Assembly Language for Intel-Based Computers, 4th Edition

Kip R. Irvine

Chapter 1: Basic Concepts

Slides prepared by Kip R. Irvine

Revision date: 07/21/2002

- Chapter corrections (Web) Assembly language sources (Web)

Chapter Overview

- Welcome to Assembly Language
- Virtual Machine Concept
- Data Representation
- Boolean Operations

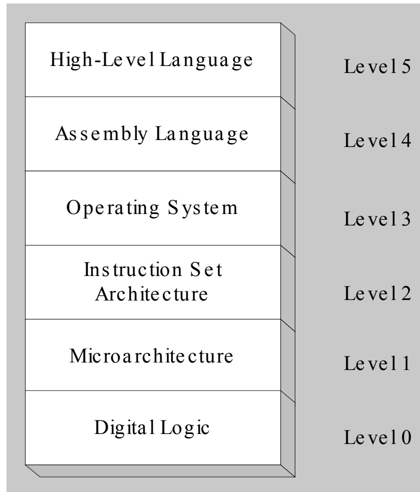
Virtual Machine Concept

- Virtual Machines
- Specific Machine Levels

Virtual Machines

- Tanenbaum: Virtual machine concept
- Programming Language analogy:
  - Each computer has a native machine language (language L0) that runs directly on its hardware
  - A more human-friendly language is usually constructed above machine language, called Language L1
- Programs written in L1 can run two different ways:
  - Interpretetation – L0 program interprets and executes L1 instructions one by one
  - Translation – L1 program is completely translated into an L0 program, which then runs on the computer hardware

Specific Machine Levels



High-Level Language

- Level 5
- Application-oriented languages
- Programs compile into assembly language (Level 4)

Assembly Language

- Level 4
- Instruction mnemonics that have a one-to-one correspondence to machine language
- Calls functions written at the operating system level (Level 3)
- Programs are translated into machine language (Level 2)

Operating System

- Level 3
- Provides services to Level 4 programs
- Programs translated and run at the instruction set architecture level (Level 2)

Instruction Set Architecture

- Level 2
- Also known as conventional machine language
- Executed by Level 1 program (microarchitecture, Level 1)

Microarchitecture

- Level 1
- Interprets conventional machine instructions (Level 2)
- Executed by digital hardware (Level 0)

Digital Logic

- Level 0
- CPU, constructed from digital logic gates
- System bus
- Memory

Data Representation

- Binary Numbers
  - Translating between binary and decimal
- Binary Addition
- Integer Storage Sizes
- Hexadecimal Integers
  - Translating between decimal and hexadecimal
  - Hexadecimal subtraction
- Signed Integers
  - Binary subtraction
- Character Storage

Binary Numbers

- Digits are 1 and 0
  - 1 = true
  - 0 = false
- MSB – most significant bit
- LSB – least significant bit
- Bit numbering:

MSB	LSB
1 0 1 1 0 0 1 0 1 0 0 1 1 1 0 0	
15	0

Binary Numbers

- Each digit (bit) is either 1 or 0
- Each bit represents a power of 2:

1	1	1	1	1	1	1	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Every binary number is a sum of powers of 2

Table 1-3 Binary Bit Position Values.

2^n	Decimal Value	2^n	Decimal Value
2^0	1	2^8	256
2^1	2	2^9	512
2^2	4	2^{10}	1024
2^3	8	2^{11}	2048
2^4	16	2^{12}	4096
2^5	32	2^{13}	8192
2^6	64	2^{14}	16384
2^7	128	2^{15}	32768

Translating Binary to Decimal

Weighted positional notation shows how to calculate the decimal value of each binary bit:

$$dec = (D_{n-1} \times 2^{n-1}) + (D_{n-2} \times 2^{n-2}) + ... + (D_1 \times 2^1) + (D_0 \times 2^0)$$

D = binary digit

binary 00001001 = decimal 9:

$(1 \times 2^3) + (1 \times 2^0) = 9$

Translating Unsigned Decimal to Binary

- Repeatedly divide the decimal integer by 2. Each remainder is a binary digit in the translated value:

Division	Quotient	Remainder
37 / 2	18	1
18 / 2	9	0
9 / 2	4	1
4 / 2	2	0
2 / 2	1	0
1 / 2	0	1

37 = 100101

Binary Addition

- Starting with the LSB, add each pair of digits, include the carry if present.

carry:					1				
	0	0	0	0	0	1	0	0	(4)
+	0	0	0	0	0	1	1	1	(7)
	0	0	0	0	1	0	1	1	(11)
bit position:	7	6	5	4	3	2	1	0	

Integer Storage Sizes

Standard sizes:

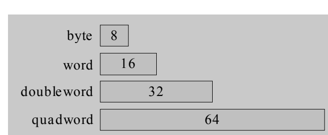


Table 1-4 Ranges of Unsigned Integers.

