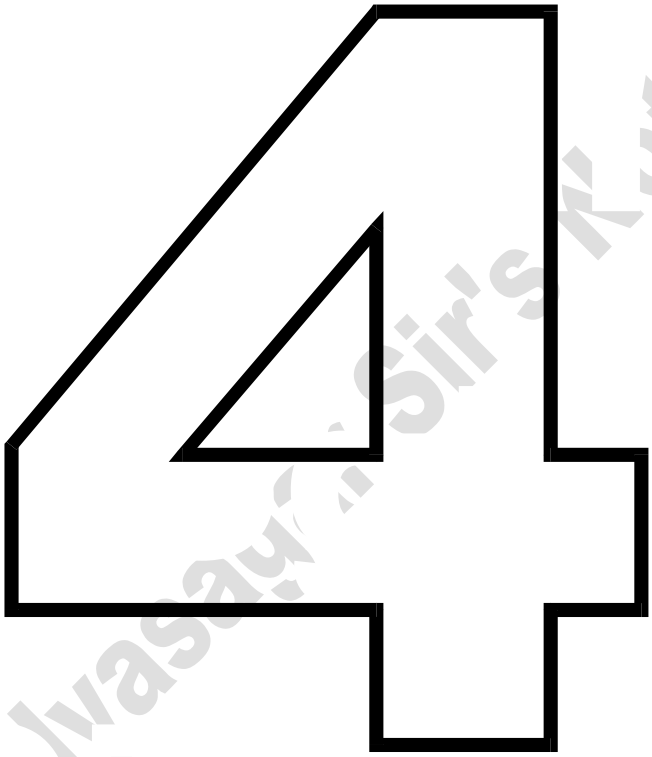


1.26 INTRODUCTION

A combinational logic circuit is a type of logic circuit, which is produced by combining number of different types of logic circuits. Hence, it is called as combinational logic circuit. The output state of this circuit at a particular instant of time depends on the input states at that the same instant. Combinational logic circuit never implements memory circuits in it. Hence, it is also called as real time functional logic circuit. In digital electronics, basically there are two types of circuits: combinational logic circuits and sequential logic circuits. In this chapter, we shall study four combinational logic circuits: multiplexer (Mux), demultiplexer (Demux), encoder and decoder.

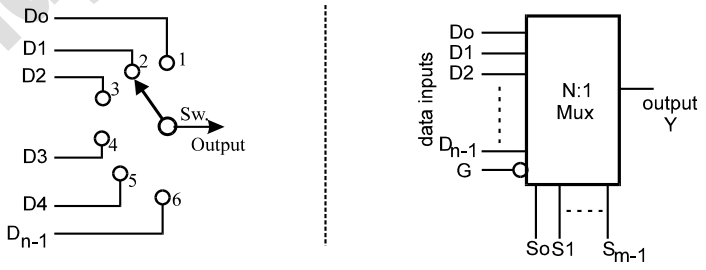
1.27 CONCEPT OF MULTIPLEXER

Definition: Multiplexer is a type of combinational logic circuit, which combines number of input signals to a common output line. It is a data selector logic circuit. Thus, it has many inputs but only one output. *Many is to one is the simple definition of a multiplexer i.e. Mux.*

Details of Mux: A multiplexer has three main sections, data inputs, control inputs and single output.

> It has 'n' number of data inputs.
> It has 'm' number of control inputs, called select inputs.
> It has only one output 'Y'.
> The number of data inputs and number of select inputs are related as $2^m = n$.

