INTRODUCTION TO MICROPROCESSORS AND MICROCOMPUTERS

1.1 The IBM and IBM-Compatible Personal Computers
1.2 General Architecture of a Microcomputer System
1.3 Evolution of the INTEL Microprocessor Architecture
1.4 Number Systems
1.1 The IBM and IBM-Compatible Personal Computers

- Most important advances in computer technology - 16-bit and 32-bit microprocessors
- Pioneered by Intel since 1970’s and dominated by INTEL since 1980’s
  - 4-bit 4004 in 1971
  - 8-bit 8008 in 1972
  - 8-bit 8080 and 8085 in 1974
  - 16-bit 8088 and 8086, brains of famous IBM PC
  - 64-bit Itanium (2001)
  - Latest 64-bit Pentium 4 and Xeon (2005)

1.1 The IBM and IBM-Compatible Personal Computers

- The original IBM personal computer
  - August 1981 - IBM announces the PC
  - Intel 8088 CPU, 4.77 MHz
  - IBM PC-DOS (Microsoft MS-DOS)
  - Cassette port, optional internal 5 1/4" single-sided 160K floppy disk drives (later double-sided 360K)
1.1 The IBM and IBM-Compatible Personal Computers

- PCXT personal computer
  - The XT stands for EXtended Technology and was introduced in early 1983
  - 8088 processor running at the ubiquitous 4.77Mhz
  - 128KB-640KB Memory (Depending on Configuration)
  - 5.25" Floppy Drive (360KB), 10 or 20MB Hard Disk Drive

- PC/AT personal computer
  - 6 or 8 Mhz 80286 microprocessor
  - Open system bus architecture – 16-bit ISA (Industrial Standard Architecture)
  - 1.2MB 5.25" Floppy, 20 or 30MB HDD
1.1 The IBM and IBM-Compatible Personal Computers

- Personal System/2 (Models 30, 50, 60, 70, 80)
  - IBM introduces the **PS/2 Model 25** in 1987 with an 8-MHz Intel 8086. Zero wait states, socket for optional i8087 math coprocessor, PS/2 ports, serial and parallel ports, audio earphone connector.
  - New Micro Channel bus architecture (16/32 bits).
  - Later expanded with Model 25, 55, 65, 90, 95.

- Pentium processor-based PC/AT-compatible computer
  - Either ISA bus or Peripheral Component Interface (PCI) bus
  - PCI bus support 32-bit and 64-bit data transfers
  - Offer a wide variety of computing capability
1.1 The IBM and IBM-Compatible Personal Computers

- Mainframe computers, minicomputers and microcomputers
- File servers and LAN
- Very Large-Scale Integration (VLSI) Circuit
- Microprocessing Unit (MPU)

