Unit 2: Digital Design Fundamentals and Boolean algebra

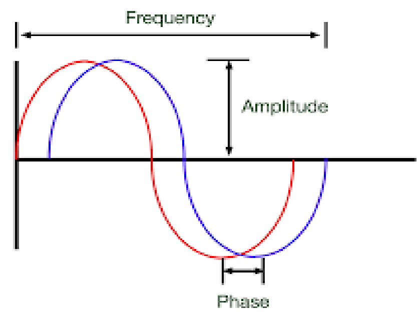
Digital and Analog signal

Signals are used to carry information from one device to another.

Analog Signal:

Analog signal is a kind of continuous wave form that changes over time. We use it most commonly to describe electrical signals. The range of value in an analog signal is not fixed. We use analog signals in a wide variety of applications, such as:

- - Audio recording and reproduction
- - Live sound/amplification devices
- - Older video signal transmission technologies (VGA, S-Video, etc.)
- - Radio signals
- - Television broadcast signals (until recently)



<u>Characteristics of analog signal</u>

1. Amplitude

- Amplitude of a signal refers to the height of the signal.
- It is equal to the vertical distance from a given point on the waveform to the horizontal axis.
- The maximum amplitude of a sine wave is equal to the highest value it reaches on the vertical axis as shown in figure.
- Amplitude is measured in volts, amperes or watts depending on the type of signal. A volt is used for voltage, ampere for current and watts for power.

2. Period

- Period refers to the amount of time in which a signal completes one cycle.
- It is measured in seconds.
- Other units used to measure period are millisecond, microsecond, nanosecond and picoseconds.

3. Frequency

- It refers to the number of wave patterns completed in a given period of time.
- To be more precise, frequency refers to number of periods in one second or number of cycles per second.
- Frequency is measured in Hertz (Hz)
- Other units used to express frequency are kilohertz (10^3 Hz) Megahertz (10^6 Hz), gigahertz (10^9 Hz) and terahertz (10^{12} Hz).
- Frequency and period are the inverse of each other. Period is the inverse of frequency and frequency is the inverse of period.

4. Phase

- Phase describes the position of the waveform relative to time zero.
- Phase describes the amount by which the waveform shifts forward or backward along the time axis.
- It indicates the status of first cycle.
- Phase is measured in degrees or radians.
- A phase shift of 3600 indicates a shift of a complete period, a phase shift of 180° indicates a shift of half period and a phase shift of 90° indicates a shift of a quarter of a period as shown in fig. below.

Digital Signal:

A digital signal - a must for computer processing - is described as using binary (0s and 1s), and therefore, cannot take on any fractional values. As illustrated in the graphic below, digital signals retain a uniform structure, providing a constant and consistent signal. Because of the inherent reliability of the digital signal, technology using it is rapidly replacing a large percentage of analog applications and devices.

Not all audio and video signals are analog. Standardized signals like HDMI for video (and audio) are all digitally transmitted.

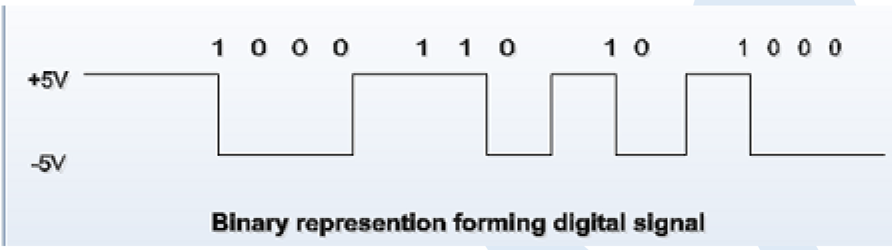
<u>Characteristics of Digital Signals</u>

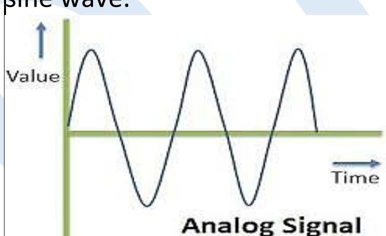
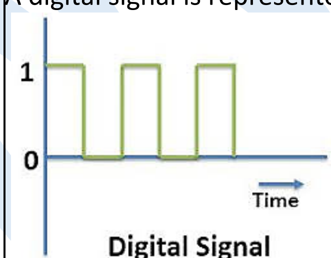
1. Bit interval

    It is the time required to send one single bit

2. Bit rate

    It refers to the number of bit intervals in one second.



BASIS FOR COMPARISON	ANALOG SIGNAL	DIGITAL SIGNAL
Basic	An analog signal is a continuous wave that changes over a time period.	A digital signal is a discrete wave that carries information in binary form.
Representation	An analog signal is represented by a sine wave. 	A digital signal is represented by square waves. 
Description	An analog signal is described by the amplitude, period or frequency, and phase.	A digital signal is described by bit rate and bit intervals.
Range	Analog signal has no fixed range.	Digital signal has a finite number i.e. 0 and 1.
Distortion	An analog signal is more prone to alteration.	A digital signal is less prone to alteration.
Transmit	An analog signal transmit data in the form of a wave.	A digital signal carries data in the binary form i.e. 0 and 1.
Example	The human voice is the best example of an analog signal.	Signals used for transmission in a computer are the digital signal.

