

Chapter 2

Instructions: Language of the Computer



Immediate Operands

- Constant data specified in an instruction
`addi $s3, $s3, 4`
- No subtract immediate instruction
 - Just use a negative constant
`addi $s2, $s1, -1`
- *Design Principle 3: Make the common case fast*
 - Small constants are common
 - Immediate operand avoids a load instruction



The Constant Zero

- MIPS register 0 (\$zero) is the constant 0
 - Cannot be overwritten
- Useful for common operations
 - E.g., move between registers
add \$t2, \$s1, \$zero



Unsigned Binary Integers

- Given an n-bit number

$$x = x_{n-1}2^{n-1} + x_{n-2}2^{n-2} + \dots + x_12^1 + x_02^0$$

- Range: 0 to $+2^n - 1$

- Example

- $0000\ 0000\ 0000\ 0000\ 0000\ 0000\ 0000\ 1011_2$
 $= 0 + \dots + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$
 $= 0 + \dots + 8 + 0 + 2 + 1 = 11_{10}$

- Using 32 bits

- 0 to +4,294,967,295



2s-Complement Signed Integers

- Given an n-bit number

$$x = -x_{n-1}2^{n-1} + x_{n-2}2^{n-2} + \dots + x_12^1 + x_02^0$$

- Range: -2^{n-1} to $+2^{n-1} - 1$

- Example

- $1111\ 1111\ 1111\ 1111\ 1111\ 1111\ 1111\ 1100_2$
 $= -1 \times 2^{31} + 1 \times 2^{30} + \dots + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$
 $= -2,147,483,648 + 2,147,483,644 = -4_{10}$

- Using 32 bits

- $-2,147,483,648$ to $+2,147,483,647$



2s-Complement Signed Integers

- Bit 31 is sign bit
 - 1 for negative numbers
 - 0 for non-negative numbers
- $-(-2^n - 1)$ can't be represented
- Non-negative numbers have the same unsigned and 2s-complement representation
- Some specific numbers
 - 0: 0000 0000 ... 0000
 - -1: 1111 1111 ... 1111
 - Most-negative: 1000 0000 ... 0000
 - Most-positive: 0111 1111 ... 1111



Signed Negation

- Complement and add 1
 - Complement means $1 \rightarrow 0, 0 \rightarrow 1$

$$x + \bar{x} = 1111 \dots 111_2 = -1$$

$$\bar{x} + 1 = -x$$

- Example: negate +2
 - $+2 = 0000 \ 0000 \dots 0010_2$
 - $-2 = 1111 \ 1111 \dots 1101_2 + 1$
 $= 1111 \ 1111 \dots 1110_2$



Sign Extension

- Representing a number using more bits
 - Preserve the numeric value
- In MIPS instruction set
 - addi : extend immediate value
 - l b, l h: extend loaded byte/halfword
 - beq, bne: extend the displacement
- Replicate the sign bit to the left
 - c.f. unsigned values: extend with 0s
- Examples: 8-bit to 16-bit
 - +2: 0000 0010 => 0000 0000 0000 0010
 - -2: 1111 1110 => 1111 1111 1111 1110

