Minimized Green Sheet for Exam 1 Questions

RISC-V **Reference Data** ①

RV321 BASE INTEGER INSTRUCTIONS, in alphabetical order

MNEMONIC	FMT	NAME	DESCRIPTION (in Verilog)	NOTE
add	R	ADD	R[rd] = R[rs1] + R[rs2]	
addi	I	ADD Immediate	R[rd] = R[rs1] + imm	
and	R	AND	R[rd] = R[rs1] & R[rs2]	
andi	I	AND Immediate	R[rd] = R[rs1] & imm	
auipc	U	Add Upper Immediate to PC	R[rd] = PC + {imm, 12'b0}	
beq	SB	Branch EQual	if(R[rs1]==R[rs2) PC=PC+{imm,1b'0}	
bge	SB	Branch Greater than or Equal	if(R[rs1]>=R[rs2) PC=PC+{imm,1b'0}	
bgeu	SB	Branch ≥ Unsigned	if(R[rs1]>=R[rs2) PC=PC+{imm,1b'0}	2)
blt	SB	Branch Less Than	if(R[rs1]<R[rs2) PC=PC+{imm,1b'0}	
bltu	SB	Branch Less Than Unsigned	if(R[rs1]<R[rs2) PC=PC+{imm,1b'0}	2)
bne	SB	Branch Not Equal	if(R[rs1]!=R[rs2) PC=PC+{imm,1b'0}	
csrrc	I	Cont./Stat.RegRead&Clear	R[rd] = CSR;CSR = CSR & ~R[rs1]	
csrrci	I	Cont./Stat.RegRead&Clear Imm	R[rd] = CSR;CSR = CSR & ~imm	
csrrs	I	Cont./Stat.RegRead&Set	R[rd] = CSR; CSR = CSR | R[rs1]	
csrrsi	I	Cont./Stat.RegRead&Set Imm	R[rd] = CSR; CSR = CSR | imm	
csrrw	I	Cont./Stat.RegRead&Write	R[rd] = CSR; CSR = R[rs1]	
csrrwi	I	Cont./Stat.Reg Read&Write Imm	R[rd] = CSR; CSR = imm	
ebreak	I	Environment BREAK	Transfer control to debugger	
ecall	I	Environment CALL	Transfer control to operating system	
fence	I	Synch thread	Synchronizes threads	
fence.i	I	Synch Instr & Data	Synchronizes writes to instruction stream	
jal	UJ	Jump & Link	R[rd] = PC+4; PC = PC + {imm,1b'0}	
jalr	I	Jump & Link Register	R[rd] = PC+4; PC = R[rs1]+imm	
lb	I	Load Byte	R[rd] = {24'bM[](7),M[R[rs1]+imm](7:0)}	3) 4)
lbu	I	Load Byte Unsigned	R[rd] = {24'b0,M[R[rs1]+imm](7:0)}	
lh	I	Load Halfword	R[rd] = {16'bM[](15),M[R[rs1]+imm](15:0)}	
lhu	I	Load Halfword Unsigned	R[rd] = {16'b0,M[R[rs1]+imm](15:0)}	4)
lui	U	Load Upper Immediate	R[rd] = {imm, 12'b0}	
lw	I	Load Word	R[rd] = {M[R[rs1]+imm](31:0)}	
or	R	OR	R[rd] = R[rs1] | R[rs2]	
ori	I	OR Immediate	R[rd] = R[rs1] | imm	4)
sb	S	Store Byte	M[R[rs1]+imm](7:0) = R[rs2](7:0)	
sh	S	Store Halfword	M[R[rs1]+imm](15:0) = R[rs2](15:0)	
sll	R	Shift Left	R[rd] = R[rs1] << R[rs2]	
slli	I	Shift Left Immediate	R[rd] = R[rs1] << imm	
slt	R	Set Less Than	R[rd] = (R[rs1] < R[rs2]) ? 1 : 0	
slti	I	Set Less Than Immediate	R[rd] = (R[rs1] < imm) ? 1 : 0	
sltiu	I	Set < Immediate Unsigned	R[rd] = (R[rs1] < imm) ? 1 : 0	
sltu	R	Set Less Than Unsigned	R[rd] = (R[rs1] < R[rs2]) ? 1 : 0	
sra	R	Shift Right Arithmetic	R[rd] = R[rs1] >> R[rs2]	2)
srai	I	Shift Right Arith Imm	R[rd] = R[rs1] >> imm	2)
srl	R	Shift Right (Word)	R[rd] = R[rs1] >> R[rs2]	5)
srli	I	Shift Right Immediate	R[rd] = R[rs1] >> imm	5)
sub,subw	R	SUBtract (Word)	R[rd] = R[rs1] – R[rs2]	
sw	S	Store Word	M[R[rs1]+imm](31:0) = R[rs2](31:0)	
xor	R	XOR	R[rd] = R[rs1] ^ R[rs2]	
xori	I	XOR Immediate	R[rd] = R[rs1] ^ imm	

