mclicip0

IRQ Pending 0

Pending bits for IRQs 0-31

4.10.1. Attributes

CSR Address	0x7f0
Length	32-bit-bit
Privilege Mode	M

4.10.2. Format

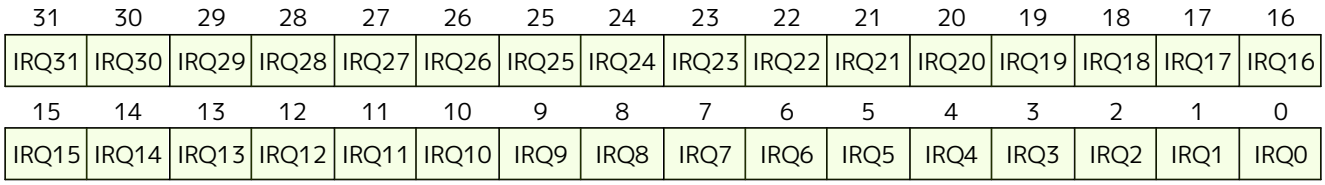


Figure 10. qc_mclicip0 format

4.10.3. Field Summary

Name	Location	Type	Reset Value
IRQ0	0	RW	0
IRQ1	1	RW	0
IRQ2	2	RW	0
IRQ3	3	RW	0
IRQ4	4	RW	0
IRQ5	5	RW	0
IRQ6	6	RW	0
IRQ7	7	RW	0
IRQ8	8	RW	0
IRQ9	9	RW	0
IRQ10	10	RW	0
IRQ11	11	RW	0
IRQ12	12	RW	0
IRQ13	13	RW	0

Name	Location	Type	Reset Value
IRQ14	14	RW	0
IRQ15	15	RW	0
IRQ16	16	RW	0
IRQ17	17	RW	0
IRQ18	18	RW	0
IRQ19	19	RW	0
IRQ20	20	RW	0
IRQ21	21	RW	0
IRQ22	22	RW	0
IRQ23	23	RW	0
IRQ24	24	RW	0
IRQ25	25	RW	0
IRQ26	26	RW	0
IRQ27	27	RW	0
IRQ28	28	RW	0
IRQ29	29	RW	0
IRQ30	30	RW	0
IRQ31	31	RW	0

4.10.4. Fields

IRQ0

Location

0

Description

IRQ0 pending

Type

RW

Reset value

0

IRQ1

Location
1

Description
IRQ1 pending

Type
RW

Reset value
0

IRQ2

Location
2

Description
IRQ2 pending

Type
RW

Reset value
0

IRQ3

Location
3

Description
IRQ3 pending

Type
RW

Reset value
0

IRQ4

Location
4

Description
IRQ4 pending

Type
RW

Reset value
0

IRQ5

Location
5

Description
IRQ5 pending

Type
RW

Reset value
0

IRQ6

Location
6

Description
IRQ6 pending

Type
RW

Reset value
0

IRQ7

Location
7

Description
IRQ7 pending

Type
RW

Reset value
0

IRQ8

Location
8

Description
IRQ8 pending

Type
RW

Reset value
0

IRQ9

Location
9

Description
IRQ9 pending

Type
RW

Reset value
0

IRQ10

Location
10

Description
IRQ10 pending

Type
RW

Reset value
0

IRQ11

Location
11

Description
IRQ11 pending

Type
RW

Reset value
0

IRQ12

Location
12

Description
IRQ12 pending

Type
RW

Reset value
0

IRQ13

Location
13

Description
IRQ13 pending

Type
RW

Reset value
0

IRQ14

Location
14

Description
IRQ14 pending

Type
RW

Reset value
0

IRQ15

Location
15

Description
IRQ15 pending

Type
RW

Reset value
0

IRQ16

Location
16

Description
IRQ16 pending

Type
RW

Reset value
0

IRQ17

Location
17

Description
IRQ17 pending

Type
RW

Reset value
0

IRQ18

Location
18

Description
IRQ18 pending

Type
RW

Reset value
0

IRQ19

Location
19

Description
IRQ19 pending

Type
RW

Reset value
0

IRQ20

Location
20

Description
IRQ20 pending

Type
RW

Reset value
0

IRQ21

Location
21

Description
IRQ21 pending

Type
RW

Reset value
0

IRQ22

Location
22

Description
IRQ22 pending

Type
RW

Reset value
0

IRQ23

Location
23

Description
IRQ23 pending

Type
RW

Reset value
0

IRQ24

Location
24

Description
IRQ24 pending

Type
RW

Reset value
0

IRQ25

Location
25

Description
IRQ25 pending

Type
RW

Reset value
0

IRQ26

Location
26

Description
IRQ26 pending

Type
RW

Reset value
0

IRQ27

Location
27

Description
IRQ27 pending

Type
RW

Reset value
0

IRQ28

Location
28

Description
IRQ28 pending

Type
RW

Reset value
0

IRQ29

Location
29

Description
IRQ29 pending

Type
RW

Reset value
0

IRQ30

Location
30

Description
IRQ30 pending

Type
RW

Reset value
0

IRQ31

Location

31

Description

IRQ31 pending

Type

RW

Reset value

0

4.11. qc_mclicip1

IRQ Pending 1

Pending bits for IRQs 32-63

4.11.1. Attributes

CSR Address	0x7f1
Length	32-bit-bit
Privilege Mode	M

4.11.2. Format

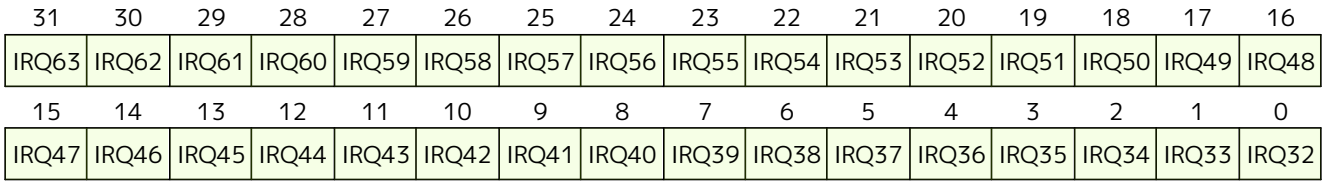


Figure 11. qc_mclicip1 format

4.11.3. Field Summary

Name	Location	Type	Reset Value
IRQ32	0	RW	0
IRQ33	1	RW	0
IRQ34	2	RW	0
IRQ35	3	RW	0
IRQ36	4	RW	0
IRQ37	5	RW	0
IRQ38	6	RW	0
IRQ39	7	RW	0
IRQ40	8	RW	0
IRQ41	9	RW	0
IRQ42	10	RW	0
IRQ43	11	RW	0
IRQ44	12	RW	0
IRQ45	13	RW	0

Name	Location	Type	Reset Value
IRQ46	14	RW	0
IRQ47	15	RW	0
IRQ48	16	RW	0
IRQ49	17	RW	0
IRQ50	18	RW	0
IRQ51	19	RW	0
IRQ52	20	RW	0
IRQ53	21	RW	0
IRQ54	22	RW	0
IRQ55	23	RW	0
IRQ56	24	RW	0
IRQ57	25	RW	0
IRQ58	26	RW	0
IRQ59	27	RW	0
IRQ60	28	RW	0
IRQ61	29	RW	0
IRQ62	30	RW	0
IRQ63	31	RW	0

4.11.4. Fields

IRQ32

Location

0

Description

IRQ32 pending

Type

RW

Reset value

0

IRQ33

Location
1

Description
IRQ33 pending

Type
RW

Reset value
0

IRQ34

Location
2

Description
IRQ34 pending

Type
RW

Reset value
0

IRQ35

Location
3

Description
IRQ35 pending

Type
RW

Reset value
0

IRQ36

Location
4

Description
IRQ36 pending

Type
RW

Reset value
0

IRQ37

Location
5

Description
IRQ37 pending

Type
RW

Reset value
0

IRQ38

Location
6

Description
IRQ38 pending

Type
RW

Reset value
0

IRQ39

Location
7

Description
IRQ39 pending

Type
RW

Reset value
0

IRQ40

Location
8

Description
IRQ40 pending

Type
RW

Reset value
0

IRQ41

Location
9

Description
IRQ41 pending

Type
RW

Reset value
0

IRQ42

Location
10

Description
IRQ42 pending

Type
RW

Reset value
0

IRQ43

Location
11

Description
IRQ43 pending

Type
RW

Reset value
0

IRQ44

Location
12

Description
IRQ44 pending

Type
RW

Reset value
0

IRQ45

Location
13

Description
IRQ45 pending

Type
RW

Reset value
0

IRQ46

Location
14

Description
IRQ46 pending

Type
RW

Reset value
0

IRQ47

Location
15

Description
IRQ47 pending

Type
RW

Reset value
0

IRQ48

Location
16

Description
IRQ48 pending

Type
RW

Reset value
0

IRQ49

Location
17

Description
IRQ49 pending

Type
RW

Reset value
0

IRQ50

Location
18

Description
IRQ50 pending

Type
RW

Reset value
0

IRQ51

Location
19

Description
IRQ51 pending

Type
RW

Reset value
0

IRQ52

Location
20

Description
IRQ52 pending

Type
RW

Reset value
0

IRQ53

Location
21

Description
IRQ53 pending

Type
RW

Reset value
0

IRQ54

Location
22

Description
IRQ54 pending

Type
RW

Reset value
0

IRQ55

Location
23

Description
IRQ55 pending

Type
RW

Reset value
0

IRQ56

Location
24

Description
IRQ56 pending

Type
RW

Reset value
0

IRQ57

Location
25

Description
IRQ57 pending

Type
RW

Reset value
0

IRQ58

Location
26

Description
IRQ58 pending

Type
RW

Reset value
0

IRQ59

Location
27

Description
IRQ59 pending

Type
RW

Reset value
0

IRQ60

Location
28

Description
IRQ60 pending

Type
RW

Reset value
0

IRQ61

Location
29

Description
IRQ61 pending

Type
RW

Reset value
0

IRQ62

Location
30

Description
IRQ62 pending

Type
RW

Reset value
0

IRQ63

Location

31

Description

IRQ63 pending

Type

RW

Reset value

0

4.12. qc_mclicip2

IRQ Pending 2

Pending bits for IRQs 64-95

4.12.1. Attributes

CSR Address	0x7f2
Length	32-bit-bit
Privilege Mode	M

4.12.2. Format

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IRQ95	IRQ94	IRQ93	IRQ92	IRQ91	IRQ90	IRQ89	IRQ88	IRQ87	IRQ86	IRQ85	IRQ84	IRQ83	IRQ82	IRQ81	IRQ80
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IRQ79	IRQ78	IRQ77	IRQ76	IRQ75	IRQ74	IRQ73	IRQ72	IRQ71	IRQ70	IRQ69	IRQ68	IRQ67	IRQ66	IRQ65	IRQ64

Figure 12. qc_mclicip2 format

4.12.3. Field Summary

Name	Location	Type	Reset Value
IRQ64	0	RW	0
IRQ65	1	RW	0
IRQ66	2	RW	0
IRQ67	3	RW	0
IRQ68	4	RW	0
IRQ69	5	RW	0
IRQ70	6	RW	0
IRQ71	7	RW	0
IRQ72	8	RW	0
IRQ73	9	RW	0
IRQ74	10	RW	0
IRQ75	11	RW	0
IRQ76	12	RW	0
IRQ77	13	RW	0

Name	Location	Type	Reset Value
IRQ78	14	RW	0
IRQ79	15	RW	0
IRQ80	16	RW	0
IRQ81	17	RW	0
IRQ82	18	RW	0
IRQ83	19	RW	0
IRQ84	20	RW	0
IRQ85	21	RW	0
IRQ86	22	RW	0
IRQ87	23	RW	0
IRQ88	24	RW	0
IRQ89	25	RW	0
IRQ90	26	RW	0
IRQ91	27	RW	0
IRQ92	28	RW	0
IRQ93	29	RW	0
IRQ94	30	RW	0
IRQ95	31	RW	0

4.12.4. Fields

IRQ64

Location

0

Description

IRQ64 pending

Type

RW

Reset value

0

IRQ65

Location
1

Description
IRQ65 pending

Type
RW

Reset value
0

IRQ66

Location
2

Description
IRQ66 pending

Type
RW

Reset value
0

IRQ67

Location
3

Description
IRQ67 pending

Type
RW

Reset value
0

IRQ68

Location
4

Description
IRQ68 pending

Type
RW

Reset value
0

IRQ69

Location
5

Description
IRQ69 pending

Type
RW

Reset value
0

IRQ70

Location
6

Description
IRQ70 pending

Type
RW

Reset value
0

IRQ71

Location
7

Description
IRQ71 pending

Type
RW

Reset value
0

IRQ72

Location
8

Description
IRQ72 pending

Type
RW

Reset value
0

IRQ73

Location
9

Description
IRQ73 pending

Type
RW

Reset value
0

IRQ74

Location
10

Description
IRQ74 pending

Type
RW

Reset value
0

IRQ75

Location
11

Description
IRQ75 pending

Type
RW

Reset value
0

IRQ76

Location
12

Description
IRQ76 pending

Type
RW

Reset value
0

IRQ77

Location
13

Description
IRQ77 pending

Type
RW

Reset value
0

IRQ78

Location
14

Description
IRQ78 pending

Type
RW

Reset value
0

IRQ79

Location
15

Description
IRQ79 pending

Type
RW

Reset value
0

IRQ80

Location
16

Description
IRQ80 pending

Type
RW

Reset value
0

IRQ81

Location
17

Description
IRQ81 pending

Type
RW

Reset value
0

IRQ82

Location
18

Description
IRQ82 pending

Type
RW

Reset value
0

IRQ83

Location
19

Description
IRQ83 pending

Type
RW

Reset value
0

IRQ84

Location
20

Description
IRQ84 pending

Type
RW

Reset value
0

IRQ85

Location
21

Description
IRQ85 pending

Type
RW

Reset value
0

IRQ86

Location
22

Description
IRQ86 pending

Type
RW

Reset value
0

IRQ87

Location
23

Description
IRQ87 pending

Type
RW

Reset value
0

IRQ88

Location
24

Description
IRQ88 pending

Type
RW

Reset value
0

IRQ89

Location
25

Description
IRQ89 pending

Type
RW

Reset value
0

IRQ90

Location
26

Description
IRQ90 pending

Type
RW

Reset value
0

IRQ91

Location
27

Description
IRQ91 pending

Type
RW

Reset value
0

IRQ92

Location
28

Description
IRQ92 pending

Type
RW

Reset value
0

IRQ93

Location
29

Description
IRQ93 pending

Type
RW

Reset value
0

IRQ94

Location
30

Description
IRQ94 pending

Type
RW

Reset value
0

IRQ95

Location

31

Description

IRQ95 pending

Type

RW

Reset value

0

4.13. qc_mclicip3

IRQ Pending 3

Pending bits for IRQs 96-127

4.13.1. Attributes

CSR Address	0x7f3
Length	32-bit-bit
Privilege Mode	M

4.13.2. Format

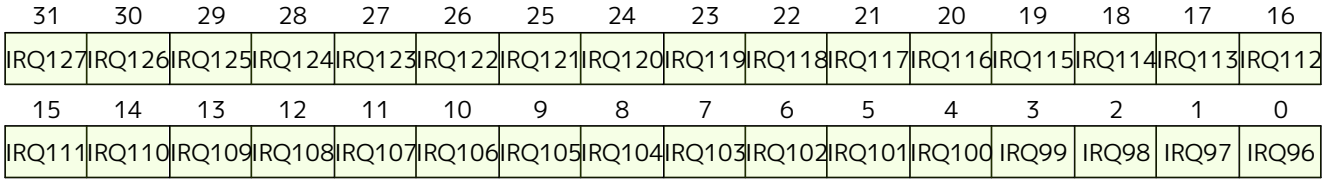


Figure 13. qc_mclicip3 format

4.13.3. Field Summary

Name	Location	Type	Reset Value
IRQ96	0	RW	0
IRQ97	1	RW	0
IRQ98	2	RW	0
IRQ99	3	RW	0
IRQ100	4	RW	0
IRQ101	5	RW	0
IRQ102	6	RW	0
IRQ103	7	RW	0
IRQ104	8	RW	0
IRQ105	9	RW	0
IRQ106	10	RW	0
IRQ107	11	RW	0
IRQ108	12	RW	0
IRQ109	13	RW	0

Name	Location	Type	Reset Value
IRQ110	14	RW	0
IRQ111	15	RW	0
IRQ112	16	RW	0
IRQ113	17	RW	0
IRQ114	18	RW	0
IRQ115	19	RW	0
IRQ116	20	RW	0
IRQ117	21	RW	0
IRQ118	22	RW	0
IRQ119	23	RW	0
IRQ120	24	RW	0
IRQ121	25	RW	0
IRQ122	26	RW	0
IRQ123	27	RW	0
IRQ124	28	RW	0
IRQ125	29	RW	0
IRQ126	30	RW	0
IRQ127	31	RW	0

4.13.4. Fields

IRQ96

Location

0

Description

IRQ96 pending

Type

RW

Reset value

0

IRQ97

Location
1

Description
IRQ97 pending

Type
RW

Reset value
0

IRQ98

Location
2

Description
IRQ98 pending

Type
RW

Reset value
0

IRQ99

Location
3

Description
IRQ99 pending

Type
RW

Reset value
0

IRQ100

Location
4

Description
IRQ100 pending

Type
RW

Reset value
0

IRQ101

Location
5

Description
IRQ101 pending

Type
RW

Reset value
0

IRQ102

Location
6

Description
IRQ102 pending

Type
RW

Reset value
0

IRQ103

Location
7

Description
IRQ103 pending

Type
RW

Reset value
0

IRQ104

Location
8

Description
IRQ104 pending

Type
RW

Reset value
0

IRQ105

Location
9

Description
IRQ105 pending

Type
RW

Reset value
0

IRQ106

Location
10

Description
IRQ106 pending

Type
RW

Reset value
0

IRQ107

Location
11

Description
IRQ107 pending

Type
RW

Reset value
0

IRQ108

Location
12

Description
IRQ108 pending

Type
RW

Reset value
0

IRQ109

Location
13

Description
IRQ109 pending

Type
RW

Reset value
0

IRQ110

Location
14

Description
IRQ110 pending

Type
RW

Reset value
0

IRQ111

Location
15

Description
IRQ111 pending

Type
RW

Reset value
0

IRQ112

Location
16

Description
IRQ112 pending

Type
RW

Reset value
0

IRQ113

Location
17

Description
IRQ113 pending

Type
RW

Reset value
0

IRQ114

Location
18

Description
IRQ114 pending

Type
RW

Reset value
0

IRQ115

Location
19

Description
IRQ115 pending

Type
RW

Reset value
0

IRQ116

Location
20

Description
IRQ116 pending

Type
RW

Reset value
0

IRQ117

Location
21

Description
IRQ117 pending

Type
RW

Reset value
0

IRQ118

Location
22

Description
IRQ118 pending

Type
RW

Reset value
0

IRQ119

Location
23

Description
IRQ119 pending

Type
RW

Reset value
0

IRQ120

Location
24

Description
IRQ120 pending

Type
RW

Reset value
0

IRQ121

Location
25

Description
IRQ121 pending

Type
RW

Reset value
0

IRQ122

Location
26

Description
IRQ122 pending

Type
RW

Reset value
0

IRQ123

Location
27

Description
IRQ123 pending

Type
RW

Reset value
0

IRQ124

Location
28

Description
IRQ124 pending

Type
RW

Reset value
0

IRQ125

Location
29

Description
IRQ125 pending

Type
RW

Reset value
0

IRQ126

Location
30

Description
IRQ126 pending

Type
RW

Reset value
0

IRQ127

Location

31

Description

IRQ127 pending

Type

RW

Reset value

0

4.14. qc_mclicip4

IRQ Pending 4

Pending bits for IRQs 128-159

4.14.1. Attributes

CSR Address	0x7f4
Length	32-bit-bit
Privilege Mode	M

4.14.2. Format

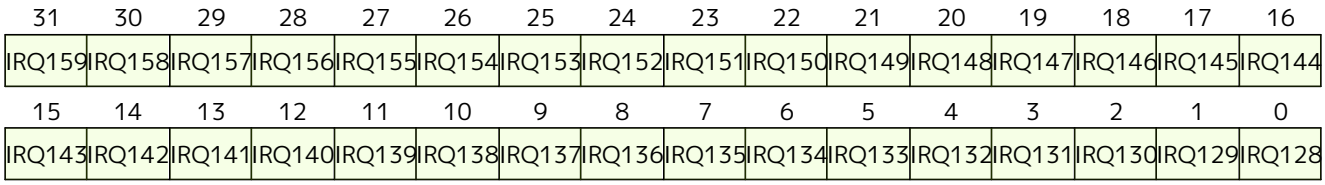


Figure 14. qc_mclicip4 format

4.14.3. Field Summary

Name	Location	Type	Reset Value
IRQ128	0	RW	0
IRQ129	1	RW	0
IRQ130	2	RW	0
IRQ131	3	RW	0
IRQ132	4	RW	0
IRQ133	5	RW	0
IRQ134	6	RW	0
IRQ135	7	RW	0
IRQ136	8	RW	0
IRQ137	9	RW	0
IRQ138	10	RW	0
IRQ139	11	RW	0
IRQ140	12	RW	0
IRQ141	13	RW	0

Name	Location	Type	Reset Value
IRQ142	14	RW	0
IRQ143	15	RW	0
IRQ144	16	RW	0
IRQ145	17	RW	0
IRQ146	18	RW	0
IRQ147	19	RW	0
IRQ148	20	RW	0
IRQ149	21	RW	0
IRQ150	22	RW	0
IRQ151	23	RW	0
IRQ152	24	RW	0
IRQ153	25	RW	0
IRQ154	26	RW	0
IRQ155	27	RW	0
IRQ156	28	RW	0
IRQ157	29	RW	0
IRQ158	30	RW	0
IRQ159	31	RW	0

4.14.4. Fields

IRQ128

Location

0

Description

IRQ128 pending

Type

RW

Reset value

0

IRQ129

Location
1

Description
IRQ129 pending

Type
RW

Reset value
0

IRQ130

Location
2

Description
IRQ130 pending

Type
RW

Reset value
0

IRQ131

Location
3

Description
IRQ131 pending

Type
RW

Reset value
0

IRQ132

Location
4

Description
IRQ132 pending

Type
RW

Reset value
0

IRQ133

Location
5

Description
IRQ133 pending

Type
RW

Reset value
0

IRQ134

Location
6

Description
IRQ134 pending

Type
RW

Reset value
0

IRQ135

Location
7

Description
IRQ135 pending

Type
RW

Reset value
0

IRQ136

Location
8

Description
IRQ136 pending

Type
RW

Reset value
0

IRQ137

Location
9

Description
IRQ137 pending

Type
RW

Reset value
0

IRQ138

Location
10

Description
IRQ138 pending

Type
RW

Reset value
0

IRQ139

Location
11

Description
IRQ139 pending

Type
RW

Reset value
0

IRQ140

Location
12

Description
IRQ140 pending

Type
RW

Reset value
0

IRQ141

Location
13

Description
IRQ141 pending

Type
RW

Reset value
0

IRQ142

Location
14

Description
IRQ142 pending

Type
RW

Reset value
0

IRQ143

Location
15

Description
IRQ143 pending

Type
RW

Reset value
0

IRQ144

Location
16

Description
IRQ144 pending

Type
RW

Reset value
0

IRQ145

Location
17

Description
IRQ145 pending

Type
RW

Reset value
0

IRQ146

Location
18

Description
IRQ146 pending

Type
RW

Reset value
0

IRQ147

Location
19

Description
IRQ147 pending

Type
RW

Reset value
0

IRQ148

Location
20

Description
IRQ148 pending

Type
RW

Reset value
0

IRQ149

Location
21

Description
IRQ149 pending

Type
RW

Reset value
0

IRQ150

Location
22

Description
IRQ150 pending

Type
RW

Reset value
0

IRQ151

Location
23

Description
IRQ151 pending

Type
RW

Reset value
0

IRQ152

Location
24

Description
IRQ152 pending

Type
RW

Reset value
0

IRQ153

Location
25

Description
IRQ153 pending

Type
RW

Reset value
0

IRQ154

Location
26

Description
IRQ154 pending

Type
RW

Reset value
0

IRQ155

Location
27

Description
IRQ155 pending

Type
RW

Reset value
0

IRQ156

Location
28

Description
IRQ156 pending

Type
RW

Reset value
0

IRQ157

Location
29

Description
IRQ157 pending

Type
RW

Reset value
0

IRQ158

Location
30

Description
IRQ158 pending

Type
RW

Reset value
0

IRQ159

Location

31

Description

IRQ159 pending

Type

RW

Reset value

0

4.15. qc_mclicip5

IRQ Pending 5

Pending bits for IRQs 160-191

4.15.1. Attributes

CSR Address	0x7f5
Length	32-bit-bit
Privilege Mode	M

4.15.2. Format

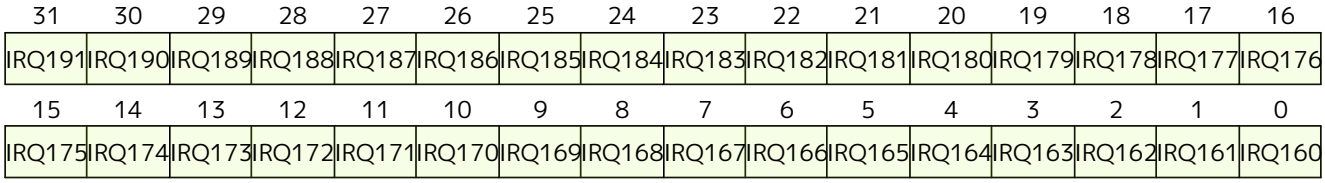


Figure 15. qc_mclicip5 format

4.15.3. Field Summary

Name	Location	Type	Reset Value
IRQ160	0	RW	0
IRQ161	1	RW	0
IRQ162	2	RW	0
IRQ163	3	RW	0
IRQ164	4	RW	0
IRQ165	5	RW	0
IRQ166	6	RW	0
IRQ167	7	RW	0
IRQ168	8	RW	0
IRQ169	9	RW	0
IRQ170	10	RW	0
IRQ171	11	RW	0
IRQ172	12	RW	0
IRQ173	13	RW	0

Name	Location	Type	Reset Value
IRQ174	14	RW	0
IRQ175	15	RW	0
IRQ176	16	RW	0
IRQ177	17	RW	0
IRQ178	18	RW	0
IRQ179	19	RW	0
IRQ180	20	RW	0
IRQ181	21	RW	0
IRQ182	22	RW	0
IRQ183	23	RW	0
IRQ184	24	RW	0
IRQ185	25	RW	0
IRQ186	26	RW	0
IRQ187	27	RW	0
IRQ188	28	RW	0
IRQ189	29	RW	0
IRQ190	30	RW	0
IRQ191	31	RW	0

