Course Code: SWE223
Course Title: Digital Electronics with Lab
Department of Software Engineering

Analog Signal

A continuously varying signal (voltage or current) is called an *analog signal*. For example, an alternating voltage varying sinusoidally is an analog signal. If such an analog signal is applied to the input of a transistor amplifier, the output voltage will also vary sinusoidally. This is the analog operation *i.e.*, the output voltage can have an infinite number of values. Due to many valued output, the analog operation is less reliable.

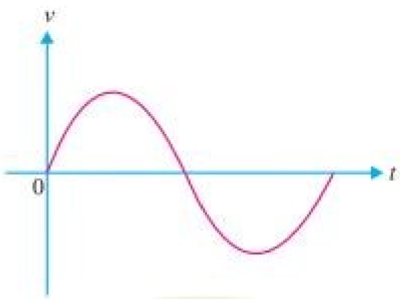

Fig: Analog Signal

Digital Signal

A signal (voltage or current) that can have only two discrete values is called a *digital signal*. For example, a square wave is a digital signal. It is because this signal has only two values viz, +5 V and 0 V and no other value. These values are labelled as *High* and *Low*. The high voltage is + 5 V and the low voltage is 0 V. If proper digital signal is applied to the input of a transistor, the transistor can be driven between *cut off* and *saturation*. In other words, the transistor will have two-state operations *i.e.*, output is either low or high. Since digital operation has only two states (*i.e.*, *ON* or *OFF*), it is far more reliable than many-valued analog operation. It is because with two states operation, all the signals are easily recognized as either low or high.

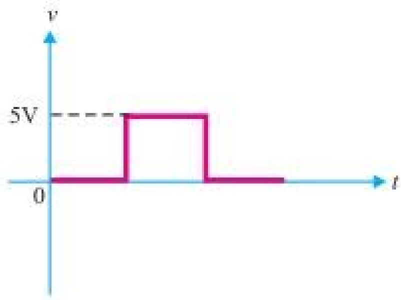

Fig: Digital Signal

Digital Circuit

An electronic circuit that handles only a digital signal is called a **digital circuit.** The output voltage of a digital circuit is either low or high and no other value. In other words, digital operation is a two-state operation. These states are expressed as (*High* or *Low*) or (*ON* or *OFF*) or (1 or 0). Therefore, a digital circuit is one that expresses the values in digits 1's or 0's.Hence the name digital. The numbering concept that uses only the two digits 1 and 0 is the *binary numbering system.*

Digital Electronics

An electronic circuit that is designed for two-state operation is called a digital circuit. The branch of electronics which deals with digital circuits is called **digital electronics**. Now digital circuits are being used in many electronic products such as video games, microwave ovens and oscilloscopes. Digital techniques have also replaced a lot of the older "analog circuits" such as radios, TV sets and high-fidelity sound recording and playback equipment.

Number Systems

A number system is a code that uses symbols to count the number of items. There are four number systems which are used in digital circuits.

- **Binary Number System**: It has base (radix) of 2. It uses only two different symbols such as 0 and 1 for counting the items.
- **Decimal Number System** It has base (radix) of 10. It uses only ten different symbols such as 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 for counting the items.
- **Octal Number System** It has base (radix) of 8. It uses only eight different symbols such as 0, 1, 2, 3, 4, 5, 6, and 7 for counting the items.
- **Hexadecimal Number System** It has base (radix) of 16. It uses only sixteen different symbols such as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F for counting the items.

Example 1: *Convert the binary number 1101.011 to its equivalent decimal number*

$$1101.011_2 = (1\times 2^3) + (1\times 2^2) + (0\times 2^1) + (1\times 2^0) + (0\times 2^{-1}) + (1\times 2^{-2}) + (1\times 2^{-3})$$
$$= 8 + 4 + 0 + 1 + 0 + \frac{1}{4} + \frac{1}{8} = 13.375_{10}$$

