

<code>.text <addr></code>	Subsequent items are put in the user text segment. In SPIM, these items may only be instructions or words (see the <code>.word</code> directive below). If the optional argument <i>addr</i> is present, subsequent items are stored starting at address <i>addr</i> .
<code>.word w1, ..., wn</code>	Store the <i>n</i> 32-bit quantities in successive memory words.

SPIM does not distinguish various parts of the data segment (`.data`, `.rdata`, and `.sdata`).

Encoding MIPS Instructions

Figure A.10.2 explains how a MIPS instruction is encoded in a binary number. Each column contains instruction encodings for a field (a contiguous group of bits) from an instruction. The numbers at the left margin are values for a field. For example, the `j` opcode has a value of 2 in the opcode field. The text at the top of a column names a field and specifies which bits it occupies in an instruction. For example, the `op` field is contained in bits 26–31 of an instruction. This field encodes most instructions. However, some groups of instructions use additional fields to distinguish related instructions. For example, the different floating-point instructions are specified by bits 0–5. The arrows from the first column show which opcodes use these additional fields.

Instruction Format

The rest of this appendix describes both the instructions implemented by actual MIPS hardware and the pseudoinstructions provided by the MIPS assembler. The two types of instructions are easily distinguished. Actual instructions depict the fields in their binary representation. For example, in

Addition (with overflow)

<code>add rd, rs, rt</code>	0	rs	rt	rd	0	0x20
	6	5	5	5	5	6

the `add` instruction consists of six fields. Each field's size in bits is the small number below the field. This instruction begins with 6 bits of 0s. Register specifiers begin with an *r*, so the next field is a 5-bit register specifier called *rs*. This is the same register that is the second argument in the symbolic assembly at the left of this line. Another common field is `imm16`, which is a 16-bit immediate number.

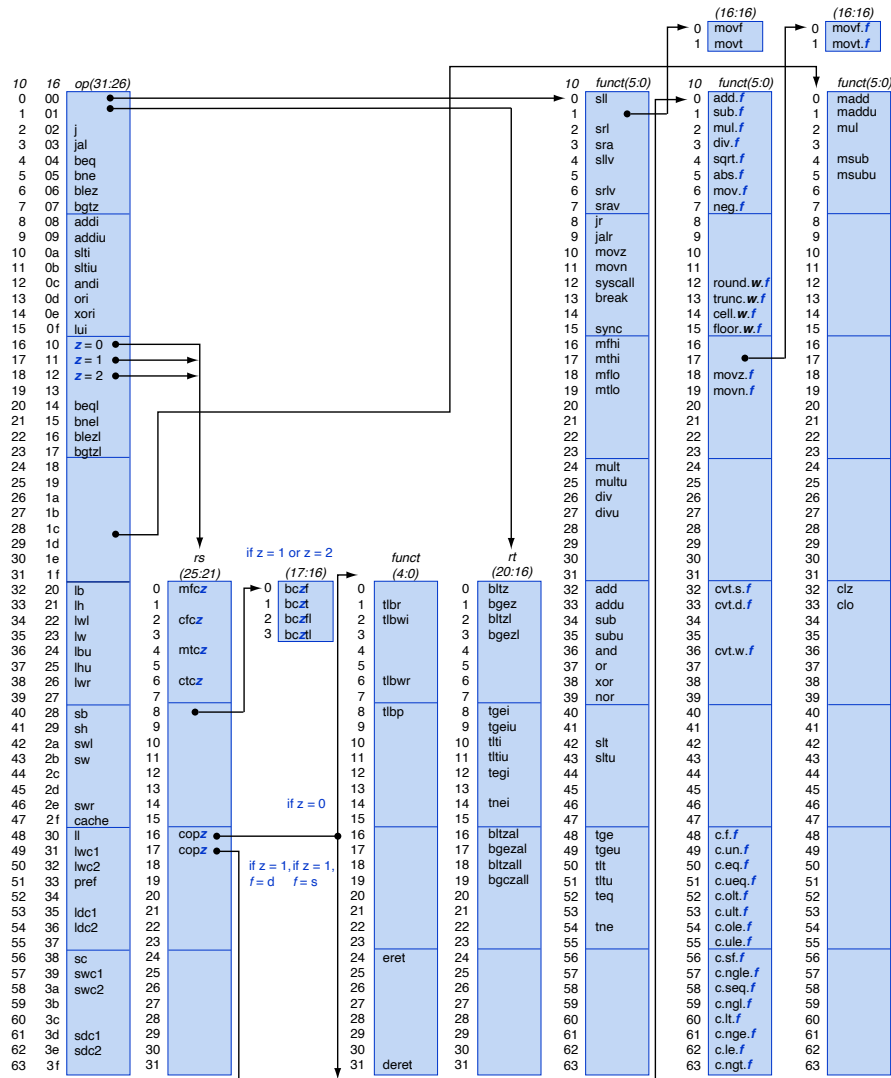


FIGURE A.10.2 MIPS opcode map. The values of each field are shown to its left. The first column shows the values in base 10 and the second shows base 16 for the op field (bits 31 to 26) in the third column. This op field completely specifies the MIPS operation except for 6 op values: 0, 1, 16, 17, 18, and 19. These operations are determined by other fields, identified by pointers. The last field (funct) uses “f” to mean “s” if rs = 16 and op = 17 or “d” if rs = 17 and op = 17. The second field (rs) uses “z” to mean “0”, “1”, “2”, or “3” if op = 16, 17, 18, or 19, respectively. If rs = 16, the operation is specified elsewhere: if z = 0, the operations are specified in the fourth field (bits 4 to 0); if z = 1, then the operations are in the last field with f = s. If rs = 17 and z = 1, then the operations are in the last field with f = d.