4.15.4. Fields

IRQ160

Location

0

Description

IRQ160 pending

Type

RW

Reset value

0

IRQ161

Location
1

Description
IRQ161 pending

Type
RW

Reset value
0

IRQ162

Location
2

Description
IRQ162 pending

Type
RW

Reset value
0

IRQ163

Location
3

Description
IRQ163 pending

Type
RW

Reset value
0

IRQ164

Location
4

Description
IRQ164 pending

Type
RW

Reset value
0

IRQ165

Location
5

Description
IRQ165 pending

Type
RW

Reset value
0

IRQ166

Location
6

Description
IRQ166 pending

Type
RW

Reset value
0

IRQ167

Location
7

Description
IRQ167 pending

Type
RW

Reset value
0

IRQ168

Location
8

Description
IRQ168 pending

Type
RW

Reset value
0

IRQ169

Location
9

Description
IRQ169 pending

Type
RW

Reset value
0

IRQ170

Location
10

Description
IRQ170 pending

Type
RW

Reset value
0

IRQ171

Location
11

Description
IRQ171 pending

Type
RW

Reset value
0

IRQ172

Location
12

Description
IRQ172 pending

Type
RW

Reset value
0

IRQ173

Location
13

Description
IRQ173 pending

Type
RW

Reset value
0

IRQ174

Location
14

Description
IRQ174 pending

Type
RW

Reset value
0

IRQ175

Location
15

Description
IRQ175 pending

Type
RW

Reset value
0

IRQ176

Location
16

Description
IRQ176 pending

Type
RW

Reset value
0

IRQ177

Location
17

Description
IRQ177 pending

Type
RW

Reset value
0

IRQ178

Location
18

Description
IRQ178 pending

Type
RW

Reset value
0

IRQ179

Location
19

Description
IRQ179 pending

Type
RW

Reset value
0

IRQ180

Location
20

Description
IRQ180 pending

Type
RW

Reset value
0

IRQ181

Location
21

Description
IRQ181 pending

Type
RW

Reset value
0

IRQ182

Location
22

Description
IRQ182 pending

Type
RW

Reset value
0

IRQ183

Location
23

Description
IRQ183 pending

Type
RW

Reset value
0

IRQ184

Location
24

Description
IRQ184 pending

Type
RW

Reset value
0

IRQ185

Location
25

Description
IRQ185 pending

Type
RW

Reset value
0

IRQ186

Location
26

Description
IRQ186 pending

Type
RW

Reset value
0

IRQ187

Location
27

Description
IRQ187 pending

Type
RW

Reset value
0

IRQ188

Location
28

Description
IRQ188 pending

Type
RW

Reset value
0

IRQ189

Location
29

Description
IRQ189 pending

Type
RW

Reset value
0

IRQ190

Location
30

Description
IRQ190 pending

Type
RW

Reset value
0

IRQ191

Location

31

Description

IRQ191 pending

Type

RW

Reset value

0

4.16. qc_mclicip6

IRQ Pending 6

Pending bits for IRQs 192-223

4.16.1. Attributes

CSR Address	0x7f6
Length	32-bit-bit
Privilege Mode	M

4.16.2. Format

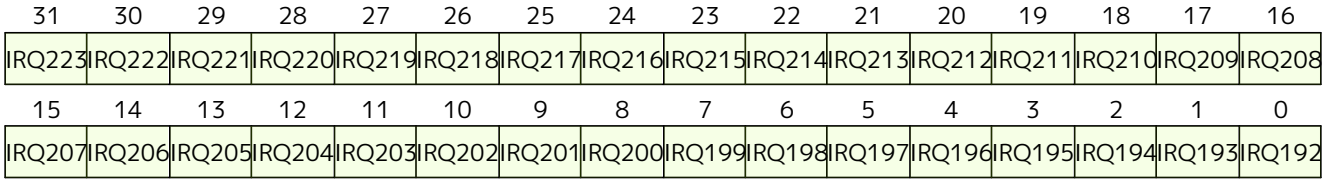


Figure 16. qc_mclicip6 format

4.16.3. Field Summary

Name	Location	Type	Reset Value
IRQ192	0	RW	0
IRQ193	1	RW	0
IRQ194	2	RW	0
IRQ195	3	RW	0
IRQ196	4	RW	0
IRQ197	5	RW	0
IRQ198	6	RW	0
IRQ199	7	RW	0
IRQ200	8	RW	0
IRQ201	9	RW	0
IRQ202	10	RW	0
IRQ203	11	RW	0
IRQ204	12	RW	0
IRQ205	13	RW	0

Name	Location	Type	Reset Value
IRQ206	14	RW	0
IRQ207	15	RW	0
IRQ208	16	RW	0
IRQ209	17	RW	0
IRQ210	18	RW	0
IRQ211	19	RW	0
IRQ212	20	RW	0
IRQ213	21	RW	0
IRQ214	22	RW	0
IRQ215	23	RW	0
IRQ216	24	RW	0
IRQ217	25	RW	0
IRQ218	26	RW	0
IRQ219	27	RW	0
IRQ220	28	RW	0
IRQ221	29	RW	0
IRQ222	30	RW	0
IRQ223	31	RW	0

4.16.4. Fields

IRQ192

Location

0

Description

IRQ192 pending

Type

RW

Reset value

0

IRQ193

Location
1

Description
IRQ193 pending

Type
RW

Reset value
0

IRQ194

Location
2

Description
IRQ194 pending

Type
RW

Reset value
0

IRQ195

Location
3

Description
IRQ195 pending

Type
RW

Reset value
0

IRQ196

Location
4

Description
IRQ196 pending

Type
RW

Reset value
0

IRQ197

Location
5

Description
IRQ197 pending

Type
RW

Reset value
0

IRQ198

Location
6

Description
IRQ198 pending

Type
RW

Reset value
0

IRQ199

Location
7

Description
IRQ199 pending

Type
RW

Reset value
0

IRQ200

Location
8

Description
IRQ200 pending

Type
RW

Reset value
0

IRQ201

Location
9

Description
IRQ201 pending

Type
RW

Reset value
0

IRQ202

Location
10

Description
IRQ202 pending

Type
RW

Reset value
0

IRQ203

Location
11

Description
IRQ203 pending

Type
RW

Reset value
0

IRQ204

Location
12

Description
IRQ204 pending

Type
RW

Reset value
0

IRQ205

Location
13

Description
IRQ205 pending

Type
RW

Reset value
0

IRQ206

Location
14

Description
IRQ206 pending

Type
RW

Reset value
0

IRQ207

Location
15

Description
IRQ207 pending

Type
RW

Reset value
0

IRQ208

Location
16

Description
IRQ208 pending

Type
RW

Reset value
0

IRQ209

Location
17

Description
IRQ209 pending

Type
RW

Reset value
0

IRQ210

Location
18

Description
IRQ210 pending

Type
RW

Reset value
0

IRQ211

Location
19

Description
IRQ211 pending

Type
RW

Reset value
0

IRQ212

Location
20

Description
IRQ212 pending

Type
RW

Reset value
0

IRQ213

Location
21

Description
IRQ213 pending

Type
RW

Reset value
0

IRQ214

Location
22

Description
IRQ214 pending

Type
RW

Reset value
0

IRQ215

Location
23

Description
IRQ215 pending

Type
RW

Reset value
0

IRQ216

Location
24

Description
IRQ216 pending

Type
RW

Reset value
0

IRQ217

Location
25

Description
IRQ217 pending

Type
RW

Reset value
0

IRQ218

Location
26

Description
IRQ218 pending

Type
RW

Reset value
0

IRQ219

Location
27

Description
IRQ219 pending

Type
RW

Reset value
0

IRQ220

Location
28

Description
IRQ220 pending

Type
RW

Reset value
0

IRQ221

Location
29

Description
IRQ221 pending

Type
RW

Reset value
0

IRQ222

Location
30

Description
IRQ222 pending

Type
RW

Reset value
0

IRQ223

Location

31

Description

IRQ223 pending

Type

RW

Reset value

0

4.17. qc_mclicip7

IRQ Pending 7

Pending bits for IRQs 224-255

4.17.1. Attributes

CSR Address	0x7f7
Length	32-bit-bit
Privilege Mode	M

4.17.2. Format

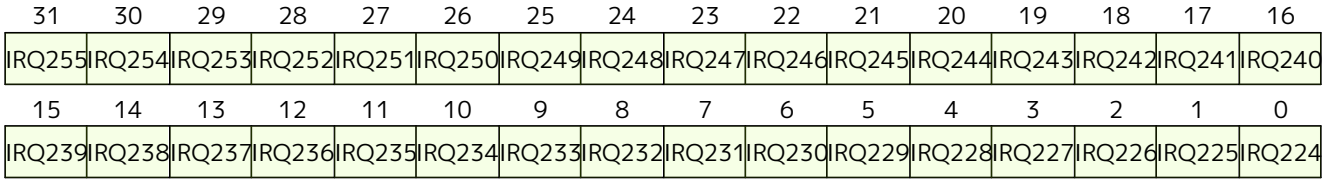


Figure 17. qc_mclicip7 format

4.17.3. Field Summary

Name	Location	Type	Reset Value
IRQ224	0	RW	0
IRQ225	1	RW	0
IRQ226	2	RW	0
IRQ227	3	RW	0
IRQ228	4	RW	0
IRQ229	5	RW	0
IRQ230	6	RW	0
IRQ231	7	RW	0
IRQ232	8	RW	0
IRQ233	9	RW	0
IRQ234	10	RW	0
IRQ235	11	RW	0
IRQ236	12	RW	0
IRQ237	13	RW	0

Name	Location	Type	Reset Value
IRQ238	14	RW	0
IRQ239	15	RW	0
IRQ240	16	RW	0
IRQ241	17	RW	0
IRQ242	18	RW	0
IRQ243	19	RW	0
IRQ244	20	RW	0
IRQ245	21	RW	0
IRQ246	22	RW	0
IRQ247	23	RW	0
IRQ248	24	RW	0
IRQ249	25	RW	0
IRQ250	26	RW	0
IRQ251	27	RW	0
IRQ252	28	RW	0
IRQ253	29	RW	0
IRQ254	30	RW	0
IRQ255	31	RW	0

4.17.4. Fields

IRQ224

Location

0

Description

IRQ224 pending

Type

RW

Reset value

0

IRQ225

Location
1

Description
IRQ225 pending

Type
RW

Reset value
0

IRQ226

Location
2

Description
IRQ226 pending

Type
RW

Reset value
0

IRQ227

Location
3

Description
IRQ227 pending

Type
RW

Reset value
0

IRQ228

Location
4

Description
IRQ228 pending

Type
RW

Reset value
0

IRQ229

Location
5

Description
IRQ229 pending

Type
RW

Reset value
0

IRQ230

Location
6

Description
IRQ230 pending

Type
RW

Reset value
0

IRQ231

Location
7

Description
IRQ231 pending

Type
RW

Reset value
0

IRQ232

Location
8

Description
IRQ232 pending

Type
RW

Reset value
0

IRQ233

Location
9

Description
IRQ233 pending

Type
RW

Reset value
0

IRQ234

Location
10

Description
IRQ234 pending

Type
RW

Reset value
0

IRQ235

Location
11

Description
IRQ235 pending

Type
RW

Reset value
0

IRQ236

Location
12

Description
IRQ236 pending

Type
RW

Reset value
0

IRQ237

Location
13

Description
IRQ237 pending

Type
RW

Reset value
0

IRQ238

Location
14

Description
IRQ238 pending

Type
RW

Reset value
0

IRQ239

Location
15

Description
IRQ239 pending

Type
RW

Reset value
0

IRQ240

Location
16

Description
IRQ240 pending

Type
RW

Reset value
0

IRQ241

Location
17

Description
IRQ241 pending

Type
RW

Reset value
0

IRQ242

Location
18

Description
IRQ242 pending

Type
RW

Reset value
0

IRQ243

Location
19

Description
IRQ243 pending

Type
RW

Reset value
0

IRQ244

Location
20

Description
IRQ244 pending

Type
RW

Reset value
0

IRQ245

Location
21

Description
IRQ245 pending

Type
RW

Reset value
0

IRQ246

Location
22

Description
IRQ246 pending

Type
RW

Reset value
0

IRQ247

Location
23

Description
IRQ247 pending

Type
RW

Reset value
0

IRQ248

Location
24

Description
IRQ248 pending

Type
RW

Reset value
0

IRQ249

Location
25

Description
IRQ249 pending

Type
RW

Reset value
0

IRQ250

Location
26

Description
IRQ250 pending

Type
RW

Reset value
0

IRQ251

Location
27

Description
IRQ251 pending

Type
RW

Reset value
0

IRQ252

Location
28

Description
IRQ252 pending

Type
RW

Reset value
0

IRQ253

Location
29

Description
IRQ253 pending

Type
RW

Reset value
0

IRQ254

Location
30

Description
IRQ254 pending

Type
RW

Reset value
0

IRQ255

Location

31

Description

IRQ255 pending

Type

RW

Reset value

0

Chapter 5. Instructions (in alphabetical order)

5.1. qc.addsat

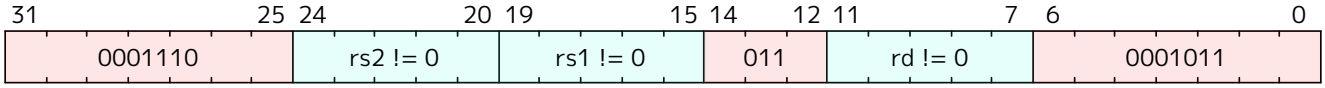
Synopsis

Saturating signed addition

Mnemonic

```
qc.addsat  rd, rs1, rs2
```

Encoding



Description

Add signed values `rs1` and `rs2`, saturate the signed result, and write to `rd`. Instruction encoded in R instruction format

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg sum = X[rs1] + X[rs2];
XReg most_negative_number = 1 << (xlen() - 1);
XReg most_positive_number = (1 << (xlen() - 1)) - 1;
if (X[rs1][xlen() - 1] == X[rs2][xlen() - 1]) {
  if (sum[xlen() - 1] != X[rs1][xlen() - 1]) {
    if ($signed(X[rs1]) < 0) {
      X[rd] = most_negative_number;
    } else {
      X[rd] = most_positive_number;
    }
  }
}
X[rd] = sum;
```

Included in

- anyOf:
- Xqci, version >= 0

- Xqcia, version >= 0

5.2. qc.addusat

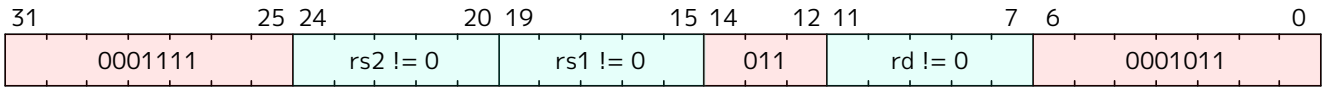
Synopsis

Saturating unsigned addition

Mnemonic

```
qc.addusat  rd, rs1, rs2
```

Encoding



Description

Add unsigned values `rs1` and `rs2`, saturate the unsigned result, and write to `rd`. Instruction encoded in R instruction format

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg sum = X[rs1] + X[rs2];
if ((X[rs1][xlen() - 1] == 1) || (X[rs2][xlen() - 1] == 1)) {
  if (sum[xlen() - 1] == 0) {
    X[rd] = ~{XLEN{1'b0}};
  }
}
X[rd] = sum;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.3. qc.beqi

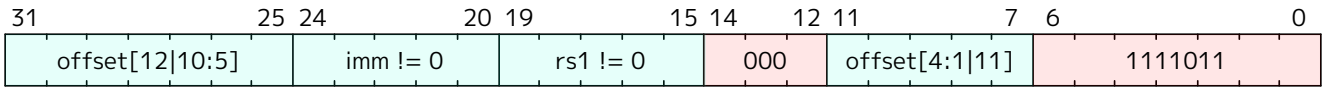
Synopsis

Branch on equal (Immediate)

Mnemonic

```
qc.beqi  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is equal to the signed immediate Instruction encoded in BI instruction format

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<5> imm = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) == $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.4. qc.bgei

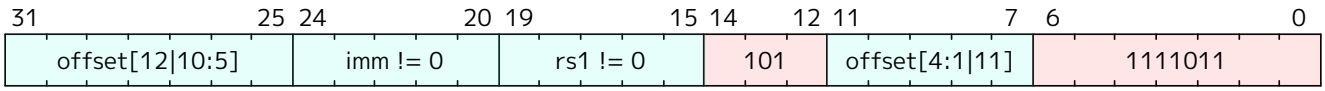
Synopsis

Branch on greater than or equal (immediate)

Mnemonic

```
qc.bgei  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is greater than or equal to the immediate. Instruction encoded in BI instruction format

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<5> imm = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) >= $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.5. qc.bgeui

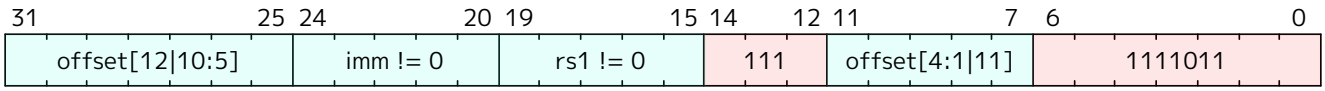
Synopsis

Branch on greater than or equal unsigned (immediate)

Mnemonic

```
qc.bgeui  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the unsigned value in `rs1` is greater than or equal to the unsigned immediate. Instruction encoded in BI instruction format

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<5> imm = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if (X[rs1] >= imm) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.6. qc.blti

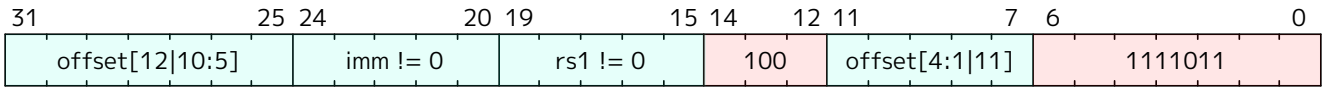
Synopsis

Branch on less than (immediate)

Mnemonic

```
qc.blti  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is less than the immediate. Instruction encoded in BI instruction format

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<5> imm = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) < $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.7. qc.bltui

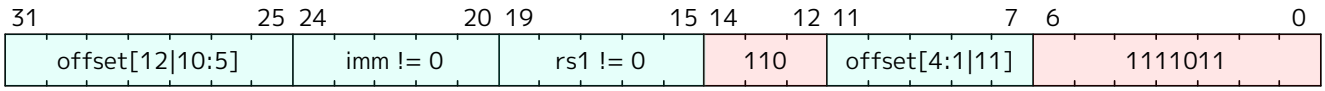
Synopsis

Branch on less than unsigned (immediate)

Mnemonic

```
qc.bltui  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the unsigned value in `rs1` is less than the unsigned immediate. Instruction encoded in BI instruction format

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<5> imm = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if (X[rs1] < imm) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.8. qc.bnei

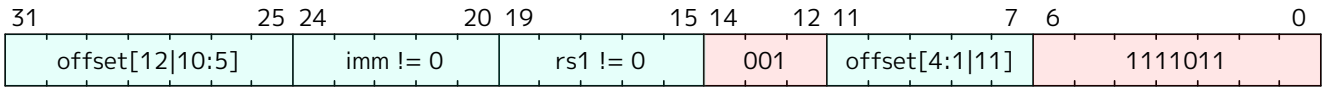
Synopsis

Branch on not equal (immediate)

Mnemonic

```
qc.bnei  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is not equal to the signed immediate. Instruction encoded in BI instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<5> imm = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) != $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.9. qc.brev32

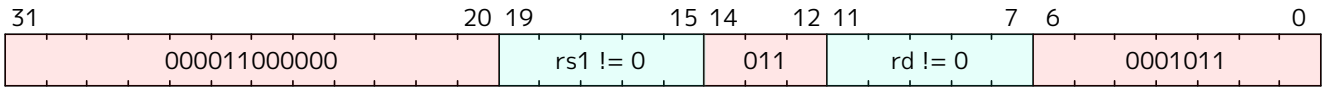
Synopsis

Reverse bit order

Mnemonic

```
qc.brev32  rd, rs1
```

Encoding



Description

Reverses the bit order of `rs1` and writes the result to `rd`. Instruction encoded in I instruction format

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg orig_val = X[rs1];
XReg tmp;
for (U32 i = 0; i < xlen(); i++) {
  tmp[xlen() - 1 - i] = orig_val[i];
}
X[rd] = tmp;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.10. qc.c.bexti

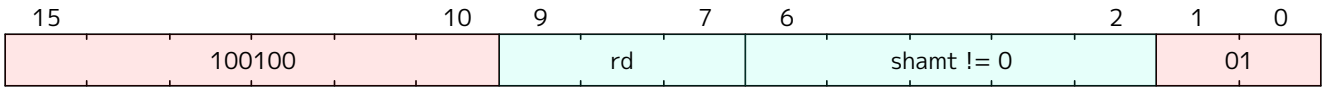
Synopsis

Single-Bit extract (Immediate)

Mnemonic

```
qc.c.bexti  rd, shamt
```

Encoding



Description

This instruction returns a single bit extracted from `rd`. The index is read from the lower log2(XLEN) bits of `shamt`. Instruction encoded in CB instruction format.

Decode Variables

```
Bits<5> shamt = $encoding[6:2];
Bits<3> rd = $encoding[9:7];
```

Operation

```
XReg index = shamt & (xlen() - 1);
XReg reg = rd + 8;
X[reg] = (X[reg] >> index) & 1;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.11. qc.c.bseti

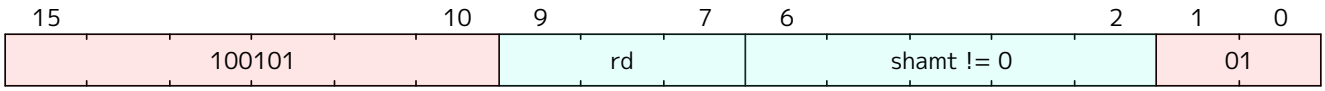
Synopsis

Single-Bit set (Immediate)

Mnemonic

```
qc.c.bseti  rd, shamt
```

Encoding



Description

This instruction returns `rd` with a single bit set at the index specified in shamt. The index is read from the lower log2(XLEN) bits of `shamt`. Instruction encoded in CB instruction format.

Decode Variables

```
Bits<5> shamt = $encoding[6:2];
Bits<3> rd = $encoding[9:7];
```

Operation

```
XReg index = shamt & (xlen() - 1);
XReg reg = rd + 8;
X[reg] = X[reg] | (1 << index);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.12. qc.c.clrint

Synopsis

Clear interrupt (Register)

Mnemonic

```
qc.c.clrint  rs1
```

Encoding

Description

Clear interrupt, interrupt number is in rs1. Instruction encoded in CI instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[11:7];
```

Operation

```
Bits<12> MCLICIP0_ADDR = CSR[qc_mclicip0].address();
XReg idx = rs1 / 32;
XReg bit = rs1 % 32;
XReg pre_csr = CSR[MCLICIP0_ADDR + idx].sw_read();
CSR[MCLICIP0_ADDR + idx].sw_write(pre_csr & ~(1 << bit));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.13. qc.c.di

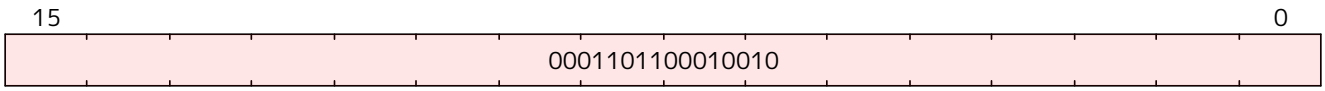
Synopsis

Disable interrupts

Mnemonic

```
qc.c.di
```

Encoding



Description

Globally disable interrupts. Equivalent to "csrrci `zero`, mstatus, 8". Instruction encoded in CI instruction format.

Decode Variables

qc.c.di has no decode variables.

Operation

```
XReg pre_mstatus = CSR[mstatus].sw_read();
CSR[mstatus].sw_write(pre_mstatus & ~8);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.14. qc.c.dir

Synopsis

Disable interrupts (Register)

Mnemonic

```
qc.c.dir  rd
```

Encoding

Description

Globally disable interrupts, write previous value of mstatus to rd. Equivalent to "csrrci rd, mstatus, 8". Instruction encoded in CI instruction format.

Decode Variables

```
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg pre_mstatus = CSR[mstatus].sw_read();
CSR[mstatus].sw_write(pre_mstatus & ~8);
X[rd] = pre_mstatus;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.15. qc.c.ei

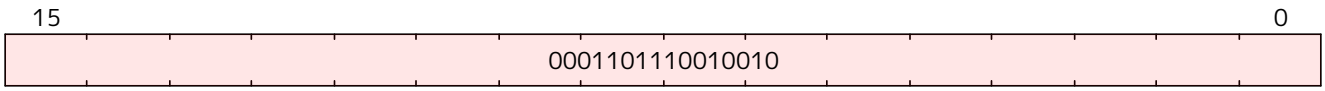
Synopsis

Enable interrupts

Mnemonic

```
qc.c.ei
```

Encoding



Description

Globally enable interrupts. Equivalent to "csrrsi `zero`, mstatus, 8". Instruction encoded in CI instruction format.

Decode Variables

qc.c.ei has no decode variables.

Operation

```
XReg pre_mstatus = CSR[mstatus].sw_read();
CSR[mstatus].sw_write(pre_mstatus | 8);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.16. qc.c.eir

Synopsis

Restore interrupts (Register)

Mnemonic

```
qc.c.eir  rs1
```

Encoding

Description

Globally restore interrupts, write `rs1` to mstatus. Equivalent to "csrrs `zero`, mstatus, `rs1`". Instruction encoded in CI instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[11:7];
```

Operation

```
CSR[mstatus].sw_write(X[rs1]);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.17. qc.c.extu

Synopsis

Extract bits unsigned

Mnemonic

```
qc.c.extu  rd, width
```

Encoding

Description

Extract a subset of bits from `rd` starting from LSB. The width of the subset is determined by (`width_minus1`[4:0] + 1) (1..32). Instruction encoded in CI instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[6:2];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = width_minus1 + 1;
X[rd] = (X[rd] >> 0) & ((1 << width) - 1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.18. qc.c.mienter.nest

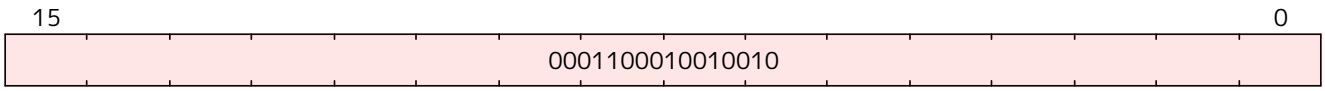
Synopsis

Machine mode interrupt enter

Mnemonic

```
qc.c.mienter.nest
```

Encoding



Description

Machine mode interrupt enter, interrupt nesting is enabled. Interrupt frame is saved in the stack. Interrupts are enabled. Instruction encoded in CI instruction format.

Decode Variables

qc.c.mienter.nest has no decode variables.

