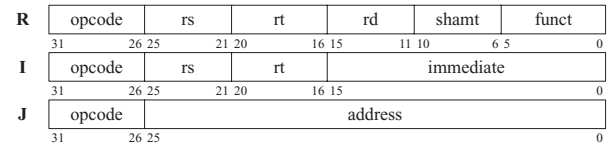
# MIPS Reference Data

## CORE INSTRUCTION SET

| NAME, MNEMONIC | | FORMAT | OPERATION (in Verilog) | | OPCODE / FUNCT (Hex) |
|---|---|---|---|---|---|
| Add | add | R | R[rd] = R[rs] + R[rt] | (1) | 0 / $20_{hex}$ |
| Add Immediate | addi | I | R[rt] = R[rs] + SignExtImm | (1,2) | $8_{hex}$ |
| Add Imm. Unsigned | addiu | I | R[rt] = R[rs] + SignExtImm | (2) | $9_{hex}$ |
| Add Unsigned | addu | R | R[rd] = R[rs] + R[rt] | | 0 / $21_{hex}$ |
| And | and | R | R[rd] = R[rs] & R[rt] | | 0 / $24_{hex}$ |
| And Immediate | andi | I | R[rt] = R[rs] & ZeroExtImm | (3) | $c_{hex}$ |
| Branch On Equal | beq | I | if(R[rs]==R[rt]) PC=PC+4+BranchAddr | (4) | $4_{hex}$ |
| Branch On Not Equal | bne | I | if(R[rs]!=R[rt]) PC=PC+4+BranchAddr | (4) | $5_{hex}$ |
| Jump | j | J | PC=JumpAddr | (5) | $2_{hex}$ |
| Jump And Link | jal | J | R[31]=PC+8;PC=JumpAddr | (5) | $3_{hex}$ |
| Jump Register | jr | R | PC=R[rs] | | 0 / $08_{hex}$ |
| Load Byte Unsigned | lbu | I | R[rt]={24'b0,M[R[rs]+SignExtImm](7:0)} | (2) | $24_{hex}$ |
| Load Halfword Unsigned | lhu | I | R[rt]={16'b0,M[R[rs]+SignExtImm](15:0)} | (2) | $25_{hex}$ |
| Load Linked | ll | I | R[rt] = M[R[rs]+SignExtImm] | (2,7) | $30_{hex}$ |
| Load Upper Imm. | lui | I | R[rt] = {imm, 16'b0} | | $f_{hex}$ |
| Load Word | lw | I | R[rt] = M[R[rs]+SignExtImm] | (2) | $23_{hex}$ |
| Nor | nor | R | R[rd] = ~ (R[rs] \| R[rt]) | | 0 / $27_{hex}$ |
| Or | or | R | R[rd] = R[rs] \| R[rt] | | 0 / $25_{hex}$ |
| Or Immediate | ori | I | R[rt] = R[rs] \| ZeroExtImm | (3) | $d_{hex}$ |
| Set Less Than | slt | R | R[rd] = (R[rs] < R[rt]) ? 1 : 0 | | 0 / $2a_{hex}$ |
| Set Less Than Imm. | slti | I | R[rt] = (R[rs] < SignExtImm)? 1 : 0 | (2) | $a_{hex}$ |
| Set Less Than Imm. Unsigned | sltiu | I | R[rt] = (R[rs] < SignExtImm) ? 1 : 0 | (2,6) | $b_{hex}$ |
| Set Less Than Unsig. | sltu | R | R[rd] = (R[rs] < R[rt]) ? 1 : 0 | (6) | 0 / $2b_{hex}$ |
| Shift Left Logical | sll | R | R[rd] = R[rt] << shamt | | 0 / $00_{hex}$ |
| Shift Right Logical | srl | R | R[rd] = R[rt] >>> shamt | | 0 / $02_{hex}$ |
| Store Byte | sb | I | M[R[rs]+SignExtImm](7:0) = R[rt](7:0) | (2) | $28_{hex}$ |
| Store Conditional | sc | I | M[R[rs]+SignExtImm] = R[rt]; R[rt] = (*atomic*) ? 1 : 0 | (2,7) | $38_{hex}$ |
| Store Halfword | sh | I | M[R[rs]+SignExtImm](15:0) = R[rt](15:0) | (2) | $29_{hex}$ |
| Store Word | sw | I | M[R[rs]+SignExtImm] = R[rt] | (2) | $2b_{hex}$ |
| Subtract | sub | R | R[rd] = R[rs] - R[rt] | (1) | 0 / $22_{hex}$ |
| Subtract Unsigned | subu | R | R[rd] = R[rs] - R[rt] | | 0 / $23_{hex}$ |

(1) May cause overflow exception
(2) SignExtImm = { 16{immediate[15]}, immediate }
(3) ZeroExtImm = { 16{1b'0}, immediate }
(4) BranchAddr = { 14{immediate[15]}, immediate, 2'b0 }
(5) JumpAddr = { PC+4[31:28], address, 2'b0 }
(6) Operands considered unsigned numbers (vs. 2's comp.)
(7) Atomic test&set pair; R[rt] = 1 if pair atomic, 0 if not atomic