Pseudoinstructions follow roughly the same conventions, but omit instruction encoding information. For example:

Multiply (without overflow)

```
mul rdest, rsrc1, src2      pseudoinstruction
```

In pseudoinstructions, *rdest* and *rsrc1* are registers and *src2* is either a register or an immediate value. In general, the assembler and SPIM translate a more general form of an instruction (e.g., `add $v1, $a0, 0x55`) to a specialized form (e.g., `addi $v1, $a0, 0x55`).

Arithmetic and Logical Instructions

Absolute value

```
abs rdest, rsrc      pseudoinstruction
```

Put the absolute value of register *rsrc* in register *rdest*.

Addition (with overflow)

```
add rd, rs, rt
```

0	rs	rt	rd	0	0x20
6	5	5	5	5	6

Addition (without overflow)

```
addu rd, rs, rt
```

0	rs	rt	rd	0	0x21
6	5	5	5	5	6

Put the sum of registers *rs* and *rt* into register *rd*.

Addition immediate (with overflow)

```
addi rt, rs, imm
```

8	rs	rt	imm
6	5	5	16

Addition immediate (without overflow)

```
addiu rt, rs, imm
```

9	rs	rt	imm
6	5	5	16

Put the sum of register *rs* and the sign-extended immediate into register *rt*.

AND

and rd, rs, rt

0	rs	rt	rd	0	0x24
6	5	5	5	5	6

Put the logical AND of registers *rs* and *rt* into register *rd*.

AND immediate

andi rt, rs, imm

0xc	rs	rt	imm
6	5	5	16

Put the logical AND of register *rs* and the zero-extended immediate into register *rt*.

Count leading ones

clo rd, rs

0x1c	rs	0	rd	0	0x21
6	5	5	5	5	6

Count leading zeros

clz rd, rs

0x1c	rs	0	rd	0	0x20
6	5	5	5	5	6

Count the number of leading ones (zeros) in the word in register *rs* and put the result into register *rd*. If a word is all ones (zeros), the result is 32.

Divide (with overflow)

div rs, rt

0	rs	rt	0	0x1a
6	5	5	10	6

Divide (without overflow)

divu rs, rt

0	rs	rt	0	0x1b
6	5	5	10	6

Divide register *rs* by register *rt*. Leave the quotient in register *lo* and the remainder in register *hi*. Note that if an operand is negative, the remainder is unspecified by the MIPS architecture and depends on the convention of the machine on which SPIM is run.

Divide (with overflow)

`div rdest, rsrc1, src2` *pseudoinstruction*

Divide (without overflow)

`divu rdest, rsrc1, src2` *pseudoinstruction*

Put the quotient of register `rsrc1` and `src2` into register `rdest`.

Multiply

0	rs	rt	0	0x18
6	5	5	10	6

`mult rs, rt`

Unsigned multiply

0	rs	rt	0	0x19
6	5	5	10	6

`multu rs, rt`

Multiply registers `rs` and `rt`. Leave the low-order word of the product in register `lo` and the high-order word in register `hi`.

Multiply (without overflow)

0x1c	rs	rt	rd	0	2
6	5	5	5	5	6

`mul rd, rs, rt`

Put the low-order 32 bits of the product of `rs` and `rt` into register `rd`.

Multiply (with overflow)

`mulo rdest, rsrc1, src2` *pseudoinstruction*

Unsigned multiply (with overflow)

`mulou rdest, rsrc1, src2` *pseudoinstruction*

Put the low-order 32 bits of the product of register `rsrc1` and `src2` into register `rdest`.

Multiply add

madd rs, rt	0x1c	rs	rt	0	0
	6	5	5	10	6

Unsigned multiply add

maddu rs, rt	0x1c	rs	rt	0	1
	6	5	5	10	6

Multiply registers *rs* and *rt* and add the resulting 64-bit product to the 64-bit value in the concatenated registers *lo* and *hi*.

Multiply subtract

msub rs, rt	0x1c	rs	rt	0	4
	6	5	5	10	6

Unsigned multiply subtract

msub rs, rt	0x1c	rs	rt	0	5
	6	5	5	10	6

Multiply registers *rs* and *rt* and subtract the resulting 64-bit product from the 64-bit value in the concatenated registers *lo* and *hi*.

Negate value (with overflow)

neg rdest, rsrc *pseudoinstruction*

Negate value (without overflow)

negu rdest, rsrc *pseudoinstruction*

Put the negative of register *rsrc* into register *rdest*.

NOR

nor rd, rs, rt	0	rs	rt	rd	0	0x27
	6	5	5	5	5	6

Put the logical NOR of registers *rs* and *rt* into register *rd*.