Operation

```
XReg virtual_address = X[2];
XReg mepc_val = CSR[mepc].sw_read();
XReg mnepc_val = CSR[qc_mnepc].sw_read();
XReg mcause_val = CSR[mcause].sw_read();
XReg flags_val = CSR[qc_flags].sw_read();
if (CSR[mcause].NMI != 1'b1) {
  write_memory<32>(virtual_address - 4, mepc_val, $encoding);
} else {
  write_memory<32>(virtual_address - 4, mnepc_val, $encoding);
}
write_memory<32>(virtual_address - 8, X[8][31:0], $encoding);
write_memory<32>(virtual_address - 12, mcause_val, $encoding);
write_memory<32>(virtual_address - 16, X[1][31:0], $encoding);
write_memory<32>(virtual_address - 20, flags_val, $encoding);
write_memory<32>(virtual_address - 24, X[5][31:0], $encoding);
write_memory<32>(virtual_address - 28, X[6][31:0], $encoding);
write_memory<32>(virtual_address - 32, X[7][31:0], $encoding);
write_memory<32>(virtual_address - 36, X[10][31:0], $encoding);
write_memory<32>(virtual_address - 40, X[11][31:0], $encoding);
write_memory<32>(virtual_address - 44, X[12][31:0], $encoding);
write_memory<32>(virtual_address - 48, X[13][31:0], $encoding);
write_memory<32>(virtual_address - 52, X[14][31:0], $encoding);
write_memory<32>(virtual_address - 56, X[15][31:0], $encoding);
write_memory<32>(virtual_address - 60, X[16][31:0], $encoding);
write_memory<32>(virtual_address - 64, X[17][31:0], $encoding);
write_memory<32>(virtual_address - 68, X[28][31:0], $encoding);
write_memory<32>(virtual_address - 72, X[29][31:0], $encoding);
write_memory<32>(virtual_address - 76, X[30][31:0], $encoding);
```

```
write_memory<32>(virtual_address - 80, X[31][31:0], $encoding);
X[2] = X[2] - 96;
CSR[mstatus].MIE = 1'b1;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.19. qc.c.mienter

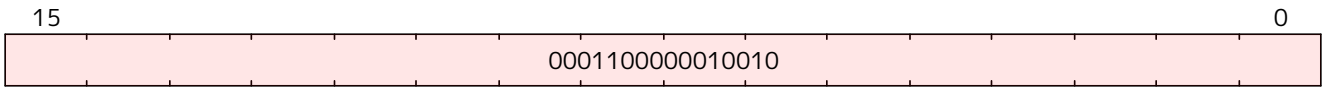
Synopsis

Machine mode interrupt enter

Mnemonic

```
qc.c.mienter
```

Encoding



Description

Machine mode interrupt enter, interrupt nesting is disabled. Interrupt frame is saved in the stack. Interrupts are disabled. Instruction encoded in CI instruction format.

Decode Variables

qc.c.mienter has no decode variables.

Operation

```
XReg virtual_address = X[2];
XReg mepc_val = CSR[mepc].sw_read();
XReg mnepc_val = CSR[qc_mnepc].sw_read();
XReg mcause_val = CSR[mcause].sw_read();
XReg flags_val = CSR[qc_flags].sw_read();
if (CSR[mcause].NMI != 1'b1) {
  write_memory<32>(virtual_address - 4, mepc_val, $encoding);
} else {
  write_memory<32>(virtual_address - 4, mnepc_val, $encoding);
}
write_memory<32>(virtual_address - 8, X[8][31:0], $encoding);
write_memory<32>(virtual_address - 12, mcause_val, $encoding);
write_memory<32>(virtual_address - 16, X[1][31:0], $encoding);
write_memory<32>(virtual_address - 20, flags_val, $encoding);
write_memory<32>(virtual_address - 24, X[5][31:0], $encoding);
write_memory<32>(virtual_address - 28, X[6][31:0], $encoding);
write_memory<32>(virtual_address - 32, X[7][31:0], $encoding);
write_memory<32>(virtual_address - 36, X[10][31:0], $encoding);
write_memory<32>(virtual_address - 40, X[11][31:0], $encoding);
write_memory<32>(virtual_address - 44, X[12][31:0], $encoding);
write_memory<32>(virtual_address - 48, X[13][31:0], $encoding);
write_memory<32>(virtual_address - 52, X[14][31:0], $encoding);
write_memory<32>(virtual_address - 56, X[15][31:0], $encoding);
write_memory<32>(virtual_address - 60, X[16][31:0], $encoding);
write_memory<32>(virtual_address - 64, X[17][31:0], $encoding);
write_memory<32>(virtual_address - 68, X[28][31:0], $encoding);
write_memory<32>(virtual_address - 72, X[29][31:0], $encoding);
write_memory<32>(virtual_address - 76, X[30][31:0], $encoding);
```

```
write_memory<32>(virtual_address - 80, X[31][31:0], $encoding);
X[2] = X[2] - 96;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.20. qc.c.mileaveret

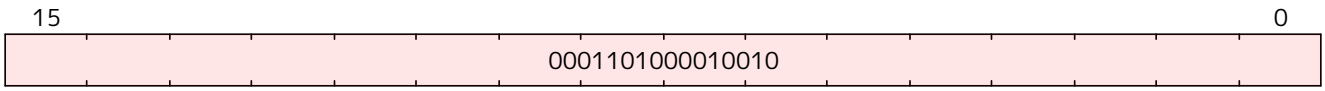
Synopsis

Machine mode interrupt exit

Mnemonic

```
qc.c.mileaveret
```

Encoding



Description

Machine mode interrupt exit. Interrupt frame is restored from the stack. Instruction encoded in CI instruction format.

Decode Variables

qc.c.mileaveret has no decode variables.

Operation

```
XReg virtual_address = X[2] + 96;
XReg prev_retpc = read_memory<32>(virtual_address - 4, $encoding);
XReg curr_retpc = (CSR[mcause].NMI == 1) ? CSR[qc_mnepc].sw_read() : CSR[mepc].
sw_read();
if (CSR[mcause].NMI != 1'b1) {
  CSR[mepc].sw_write(prev_retpc);
} else {
  CSR[qc_mnepc].sw_write(prev_retpc);
}
X[8] = read_memory<32>(virtual_address - 8, $encoding);
CSR[mcause].sw_write(read_memory<32>(virtual_address - 12, $encoding));
X[1] = read_memory<32>(virtual_address - 16, $encoding);
CSR[qc_flags].sw_write(read_memory<32>(virtual_address - 20, $encoding));
X[5] = read_memory<32>(virtual_address - 24, $encoding);
X[6] = read_memory<32>(virtual_address - 28, $encoding);
X[7] = read_memory<32>(virtual_address - 32, $encoding);
X[10] = read_memory<32>(virtual_address - 36, $encoding);
X[11] = read_memory<32>(virtual_address - 40, $encoding);
X[12] = read_memory<32>(virtual_address - 44, $encoding);
X[13] = read_memory<32>(virtual_address - 48, $encoding);
X[14] = read_memory<32>(virtual_address - 52, $encoding);
X[15] = read_memory<32>(virtual_address - 56, $encoding);
X[16] = read_memory<32>(virtual_address - 60, $encoding);
X[17] = read_memory<32>(virtual_address - 64, $encoding);
X[28] = read_memory<32>(virtual_address - 68, $encoding);
X[29] = read_memory<32>(virtual_address - 72, $encoding);
X[30] = read_memory<32>(virtual_address - 76, $encoding);
X[31] = read_memory<32>(virtual_address - 80, $encoding);
```

```
X[2] = X[2] + 96;
$pc = curr_retpc;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.21. qc.c.muladdi

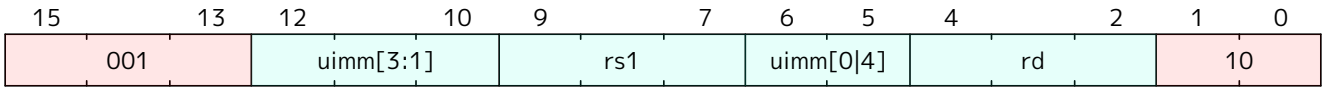
Synopsis

Multiply and accumulate (Immediate)

Mnemonic

```
qc.c.muladdi  rd, rs1, uimm
```

Encoding



Description

Increments `rd` by the multiplication of `rs1` and an unsigned immediate Instruction encoded in CL instruction format.

Decode Variables

```
Bits<5> uimm = {$encoding[5], $encoding[12:10], $encoding[6]};
Bits<3> rs1 = $encoding[9:7];
Bits<3> rd = $encoding[4:2];
```

Operation

```
XReg orig_val = X[rd + 8];
X[rd + 8] = orig_val + (X[rs1 + 8] * uimm);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciac, version >= 0

5.22. qc.c.mveqz

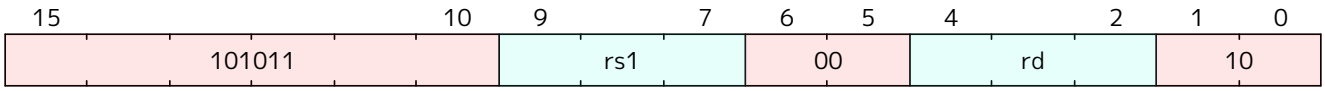
Synopsis

Conditional Move if equal to zero

Mnemonic

```
qc.c.mveqz  rd, rs1
```

Encoding



Description

Move `rs1` to `rd` if `rd` == 0, keep `rd` value otherwise Instruction encoded in CL instruction format.

Decode Variables

```
Bits<3> rs1 = $encoding[9:7];
Bits<3> rd = $encoding[4:2];
```

Operation

```
XReg orig_val = X[rd + 8];
X[rd + 8] = (orig_val == 0) ? X[rs1 + 8] : orig_val;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.23. qc.c.setint

Synopsis

Set interrupt (Register)

Mnemonic

```
qc.c.setint  rs1
```

Encoding

Description

Set interrupt, interrupt number is in rs1. Instruction encoded in CI instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[11:7];
```

Operation

```
Bits<12> MCLICIP0_ADDR = CSR[qc_mclicip0].address();
XReg idx = rs1 / 32;
XReg bit = rs1 % 32;
XReg pre_csr = CSR[MCLICIP0_ADDR + idx].sw_read();
CSR[MCLICIP0_ADDR + idx].sw_write(pre_csr | (1 << bit));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.24. qc.clo

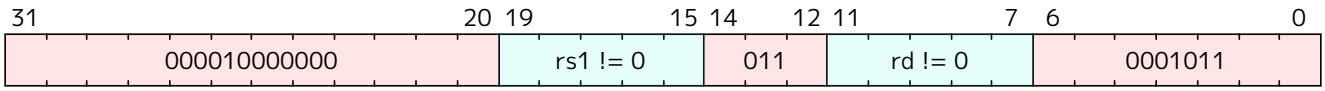
Synopsis

Count leading ones

Mnemonic

```
qc.clo  rd, rs1
```

Encoding



Description

Count the number of ones before the first zero in `rs1`, starting from the MSB and progressing to the LSB. Accordingly, if the input is ~0, the output is XLEN, and if the most-significant bit of the input is a 0, the output is 0. output written to the `rd` Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = (xlen() - 1) - $signed(highest_set_bit(~X[rs1]));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.25. qc.clrinti

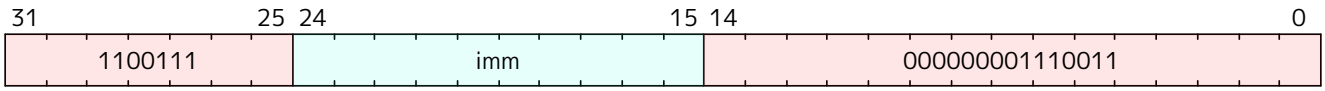
Synopsis

Clear interrupt (Immediate)

Mnemonic

```
qc.clrinti  imm
```

Encoding



Description

Clear interrupt, interrupt number is in `imm` (0 - 1023). Instruction encoded in I instruction format.

Decode Variables

```
Bits<10> imm = $encoding[24:15];
```

Operation

```
Bits<12> MCLICIP0_ADDR = CSR[qc_mclicip0].address();
XReg idx = imm / 32;
XReg bit = imm % 32;
XReg pre_csr = CSR[MCLICIP0_ADDR + idx].sw_read();
CSR[MCLICIP0_ADDR + idx].sw_write(pre_csr & ~(1 << bit));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.26. qc.compress2

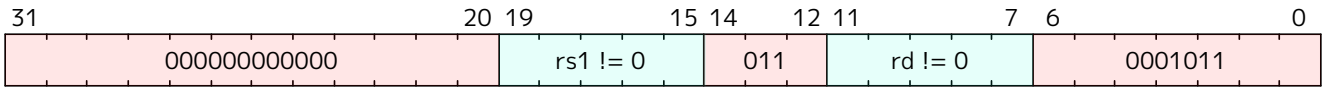
Synopsis

Bit compression (every 2nd bit)

Mnemonic

```
qc.compress2  rd, rs1
```

Encoding



Description

Bit compression (every 2nd bit) of `rs1`, zero-pad bits [31:16] of the result. Write result to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg b0 = {X[rs1][14], X[rs1][12], X[rs1][10], X[rs1][8], X[rs1][6], X[rs1][4], X[
rs1][2], X[rs1][0]};
XReg b1 = {X[rs1][30], X[rs1][28], X[rs1][26], X[rs1][24], X[rs1][22], X[rs1][20], X
[rs1][18], X[rs1][16]};
X[rd] = {16'b0, b1[7:0], b0[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.27. qc.compress3

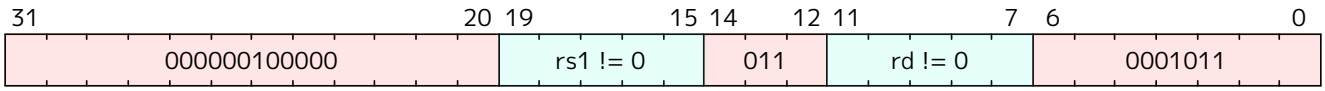
Synopsis

Bit compression (every 3rd bit)

Mnemonic

```
qc.compress3  rd, rs1
```

Encoding



Description

Bit compression (every 3rd bit) of `rs1`, zero-pad bits [31:11] of the result. Write result to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg b0 = {X[rs1][21], X[rs1][18], X[rs1][15], X[rs1][12], X[rs1][9], X[rs1][6], X[
rs1][3], X[rs1][0]};
XReg b1 = {5'b0, X[rs1][30], X[rs1][27], X[rs1][24]};
X[rd] = {21'b0, b1[2:0], b0[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.28. qc.csrrwr

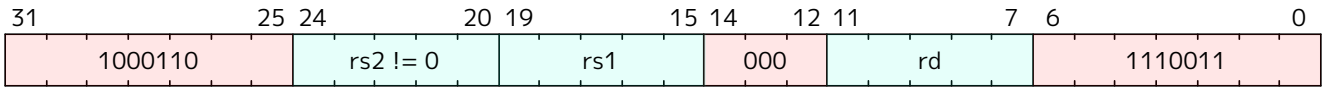
Synopsis

Atomic Read/Write CSR (Register)

Mnemonic

```
qc.csrrwr rd, rs1, rs2
```

Encoding



Description

Atomically swap values in the CSRs and integer registers. Read the old value of the CSR, zero-extends the value to `XLEN` bits, and then write it to integer register `rd`. The CSR number is in `rs2` register. The initial value in `rs1` is written to the CSR. If `rd=x0`, then the instruction shall not read the CSR and shall not cause any of the side effects that might occur on a CSR read. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg csr = X[rs2];
if (rd != 0) {
  X[rd] = CSR[csr].sw_read();
}
CSR[csr].sw_write(X[rs1]);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicsr, version >= 0

5.29. qc.csrrwri

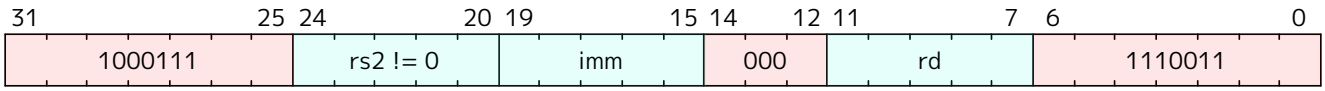
Synopsis

Atomic Read/Write CSR (Register) Immediate

Mnemonic

```
qc.csrrwri  rd, imm, rs2
```

Encoding



Description

Atomically write CSR using a 5-bit immediate `imm`, and load the previous value into `rd`. Read the old value of the CSR, zero-extends the value to `XLEN` bits, and then write it to integer register `rd`. The CSR number is in `rs2` register. The 5-bit uimm field is zero-extended and written to the CSR. If `rd=x0`, then the instruction shall not read the CSR and shall not cause any of the side effects that might occur on a CSR read. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> imm = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg csr = X[rs2];
if (rd != 0) {
  X[rd] = CSR[csr].sw_read();
}
CSR[csr].sw_write({{XLEN - 5{1'b0}}, imm});
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicsr, version >= 0

5.30. qc.cto

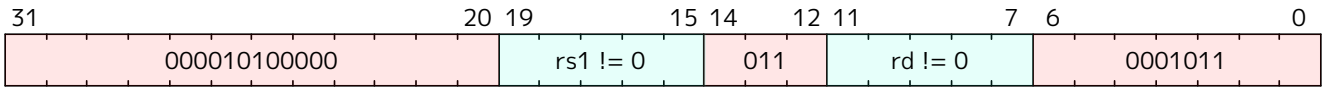
Synopsis

Count trailing ones

Mnemonic

```
qc.cto  rd, rs1
```

Encoding



Description

Count the number of ones before the first zero in `rs1`, starting from the LSB and progressing to the MSB. Accordingly, if the input is ~0, the output is XLEN, and if the least-significant bit of the input is a 0, the output is 0. Output written to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = (xlen() - 1) - $signed(lowest_set_bit(~X[rs1]));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.31. qc.e.addai

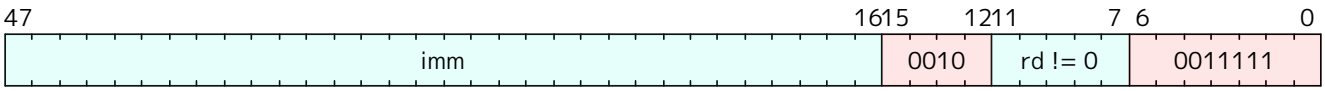
Synopsis

Add immediate

Mnemonic

```
qc.e.addai  rd, imm
```

Encoding



Description

Add a 32-bit immediate `imm` to the value in `rd`, and store the result back in `rd`. Instruction encoded in QC.EAI instruction format.

Decode Variables

```
Bits<32> imm = $encoding[47:16];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rd] + imm;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.32. qc.e.addi

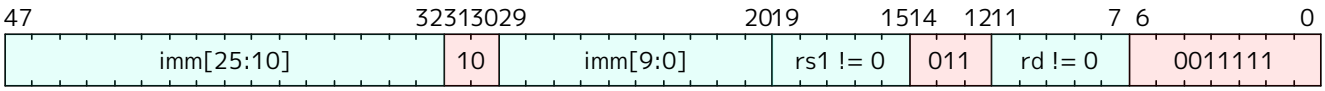
Synopsis

Add immediate

Mnemonic

```
qc.e.addi  rd, rs1, imm
```

Encoding



Description

Add a sign-extended 26-bit immediate `imm` to the value in `rs1`, and store the result in `rd`. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rs1] + sext(imm, 26);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.33. qc.e.andai

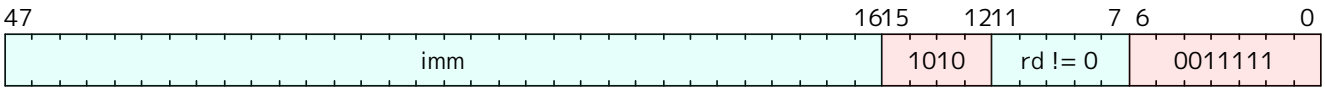
Synopsis

And immediate

Mnemonic

```
qc.e.andai  rd, imm
```

Encoding



Description

And a 32-bit immediate `imm` to the value in `rd`, and store the result back in `rd`. Instruction encoded in QC.EAI instruction format.

Decode Variables

```
Bits<32> imm = $encoding[47:16];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rd] & imm;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.34. qc.e.andi

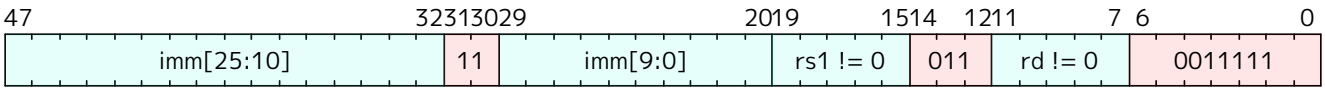
Synopsis

Add immediate

Mnemonic

```
qc.e.andi  rd, rs1, imm
```

Encoding



Description

And a sign-extended 26-bit immediate `imm` to the value in `rs1`, and store the result in `rd`. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rs1] & sext(imm, 26);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.35. qc.e.beqi

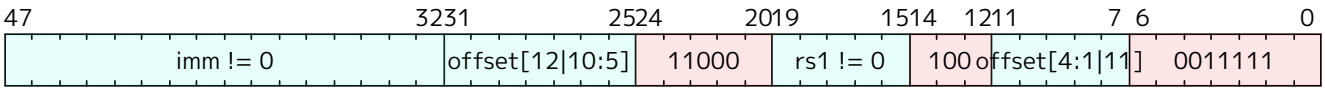
Synopsis

Branch on equal (immediate)

Mnemonic

```
qc.e.beqi  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is equal to the signed immediate `imm` Instruction encoded in QC.EB instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<16> imm = $encoding[47:32];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) == $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.36. qc.e.bgei

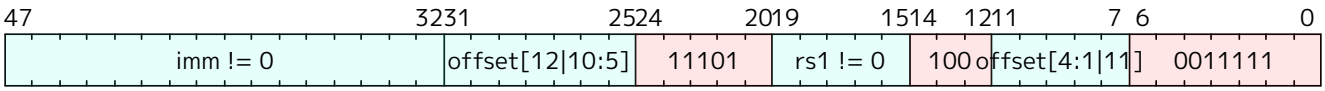
Synopsis

Branch on greater than or equal (immediate)

Mnemonic

```
qc.e.bgei  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is greater than or equal to the immediate `imm`. Instruction encoded in QC.EB instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<16> imm = $encoding[47:32];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) >= $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.37. qc.e.bgeui

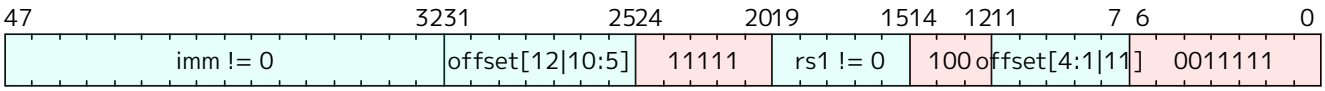
Synopsis

Branch on greater than or equal unsigned (immediate)

Mnemonic

```
qc.e.bgeui  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the unsigned value in `rs1` is greater than or equal to the unsigned immediate `imm`. Instruction encoded in QC.EB instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<16> imm = $encoding[47:32];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if (X[rs1] >= imm) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.38. qc.e.blti

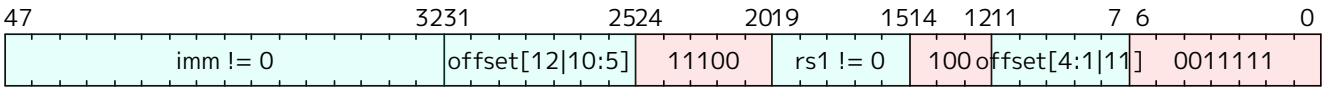
Synopsis

Branch on less than (immediate)

Mnemonic

```
qc.e.blti  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is less than the immediate `imm`. Instruction encoded in QC.EB instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<16> imm = $encoding[47:32];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) < $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.39. qc.e.bltui

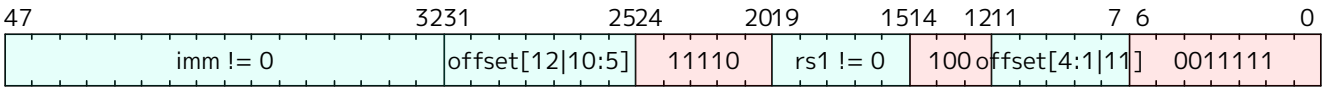
Synopsis

Branch on less than unsigned (immediate)

Mnemonic

```
qc.e.bltui  rs1, imm, offset
```

Encoding



Description

Branches to PC + offset if the unsigned value in rs1 is less than the unsigned immediate imm. Instruction encoded in QC.EB instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<16> imm = $encoding[47:32];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if (X[rs1] < imm) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.40. qc.e.bnei

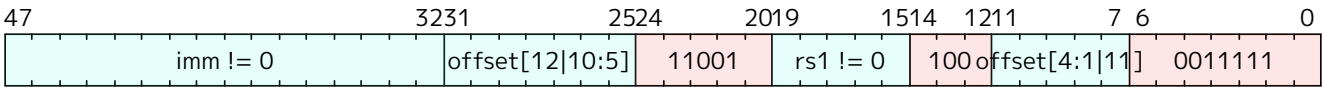
Synopsis

Branch on not equal (immediate)

Mnemonic

```
qc.e.bnei  rs1, imm, offset
```

Encoding



Description

Branches to `PC + offset` if the value in `rs1` is not equal to the signed immediate `imm`. Instruction encoded in QC.EB instruction format.

Decode Variables

```
signed Bits<13> offset = sext({$encoding[31], $encoding[7], $encoding[30:25],
$encoding[11:8], 1'd0});
Bits<16> imm = $encoding[47:32];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
if ($signed(X[rs1]) != $signed(imm)) {
  jump_halfword($pc + $signed(offset));
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibi, version >= 0

5.41. qc.e.j

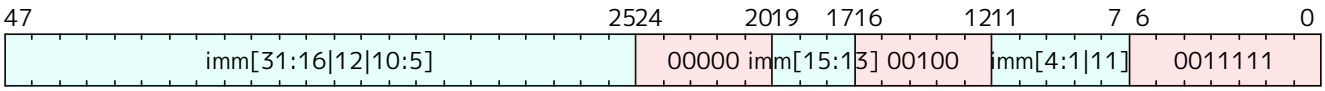
Synopsis

Jump

Mnemonic

```
qc.e.j  imm
```

Encoding



Description

Jump to a PC-relative offset. Instruction encoded in QC.EJ instruction format.

Decode Variables

```
signed Bits<32> imm = sext({$encoding[47:32], $encoding[19:17], $encoding[31],
$encoding[7], $encoding[30:25], $encoding[11:8], 1'd0});
```

Operation

```
jump_halfword($pc + imm);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilb, version >= 0

5.42. qc.e.jal

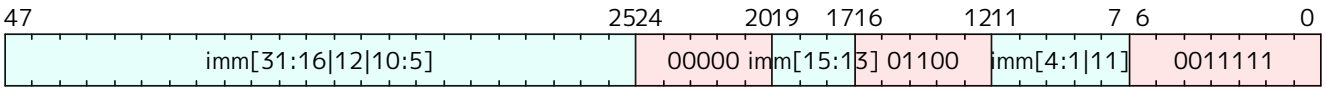
Synopsis

Jump and link

Mnemonic

```
qc.e.jal  imm
```

Encoding



Description

Jump to a PC-relative offset and store the return. Instruction encoded in QC.EJ instruction format. address in x1.