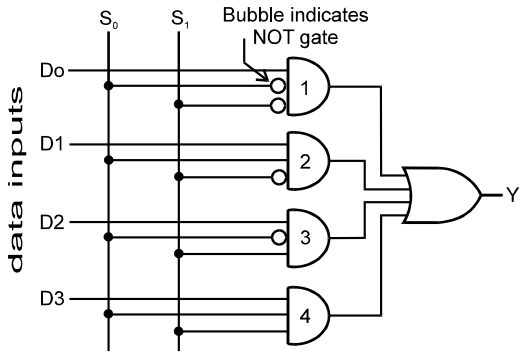
The data inputs are generally indicated as D_0, D_1, D_2, D_3… and the output is indicated by Y. Now to link a particular data input signal at the output terminal, it is selected by number of select inputs of multiplexer like S_0, S_1, S_2, S_3, etc. However, the number of select inputs is decided by the equation $2^m = n$. So if we have a multiplexer circuit with four data inputs (4:1 mux), n = 4, i.e. $D_0D_1D_2D_3$ and the number of select inputs will be m = 2 i.e. S_0 and S_1. The following diagram (left) shows an equivalent arrangement of multiplexer using a rotary switch. When the switch is rotated, only one out of several input signal will be selected at the output. In the same way, the diagram (right) shows a general block diagram of multiplexer. It has (n–1) number of data inputs with only one output. Also it has (m–1) number of select inputs. Every multiplexer has one more input terminal known as Strobe input (G). It helps in cascading number of multiplexers one after another in some applications.



> In circuit diagram *(left)*, when switch is in position-1, only D_0 is available at the output. When the switch is put in position-2, only D_1 is connected to the output and D_0 is cut off. Same action takes place in the circuit diagram *(right)*.

1.27.1 THE 4:1 LINE MULTIPLEXER

The 4:1 line multiplexer combinational logic circuit has 4 data inputs, $D_0D_1D_2D_3$ with single output Y. Also it has two select inputs S_0 and S_1, as shown in the following circuit diagram. By changing the combination of 1's and 0's at the select inputs we can select any one input signal out of four data signals. The combination of 1's and 0's connected to select inputs is called as "control word".



Select inputs		Signal available at output Y
S_0	S_1	
0	0	D_0
1	0	D_1
0	1	D_2
1	1	D_3

Now as per Boolean algebra, we can obtain the output equation as follows –

$$Y = D_0.\overline{S_0}.\overline{S_1} + D_1.S_0.\overline{S_1} + D_2.\overline{S_0}.S_1 + D_3.S_0.S_1$$

Working: The working of the circuit can be explained in four steps as given below –

Suppose $S_0 = S_1 = 0$, then $Y = D_0.\overline{S_0}.\overline{S_1} = D_0.1.1 = D_0$
Suppose $S_0 = 1, S_1 = 0$, then $Y = D_1.S_0.\overline{S_1} = D_1.1.1 = D_1$
Suppose $S_0 = 0, S_1 = 1$, then $Y = D_2.\overline{S_0}.S_1 = D_2.1.1 = D_2$
Suppose $S_0 = 0, S_1 = 1$, then $Y = D_3.S_0.S_1 = D_3.1.1 = D_3$

In this way, only one data signal will be selected out of four data inputs and other signals will be rejected at that particular time.

Multiplexer ICs code numbers

IC 74153 and IC 74352: These are the TTL ICs with dual 4:1 line multiplexer circuit in single package.
IC 74157 and IC 74158: The TTL ICs with quad 2:1 line multiplexer circuit in single IC package.
IC 74150: TTL IC with single multiplexer circuit of 16:1 line Mux.

Advantages of multiplexer

It minimizes the number of ICs and the system cost.
It simplifies the logic design and improves the reliability of the system.
It also reduces the number of signal lines i.e. connecting wires.
Thus, it reduces the thickness of bus.

Applications of Multiplexer

In cable TV network, where a number of channels are multiplexed into a single output.
In closed circuit TV network, where a number of video camera outputs are multiplexed into a single output for single TV monitor.
In RADAR applications, where a number of RADAR signals are multiplexed into a single output.