NOT

not rdest, rsrc *pseudoinstruction*

Put the bitwise logical negation of register *rsrc* into register *rdest*.

OR

or rd, rs, rt

0	rs	rt	rd	0	0x25
6	5	5	5	5	6

Put the logical OR of registers *rs* and *rt* into register *rd*.

OR immediate

ori rt, rs, imm

0xd	rs	rt	imm
6	5	5	16

Put the logical OR of register *rs* and the zero-extended immediate into register *rt*.

Remainder

rem rdest, rsrc1, rsrc2 *pseudoinstruction*

Unsigned remainder

remu rdest, rsrc1, rsrc2 *pseudoinstruction*

Put the remainder of register *rsrc1* divided by register *rsrc2* into register *rdest*. Note that if an operand is negative, the remainder is unspecified by the MIPS architecture and depends on the convention of the machine on which SPIM is run.

Shift left logical

sll rd, rt, shamt

0	rs	rt	rd	shamt	0
6	5	5	5	5	6

Shift left logical variable

sllv rd, rt, rs

0	rs	rt	rd	0	4
6	5	5	5	5	6

Shift right arithmetic

sra rd, rt, shamt	0	rs	rt	rd	shamt	3
	6	5	5	5	5	6

Shift right arithmetic variable

sra _v rd, rt, rs	0	rs	rt	rd	0	7
	6	5	5	5	5	6

Shift right logical

srl rd, rt, shamt	0	rs	rt	rd	shamt	2
	6	5	5	5	5	6

Shift right logical variable

srl _v rd, rt, rs	0	rs	rt	rd	0	6
	6	5	5	5	5	6

Shift register *rt* left (right) by the distance indicated by immediate *shamt* or the register *rs* and put the result in register *rd*. Note that argument *rs* is ignored for *sll*, *sra*, and *srl*.

Rotate left

rol rdest, rsrc1, rsrc2 *pseudoinstruction*

Rotate right

ror rdest, rsrc1, rsrc2 *pseudoinstruction*

Rotate register *rsrc1* left (right) by the distance indicated by *rsrc2* and put the result in register *rdest*.

Subtract (with overflow)

sub rd, rs, rt	0	rs	rt	rd	0	0x22
	6	5	5	5	5	6

Subtract (without overflow)

subu rd, rs, rt	0	rs	rt	rd	0	0x23
	6	5	5	5	5	6

Put the difference of registers *rs* and *rt* into register *rd*.

Exclusive OR

xor rd, rs, rt	0	rs	rt	rd	0	0x26
	6	5	5	5	5	6

Put the logical XOR of registers *rs* and *rt* into register *rd*.

XOR immediate

xori rt, rs, imm	0xe	rs	rt	imm
	6	5	5	16

Put the logical XOR of register *rs* and the zero-extended immediate into register *rt*.

Constant-Manipulating Instructions**Load upper immediate**

lui rt, imm	0xf	0	rt	imm
	6	5	5	16

Load the lower halfword of the immediate *imm* into the upper halfword of register *rt*. The lower bits of the register are set to 0.

Load immediate

li rdest, imm *pseudoinstruction*

Move the immediate *imm* into register *rdest*.

Comparison Instructions**Set less than**

slt rd, rs, rt	0	rs	rt	rd	0	0x2a
	6	5	5	5	5	6

Set less than unsigned

sltu rd, rs, rt

0	rs	rt	rd	0	0x2b
6	5	5	5	5	6

Set register *rd* to 1 if register *rs* is less than *rt*, and to 0 otherwise.

Set less than immediate

slti rt, rs, imm

0xa	rs	rt	imm
6	5	5	16

Set less than unsigned immediate

sltiu rt, rs, imm

0xb	rs	rt	imm
6	5	5	16

Set register *rt* to 1 if register *rs* is less than the sign-extended immediate, and to 0 otherwise.

Set equal

seq rdest, rsrc1, rsrc2 *pseudoinstruction*

Set register *rdest* to 1 if register *rsrc1* equals *rsrc2*, and to 0 otherwise.

Set greater than equal

sge rdest, rsrc1, rsrc2 *pseudoinstruction*

Set greater than equal unsigned

sgeu rdest, rsrc1, rsrc2 *pseudoinstruction*

Set register *rdest* to 1 if register *rsrc1* is greater than or equal to *rsrc2*, and to 0 otherwise.

Set greater than

sgt rdest, rsrc1, rsrc2 *pseudoinstruction*

Set greater than unsigned

```
sgtu rdest, rsrc1, rsrc2      pseudoinstruction
```

Set register `rdest` to 1 if register `rsrc1` is greater than `rsrc2`, and to 0 otherwise.

Set less than equal

```
sle rdest, rsrc1, rsrc2      pseudoinstruction
```

Set less than equal unsigned

```
sleu rdest, rsrc1, rsrc2     pseudoinstruction
```

Set register `rdest` to 1 if register `rsrc1` is less than or equal to `rsrc2`, and to 0 otherwise.

Set not equal

```
sne rdest, rsrc1, rsrc2      pseudoinstruction
```

Set register `rdest` to 1 if register `rsrc1` is not equal to `rsrc2`, and to 0 otherwise.