Decode Variables

```
signed Bits<32> imm = sext({$encoding[47:32], $encoding[19:17], $encoding[31],
$encoding[7], $encoding[30:25], $encoding[11:8], 1'd0});
```

Operation

```
XReg retrun_addr = $pc + 6;
jump_halfword($pc + imm);
X[1] = retrun_addr;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilb, version >= 0

5.43. qc.e.lb

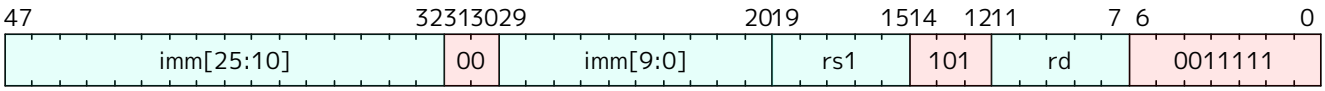
Synopsis

Load byte

Mnemonic

```
qc.e.lb  rd, imm(rs1)
```

Encoding



Description

Load 8 bits of data into register `rd` from an address formed by adding `rs1` to a signed offset `imm`. Sign extend the result. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + imm;
X[rd] = sext(read_memory<8>(virtual_address, $encoding), 7);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.44. qc.e.lbu

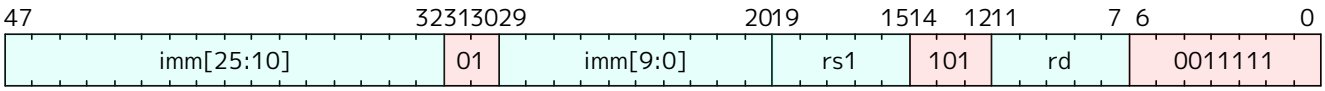
Synopsis

Load byte unsigned

Mnemonic

```
qc.e.lbu  rd, imm(rs1)
```

Encoding



Description

Load 8 bits of data into register `rd` from an address formed by adding `rs1` to a signed offset `imm`. Zero extend the result. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + imm;
X[rd] = read_memory<8>(virtual_address, $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.45. qc.e.lh

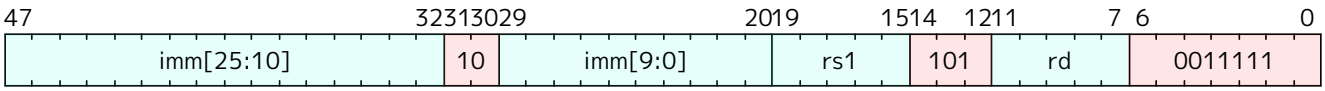
Synopsis

Load halfword

Mnemonic

```
qc.e.lh  rd, imm(rs1)
```

Encoding



Description

Load 16 bits of data into register `rd` from an address formed by adding `rs1` to a signed offset `imm`. Sign extend the result. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + imm;
X[rd] = sext(read_memory<16>(virtual_address, $encoding), 15);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.46. qc.e.lhu

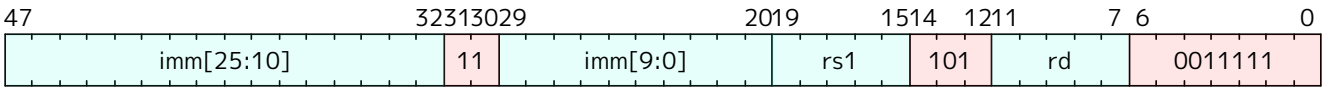
Synopsis

Load halfword unsigned

Mnemonic

```
qc.e.lhu  rd, imm(rs1)
```

Encoding



Description

Load 16 bits of data into register `rd` from an address formed by adding `rs1` to a signed offset `imm`. Zero extend the result. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + imm;
X[rd] = read_memory<16>(virtual_address, $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.47. qc.e.li

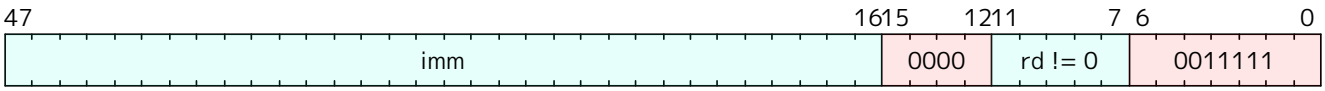
Synopsis

Load immediate large

Mnemonic

```
qc.e.li  rd, imm
```

Encoding



Description

Loads the 32-bit immediate `imm` into `rd`. Instruction encoded in QC.EAI instruction format.

Decode Variables

```
Bits<32> imm = $encoding[47:16];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = imm;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcili, version >= 0

5.48. qc.e.lw

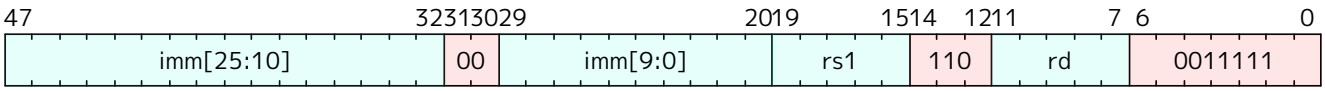
Synopsis

Load word

Mnemonic

```
qc.e.lw  rd, imm(rs1)
```

Encoding



Description

Load 32 bits of data into register `rd` from an address formed by adding `rs1` to a signed offset `imm`. Sign extend the result. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + imm;
X[rd] = read_memory<32>(virtual_address, $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.49. qc.e.orai

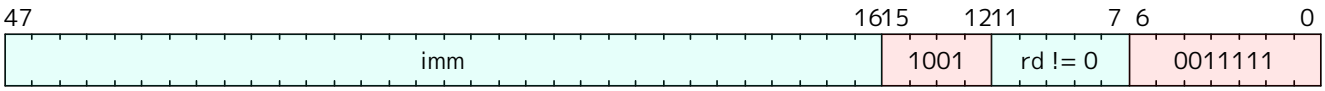
Synopsis

Or immediate

Mnemonic

```
qc.e.orai  rd, imm
```

Encoding



Description

Or a 32-bit immediate `imm` to the value in `rd`, and store the result back in `rd`. Instruction encoded in QC.EAI instruction format.

Decode Variables

```
Bits<32> imm = $encoding[47:16];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rd] | imm;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.50. qc.e.ori

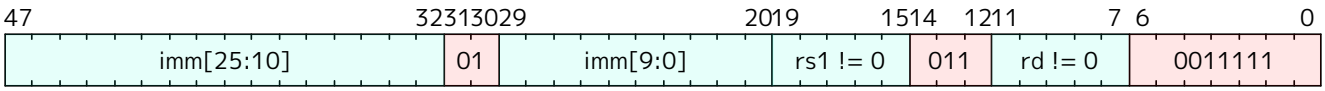
Synopsis

Or immediate

Mnemonic

```
qc.e.ori  rd, rs1, imm
```

Encoding



Description

Or a sign-extended 26-bit immediate `imm` to the value in `rs1`, and store the result in `rd`. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rs1] | sext(imm, 26);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.51. qc.e.sb

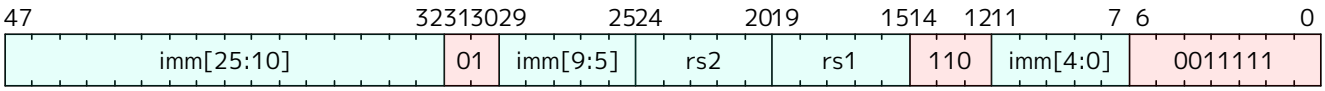
Synopsis

Store byte

Mnemonic

```
qc.e.sb  rs2, imm(rs1)
```

Encoding



Description

Store 8 bits of data from register `rs2` to an address formed by adding `rs1` to a signed offset `imm`. Instruction encoded in QC.ES instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:25], $encoding[11:7]};
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
XReg virtual_address = X[rs1] + $signed(imm);
write_memory<8>(virtual_address, X[rs2][7:0], $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.52. qc.e.sh

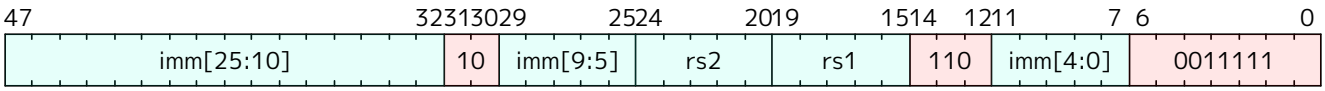
Synopsis

Store halfword

Mnemonic

```
qc.e.sh  rs2, imm(rs1)
```

Encoding



Description

Store 16 bits of data from register `rs2` to an address formed by adding `rs1` to a signed offset `imm`. Instruction encoded in QC.ES instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:25], $encoding[11:7]};
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
XReg virtual_address = X[rs1] + $signed(imm);
write_memory<16>(virtual_address, X[rs2][15:0], $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.53. qc.e.sw

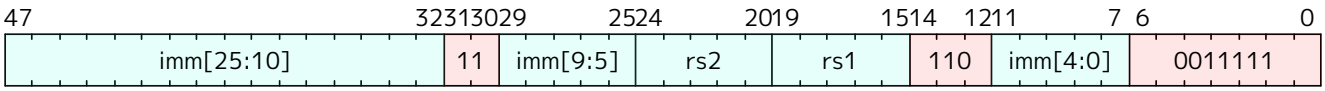
Synopsis

Store word

Mnemonic

```
qc.e.sw  rs2, imm(rs1)
```

Encoding



Description

Store 32 bits of data from register `rs2` to an address formed by adding `rs1` to a signed offset `imm`. Instruction encoded in QC.ES instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:25], $encoding[11:7]};
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
```

Operation

```
XReg virtual_address = X[rs1] + $signed(imm);
write_memory<32>(virtual_address, X[rs2][31:0], $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilo, version >= 0

5.54. qc.e.xorai

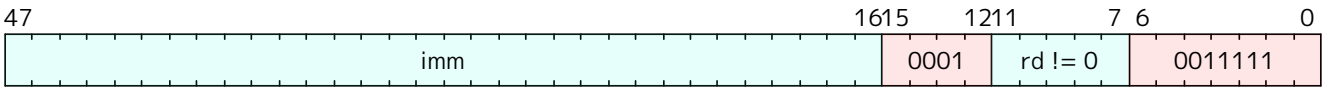
Synopsis

Exclusive Or immediate

Mnemonic

```
qc.e.xorai  rd, imm
```

Encoding



Description

Exclusive or a 32-bit immediate `imm` to the value in `rd`, and store the result back in `rd`. Instruction encoded in QC.EAI instruction format.

Decode Variables

```
Bits<32> imm = $encoding[47:16];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rd] ^ imm;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.55. qc.e.xori

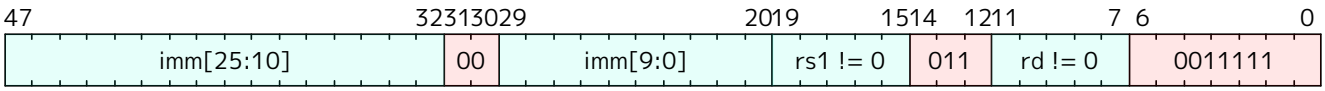
Synopsis

Exclusive Or immediate

Mnemonic

```
qc.e.xori  rd, rs1, imm
```

Encoding



Description

Exclusive or a sign-extended 26-bit immediate `imm` to the value in `rs1`, and store the result in `rd`. Instruction encoded in QC.EI instruction format.

Decode Variables

```
Bits<26> imm = {$encoding[47:32], $encoding[29:20]};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = X[rs1] ^ sext(imm, 26);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilia, version >= 0

5.56. qc.expand2

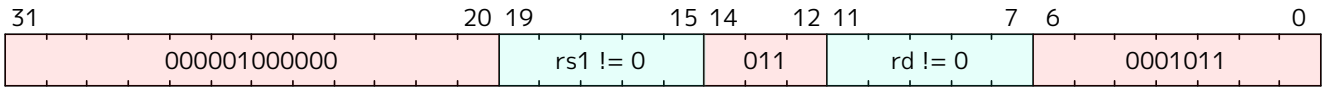
Synopsis

Bit expansion (every 2nd bit)

Mnemonic

```
qc.expand2  rd, rs1
```

Encoding



Description

Bit expansion (every 2nd bit) of `rs1`, bits [31:16] of `rs1` are ignored. Write result to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg b0 = {X[rs1][3], X[rs1][3], X[rs1][2], X[rs1][2], X[rs1][1], X[rs1][1], X[rs1][
0], X[rs1][0]};
XReg b1 = {X[rs1][7], X[rs1][7], X[rs1][6], X[rs1][6], X[rs1][5], X[rs1][5], X[rs1][
4], X[rs1][4]};
XReg b2 = {X[rs1][11], X[rs1][11], X[rs1][10], X[rs1][10], X[rs1][9], X[rs1][9], X[
rs1][8], X[rs1][8]};
XReg b3 = {X[rs1][15], X[rs1][15], X[rs1][14], X[rs1][14], X[rs1][13], X[rs1][13], X
[rs1][12], X[rs1][12]};
X[rd] = {b3[7:0], b2[7:0], b1[7:0], b0[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.57. qc.expand3

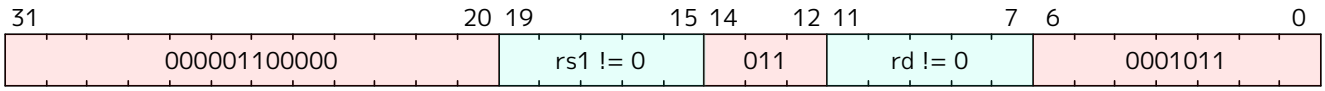
Synopsis

Bit expansion (every 3rd bit)

Mnemonic

```
qc.expand3  rd, rs1
```

Encoding



Description

Bit expansion (every 3rd bit) of `rs1`, bits [31:11] of `rs1` are ignored. Write result to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg b0 = {X[rs1][2], X[rs1][2], X[rs1][1], X[rs1][1], X[rs1][1], X[rs1][0], X[rs1][
0], X[rs1][0]};
XReg b1 = {X[rs1][5], X[rs1][4], X[rs1][4], X[rs1][4], X[rs1][3], X[rs1][3], X[rs1][
3], X[rs1][2]};
XReg b2 = {X[rs1][7], X[rs1][7], X[rs1][7], X[rs1][6], X[rs1][6], X[rs1][6], X[rs1][
5], X[rs1][5]};
XReg b3 = {X[rs1][10], X[rs1][10], X[rs1][9], X[rs1][9], X[rs1][9], X[rs1][8], X[rs1
][8], X[rs1][8]};
X[rd] = {b3[7:0], b2[7:0], b1[7:0], b0[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.58. qc.ext

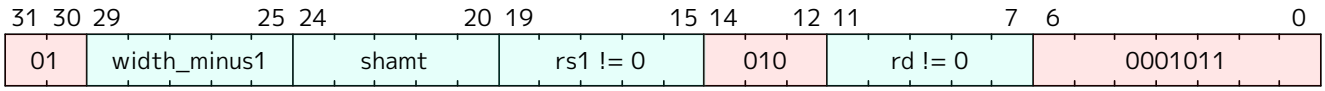
Synopsis

Extract bits signed

Mnemonic

```
qc.ext  rd, rs1, width, shamt
```

Encoding



Description

Extract a subset of bits from rs1 into rd, and sign-extend the result. The width of the subset is determined by (width_minus1 + 1) (1..32), and the offset of the subset is determined by shamt. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = width_minus1 + 1;
XReg unsigned_extraction = (X[rs1] >> shamt) & ((1 << width) - 1);
X[rd] = sext(unsigned_extraction, width_minus1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.59. qc.extd

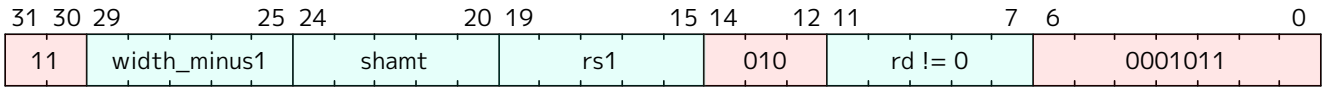
Synopsis

Extract bits from pair signed (Immediate)

Mnemonic

```
qc.extd  rd, rs1, width, shamt
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd, and sign extend the result. The width of the subset is determined by (width_minus1 + 1) (1..32), and the offset (into the pair) of the subset is determined by shamt. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = width_minus1 + 1;
X[rd] = sext((pair >> shamt) & ((1 << width) - 1), width_minus1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.60. qc.extdpr

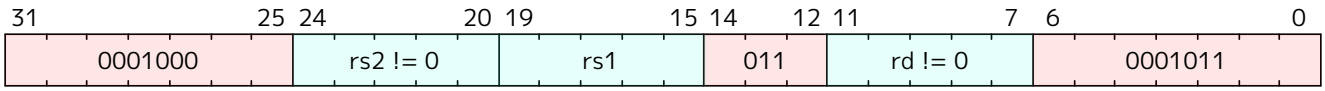
Synopsis

Extract bits from pair signed, packed descriptor (Register)

Mnemonic

```
qc.extdpr  rd, rs1, rs2
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd, and sign extend the result. The width of the subset is determined by rs2 bits [15:8] + 1 (1..32), and the offset of the subset is determined by rs2 bits [7:0]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = X[rs2][15:8] + 1;
XReg shamt = X[rs2][7:0];
X[rd] = sext((pair >> shamt) & 1 << width) - 1), (width - 1;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.61. qc.extdprh

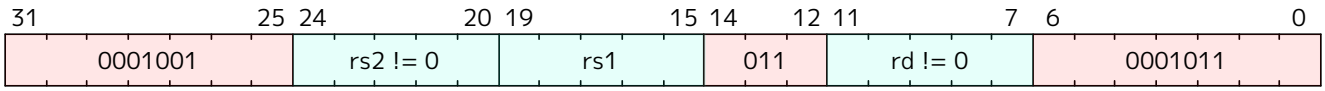
Synopsis

Extract bits from pair signed, packed descriptor high part (Register)

Mnemonic

```
qc.extdprh  rd, rs1, rs2
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd, and sign extend the result. The width of the subset is determined by rs2 bits [31:24] + 1 (1..32), and the offset of the subset is determined by rs2 bits [23:16]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = X[rs2][31:24] + 1;
XReg shamt = X[rs2][23:16];
X[rd] = sext((pair >> shamt) & 1 << width) - 1), (width - 1;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.62. qc.extdr

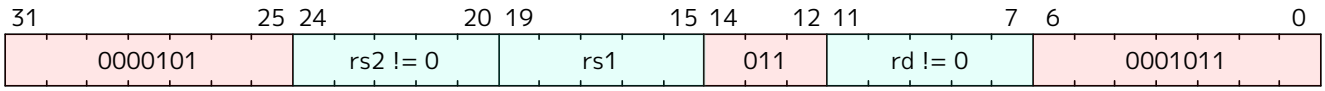
Synopsis

Extract bits from pair signed (Register)

Mnemonic

```
qc.extdr  rd, rs1, rs2
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd, and sign extend the result. The width of the subset is determined by rs2 bits [31:16] + 1 (1..32), and the offset of the subset is determined by rs2 bits [15:0]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = X[rs2][31:16] + 1;
XReg shamt = X[rs2][15:0];
X[rd] = sext((pair >> shamt) & 1 << width) - 1), (width - 1;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.63. qc.extdu

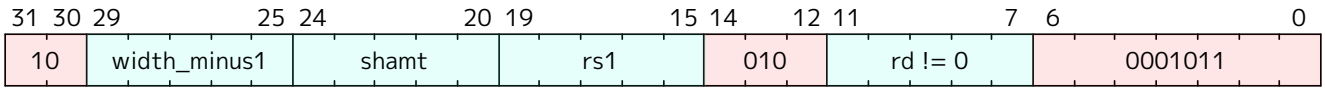
Synopsis

Extract bits from pair unsigned (Immediate)

Mnemonic

```
qc.extdu  rd, rs1, width, shamt
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd. The width of the subset is determined by (width_minus1 + 1) (1..32), and the offset (into the pair) of the subset is determined by shamt. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = width_minus1 + 1;
X[rd] = (pair >> shamt) & ((1 << width) - 1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.64. qc.extdupr

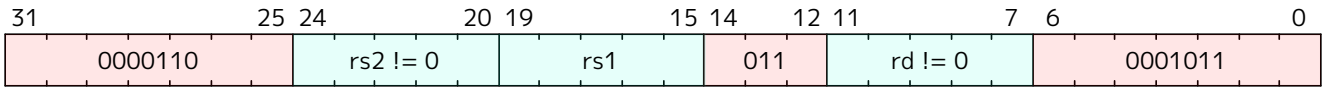
Synopsis

Extract bits from pair unsigned, packed descriptor (Register)

Mnemonic

```
qc.extdupr  rd, rs1, rs2
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd. The width of the subset is determined by rs2 bits [15:8] + 1 (1..32), and the offset of the subset is determined by rs2 bits [7:0]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = X[rs2][15:8] + 1;
XReg shamt = X[rs2][7:0];
X[rd] = (pair >> shamt) & ((1 << width) - 1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.65. qc.extduprh

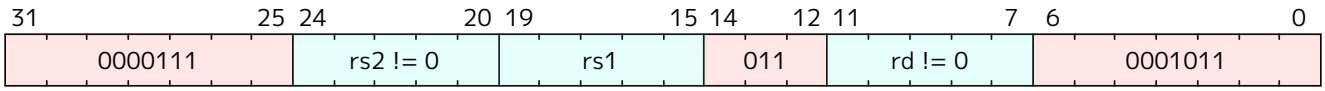
Synopsis

Extract bits from pair unsigned, packed descriptor high part (Register)

Mnemonic

```
qc.extduprh  rd, rs1, rs2
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd. The width of the subset is determined by rs2 bits [31:24] + 1 (1..32), and the offset of the subset is determined by rs2 bits [23:16]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = X[rs2][31:24] + 1;
XReg shamt = X[rs2][23:16];
X[rd] = (pair >> shamt) & ((1 << width) - 1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.66. qc.extdur

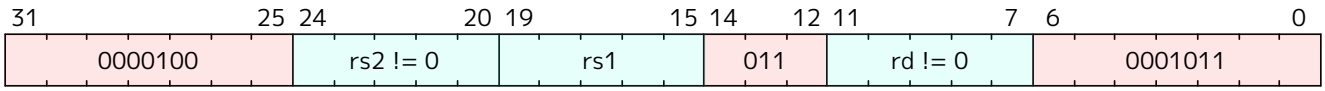
Synopsis

Extract bits from pair unsigned (Register)

Mnemonic

```
qc.extdur  rd, rs1, rs2
```

Encoding



Description

Extract a subset of bits from the register pair [rs1, rs1+1] into rd. The width of the subset is determined by rs2 bits [31:16] + 1 (1..32), and the offset of the subset is determined by rs2 bits [15:0]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> pair = {X[rs1 + 1], X[rs1]};
XReg width = X[rs2][31:16] + 1;
XReg shamt = X[rs2][15:0];
X[rd] = (pair >> shamt) & ((1 << width) - 1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.67. qc.extu

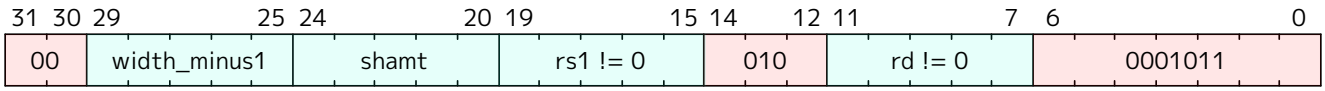
Synopsis

Extract bits unsigned

Mnemonic

```
qc.extu  rd, rs1, width, shamt
```

Encoding



Description

Extract a subset of bits from `rs1` into `rd`. The width of the subset is determined by (`width_minus1` + 1) (1..32), and the offset of the subset is determined by `shamt`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = width_minus1 + 1;
X[rd] = (X[rs1] >> shamt) & ((1 << width) - 1);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.68. qc.insb

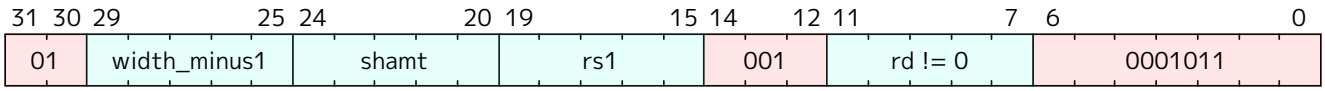
Synopsis

Insert bits (Register)

Mnemonic

```
qc.insb  rd, rs1, width, shamt
```

Encoding



Description

Insertion of a subset of bits from `rs1` into `rd`. The width of the subset is determined by (`width_minus1` + 1) (1..32), and the offset of the subset is determined by `shamt`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = width_minus1 + 1;
XReg mask = ((1 << width) - 1) << shamt;
XReg orig_val = X[rd];
X[rd] = (orig_val & ~mask) | ((X[rs1] << shamt) & mask);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.69. qc.insbh

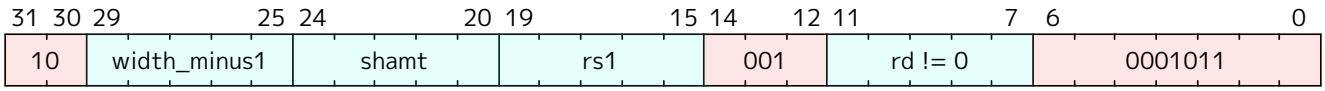
Synopsis

Insert bits in 64-bit higher part (Register)

Mnemonic

```
qc.insbh  rd, rs1, width, shamt
```

Encoding



Description

Insertion of a subset of bits from `rs1` into `rd`. Instruction intended for insertion bits into bitfield within 64-bits, when bitfield crosses 32-bit bundary. Lower part of 64-bit destination is inserted using QC32.INSB, higher part using QC32.INSBH. The width of the subset is determined by (`width_minus1` + 1) (1..32), and the offset of the subset is determined by `shamt`. In case when width + offset ⇐ 32, the destination register is left unchanged. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = width_minus1 + 1;
if (width + shamt > 32) {
  XReg mask = 1 << (width + shamt - 32 - 1);
  XReg orig_val = X[rd];
  X[rd] = (orig_val & ~mask) | X[rs1] & mask);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.70. qc.insbhr

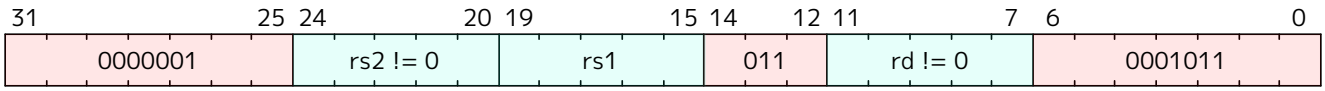
Synopsis

Insert bits in 64-bit higher part (Register)

Mnemonic

```
qc.insbhr  rd, rs1, rs2
```

Encoding



Description

Insertion of a subset of bits from `rs1` into `rd`. Instruction intended for insertion bits into bitfield within 64-bits, when bitfield crosses 32-bit bundary. Lower part of 64-bit destination is inserted using QC32.INSB, higher part using QC32.INSBH. The width of the subset is determined by `rs2` bits [31:16] + 1 (1..32), and the offset of the subset is determined by `rs2` bits [15:0]. In case when width + offset ⇐ 32, the destination register is left unchanged. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = X[rs2][31:16] + 1;
XReg shamt = X[rs2][15:0];
if (width + shamt > 32) {
  XReg mask = 1 << (width + shamt - 32 - 1);
  XReg orig_val = X[rd];
  X[rd] = (orig_val & ~mask) | X[rs1] & mask);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.71. qc.insbi

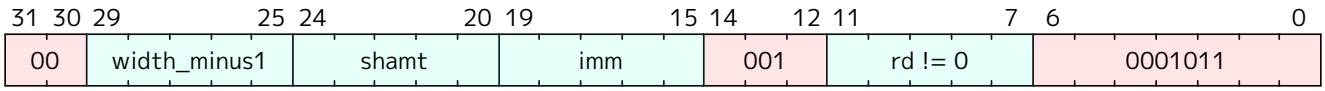
Synopsis

Insert bits (Immediate)

Mnemonic

```
qc.insbi  rd, imm, width, shamt
```

Encoding



Description

Insertion of a subset of bits of an `imm` into `rd`. The width of the subset is determined by (`width_minus1` + 1) (1..32), and the offset of the subset is determined by `shamt`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> width_minus1 = $encoding[29:25];
Bits<5> shamt = $encoding[24:20];
Bits<5> imm = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = width_minus1 + 1;
XReg mask = ((1 << width) - 1) << shamt;
XReg orig_val = X[rd];
X[rd] = (orig_val & ~mask) | ((imm << shamt) & mask);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.72. qc.insbpr

