MIPS Instructions

B

This appendix summarizes MIPS instructions used in this book. Tables B.1–B.3 define the `opcode` and `funct` fields for each instruction, along with a short description of what the instruction does. The following notations are used:

- `[reg]`: contents of the register
- `imm`: 16-bit immediate field of the I-type instruction
- `addr`: 26-bit address field of the J-type instruction
- `SignImm`: sign-extended immediate
  `= {{16{imm[15]}}, imm}`
- `ZeroImm`: zero-extended immediate
  `= {16'b0, imm}`
- `Address`: `[rs] + SignImm`
- `[Address]`: contents of memory location `Address`
- `BTA`: branch target address[1]
  `= PC + 4 + (SignImm << 2)`
- `JTA`: jump target address
  `= {(PC + 4)[31:28], addr, 2'b0}`

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[1] The SPIM simulator has no branch delay slot, so BTA is PC + (SignImm << 2). Thus, if you use the SPIM assembler to create machine code for a real MIPS processor, you must decrement the immediate field by 1 to compensate.

Table B.1 **Instructions, sorted by opcode**

Opcode	Name	Description	Operation
000000 (0)	R-type	all R-type instructions	see Table B.2
000001 (1) (rt = 0/1)	bltz/bgez	branch less than zero/ branch greater than or equal to zero	if ([rs] < 0) PC = BTA/ if ([rs] ≥ 0) PC = BTA
000010 (2)	j	jump	PC = JTA
000011 (3)	jal	jump and link	$ra = PC+4, PC = JTA
000100 (4)	beq	branch if equal	if ([rs]==[rt]) PC = BTA
000101 (5)	bne	branch if not equal	if ([rs]!=[rt]) PC = BTA
000110 (6)	blez	branch if less than or equal to zero	if ([rs] ≤ 0) PC = BTA
000111 (7)	bgtz	branch if greater than zero	if ([rs] > 0) PC = BTA
001000 (8)	addi	add immediate	[rt] = [rs] + SignImm
001001 (9)	addiu	add immediate unsigned	[rt] = [rs] + SignImm
001010 (10)	slti	set less than immediate	[rs] < SignImm ? [rt]=1 : [rt]=0
001011 (11)	sltiu	set less than immediate unsigned	[rs] < SignImm ? [rt]=1 : [rt]=0
001100 (12)	andi	and immediate	[rt] = [rs] & ZeroImm
001101 (13)	ori	or immediate	[rt] = [rs] | ZeroImm
001110 (14)	xori	xor immediate	[rt] = [rs] ^ ZeroImm
001111 (15)	lui	load upper immediate	[rt] = {Imm, 16'b0}
010000 (16) (rs = 0/4)	mfc0, mtc0	move from/to coprocessor 0	[rt] = [rd]/[rd] = [rt] (rd is in coprocessor 0)
010001 (17)	F-type	fop = 16/17: F-type instructions	see Table B.3
010001 (17) (rt = 0/1)	bc1f/bc1t	fop = 8: branch if fpcond is FALSE/TRUE	if (fpcond == 0) PC = BTA/ if (fpcond == 1) PC = BTA
100000 (32)	lb	load byte	[rt] = SignExt([Address]$_{7:0}$)
100001 (33)	lh	load halfword	[rt] = SignExt([Address]$_{15:0}$)
100011 (35)	lw	load word	[rt] = [Address]
100100 (36)	lbu	load byte unsigned	[rt] = ZeroExt([Address]$_{7:0}$)
100101 (37)	lhu	load halfword unsigned	[rt] = ZeroExt([Address]$_{15:0}$)
101000 (40)	sb	store byte	[Address]$_{7:0}$ = [rt]$_{7:0}$

(*continued*)

