University of Arizona

# CSc 340

Foundations of Computer Systems

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## Addressing Modes



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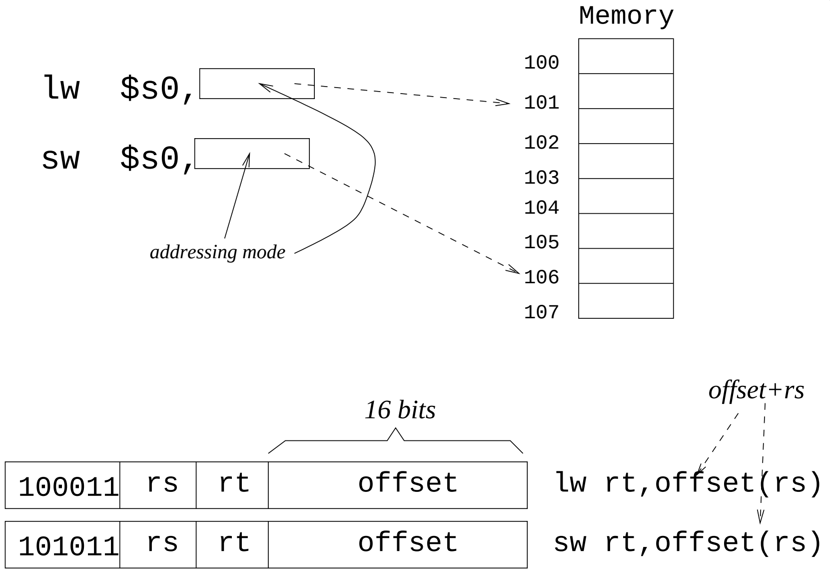


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## MIPS Addressing Modes

- MIPS is a load/store architecture. Only the load & store instructions take a memory address operand.
- MIPS hardware supports a single addressing mode:

  `c(rx)`

  `c` is a 16-bit 2's complement literal integer, `rx` is a register.
- The addressing mode computes ⌜`rx + c`⌝, i.e. the sum of the value in `rx` and `c`.
- This is called register indirect with offset addressing, and can be used to implement pointers.

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## Pointers

- A pointer is a memory location (variable) that contains the address of another variable.
- Let variable `B` be stored at address 100 and have value 42. Let variable `A` be a pointer to `B` stored at address 108. `A`'s value is 100:

| Variable | Address | Memory |
|---|---|---|
| | 110 | |
| | 10C | |
| A | 108 | 100 |
| | 104 | |
| B | 100 | 42 |

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## Pointers ...

- Suppose we want to use `A` to get the value of `B`:

```
        .data
A:      .word B              # A = &B (B address)
B:      .word 42
        .text
main:   lw    $s0, A         # $s0 = A (&B)
        lw    $s1, 0($s0)    # $s1 = *A (B)
```

- \$s0 now contains the address of the variable B, and \$s1 contains its value (42).
- We never used the label `'B'` in the code; instead we got the value of `B` through the pointer `A`.

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## Addressing Modes – Direct memory

- The address format of the MIPS hardware enables several addressing modes.
- For short addresses we can use *direct memory* addressing:

```
lw $s0, 32($zero)
```

- This instruction loads the value at address 32. This is called direct memory addressing because the instruction contains the exact address.
- The immediate value (address) must fit in 16 bits.

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## Addressing Modes – Register indirect

- Register indirect addressing:

```
lw $s0, 0($s1)
```

- This instruction loads the value from memory at the address contained in register \$s1.
- Register indirect is often used to implement pointers.