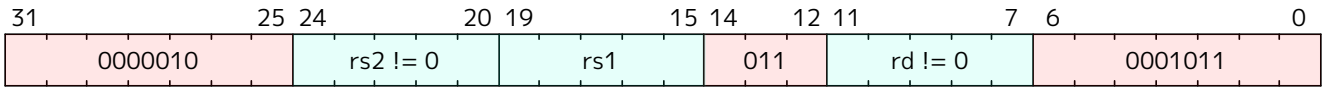
Synopsis

Insert bits, packed descriptor (Register)

Mnemonic

```
qc.insbpr  rd, rs1, rs2
```

Encoding



Description

Insertion of a subset of bits from `rs1` into `rd`. The width of the subset is determined by `rs2` bits [15:8] + 1 (1..32), and the offset of the subset is determined by `rs2` bits [7:0]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = X[rs2][15:8] + 1;
XReg shamt = X[rs2][7:0];
XReg mask = ((1 << width) - 1) << shamt;
XReg orig_val = X[rd];
X[rd] = (orig_val & ~mask) | ((X[rs1] << shamt) & mask);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.73. qc.insbprh

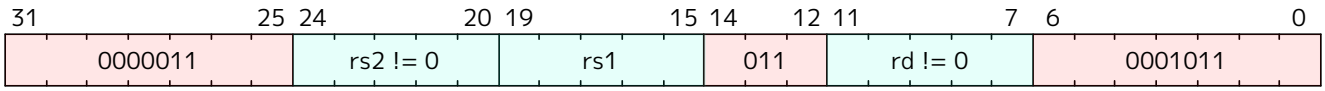
Synopsis

Insert bits, packed descriptor high part (Register)

Mnemonic

```
qc.insbprh  rd, rs1, rs2
```

Encoding



Description

Insertion of a subset of bits from `rs1` into `rd`. The width of the subset is determined by `rs2` bits [31:24] + 1 (1..32), and the offset of the subset is determined by `rs2` bits [23:15]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = X[rs2][31:24] + 1;
XReg shamt = X[rs2][23:16];
XReg mask = ((1 << width) - 1) << shamt;
XReg orig_val = X[rd];
X[rd] = (orig_val & ~mask) | ((X[rs1] << shamt) & mask);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.74. qc.insbr

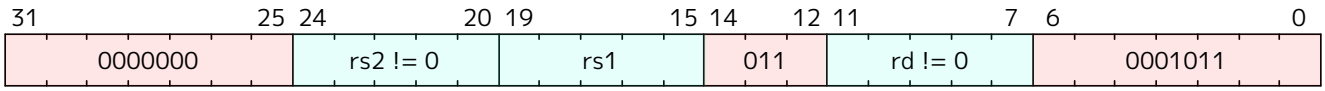
Synopsis

Insert bits (Register)

Mnemonic

```
qc.insbr  rd, rs1, rs2
```

Encoding



Description

Insertion of a subset of bits from `rs1` into `rd`. The width of the subset is determined by `rs2` bits [31:16] + 1 (1..32), and the offset of the subset is determined by `rs2` bits [15:0]. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = X[rs2][31:16] + 1;
XReg shamt = X[rs2][15:0];
XReg mask = ((1 << width) - 1) << shamt;
XReg orig_val = X[rd];
X[rd] = (orig_val & ~mask) | ((X[rs1] << shamt) & mask);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.75. qc.insbri

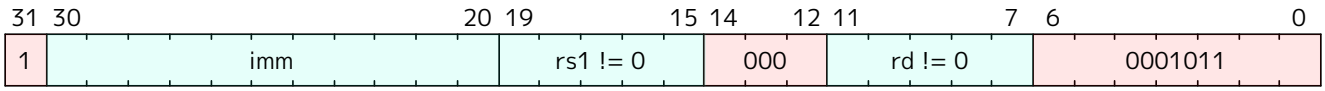
Synopsis

Insert bits (Immediate)

Mnemonic

```
qc.insbri  rd, rs1, imm
```

Encoding



Description

Insertion of a subset of bits of an `imm` into `rd`. The width of the subset is determined by `rs1` bits [31:16] + 1, and the offset of the subset is determined by `rs1` bits [15:0]. Instruction encoded in I instruction format.

Decode Variables

```
Bits<11> imm = $encoding[30:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg width = X[rs1][31:16] + 1;
XReg shamt = X[rs1][15:0];
XReg mask = ((1 << width) - 1) << shamt;
XReg orig_val = X[rd];
X[rd] = (orig_val & ~mask) | ((imm << shamt) & mask);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcibm, version >= 0

5.76. qc.li

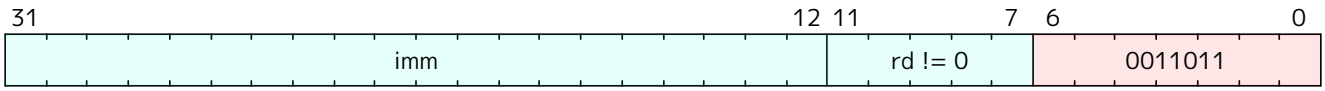
Synopsis

Load immediate large

Mnemonic

```
qc.li  rd, imm
```

Encoding



Description

Loads the 20-bit immediate `imm` into `rd`. Instruction encoded in U instruction format.

Decode Variables

```
Bits<20> imm = {$encoding[31], $encoding[15:12], $encoding[30:16]};
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = sext(imm, 20);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcili, version >= 0

5.77. qc.lieq

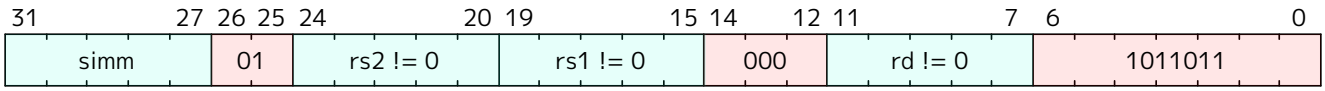
Synopsis

Conditional load immediate if equal (Register)

Mnemonic

```
qc.lieq  rd, rs1, rs2, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is equal to value `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] == X[rs2]) {
  X[rd] = sext(simm, 20);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.78. qc.lieqi

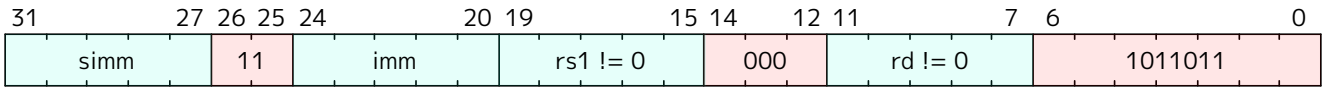
Synopsis

Conditional load immediate if equal (Immediate)

Mnemonic

```
qc.lieqi  rd, rs1, imm, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is equal to value `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) == $signed(imm)) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.79. qc.lige

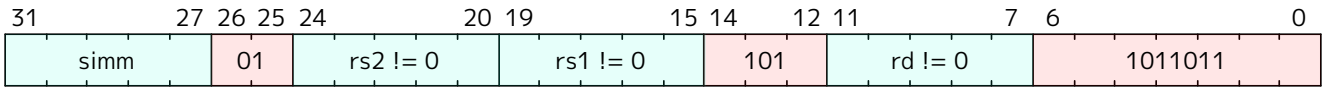
Synopsis

Conditional load immediate if great or equal than (Register)

Mnemonic

```
qc.lige  rd, rs1, rs2, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is great or equal than value `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) >= $signed(X[rs2])) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.80. qc.ligei

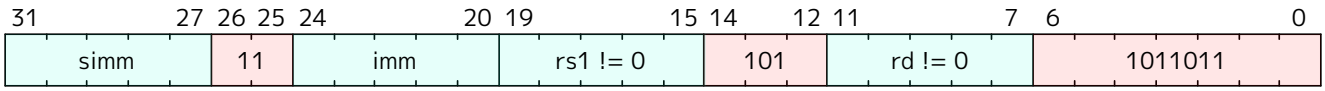
Synopsis

Conditional load immediate if great or equal than (Immediate)

Mnemonic

```
qc.ligei  rd, rs1, imm, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is great or equal than value `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) >= $signed(imm)) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.81. qc.ligeu

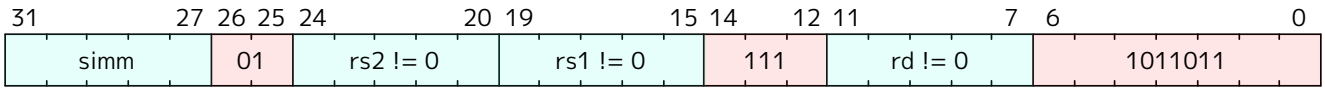
Synopsis

Conditional load immediate if great or equal than unsigned (Register)

Mnemonic

```
qc.ligeu  rd, rs1, rs2, simm
```

Encoding



Description

Move `simm` to `rd` if the unsigned value in `rs1` is great or equal than unsigned value `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] >= X[rs2]) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.82. qc.ligeui

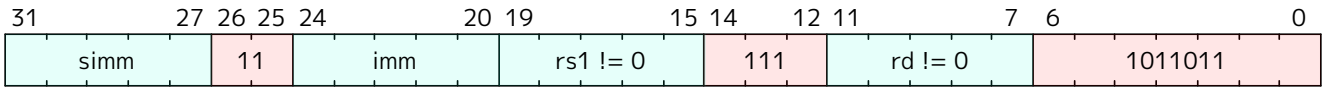
Synopsis

Conditional load immediate if great or equal than unsigned (Immediate)

Mnemonic

```
qc.ligeui  rd, rs1, imm, simm
```

Encoding



Description

Move `simm` to `rd` if the unsigned value in `rs1` is great or equal than unsigned value `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] >= imm) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.83. qc.lilt

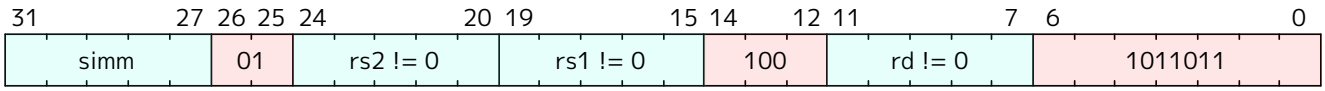
Synopsis

Conditional load immediate if less than (Register)

Mnemonic

```
qc.lilt  rd, rs1, rs2, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is less than value `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) < $signed(X[rs2])) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.84. qc.lilti

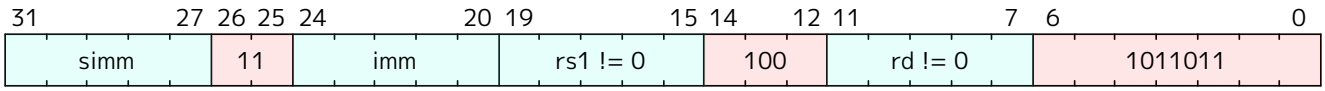
Synopsis

Conditional load immediate if less than (Immediate)

Mnemonic

```
qc.lilti  rd, rs1, imm, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is less than value `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) < $signed(imm)) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.85. qc.liltu

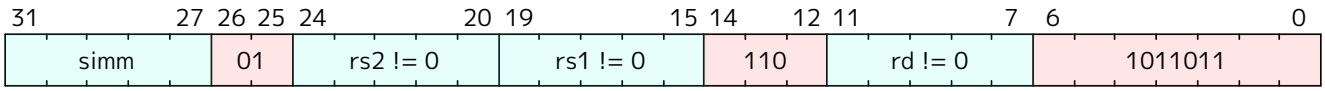
Synopsis

Conditional load immediate if less than unsigned (Register)

Mnemonic

```
qc.liltu  rd, rs1, rs2, simm
```

Encoding



Description

Move `simm` to `rd` if the unsigned value in `rs1` is less than unsigned value `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] < X[rs2]) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.86. qc.liltui

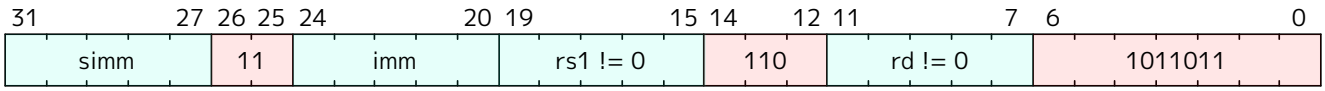
Synopsis

Conditional load immediate if less than unsigned (Immediate)

Mnemonic

```
qc.liltui  rd, rs1, imm, simm
```

Encoding



Description

Move `simm` to `rd` if the unsigned value in `rs1` is less than unsigned value `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] < imm) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.87. qc.line

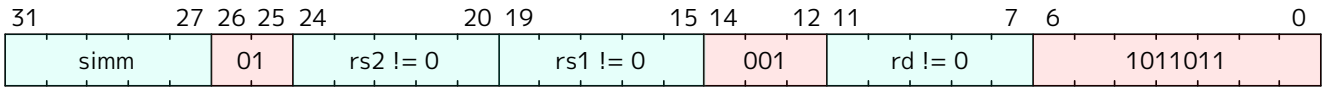
Synopsis

Conditional load immediate if not equal (Register)

Mnemonic

```
qc.line  rd, rs1, rs2, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is not equal to value `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) != $signed(X[rs2])) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.88. qc.linei

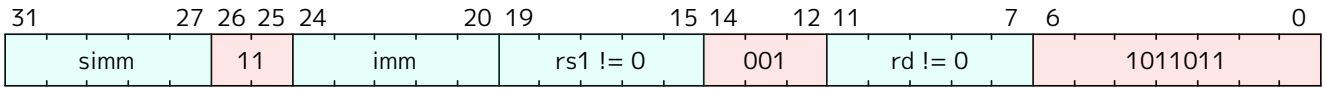
Synopsis

Conditional load immediate if not equal (Immediate)

Mnemonic

```
qc.linei  rd, rs1, imm, simm
```

Encoding



Description

Move `simm` to `rd` if the value in `rs1` is not equal to value `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> simm = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) != $signed(imm)) {
  X[rd] = sext(simm, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicli, version >= 0

5.89. qc.lrb

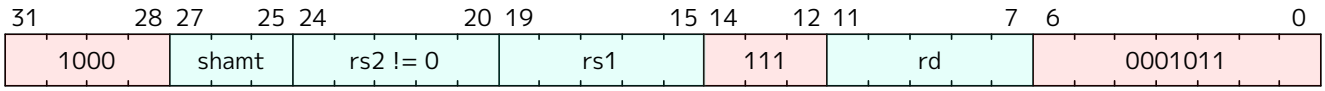
Synopsis

Load indexed byte

Mnemonic

```
qc.lrb  rd, rs1, rs2, shamt
```

Encoding



Description

Load 8 bits of data into register `rd` from an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Sign extend the result. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
X[rd] = sext(read_memory<8>(virtual_address, $encoding), 8);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.90. qc.lrbu

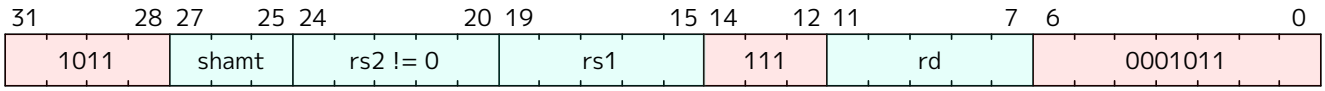
Synopsis

Load indexed unsigned byte

Mnemonic

```
qc.lrbu  rd, rs1, rs2, shamt
```

Encoding



Description

Load 8 bits of data into register `rd` from an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
X[rd] = read_memory<8>(virtual_address, $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.91. qc.lrh

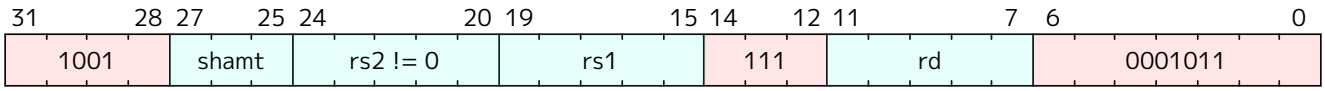
Synopsis

Load indexed halfword

Mnemonic

```
qc.lrh  rd, rs1, rs2, shamt
```

Encoding



Description

Load 16 bits of data into register `rd` from an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Sign extend the result. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
X[rd] = sext(read_memory<16>(virtual_address, $encoding), 16);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.92. qc.lrhu

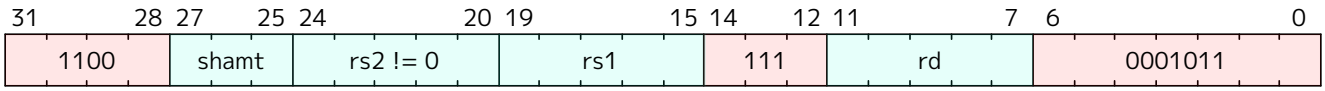
Synopsis

Load indexed unsigned halfword

Mnemonic

```
qc.lrhu  rd, rs1, rs2, shamt
```

Encoding



Description

Load 16 bits of data into register `rd` from an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
X[rd] = read_memory<16>(virtual_address, $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.93. qc.lrw

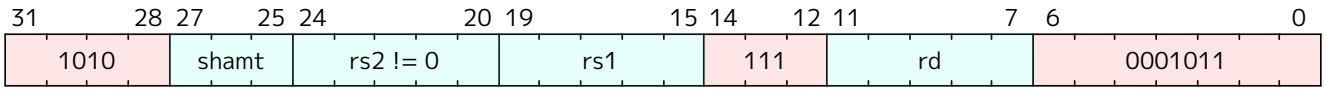
Synopsis

Load indexed word

Mnemonic

```
qc.lrw rd, rs1, rs2, shamt
```

Encoding



Description

Load 32 bits of data into register `rd` from an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
X[rd] = read_memory<32>(virtual_address, $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.94. qc.lwm

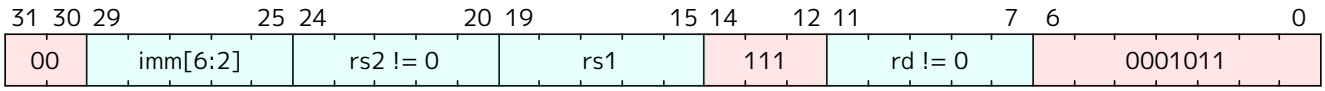
Synopsis

Load word multiple

Mnemonic

```
qc.lwm  rd, rs2, imm(rs1)
```

Encoding



Description

Loads multiple words starting from address (`rs1 + imm`) to registers, starting from `rd`. The number of words is in `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<7> imm = {$encoding[29:25], 2'd0};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg vaddr = X[rs1] + imm;
XReg num_words = X[rs2];
raise(ExceptionCode::IllegalInstruction, effective_ldst_mode(), $encoding) if (rd +
num_words) > 32;
for (U32 i = 0; i < num_words; i++) {
  X[rd + i] = read_memory<32>(vaddr, $encoding);
  vaddr = vaddr + 4;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilsm, version >= 0

5.95. qc.lwmi

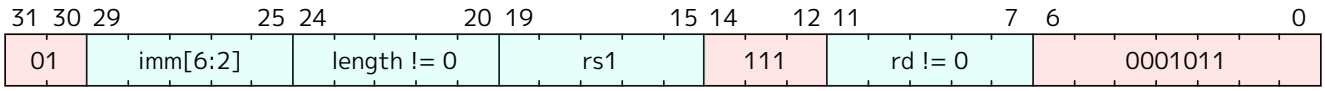
Synopsis

Load word multiple (Immediate)

Mnemonic

```
qc.lwmi  rd, length, imm(rs1)
```

Encoding



Description

Loads multiple words starting from address (`rs1 + imm`) to registers, starting from `rd`. The number of words is in the `length` immediate. Instruction encoded in I instruction format.

Decode Variables

```
Bits<7> imm = {$encoding[29:25], 2'd0};
Bits<5> rs1 = $encoding[19:15];
Bits<5> length = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg vaddr = X[rs1] + imm;
raise(ExceptionCode::IllegalInstruction, effective_ldst_mode(), $encoding) if (rd +
length) > 32;
for (U32 i = 0; i < length; i++) {
  X[rd + i] = read_memory<32>(vaddr, $encoding);
  vaddr = vaddr + 4;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilsm, version >= 0

5.96. qc.muladdi

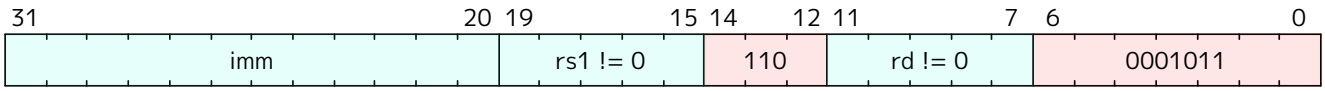
Synopsis

Multiply and accumulate (Immediate)

Mnemonic

```
qc.muladdi  rd, rs1, imm
```

Encoding



Description

Increments `rd` by the multiplication of `rs1` and a signed immediate `imm`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<12> imm = $encoding[31:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg orig_val = X[rd];
X[rd] = orig_val + (X[rs1] * sext(imm, 12));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciac, version >= 0

5.97. qc.mveq

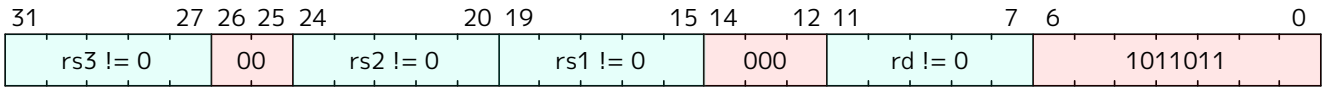
Synopsis

Conditional move if equal (Register)

Mnemonic

```
qc.mveq  rd, rs1, rs2, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is equal to value `rs2`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] == X[rs2]) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.98. qc.mveqi

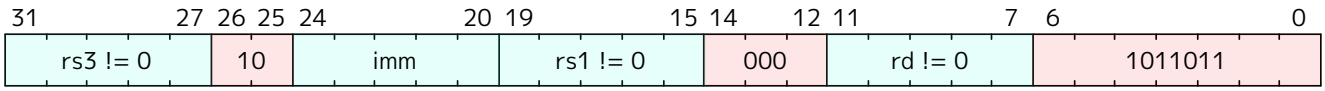
Synopsis

Conditional move if equal (Immediate)

Mnemonic

```
qc.mveqi  rd, rs1, imm, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is equal to value of `imm`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) == $signed(imm)) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.99. qc.mvge

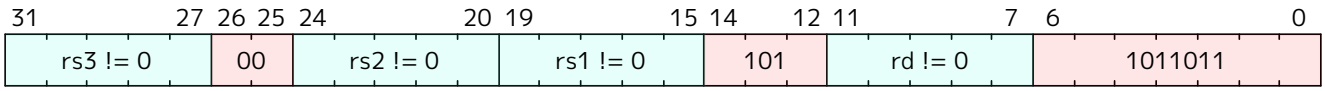
Synopsis

Conditional move if great or equal than (Register)

Mnemonic

```
qc.mvge  rd, rs1, rs2, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is great or equal than value `rs2`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) >= $signed(X[rs2])) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.100. qc.mvgei

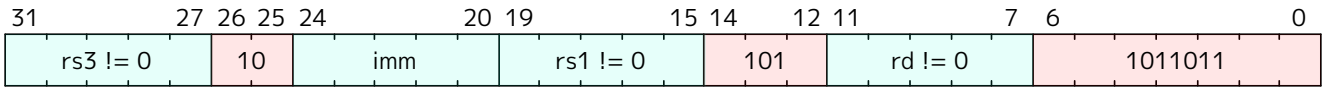
Synopsis

Conditional move if great or equal than (Immediate)

Mnemonic

```
qc.mvgei  rd, rs1, imm, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is great or equal than value of `imm`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) >= $signed(imm)) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.101. qc.mvgeu

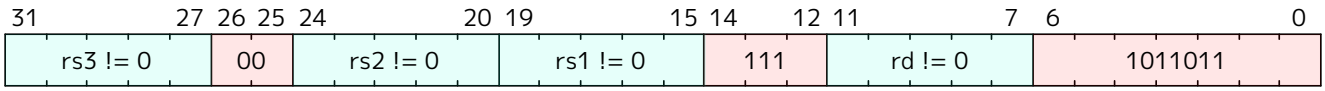
Synopsis

Conditional move if great or equal than unsigned (Register)

Mnemonic

```
qc.mvgeu  rd, rs1, rs2, rs3
```

Encoding



Description

Move `rs3` to `rd` if the unsigned value in `rs1` is great or equal than unsigned value `rs2`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] >= X[rs2]) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.102. qc.mvgeui

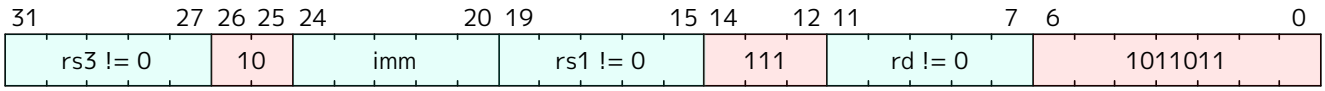
Synopsis

Conditional move if great or equal than unsigned (Immediate)

Mnemonic

```
qc.mvgeui  rd, rs1, imm, rs3
```

Encoding



Description

Move `rs3` to `rd` if the unsigned value in `rs1` is great or equal than unsigned value of `imm`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] >= imm) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.103. qc.mvlt

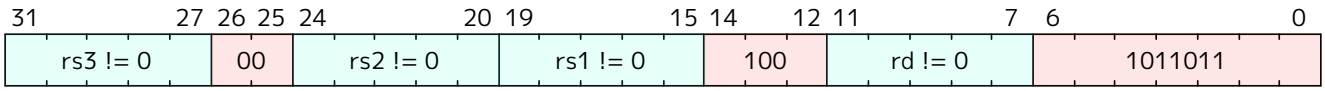
Synopsis

Conditional move if less than (Register)

Mnemonic

```
qc.mvlt  rd, rs1, rs2, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is less than value `rs2`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) < $signed(X[rs2])) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.104. qc.mvlti

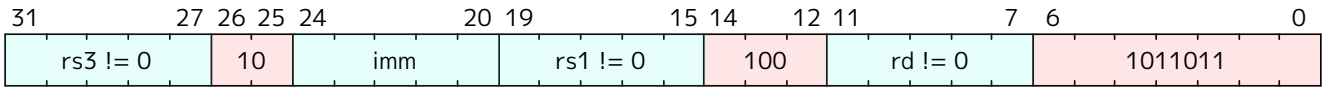
Synopsis

Conditional move if less than (Immediate)

Mnemonic

```
qc.mvlti  rd, rs1, imm, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is less than value of `imm`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) < $signed(imm)) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.105. qc.mvltu

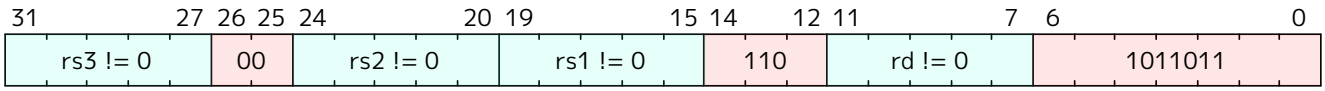
Synopsis

Conditional move if less than unsigned (Register)

Mnemonic

```
qc.mvltu  rd, rs1, rs2, rs3
```

Encoding



Description

Move `rs3` to `rd` if the unsigned value in `rs1` is less than unsigned value `rs2`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] < X[rs2]) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.106. qc.mvltui

