RISC-V Reference

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RISC-V Instruction Set

Core Instruction Formats

31 27	26 25	24 20	19 15	14 12	11 7	6 0	
funct7		rs2	rs1	funct3	rd	opcode	R-type
imm[11:0]			rs1	funct3	rd	opcode	I-type
imm[11:5]		rs2	rs1	funct3	imm[4:0]	opcode	S-type
imm[12|10:5]		rs2	rs1	funct3	imm[4:1|11]	opcode	B-type
imm[31:12]					rd	opcode	U-type
imm[20|10:1|11|19:12]					rd	opcode	J-type

RV32I Base Integer Instructions

Inst	Name	FMT	Opcode	funct3	funct7	Description (C)	Note
`add`	ADD	R	`0110011`	`0x0`	`0x00`	`rd = rs1 + rs2`	
`sub`	SUB	R	`0110011`	`0x0`	`0x20`	`rd = rs1 - rs2`	
`xor`	XOR	R	`0110011`	`0x4`	`0x00`	`rd = rs1 ^ rs2`	
`or`	OR	R	`0110011`	`0x6`	`0x00`	`rd = rs1 | rs2`	
`and`	AND	R	`0110011`	`0x7`	`0x00`	`rd = rs1 & rs2`	
`sll`	Shift Left Logical	R	`0110011`	`0x1`	`0x00`	`rd = rs1 << rs2`	
`srl`	Shift Right Logical	R	`0110011`	`0x5`	`0x00`	`rd = rs1 >> rs2`	
`sra`	Shift Right Arith*	R	`0110011`	`0x5`	`0x20`	`rd = rs1 >> rs2`	msb-extends
`slt`	Set Less Than	R	`0110011`	`0x2`	`0x00`	`rd = (rs1 < rs2)?1:0`	
`sltu`	Set Less Than (U)	R	`0110011`	`0x3`	`0x00`	`rd = (rs1 < rs2)?1:0`	zero-extends
`addi`	ADD Immediate	I	`0010011`	`0x0`		`rd = rs1 + imm`	
`xori`	XOR Immediate	I	`0010011`	`0x4`		`rd = rs1 ^ imm`	
`ori`	OR Immediate	I	`0010011`	`0x6`		`rd = rs1 | imm`	
`andi`	AND Immediate	I	`0010011`	`0x7`		`rd = rs1 & imm`	
`slli`	Shift Left Logical Imm	I	`0010011`	`0x1`	`imm[5:11]=0x00`	`rd = rs1 << imm[0:4]`	
`srli`	Shift Right Logical Imm	I	`0010011`	`0x5`	`imm[5:11]=0x00`	`rd = rs1 >> imm[0:4]`	
`srai`	Shift Right Arith Imm	I	`0010011`	`0x5`	`imm[5:11]=0x20`	`rd = rs1 >> imm[0:4]`	msb-extends
`slti`	Set Less Than Imm	I	`0010011`	`0x2`		`rd = (rs1 < imm)?1:0`	
`sltiu`	Set Less Than Imm (U)	I	`0010011`	`0x3`		`rd = (rs1 < imm)?1:0`	zero-extends
`lb`	Load Byte	I	`0000011`	`0x0`		`rd = M[rs1+imm][0:7]`	
`lh`	Load Half	I	`0000011`	`0x1`		`rd = M[rs1+imm][0:15]`	
`lw`	Load Word	I	`0000011`	`0x2`		`rd = M[rs1+imm][0:31]`	
`lbu`	Load Byte (U)	I	`0000011`	`0x4`		`rd = M[rs1+imm][0:7]`	zero-extends
`lhu`	Load Half (U)	I	`0000011`	`0x5`		`rd = M[rs1+imm][0:15]`	zero-extends
`sb`	Store Byte	S	`0100011`	`0x0`		`M[rs1+imm][0:7] = rs2[0:7]`	
`sh`	Store Half	S	`0100011`	`0x1`		`M[rs1+imm][0:15] = rs2[0:15]`	
`sw`	Store Word	S	`0100011`	`0x2`		`M[rs1+imm][0:31] = rs2[0:31]`	
`beq`	Branch ==	B	`1100011`	`0x0`		`if(rs1 == rs2) PC += imm`	
`bne`	Branch !=	B	`1100011`	`0x1`		`if(rs1 != rs2) PC += imm`	
`blt`	Branch <	B	`1100011`	`0x4`		`if(rs1 <  rs2) PC += imm`	
`bge`	Branch ≤	B	`1100011`	`0x5`		`if(rs1 >= rs2) PC += imm`	
`bltu`	Branch < (U)	B	`1100011`	`0x6`		`if(rs1 <  rs2) PC += imm`	zero-extends
`bgeu`	Branch ≥ (U)	B	`1100011`	`0x7`		`if(rs1 >= rs2) PC += imm`	zero-extends
`jal`	Jump And Link	J	`1101111`			`rd = PC+4; PC += imm`	
`jalr`	Jump And Link Reg	I	`1100111`	`0x0`		`rd = PC+4; PC = rs1 + imm`	
`lui`	Load Upper Imm	U	`0110111`			`rd = imm << 12`	
`auipc`	Add Upper Imm to PC	U	`0010111`			`rd = PC + (imm << 12)`	
`ecall`	Environment Call	I	`1110011`	`0x0`	`imm=0x0`	`Transfer control to OS`	
`ebreak`	Environment Break	I	`1110011`	`0x0`	`imm=0x1`	`Transfer control to debugger`	