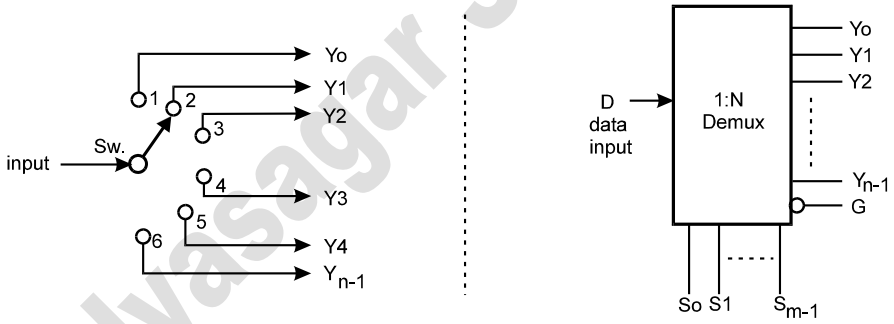
1.28 CONCEPT OF DEMULTIPLEXER

Definition: Demultiplexer is a type of combinational logic circuit, which distributes one input signal to number of output lines. It is a data *distributor* logic circuit. Thus, it has many outputs but only one input. *One is to many, is the simple definition of a demultiplexer i.e. Demux*.

Details of Demux: A demultiplexer has three main sections, data input, control inputs and outputs.

> It has 'n' number of data outputs.
> It has 'm' number of control inputs, called select inputs.
> It has only one input 'D'.
> The number of data outputs and number of select inputs are related as $2^m = n$.

The data outputs are generally indicated as Y_0, Y_1, Y_2, Y_3… and the input is indicated by D. Now to link the input signal to a particular data output terminal, it is selected by number of select inputs like S_0, S_1, S_2, S_3, etc. of the demultiplexer. The number of select inputs is decided by the equation $2^m = n$. So if we have a demultiplexer circuit with four data outputs (1:4 demux), n = 4, i.e. $Y_0Y_1Y_2Y_3$ then the number of select inputs will be m = 2 i.e. S_0 and S_1. The following diagram *(left)* shows an equivalent arrangement of demultiplexer using a rotary switch. When the switch is rotated, the input signal D is available at only one output, out of several output terminals. In the same way, the diagram *(right)* shows a general block diagram of demultiplexer. It has (n–1) number of data outputs with only one input. Also it has (m–1) number of select inputs. Every demultiplexer has one more terminal known as Strobe input (G). It helps in cascading number of demultiplexers one after another in some applications.



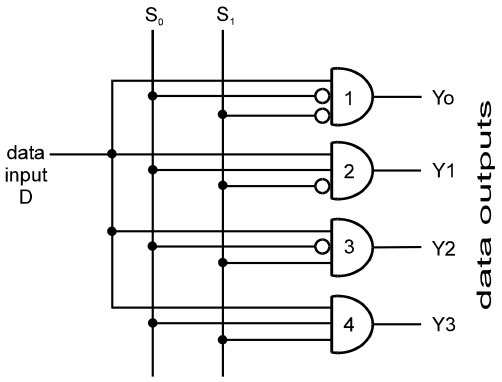
> In circuit diagram *(left)*, when switch is in position-1, the input signal is available at Y_0 only. When the switch is put in position-2, the input signal is available at Y_0 only and Y_0 is cut off. Same action takes place in the circuit diagram *(right)*.

1.28.1 THE 1:4 LINE DEMULTIPLEXER

The 1:4 line demultiplexer combinational logic circuit has 4 data outputs, $Y_0Y_1Y_2Y_3$ with single input D. Also it has two select inputs S_0 and S_1, as shown in the following circuit diagram. By changing the combination of 1's and 0's at the select inputs we can distribute the input signal at any one output terminal. The combination of 1's and 0's connected to select inputs is called as "control word".

