RISC-V REFERENCE

RISC-V Instruction Set

Core Instruction Formats

31 27 26 25	24 20	19	15	14	12	11	7	6	0	
funct7	rs2	rs1		fun	ct3	1	rd	opcode		R-type
imm[11:	0]	rs1		fun	ct3	1	rd	opcode		I-type
imm[11:5]	rs2	rs1		fun	ct3	imm	1[4:0]	opcode		S-type
imm[12 10:5]	rs2	rs1		fun	ct3	imm[4:1 11]	opcode		B-type
imm[31:12]						1	rd	opcode		U-type
imm[20 10:1 11 19:12]						1	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]	
1bu	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 ==	В	1100011	0x0		if(rs1 == rs2) PC += imm	
bne	Branch !=	В	1100011	0x1		if(rs1 != rs2) PC += imm	
blt	Branch <	В	1100011	0x4		if(rs1 < rs2) PC += imm	
bge	Branch ≥	В	1100011	0x5		if(rs1 >= rs2) PC += imm	
bltu	Branch < (U)	В	1100011	0x6		if(rs1 < rs2) PC += imm	zero-extends
bgeu	Branch \geq (U)	В	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	

Standard Extensions

RV32M Multiply Extension

Inst	Name	FMT	Opcode	funct3	funct7	Description (C)
mul	MUL	R	0110011	0x0	0x01	rd = (rs1 * rs2)[31:0]
mulh	MUL High	R	0110011	0x1	0x01	rd = (rs1 * rs2)[63:32]
mulsu	MUL High (S) (U)	R	0110011	0x2	0x01	rd = (rs1 * rs2)[63:32]
mulu	MUL High (U)	R	0110011	0x3	0x01	rd = (rs1 * rs2)[63:32]
div	DIV	R	0110011	0x4	0x01	rd = rs1 / rs2
divu	DIV (U)	R	0110011	0x5	0x01	rd = rs1 / rs2
rem	Remainder	R	0110011	0x6	0x01	rd = rs1 % rs2
remu	Remainder (U)	R	0110011	0x7	0x01	rd = rs1 % rs2

RV32A Atomic Extension

31	27	26	25	24	20	19	15 1	.4	12 11 7	7 6 0		
func	t5	aq	rl	r	s2	rs1		funct3	nct3 rd opcode			
5		1	1		5	5		3	3 5 7			
Inst	Name			FMT	Opcode	funct3	func	t5 D	escription (C)			
lr.w	Load	Reserv	ed	R	0101111	0x2	0x02	ro	rd = M[rs1], reserve M[rs1]			
SC.W	Store	Condit	ional	R	0101111	0x2	0x03	if	if (reserved) { M[rs1] = rs2; rd = 0			
								e]	else { rd = 1 }			
amoswap.w	Atomi	c Swap)	R	0101111	0x2	0x01	ro	d = M[rs1]; swap	(rd, rs2); M[rs1] = rd		
amoadd.w	Atomi	c ADD		R	0101111	0x2	0x00	ro	d = M[rs1] + rs2	; M[rs1] = rd		
amoand.w	Atomi	c AND		R	0101111	0x2	0x0C	ro	d = M[rs1] & rs2	; M[rs1] = rd		
amoor.w	Atomi	c OR		R	0101111	0x2	0x0A		rd = M[rs1] rs2; M[rs1] = rd			
amoxor.w	Atomi	x XOR		R	0101111	0x2	0x04	ro	rd = M[rs1] ^ rs2; M[rs1] = rd			
amomax.w	Atomi	c MAX		R	0101111	0x2	0x14	ro	rd = max(M[rs1], rs2); M[rs1] = rd			
_amomin.w	Atomi	c MIN		R	0101111	0x2	0x10	ro	d = min(M[rs1],	rs2); M[rs1] = rd		