Pseudo Instructions

Pseudoinstruction	Base Instruction(s)	Meaning
`la rd, symbol`	`auipc rd, symbol[31:12]` `addi rd, rd, symbol[11:0]`	Load address
`l{b|h|w|d} rd, symbol`	`auipc rd, symbol[31:12]` `l{b|h|w|d} rd, symbol[11:0](rd)`	Load global
`s{b|h|w|d} rd, symbol, rt`	`auipc rt, symbol[31:12]` `s{b|h|w|d} rd, symbol[11:0](rt)`	Store global
`fl{w|d} rd, symbol, rt`	`auipc rt, symbol[31:12]` `fl{w|d} rd, symbol[11:0](rt)`	Floating-point load global
`fs{w|d} rd, symbol, rt`	`auipc rt, symbol[31:12]` `fs{w|d} rd, symbol[11:0](rt)`	Floating-point store global
`nop`	`addi x0, x0, 0`	No operation
`li rd, immediate`	*Myriad sequences*	Load immediate
`mv rd, rs`	`addi rd, rs, 0`	Copy register
`not rd, rs`	`xori rd, rs, -1`	One's complement
`neg rd, rs`	`sub rd, x0, rs`	Two's complement
`negw rd, rs`	`subw rd, x0, rs`	Two's complement word
`sext.w rd, rs`	`addiw rd, rs, 0`	Sign extend word
`seqz rd, rs`	`sltiu rd, rs, 1`	Set if $=$ zero
`snez rd, rs`	`sltu rd, x0, rs`	Set if $\neq$ zero
`sltz rd, rs`	`slt rd, rs, x0`	Set if $<$ zero
`sgtz rd, rs`	`slt rd, x0, rs`	Set if $>$ zero
`fmv.s rd, rs`	`fsgnj.s rd, rs, rs`	Copy single-precision register
`fabs.s rd, rs`	`fsgnjx.s rd, rs, rs`	Single-precision absolute value
`fneg.s rd, rs`	`fsgnjn.s rd, rs, rs`	Single-precision negate
`fmv.d rd, rs`	`fsgnj.d rd, rs, rs`	Copy double-precision register
`fabs.d rd, rs`	`fsgnjx.d rd, rs, rs`	Double-precision absolute value
`fneg.d rd, rs`	`fsgnjn.d rd, rs, rs`	Double-precision negate
`beqz rs, offset`	`beq rs, x0, offset`	Branch if $=$ zero
`bnez rs, offset`	`bne rs, x0, offset`	Branch if $\neq$ zero
`blez rs, offset`	`bge x0, rs, offset`	Branch if $\leq$ zero
`bgez rs, offset`	`bge rs, x0, offset`	Branch if $\geq$ zero
`bltz rs, offset`	`blt rs, x0, offset`	Branch if $<$ zero
`bgtz rs, offset`	`blt x0, rs, offset`	Branch if $>$ zero
`bgt rs, rt, offset`	`blt rt, rs, offset`	Branch if $>$
`ble rs, rt, offset`	`bge rt, rs, offset`	Branch if $\leq$
`bgtu rs, rt, offset`	`bltu rt, rs, offset`	Branch if $>$, unsigned
`bleu rs, rt, offset`	`bgeu rt, rs, offset`	Branch if $\leq$, unsigned
`j offset`	`jal x0, offset`	Jump
`jal offset`	`jal x1, offset`	Jump and link
`jr rs`	`jalr x0, rs, 0`	Jump register
`jalr rs`	`jalr x1, rs, 0`	Jump and link register
`ret`	`jalr x0, x1, 0`	Return from subroutine
`call offset`	`auipc x1, offset[31:12]` `jalr x1, x1, offset[11:0]`	Call far-away subroutine
`tail offset`	`auipc x6, offset[31:12]` `jalr x0, x6, offset[11:0]`	Tail call far-away subroutine
`fence`	`fence iorw, iorw`	Fence on all memory and I/O

Registers

Register	ABI Name	Description	Saver
x0	zero	Zero constant	—
x1	ra	Return address	Caller
x2	sp	Stack pointer	—
x3	gp	Global pointer	—
x4	tp	Thread pointer	Callee
x5	t0-t2	Temporaries	Caller
x8	s0 / fp	Saved / frame pointer	Callee
x9	s1	Saved register	Callee
x10-x11	a0-a1	Fn args/return values	Caller
x12-x17	a2-a7	Fn args	Caller
x18-x27	s2-s11	Saved registers	Callee
x28-x31	t3-t6	Temporaries	Caller
f0-7	ft0-7	FP temporaries	Caller
f8-9	fs0-1	FP saved registers	Callee
f10-11	fa0-1	FP args/return values	Caller
f12-17	fa2-7	FP args	Caller
f18-27	fs2-11	FP saved registers	Callee
f28-31	ft8-11	FP temporaries	Caller