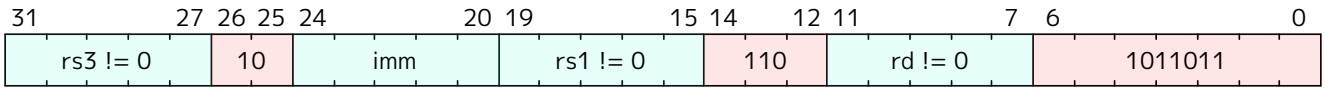
Synopsis

Conditional move if less than unsigned (Immediate)

Mnemonic

```
qc.mvltui  rd, rs1, imm, rs3
```

Encoding



Description

Move `rs3` to `rd` if the unsigned value in `rs1` is less than unsigned value of `imm`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] < imm) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.107. qc.mvne

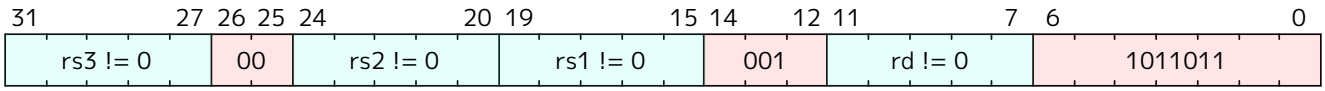
Synopsis

Conditional move if not equal (Register)

Mnemonic

```
qc.mvne  rd, rs1, rs2, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is not equal to value `rs2`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rs1] != X[rs2]) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.108. qc.mvnei

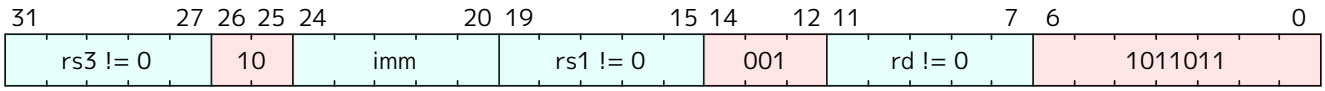
Synopsis

Conditional move if not equal (Immediate)

Mnemonic

```
qc.mvnei  rd, rs1, imm, rs3
```

Encoding



Description

Move `rs3` to `rd` if the value in `rs1` is not equal to value `imm`. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> imm = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rs1]) != $signed(imm)) {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcicm, version >= 0

5.109. qc.norm

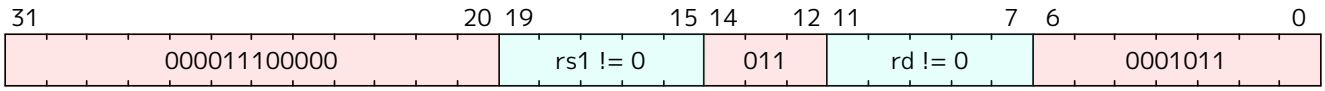
Synopsis

Signed Normalization

Mnemonic

```
qc.norm  rd, rs1
```

Encoding



Description

Signed normalization of `rs1`. Exponent written in bits[7:0] of the result. Mantissa written in bits[31:8] of the result. Write result to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg clz = (xlen() - 1) - $signed(highest_set_bit(X[rs1]));
XReg clo = (xlen() - 1) - $signed(highest_set_bit(~X[rs1]));
XReg exp = (X[rs1][31] == 1) ? (X[rs1] << (clo - 1)) : (X[rs1] << (clz - 1));
XReg mnt = (X[rs1][31] == 1) ? (-(clo - 1)) : (-(clz - 1));
X[rd] = {mnt[23:0], exp[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.110. qc.normeu

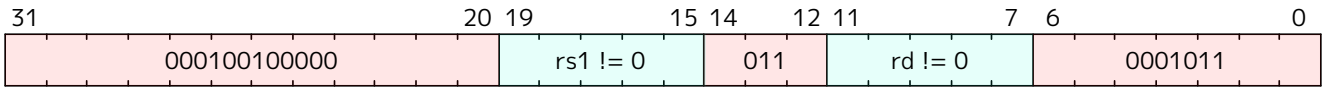
Synopsis

Unsigned Even Normalization

Mnemonic

```
qc.normeu  rd, rs1
```

Encoding



Description

Unsigned even normalization of `rs1` (exponent is even). Even exponent written in bits[7:0] of the result. Mantissa (based on even exponent) written in bits[31:8] of the result. Write result to `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg clz = xlen() - 1) - $signed(highest_set_bit(X[rs1]) & ~1;
XReg exp = (X[rs1] << clz);
XReg mnt = (-clz);
X[rd] = {mnt[23:0], exp[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.111. qc.normu

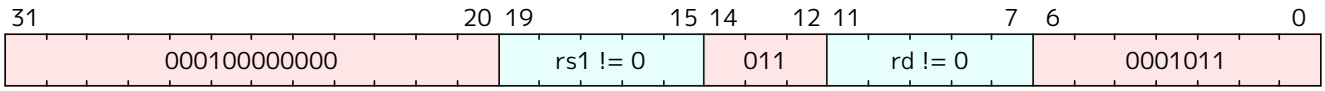
Synopsis

Unsigned Normalization

Mnemonic

```
qc.normu  rd, rs1
```

Encoding



Description

Unsigned normalization of rs1. Exponent written in bits[7:0] of the result. Mantissa written in bits[31:8] of the result. Write result to rd. Instruction encoded in I instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg clz = (xlen() - 1) - $signed(highest_set_bit(X[rs1]));
XReg exp = (X[rs1] << clz);
XReg mnt = (-clz);
X[rd] = {mnt[23:0], exp[7:0]};
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.112. qc.selecteqi

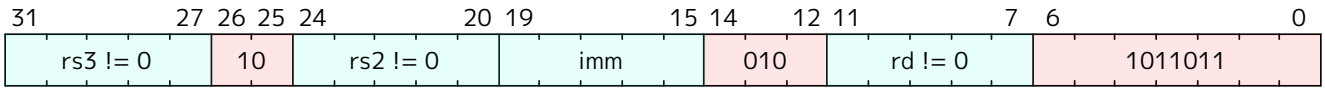
Synopsis

Select load immediate or register if equal (Immediate)

Mnemonic

```
qc.selecteqi  rd, imm, rs2, rs3
```

Encoding



Description

Move `rs2` to `rd` if the value in `rd` is equal to value `imm`, move `rs3` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> imm = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) == $signed(imm)) {
  X[rd] = X[rs2];
} else {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.113. qc.selectieq

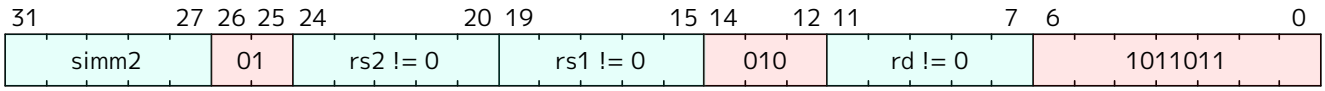
Synopsis

Select load immediate or register if equal (Register)

Mnemonic

```
qc.selectieq  rd, rs1, rs2, simm2
```

Encoding



Description

Move `rs2` to `rd` if the value in `rd` is equal to value `rs1`, move `simm2` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm2 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if (X[rd] == X[rs1]) {
  X[rd] = X[rs2];
} else {
  X[rd] = sext(simm2, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.114. qc.selectieqi

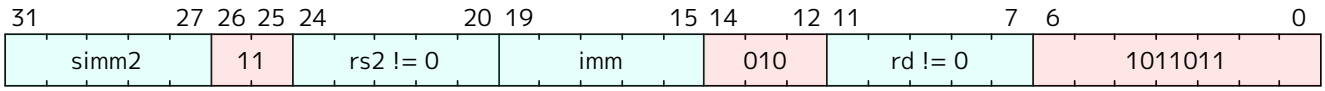
Synopsis

Select load immediate or register if equal (Immediate)

Mnemonic

```
qc.selectieqi  rd, imm, rs2, simm2
```

Encoding



Description

Move `rs2` to `rd` if the value in `rd` is equal to value `imm`, move `simm2` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> imm = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm2 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) == $signed(imm)) {
  X[rd] = X[rs2];
} else {
  X[rd] = sext(simm2, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.115. qc.selectiieq

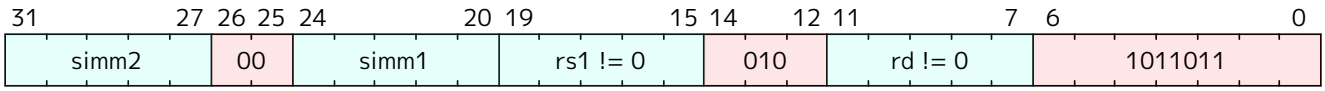
Synopsis

Select load immediate if equal (Register)

Mnemonic

```
qc.selectiieq  rd, rs1, simm1, simm2
```

Encoding



Description

Move `simm1` to `rd` if the value in `rd` is equal to value `rs1`, move `simm2` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> simm1 = $encoding[24:20];
Bits<5> simm2 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) == $signed(X[rs1])) {
  X[rd] = sext(simm1, 5);
} else {
  X[rd] = sext(simm2, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.116. qc.selectiine

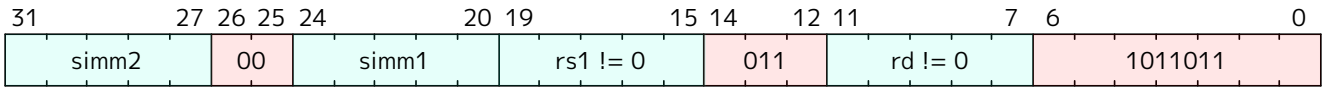
Synopsis

Select load immediate if not equal (Register)

Mnemonic

```
qc.selectiine  rd, rs1, simm1, simm2
```

Encoding



Description

Move `simm1` to `rd` if the value in `rd` is not equal to value `rs1`, move `simm2` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> simm1 = $encoding[24:20];
Bits<5> simm2 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) != $signed(X[rs1])) {
  X[rd] = sext(simm1, 5);
} else {
  X[rd] = sext(simm2, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.117. qc.selectine

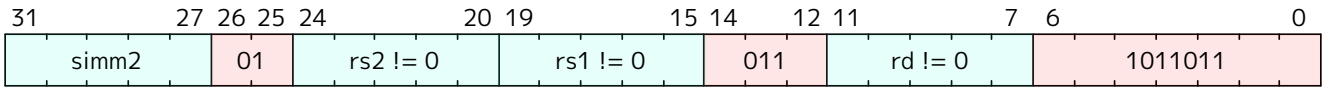
Synopsis

Select load immediate or register if not equal (Register)

Mnemonic

```
qc.selectine  rd, rs1, rs2, simm2
```

Encoding



Description

Move `rs2` to `rd` if the value in `rd` is not equal to value `rs1`, move `simm2` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm2 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) != $signed(X[rs1])) {
  X[rd] = X[rs2];
} else {
  X[rd] = sext(simm2, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.118. qc.selectinei

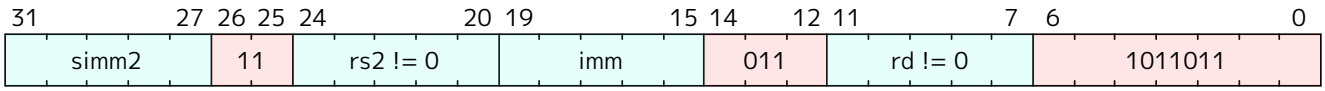
Synopsis

Select load immediate or register if not equal (Immediate)

Mnemonic

```
qc.selectinei  rd, imm, rs2, simm2
```

Encoding



Description

Move `rs2` to `rd` if the value in `rd` is not equal to value `imm`, move `simm2` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> imm = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> simm2 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) != $signed(imm)) {
  X[rd] = X[rs2];
} else {
  X[rd] = sext(simm2, 5);
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.119. qc.selectnei

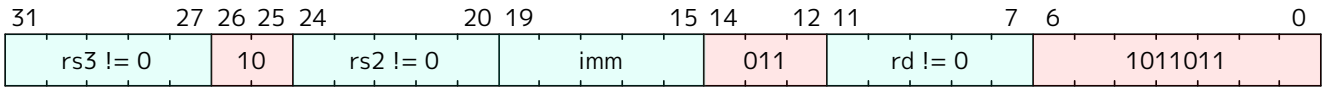
Synopsis

Select load immediate or register if not equal (Immediate)

Mnemonic

```
qc.selectnei  rd, imm, rs2, rs3
```

Encoding



Description

Move `rs2` to `rd` if the value in `rd` is not equal to value `imm`, move `rs3` to `rd` otherwise. Instruction encoded in R4 instruction format.

Decode Variables

```
Bits<5> imm = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[31:27];
Bits<5> rd = $encoding[11:7];
```

Operation

```
if ($signed(X[rd]) != $signed(imm)) {
  X[rd] = X[rs2];
} else {
  X[rd] = X[rs3];
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcics, version >= 0

5.120. qc.setinti

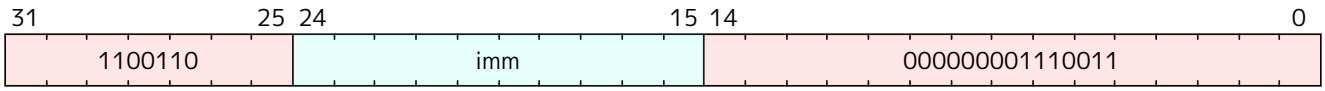
Synopsis

Set interrupt (Immediate)

Mnemonic

```
qc.setinti  imm
```

Encoding



Description

Set interrupt, interrupt number is in `imm` (0 - 1023). Instruction encoded in I instruction format.

Decode Variables

```
Bits<10> imm = $encoding[24:15];
```

Operation

```
Bits<12> MCLICIP0_ADDR = CSR[qc_mclicip0].address();
XReg idx = imm / 32;
XReg bit = imm % 32;
XReg pre_csr = CSR[MCLICIP0_ADDR + idx].sw_read();
CSR[MCLICIP0_ADDR + idx].sw_write(pre_csr | (1 << bit));
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqciint, version >= 0

5.121. qc.setwm

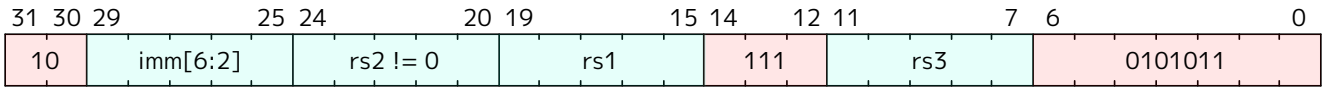
Synopsis

Set word multiple (Register)

Mnemonic

```
qc.setwm  rs3, rs2, imm(rs1)
```

Encoding



Description

Stores the value of rs3 multiple times into the address starting at (rs1 + imm). The number of writes is in rs2. Instruction encoded in R instruction format.

Decode Variables

```
Bits<7> imm = {$encoding[29:25], 2'd0};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg vaddr = X[rs1] + imm;
Bits<32> write_value = X[rs3][31:0];
XReg num_words = X[rs2];
for (U32 i = 0; i < num_words; i++) {
  write_memory<32>(vaddr, write_value, $encoding);
  vaddr = vaddr + 4;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilsm, version >= 0

5.122. qc.setwmi

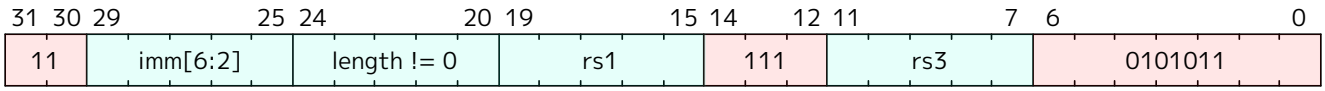
Synopsis

Set word multiple (Immediate)

Mnemonic

```
qc.setwmi rs3, length, imm(rs1)
```

Encoding



Description

Stores the value of rs3 multiple times into the address starting at (rs1 + imm). The number of writes is in length. Instruction encoded in I instruction format.

Decode Variables

```
Bits<7> imm = {$encoding[29:25], 2'd0};
Bits<5> rs1 = $encoding[19:15];
Bits<5> length = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg vaddr = X[rs1] + imm;
Bits<32> write_value = X[rs3][31:0];
for (U32 i = 0; i < length; i++) {
  write_memory<32>(vaddr, write_value, $encoding);
  vaddr = vaddr + 4;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilsm, version >= 0

5.123. qc.shladd

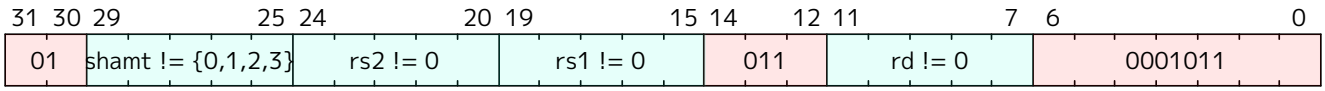
Synopsis

Shift left and add (immediate)

Mnemonic

```
qc.shladd  rs1, rs2, shamt
```

Encoding



Description

Left shift *rs1* by *shamt* and add the value in *rs2*. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> shamt = $encoding[29:25];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = (X[rs1] << shamt) + X[rs2];
```

Included in

- anyOf:
- Xqci, version >= 0.2
- Xqciac, version >= 0

5.124. qc.slasat

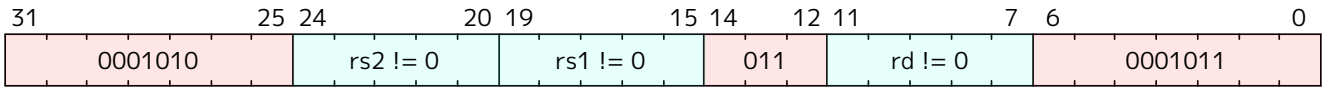
Synopsis

Saturating arithmetic left shift

Mnemonic

```
qc.slasat  rd, rs1, rs2
```

Encoding



Description

Left shift `rs1` by the value of `rs2`, and saturate the signed result. The number of words is in `length`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> shifted_value = X[rs1] << X[rs2][4:0];
XReg most_negative_number = 1 << (xlen() - 1);
XReg most_positive_number = (1 << (xlen() - 1) - 1);
if ($signed(shifted_value) < $signed(most_negative_number)) {
  X[rd] = most_negative_number;
} else if ($signed(shifted_value) > $signed(most_positive_number)) {
  X[rd] = most_positive_number;
} else {
  X[rd] = shifted_value;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.125. qc.sllsat

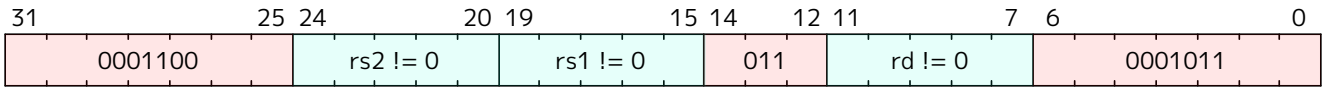
Synopsis

Saturating logical left shift

Mnemonic

```
qc.sllsat  rd, rs1, rs2
```

Encoding



Description

Left shift `rs1` by the value of `rs2`, and saturate the unsigned result. The number of words is in `length`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
Bits<{1'b0, XLEN} * 2> sext_double_width_rs1 = {{XLEN{X[rs1][xlen() - 1]}}, X[rs1]};
Bits<{1'b0, XLEN} * 2> shifted_value = sext_double_width_rs1 << X[rs2][4:0];
XReg largest_unsigned_value = {XLEN{1'b1}};
if (shifted_value > largest_unsigned_value) {
  X[rd] = largest_unsigned_value;
} else {
  X[rd] = shifted_value;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.126. qc.srb

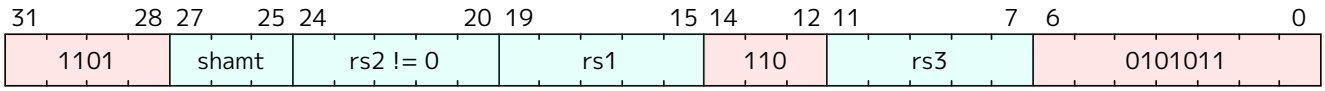
Synopsis

Store indexed byte

Mnemonic

```
qc.srb  rs3, rs1, rs2, shamt
```

Encoding



Description

Store 8 bits of data from register `rs3` to an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
write_memory<8>(virtual_address, X[rs3][7:0], $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.127. qc.srh

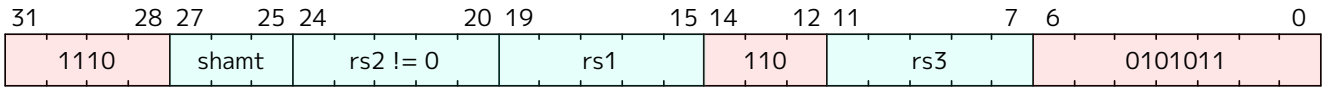
Synopsis

Store indexed halfword

Mnemonic

```
qc.srh  rs3, rs1, rs2, shamt
```

Encoding



Description

Store 16 bits of data from register `rs3` to an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
write_memory<16>(virtual_address, X[rs3][15:0], $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.128. qc.srw

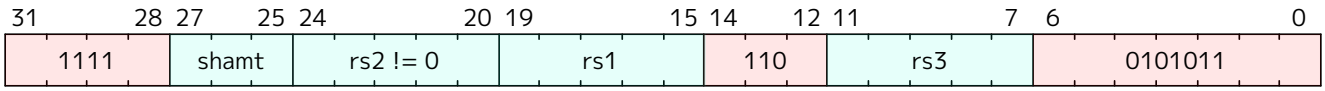
Synopsis

Store indexed word

Mnemonic

```
qc.srw  rs3, rs1, rs2, shamt
```

Encoding



Description

Store 32 bits of data from register `rs3` to an address formed by adding `rs1` to `rs2`, shifted by `shamt`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<3> shamt = $encoding[27:25];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg virtual_address = X[rs1] + (X[rs2] << shamt);
write_memory<32>(virtual_address, X[rs3][31:0], $encoding);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcisls, version >= 0

5.129. qc.subsat

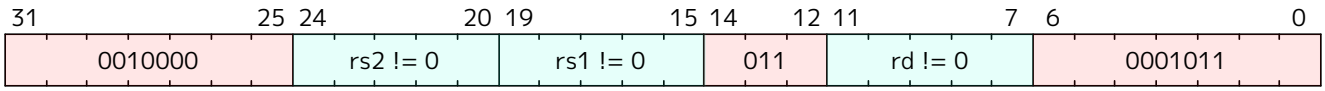
Synopsis

Saturating signed subtraction

Mnemonic

```
qc.subsat  rd, rs1, rs2
```

Encoding



Description

Subtract signed values `rs1` and `rs2`, saturate the signed result, and write to `rd`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg result = X[rs1] - X[rs2];
XReg most_negative_number = 1 << (xlen() - 1);
XReg most_positive_number = (1 << (xlen() - 1)) - 1;
if (X[rs1][xlen() - 1] != X[rs2][xlen() - 1]) {
  if (result[xlen() - 1] != X[rs1][xlen() - 1]) {
    if ($signed(X[rs1]) < 0) {
      X[rd] = most_negative_number;
    } else {
      X[rd] = most_positive_number;
    }
  }
}
X[rd] = result;
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.130. qc.subusat

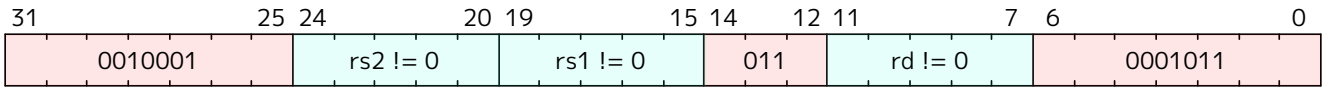
Synopsis

Saturating unsigned subtraction

Mnemonic

```
qc.subusat  rd, rs1, rs2
```

Encoding



Description

Subtract unsigned values `rs1` and `rs2`, saturate the unsigned result, and write to `rd`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
X[rd] = (X[rs1] < X[rs2]) ? 0 : X[rs1] - X[rs2];
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.131. qc.swm

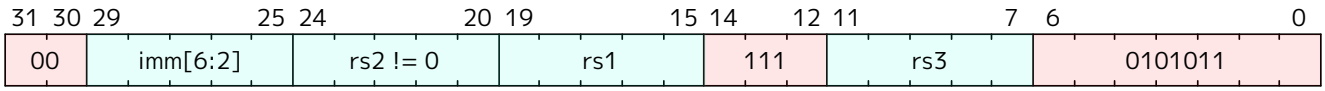
Synopsis

Store word multiple

Mnemonic

```
qc.swm  rs3, rs2, imm(rs1)
```

Encoding



Description

Stores multiple words from the registers starting at `rs3` to the address starting at (`rs1` + `imm`). The number of words is in `rs2`. Instruction encoded in R instruction format.

Decode Variables

```
Bits<7> imm = {$encoding[29:25], 2'd0};
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg vaddr = X[rs1] + imm;
XReg num_words = X[rs2];
raise(ExceptionCode::IllegalInstruction, effective_ldst_mode(), $encoding) if (rs3 +
num_words) > 32;
for (U32 i = 0; i < num_words; i++) {
  write_memory<32>(vaddr, X[rs3 + i], $encoding);
  vaddr = vaddr + 4;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilsm, version >= 0

5.132. qc.swmi

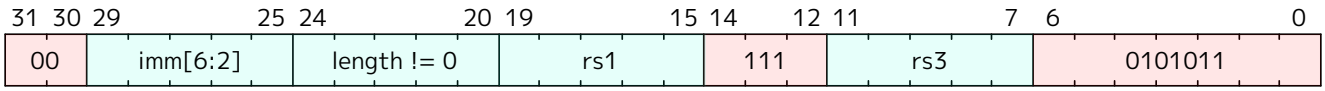
Synopsis

Store word multiple (immediate)

Mnemonic

```
qc.swmi  rs3, length, imm(rs1)
```

Encoding



Description

Stores multiple words from the registers starting at `rs3` to the address starting at (`rs1` + `imm`). The number of words is in `length` immediate. Instruction encoded in I instruction format.

Decode Variables

```
Bits<7> imm = {$encoding[29:25], 2'd0};
Bits<5> rs1 = $encoding[19:15];
Bits<5> length = $encoding[24:20];
Bits<5> rs3 = $encoding[11:7];
```

Operation

```
XReg vaddr = X[rs1] + imm;
raise(ExceptionCode::IllegalInstruction, effective_ldst_mode(), $encoding) if (rs3 +
length) > 32;
for (U32 i = 0; i < length; i++) {
  write_memory<32>(vaddr, X[rs3 + i], $encoding);
  vaddr = vaddr + 4;
}
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcilsm, version >= 0

5.133. qc.wrap

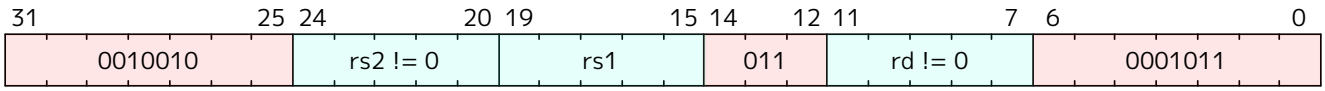
Synopsis

Wraparound (Register)

Mnemonic

```
qc.wrap  rd, rs1, rs2
```

Encoding



Description

If rs1 >= rs2 perform subtraction between rs1 and rs2. If rs1 < 0, perform addition between rs1 and rs2, else, select rs1. The result is stored in rd. Instruction encoded in R instruction format.

