

# MIPS REFERENCE SHEET

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There are a few special notations outlined here for reference.

Notation	Meaning	Example
$\{X, Y\}$	Concatenate the bits of X and Y together.	$\{10, 11, 011\} = 1011011$
$X \times Y$	Repeat bit X exactly Y times.	$\{1, 0 \times 3\} = 1000$
$(X)[B:A]$	Slice bits A through B (inclusive) out of X.	$(1100110101)[4:0] = 10101$
$\text{SignExt}_{Nb}(X)$	Sign-extend X from N bits to 32 bits.	$\text{SignExt}_{4b}(1001) = \{1 \times 28, 1001\}$
$\text{Mem}_{NB}(X)$	Refers to the N-byte quantity in memory at byte address X.	
$R[N]$	Refers to the general-purpose register number N.	

## INSTRUCTION FORMATS

There are 3 main instruction formats in MIPS. The fields in each type are laid out in such a way that the same fields are always in the same place for each type.

Type	3126	2521	2016	1511	1006	0500
R-Type	opcode	\$rs	\$rt	\$rd	shamt	funct
I-Type	opcode	\$rs	\$rt	imm		
J-Type	opcode	address				

## R-TYPE INSTRUCTIONS

These instructions are identified by an opcode of 0, and are differentiated by their funct values. Except for the first 3 shift instructions, these operations only use registers. Note that in addition to arithmetic operations, these instructions also include jumps and the system call instruction.

	Instruction	RTL	Notes
00	sll \$rd, \$rt, shamt	$R[\$rd] \leftarrow R[\$rt] \ll \text{shamt}$	
02	srl \$rd, \$rt, shamt	$R[\$rd] \leftarrow R[\$rt] \gg \text{shamt}$	Unsigned right shift
03	sra \$rd, \$rt, shamt	$R[\$rd] \leftarrow R[\$rt] \gg \text{shamt}$	Signed right shift
04	sllv \$rd, \$rt, \$rs	$R[\$rd] \leftarrow R[\$rt] \ll R[\$rs]$	
06	srlv \$rd, \$rt, \$rs	$R[\$rd] \leftarrow R[\$rt] \gg R[\$rs]$	Unsigned right shift
07	srav \$rd, \$rt, \$rs	$R[\$rd] \leftarrow R[\$rt] \gg R[\$rs]$	Signed right shift
08	jr \$rs	$PC \leftarrow R[\$rs]$	$R[\$rs]$ must be a multiple of 4
09	jalr \$rd, \$rs	$\text{tmp} \leftarrow R[\$rs]$ $R[\$rd] \leftarrow PC + 8$ $PC \leftarrow \text{tmp}$	$R[\$rs]$ must be a multiple of 4; Undefined if $\$rs = \$rd$
09	jalr \$rs	(special form of “jalr \$rd, \$rs” where $\$rd = 31$ , implicitly)	
12	syscall	System Call	
16	mfhi \$rd	$R[\$rd] \leftarrow HI$	
17	mthi \$rs	$HI \leftarrow R[\$rs]$	
18	mflo \$rd	$R[\$rd] \leftarrow LO$	
19	mtlo \$rs	$LO \leftarrow R[\$rs]$	

	Instruction	RTL	Notes
24	mult \$rs, \$rt	$\{HI, LO\} \leftarrow R[\$rs] * R[\$rt]$	Signed multiplication
25	multu \$rs, \$rt	$\{HI, LO\} \leftarrow R[\$rs] * R[\$rt]$	Unsigned multiplication
26	div \$rs, \$rt	$LO \leftarrow R[\$rs] / R[\$rt]$ $HI \leftarrow R[\$rs] \% R[\$rt]$	Signed division
27	divu \$rs, \$rt	$LO \leftarrow R[\$rs] / R[\$rt]$ $HI \leftarrow R[\$rs] \% R[\$rt]$	Unsigned division
32	add \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] + R[\$rt]$	Exception on signed overflow
33	addu \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] + R[\$rt]$	
34	sub \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] - R[\$rt]$	Exception on signed overflow
35	subu \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] - R[\$rt]$	
36	and \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] \& R[\$rt]$	
37	or \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs]   R[\$rt]$	
38	xor \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] \wedge R[\$rt]$	
39	nor \$rd, \$rs, \$rt	$R[\$rd] \leftarrow \neg(R[\$rs]   R[\$rt])$	
42	slt \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] < R[\$rt]$	Signed comparison
43	sltu \$rd, \$rs, \$rt	$R[\$rd] \leftarrow R[\$rs] < R[\$rt]$	Unsigned comparison

#### J-TYPE INSTRUCTIONS

These instructions are identified and differentiated by their opcode numbers (2 and 3). Jump instructions use pseudo-absolute addressing, in which the upper 4 bits of the computed address are taken relatively from the program counter.