Now as per Boolean algebra, we can obtain the output equation as follows –

$$Y_0 = D.\overline{S_0}.\overline{S_1} \qquad Y_1 = D.S_0.\overline{S_1} \qquad Y_2 = D.\overline{S_0}.S_1 \qquad Y_3 = D.S_0.S_1$$



Select inputs		D input available at the output
S_0	S_1	
0	0	Y_0
1	0	Y_1
0	1	Y_2
1	1	Y_3

Working: The working of the circuit can be explained in four steps as given below –

Suppose $S_0 = S_1 = 0$, then $Y_0 = D.\overline{S_0}.\overline{S_1} = D.1.1 \quad \therefore Y_0 = D$
Suppose $S_0 = 1,\ S_1 = 0$, then $Y_1 = D.S_0.\overline{S_1} = D.1.1 \quad \therefore Y_1 = D$
Suppose $S_0 = 0,\ S_1 = 1$, then $Y_2 = D.\overline{S_0}.S_1 = D.1.1 \quad \therefore Y_2 = D$
Suppose $S_0 = 0,\ S_1 = 1$, then $Y_3 = D.S_0.S_1 = D.1.1 \quad \therefore Y_3 = D$

In this way, the data signal will be distributed to only one output terminal and other outputs will be rejected at that particular time.

Demultiplexer ICs code numbers

IC 74139 & IC 74155: It is the TTL IC with dual 1:4 line demultiplexer circuit in single package.
IC 74138: The TTL IC with dual 1:8 line demultiplexer circuit in single IC package.
IC 74154: TTL IC with single multiplexer circuit of 1:16 line demux.

Advantages of demultiplexer

It minimizes the number of ICs and the system cost.
It simplifies the logic design and improves the reliability of the system.
It also reduces the number of signal lines i.e. connecting wires. Thus, it reduces the thickness of bus.

Applications of demultiplexer

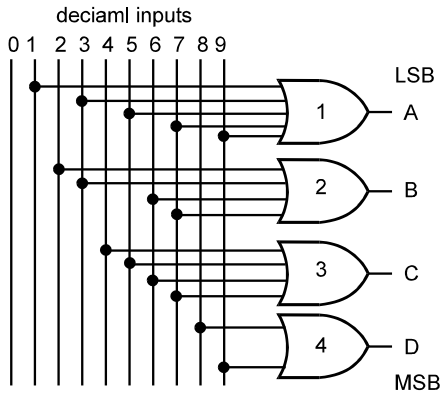
In cable TV network, where a number of channels are demultiplexed into a single output.
In closed circuit TV network, where a number of video camera outputs are demultiplexed into a single output for single TV monitor. In RADAR applications, where a number of RADAR signals are demultiplexed into a single output. *Thus, the applications of mux and demux are same.*

1.29 ENCODER

Definition: Encoder is a combinational logic circuit, which converts decimal value into binary coded form. Hence, the circuit is also called as decimal to BCD encoder.

A simple circuit of encoder is given below. There are four OR gates used in the circuit. Their input terminals are connected to ten different decimal values i.e. from 0 to 9. The outputs of four OR gates are $DCBA$. The output A is at LSB and output D is at MSB.

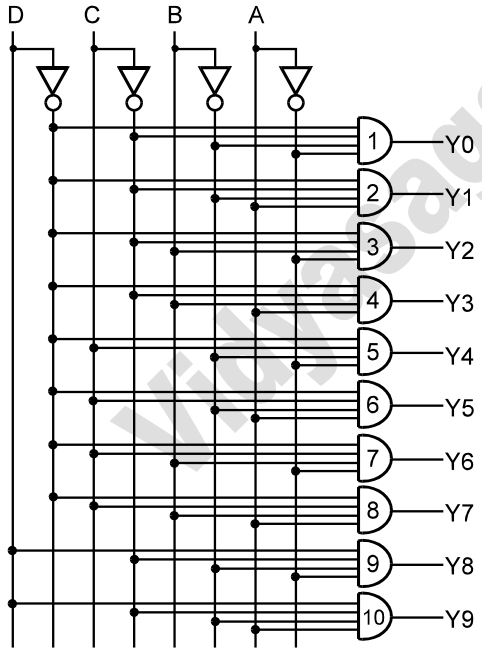
Working: Suppose we apply '1' as decimal input to the circuit, then the output of the circuit will be $DCBA = 0001$. If we apply '5' as decimal input then the circuit converts it into a binary output of $DCBA = 0101$. For decimal input as '0' the output will be $DCBA = 0000$, because the decimal input terminal '0' is actually a dummy input terminal.