Decode Variables

```
Bits<5> rs1 = $encoding[19:15];
Bits<5> rs2 = $encoding[24:20];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg rs1_value = X[rs1];
X[rd] = ($signed(rs1_value) >= $signed(X[rs2])) ? rs1_value - X[rs2] : (($signed
(rs1_value) < 0) ? (rs1_value + X[rs2]) : rs1_value);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

5.134. qc.wrapi

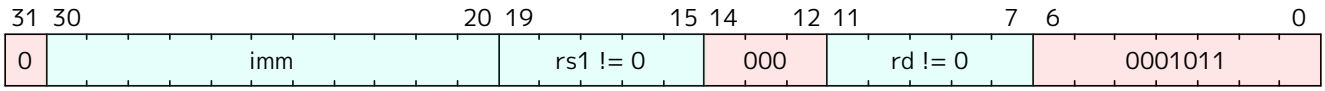
Synopsis

Wraparound (Immediate)

Mnemonic

```
qc.wrapi  rd, rs1, imm
```

Encoding



Description

If `rs1 >= imm` perform subtraction between `rs1` and `imm`. If `rs1 < 0`, perform addition between `rs1` and `imm`, else, select `rs1`. The result is stored in `rd`. Instruction encoded in I instruction format.

Decode Variables

```
Bits<11> imm = $encoding[30:20];
Bits<5> rs1 = $encoding[19:15];
Bits<5> rd = $encoding[11:7];
```

Operation

```
XReg rs1_value = X[rs1];
X[rd] = ($signed(rs1_value) >= $signed(imm)) ? rs1_value - imm : (($signed(rs1_value)
< 0) ? (rs1_value + imm) : rs1_value);
```

Included in

- anyOf:
- Xqci, version >= 0
- Xqcia, version >= 0

Chapter 6. IDL Functions

6.1. abort_current_instruction (builtin)

Abort the current instruction, and start refetching from $pc.

Return Type	void
Arguments	

6.2. access_check

Checks if the physical address paddr is able to access memory, and raises the appropriate exception if not.

Return Type	void
Arguments	Bits<PHYS_ADDR_WIDTH> paddr, U32 access_size, XReg vaddr, MemoryOperation type, ExceptionCode fault_type, PrivilegeMode from_mode

```
if (paddr > 1 << PHYS_ADDR_WIDTH) - access_size {
  raise(fault_type, from_mode, vaddr);
}
if (!pmp_check<access_size>(paddr[PHYS_ADDR_WIDTH - 1:0], type)) {
  raise(fault_type, from_mode, vaddr);
}
```

6.3. assert (builtin)

Assert that a condition is true. Failure represents an error in the IDL model.

Return Type	void
Arguments	Boolean test, String message

6.4. atomic_check_then_write_32 (builtin)

Atomically:

- Reads 32-bits from paddr
- Compares the read value to compare_value
- Writes write_value to paddr **if** the comparison was bitwise-equal

returns true if the write occurs, and false otherwise

Preconditions:

- paddr will be aligned to 32-bits

Return Type	Boolean
Arguments	Bits<PHYS_ADDR_WIDTH> paddr, Bits<32> compare_value, Bits<32> write_value

6.5. atomic_check_then_write_64 (builtin)

Atomically:

- Reads 64-bits from paddr
- Compares the read value to compare_value
- Writes write_value to paddr **if** the comparison was bitwise-equal

returns true if the write occurs, and false otherwise

Preconditions:

- paddr will be aligned to 64-bits

Return Type	Boolean
Arguments	Bits<PHYS_ADDR_WIDTH> paddr, Bits<64> compare_value, Bits<64> write_value

6.6. cached_translation (builtin)

Possibly returns a cached translation result matching vaddr.

If the result is value, the first return value will be true. paddr is the full translation of vaddr, including the page offset pbmt is the result of any paged-based attributes for the translation

Return Type	Boolean, TranslationResult
Arguments	XReg vaddr, MemoryOperation op

6.7. current_translation_mode

Returns the current first-stage translation mode for an explicit load or store from mode given the machine state (e.g., value of satp or vsatp csr).

Returns SatpMode::Reserved if the setting fouund in satp or vsatp is invalid.

Return Type	SatpMode
Arguments	PrivilegeMode mode

```
PrivilegeMode effective_mode = effective_ldst_mode();
if (effective_mode == PrivilegeMode::M) {
  return SatpMode::Bare;
}
if (CSR[misa].H == 1'b1) {
  if (effective_mode == PrivilegeMode::VS || effective_mode == PrivilegeMode::VU) {
    Bits<4> mode_val = CSR[vsatp].MODE;
    if (mode_val == $bits(SatpMode::Sv32)) {
      if (XLEN == 64) {
        if ((effective_mode == PrivilegeMode::VS) && (CSR[hstatus].VSXL != $bits
(XRegWidth::XLEN32))) {
          return SatpMode::Reserved;
        }
        if ((effective_mode == PrivilegeMode::VU) && (CSR[vsstatus].UXL != $bits
(XRegWidth::XLEN32))) {
          return SatpMode::Reserved;
        }
      }
      if (!SV32_VSMODE_TRANSLATION) {
        return SatpMode::Reserved;
      }
      return SatpMode::Sv32;
    } else if ((XLEN == 64) && (mode_val == $bits(SatpMode::Sv39))) {
      if (effective_mode == PrivilegeMode::VS && CSR[hstatus].VSXL != $bits(
XRegWidth::XLEN64)) {
        return SatpMode::Reserved;
      }
      if (effective_mode == PrivilegeMode::VU && CSR[vsstatus].UXL != $bits(
XRegWidth::XLEN64)) {
        return SatpMode::Reserved;
      }
      if (!SV39_VSMODE_TRANSLATION) {
        return SatpMode::Reserved;
      }
      return SatpMode::Sv39;
    } else if ((XLEN == 64) && (mode_val == $bits(SatpMode::Sv48))) {
      if (effective_mode == PrivilegeMode::VS && CSR[hstatus].VSXL != $bits(
XRegWidth::XLEN64)) {
        return SatpMode::Reserved;
      }
      if (effective_mode == PrivilegeMode::VU && CSR[vsstatus].UXL != $bits(
XRegWidth::XLEN64)) {
        return SatpMode::Reserved;
      }
      if (!SV48_VSMODE_TRANSLATION) {
        return SatpMode::Reserved;
      }
      return SatpMode::Sv48;
    } else if ((XLEN == 64) && (mode_val == $bits(SatpMode::Sv57))) {
      if (effective_mode == PrivilegeMode::VS && CSR[hstatus].VSXL != $bits(
XRegWidth::XLEN64)) {
        return SatpMode::Reserved;
      }
      if (effective_mode == PrivilegeMode::VU && CSR[vsstatus].UXL != $bits(
```

```
XRegWidth::XLEN64)) {
        return SatpMode::Reserved;
      }
      if (!SV57_VSMODE_TRANSLATION) {
        return SatpMode::Reserved;
      }
      return SatpMode::Sv57;
    } else {
      return SatpMode::Reserved;
    }
  }
}
assert(effective_mode == PrivilegeMode::S || effective_mode == PrivilegeMode::U,
"unexpected priv mode");
Bits<4> mode_val = CSR[vsatp].MODE;
if (mode_val == $bits(SatpMode::Sv32)) {
  if (XLEN == 64) {
    if (effective_mode == PrivilegeMode::S && CSR[mstatus].SXL != $bits(XRegWidth
::XLEN32)) {
      return SatpMode::Reserved;
    }
    if (effective_mode == PrivilegeMode::U && CSR[sstatus].UXL != $bits(XRegWidth
::XLEN32)) {
      return SatpMode::Reserved;
    }
  }
  if (!implemented?(ExtensionName::Sv32)) {
    return SatpMode::Reserved;
  }
} else if ((XLEN == 64) && (mode_val == $bits(SatpMode::Sv39))) {
  if (effective_mode == PrivilegeMode::S && CSR[mstatus].SXL != $bits(XRegWidth
::XLEN64)) {
    return SatpMode::Reserved;
  }
  if (effective_mode == PrivilegeMode::U && CSR[sstatus].UXL != $bits(XRegWidth
::XLEN64)) {
    return SatpMode::Reserved;
  }
  if (!implemented?(ExtensionName::Sv39)) {
    return SatpMode::Reserved;
  }
  return SatpMode::Sv39;
} else if ((XLEN == 64) && (mode_val == $bits(SatpMode::Sv48))) {
  if (effective_mode == PrivilegeMode::S && CSR[mstatus].SXL != $bits(XRegWidth
::XLEN64)) {
    return SatpMode::Reserved;
  }
  if (effective_mode == PrivilegeMode::U && CSR[sstatus].UXL != $bits(XRegWidth
::XLEN64)) {
    return SatpMode::Reserved;
  }
  if (!implemented?(ExtensionName::Sv48)) {
    return SatpMode::Reserved;
  }
  return SatpMode::Sv48;
```

```
} else if ((XLEN == 64) && (mode_val == $bits(SatpMode::Sv57))) {
  if (effective_mode == PrivilegeMode::S && CSR[mstatus].SXL != $bits(XRegWidth
::XLEN64)) {
    return SatpMode::Reserved;
  }
  if (effective_mode == PrivilegeMode::U && CSR[sstatus].UXL != $bits(XRegWidth
::XLEN64)) {
    return SatpMode::Reserved;
  }
  if (!implemented?(ExtensionName::Sv57)) {
    return SatpMode::Reserved;
  }
  return SatpMode::Sv57;
} else {
  return SatpMode::Reserved;
}
```

6.8. effective_ldst_mode

Returns the effective privilege mode for normal explicit loads and stores, taking into account the current actual privilege mode and modifications from mstatus.MPRV.

Return Type	PrivilegeMode
Arguments	

```
if (mode() == PrivilegeMode::M) {
  if (CSR[misa].U == 1 && CSR[mstatus].MPRV == 1) {
    if (CSR[mstatus].MPP == 0b00) {
      if (CSR[misa].H == 1 && mpv() == 0b1) {
        return PrivilegeMode::VU;
      } else {
        return PrivilegeMode::U;
      }
    } else if (CSR[misa].S == 1 && CSR[mstatus].MPP == 0b01) {
      if (CSR[misa].H == 1 && mpv() == 0b1) {
        return PrivilegeMode::VS;
      } else {
        return PrivilegeMode::S;
      }
    }
  }
}
return mode();
```

6.9. exception_handling_mode

Returns the target privilege mode that will handle synchronous exception `exception_code`

Return Type	PrivilegeMode
Arguments	ExceptionCode exception_code

```
if (mode() == PrivilegeMode::M) {
  return PrivilegeMode::M;
} else if (implemented?(ExtensionName::S) && mode() == PrivilegeMode::HS) || (mode()
== PrivilegeMode::U) {
  if (($bits(CSR[medeleg]) & (1 << $bits(exception_code))) != 0) {
    return PrivilegeMode::HS;
  } else {
    return PrivilegeMode::M;
  }
} else {
  assert(implemented?(ExtensionName::H) && mode() == PrivilegeMode::VS) || (mode() ==
PrivilegeMode::VU, "Unexpected mode");
  if (($bits(CSR[medeleg]) & (1 << $bits(exception_code))) != 0) {
    if (($bits(CSR[hedeleg]) & (1 << $bits(exception_code))) != 0) {
      return PrivilegeMode::VS;
    } else {
      return PrivilegeMode::HS;
    }
  } else {
    return PrivilegeMode::M;
  }
}
```

6.10. gstage_page_walk

Translate guest physical address to physical address through a page walk.

May raise a Guest Page Fault if an error involving the page table structure occurs along the walk.

Implicit reads of the page table are accessed check, and may raise Access Faults. Implicit writes (updates of A/D) are also accessed checked, and may raise Access Faults

The translated address *is not* accessed checked.

Returns the translated physical address.

Return Type	TranslationResult
Arguments	XReg gpaddr, XReg vaddr, MemoryOperation op, PrivilegeMode effective_mode, Boolean for_final_vs_pte, Bits<INSTR_ENC_SIZE> encoding

```
Bits<PA_SIZE> ppn;
TranslationResult result;
U32 VPN_SIZE = (LEVELS == 2) ? 10 : 9;
ExceptionCode access_fault_code = op == MemoryOperation::Read ? ExceptionCode
```

```
::LoadAccessFault : (op == MemoryOperation::Fetch ? ExceptionCode
::InstructionAccessFault : ExceptionCode::StoreAmoAccessFault);
ExceptionCode page_fault_code = op == MemoryOperation::Read ? ExceptionCode
::LoadGuestPageFault : (op == MemoryOperation::Fetch ? ExceptionCode
::InstructionGuestPageFault : ExceptionCode::StoreAmoGuestPageFault);
Boolean mxr = for_final_vs_pte && (CSR[mstatus].MXR == 1);
Boolean pbmte = CSR[menvcfg].PBMTE == 1;
Boolean adue = CSR[menvcfg].ADUE == 1;
Bits<32> tinst = tinst_value_for_guest_page_fault(op, encoding, for_final_vs_pte);
U32 max_gpa_width = LEVELS * VPN_SIZE + 2 + 12;
if (gpaddr >> max_gpa_width != 0) {
  raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
}
ppn = CSR[hgatp].PPN;
for (U32 i = (LEVELS - 1); i >= 0; i--) {
  U32 this_vpn_size = (i == (LEVELS - 1)) ? VPN_SIZE + 2 : VPN_SIZE;
  U32 vpn = (gpaddr >> (12 + VPN_SIZE * i)) & 1 << this_vpn_size) - 1);   Bits<PA
_SIZE> pte_paddr = (ppn << 12) + (vpn * (PTESIZE / 8;
  if (!pma_applies?(PmaAttribute::HardwarePageTableRead, pte_paddr, PTESIZE)) {
    raise(access_fault_code, PrivilegeMode::U, vaddr);
  }
  access_check(pte_paddr, PTESIZE, vaddr, MemoryOperation::Read, access_fault_code,
effective_mode);
  Bits<PTESIZE> pte = read_physical_memory<PTESIZE>(pte_paddr);
  PteFlags pte_flags = pte[9:0];
  if ((VA_SIZE != 32) && (pte[60:54] != 0)) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
  }
  if (!implemented?(ExtensionName::Svnapot)) {
    if ((PTESIZE >= 64) && pte[63] != 0) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    }
  }
  if ((PTESIZE >= 64) && !pbmte && (pte[62:61] != 0)) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
  }
  if ((PTESIZE >= 64) && pbmte && (pte[62:61] == 3)) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
  }
  if (pte_flags.V == 0) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
  }
  if (pte_flags.R == 0 && pte_flags.W == 1) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
  }
  if (pte_flags.R == 1 || pte_flags.X == 1) {
    if (pte_flags.U == 0) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    }
    if (op == MemoryOperation::Write) || (op == MemoryOperation::ReadModifyWrite &&
(pte_flags.W == 0)) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    } else if ((op == MemoryOperation::Fetch) && (pte_flags.X == 0)) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    } else if ((op == MemoryOperation::Read) || (op == MemoryOperation
```

```
::ReadModifyWrite)) {
      if (!mxr) && (pte_flags.R == 0 || mxr) && (pte_flags.X == 0 && pte_flags.R == 0)
{
        raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
      }
    }
    if ((i > 0) && (pte[(i - 1) * VPN_SIZE:10] != 0)) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    }
    if ((pte_flags.A == 0) || pte_flags.D == 0) && ((op == MemoryOperation::Write) ||
(op == MemoryOperation::ReadModifyWrite)) {
      if (adue) {
        if (!pma_applies?(PmaAttribute::RsrvEventual, pte_paddr, PTESIZE)) {
          raise(access_fault_code, PrivilegeMode::U, vaddr);
        }
        if (!pma_applies?(PmaAttribute::HardwarePageTableWrite, pte_paddr, PTESIZE)) {
          raise(access_fault_code, PrivilegeMode::U, vaddr);
        }
        access_check(pte_paddr, PTESIZE, vaddr, MemoryOperation::Write,
access_fault_code, effective_mode);
        Boolean success;
        Bits<PTESIZE> updated_pte;
        if (pte_flags.D == 0 && (op == MemoryOperation::Write || op ==
MemoryOperation::ReadModifyWrite)) {
          updated_pte = pte | 0b11000000;
        } else {
          updated_pte = pte | 0b01000000;
        }
        if (PTESIZE == 32) {
          success = atomic_check_then_write_32(pte_paddr, pte, updated_pte);
        } else if (PTESIZE == 64) {
          success = atomic_check_then_write_64(pte_paddr, pte, updated_pte);
        } else {
          assert(false, "Unexpected PTESIZE");
        }
        if (!success) {
          i = i + 1;
        } else {
          result.paddr = pte_paddr;
          if (PTESIZE >= 64) {
            result.pbmt = pte[62:61];
          }
          result.pte_flags = pte_flags;
          return result;
        }
      } else {
        raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
      }
    }
  } else {
    if (i == 0) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    }
    if (pte_flags.D == 1 || pte_flags.A == 1 || pte_flags.U == 1) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
```

```
    }
    if ((VA_SIZE != 32) && (pte[62:61] != 0)) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    }
    if ((VA_SIZE != 32) && pte[63] != 0) {
      raise_guest_page_fault(op, gpaddr, vaddr, tinst, effective_mode);
    }
    ppn = pte[PA_SIZE - 3:10] << 12;
  }
}
```

6.11. highest_set_bit

Returns the position of the highest (nearest MSB) bit that is '1', or -1 if value is zero.

Return Type	XReg
Arguments	XReg value

```
for (U32 i = xlen() - 1; i >= 0; i--) {
  if (value[i] == 1) {
    return i;
  }
}
return -'sd1;
```

6.12. is_naturally_aligned

Checks if value is naturally aligned to N bits.

Return Type	Boolean
Arguments	XReg value

```
return true if (N == 8);
XReg Mask = (N / 8) - 1;
return (value & ~Mask) == value;
```

6.13. jump_halfword

Jump to virtual halfword address `target_hw_addr`.

If target address is misaligned, raise a `MisalignedAddress` exception.

Return Type	void

Arguments	XReg target_hw_addr

```
assert((target_hw_addr & 0x1) == 0x0, "Expected halfword-aligned address in
jump_halfword");
if (ialign() != 16) {
  if ((target_hw_addr & 0x3) != 0) {
    raise(ExceptionCode::InstructionAddressMisaligned, mode(), target_hw_addr);
  }
}
$pc = target_hw_addr;
```

6.14. lowest_set_bit

Returns the position of the lowest (nearest LSB) bit that is '1', or XLEN if value is zero.

Return Type	XReg
Arguments	XReg value

```
for (U32 i = 0; i < xlen(); i++) {
  if (value[i] == 1) {
    return i;
  }
}
return xlen();
```

6.15. maybe_cache_translation (builtin)

Given a translation result, potentially cache the result for later use. This function models a TLB fill operation. A valid implementation does nothing.

Return Type	void
Arguments	XReg vaddr, MemoryOperation op, TranslationResult result

6.16. mode

Returns the current active privilege mode.

Return Type	PrivilegeMode
Arguments	

```
if (!implemented?(ExtensionName::S) && !implemented?(ExtensionName::U) && !
implemented?(ExtensionName::H)) {
```

```
  return PrivilegeMode::M;
} else {
  return current_mode;
}
```

6.17. mtval_for

Given an exception code and a **legal** non-zero value for mtval, returns the value to be written in mtval considering implementation options

Return Type	XReg
Arguments	ExceptionCode exception_code, XReg tval

```
if (exception_code == ExceptionCode::Breakpoint) {
  return REPORT_VA_IN_MTVAL_ON_BREAKPOINT ? tval : 0;
} else if (exception_code == ExceptionCode::LoadAddressMisaligned) {
  return REPORT_VA_IN_MTVAL_ON_LOAD_MISALIGNED ? tval : 0;
} else if (exception_code == ExceptionCode::StoreAmoAddressMisaligned) {
  return REPORT_VA_IN_MTVAL_ON_STORE_AMO_MISALIGNED ? tval : 0;
} else if (exception_code == ExceptionCode::InstructionAddressMisaligned) {
  return REPORT_VA_IN_MTVAL_ON_INSTRUCTION_MISALIGNED ? tval : 0;
} else if (exception_code == ExceptionCode::LoadAccessFault) {
  return REPORT_VA_IN_MTVAL_ON_LOAD_ACCESS_FAULT ? tval : 0;
} else if (exception_code == ExceptionCode::StoreAmoAccessFault) {
  return REPORT_VA_IN_MTVAL_ON_STORE_AMO_ACCESS_FAULT ? tval : 0;
} else if (exception_code == ExceptionCode::InstructionAccessFault) {
  return REPORT_VA_IN_MTVAL_ON_INSTRUCTION_ACCESS_FAULT ? tval : 0;
} else if (exception_code == ExceptionCode::LoadPageFault) {
  return REPORT_VA_IN_MTVAL_ON_LOAD_PAGE_FAULT ? tval : 0;
} else if (exception_code == ExceptionCode::StoreAmoPageFault) {
  return REPORT_VA_IN_MTVAL_ON_STORE_AMO_PAGE_FAULT ? tval : 0;
} else if (exception_code == ExceptionCode::InstructionPageFault) {
  return REPORT_VA_IN_MTVAL_ON_INSTRUCTION_PAGE_FAULT ? tval : 0;
} else if (exception_code == ExceptionCode::IllegalInstruction) {
  return REPORT_ENCODING_IN_MTVAL_ON_ILLEGAL_INSTRUCTION ? tval : 0;
} else if (exception_code == ExceptionCode::SoftwareCheck) {
  return tval;
} else {
  return 0;
}
```

6.18. notify_mode_change (builtin)

Called whenever the privilege mode changes. Downstream tools can use this to hook events.

Return Type	void

Arguments	PrivilegeMode new_mode, PrivilegeMode old_mode

6.19. raise

Raise synchronous exception number `exception_code`.

The exception may be imprecise, and will cause exectuion to enter an unpredictable state, if PRECISE_SYNCHRONOUS_EXCEPTIONS is false.

Otherwise, the exception will be precise.

Return Type	void
Arguments	ExceptionCode exception_code, PrivilegeMode from_mode, XReg tval

```
if (!PRECISE_SYNCHRONOUS_EXCEPTIONS) {
  unpredictable("Imprecise synchronous exception");
} else {
  raise_precise(exception_code, from_mode, tval);
}
```

6.20. raise_guest_page_fault

Raise a guest page fault exception.

Return Type	void
Arguments	MemoryOperation op, XReg gpa, XReg gva, XReg tinst_value, PrivilegeMode from_mode

```
ExceptionCode code;
Boolean write_gpa_in_tval;
if (op == MemoryOperation::Read) {
  code = ExceptionCode::LoadGuestPageFault;
  write_gpa_in_tval = REPORT_GPA_IN_TVAL_ON_LOAD_GUEST_PAGE_FAULT;
} else if (op == MemoryOperation::Write || op == MemoryOperation::ReadModifyWrite) {
  code = ExceptionCode::StoreAmoGuestPageFault;
  write_gpa_in_tval = REPORT_GPA_IN_TVAL_ON_STORE_AMO_GUEST_PAGE_FAULT;
} else {
  assert(op == MemoryOperation::Fetch, "unexpected memory operation");
  code = ExceptionCode::InstructionGuestPageFault;
  write_gpa_in_tval = REPORT_GPA_IN_TVAL_ON_INSTRUCTION_GUEST_PAGE_FAULT;
}
PrivilegeMode handling_mode = exception_handling_mode(code);
if (handling_mode == PrivilegeMode::S) {
  CSR[htval].VALUE = write_gpa_in_tval ? (gpa >> 2) : 0;
  CSR[htinst].VALUE = tinst_value;
  CSR[sepc].PC = $pc;
```

```
  if (!stval_readonly?()) {
    CSR[stval].VALUE = stval_for(code, gva);
  }
  $pc = {CSR[stvec].BASE, 2'b00};
  CSR[scause].INT = 1'b0;
  CSR[scause].CODE = $bits(code);
  CSR[hstatus].GVA = 1;
  CSR[hstatus].SPV = 1;
  CSR[hstatus].SPVP = $bits(from_mode)[0];
  CSR[mstatus].SPP = $bits(from_mode)[0];
} else {
  assert(handling_mode == PrivilegeMode::M, "unexpected privilege mode");
  CSR[mtval2].VALUE = write_gpa_in_tval ? (gpa >> 2) : 0;
  CSR[mtinst].VALUE = tinst_value;
  CSR[mstatus].MPP = $bits(from_mode)[1:0];
  if (XLEN == 64) {
    CSR[mstatus].MPV = 1;
  } else {
    CSR[mstatush].MPV = 1;
  }
}
set_mode(handling_mode);
abort_current_instruction();
```

6.21. raise_precise

Raise synchronous exception number exception_code.

Return Type	void
Arguments	ExceptionCode exception_code, PrivilegeMode from_mode, XReg tval

```
PrivilegeMode handling_mode = exception_handling_mode(exception_code);
if (handling_mode == PrivilegeMode::M) {
  CSR[mepc].PC = $pc;
  if (!mtval_readonly?()) {
    CSR[mtval].VALUE = mtval_for(exception_code, tval);
  }
  $pc = {CSR[mtvec].BASE, 2'b00};
  CSR[mcause].INT = 1'b0;
  CSR[mcause].CODE = $bits(exception_code);
  if (CSR[misa].H == 1) {
    CSR[mtval2].VALUE = 0;
    CSR[mtinst].VALUE = 0;
    if (from_mode == PrivilegeMode::VU || from_mode == PrivilegeMode::VS) {
      if (XLEN == 32) {
        CSR[mstatush].MPV = 1;
      } else {
        CSR[mstatus].MPV = 1;
      }
    } else {
```

```
      if (XLEN == 32) {
        CSR[mstatush].MPV = 0;
      } else {
        CSR[mstatus].MPV = 0;
      }
    }
  }
  CSR[mstatus].MPP = $bits(from_mode);
} else if (CSR[misa].S == 1 && (handling_mode == PrivilegeMode::S)) {
  CSR[sepc].PC = $pc;
  if (!stval_readonly?()) {
    CSR[stval].VALUE = stval_for(exception_code, tval);
  }
  $pc = {CSR[stvec].BASE, 2'b00};
  CSR[scause].INT = 1'b0;
  CSR[scause].CODE = $bits(exception_code);
  CSR[mstatus].SPP = $bits(from_mode)[0];
  if (CSR[misa].H == 1) {
    CSR[htval].VALUE = 0;
    CSR[htinst].VALUE = 0;
    CSR[hstatus].SPV = $bits(from_mode)[2];
    if (from_mode == PrivilegeMode::VU || from_mode == PrivilegeMode::VS) {
      CSR[hstatus].SPV = 1;
      if (exception_code == ExceptionCode::Breakpoint) && (
REPORT_VA_IN_STVAL_ON_BREAKPOINT || exception_code == ExceptionCode
::LoadAddressMisaligned) && (REPORT_VA_IN_STVAL_ON_LOAD_MISALIGNED || exception_code
== ExceptionCode::StoreAmoAddressMisaligned) && (
REPORT_VA_IN_STVAL_ON_STORE_AMO_MISALIGNED || exception_code == ExceptionCode
::InstructionAddressMisaligned) && (REPORT_VA_IN_STVAL_ON_INSTRUCTION_MISALIGNED ||
exception_code == ExceptionCode::LoadAccessFault) && (
REPORT_VA_IN_STVAL_ON_LOAD_ACCESS_FAULT || exception_code == ExceptionCode
::StoreAmoAccessFault) && (REPORT_VA_IN_STVAL_ON_STORE_AMO_ACCESS_FAULT ||
exception_code == ExceptionCode::InstructionAccessFault) && (
REPORT_VA_IN_STVAL_ON_INSTRUCTION_ACCESS_FAULT || exception_code == ExceptionCode
::LoadPageFault) && (REPORT_VA_IN_STVAL_ON_LOAD_PAGE_FAULT || exception_code ==
ExceptionCode::StoreAmoPageFault) && (REPORT_VA_IN_STVAL_ON_STORE_AMO_PAGE_FAULT ||
exception_code == ExceptionCode::InstructionPageFault) && (
REPORT_VA_IN_STVAL_ON_INSTRUCTION_PAGE_FAULT) {
        CSR[hstatus].GVA = 1;
      } else {
        CSR[hstatus].GVA = 0;
      }
      CSR[hstatus].SPVP = $bits(from_mode)[0];
    } else {
      CSR[hstatus].SPV = 0;
      CSR[hstatus].GVA = 0;
    }
  }
} else if (CSR[misa].H == 1 && (handling_mode == PrivilegeMode::VS)) {
  CSR[vsepc].PC = $pc;
  if (!vstval_readonly?()) {
    CSR[vstval].VALUE = vstval_for(exception_code, tval);
  }
  $pc = {CSR[vstvec].BASE, 2'b00};
  CSR[vscause].INT = 1'b0;
```

