

Risc V Reference Card

Instruction Formats

31	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
funct7		Shamt		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[20:10:11:19:12]						rd		opcode		J-type

* This is a special case of the RV64I I-type format used by slli, srli and srai instructions where the lower 5 bits in the immediate are used to determine the shift amount (shamt). If slliw, srlw and sraiw are used it should generate an error if $\text{imm}[5] \neq 0$

RV64I Base Instructions

Name	Fmt	Opcode	Funct3	Funct7/ imm[11:5]	Assembly	Description (in C)
Add	R	0110011	000	0000000	add rd, rs1, rs2	$\text{rd} = \text{rs1} + \text{rs2}$
Subtract	R	0110011	000	0100000	sub rd, rs1, rs2	$\text{rd} = \text{rs1} - \text{rs2}$
AND	R	0110011	111	0000000	and rd, rs1, rs2	$\text{rd} = \text{rs1} \& \text{rs2}$
OR	R	0110011	110	0000000	or rd, rs1, rs2	$\text{rd} = \text{rs1} \text{rs2}$
XOR	R	0110011	100	0000000	xor rd, rs1, rs2	$\text{rd} = \text{rs1} \wedge \text{rs2}$
Shift Left Logical	R	0110011	001	0000000	sll rd, rs1, rs2	$\text{rd} = \text{rs1} \ll \text{rs2}$
Set Less Than	R	0110011	010	0000000	slt rd, rs1, rs2	$\text{rd} = (\text{rs1} < \text{rs2}) ? 1 : 0$
Set Less Than (U)*	R	0110011	011	0000000	sltu rd, rs1, rs2	$\text{rd} = (\text{rs1} < \text{rs2}) ? 1 : 0$
Shift Right Logical	R	0110011	101	0000000	srl rd, rs1, rs2	$\text{rd} = \text{rs1} \gg \text{rs2}$
Shift Right Arithmetic†	R	0110011	101	0100000	sra rd, rs1, rs2	$\text{rd} = \text{rs1} \ggg \text{rs2}$
Add Word	R	0111011	000	0000000	addw rd, rs1, rs2	$\text{rd} = \text{rs1} + \text{rs2}$
Subtract Word	R	0111011	000	0100000	subw rd, rs1, rs2	$\text{rd} = \text{rs1} - \text{rs2}$
Shift Left Logical Word	R	0111011	001	0000000	sllw rd, rs1, rs2	$\text{rd} = \text{rs1} \ll \text{rs2}$
Shift Right Logical Word	R	0111011	101	0000000	srlw rd, rs1, rs2	$\text{rd} = \text{rs1} \gg \text{rs2}$
Shift Right Arithmetic Word†	R	0111011	101	0100000	sraw rd, rs1, rs2	$\text{rd} = \text{rs1} \ggg \text{rs2}$
Add Immediate	I	0010011	000		addi rd, rs1, imm	$\text{rd} = \text{rs1} + \text{imm}$
AND Immediate	I	0010011	111		andi rd, rs1, imm	$\text{rd} = \text{rs1} \& \text{imm}$
OR Immediate	I	0010011	110		ori rd, rs1, imm	$\text{rd} = \text{rs1} \text{imm}$
XOR Immediate	I	0010011	100		xori rd, rs1, imm	$\text{rd} = \text{rs1} \wedge \text{imm}$
Shift Left Logical Immediate	I	0010011	001	0000000	slli rd, rs1, shamt	$\text{rd} = \text{rs1} \ll \text{shamt}$
Shift Right Logical Immediate	I	0010011	101	0000000	srli rd, rs1, shamt	$\text{rd} = \text{rs1} \gg \text{shamt}$
Shift Right Arithmetic Immediate†	I	0010011	101	0100000	sraiw rd, rs1, shamt	$\text{rd} = \text{rs1} \ggg \text{shamt}$
Set Less Than Immediate	I	0010011	010		slti rd, rs1, imm	$\text{rd} = (\text{rs1} < \text{imm}) ? 1 : 0$
Set Less Than Immediate (U)*	I	0010011	011		sltiu rd, rs1, imm	$\text{rd} = (\text{rs1} < \text{imm}) ? 1 : 0$
Add Immediate Word	I	0011011	000		addiw rd, rs1, imm	$\text{rd} = \text{rs1} + \text{imm}$
Shift Left Logical Immediate Word	I	0011011	001	0000000	slliw rd, rs1, shamt	$\text{rd} = \text{rs1} \ll \text{shamt}$
Shift Right Logical Immediate Word	I	0011011	101	0000000	srlw rd, rs1, shamt	$\text{rd} = \text{rs1} \gg \text{shamt}$
Shift Right Arithmetic Imm Word†	I	0011011	101	0100000	sraiw rd, rs1, shamt	$\text{rd} = \text{rs1} \ggg \text{shamt}$
Load Byte	I	0000011	000		lb rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:7]$
Load Half	I	0000011	001		lh rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:15]$
Load Word	I	0000011	010		lw rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:31]$
Load Doubleword	I	0000011	011		ld rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:63]$
Load Byte (U)*	I	0000011	100		lbu rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:7]$
Load Half (U)*	I	0000011	101		lhu rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:15]$
Load Word (U)*	I	0000011	110		lwu rd, rs1, imm	$\text{rd} = \text{M}[\text{rs1} + \text{imm}][0:31]$
Store Byte	S	0100011	000		sb rs1, rs2, imm	$\text{M}[\text{rs1} + \text{imm}][0:7] = \text{rs2}[0:7]$
Store Half	S	0100011	001		sh rs1, rs2, imm	$\text{M}[\text{rs1} + \text{imm}][0:15] = \text{rs2}[0:15]$
Store Word	S	0100011	010		sw rs1, rs2, imm	$\text{M}[\text{rs1} + \text{imm}][0:31] = \text{rs2}[0:31]$
Store Doubleword	S	0100011	011		sd rs1, rs2, imm	$\text{M}[\text{rs1} + \text{imm}][0:63] = \text{rs2}[0:63]$
Branch If Equal	B	1100011	000		beq rs1, rs2, imm	if(rs1 == rs2) PC += imm
Branch Not Equal	B	1100011	001		bne rs1, rs2, imm	if(rs1 != rs2) PC += imm
Branch Less Than	B	1100011	100		blt rs1, rs2, imm	if(rs1 < rs2) PC += imm
Branch Greater Than Or Equal	B	1100011	101		bge rs1, rs2, imm	if(rs1 ≥ rs2) PC += imm
Branch Less Than (U)*	B	1100011	110		bltu rs1, rs2, imm	if(rs1 < rs2) PC += imm
Branch Greater Than Or Equal (U)*	B	1100011	111		bgeu rs1, rs2, imm	if(rs1 ≥ rs2) PC += imm
Load Upper Immediate	U	0110111			lui rd, imm	$\text{rd} = \text{imm} \ll 12$
Add Upper Immediate To PC	U	0010111			auipc rd, imm	$\text{rd} = \text{PC} + (\text{imm} \ll 12)$
Jump And Link	J	1101111			jal rd, imm	$\text{rd} = \text{PC} + 4; \text{PC} += \text{imm}$
Jump And Link Register	I	1100111	000		jalr rd, rs1, imm	$\text{rd} = \text{PC} + 4; \text{PC} = \text{rs1} + \text{imm}$