Example 2: *Convert the binary number 100111010 to its equivalent octal number*

$$\underbrace{100}_{\downarrow\, 4} \quad \underbrace{111}_{\downarrow\, 7} \quad \underbrace{010}_{\downarrow\, 2}$$

$$(100111010)_2 = (472)_8$$

Example 3: *Convert the binary number 1110100110 to its equivalent hexadecimal number*

$$\underbrace{0011}_{3} \quad \underbrace{1010}_{A} \quad \underbrace{0110}_{6}$$

$$(1110100110)_2 = (3A6)_{16}$$

Example 4: *Convert the decimal number 25.625 to its equivalent binary number*

(*a*) **Integer**	(*b*) **fraction**
$25 \div 2 = 12 + 1$	$0.625 \times 2 = 1.25 = 0.25 + 1$
$12 \div 2 = 6 + 0$	$0.25 \times 2 = 0.5 = 0.5 + 0$
$6 \div 2 = 3 + 0$	$0.5 \times 2 = 1.0 = 0.0 + 1$
$3 \div 2 = 1 + 1$	
$1 \div 2 = 0 + 1$	
$\therefore\ 25_{10} = 11001_2$	$\therefore\ 0.625_{10} = 0.101_2$

Considering the complete number, we have $25.625_{10} = 11001.101_2$

Example 5: *Convert the decimal number 175.15 to its equivalent octal number*

Let us see how we can convert 175_{10} into its octal equivalent.

$175 \div 8 = 21$	with 7 remainder
$21 \div 8 = 2$	with 5 remainder
$2 \div 8 = 0$	with 2 remainder

Taking the remainders in the **reverse order**, we get 257_8. $\therefore\ 175_{10} = 257_8$

Let us now take decimal fraction 0.15. Its octal equivalent can be found as under:

$0.15 \times 8 = 1.20 = 0.20$	with a carry of 1
$0.20 \times 8 = 1.60 = 0.60$	with a carry of 1
$0.60 \times 8 = 4.80 = 0.80$	with a carry of 4
$\therefore\ 0.15_{10} = 114_8$	

The complete number is $175.15_{10} = 257.114_8$

Example 6: *Convert the decimal number 1983 to its equivalent hexadecimal number*

Hence, $1983_{10} = 7BF_{16}$	$1983 \div 16 = 123 + 15$	→	F
	$123 \div 16 = 7 + 11$	→	B
	$7 \div 16 = 0 + 7$	→	7

Example 7: *Convert the octal number 74.562$_8$ to its equivalent binary number*

$$\begin{array}{ccccccc} 7 & 4 & . & 5 & 6 & 2 \\ \downarrow & \downarrow & & \downarrow & \downarrow & \downarrow \\ 111 & 100 & & 101 & 110 & 010 \end{array} \quad : \quad 74.562_8 = 111\ 100.101\ 110\ 010_2$$

Example 8: *Convert the octal number 206.104$_8$ to its equivalent decimal number*

$$\begin{array}{ccccccc} 2 & 0 & 6 & . & 1 & 0 & 4 \\ 8^2 & 8^1 & 8^0 & & 8^{-1} & 8^{-2} & 8^{-3} \end{array}$$

$$206.104_8 = 2\times 8^2 + 6\times 8^0 + \frac{1}{8} + \frac{4}{8^3} = 128 + 6 + \frac{1}{8} + \frac{1}{128} = \left(134\frac{17}{128}\right)_{10}$$

Example 9: *Convert the octal number (752)$_8$ to its equivalent hexadecimal number*

Step 1:

Octal to Binary Conversion

7	5	2
111	101	010

So the binary equivalent is 111101010

Step 2:

Binary to Hex Conversion

0001	1110	1010
1	D	9

The hex number equivalent is $(1D9)_8$

Example 10: *Convert the hexadecimal number 23A$_{16}$ to its equivalent binary number*

$$\begin{array}{ccc} 2 & 3 & A \\ \downarrow & \downarrow & \downarrow \\ 0010 & 0011 & 1010 \end{array} \quad : \quad 23A_{16} = 0010\ 0011\ 1010_2$$

Example 11: *Convert the hexadecimal number F6D9$_{16}$ to its equivalent decimal number*

$$\begin{aligned} F6D9 &= F(16^3) + 6(16^2) + D(16^1) + 9(16^0) = 15\times 16^3 + 6\times 16^2 + 13\times 16^1 + 9\times 16^0 \\ &= 61{,}440 + 1536 + 208 + 9 = 63{,}193_{10} \end{aligned}$$

Example 12: *Convert the hexadecimal number $(B5A)_{16}$ to its equivalent octal number*

Step 1:

Hex to Binary Conversion

B	5	A
1011	0101	1010

So the binary equivalent is 101101011010

Step 2:

Binary to Octal Conversion

<u>101</u>	<u>101</u>	<u>011</u>	<u>010</u>
5	5	3	2

The equivalent octal number is $(5532)_8$