RV32F / D Floating-Point Extensions

Inst	Name	FMT	Opcode	funct3	funct5	Description (C)
flw	Flt Load Word	*				rd = M[rs1 + imm]
fsw	Flt Store Word	*				M[rs1 + imm] = rs2
fmadd.s	Flt Fused Mul-Add	*				rd = rs1 * rs2 + rs3
fmsub.s	Flt Fused Mul-Sub	*				rd = rs1 * rs2 - rs3
fnmadd.s	Flt Neg Fused Mul-Add	*				rd = -rs1 * rs2 + rs3
fnmsub.s	Flt Neg Fused Mul-Sub	*				rd = -rs1 * rs2 - rs3
fadd.s	Flt Add	*				rd = rs1 + rs2
fsub.s	Flt Sub	*				rd = rs1 - rs2
fmul.s	Flt Mul	*				rd = rs1 * rs2
fdiv.s	Flt Div	*				rd = rs1 / rs2
fsqrt.s	Flt Square Root	*				rd = sqrt(rs1)
fsgnj.s	Flt Sign Injection	*				rd = abs(rs1) * sgn(rs2)
fsgnjn.s	Flt Sign Neg Injection	*				rd = abs(rs1) * -sgn(rs2)
fsgnjx.s	Flt Sign Xor Injection	*				rd = rs1 * sgn(rs2)
fmin.s	Flt Minimum	*				rd = min(rs1, rs2)
fmax.s	Flt Maximum	*				rd = max(rs1, rs2)
fcvt.s.w	Flt Conv from Sign Int	*				rd = (float) rs1
fcvt.s.wu	Flt Conv from Uns Int	*				rd = (float) rs1
fcvt.w.s	Flt Convert to Int	*				rd = (int32_t) rs1
fcvt.wu.s	Flt Convert to Int	*				rd = (uint32_t) rs1
fmv.x.w	Move Float to Int	*				rd = *((int*) &rs1)
fmv.w.x	Move Int to Float	*				rd = *((float*) &rs1)
feq.s	Float Equality	*				rd = (rs1 == rs2) ? 1 : 0
flt.s	Float Less Than	*				rd = (rs1 < rs2) ? 1 : 0
fle.s	Float Less / Equal	*				rd = (rs1 <= rs2) ? 1 : 0
fclass.s	Float Classify	*				rd = 09

RV32C Compressed Extension

15 14 13	12	11	10	9	8	7	6	5	4	3	2	1	0		
funct	4		rd,	/rs1	L		rs2				0	p	CR-type		
funct3	imm		rd/rs1						imm			op CI-type			
funct3		imm					rs2				op CSS-type				
funct3		imm						rd'				0	p	CIW-type	
funct3	im	ım		1	rs1'		imm rd'				0	p	CL-type		
funct3	im	imm rd'/rs1'			imı	imm rs2'				0	p	CS-type			
funct3	im	imm rs1'					imm				0	p	CB-type		
funct3		offset										0	p	CJ-type	
														-	

Inst	Name	FMT	OP	Funct	Description
c.lwsp	Load Word from SP	CI	10	010	lw rd, (4*imm)(sp)
c.swsp	Store Word to SP	CSS	10	110	sw rs2, (4*imm)(sp)
c.lw	Load Word	CL	00	010	lw rd', (4*imm)(rs1')
C.SW	Store Word	CS	00	110	sw rs1', (4*imm)(rs2')
c.j	Jump	CJ	01	101	jal x0, 2*offset
c.jal	Jump And Link	CJ	01	001	jal ra, 2*offset
c.jr	Jump Reg	CR	10	1000	jalr x0, rs1, 0
c.jalr	Jump And Link Reg	CR	10	1001	jalr ra, rs1, 0
c.beqz	Branch == 0	CB	01	110	beq rs', x0, 2*imm
c.bnez	Branch != 0	CB	01	111	bne rs', x0, 2*imm
c.li	Load Immediate	CI	01	010	addi rd, x0, imm
c.lui	Load Upper Imm	CI	01	011	lui rd, imm
c.addi	ADD Immediate	CI	01	000	addi rd, rd, imm
c.addi16sp	ADD Imm * 16 to SP	CI	01	011	addi sp, sp, 16*imm
c.addi4spn	ADD Imm * 4 + SP	CIW	00	000	addi rd', sp, 4*imm
c.slli	Shift Left Logical Imm	CI	10	000	slli rd, rd, imm
c.srli	Shift Right Logical Imm	CB	01	100x00	srli rd', rd', imm
c.srai	Shift Right Arith Imm	CB	01	100x01	srai rd', rd', imm
c.andi	AND Imm	CB	01	100x10	andi rd', rd', imm
c.mv	MoVe	CR	10	1000	add rd, x0, rs2
c.add	ADD	CR	10	1001	add rd, rd, rs2
c.and	AND	CS	01	10001111	and rd', rd', rs2'
c.or	OR	CS	01	10001110	or rd', rd', rs2'
c.xor	XOR	CS	01	10001101	xor rd', rd', rs2'
c.sub	SUB	CS	01	10001100	sub rd', rd', rs2'
c.nop	No OPeration	CI	01	000	addi x0, x0, 0
c.ebreak	Environment BREAK	CR	10	1001	ebreak