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## Register indirect with offset

```
lw $s0, 4($s1)
```

- This loads the value from memory address `$s1 + 4`.
- This is useful for creating structures or records – a collection of related data:

```
        .data
info:   .word 10,11,12
        .text
main:   la    $s0, info      # $s0 = &info
        lw    $s1, 0($s0)    # $s1 = 10
        lw    $s1, 4($s0)    # $s1 = 11
        lw    $s1, 8($s0)    # $s1 = 12
```

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## Large addresses

- The addressing mode provided by the MIPS hardware is rather limited, primarily because the constant value is only 16 bits.
- The assembler supports full 32-bit addresses, but may have to generate additional instructions to handle them (using register \$at (\$r1) if necessary).
- This instruction loads from the address associated with the `label`.

```
lw $s0, label
```

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## Large addresses. . .

- This may require two instructions if label is larger than 16 bits, e.g.

```
lw    $s0, 0x12345678
      ⇓
lui   $at, 0x1234
lw    $s0, 0x5678($at)
```

- The assembler will make this translation automatically.

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## Complex addressing modes . . .

- This instruction loads from the address ⌜`label ± 32`⌝ (either +32 or -32 works):

```
lw $s0, label ± 32
```

- This instruction loads from the address ⌜`label ± (4 + $s1)`⌝:

```
lw $s0, label ± 4($s1)
```

  This form is useful for indexing arrays.

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## Example I

- Load each integer in array into register `s3`.

```
      .data
array:.word 1,3,5,7
      .text
main: move  $s1, $zero           # i = 0 (index)
loop:                            # do
      mul   $s2, $s1, 4          # offset = i * 4
      lw    $s3, array + 0($s2)  # next element
      add   $s1, $s1, 1          # i = i+1
      blt   $s1, 4, loop         # while i < 4
```

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## Example I. . .

- You can eliminate the `mul` and register `s2` if you count by 4s. This changes the loop limit to 4*4:

```
      .data
array:.word 1,3,5,7
      .text
main: move  $s1, $zero              # i = 0 (index)
loop:                               # do
      lw    $s3, array + 0($s1)     # next element
      add   $s1, $s1, 4             # i = i+1
      blt   $s1, 16, loop           # while i < 4
```

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## Example II

- Consider an array of 3 structures, each with two fields.
- The first field is an integer and the second a character.
- Write a program that does the following:
  1. Sum the first field for all structures, and
  2. print the ASCII value of the character in each.

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- First declare the data-structures:

```
        .data           # Data starts here.
        .align   2      # Align on 4-byte boundary
  array:                # array starts here.
        .word    10     # 1st record starts here.
        .byte    'A'    #
        .align   2      #
        .word    17     # 2nd record starts here.
        .byte    'B'    #
        .align   2      #
        .word    89     # 3rd record starts here.
        .byte    'Z'    #
```

- Then declare the code:

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```
      .text
main: move  $s0, $zero              # sum = 0
      move  $s1, $zero              # i = 0
      bge   $s1, 3, done
loop: mul   $s2, $s1, 8             # s2 = offset
      lw    $s3, array + 0($s2)     # s3 = array[i].int
      add   $s0, $s0, $s3           # sum = sum + s3
      lbu   $a0, array + 4($s2)     # a0 = array[i].ch
      li    $v0, 1                  # print_int
      syscall
      add   $s1, $s1, 1             # i = i + 1
      blt   $s1, 3, loop
done:
```

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## Example II. . .

- The ⌜`.align 2`⌝ directives are necessary because each structure requires 5 bytes (4 for the integer and 1 for the character), but the word in the next structure must be word aligned.
- The ⌜`.align n`⌝ directive aligns what follows it on a $2^n$ boundary.
- Counting by 8 eliminates the multiply.
- You could also shift left by 3 to avoid the multiply.

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## Example II. . .

- As a result, each structure is 8 bytes long (the last 3 bytes aren't used) so we multiply by 8 to get the offset. Pictorially:

| | | | | |
|---|---|---|---|---|
| | Z | | | |
| n+16 | 89 | | | |
| | B | | | |
| n+8 | 17 | | | |
| | A | | | |
| n | 10 | | | |

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## Readings and References

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