Introduction

All of us are familiar with the impact of digital calculators, watches, modern communication systems and computers in every day life. All persons working in various fields related to electronics must understand the performance of Digital Electronic Circuits. All sizes of computers, as we know, perform complicated task with fantastic speed and accuracy. At stores, the cash register read out digital display digital clock and watches flash the time in all city shops and restaurants. Most automobiles use microprocessors to control engine functions. Aircraft's defense sectors, factory machines and modern diagnostic in medical science are controlled by digital circuits.

Therefore, one asks obvious questions like:

- What is a digital circuit?
- How digital circuits work?
- Why use digital circuits?
- How one makes a digital signal? How does one test a digital signal? And so on, a long list of queries.

This revolution took place with the advent of integrated circuits (IC) which is an offspring of semiconductor technology. The inexpensive fabrication of ICs has made the subject Digital Electronics easy to study. One small IC can perform the task of thousands of Transistors Diodes and Resistors. Many ICs are used to construct Digital Circuits. This is an exciting and rapidly growing field, which uses several principles for the working of computers, Communication systems, Digital machinery's etc. The basic idea is to let the beginners understand the operation of the Digital system and many other systems based on the principles of Digital Techniques. Any device working under Digital Techniques are called Digital Systems and the Electronic Network used to make them operational are called Digital Circuits. The subject as a whole is often referred as **Modern Digital Electronics.**

Electronic circuits use two kinds of signals. They are **Analog Signals** (continuous supply of voltages and currents) and **Digital Signals** (discrete voltages and current). For example, Circuits (electronic network) using Analog signals are known as **Linear or Analog Circuits**. Similarly, the electronic network of an electronic calculator or digital watch that uses Digital signals are called **Digital Circuits**.

An analog device, then, is one that has a signal, which varies continuously in time with the input, whereas, a digital device operates with a digital signal that varies discontinuously. As a result, the Digital Electronics is the world of **ZEROS'** (OFF/LOW/DOWN/FALSE) and '**ONES**' (ON/HIGH/UP/TRUE). Figure1.1 shows the behavior of Analog and Digital signal and the possibility of conversion from Analog to Digital. Figure 1.2 represents a symbol of some devices using Analog and Digital world. This example is set to explain how real life problem like movement of a pivot on a water tank that indicates the level of water can be translated to analog/digital form.

Figure

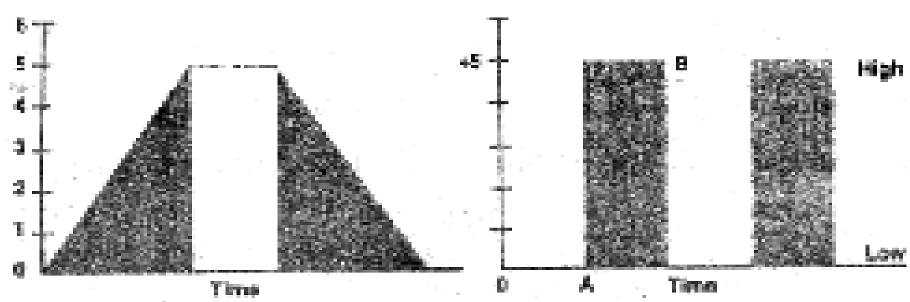

Figure 1.1 (a) Analog Signal Waveform

Figure 1.1 (b) Digital Signal Waveform

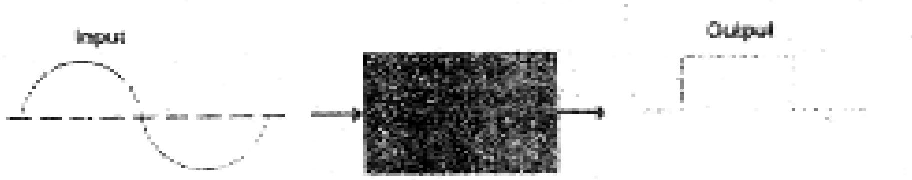

Figure 1.1 (c) Block Diagram of Electronic Circuit Shaping a Sine Wave Into a Square Wave