Storage Type	Range (low–high)	Powers of 2
Unsigned byte	0 to 255	0 to $(2^8 - 1)$
Unsigned word	0 to 65,535	0 to $(2^{16} - 1)$
Unsigned doubleword	0 to 4,294,967,295	0 to $(2^{32} - 1)$
Unsigned quadword	0 to 18,446,744,073,709,551,615	0 to $(2^{64} - 1)$

Practice: What is the largest unsigned integer that may be stored in 20 bits?

Hexadecimal Integers

All values in memory are stored in binary. Because long binary numbers are hard to read, we use hexadecimal representation.

Table 1-5 Binary, Decimal, and Hexadecimal Equivalents.

Binary	Decimal	Hexadecimal	Binary	Decimal	Hexadecimal
0000	0	0	1000	8	8
0001	1	1	1001	9	9
0010	2	2	1010	10	A
0011	3	3	1011	11	B
0100	4	4	1100	12	C
0101	5	5	1101	13	D
0110	6	6	1110	14	E
0111	7	7	1111	15	F

Translating Binary to Hexadecimal

- Each hexadecimal digit corresponds to 4 binary bits.
- Example: Translate the binary integer 000101101010011110010100 to hexadecimal:

1	6	A	7	9	4
0001	0110	1010	0111	1001	0100

Converting Hexadecimal to Decimal

- Multiply each digit by its corresponding power of 16:

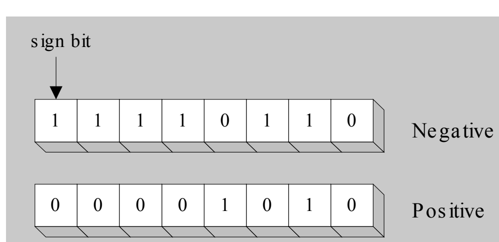
$$dec = (D_3 \times 16^3) + (D_2 \times 16^2) + (D_1 \times 16^1) + (D_0 \times 16^0)$$

- Hex 1234 equals $(1 \times 16^3) + (2 \times 16^2) + (3 \times 16^1) + (4 \times 16^0)$, or decimal 4,660.

- Hex 3BA4 equals $(3 \times 16^3) + (11 * 16^2) + (10 \times 16^1) + (4 \times 16^0)$, or decimal 15,268.

Signed Integers

- The highest bit indicates the sign. 1 = negative, 0 = positive



If the highest digit of a hexadecmal integer is > 7, the value is negative. Examples: 8A, C5, A2, 9D

Forming the Two's Complement

- Negative numbers are stored in two's complement notation
- Additive Inverse of any binary integer
- Steps:
  - Complement (reverse) each bit
  - Add 1

Starting value	00000001
Step 1: reverse the bits	11111110
Step 2: add 1 to the value from Step 1	11111110 +00000001
Sum: two's complement representation	11111111

Note that 00000001 + 11111111 = 00000000

Binary Subtraction

- When subtracting A – B, convert B to its two's complement
- Add A to (–B)

$$\begin{array}{r} 1\,1\,0\,0 \\ -\ 0\,0\,1\,1 \\ \hline \end{array} \longrightarrow \begin{array}{r} 1\,1\,0\,0 \\ 1\,1\,0\,1 \\ \hline 1\,0\,0\,1 \end{array}$$

Practice: Subtract 0101 from 1001.

Learn How To Do the Following:

- Form the two's complement of a hexadecimal integer
- Convert signed binary to decimal
- Convert signed decimal to binary
- Convert signed decimal to hexadecimal
- Convert signed hexadecimal to decimal

Ranges of Signed Integers

The highest bit is reserved for the sign. This limits the range:

Storage Type	Range (low–high)	Powers of 2
Signed byte	−128 to +127	-2^7 to $(2^7 - 1)$
Signed word	−32,768 to +32,767	-2^{15} to $(2^{15} - 1)$
Signed doubleword	−2,147,483,648 to 2,147,483,647	-2^{31} to $(2^{31} - 1)$
Signed quadword	−9,223,372,036,854,775,808 to +9,223,372,036,854,775,807	-2^{63} to $(2^{63} - 1)$

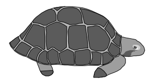
Practice: What is the largest positive value that may be stored in 20 bits?

Character Storage

- Character sets
  - Standard ASCII (0 – 127)
  - Extended ASCII (0 – 255)
  - ANSI (0 – 255)
  - Unicode (0 – 65,535)
- Null-terminated String
  - Array of characters followed by a *null byte*
- Using the ASCII table
  - back inside cover of book

Numeric Data Representation

- pure binary
  - can be calculated directly
- ASCII binary
  - string of digits: "01010101"
- ASCII decimal
  - string of digits: "65"
- ASCII hexadecimal
  - string of digits: "9C"



54 68 65 20 45 6E 64

What do these numbers represent?