Loading Constants into a Register

If the constant will fit into 16 bits, use **li** (load immediate)

```
li  $14,8        # $14 = 8
```

- **li** is a pseudoinstruction for something like:

```
addi   $14,$0,8
```

or

```
ori    $14,$0,8
```

If the constant does not fit into 16 bits, use **lui** (load upper immediate)

- **lui** puts a constant in the most significant halfword

```
lui    rt, immed      # rt<31,16> = immed
                      # rt<15,0> = 0
```

- **addi** (or **ori**) puts a constant into the least significant halfword

Example: load the constant 0x1b236723 into $t0

```
lui    $t0,0x1b23
addi   $t0,$t0,0x6723
```


Getting the Base Address into a Register

Method 1: **let the assembler do it**

```
        .data           # define the data section
xyz:    .word 1         # store the value 1 here
        ...             # some other data
        .text           # define the code section
        ...             # lines of code
        lw  $5,xyz      # loads contents of xyz into $5
```

(the assembler generates **lw $5,offset($gp)**)

Method 2: **use la** (pseudoinstruction load address)

- loads an address rather than the contents of the address
- not really a load, but **lui** followed by **addi**
- example:

```
la  $6,xyz      # $6 contains the address of memory
                   location xyz
lw  $5,0($6)    # $5 contains the contents of memory
                   location xyz
```

Method 3: when the address is a constant & you know what it is

- use **li** (if < ± 32K)
- use **lui** and **addi** (or **ori**) otherwise

Masking with Logical Instructions

Example: **create a mask** of all 1's for the low-order byte of $6 --- don't care about the other bits

```
ori     $6,$6,0x00ff  # set $6<7:0> to 1's
```

Example: **use a mask** to clear the high-order byte of $6 but leave the 3 other bytes the same

```
lui     $5,0x00ff     # set $5<23:16> to 1's,
                      # $5<31:24> and the other bits
                      # to 0's
ori     $5,$5,0xffff  # set $5<15:0> to 1's
and     $6,$6,$5      # clear the high-order byte
```


Shifting

Arithmetic shifts to the right: the sign bit is extended

Logical shifts & arithmetic shifts to the left: zeros are shifted in

Examples:

$5 contains: 1111 1111 0000 0000 0000 0000 0000 0000

```
srl     $5,$5,6   # shift right logical 6 bits
                  # $5 = 0000 0011 1111 1100 0000
sra     $5,$5,6   # shift right arithmetic 6 bits
                  # $5 = 1111 1111 1111 1100 0000
```

HI & LO

Used for holding the product of a multiply (multiplying two 32-bit numbers may yield a 64-bit product)

- HI gets the upper 32 result bits
- LO gets the lower 32

Used for the quotient and remainder of a divide

- LO gets the quotient
- HI gets the remainder
- if an operand is negative, the remainder is not specified by the MIPS architecture

Instructions to move between HI/LO & the GPRs.

```
mfhi   rd      # move from HI to rd
mflo   rd      # move from LO to rd
mthi   rd      # move to HI from rd
mtlo   rd      # move to LO from rd
```

```
mul  rd,rs,rt        # a pseudoinstruction for
       mult   rs,rt
       mflo   rd
```


Addressing Modes

A function to calculate the address of an operand

operand specifier vs. **operand**

MIPS has few (RISC again)

- **register** addressing
  - operand specifier is a register number
  - operand is the register contents
- **immediate** addressing
  - operand specifier/operand is a constant in the instruction stream
- **base or displacement** addressing
  - operand specifier is a register contents plus a constant in the instruction
  - operand is the contents of the memory location whose address is that specifier

Addressing Modes

- **PC-relative** addressing
  - operand specifier is the contents of the PC plus a constant in the instruction
  - operand is the instruction at the memory location whose address is that specifier

- **pseudodirect** addressing
  - operand specifier is the address in the jump instruction
  - operand is the instruction at the memory location whose address is that specifier

Addressing Modes

User-generated addressing modes:

- register, immediate, displacement

Compiler & assembler-generated addressing modes

- PC-relative
- example:

```
loop:  lw  $8, offset($9)
       bne $8, $21, exit     # 2 instructions
       add $19,$19,20
       j   loop              #  -4 instructions
exit:
```

+ need fewer bits to specify the operand address
+ **position-independent code**: can load anywhere in memory

- why programmers don't use PC-relative

  bne $8, $21, 2($pc)

  If you insert additional code here, you ***must change the hardcoded displacement***

Other Addressing Modes

Indexed addressing

- use 2 registers as the operand specifier
- `lw $t1, $s1, $s2` # $t1 gets Memory[$s1+$s2]
- in MIPS:

```
add   $s0, $s1, $s2
lw    $t1, 0($s0)
```

Update addressing

- increment the memory address as part of a data transfer
  - autoincrement, autodecrement
- useful when marching through an array
- `lwu $t1, 4($s0)` # $t1 gets Memory[$s0+4]; $s0 = $s0 + 4
- in MIPS:

```
lw    $t1, 4($s0)
addi  $s0, $s0, 4
```


A Longer Example

High-level language version

```
int a[100];
int i;
for (i=0; i<100; i++) {
    a[i] = 5;
}
```

Assembly language version

- base address of array **a** in $15
- $8 contains the value of **i**, $9 the value **5**

```
        add   $8,$0,$0      # initialize i
        li    $9,5          # $9 has the constant 5
loop:   sla   $10,$8,2      # $10 has i in bytes
        addu  $14,$10,$15   # address of a[i]
        sw    $9,0($14)     # store 5 in a[i]
        addiu $8,$8,1       # increment i
        blt   $8,100,Loop   # branch if loop not finished
```

A Longer Example

Machine-language version generated by a compiler

```
[0x00400020]  0x00004020  add $8,$0,$0       ; same
[0x00400024]  0x34090005  ori $9,$0,5        ; li $9,5
[0x00400028]  0x34010004  ori $1,$0,4        ; mul $10,$8,4
[0x0040002c]  0x01010018  mult $8,$1         ; loop head
[0x00400030]  0x00005012  mflo $10
[0x00400034]  0x014f7021  addu $14,$0,$15  ; same
[0x00400038]  0xadc90000  sw $9,0($14)       ; same
[0x0040003c]  0x25080001  addiu $8,$8,1      ; same
[0x00400040]  0x2010064   slti $2,$8,100     ; blt $8,100,Loop
[0x00400044]  0x1420fff9  bne $2,$0,-28
```


Assembly Language Programming or How to be Nice to Your TA

- Use lots of detailed comments
- Don’t be too fancy
- Use lots of detailed comments
- Use words whenever possible
- Use lots of detailed comments
- Remember that the address of a word is evenly divisible by 4
- Use lots of detailed comments
- The word following the word at address *i* is at address *i + 4*.
- Use lots of detailed comments