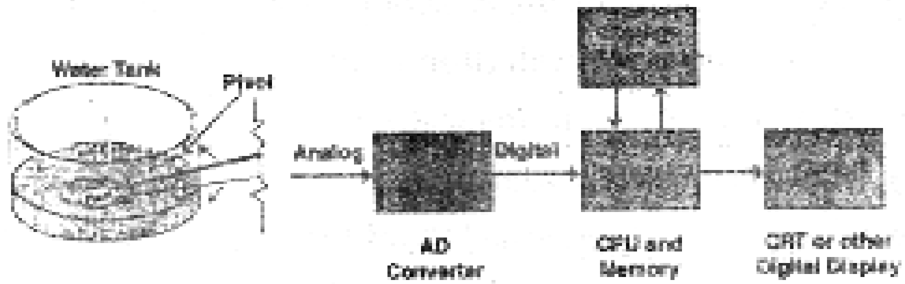

Figure 1.2 Digital System used to Interpret Float Level in Water Tank

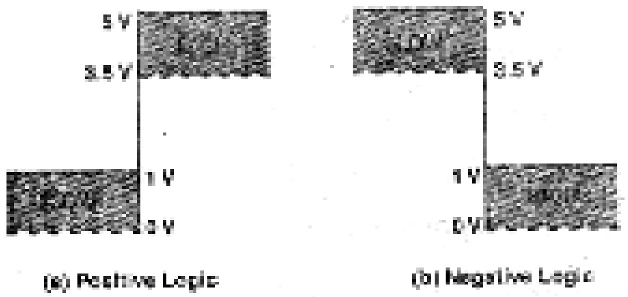

Figure 1.3 Digital Signal Representation

Digital system works under logic and hence they are called **Logic Circuits**, whose building blocks are known as **Gates.** These circuits employ two different representations of digital signal known as Positive Logic Systems and Negative Logic Systems as shown in Figure 1.3. The two discrete signal levels HIGH and LOW are generally represented by **Binary Digits** 1 and 0 respectively is referred to as **bit** and binary number with 8 bits is known as a **byte**.

Since a digital signal can have only one of the two possible level 1 and 0, the **Binary Number System** can be used for the analysis and design of digital system, which was introduced by George Boolean in 1854 and the corresponding algebra is known as **Boolean Algebra**. These logic concepts have been adopted for the design of digital circuit.

The number system that we use in day-to-day life is called **Decimal Number System**. In this system, one works with 10 different Digits, (0 through 9) and is known as based-ten system. But digital electronic devices used a ‘strange’ number system called **binary**. Digital computers and microprocessor-based systems use other strange number systems called **Hexadecimal** and **Octal**. One who works in electronics must know how to convert numbers from the everyday decimal system to binary, to Hexadecimal, and to Octal system.

The hexadecimal number system uses the 16 symbol: 0 through 9,A, B, C, D, E, and F and is referred to as base-sixteen system. The letter 'A' stands for decimal 10, 'B' for decimal 11, and so on. The Octal number system uses the 8 symbols: 0 through 7 and are referred to as base-eight system

Any **Decimal number** of any magnitude can be expressed by using the system of positional weighting in which the right most digit of the number called the 'least significant digit' is multiplied by 10^0 to the number, the digit left to the least significant digit is multiplied by 10^1. Similarly, as we move in the number towards left side the power increases in steps of 1.

For example in decimal number $(386)_{10}$ the weightage of digit 6 is $6x10^0=6$, the weightage of digit 8 is $8x10^1= 80$ and for digit 3 is $3x10^2=300$.