Branch Instructions

Branch instructions use a signed 16-bit instruction *offset* field; hence they can jump $2^{15} - 1$ *instructions* (not bytes) forward or 2^{15} instructions backwards. The *jump* instruction contains a 26-bit address field. In actual MIPS processors, branch instructions are delayed branches, which do not transfer control until the instruction following the branch (its "delay slot") has executed (see Chapter 6). Delayed branches affect the offset calculation, since it must be computed relative to the address of the delay slot instruction ($PC + 4$), which is when the branch occurs. SPIM does not simulate this delay slot, unless the `-bare` or `-delayed_branch` flags are specified.

In assembly code, offsets are not usually specified as numbers. Instead, an instructions branch to a label, and the assembler computes the distance between the branch and the target instructions.

In MIPS32, all actual (not pseudo) conditional branch instructions have a "likely" variant (for example, `beq`'s likely variant is `beql`), which does *not* execute the

instruction in the branch's delay slot if the branch is not taken. Do not use these instructions; they may be removed in subsequent versions of the architecture. SPIM implements these instructions, but they are not described further.

Branch instruction

b label *pseudoinstruction*

Unconditionally branch to the instruction at the label.

Branch coprocessor false

bclf cc label

0x11	8	cc	0	Offset
6	5	3	2	16

Branch coprocessor true

bclt cc label

0x11	8	cc	1	Offset
6	5	3	2	16

Conditionally branch the number of instructions specified by the offset if the floating point coprocessor's condition flag numbered *cc* is false (true). If *cc* is omitted from the instruction, condition code flag 0 is assumed.

Branch on equal

beq rs, rt, label

4	rs	rt	Offset
6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* equals *rt*.

Branch on greater than equal zero

bgez rs, label

1	rs	1	Offset
6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* is greater than or equal to 0.

Branch on greater than equal zero and link

bgezal rs, label	1	rs	0x11	Offset
	6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* is greater than or equal to 0. Save the address of the next instruction in register 31.

Branch on greater than zero

bgtz rs, label	7	rs	0	Offset
	6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* is greater than 0.

Branch on less than equal zero

blez rs, label	6	rs	0	Offset
	6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* is less than or equal to 0.

Branch on less than and link

bltzal rs, label	1	rs	0x10	Offset
	6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* is less than 0. Save the address of the next instruction in register 31.

Branch on less than zero

bltz rs, label	1	rs	0	Offset
	6	5	5	16

Conditionally branch the number of instructions specified by the offset if register *rs* is less than 0.

Branch on not equal

bne rs, rt, label	5	rs	rt	Offset
	6	5	5	16

Conditionally branch the number of instructions specified by the offset if register `rs` is not equal to `rt`.

Branch on equal zero

beq rsrc, label *pseudoinstruction*

Conditionally branch to the instruction at the label if `rsrc` equals 0.

Branch on greater than equal

bge rsrc1, rsrc2, label *pseudoinstruction*

Branch on greater than equal unsigned

bgeu rsrc1, rsrc2, label *pseudoinstruction*

Conditionally branch to the instruction at the label if register `rsrc1` is greater than or equal to `rsrc2`.

Branch on greater than

bgt rsrc1, src2, label *pseudoinstruction*

Branch on greater than unsigned

bgtu rsrc1, src2, label *pseudoinstruction*

Conditionally branch to the instruction at the label if register `rsrc1` is greater than `src2`.

Branch on less than equal

ble rsrc1, src2, label *pseudoinstruction*

Branch on less than equal unsigned

```
bleu rsrc1, src2, label      pseudoinstruction
```

Conditionally branch to the instruction at the label if register `rsrc1` is less than or equal to `src2`.

Branch on less than

```
blt rsrc1, rsrc2, label     pseudoinstruction
```

Branch on less than unsigned

```
bltu rsrc1, rsrc2, label    pseudoinstruction
```

Conditionally branch to the instruction at the label if register `rsrc1` is less than `rsrc2`.

Branch on not equal zero

```
bnez rsrc, label           pseudoinstruction
```

Conditionally branch to the instruction at the label if register `rsrc` is not equal to 0.

Jump Instructions**Jump**

```
j target
```

2	target
6	26

Unconditionally jump to the instruction at target.

Jump and link

```
jal target
```

3	target
6	26

Unconditionally jump to the instruction at target. Save the address of the next instruction in register `$ra`.

Jump and link register

jlr rs, rd	0	rs	0	rd	0	9
	6	5	5	5	5	6

Unconditionally jump to the instruction whose address is in register *rs*. Save the address of the next instruction in register *rd* (which defaults to 31).

Jump register

jr rs	0	rs	0	8
	6	5	15	6

Unconditionally jump to the instruction whose address is in register *rs*.

Trap Instructions**Trap if equal**

teq rs, rt	0	rs	rt	0	0x34
	6	5	5	10	6

If register *rs* is equal to register *rt*, raise a Trap exception.

Trap if equal immediate

teqi rs, imm	1	rs	0xc	imm
	6	5	5	16

If register *rs* is equal to the sign extended value *imm*, raise a Trap exception.