Logic Operations

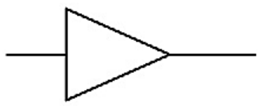
Logic operations include any operations that manipulate Boolean values. Boolean values are either true or false. They are named after English mathematician George Boole, who invented Boolean algebra, and is widely considered the founder of computer science theory. The basic Boolean operators are AND, OR and NOT.

Logic gates

Logic gates are the basic building blocks of any digital system. It is an electronic circuit having one or more than one input and only one output. The relationship between the input and the output is based on a certain logic.

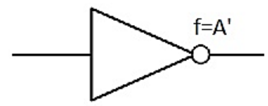
Logic gates with their logic symbol, truth table and logic functions are given below:

Buffer



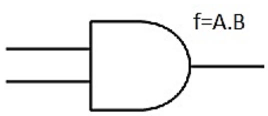
INPUT	OUTPUT
0	0
1	1

NOT gate



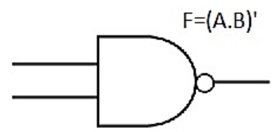
INPUT	OUTPUT
0	1
1	0

AND gate



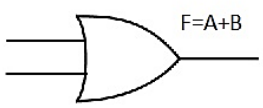
INPUT		OUTPUT
A	B	
0	0	0
0	1	0
1	0	0
1	1	1

NAND gate



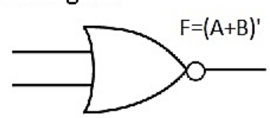
INPUT		OUTPUT
A	B	
0	0	1
0	1	1
1	0	1
1	1	0

OR gate



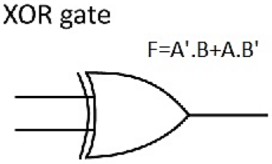
INPUT		OUTPUT
A	B	
0	0	0
0	1	1
1	0	1
1	1	1

NOR gate



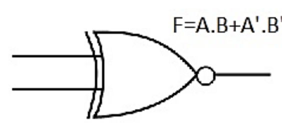
INPUT		OUTPUT
A	B	
0	0	1
0	1	0
1	0	0
1	1	0

XOR gate



INPUT		OUTPUT
A	B	
0	0	0
0	1	1
1	0	1
1	1	0

XNOR gate



INPUT		OUTPUT
A	B	
0	0	1
0	1	0
1	0	0
1	1	1

Logic function and Boolean algebra

Boolean algebra is used to analyze and simplify the digital (logic) circuits. It uses only the binary numbers i.e. 0 and 1. It is also called as Binary Algebra or logical Algebra. Boolean algebra was invented by George Boole in 1854.

Following are the important rules used in Boolean algebra.

- Variable used can have only two values. Binary 1 for HIGH and Binary 0 for LOW.
- Complement of a variable is represented by an overbar (-). Thus, complement of variable B is represented as B Bar. Thus, if B = 0 then B Bar = 1 and B = 1 then B Bar = 0.
- ORing of the variables is represented by a plus (+) sign between them. For example, ORing of A, B, C is represented as A + B + C.
- Logical ANDing of the two or more variable is represented by writing a dot between them such as A.B.C. Sometime the dot may be omitted like ABC.

Boolean Laws

There are six types of Boolean Laws.

1. Commutative law

Commutative law states that changing the sequence of the variables does not have any effect on the output of a logic circuit.

(i) $A.B = B.A$ (ii) $A + B = B + A$

2. Associative law

   This law states that the order in which the logic operations are performed is irrelevant as their effect is the same.

   (i) $(A.B).C = A.(B.C)$ (ii) $(A + B) + C = A + (B + C)$

3. Distributive law

   Distributive law states the following condition.

   $A.(B + C) = A.B + A.C$

4. AND law

   These laws use the AND operation. Therefore they are called as AND laws.

   (i) $A.0 = 0$ (ii) $A.1 = A$

   (iii) $A.A = A$ (iv) $A.\overline{A} = 0$

5. OR law

   These laws use the OR operation. Therefore they are called as OR laws.

   (i) $A + 0 = A$ (ii) $A + 1 = 1$

   (iii) $A + A = A$ (iv) $A + \overline{A} = 1$

6. INVERSION law

   This law uses the NOT operation. The inversion law states that double inversion of a variable results in the original variable itself.

   $\overline{\overline{A}} = A$

7. Demorgans Law

   i) $\overline{A+B} = \overline{A}\,.\,\overline{B}$ ii) $\overline{A.B} = \overline{A} + \overline{B}$

Problems:

1. Obtain the truth table for the function:
   - F= xy + xy' + y'z
   - F = xy + x'y
2. Given the Boolean functions:

   F=xy+x'y'
   - Implement it with AND, OR and NOT gate
   - Implement it with only NOR gate
   - Implement it with only NAND gate
3. What is logic gate? Explain the different logic gates with logic diagram and truth table.
4. Explain different Boolean laws.
5. Prove Demorgans law.
6. Why NAND and NOR gate are called universal gates explain.
7. Differentiate between digital and analog signal.
8. Explain the characteristics of digital and analog signals.

- End of Unit 2 -