(*) Introduction

Digital design is concerned with the design of DIGITAL electronic circuits.
A DIGITAL COMPUTER can follow a sequence of INSTRUCTIONS, called a PROGRAM, that operates on given DATA. The USER can change programs and/or data according to the specific need. Examples of digital systems include digital computers, electronic calculators, etc.

Even though DATA and INFORMATION are slightly different terms, they are often used interchangeably.

^ The main characteristic of a digital system is its manipulation of DISCRETE elements of information, for eg., electric impulses, the decimal digits, the letters of an alphabet, etc.

The JUXTAPOSITION of discrete elements of INFORMATION represents a QUANTITY of information.
For eg., the letters d, o and g placed one after another form the word dog.
Thus, a SEQUENCE of discrete elements forms a LANGUAGE.

Discrete elements of information are represented in a digital system by physical quantities called SIGNALS, such as ELECTRICAL signals (for eg., voltages, currents, etc.).

The signals in all present-day electronic digital systems have only TWO discrete values and are said to be BINARY. This is because MANY-VALUED electronic circuits, for eg., a circuit with ten states (one discrete voltage value for each state), have low RELIABILITY of operation.

Discrete quantities of information arise either from the NATURE of a process or may be QUANTIZED from a continuous process.
For eg., An employee's paycheck is processed using DISCRETE data values such as letters (for name), digits (for salary), and special symbols such as $.
On the other hand, a scientist may observe a CONTINUOUS phenomenon but record only specific quantities in tabular form.

An ANALOG computer performs a direct SIMULATION of a continuous physical system.
However, to simulate a continuous physical process in a DIGITAL computer, the quantities must be QUANTIZED.
The terms DIGITAL SIGNAL & ANALOG SIGNAL are sometimes substituted for DISCRETE SIGNAL & CONTINUOUS SIGNAL, respectively.

^

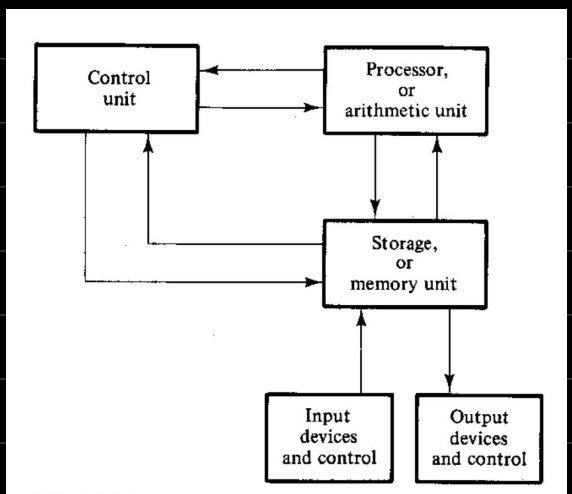

FIGURE 1-1
Block diagram of a digital computer

The MEMORY unit stores PROGRAMS as well as INPUT, OUTPUT and INTERMEDIATE data.
The PROCESSING unit performs data-processing tasks as specified by a PROGRAM.
The CONTROL unit retrieves the INTSTRUCTIONS of a program one by one and for each instruction, it informs the PROCESSOR to execute the OPERATION specified by the instruction.

The PROGRAM and DATA prepared by the USER are transferred into the MEMORY unit by means of INPUT devices, and OUTPUT devices receive the RESULTS of the computations.

(*) Number Systems (Unsigned)

An UNSIGNED (non-negative) number in any BASE (or RADIX) is represented by a series of COEFFICIENTS as $\ldots a_3 a_2 a_1 a_0 . a_{-1} a_{-2} a_{-3} \ldots$

The common bases are 10, 2, 8 & 16, and a similar logic works for any base r other than these.

TABLE 1-1
Numbers with Different Bases

Decimal (base 10)	Binary (base 2)	Octal (base 8)	Hexadecimal (base 16)
00	0000	00	0
01	0001	01	1
02	0010	02	2
03	0011	03	3
04	0100	04	4
05	0101	05	5
06	0110	06	6
07	0111	07	7
08	1000	10	8
09	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

^ The DECIMAL Number System

For base 10, the a_j coefficients are one of 0, 1, 2, 3, 4, 5, 6, 7, 8 & 9, and the subscript j gives the power of 10 by which the coefficient must be multiplied.