Trap if not equal

tneg rs, rt	0	rs	rt	0	0x36
	6	5	5	10	6

If register *rs* is not equal to register *rt*, raise a Trap exception.

Trap if not equal immediate

tnegi rs, imm	1	rs	0xe	imm
	6	5	5	16

If register *rs* is not equal to the sign extended value *imm*, raise a Trap exception.

Trap if greater equal

tge rs, rt	0	rs	rt	0	0x30
	6	5	5	10	6

Unsigned trap if greater equal

tgeu rs, rt	0	rs	rt	0	0x31
	6	5	5	10	6

If register *rs* is greater than or equal to register *rt*, raise a Trap exception.

Trap if greater equal immediate

tgei rs, imm	1	rs	8	imm
	6	5	5	16

Unsigned trap if greater equal immediate

tgeiu rs, imm	1	rs	9	imm
	6	5	5	16

If register *rs* is greater than or equal to the sign extended value *imm*, raise a Trap exception.

Trap if less than

slt rs, rt	0	rs	rt	0	0x32
	6	5	5	10	6

Unsigned trap if less than

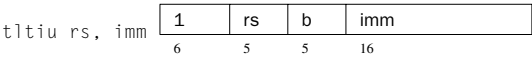
sltu rs, rt	0	rs	rt	0	0x33
	6	5	5	10	6

If register *rs* is less than register *rt*, raise a Trap exception.

Trap if less than immediate

slti rs, imm	1	rs	a	imm
	6	5	5	16

Unsigned trap if less than immediate



If register *rs* is less than the sign extended value *imm*, raise a Trap exception.

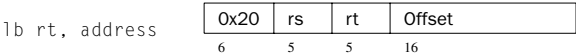
Load Instructions

Load address

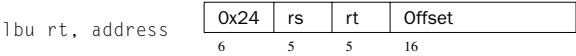


Load computed *address*—not the contents of the location—into register *rdest*.

Load byte

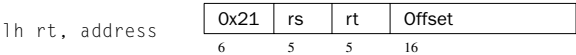


Load unsigned byte

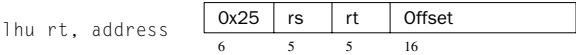


Load the byte at *address* into register *rt*. The byte is sign-extended by *lb*, but not by *lbu*.

Load halfword



Load unsigned halfword



Load the 16-bit quantity (halfword) at *address* into register *rt*. The halfword is sign-extended by *lh*, but not by *lhu*.

Load word

lw rt, address	0x23	rs	rt	Offset
	6	5	5	16

Load the 32-bit quantity (word) at *address* into register *rt*.

Load word coprocessor 1

lwc1 ft, address	0x31	rs	ft	Offset
	6	5	5	16

Load the word at *address* into register *ft* in the floating-point unit.

Load word left

lwl rt, address	0x22	rs	rt	Offset
	6	5	5	16

Load word right

lwr rt, address	0x26	rs	rt	Offset
	6	5	5	16

Load the left (right) bytes from the word at the possibly unaligned *address* into register *rt*.

Load doubleword

ld rdest, address	<i>pseudoinstruction</i>			
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Load the 64-bit quantity at *address* into registers *rdest* and *rdest + 1*.

Unaligned load halfword

ulh rdest, address	<i>pseudoinstruction</i>			
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Unaligned load halfword unsigned

```
ulhu rdest, address pseudoinstruction
```

Load the 16-bit quantity (halfword) at the possibly unaligned *address* into register *rdest*. The halfword is sign-extended by *ulh*, but not *ulhu*.

Unaligned load word

```
ulw rdest, address pseudoinstruction
```

Load the 32-bit quantity (word) at the possibly unaligned *address* into register *rdest*.

Load linked

```
ll rt, address
```

0x30	rs	rt	Offset
6	5	5	16

Load the 32-bit quantity (word) at *address* into register *rt* and start an atomic read-modify-write operation. This operation is completed by a store conditional (*sc*) instruction, which will fail if another processor writes into the block containing the loaded word. Since SPIM does not simulate multiple processors, the store conditional operation always succeeds.

Store Instructions**Store byte**

```
sb rt, address
```

0x28	rs	rt	Offset
6	5	5	16

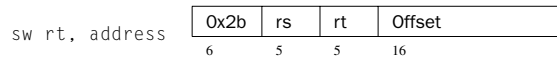
Store the low byte from register *rt* at *address*.

Store halfword

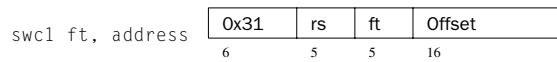
```
sh rt, address
```

0x29	rs	rt	Offset
6	5	5	16

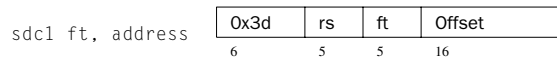
Store the low halfword from register *rt* at *address*.

Store word

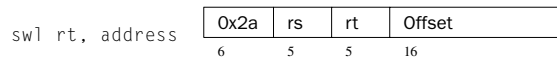
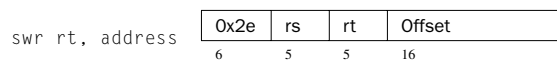
Store the word from register *rt* at *address*.

