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:

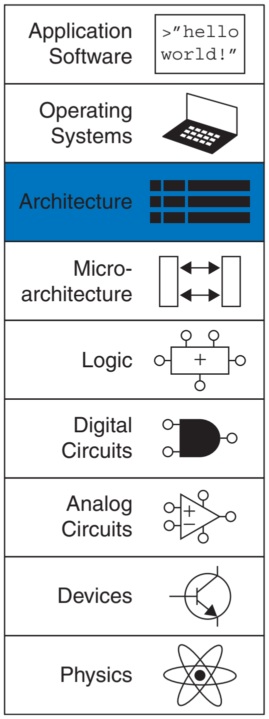
- `[reg]`: contents of the register
- `imm`: 16-bit immediate field of the I-type instruction
- `addr`: 26-bit address field of the J-type instruction
- `SignImm`: 32-bit sign-extended immediate

  `= {{16{imm[15]}}, imm}`
- `ZeroImm`: 32-bit 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}`
- `label`: text indicating an instruction location



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

Digital Design and Computer Architecture, Second Edition. DOI: 10.1016/B978-0-12-394424-5.00010-0

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 rs, label` / `bgez rs, label`	branch less than zero/branch greater than or equal to zero	`if ([rs] < 0) PC = BTA/` `if ([rs] ≥ 0) PC = BTA`
000010 (2)	`j label`	jump	`PC = JTA`
000011 (3)	`jal label`	jump and link	`$ra = PC + 4, PC = JTA`
000100 (4)	`beq rs, rt, label`	branch if equal	`if ([rs] == [rt]) PC = BTA`
000101 (5)	`bne rs, rt, label`	branch if not equal	`if ([rs] != [rt]) PC = BTA`
000110 (6)	`blez rs, label`	branch if less than or equal to zero	`if ([rs] ≤ 0) PC = BTA`
000111 (7)	`bgtz rs, label`	branch if greater than zero	`if ([rs] > 0) PC = BTA`
001000 (8)	`addi rt, rs, imm`	add immediate	`[rt] = [rs] + SignImm`
001001 (9)	`addiu rt, rs, imm`	add immediate unsigned	`[rt] = [rs] + SignImm`
001010 (10)	`slti rt, rs, imm`	set less than immediate	`[rs] < SignImm ? [rt] = 1 : [rt] = 0`
001011 (11)	`sltiu rt, rs, imm`	set less than immediate unsigned	`[rs] < SignImm ? [rt] = 1 : [rt] = 0`
001100 (12)	`andi rt, rs, imm`	and immediate	`[rt] = [rs] & ZeroImm`
001101 (13)	`ori rt, rs, imm`	or immediate	`[rt] = [rs] | ZeroImm`
001110 (14)	`xori rt, rs, imm`	xor immediate	`[rt] = [rs] ^ ZeroImm`
001111 (15)	`lui rt, imm`	load upper immediate	`[rt] = {imm, 16'b0}`
010000 (16) (`rs` = 0/4)	`mfc0 rt, rd` / `mtc0 rt, rd`	move from/to coprocessor 0	`[rt] = [rd]/[rd] = [rt]` `(rd is in coprocessor 0)`
010001 (17)	`F-type`	`fop` = 16/17: F-type instructions	see Table B.3
010001 (17) (`rt` = 0/1)	`bc1f label/` `bc1t label`	`fop` = 8: branch if `fpcond` is FALSE/TRUE	`if (fpcond == 0) PC = BTA/` `if (fpcond == 1) PC = BTA`
011100 (28) (`func` = 2)	`mul rd, rs, rt`	multiply (32-bit result)	`[rd] = [rs] x [rt]`
100000 (32)	`lb rt, imm(rs)`	load byte	`[rt] = SignExt ([Address]`$_{7:0}$`)`
100001 (33)	`lh rt, imm(rs)`	load halfword	`[rt] = SignExt ([Address]`$_{15:0}$`)`
100011 (35)	`lw rt, imm(rs)`	load word	`[rt] = [Address]`
100100 (36)	`lbu rt, imm(rs)`	load byte unsigned	`[rt] = ZeroExt ([Address]`$_{7:0}$`)`
100101 (37)	`lhu rt, imm(rs)`	load halfword unsigned	`[rt] = ZeroExt ([Address]`$_{15:0}$`)`

(*continued*)