Decimal input	Encoded binary outputs			
	D	***C***	***B***	***A***
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

1.30 DECODER

Definition: Decoder is a combinational logic circuit, which converts binary value into decimal form. Hence, the circuit is also called as BCD to decimal decoder. *A decoder is the opposite of encoder. If the output of encoder is DIRECTLY connected to input of decoder, then we get input = output.*

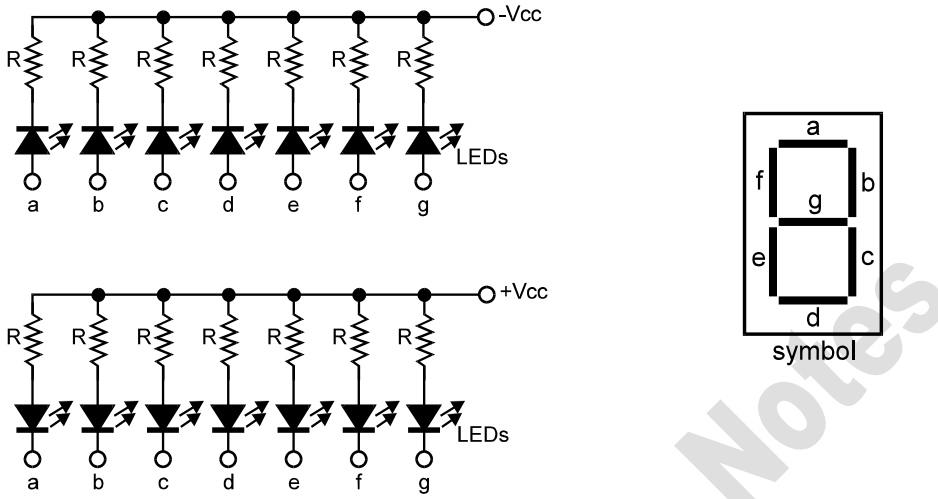


Binary inputs				Outputs
D	***C***	***B***	***A***	
0	0	0	0	$Y_0 = 1$
0	0	0	1	$Y_1 = 1$
0	0	1	0	$Y_2 = 1$
0	0	1	1	$Y_3 = 1$
0	1	0	0	$Y_4 = 1$
0	1	0	1	$Y_5 = 1$
0	1	1	0	$Y_6 = 1$
0	1	1	1	$Y_7 = 1$
1	0	0	0	$Y_8 = 1$
1	0	0	1	$Y_9 = 1$

A general-purpose circuit of decoder is given below. It has 10 AND gates with 4-inputs each. The inputs of each AND gate are connected in a particular combination, to the 8-line network. Out of 8-lines 4-lines are directly connected to input terminals $DCBA$ and other 4-lines are connected to the outputs of 4 NOT gates, which are $\bar{D}\bar{C}\bar{B}\bar{A}$. The outputs of the circuit are taken as $Y_0 - Y_9$. With the help of decoder we can visualize the output in sequential decimal format or in digital format.

1.30.1 SEVEN-SEGMENT LED DISPLAY

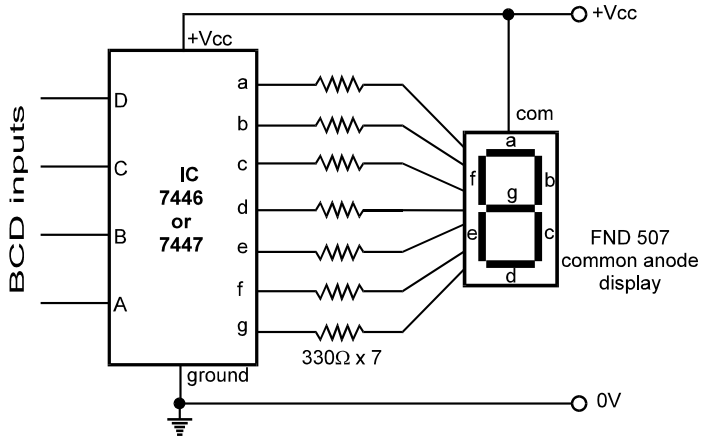
It is a luminescent display, made-up of LEDs of different colors. In such display, seven LEDs are used. They are connected either in *"common anode or common cathode"* styles. Their connection diagrams and symbol are given below –