Store word coprocessor 1

Store the floating-point value in register *ft* of floating-point coprocessor at *address*.

Store double coprocessor 1

Store the double word floating-point value in registers *ft* and *ft + 1* of floating-point coprocessor at *address*. Register *ft* must be even numbered.

Store word left**Store word right**

Store the left (right) bytes from register *rt* at the possibly unaligned *address*.

Store doubleword

sd rsrc, address *pseudoinstruction*

Store the 64-bit quantity in registers *rsrc* and *rsrc + 1* at *address*.

Unaligned store halfword

ush *rsrc*, *address* *pseudoinstruction*

Store the low halfword from register *rsrc* at the possibly unaligned *address*.

Unaligned store word

usw *rsrc*, *address* *pseudoinstruction*

Store the word from register *rsrc* at the possibly unaligned *address*.

Store conditional

sc *rt*, *address*

0x38	<i>rs</i>	<i>rt</i>	Offset
6	5	5	16

Store the 32-bit quantity (word) in register *rt* into memory at *address* and complete an atomic read-modify-write operation. If this atomic operation is successful, the memory word is modified and register *rt* is set to 1. If the atomic operation fails because another processor wrote to a location in the block containing the addressed word, this instruction does not modify memory and writes 0 into register *rt*. Since SPIM does not simulate multiple processors, the instruction always succeeds.

Data Movement Instructions**Move**

move *rdest*, *rsrc* *pseudoinstruction*

Move register *rsrc* to *rdest*.

Move from hi

mfhi *rd*

0	0	<i>rd</i>	0	0x10
6	10	5	5	6

Move from lo

mflo rd	0	0	rd	0	0x12
	6	10	5	5	6

The multiply and divide unit produces its result in two additional registers, *hi* and *lo*. These instructions move values to and from these registers. The multiply, divide, and remainder pseudoinstructions that make this unit appear to operate on the general registers move the result after the computation finishes.

Move the *hi* (*lo*) register to register *rd*.

Move to hi

mthi rs	0	rs	0	0x11
	6	5	15	6

Move to lo

mtlo rs	0	rs	0	0x13
	6	5	15	6

Move register *rs* to the *hi* (*lo*) register.

Move from coprocessor 0

mfc0 rt, rd	0x10	0	rt	rd	0
	6	5	5	5	11

Move from coprocessor 1

mfcl rt, fs	0x11	0	rt	fs	0
	6	5	5	5	11

Coprocessors have their own register sets. These instructions move values between these registers and the CPU's registers.

Move register *rd* in a coprocessor (register *fs* in the FPU) to CPU register *rt*. The floating-point unit is coprocessor 1.

Move double from coprocessor 1

mfc1.d rdest, frsrcl *pseudoinstruction*

Move floating-point registers frsrcl and frsrcl + 1 to CPU registers rdest and rdest + 1.

Move to coprocessor 0

mtc0 rd, rt

0x10	4	rt	rd	0
6	5	5	5	11

Move to coprocessor 1

mtc1 rd, fs

0x11	4	rt	fs	0
6	5	5	5	11

Move CPU register rt to register rd in a coprocessor (register fs in the FPU).

Move conditional not zero

movn rd, rs, rt

0	rs	rt	rd	0xb
6	5	5	5	11

Move register rs to register rd if register rt is not 0.

Move conditional zero

movz rd, rs, rt

0	rs	rt	rd	0xa
6	5	5	5	11

Move register rs to register rd if register rt is 0.

Move conditional on FP false

movf rd, rs, cc

0	rs	cc	0	rd	0	1
6	5	3	2	5	5	6

Move CPU register rs to register rd if FPU condition code flag number cc is 0. If cc is omitted from the instruction, condition code flag 0 is assumed.

Move conditional on FP true

movt rd, rs, cc	0	rs	cc	1	rd	0	1
	6	5	3	2	5	5	6

Move CPU register *rs* to register *rd* if FPU condition code flag number *cc* is 1. If *cc* is omitted from the instruction, condition code bit 0 is assumed.

Floating-Point Instructions

The MIPS has a floating-point coprocessor (numbered 1) that operates on single precision (32-bit) and double precision (64-bit) floating-point numbers. This coprocessor has its own registers, which are numbered \$f0–\$f31. Because these registers are only 32 bits wide, two of them are required to hold doubles, so only floating-point registers with even numbers can hold double precision values. The floating-point coprocessor also has 8 condition code (*cc*) flags, numbered 0–7, which are set by compare instructions and tested by branch (*bclf* or *bclt*) and conditional move instructions.

Values are moved in or out of these registers one word (32 bits) at a time by *lwcl*, *swcl*, *mtcl*, and *mfccl* instructions or one double (64 bits) at a time by *ldcl* and *sdcl* described above, or by the *l.s*, *l.d*, *s.s*, and *s.d* pseudoinstructions described below.

In the actual instructions below, bits 21–26 are 0 for single precision and 1 for double precision. In the pseudoinstructions below, *fdest* is a floating-point register (e.g., \$f2).