Table B.1 Instructions, sorted by opcode—Cont'd

Opcode	Name	Description	Operation
101001 (41)	sh	store halfword	$[\texttt{Address}]_{15:0}$ = $[\texttt{rt}]_{15:0}$
101011 (43)	sw	store word	[Address] = [rt]
110001 (49)	lwc1	load word to FP coprocessor 1	[ft] = [Address]
111001 (56)	swc1	store word to FP coprocessor 1	[Address] = [ft]

Table B.2 R-type instructions, sorted by funct field

Funct	Name	Description	Operation
000000 (0)	sll	shift left logical	[rd] = [rt] << shamt
000010 (2)	srl	shift right logical	[rd] = [rt] >> shamt
000011 (3)	sra	shift right arithmetic	[rd] = [rt] >>> shamt
000100 (4)	sllv	shift left logical variable	[rd] = [rt] << $[\texttt{rs}]_{4:0}$ assembly: sllv rd, rt, rs
000110 (6)	srlv	shift right logical variable	[rd] = [rt] >> $[\texttt{rs}]_{4:0}$ assembly: srlv rd, rt, rs
000111 (7)	srav	shift right arithmetic variable	[rd] = [rt] >>> $[\texttt{rs}]_{4:0}$ assembly: srav rd, rt, rs
001000 (8)	jr	jump register	PC = [rs]
001001 (9)	jalr	jump and link register	$ra = PC + 4, PC = [rs]
001100 (12)	syscall	system call	system call exception
001101 (13)	break	break	break exception
010000 (16)	mfhi	move from hi	[rd] = [hi]
010001 (17)	mthi	move to hi	[hi] = [rs]
010010 (18)	mflo	move from lo	[rd] = [lo]
010011 (19)	mtlo	move to lo	[lo] = [rs]
011000 (24)	mult	multiply	{[hi], [lo]} = [rs] × [rt]
011001 (25)	multu	multiply unsigned	{[hi], [lo]} = [rs] × [rt]
011010 (26)	div	divide	[lo] = [rs]/[rt], [hi] = [rs]%[rt]

(continued)

Table B.2 R-type instructions, sorted by funct field—Cont'd

Funct	Name	Description	Operation
011011 (27)	divu	divide unsigned	[lo] = [rs]/[rt], [hi] = [rs]%[rt]
100000 (32)	add	add	[rd] = [rs] + [rt]
100001 (33)	addu	add unsigned	[rd] = [rs] + [rt]
100010 (34)	sub	subtract	[rd] = [rs] – [rt]
100011 (35)	subu	subtract unsigned	[rd] = [rs] – [rt]
100100 (36)	and	and	[rd] = [rs] & [rt]
100101 (37)	or	or	[rd] = [rs] | [rt]
100110 (38)	xor	xor	[rd] = [rs] ^ [rt]
100111 (39)	nor	nor	[rd] = ~([rs] | [rt])
101010 (42)	slt	set less than	[rs] < [rt] ? [rd] = 1 : [rd] = 0
101011 (43)	sltu	set less than unsigned	[rs] < [rt] ? [rd] = 1 : [rd] = 0

Table B.3 F-type instructions (fop = 16/17)

Funct	Name	Description	Operation
000000 (0)	add.s/add.d	FP add	[fd] = [fs] + [ft]
000001 (1)	sub.s/sub.d	FP subtract	[fd] = [fs] – [ft]
000010 (2)	mul.s/mul.d	FP multiply	[fd] = [fs] * [ft]
000011 (3)	div.s/div.d	FP divide	[fd] = [fs]/[ft]
000101 (5)	abs.s/abs.d	FP absolute value	[fd] = ([fs] < 0) ? [–fs] : [fs]
000111 (7)	neg.s/neg.d	FP negation	[fd] = [–fs]
111010 (58)	c.seq.s/c.seq.d	FP equality comparison	fpcond = ([fs] == [ft])
111100 (60)	c.lt.s/c.lt.d	FP less than comparison	fpcond = ([fs] < [ft])
111110 (62)	c.le.s/c.le.d	FP less than or equal comparison	fpcond = ([fs] ≤ [ft])