As shown in above figures, LEDs are connected in either common anode or common cathode styles. These LEDs are fitted in a *plastic case* called display as shown above. For common cathode display, supply voltage is negative and for common anode display supply voltage is positive. Suppose we want to show the digit '5' on common cathode display. In this digit, segments a, f, g, c, d are ON and the remaining are OFF. Thus when terminals $a, f, g, c, d = 1$, decimal '5' will be displayed on it. Similarly, other digits from $0 - 9$ can be displayed by changing the combination. In similar way, common anode display can be used, but the working will be exactly opposite.

1.30.2 BCD TO 7-SEGMENT DECODER IC 7446/IC 7447

This type of integrated circuit can be used to drive a *common anode display* directly. Following circuit diagram shows a simple of decoder circuit using IC 7446/7447. It has 7-outputs, $abcdefg$ with four inputs as $DCBA$, such that D is at MSB and A is at LSB position. The binary input is connected to these inputs and the IC converts each input into its equivalent 7-segment decimal output. This output value is displayed on the FND 507 common anode display.



Working: When BCD signals from $0000 - 1111$ are applied at the input terminals, the IC produces equivalent outputs at its output terminals from $a - g$. The 7-segment display is common anode type. Suppose BCD input is $DCBA = 0101$. It is equivalent to decimal 5. This input is converted into equivalent 7-segment code by the IC and its outputs become $abcde = 0100100$. For the input $DCBA = 1000$, all segments of the display will glow and outputs $abcde = 0000000$ and so on. Following truth table gives more details on the working of the circuit.

BCD inputs	**Decimal outputs**							**Display**
	a	**b**	**c**	**d**	**e**	**f**	**g**	
0000	0	0	0	0	0	0	1	**0**
0001	1	0	0	1	1	1	1	**1**
0010	0	0	1	0	0	1	0	**2**
0011	0	0	0	0	1	1	0	**3**
0100	1	0	0	1	1	0	0	**4**
0101	0	1	0	0	1	0	0	**5**
0110	1	1	0	0	0	0	0	**6**
0111	0	0	0	1	1	1	1	**7**
1000	0	0	0	0	0	0	0	**8**
1001	0	0	0	1	1	0	0	**9**

Self Examination

Objective questions

1. The logic circuit which has many outputs but only one input, such circuit is called as _____.
2. The logic circuit which has many inputs but only one output, such circuit is called as _____.
3. The 8:1 line multiplexer has _____ select input terminals.
4. In demultiplexer circuit, if there are 32 outputs, then the select inputs will be _____.
5. The logic circuit which is used to convert the _____ input into its equivalent binary is called as encoder.
6. The decoder IC 7448 uses _____ 7-segment LED display.
7. In combinational logic circuit the output at any instant of time depends upon _____ input. Thus it does not have any memory.
8. The IC 74153 is known as _____ IC.
9. The IC _____ is used in encoder circuits.
10. A 16:1 multiplexer logic circuit can be constructed using two _____ line multiplexer circuits.

Long answer questions (4 Marks)

1. Explain the procedure of combination of logic design using multiplexer and demultiplexer logic circuits.
2. How an encoder circuit works? Draw its neat logic diagram and explain its working.
3. Draw the circuit of decoder using decoder/driver IC and explain its working with truth table.
4. How will you construct 4:1 line mux? Draw the circuit and explain its working with truth table and output equation.
5. Draw the circuit of 1:4 line demux and explain its working with truth table and also write down its output equations.
6. What are the applications of mux and demux? Give at least two applications of each.
7. What are the IC numbers of multiplexer and demultiplexer ICs? Give at least two code numbers of each logic circuit.

NOTES SPACE