Notes: 1) Operation assumes unsigned integers (instead of 2's complement)
2) The least significant bit of the branch address in jalr is set to 0
3) (signed) Load instructions extend the sign bit of data to fill the 32-bit register
4) Replicates the sign bit to fill in the leftmost bits of the result during right shift
5) Multiply with one operand signed and one unsigned
6) The Single version does a single-precision operation using the rightmost 32 bits of a 64-bit F register
7) Classify writes a 10-bit mask to show which properties are true (e.g., –inf, -0,+0, +inf, denorm, ...)
8) Atomic memory operation; nothing else can interpose itself between the read and the write of the memory location
The immediate field is sign-extended in RISC-V

Instruction	ALUOp1	ALUOp0
R-format	1	0
lw	0	0
sw	0	0
beq	0	1

ALU control lines	Function
0000	AND
0001	OR
0010	add
0110	subtract

CORE INSTRUCTION FORMATS

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

OPCODES IN NUMERICAL ORDER BY OPCODE

MNEMONIC	FMT	OPCODE	FUNCT3	FUNCT7 OR IMM	HEXADECIMAL
lb	I	0000011	000		03/0
lh	I	0000011	001		03/1
lw	I	0000011	010		03/2
lbu	I	0000011	100		03/4
lhu	I	0000011	101		03/5
fence	I	0001111	000		0F/0
fence.i	I	0001111	001		0F/1
addi	I	0010011	000		13/0
slli	I	0010011	001	0000000	13/1/00
slti	I	0010011	010		13/2
sltiu	I	0010011	011		13/3
xori	I	0010011	100		13/4
srli	I	0010011	101	0000000	13/5/00
srai	I	0010011	101	0100000	13/5/20
ori	I	0010011	110		13/6
andi	I	0010011	111		13/7
sb	S	0100011	000		23/0
sh	S	0100011	001		23/1
sw	S	0100011	010		23/2
add	R	0110011	000	0000000	33/0/00
sub	R	0110011	000	0100000	33/0/20
sll	R	0110011	001	0000000	33/1/00
slt	R	0110011	010	0000000	33/2/00
sltu	R	0110011	011	0000000	33/3/00
xor	R	0110011	100	0000000	33/4/00
srl	R	0110011	101	0000000	33/5/00
sra	R	0110011	101	0100000	33/5/20
or	R	0110011	110	0000000	33/6/00
and	R	0110011	111	0000000	33/7/00
lui	U	0110111			37
beq	SB	1100011	000		63/0
bne	SB	1100011	001		63/1
blt	SB	1100011	100		63/4
bge	SB	1100011	101		63/5
bltu	SB	1100011	110		63/6
bgeu	SB	1100011	111		63/7
jalr	I	1100111	000		67/0
jal	UJ	1101111			6F

REGISTER NAME, USE, CALLING CONVENTION ④

REGISTER	NAME	USE	SAVER
x0	zero	The constant value 0	N.A.
x1	ra	Return address	Caller
x2	sp	Stack pointer	Callee
x3	gp	Global pointer	--
x4	tp	Thread pointer	--
x5–x7	t0–t2	Temporaries	Caller
x8	s0/fp	Saved register/Frame pointer	Callee
x9	s1	Saved register	Callee
x10–x11	a0–a1	Function arguments/Return values	Caller
x12–x17	a2–a7	Function arguments	Caller
x18–x27	s2–s11	Saved registers	Callee
x28–x31	t3–t6	Temporaries	Caller
f0–f7	ft0–ft7	FP Temporaries	Caller
f8–f9	fs0–fs1	FP Saved registers	Callee
f10–f11	fa0–fa1	FP Function arguments/Return values	Caller
f12–f17	fa2–fa7	FP Function arguments	Caller
f18–f27	fs2–fs11	FP Saved registers	Callee
f28–f31	ft8–ft11	R[rd] = R[rs1] + R[rs2]	Caller