```
  CSR[vscause].CODE = $bits(exception_code);
  CSR[vsstatus].SPP = $bits(from_mode)[0];
}
set_mode(handling_mode);
abort_current_instruction();
```

6.22. read_memory

Read from virtual memory.

Return Type	Bits<LEN>
Arguments	XReg virtual_address, Bits<INSTR_ENC_SIZE> encoding

```
Boolean aligned = is_naturally_aligned<LEN>(virtual_address);
XReg physical_address;
if (aligned) {
  return read_memory_aligned<LEN>(virtual_address, encoding);
}
if (MISALIGNED_MAX_ATOMICITY_GRANULE_SIZE > 0) {
  assert(MISALIGNED_LDST_EXCEPTION_PRIORITY == "low", "Invalid config: can't mix low-
priority misaligned exceptions with large atomicity granule");
  physical_address = (CSR[misa].S == 1) ? translate(virtual_address, MemoryOperation
::Read, effective_ldst_mode(), encoding).paddr : virtual_address;
  if (misaligned_is_atomic?<LEN>(physical_address)) {
    access_check(physical_address, LEN, virtual_address, MemoryOperation::Read,
ExceptionCode::LoadAccessFault, effective_ldst_mode());
    return read_physical_memory<LEN>(physical_address);
  }
}
if (!MISALIGNED_LDST) {
  if (MISALIGNED_LDST_EXCEPTION_PRIORITY == "low") {
    physical_address = (CSR[misa].S == 1) ? translate(virtual_address,
MemoryOperation::Read, effective_ldst_mode(), encoding).paddr : virtual_address;
    access_check(physical_address, LEN, virtual_address, MemoryOperation::Read,
ExceptionCode::LoadAccessFault, effective_ldst_mode());
  }
  raise(ExceptionCode::LoadAddressMisaligned, effective_ldst_mode(), virtual_address);
} else {
  if (MISALIGNED_SPLIT_STRATEGY == "by_byte") {
    Bits<LEN> result = 0;
    for (U32 i = 0; i <= LEN; i++) {
      result = result | (read_memory_aligned<8>(virtual_address + i, encoding) << (8 *
i));
    }
    return result;
  } else if (MISALIGNED_SPLIT_STRATEGY == "custom") {
    unpredictable("An implementation is free to break a misaligned access any way,
leading to unpredictable behavior when any part of the misaligned access causes an
exception");
  }
```

```
}
```

6.23. read_memory_aligned

Read from virtual memory using a known aligned address.

Return Type	Bits<LEN>
Arguments	XReg virtual_address, Bits<INSTR_ENC_SIZE> encoding

```
TranslationResult result;
if (CSR[misa].S == 1) {
  result = translate(virtual_address, MemoryOperation::Read, effective_ldst_mode(),
encoding);
} else {
  result.paddr = virtual_address;
}
access_check(result.paddr, LEN, virtual_address, MemoryOperation::Read,
ExceptionCode::LoadAccessFault, effective_ldst_mode());
return read_physical_memory<LEN>(result.paddr);
```

6.24. read_physical_memory (builtin)

Read from physical memory.

Return Type	Bits<len>
Arguments	XReg paddr

6.25. set_mode

Set the current privilege mode to new_mode

Return Type	void
Arguments	PrivilegeMode new_mode

```
if (new_mode != current_mode) {
  notify_mode_change(new_mode, current_mode);
  current_mode = new_mode;
}
```

6.26. sext

Sign extend `value` starting at `first_extended_bit`.

Bits [XLEN-1:`first_extended_bit`] of the return value should get the value of bit (`first_extended bit - 1`).

Return Type	XReg
Arguments	XReg value, XReg first_extended_bit

```
if (first_extended_bit == XLEN) {
  return value;
} else {
  Bits<1> sign = value[first_extended_bit - 1];
  for (U32 i = XLEN - 1; i >= first_extended_bit; i--) {
    value[i] = sign;
  }
  return value;
}
```

6.27. stage1_page_walk

Translate virtual address to physical address through a page walk.

May raise a Page Fault if an error involving the page table structure occurs along the walk.

Implicit reads of the page table are accessed check, and may raise Access Faults. Implicit writes (updates of A/D) are also accessed checked, and may raise Access Faults

The translated address *is not* accessed checked.

Returns the translated guest physical address.

Return Type	TranslationResult
Arguments	Bits<XLEN> vaddr, MemoryOperation op, PrivilegeMode effective_mode, Bits<INSTR_ENC_SIZE> encoding

```
Bits<PA_SIZE> ppn;
TranslationResult result;
U32 VPN_SIZE = (LEVELS == 2) ? 10 : 9;
ExceptionCode access_fault_code = op == MemoryOperation::Read ? ExceptionCode
::LoadAccessFault : (op == MemoryOperation::Fetch ? ExceptionCode
::InstructionAccessFault : ExceptionCode::StoreAmoAccessFault);
ExceptionCode page_fault_code = op == MemoryOperation::Read ? ExceptionCode
::LoadPageFault : (op == MemoryOperation::Fetch ? ExceptionCode::InstructionPageFault
: ExceptionCode::StoreAmoPageFault);
Boolean sse = false;
Boolean adue;
```

```
if (CSR[misa].H == 1 && (effective_mode == PrivilegeMode::VS || effective_mode ==
PrivilegeMode::VU)) {
  adue = CSR[henvcfg].ADUE == 1;
} else {
  adue = CSR[menvcfg].ADUE == 1;
}
Boolean pbmte;
if (VA_SIZE == 32) {
  pbmte = false;
} else {
  if (CSR[misa].H == 1 && (effective_mode == PrivilegeMode::VS || effective_mode ==
PrivilegeMode::VU)) {
    pbmte = CSR[henvcfg].PBMTE == 1;
  } else {
    pbmte = CSR[menvcfg].PBMTE == 1;
  }
}
Boolean mxr;
if (CSR[misa].H == 1 && (effective_mode == PrivilegeMode::VS || effective_mode ==
PrivilegeMode::VU)) {
  mxr = (CSR[mstatus].MXR == 1) || (CSR[vsstatus].MXR == 1);
} else {
  mxr = CSR[mstatus].MXR == 1;
}
Boolean sum;
if (CSR[misa].H == 1 && (effective_mode == PrivilegeMode::VS)) {
  sum = CSR[vsstatus].SUM == 1;
} else {
  sum = CSR[mstatus].SUM == 1;
}
ppn = CSR[vsatp].PPN;
if ((VA_SIZE < xlen()) && (vaddr[xlen() - 1:VA_SIZE] != {xlen() - VA_SIZE{vaddr[
VA_SIZE - 1]}})) {
  raise(page_fault_code, effective_mode, vaddr);
}
for (U32 i = (LEVELS - 1); i >= 0; i--) {
  U32 vpn = (vaddr >> (12 + VPN_SIZE * i)) & 1 << VPN_SIZE) - 1);   Bits<PA_SIZE>
pte_gpaddr = (ppn << 12) + (vpn * (PTESIZE / 8;
  TranslationResult pte_phys = translate_gstage(pte_gpaddr, vaddr, MemoryOperation
::Read, effective_mode, encoding);
  if (!pma_applies?(PmaAttribute::HardwarePageTableRead, pte_phys.paddr, PTESIZE)) {
    raise(access_fault_code, effective_mode, vaddr);
  }
  access_check(pte_phys.paddr, PTESIZE, vaddr, MemoryOperation::Read,
access_fault_code, effective_mode);
  Bits<PTESIZE> pte = read_physical_memory<PTESIZE>(pte_phys.paddr);
  PteFlags pte_flags = pte[9:0];
  Boolean ss_page = (pte_flags.R == 0) && (pte_flags.W == 1) && (pte_flags.X == 0);
  if ((VA_SIZE != 32) && (pte[60:54] != 0)) {
    raise(page_fault_code, effective_mode, vaddr);
  }
  if (pte_flags.V == 0) {
    raise(page_fault_code, effective_mode, vaddr);
  }
  if (!sse) {
```

```
    if ((pte_flags.R == 0) && (pte_flags.W == 1)) {
      raise(page_fault_code, effective_mode, vaddr);
    }
  }
  if (pbmte) {
    if (pte[62:61] == 3) {
      raise(page_fault_code, effective_mode, vaddr);
    }
  } else {
    if ((PTESIZE >= 64) && (pte[62:61] != 0)) {
      raise(page_fault_code, effective_mode, vaddr);
    }
  }
  if (!implemented?(ExtensionName::Svnapot)) {
    if ((PTESIZE >= 64) && (pte[63] != 0)) {
      raise(page_fault_code, effective_mode, vaddr);
    }
  }
  if (pte_flags.R == 1 || pte_flags.X == 1) {
    if (op == MemoryOperation::Read || op == MemoryOperation::ReadModifyWrite) {
      if (!mxr) && (pte_flags.R == 0 || mxr) && (pte_flags.X == 0 && pte_flags.R == 0)
{
        raise(page_fault_code, effective_mode, vaddr);
      }
      if (effective_mode == PrivilegeMode::U && pte_flags.U == 0) {
        raise(page_fault_code, effective_mode, vaddr);
      } else if (CSR[misa].H == 1 && effective_mode == PrivilegeMode::VU && pte_flags
.U == 0) {
        raise(page_fault_code, effective_mode, vaddr);
      } else if (effective_mode == PrivilegeMode::S && pte_flags.U == 1 && !sum) {
        raise(page_fault_code, effective_mode, vaddr);
      } else if (effective_mode == PrivilegeMode::VS && pte_flags.U == 1 && !sum) {
        raise(page_fault_code, effective_mode, vaddr);
      }
    }
    if (op == MemoryOperation::Write) || (op == MemoryOperation::ReadModifyWrite &&
(pte_flags.W == 0)) {
      raise(page_fault_code, effective_mode, vaddr);
    } else if ((op == MemoryOperation::Fetch) && (pte_flags.X == 0)) {
      raise(page_fault_code, effective_mode, vaddr);
    } else if ((op == MemoryOperation::Fetch) && ss_page) {
      raise(page_fault_code, effective_mode, vaddr);
    }
    raise(page_fault_code, effective_mode, vaddr) if ;
    if ((pte_flags.A == 0) || pte_flags.D == 0) && ((op == MemoryOperation::Write) ||
(op == MemoryOperation::ReadModifyWrite)) {
      if (adue) {
        TranslationResult pte_phys = translate_gstage(pte_gpaddr, vaddr,
MemoryOperation::Write, effective_mode, encoding);
        if (!pma_applies?(PmaAttribute::RsrvEventual, pte_phys.paddr, PTESIZE)) {
          raise(access_fault_code, effective_mode, vaddr);
        }
        if (!pma_applies?(PmaAttribute::HardwarePageTableWrite, pte_phys.paddr,
PTESIZE)) {
          raise(access_fault_code, effective_mode, vaddr);
```

```
        }
        access_check(pte_phys.paddr, PTESIZE, vaddr, MemoryOperation::Write,
access_fault_code, effective_mode);
        Boolean success;
        Bits<PTESIZE> updated_pte;
        if (pte_flags.D == 0 && (op == MemoryOperation::Write || op ==
MemoryOperation::ReadModifyWrite)) {
          updated_pte = pte | 0b11000000;
        } else {
          updated_pte = pte | 0b01000000;
        }
        if (PTESIZE == 32) {
          success = atomic_check_then_write_32(pte_phys.paddr, pte, updated_pte);
        } else if (PTESIZE == 64) {
          success = atomic_check_then_write_64(pte_phys.paddr, pte, updated_pte);
        } else {
          assert(false, "Unexpected PTESIZE");
        }
        if (!success) {
          i = i + 1;
        } else {
          TranslationResult pte_phys = translate_gstage({(pte[PA_SIZE - 3:(i *
VPN_SIZE) + 10] << 2), vaddr[11:0]}, vaddr, op, effective_mode, encoding);
          result.paddr = pte_phys.paddr;
          result.pbmt = pte_phys.pbmt == 0 ? pte[62:61] : pte_phys.pbmt;
          result.pte_flags = pte_flags;
          return result;
        }
      } else {
        raise(page_fault_code, effective_mode, vaddr);
      }
    }
    TranslationResult pte_phys = translate_gstage({(pte[PA_SIZE - 3:(i * VPN_SIZE) +
10] << 2), vaddr[11:0]}, vaddr, op, effective_mode, encoding);
    result.paddr = pte_phys.paddr;
    if (PTESIZE >= 64) {
      result.pbmt = pte_phys.pbmt == Pbmt::PMA ? $enum(Pbmt, pte[62:61]) : pte_phys
.pbmt;
    }
    result.pte_flags = pte_flags;
    return result;
  } else {
    if (i == 0) {
      raise(page_fault_code, effective_mode, vaddr);
    }
    if (pte_flags.D == 1 || pte_flags.A == 1 || pte_flags.U == 1) {
      raise(page_fault_code, effective_mode, vaddr);
    }
    if ((VA_SIZE != 32) && (pte[62:61] != 0)) {
      raise(page_fault_code, effective_mode, vaddr);
    }
    if ((VA_SIZE != 32) && pte[63] != 0) {
      raise(page_fault_code, effective_mode, vaddr);
    }
    ppn = pte[PA_SIZE - 3:10] << 12;
```

```
  }
}
```

6.28. tinst_transform

Returns the standard transformation of an encoding for htinst/mtinst

Return Type	Bits<INSTR_ENC_SIZE>
Arguments	Bits<INSTR_ENC_SIZE> encoding, Bits<5> addr_offset

```
if (encoding[1:0] == 0b11) {
  if (encoding[6:2] == 5'b00001) {
    return {{12{1'b0}}, addr_offset, encoding[14:0]};
  } else if (encoding[6:2] == 5'b01000) {
    return {{7{1'b0}}, encoding[24:20], addr_offset, encoding[14:12], {5{1'b0}},
encoding[6:0]};
  } else if (encoding[6:2] == 5'b01011) {
    return {encoding[31:20], addr_offset, encoding[14:0]};
  } else if (encoding[6:2] == 5'b00011) {
    return {encoding[31:20], addr_offset, encoding[14:0]};
  } else {
    assert(false, "Bad transform");
  }
} else {
  assert(false, "TODO: compressed instruction");
}
```

6.29. tinst_value_for_guest_page_fault

Returns the value of htinst/mtinst for a Guest Page Fault

Return Type	XReg
Arguments	MemoryOperation op, Bits<INSTR_ENC_SIZE> encoding, Boolean for_final_vs_pte

```
if (for_final_vs_pte) {
  if (op == MemoryOperation::Fetch) {
    if (TINST_VALUE_ON_FINAL_INSTRUCTION_GUEST_PAGE_FAULT == "always zero") {
      return 0;
    } else {
      assert(TINST_VALUE_ON_FINAL_INSTRUCTION_GUEST_PAGE_FAULT == "always
pseudoinstruction", "Instruction guest page faults can only report zero/pseudo
instruction in tval");
      return 0x00002000;
    }
  } else if (op == MemoryOperation::Read) {
```

```
    if (TINST_VALUE_ON_FINAL_LOAD_GUEST_PAGE_FAULT == "always zero") {
      return 0;
    } else if (TINST_VALUE_ON_FINAL_LOAD_GUEST_PAGE_FAULT == "always
pseudoinstruction") {
      if ((VSXLEN == 32) || XLEN == 64) && (CSR[hstatus].VSXL == $bits(XRegWidth
::XLEN32)) {
        return 0x00002000;
      } else {
        return 0x00003000;
      }
    } else if (TINST_VALUE_ON_FINAL_LOAD_GUEST_PAGE_FAULT == "always transformed
standard instruction") {
      return tinst_transform(encoding, 0);
    } else {
      unpredictable("Custom value written into htinst/mtinst");
    }
  } else if (op == MemoryOperation::Write || op == MemoryOperation::ReadModifyWrite) {
    if (TINST_VALUE_ON_FINAL_STORE_AMO_GUEST_PAGE_FAULT == "always zero") {
      return 0;
    } else if (TINST_VALUE_ON_FINAL_STORE_AMO_GUEST_PAGE_FAULT == "always
pseudoinstruction") {
      if ((VSXLEN == 32) || XLEN == 64) && (CSR[hstatus].VSXL == $bits(XRegWidth
::XLEN32)) {
        return 0x00002020;
      } else {
        return 0x00003020;
      }
    } else if (TINST_VALUE_ON_FINAL_STORE_AMO_GUEST_PAGE_FAULT == "always transformed
standard instruction") {
      return tinst_transform(encoding, 0);
    } else {
      unpredictable("Custom value written into htinst/mtinst");
    }
  }
} else {
  if (REPORT_GPA_IN_TVAL_ON_INTERMEDIATE_GUEST_PAGE_FAULT) {
    if ((VSXLEN == 32) || XLEN == 64) && (CSR[hstatus].VSXL == $bits(XRegWidth::
XLEN32)) {
      return 0x00002000;
    } else if ((VSXLEN == 64) || XLEN == 64) && (CSR[hstatus].VSXL == $bits(
XRegWidth::XLEN64)) {
      return 0x00003000;
    }
  }
}
```

6.30. translate

Translate a virtual address for operation type op that appears to execute at effective_mode.

The translation will depend on the effective privilege mode.

May raise a Page Fault or Access Fault.

The final physical address is **not** access checked (for PMP, PMA, etc., violations). (though intermediate page table reads will be)

Return Type	TranslationResult
Arguments	XReg vaddr, MemoryOperation op, PrivilegeMode effective_mode, Bits<INSTR_ENC_SIZE> encoding

```
Boolean cached_translation_valid;
TranslationResult cached_translation_result;
(cached_translation_valid, cached_translation_result = cached_translation(vaddr, op));
if (cached_translation_valid) {
  return cached_translation_result;
}
TranslationResult result;
if (effective_mode == PrivilegeMode::M) {
  return vaddr;
}
SatpMode translation_mode = current_translation_mode(effective_mode);
if (translation_mode == SatpMode::Reserved) {
  if (op == MemoryOperation::Read) {
    raise(ExceptionCode::LoadPageFault, effective_mode, vaddr);
  } else if (op == MemoryOperation::Write || op == MemoryOperation::ReadModifyWrite) {
    raise(ExceptionCode::StoreAmoPageFault, effective_mode, vaddr);
  } else {
    assert(op == MemoryOperation::Fetch, "Unexpected memory operation");
    raise(ExceptionCode::InstructionPageFault, effective_mode, vaddr);
  }
}
if (translation_mode == SatpMode::Sv32) {
  result = stage1_page_walk<32, 34, 32, 2>(vaddr, op, effective_mode, encoding);
} else if (translation_mode == SatpMode::Sv39) {
  result = stage1_page_walk<39, 56, 64, 3>(vaddr, op, effective_mode, encoding);
} else if (translation_mode == SatpMode::Sv48) {
  result = stage1_page_walk<48, 56, 64, 4>(vaddr, op, effective_mode, encoding);
} else if (translation_mode == SatpMode::Sv57) {
  result = stage1_page_walk<57, 56, 64, 5>(vaddr, op, effective_mode, encoding);
} else {
  assert(false, "Unexpected SatpMode");
}
maybe_cache_translation(vaddr, op, result);
return result;
```

6.31. translate_gstage

Translates a guest physical address to a physical address.

Return Type	TranslationResult

Arguments	XReg gpaddr, XReg vaddr, MemoryOperation op, PrivilegeMode effective_mode, Bits<INSTR_ENC_SIZE> encoding

```
TranslationResult result;
if (effective_mode == PrivilegeMode::S || effective_mode == PrivilegeMode::U) {
  result.paddr = gpaddr;
  return result;
}
Boolean mxr = CSR[mstatus].MXR == 1;
if (GSTAGE_MODE_BARE && CSR[hgatp].MODE == $bits(HgatpMode::Bare)) {
  result.paddr = gpaddr;
  return result;
} else if (SV32X4_TRANSLATION && CSR[hgatp].MODE == $bits(HgatpMode::Sv32x4)) {
  return gstage_page_walk<32, 34, 32, 2>(gpaddr, vaddr, op, effective_mode, false,
encoding);
} else if (SV39X4_TRANSLATION && CSR[hgatp].MODE == $bits(HgatpMode::Sv39x4)) {
  return gstage_page_walk<39, 56, 64, 3>(gpaddr, vaddr, op, effective_mode, false,
encoding);
} else if (SV48X4_TRANSLATION && CSR[hgatp].MODE == $bits(HgatpMode::Sv48x4)) {
  return gstage_page_walk<48, 56, 64, 4>(gpaddr, vaddr, op, effective_mode, false,
encoding);
} else if (SV57X4_TRANSLATION && CSR[hgatp].MODE == $bits(HgatpMode::Sv57x4)) {
  return gstage_page_walk<57, 56, 64, 5>(gpaddr, vaddr, op, effective_mode, false,
encoding);
} else {
  if (op == MemoryOperation::Read) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst_value_for_guest_page_fault(op,
encoding, true), effective_mode);
  } else if (op == MemoryOperation::Write || op == MemoryOperation::ReadModifyWrite) {
    raise_guest_page_fault(op, gpaddr, vaddr, tinst_value_for_guest_page_fault(op,
encoding, true), effective_mode);
  } else {
    assert(op == MemoryOperation::Fetch, "unexpected memory op");
    raise_guest_page_fault(op, gpaddr, vaddr, tinst_value_for_guest_page_fault(op,
encoding, true), effective_mode);
  }
}
```

6.32. unpredictable (builtin)

Indicate that the hart has reached a state that is unpredictable because the RISC-V spec allows multiple behaviors. Generally, this will be a fatal condition to any emulation, since it is unclear what to do next.

The single argument *why* is a string describing why the hart entered an unpredictable state.

Return Type	void
Arguments	String why

6.33. write_memory

Write to virtual memory

Return Type	void
Arguments	XReg virtual_address, Bits<LEN> value, Bits<INSTR_ENC_SIZE> encoding

```
Boolean aligned = is_naturally_aligned<LEN>(virtual_address);
XReg physical_address;
if (aligned) {
  write_memory_aligned<LEN>(virtual_address, value, encoding);
}
if (MISALIGNED_MAX_ATOMICITY_GRANULE_SIZE > 0) {
  assert(MISALIGNED_LDST_EXCEPTION_PRIORITY == "low", "Invalid config: can't mix low-
priority misaligned exceptions with large atomicity granule");
  physical_address = (CSR[misa].S == 1) ? translate(virtual_address, MemoryOperation
::Write, effective_ldst_mode(), encoding).paddr : virtual_address;
  if (misaligned_is_atomic?<LEN>(physical_address)) {
    access_check(physical_address, LEN, virtual_address, MemoryOperation::Write,
ExceptionCode::StoreAmoAccessFault, effective_ldst_mode());
    write_physical_memory<LEN>(physical_address, value);
  }
}
if (!MISALIGNED_LDST) {
  if (MISALIGNED_LDST_EXCEPTION_PRIORITY == "low") {
    physical_address = (CSR[misa].S == 1) ? translate(virtual_address,
MemoryOperation::Write, effective_ldst_mode(), encoding).paddr : virtual_address;
    access_check(physical_address, LEN, virtual_address, MemoryOperation::Write,
ExceptionCode::StoreAmoAccessFault, effective_ldst_mode());
  }
  raise(ExceptionCode::StoreAmoAddressMisaligned, effective_ldst_mode(),
virtual_address);
} else {
  if (MISALIGNED_SPLIT_STRATEGY == "by_byte") {
    for (U32 i = 0; i <= LEN; i++) {
      write_memory_aligned<8>(virtual_address + i, (value >> (8 * i))[7:0], encoding);
    }
  } else if (MISALIGNED_SPLIT_STRATEGY == "custom") {
    unpredictable("An implementation is free to break a misaligned access any way,
leading to unpredictable behavior when any part of the misaligned access causes an
exception");
  }
}
```

6.34. write_memory_aligned

Write to virtual memory using a known aligned address.

Return Type	void

Arguments	XReg virtual_address, Bits<LEN> value, Bits<INSTR_ENC_SIZE> encoding

```
XReg physical_address;
physical_address = (CSR[misa].S == 1) ? translate(virtual_address, MemoryOperation
::Write, effective_ldst_mode(), encoding).paddr : virtual_address;
access_check(physical_address, LEN, virtual_address, MemoryOperation::Write,
ExceptionCode::StoreAmoAccessFault, effective_ldst_mode());
write_physical_memory<LEN>(physical_address, value);
```

6.35. write_physical_memory (builtin)

Write to physical memory.

Return Type	void
Arguments	XReg paddr, Bits<len> value

6.36. xlen

Returns the effective XLEN for the current privilege mode.

Return Type	Bits<8>
Arguments	

```
if (XLEN == 32) {
  return 32;
} else {
  if (mode() == PrivilegeMode::M) {
    if (CSR[misa].MXL == $bits(XRegWidth::XLEN32)) {
      return 32;
    } else if (CSR[misa].MXL == $bits(XRegWidth::XLEN64)) {
      return 64;
    }
  } else if (implemented?(ExtensionName::S) && mode() == PrivilegeMode::S) {
    if (CSR[mstatus].SXL == $bits(XRegWidth::XLEN32)) {
      return 32;
    } else if (CSR[mstatus].SXL == $bits(XRegWidth::XLEN64)) {
      return 64;
    }
  } else if (implemented?(ExtensionName::U) && mode() == PrivilegeMode::U) {
    if (CSR[mstatus].UXL == $bits(XRegWidth::XLEN32)) {
      return 32;
    } else if (CSR[mstatus].UXL == $bits(XRegWidth::XLEN64)) {
      return 64;
    }
  } else if (implemented?(ExtensionName::H) && mode() == PrivilegeMode::VS) {
    if (CSR[hstatus].VSXL == $bits(XRegWidth::XLEN32)) {
      return 32;
```

```
    } else if (CSR[hstatus].VSXL == $bits(XRegWidth::XLEN64)) {
      return 64;
    }
  } else if (implemented?(ExtensionName::H) && mode() == PrivilegeMode::VU) {
    if (CSR[vsstatus].UXL == $bits(XRegWidth::XLEN32)) {
      return 32;
    } else if (CSR[vsstatus].UXL == $bits(XRegWidth::XLEN64)) {
      return 64;
    }
  }
}
```