Floating-point absolute value double

abs.d fd, fs	0x11	1	0	fs	fd	5
	6	5	5	5	5	6

Floating-point absolute value single

abs.s fd, fs	0x11	0	0	fs	fd	5
	6	5	5	5	5	6

Compute the absolute value of the floating-point double (single) in register *fs* and put it in register *fd*.

Floating-point addition double

add.d fd, fs, ft	0x11	0x11	ft	fs	fd	0
	6	5	5	5	5	6

Floating-point addition single

add.s fd, fs, ft	0x11	0x10	ft	fs	fd	0
	6	5	5	5	5	6

Compute the sum of the floating-point doubles (singles) in registers *fs* and *ft* and put it in register *fd*.

Floating-point ceiling to word

ceil.w.d fd, fs	0x11	0x11	0	fs	fd	0xe
	6	5	5	5	5	6

ceil.w.s fd, fs	0x11	0x10	0	fs	fd	0xe
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Compute the ceiling of the floating-point double (single) in register *fs*, convert to a 32-bit fixed-point value, and put the resulting word in register *fd*.

Compare equal double

c.eq.d cc fs, ft	0x11	0x11	ft	fs	cc	0	FC	2
	6	5	5	5	3	2	2	4

Compare equal single

c.eq.s cc fs, ft	0x11	0x10	ft	fs	cc	0	FC	2
	6	5	5	5	3	2	2	4

Compare the floating-point double (single) in register *fs* against the one in *ft* and set the floating-point condition flag *cc* to 1 if they are equal. If *cc* is omitted, condition code flag 0 is assumed.

Compare less than equal double

c.le.d cc fs, ft	0x11	0x11	ft	fs	cc	0	FC	0xe
	6	5	5	5		2	2	4

Compare less than equal single

c.le.s cc fs, ft	0x11	0x10	ft	fs	cc	0	FC	0xe
	6	5	5	5	3	2	2	4

Compare the floating-point double (single) in register *fs* against the one in *ft* and set the floating-point condition flag *cc* to 1 if the first is less than or equal to the second. If *cc* is omitted, condition code flag 0 is assumed.

Compare less than double

c.lt.d cc fs, ft	0x11	0x11	ft	fs	cc	0	FC	0xc
	6	5	5	5	3	2	2	4

Compare less than single

c.lt.s cc fs, ft	0x11	0x10	ft	fs	cc	0	FC	0xc
	6	5	5	5	3	2	2	4

Compare the floating-point double (single) in register *fs* against the one in *ft* and set the condition flag *cc* to 1 if the first is less than the second. If *cc* is omitted, condition code flag 0 is assumed.

Convert single to double

cvt.d.s fd, fs	0x11	0x10	0	fs	fd	0x21
	6	5	5	5	5	6

Convert integer to double

cvt.d.w fd, fs	0x11	0x14	0	fs	fd	0x21
	6	5	5	5	5	6

Convert the single precision floating-point number or integer in register *fs* to a double (single) precision number and put it in register *fd*.

Convert double to single

cvt.s.d fd, fs	0x11	0x11	0	fs	fd	0x20
	6	5	5	5	5	6

Convert integer to single

cvt.s.w fd, fs	0x11	0x14	0	fs	fd	0x20
	6	5	5	5	5	6

Convert the double precision floating-point number or integer in register *fs* to a single precision number and put it in register *fd*.

Convert double to integer

cvt.w.d fd, fs	0x11	0x11	0	fs	fd	0x24
	6	5	5	5	5	6

Convert single to integer

cvt.w.s fd, fs	0x11	0x10	0	fs	fd	0x24
	6	5	5	5	5	6

Convert the double or single precision floating-point number in register *fs* to an integer and put it in register *fd*.

Floating-point divide double

div.d fd, fs, ft	0x11	0x11	ft	fs	fd	3
	6	5	5	5	5	6

Floating-point divide single

div.s fd, fs, ft	0x11	0x10	ft	fs	fd	3
	6	5	5	5	5	6

Compute the quotient of the floating-point doubles (singles) in registers *fs* and *ft* and put it in register *fd*.

Floating-point floor to word

floor.w.d fd, fs	0x11	0x11	0	fs	fd	0xf
	6	5	5	5	5	6

floor.w.s fd, fs	0x11	0x10	0	fs	fd	0xf
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Compute the floor of the floating-point double (single) in register *fs* and put the resulting word in register *fd*.

Load floating-point double

l.d fdest, address *pseudoinstruction*

Load floating-point single

`l.s fdest, address` *pseudoinstruction*

Load the floating-point double (single) at address into register fdest.

Move floating-point double

`mov.d fd, fs`

0x11	0x11	0	fs	fd	6
6	5	5	5	5	6

Move floating-point single

`mov.s fd, fs`

0x11	0x10	0	fs	fd	6
6	5	5	5	5	6

Move the floating-point double (single) from register fs to register fd.

Move conditional floating-point double false

`movf.d fd, fs, cc`

0x11	0x11	cc	0	fs	fd	0x11
6	5	3	2	5	5	6

Move conditional floating-point single false

`movf.s fd, fs, cc`

0x11	0x10	cc	0	fs	fd	0x11
6	5	3	2	5	5	6

Move the floating-point double (single) from register fs to register fd if condition code flag cc is 0. If cc is omitted, condition code flag 0 is assumed.