Summing all three values 6, 80, and 300 we get

386 =3 x hundred + 8 x ten + 6 x unity

$=3x10^2 + 8x10^1 + 6x10^0$

=3x100 + 8x10 + 6x1

$=300 + 80 + 6=(386)_{10}$

The **binary number system** is exactly like the Decimal system except that the base is 2 instead of 10. Again each position in a binary number represent a power of the base 2. In this system, the right most position is the unit 2^o position, the second position from the right is the 2's (2^1), and proceeding in this way, we have 4's (2^2), 8's (2^3) position, and so on.

Thus, the decimal equivalent of the binary number 10101 (written as $10101)_2$ is

$1x2^4+0x2^3+1x2^2+0x2^1+1x2^0$

or 16+0+4+0+1 or 21

Thus, we write $(10101)_2 = (21)_{10}$

In the **octal system** the largest single digit is 7 (one less than the base). Again each position an octal number represent a power of the base 8.

Thus the decimal equivalent of the octal number 943 (written as $943)_8$ is

$9x8^2+4x8^1+3x8^0$

or 9x64+32+3

or 576+32+3

or 611

so we have $(943)_8 = (6!!)_{10}$

In hexadecimal system, the largest single digit is F or 15 (one less than the base). Again, each position in a Hexadecimal system represents a power of the base 16.

Thus, the decimal equivalent of the Hexadecimal number 3AF written as $(3AF)_{16}$ or H is

$3x16^2+Ax16^1+Fx16^0$

or 3x256+10x16+15x1

or 768+160+15

or 943

Thus $(3AF)_{16} =(943)_{10}$

And $(3AF)_{16} = (1110101111)_2$

The **Binary Coded Decimal (BCD)** Code is one of the early memory codes. It is based on idea of converting each digit of a decimal number into its binary equivalent rather than converting the entire decimal value into a pure binary form.

Converting $(943)_{10}$ into BCD, results the following

$(943)_{10} = \underbrace{1001}_{9} \quad \underbrace{0100}_{4} \quad \underbrace{0011}_{3}$

or 100101000011 in BCD

Table 1.1 represents binary, hexadecimal, BCD equivalence to decimal numbers and Table1.2 represent alphabetic and numeric characters in BCD along with their octal equivalent

Decimal	*Binary*	*Hexadecimal*	*BCD Equivalent*
0	***0000***	***0***	***0000***
1	***0001***	***1***	***0001***
2	***0010***	***2***	***0010***
3	***0011***	***3***	***0011***
4	***0100***	***4***	***0100***
5	***0101***	***5***	***0101***
6	***0110***	***6***	***0110***
7	***0111***	***7***	***0111***
8	***1000***	***8***	***1000***
9	***1001***	***9***	***1001***
10	***1010***	***A***	***00010000***
11	***1011***	***B***	***00010001***
12	***1100***	***C***	***00010010***
13	***1101***	***D***	***00010011***
14	***1110***	***E***	***00010100***
15	***1111***	***F***	***00010101***
16	***10000***	***10***	***00010110***
17	***10001***	***11***	***00010111***

Table 1.1

Characters	*Code Digit (BCD)*	*Octal Equivalent*
A	0001	61
B	0010	62
C	0011	63
D	0100	64
E	0101	65
F	0110	66
G	0111	67
H	1000	70
I	1001	71

J	0001	41
K	0010	42
L	0011	43
M	0100	44
N	0101	45
O	0110	46
P	0111	47
Q	1000	50
R	1001	51
S	0010	22
T	0011	23
U	0100	24
V	0101	25
W	0110	26
X	0111	27
Y	1000	30
Z	1001	31
1	0001	01
2	0010	02
3	0011	03
4	0100	04
5	0101	05
6	1001	06
7	0111	07
8	1000	10
9	1001	11
0	1010	12

Table 1.2

Characters	***Digit***	***ASCII-7 code Hexadecimal equivalent***	***Digit***	***ASCII-7 code Hexadecimal equivalent***
0	0	30	0	50
1	1	31	1	51
2	10	32	10	52
3	11	33	11	53
4	100	34	100	54