1.2 General Architecture of a Microcomputer System

```
Memory Unit

Primary Storage Memory
  Program Storage Memory

Data Storage Memory

Secondary Storage Memory

Input Unit → CPU → Output Unit
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1.2 General Architecture of a Microcomputer System

- The 8088 and 8086 microprocessor
  - 8088 – 8-bit external bus, 16-bit internal architecture
  - 8086 – 16-bit external bus, 16-bit internal architecture
- MPU performs arithmetic operation and logical decision

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1.2 General Architecture of a Microcomputer System

- Input unit
  - keyboard, joystick, mouse, scanner
- Output unit
  - CRT display, LCD display, printer
- Memory unit
  - Primary storage memory: ROM, RAM
  - Secondary storage memory: floppy-diskette, hard disk drive, CD-ROM, CD-RW, magnetic tape
1.3 Evolution of the INTEL Microprocessor Architecture

- 1971 Intel introduces its first microprocessor, the 4004, which contained 2250 transistors. The 4004 was designed to process data arranged as 4-bit words.

SOURCE: Intel’s microprocessor hall of fame

- Beginning in 1974 a second generation of microprocessors was introduced. These devices, the 8008, 8080, and 8085, were 8-bit microprocessors.

SOURCE: Intel’s microprocessor hall of fame
1.3 Evolution of the INTEL Microprocessor Architecture

- Microprocessor Performance: MIPS
  - MIPS, million instructions executed per second
  - Measured by running a test program called the Drystone program, the resulting performance are normalized to those of a VAX 1.1 computer.
  - P4 1GHz RDRAM is capable of delivering up to 1924 VAX MIPS performance

- Microprocessor Performance: iCOMP
  - iCOMP index is provided by the Intel Corporation for comparing the performance of their 32-bit microprocessors in a personal computer environment
  - iCOMP rating encompasses performance components that represent integer mathematics, floating-point mathematics, graphics, and video. The weighting indicated in percent are:
    - #1,2: Multimedia and Internet application (25%)
    - #3: Two integer productivity applications (20% each)
    - #4: 3D geometry and lighting calculations (20%)
    - #5: Java application (10%)
    - #6: Floating point: engineering, game applications (5%)
### 1.3 Evolution of the INTEL Microprocessor Architecture

- **Microprocessor Performance: iCOMP**

![Chart showing Microprocessor Performance](image)

**Figure 1-9**: iCOMP sales rating chart. Reprinted by permission of Intel Corp. Copyright Intel Corp. 1987.

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![Chart showing Microprocessor Performance](image)
1.3 Evolution of the INTEL Microprocessor Architecture

In 1965 Gordon Moore predicted that the number of transistors in a microprocessor will double every 18 months and this trend will hold till 1975…

The complexity for minimum component costs has increased at a rate of roughly a factor of two per year ... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65,000. I believe that such a large circuit can be built on a single wafer. *

Electronics Magazine 19, April 1965
1.3 Evolution of the INTEL Microprocessor Architecture

- Moore’s law is good for the last 26 years!

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Transistors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>4004</td>
<td>2,250</td>
</tr>
<tr>
<td>1972</td>
<td>8008</td>
<td>2,500</td>
</tr>
<tr>
<td>1974</td>
<td>8080</td>
<td>5,000</td>
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<tr>
<td>1978</td>
<td>8086</td>
<td>29,000</td>
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<tr>
<td>1982</td>
<td>80286</td>
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<tr>
<td>1985</td>
<td>80386</td>
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</tr>
<tr>
<td>1989</td>
<td>80486 DX</td>
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<tr>
<td>1993</td>
<td>Pentium</td>
<td>3,100,000</td>
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<tr>
<td>1997</td>
<td>Pentium II</td>
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<td>1999</td>
<td>Pentium III</td>
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<tr>
<td>2000</td>
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</tr>
<tr>
<td>2006</td>
<td>Pentium D 900</td>
<td>376,000,000</td>
</tr>
</tbody>
</table>

Reprogrammable and embedded microprocessors

- Embedded control applications
  - Event control - e.g. Industrial process control
  - Data control – e.g. Hard disk controller interface

- Microcontroller
- Microprocessor for a general-purpose microcomputer
1.3 Evolution of the INTEL Microprocessor Architecture

- Reprogrammable and embedded microprocessors
  - Architectural compatibility is a critical need of microprocessors developed for use in reprogrammable applications
  - Real-address mode and protected-address mode