	Instruction	RTL
02	j address	$PC \leftarrow \{(PC + 4)[31:28], \text{address}, 00\}$
03	jal address	$R[31] \leftarrow PC + 8$ $PC \leftarrow \{(PC + 4)[31:28], \text{address}, 00\}$

#### I-TYPE INSTRUCTIONS

These instructions are identified and differentiated by their opcode numbers (any number greater than 3). All of these instructions feature a 16-bit immediate, which is sign-extended to a 32-bit value in every instruction (except for the and, or, and xor instructions which zero-extend and the lui instruction in which it does not matter). Branch instructions also effectively multiply the immediate by 4, to get a byte offset.

	Instruction	RTL	Notes
04	beq \$rs, \$rt, imm	$\text{if}(R[\$rs] = R[\$rt])$ $PC \leftarrow PC + 4 + \text{SignExt}_{18b}(\{\text{imm}, 00\})$	
05	bne \$rs, \$rt, imm	$\text{if}(R[\$rs] \neq R[\$rt])$ $PC \leftarrow PC + 4 + \text{SignExt}_{18b}(\{\text{imm}, 00\})$	
06	blez \$rs, imm	$\text{if}(R[\$rs] \leq 0)$ $PC \leftarrow PC + 4 + \text{SignExt}_{18b}(\{\text{imm}, 00\})$	Signed comparison
07	bgtz \$rs, imm	$\text{if}(R[\$rs] > 0)$ $PC \leftarrow PC + 4 + \text{SignExt}_{18b}(\{\text{imm}, 00\})$	Signed comparison
08	addi \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] + \text{SignExt}_{16b}(\text{imm})$	Exception on signed overflow
09	addiu \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] + \text{SignExt}_{16b}(\text{imm})$	

	Instruction	RTL	Notes
10	slti \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] < \text{SignExt}_{16b}(\text{imm})$	Signed comparison
11	sltiu \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] < \text{SignExt}_{16b}(\text{imm})$	Unsigned comparison
12	andi \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] \& \{0 \times 16, \text{imm}\}$	
13	ori \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] \mid \{0 \times 16, \text{imm}\}$	
14	xori \$rt, \$rs, imm	$R[\$rt] \leftarrow R[\$rs] \wedge \{0 \times 16, \text{imm}\}$	
15	lui \$rt, imm	$R[\$rt] \leftarrow \{(\text{imm})[15:0], 0 \times 16\}$	
32	lb \$rt, imm(\$rs)	$R[\$rt] \leftarrow \text{SignExt}_{8b}(\text{Mem}_{1B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm})))$	
33	lh \$rt, imm(\$rs)	$R[\$rt] \leftarrow \text{SignExt}_{16b}(\text{Mem}_{2B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm})))$	Computed address must be a multiple of 2
34	lw \$rt, imm(\$rs)	$R[\$rt] \leftarrow \text{Mem}_{4B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm}))$	Computed address must be a multiple of 4
36	lbu \$rt, imm(\$rs)	$R[\$rt] \leftarrow \{0 \times 24, \text{Mem}_{1B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm}))\}$	
37	lhu \$rt, imm(\$rs)	$R[\$rt] \leftarrow \{0 \times 16, \text{Mem}_{2B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm}))\}$	Computed address must be a multiple of 2
40	sb \$rt, imm(\$rs)	$\text{Mem}_{1B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm})) \leftarrow (R[\$rt])[7:0]$	
41	sh \$rt, imm(\$rs)	$\text{Mem}_{2B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm})) \leftarrow (R[\$rt])[15:0]$	Computed address must be a multiple of 2
43	sw \$rt, imm(\$rs)	$\text{Mem}_{4B}(R[\$rs] + \text{SignExt}_{16b}(\text{imm})) \leftarrow R[\$rt]$	Computed address must be a multiple of 4