For eg.,

1. $(7392)_{10} = (7 \times 10^3) + (3 \times 10^2) + (9 \times 10^1) + (2 \times 10^0)$
2. $(12.36)_{10} = (1 \times 10^1) + (2 \times 10^0) + (3 \times 10^{-1}) + (6 \times 10^{-2})$

^ The BINARY Number System

For base 2, the a_j coefficients are one of 0 & 1, and the subscript j gives the power of 2 by which the coefficient must be multiplied.

For eg.,

1. $(1011)_2 = (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$

$= (11)_{10}$

2. $(11010.11)_2 = (1 \times 2^4) + (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (0 \times 2^0) + (1 \times 2^{-1}) + (1 \times 2^{-2})$

$= (26.75)_{10}$

^ The OCTAL Number System

For base 8, the a_j coefficients are one of 0, 1, 2, 3, 4, 5, 6 & 7, and the subscript j gives the power of 8 by which the coefficient must be multiplied.

For eg.,

1. $(6471)_8 = (6 \times 8^3) + (4 \times 8^2) + (7 \times 8^1) + (1 \times 8^0)$

$= (3385)_{10}$

2. $(231.4)_8 = (2 \times 8^2) + (3 \times 8^1) + (1 \times 8^0) + (4 \times 8^{-1})$

$= (153.5)_{10}$

^ The HEXADECIMAL Number System

For base 16, the a_j coefficients are one of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A (10), B (11), C (12), D (13), E (14) & F (15), and the subscript j gives the power of 16 by which the coefficient must be multiplied.

For eg.,

1. $(B65F)_{16} = (11 \times 16^3) + (6 \times 16^2) + (5 \times 16^1) + (15 \times 16^0)$

$= (46687)_{10}$

2. $(3F9.C)_{16} = (3 \times 16^2) + (15 \times 16^1) + (9 \times 16^0) + (12 \times 16^{-1})$

$= (1017.75)_{10}$

^ Arithmetic operations with unsigned numbers in base r follow the SAME rules as for decimal numbers. For eg.,

1. $(23.5)_{10} + (1.67)_{10} = (25.17)_{10}$

```
        0            1 0           01 0           01 0
    23.50          23.50          23.50          23.50
            --->           --->           --->
  + 01.67        + 01.67        + 01.67        + 01.67
  -------        -------        -------        -------
      . 7            .17           5.17          25.17
```

2. $(11.1)_2 - (1.01)_2 = (10.01)_2$

```
          0 10                0 10                0 10                0 10
    1 1 . 1 0           1 1 . 1 0           1 1 . 1 0           1 1 . 1 0
                --->                --->                ---->
  - 0 1 . 0 1         - 0 1 . 0 1         - 0 1 . 0 1         - 0 1 . 0 1
  ------------        ------------        ------------        ------------
        .   1               . 0 1             0 . 0 1           1 0 . 0 1
```

3. $(3.24)_8 \times (7.1)_8 = (27.464)_8$

```
                                                                  3
    324            324            324            324            324

  x  71          x  71          x  71          x  71          x  71
  -----   --->   -----   --->   -----   --->   -----   --->   -----   --->
      4             24            324            324            324

                                                   0             40
                                                 -----          -----
```

```
    23             23             23
    324            324            324            3.24

  x  71          x  71          x  71          x  7.1
  -----   --->   -----   --->   -----   --->   ------
    324            324            324          27.464

    140        + 27140        + 27140
  -----          -----          -----
                                27464
```

Note that in octal,
7 x 2 = 16
7 x 3 = 25
7 x 4 = 34
and so on

Just like with decimal numbers, division with unsigned numbers in base r may also result in a NON-TERMINATING quotient.

4. $(2B.E)_{16}$ / $(3.4)_{16}$ = $(D.8)_{16}$

```
        D                   D                   D.                  D.8
      ------              ------              ------              ------
  3.4 | 2B.E          3.4 | 2B.E          3.4 | 2B.E          3.4 | 2B.E
  ----|                ----|                ----|                ----|
      - 2A.4              - 2A.4              - 2A.4              - 2A.4
      ------   --->      ------   --->      ------   --->      ------
                            1.A                 1A                 1A

                                                                  - 1A
                                                                 ------
                                                                    0
```

^ Binary to Decimal, Octal to Decimal and Hexadecimal to Decimal Conversions

Previously explained.

^ Decimal to Binary Conversion