5	101	35	101	55
6	110	36	110	56
7	111	37	111	57
8	1000	38	1000	58
9	1001	39	1001	59
A	1	41	1	A1
B	10	42	10	A2
C	11	43	11	A3
D	100	44	100	A4
E	101	45	101	A5
F	110	46	110	A6
G	111	47	100	A7
H	1000	48	1000	A8
I	1001	49	1001	A9
J	1010	4A	1010	AA
K	1011	4B	1011	AB
L	1100	4C	1100	AC
M	1101	4D	1101	AD
N	1110	4E	1110	AE
O	1111	4F	1111	AF
P	0	50	0	B0
Q	1	51	1	B1
R	10	52	10	B2
S	11	53	11	B3
T	100	54	100	B4
U	101	55	101	B5
V	110	56	110	B6
W	111	57	111	B7
X	1000	58	1000	B8
Y	1001	59	1001	B9
Z	1010	5A	1010	BA

Table 1.3 Represents Numeric and Alphabetic Characters in ASCII- and ASCII-8 Notation along with their Hexadecimal Equivalent

Another important code that is very widely used in computer is the American Standard Code for Information Interchange (ASCII). This code is popular in data communications. ASCII is of two types: ASCII-7 and ASCII-8. ASCII-7 is a 7 bit code that allows 2^7(128) different characters. ASCII-8 (8bit code) is an extended version of ASCII-7 that allows 28(256) different characters as shown in Table 1.3.

The binary code for the word BOY in ASCII-7 can be represented as

<u>1000010</u>	<u>1001111</u>	<u>1011001</u>
B	O	Y

The first 3 bits in each of the character (for example 100 for B, 100 for O and 101 for Y), are used as 'zone' bits which is internal code for ASCII. In ASCII-8, the representation of BOY will be

<u>1000010</u>	<u>1001111</u>	<u>1011001</u>
B	O	Y

The first 4 bit in each of the character are used as zone bits.

It is therefore important to highlight the superiority of digital circuits and systems over the analog circuits. The 'Real-world' information deals with time, speed, weight, pressure, light intensity, and position measurement and is all analog in nature. Digital systems are required when data must be stored, used for calculations, or displayed as numbers/or letters. They are valuable when calculations, data manipulations, and alphanumeric outputs are required. The "**Central Processing Unit**"(CPU) of a computer can manipulate the input data, output the information, store the information and so forth.

Some of the **advantages** highlighted for the widespread use of digital circuitry in over analog are as follows

1. Inexpensive ICs can be used with few external components.
2. Operate in one of the two **states**, known as ON and OFF makes it very simple.
3. Only a few basic operations are required and are very easy to understand.

4. Digital techniques deal with simple logic mathematics called Boolean algebra.
5. Operation and network analysis of digital circuitry require simple basic concepts like switching speed and loading on the other hand, analysis of analog circuitry (Involved frequency and time domain) are quite complicated.
6. Information can be stored for short periods or indefinitely.
7. Data can be used for precise calculations.
8. Systems can be designed more easily using compatible digital logic families.
9. Systems can be programmed which show some manner of 'intelligence'. A number of programmable ICs are also available.
10. The display of data and other information is very convenient, accurate and elegant by using digital techniques.
11. Digital circuits have capability of memory, which makes these circuits highly suitable for computers, calculators, watches, telephones, medical diagnostics, etc.
12. To learn programming of digital computers it is worth knowing, the way the digital hardware works.

The limitations of digital circuitry are as follows:

Most 'real-world' events are analog in nature.

Analog processing is usually simpler and faster.

Digital circuits are appearing in more and more products primarily because of low-cost, reliable digital ICs. Other reasons for their growing popularity are accuracy, added stability, computer compatibility, memory, ease of use, simplicity of design, and compatibility with at alphanumeric displays.