  - 8086/8088 code can run on the 80286, 80386, 80486, and Pentium processor, but the reverse is not true

Peripheral support for the MPU
1.4 Number Systems

- Decimal number system
  - The number of symbols used is called the **base** or **radix** of the number system.
  - Most significant digit (MSD) and least significant digit (LSD).

(a) Decimal number system symbols. (b) Digit notation and weights.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
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<tbody>
<tr>
<td>10^-13</td>
<td>10^-12</td>
<td>10^-11</td>
<td>10^-10</td>
<td>10^-9</td>
<td>10^-8</td>
<td>10^-7</td>
<td>10^-6</td>
<td>10^-5</td>
<td>10^-4</td>
</tr>
<tr>
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<td>100</td>
<td>10</td>
<td>1</td>
<td>1/10</td>
<td>1/100</td>
<td>1/1000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.4 Number Systems

- Binary number system

\[1100_2 = 1(2^3) + 1(2^2) + 0(2^1) + 0(2^0) = 1(8) + 1(4) + 0(2) + 0(1) = 12_{10}\]

\[12_{10} = 0000000000001100_2\]

(a) Binary number system symbols. (b) Bit notation and weights.
1.4 Number Systems

Conversion between decimal and binary numbers

<table>
<thead>
<tr>
<th>Decimal number</th>
<th>Binary number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
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<tr>
<td>4</td>
<td>100</td>
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<td>5</td>
<td>101</td>
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</tr>
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<td>10</td>
<td>1010</td>
</tr>
<tr>
<td>11</td>
<td>1011</td>
</tr>
<tr>
<td>12</td>
<td>1100</td>
</tr>
<tr>
<td>13</td>
<td>1101</td>
</tr>
<tr>
<td>14</td>
<td>1110</td>
</tr>
<tr>
<td>15</td>
<td>1111</td>
</tr>
</tbody>
</table>

EXAMPLE

Evaluate the decimal equivalent of binary number 101.01₂.

Solution:

\[ 101.01₂ = 1\times2^2 + 0\times2^1 + 1\times2^0 + 0\times(2^{-1}) + 1\times(2^{-2}) \]
\[ = 1(4) + 0(2) + 1(1) + 0(1/2) + 1(1/4) \]
\[ = 4 + 0 + 1 + 0 + 1/4 \]
\[ = 4 + 1/4 \]
\[ = 5.25₁₀ \]

101.0₁₂ = 5.25₁₀
1.4 Number Systems

EXAMPLE

Convert decimal number $31_{10}$ to binary form. Also, express the answer as a byte-wide binary number.

Solution:

$$
\begin{array}{c|c}
\text{2} & 31 \rightarrow 1 \text{ LSB} \\
\text{2} & 15 \rightarrow 1 \\
\text{2} & 7 \rightarrow 1 \\
\text{2} & 3 \rightarrow 1 \\
\text{2} & 1 \rightarrow 1 \text{ MSB} \\
\end{array}
$$

$31_{10} = 11111_2$

1.4 Number Systems

EXAMPLE

Convert decimal fraction $.8125$ to binary form. Also, express the answer as a byte-wide binary number.

Solution:

$$
\begin{array}{c|c}
\text{2} \times .8125 & \rightarrow 1 \text{ MSB} \\
\text{2} \times .625 & \rightarrow 1 \\
\text{2} \times .25 & \rightarrow 0 \\
\text{2} \times .5 & \rightarrow 1 \\
\text{2} \times 0 & \\
\end{array}
$$

$.8125 = .1101_2$
1.4 Number Systems

- Hexadecimal number system
  - Machine language programs, addresses, and data are normally expressed as hexadecimal number.

(a) Hexadecimal number system symbols. (b) Digit notation and weights.

EXAMPLE

What decimal number does $102A_{16}$ represent?

Solution:

$$102A_{16} = 1(16^3) + 0(16^2) + 2(16^1) + A(16^0)$$
$$= 1(4096) + 0(256) + 2(16) + A(1)$$
$$= 4096 + 32 + 10$$
$$= 4138_{10}$$
1.4 Number Systems

EXAMPLE

Convert decimal number 4138\(_{10}\) to hexadecimal form.

Solution:

\[
\begin{array}{c|c}
\text{16} & 4138 \\
\text{16} & 258 \rightarrow A \quad \text{LSB} \\
\text{16} & 16 \rightarrow 2 \\
\text{16} & 1 \rightarrow 0 \\
\text{16} & 0 \rightarrow 1 \quad \text{MSB} \\
\end{array}
\]

\[4138_{10} = 102A_{16}\]

Conversion between hexadecimal and binary numbers

- An H is frequently used instead of a subscript 16 to denote that a value is a hexadecimal number.

<table>
<thead>
<tr>
<th>Binary number</th>
<th>Hexadecimal number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>0010</td>
<td>2</td>
</tr>
<tr>
<td>0011</td>
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<td>0100</td>
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<td>B</td>
</tr>
<tr>
<td>1100</td>
<td>C</td>
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<tr>
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<tr>
<td>1110</td>
<td>E</td>
</tr>
<tr>
<td>1111</td>
<td>F</td>
</tr>
</tbody>
</table>

(a) Equivalent binary and hexadecimal numbers.
(b) Binary bits and hexadecimal digits.
1.4 Number Systems

EXAMPLE
Express the binary number $111100100001010_2$ as a hexadecimal number.

Solution:

\[
111100100001010_2 = 1111 \quad 1001 \quad 0000 \quad 1010 \\
= \text{F} \quad 9 \quad 0 \quad \text{A}
\]

\[
111100100001010_2 = \text{F90A}_{16}
\]

= \text{F90AH}

1.4 Number Systems

EXAMPLE
What is the binary equivalent of the number $\text{C315}_{16}$?

Solution:

\[
\text{C315}_{16} = 1100 \quad 0011 \quad 0001 \quad 0101
\]

= $1100001100010101_2$