Pseudo Instructions

1a rd, symbol	Pseudoinstruction	Base Instruction(s)	Meaning
	la rd, symbol	The state of the s	Load address
S(b h w d) rd, symbol, rt S(b h w d) rd, symbol[31:12] s(b h w d) rd, symbol[31:12] fl(w d) rd, symbol[31	l{b h w d} rd, symbol		Load global
## F1(w d} rd, symbol, rt	s{b h w d} rd, symbol, rt		Store global
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	fl{w d} rd, symbol, rt	auipc rt, symbol[31:12]	Floating-point load global
No operation No operation	fs{w d} rd, symbol, rt	auipc rt, symbol[31:12]	Floating-point store global
1	nop		No operation
mv rd, rs not rd, rs not rd, rs neg rd, rs sub rd, x0, rs negw rd, rs subw rd, x0, rs sext.w rd, rs set if > zero sext.x rd, rs set if > zero sitz.x rs set if > zero single-precision register single-precision register single-precision register sext.y rs, offset branch if < zero br	•		
not rd, rs	,		Copy register
neg rd, rs negw rd, rs subw rd, x0, rs sext.w rd, rs seqz rd, rs sltu rd, rs, 1 seqz rd, rs sltu rd, x0, rs set if ≠ zero set if ≥ zero set i	•		
negw rd, rs sext.w rd, rs sext.w rd, rs sext.w rd, rs set.w rd, rs set.if ≠ zero set.w rd, rs set.if ≠ zero set.w rd, rs single-precision absolute value free,s rd, rs single-precision register Single-precision negate set.w rd, rs single-precision register set.w rd, rs set.if ≠ zero set.w rd, rs single-precision register Double-precision negate set.w rd, rs single-precision absolute value free,s rt, set.w rd, rs single-precision register Double-precision negate single-precision absolute value free,s rt, set.w rd, rs set.w rd, rs set.if ≠ zero single-precision register Branch if = zero single-precision absolute value free,s rt, set.w rd, rs, rs single-precision absolute value free,s rt, set.w rd, rs, rs single-precision register Branch if = zero single-precision register Branch if = zero single-precision register Branch if = zero single-precision absolute value free,s rd, rs, rs single-precision register Branch if = zero single-precision register Branch if = zero single-precision register Branch if = zero single-precision register set.w rd, rs, rs single-precision regi	,		
			-
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 \neq zero sgtz rd, rs slt rd, x0, rs Set if \neq zero sgtz rd, rs slt rd, x0, rs Set if \neq zero fmw.s rd, rs fsgnjs. rd, rs, rs Copy single-precision register fabs.s rd, rs fsgnjx.s rd, rs, rs Single-precision absolute value fneg.s rd, rs fsgnjx.s rd, rs, rs Single-precision negate fmv.d rd, rs fsgnjx.d rd, rs, rs Copy double-precision register fabs.d rd, rs fsgnjx.d rd, rs, rs Copy double-precision negate fmv.d rd, rs fsgnjx.d rd, rs, rs Double-precision absolute value fneg.d rd, rs fsgnjx.d rd, rs, rs Double-precision negate beqz rs, offset beq rs, x0, offset Branch if = zero branch if \neq zero blez rs, offset bge x0, rs, offset Branch if \neq zero blez rs, offset bge x0, rs, offset Branch if \neq zero bltz rs, offset blt rs, x0, offset Branch if \neq zero bttz rs, offset blt x0, rs, offset Branch if \neq zero bgtz rs, rt, offset blt x0, rs, offset Branch if \neq zero bgt rs, rt, offset blt rt, rs, offset Branch if \neq bge rt, rs, offset Branch if \neq bge rt, rs, offset Branch if \neq bgu rt, rs, offset Branch if \neq bgu rt, rs, offset Branch if \neq bgu rt, rs, offset Branch if \neq bltu rt, rs, offset Branch if \neq bltu rt, rs, offset Branch if \neq branch if \neq bgu rt, rs, offset Branch if \neq branch if \neq bltu rt, rs, offset Branch if \neq branch if \neq branch if \neq bltu rt, rs, offset Branch if \neq bran			