Move conditional floating-point double true

`movt.d fd, fs, cc`

0x11	0x11	cc	1	fs	fd	0x11
6	5	3	2	5	5	6

Move conditional floating-point single true

`movt.s fd, fs, cc`

0x11	0x10	cc	1	fs	fd	0x11
6	5	3	2	5	5	6

Move the floating-point double (single) from register `fs` to register `fd` if condition code flag `cc` is 1. If `cc` is omitted, condition code flag 0 is assumed.

Move conditional floating-point double not zero

0x11	0x11	rt	fs	fd	0x13
6	5	5	5	5	6

`movn.d fd, fs, rt`

Move conditional floating-point single not zero

0x11	0x10	rt	fs	fd	0x13
6	5	5	5	5	6

`movn.s fd, fs, rt`

Move the floating-point double (single) from register `fs` to register `fd` if processor register `rt` is not 0.

Move conditional floating-point double zero

0x11	0x11	rt	fs	fd	0x12
6	5	5	5	5	6

`movz.d fd, fs, rt`

Move conditional floating-point single zero

0x11	0x10	rt	fs	fd	0x12
6	5	5	5	5	6

`movz.s fd, fs, rt`

Move the floating-point double (single) from register `fs` to register `fd` if processor register `rt` is 0.

Floating-point multiply double

0x11	0x11	ft	fs	fd	2
6	5	5	5	5	6

`mul.d fd, fs, ft`

Floating-point multiply single

0x11	0x10	ft	fs	fd	2
6	5	5	5	5	6

`mul.s fd, fs, ft`

Compute the product of the floating-point doubles (singles) in registers `fs` and `ft` and put it in register `fd`.

Negate double

neg.d fd, fs	0x11	0x11	0	fs	fd	7
	6	5	5	5	5	6

Negate single

neg.s fd, fs	0x11	0x10	0	fs	fd	7
	6	5	5	5	5	6

Negate the floating-point double (single) in register *fs* and put it in register *fd*.

Floating-point round to word

round.w.d fd, fs	0x11	0x11	0	fs	fd	0xc
	6	5	5	5	5	6

round.w.s fd, fs	0x11	0x10	0	fs	fd	0xc
	6	5	5	5	5	6

Round the floating-point double (single) value in register *fs*, convert to a 32-bit fixed-point value, and put the resulting word in register *fd*.

Square root double

sqrt.d fd, fs	0x11	0x11	0	fs	fd	4
	6	5	5	5	5	6

Square root single

sqrt.s fd, fs	0x11	0x10	0	fs	fd	4
	6	5	5	5	5	6

Compute the square root of the the floating-point double (single) in register *fs* and put it in register *fd*.

Store floating-point double

s.d fdest, address *pseudoinstruction*

Store floating-point single

s.s fdest, address *pseudoinstruction*

Store the floating-point double (single) in register fdest at address.

Floating-point subtract double

sub.d fd, fs, ft

0x11	0x11	ft	fs	fd	1
6	5	5	5	5	6

Floating-point subtract single

sub.s fd, fs, ft

0x11	0x10	ft	fs	fd	1
6	5	5	5	5	6

Compute the difference of the floating-point doubles (singles) in registers fs and ft and put it in register fd.

Floating-point truncate to word

trunc.w.d fd, fs

0x11	0x11	0	fs	fd	0xd
6	5	5	5	5	6

trunc.w.s fd, fs

0x11	0x10	0	fs	fd	0xd
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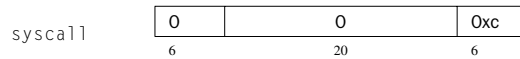
Truncate the floating-point double (single) value in register fs, convert to a 32-bit fixed-point value, and put the resulting word in register fd.

Exception and Interrupt Instructions**Exception return**

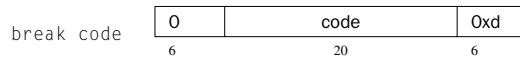
eret

0x10	1	0	0x18
6	1	19	6

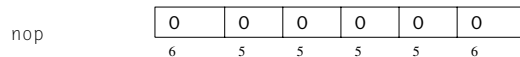
Set the EXL bit in coprocessor 0's Status register to 0 and return to the instruction pointed to by coprocessor 0's EPC register.

System call

Register \$v0 contains the number of the system call (see Figure A.9.1) provided by SPIM.

Break

Cause exception *code*. Exception 1 is reserved for the debugger.

No operation

Do nothing.

A.11**Concluding Remarks**

Programming in assembly language requires a programmer to trade off helpful features of high-level languages—such as data structures, type checking, and control constructs—for complete control over the instructions that a computer executes. External constraints on some applications, such as response time or program size, require a programmer to pay close attention to every instruction. However, the cost of this level of attention is assembly language programs that are longer, more time-consuming to write, and more difficult to maintain than high-level language programs.

Moreover, three trends are reducing the need to write programs in assembly language. The first trend is toward the improvement of compilers. Modern compilers produce code that is typically comparable to the best handwritten code—and is sometimes better. The second trend is the introduction of new processors that are not only faster, but in the case of processors that execute multiple instructions simultaneously, also more difficult to program by hand. In addition, the