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

Opcode	Name	Description	Operation
101000 (40)	`sb rt, imm(rs)`	store byte	$[\text{Address}]_{7:0} = [\text{rt}]_{7:0}$
101001 (41)	`sh rt, imm(rs)`	store halfword	$[\text{Address}]_{15:0} = [\text{rt}]_{15:0}$
101011 (43)	`sw rt, imm(rs)`	store word	`[Address] = [rt]`
110001 (49)	`lwc1 ft, imm(rs)`	load word to FP coprocessor 1	`[ft] = [Address]`
111001 (56)	`swc1 ft, imm(rs)`	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 rd, rt, shamt`	shift left logical	`[rd] = [rt] << shamt`
000010 (2)	`srl rd, rt, shamt`	shift right logical	`[rd] = [rt] >> shamt`
000011 (3)	`sra rd, rt, shamt`	shift right arithmetic	`[rd] = [rt] >>> shamt`
000100 (4)	`sllv rd, rt, rs`	shift left logical variable	$[\text{rd}] = [\text{rt}] << [\text{rs}]_{4:0}$
000110 (6)	`srlv rd, rt, rs`	shift right logical variable	$[\text{rd}] = [\text{rt}] >> [\text{rs}]_{4:0}$
000111 (7)	`srav rd, rt, rs`	shift right arithmetic variable	$[\text{rd}] = [\text{rt}] >>> [\text{rs}]_{4:0}$
001000 (8)	`jr rs`	jump register	`PC = [rs]`
001001 (9)	`jalr rs`	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 rd`	move from hi	`[rd] = [hi]`
010001 (17)	`mthi rs`	move to hi	`[hi] = [rs]`
010010 (18)	`mflo rd`	move from lo	`[rd] = [lo]`
010011 (19)	`mtlo rs`	move to lo	`[lo] = [rs]`
011000 (24)	`mult rs, rt`	multiply	`{[hi], [lo]} = [rs] × [rt]`
011001 (25)	`multu rs, rt`	multiply unsigned	`{[hi], [lo]} = [rs] × [rt]`
011010 (26)	`div rs, rt`	divide	`[lo] = [rs]/[rt],` `[hi] = [rs]%[rt]`
011011 (27)	`divu rs, rt`	divide unsigned	`[lo] = [rs]/[rt],` `[hi] = [rs]%[rt]`

(*continued*)

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

Funct	Name	Description	Operation
100000 (32)	`add rd, rs, rt`	add	`[rd] = [rs] + [rt]`
100001 (33)	`addu rd, rs, rt`	add unsigned	`[rd] = [rs] + [rt]`
100010 (34)	`sub rd, rs, rt`	subtract	`[rd] = [rs] - [rt]`
100011 (35)	`subu rd, rs, rt`	subtract unsigned	`[rd] = [rs] - [rt]`
100100 (36)	`and rd, rs, rt`	and	`[rd] = [rs] & [rt]`
100101 (37)	`or rd, rs, rt`	or	`[rd] = [rs] | [rt]`
100110 (38)	`xor rd, rs, rt`	xor	`[rd] = [rs] ^ [rt]`
100111 (39)	`nor rd, rs, rt`	nor	`[rd] = ~([rs] | [rt])`
101010 (42)	`slt rd, rs, rt`	set less than	`[rs] < [rt] ? [rd] = 1 : [rd] = 0`
101011 (43)	`sltu rd, rs, rt`	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 fd, fs, ft /` `add.d fd, fs, ft`	FP add	`[fd] = [fs] + [ft]`
000001 (1)	`sub.s fd, fs, ft /` `sub.d fd, fs, ft`	FP subtract	`[fd] = [fs] - [ft]`
000010 (2)	`mul.s fd, fs, ft /` `mul.d fd, fs, ft`	FP multiply	`[fd] = [fs] × [ft]`
000011 (3)	`div.s fd, fs, ft /` `div.d fd, fs, ft`	FP divide	`[fd] = [fs]/[ft]`
000101 (5)	`abs.s fd, fs /` `abs.d fd, fs`	FP absolute value	`[fd] = ([fs] < 0) ? [-fs] : [fs]`
000111 (7)	`neg.s fd, fs /` `neg.d fd, fs`	FP negation	`[fd] = [-fs]`
111010 (58)	`c.seq.s fs, ft /` `c.seq.d fs, ft`	FP equality comparison	`fpcond = ([fs] == [ft])`
111100 (60)	`c.lt.s fs, ft /` `c.lt.d fs, ft`	FP less than comparison	`fpcond = ([fs] < [ft])`
111110 (62)	`c.le.s fs, ft /` `c.le.d fs, ft`	FP less than or equal comparison	`fpcond = ([fs] ≤ [ft])`