* Assumes values are unsigned integers and zero extends † Fills in with sign bit during right shift and msb (most significant bit) extends

RV64M Standard Extension Instructions

Name	Fmt	Opcode	Funct3	Funct7	Assembly	Description (in C)
Multiply	R	0110011	000	0000001	mul rd, rs1, rs2	$rd = (rs1 \cdot rs2)[63:0]$
Multiply Upper Half	R	0110011	001	0000001	mulh rd, rs1, rs2	$rd = (rs1 \cdot rs2)[127:64]$
Multiply Upper Half Sign/Unsigned [†]	R	0110011	010	0000001	mulhsu rd, rs1, rs2	$rd = (rs1 \cdot rs2)[127:64]$
Multiply Upper Half (U) [*]	R	0110011	011	0000001	mulhu rd, rs1, rs2	$rd = (rs1 \cdot rs2)[127:64]$
Divide	R	0110011	100	0000001	div rd, rs1, rs2	$rd = rs1 / rs2$
Divide (U) [*]	R	0110011	101	0000001	divu rd, rs1, rs2	$rd = rs1 / rs2$
Remainder	R	0110011	110	0000001	rem rd, rs1, rs2	$rd = rs1 \% rs2$
Remainder (U) [*]	R	0110011	111	0000001	remu rd, rs1, rs2	$rd = rs1 \% rs2$
Multiply Word	R	0111011	000	0000001	mulw rd, rs1, rs2	$rd = (rs1 \cdot rs2)[63:0]$
Divide Word	R	0111011	100	0000001	divw rd, rs1, rs2	$rd = rs1 / rs2$
Divide Word (U) [*]	R	0111011	101	0000001	divuw rd, rs1, rs2	$rd = rs1 / rs2$
Remainder Word	R	0111011	110	0000001	remw rd, rs1, rs2	$rd = rs1 \% rs2$
Remainder Word (U) [*]	R	0111011	111	0000001	remuw rd, rs1, rs2	$rd = rs1 \% rs2$

^{*} Assumes values are unsigned integers and zero extends [†] Multiply with one operand signed and the other unsigned

Bibliography

- [1] C. A. R. Hoare. Communicating sequential processes. *Communications of the ACM*, 21(8):666–677, 1978. ISSN 1557-7317.
- [2] B. Vinter and K. Skovhede. Synchronous message exchange for hardware designs. *Communicating Process Architectures*, pages 201–212, 2014.