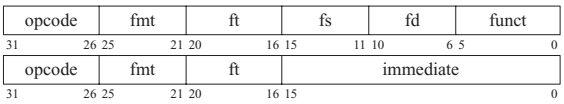
## BASIC INSTRUCTION FORMATS




## ARITHMETIC CORE INSTRUCTION SET

| NAME, MNEMONIC | | FORMAT | OPERATION | | OPCODE / FMT /FT / FUNCT (Hex) |
|---|---|---|---|---|---|
| Branch On FP True | bc1t | FI | if(FPcond)PC=PC+4+BranchAddr | (4) | 11/8/1/-- |
| Branch On FP False | bc1f | FI | if(!FPcond)PC=PC+4+BranchAddr | (4) | 11/8/0/-- |
| Divide | div | R | Lo=R[rs]/R[rt]; Hi=R[rs]%R[rt] | | 0/--/--/1a |
| Divide Unsigned | divu | R | Lo=R[rs]/R[rt]; Hi=R[rs]%R[rt] | (6) | 0/--/--/1b |
| FP Add Single | add.s | FR | F[fd ]= F[fs] + F[ft] | | 11/10/--/0 |
| FP Add Double | add.d | FR | {F[fd],F[fd+1]} = {F[fs],F[fs+1]} + {F[ft],F[ft+1]} | | 11/11/--/0 |
| FP Compare Single | c.*x*.s* | FR | FPcond = (F[fs] *op* F[ft]) ? 1 : 0 | | 11/10/--/*y* |
| FP Compare Double | c.*x*.d* | FR | FPcond = ({F[fs],F[fs+1]} *op* {F[ft],F[ft+1]}) ? 1 : 0 | | 11/11/--/*y* |
| * (*x* is eq, lt, or le) (*op* is ==, <, or <=) ( *y* is 32, 3c, or 3e) | | | | | |
| FP Divide Single | div.s | FR | F[fd] = F[fs] / F[ft] | | 11/10/--/3 |
| FP Divide Double | div.d | FR | {F[fd],F[fd+1]} = {F[fs],F[fs+1]} / {F[ft],F[ft+1]} | | 11/11/--/3 |
| FP Multiply Single | mul.s | FR | F[fd] = F[fs] * F[ft] | | 11/10/--/2 |
| FP Multiply Double | mul.d | FR | {F[fd],F[fd+1]} = {F[fs],F[fs+1]} * {F[ft],F[ft+1]} | | 11/11/--/2 |
| FP Subtract Single | sub.s | FR | F[fd]=F[fs] - F[ft] | | 11/10/--/1 |
| FP Subtract Double | sub.d | FR | {F[fd],F[fd+1]} = {F[fs],F[fs+1]} - {F[ft],F[ft+1]} | | 11/11/--/1 |
| Load FP Single | lwc1 | I | F[rt]=M[R[rs]+SignExtImm] | (2) | 31/--/--/-- |
| Load FP Double | ldc1 | I | F[rt]=M[R[rs]+SignExtImm]; F[rt+1]=M[R[rs]+SignExtImm+4] | (2) | 35/--/--/-- |
| Move From Hi | mfhi | R | R[rd] = Hi | | 0 /--/--/10 |
| Move From Lo | mflo | R | R[rd] = Lo | | 0 /--/--/12 |
| Move From Control | mfc0 | R | R[rd] = CR[rs] | | 10 /0/--/0 |
| Multiply | mult | R | {Hi,Lo} = R[rs] * R[rt] | | 0/--/--/18 |
| Multiply Unsigned | multu | R | {Hi,Lo} = R[rs] * R[rt] | (6) | 0/--/--/19 |
| Shift Right Arith. | sra | R | R[rd] = R[rt] >> shamt | | 0/--/--/3 |
| Store FP Single | swc1 | I | M[R[rs]+SignExtImm] = F[rt] | (2) | 39/--/--/-- |
| Store FP Double | sdc1 | I | M[R[rs]+SignExtImm] = F[rt]; M[R[rs]+SignExtImm+4] = F[rt+1] | (2) | 3d/--/--/-- |

## FLOATING-POINT INSTRUCTION FORMATS




## PSEUDOINSTRUCTION SET

| NAME | MNEMONIC | OPERATION |
|---|---|---|
| Branch Less Than | blt | if(R[rs]<R[rt]) PC = Label |
| Branch Greater Than | bgt | if(R[rs]>R[rt]) PC = Label |
| Branch Less Than or Equal | ble | if(R[rs]<=R[rt]) PC = Label |
| Branch Greater Than or Equal | bge | if(R[rs]>=R[rt]) PC = Label |
| Load Immediate | li | R[rd] = immediate |
| Move | move | R[rd] = R[rs] |

## REGISTER NAME, NUMBER, USE, CALL CONVENTION

| NAME | NUMBER | USE | PRESERVED ACROSS A CALL? |
|---|---|---|---|
| $zero | 0 | The Constant Value 0 | N.A. |
| $at | 1 | Assembler Temporary | No |
| $v0-$v1 | 2-3 | Values for Function Results and Expression Evaluation | No |
| $a0-$a3 | 4-7 | Arguments | No |
| $t0-$t7 | 8-15 | Temporaries | No |
| $s0-$s7 | 16-23 | Saved Temporaries | Yes |
| $t8-$t9 | 24-25 | Temporaries | No |
| $k0-$k1 | 26-27 | Reserved for OS Kernel | No |
| $gp | 28 | Global Pointer | Yes |
| $sp | 29 | Stack Pointer | Yes |
| $fp | 30 | Frame Pointer | Yes |
| $ra | 31 | Return Address | Yes |