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 fsgnjx.s rd, rs, rs Single-precision absolute value fneg, s rd, rs fsgnjx.s rd, rs, rs Single-precision absolute value fneg, s rd, rs fsgnjx.s rd, rs, rs Single-precision negate fmv.d rd, rs fsgnjx.d rd, rs, rs Copy double-precision register fabs.d rd, rs fsgnjx.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 fsgnjx.d rd, rs, rs Double-precision absolute value fneg.d rd, rs fsgnjx.d rd, rs, rs Double-precision negate beqz rs, offset beq rs, x0, offset Branch if = zero brez rs, offset by sex x0, rs, offset Branch if \neq zero blez rs, offset bge x0, rs, offset Branch if \neq zero blez rs, offset bge x0, rs, offset Branch if \neq zero bltz rs, offset blt rs, x0, offset Branch if \neq zero bgtz rs, offset blt rs, x0, offset Branch if \neq zero bgtz rs, offset blt rx, x0, offset Branch if \neq zero bgt rs, rt, offset blt rt, rs, offset Branch if \neq zero bgt rs, rt, offset blt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bge rt, rs, offset Branch if \neq zero bgt rs, rt, offset bge rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rs, rt, offset bgt rx, rt, offset bgt rt, rs, offset Branch if \neq zero bgt rx, rt, offset bgt rx, rt, offset bgt rx, rx, offset Branch if \neq zero bgt rx, rx, offset			
sltz rd, rs sgtz rd, rs sgt rd, x0 sgt rf sct slir > single-precision register Copy double-precision negate Copy double-precision negate Double-precision negate Supple-precision register Double-precision negate Copy double-precision register Brach if = zero Double-precision negate Copy double-precision register Branch if = zero Double-precision negate Copy double-precision register Branch if = zero Double-precision negate Branch if = zero Bouble-precision negate Branch if = zero Bouble-precision negate Branch if = zero Branch if = zero Branch if > ber rd, rs, offset Branch if > ber rd, rs, offset Branch if > ber rd, rs, offset Branch if > granch if > granc			
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fabs.s rd, rs fsgnjx.s rd, rs, rs fsgnjn.s rd, rs, rs fsgnjn.d rd, rs, rs fsgnjx.d rd, rs, rs fopy double-precision negate Copy double-precision register Double-precision absolute value Double-precision negate beqz rs, offset beq rs, x0, offset beqz rs, offset beqz rs, v0, offset blez rs, offset begz rs, v0, offset blez rs, offset bltz rs, offset bltz rs, offset bltz rs, v0, offset bltz rs, offset bltz rs, offset blt rs, x0, offset blt rs, x0, offset blt rs, x0, offset blt rs, rt, offset blt rt, rs, offset ble rs, rt, offset blu rt, rs, offset blu rt, rs, offset blu rt, rs, offset blu rs, rt, offset blu rt, rs, offset bleu rs, rt, offset bleu rs, rt, offset jal x0, offset jal x0, offset jal x1, offset jal x2, x1, 0 Call far-away subroutine tail offset jal x0, x6, offset[11:0] Tail call far-away subroutine			
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fabs.d rd, rs fneg.d rd, rs fneg.d rd, rs fneg.d rd, rs fsgnjn.d rd, rs, rs beqz rs, offset beq rs, x0, offset bnez rs, offset bnez rs, offset bnez rs, offset bge x0, rs, offset bgez rs, offset bltz rs, rt, offset bltz rs, rt			
fneg.d rd, rsfsgnjn.d rd, rs, rsDouble-precision negatebeqz rs, offsetbeq rs, x0, offsetBranch if = zerobnez rs, offsetbne rs, x0, offsetBranch if ≠ zeroblez rs, offsetbge x0, rs, offsetBranch if ≤ zerobgez rs, offsetbge rs, x0, offsetBranch if ≥ zerobltz rs, offsetblt rs, x0, offsetBranch if < zero			
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jalr x0, x6, offset[11:0]	call offset	jalr x1, x1, offset[11:0]	Call far-away subroutine
	tail offset		Tail call far-away subroutine
<u> </u>	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	Callee
x2	sp	Stack pointer	Callee
x3	gp	Global pointer	_
x4	tp	Thread pointer	_
x5-x7	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
f28-31	ft8-11	FP temporaries	Ca