What is a Decoder?

In digital electronics, a combinational logic circuit that converts an N-bit binary input code into M output channels in such a way that only one output channel is activated for each one of the possible combinations of inputs is known as a **decoder**.

In other words, a combinational logic circuit which converts N input lines into a maximum of 2_N output lines is called a **decoder**.

Therefore, a decoder is a combination logic circuit that is capable of identifying or detecting a particular code. The operation that a decoder performs is referred to as decoding. A general block diagram of a decoder is shown in Figure-1.

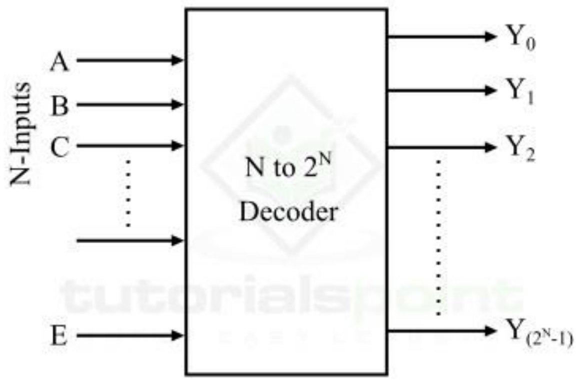


Figure 1 - Decoder

Here, the decoder has N input lines and M (2^N) output lines. In a decoder, each of the N input lines can be a 0 or a 1, hence the number of possible input combinations or codes be equal to 2^N. For each of these input combinations, only one of the M output lines will be active, and all other output lines will remain inactive.

Types of Decoders

There are several types of decoder present. But, based on the input and output lines present, decoders may classified into the following three types −

- 2 to 4 Decoder
- 3 to 8 Decoder
- 4 to 16 Decoder

Now, let us discuss each type of decoder in detail one by one.

2 to 4 Decoder

The 2 to 4 decoder is one that has 2 input lines and 4 (2^2) output lines. The functional block diagram of the 2 to 4 decoder is shown in Figure-2.

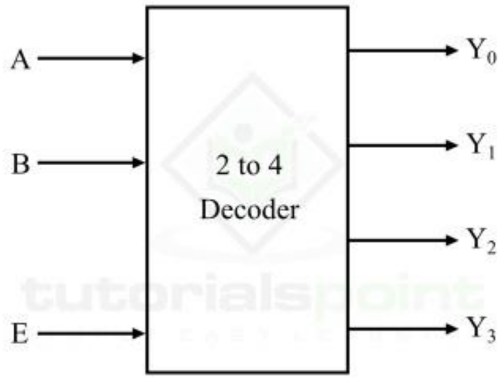


Figure 2 - 2 to 4 Decoder

When this decoder is enabled with the help of enable input E, then its one of the four outputs will be active for each combination of inputs. The operation of this 2-line to 4-line decoder can be analyzed with the help of its truth table which is given below.

Inputs			**Outputs**			
E	**A**	**B**	**Y_3**	**Y_2**	**Y_1**	**Y_0**
0	X	X	0	0	0	0
1	0	0	0	0	0	1
1	0	1	0	0	1	0
1	1	0	0	1	0	0
1	1	1	1	0	0	0

Using this truth table, we can derive the Boolean expression for each output as follows −

$$Y_0 = E \cdot \bar{A} \cdot \bar{B}$$

$$Y_1 = E \cdot \bar{A} \cdot B$$

$$Y_2 = E \cdot A \cdot \bar{B}$$

$$Y_3 = E \cdot A \cdot B$$

As each output term contains products of input variables that can be implemented with the help of AND gates. Therefore, the logic circuit diagram of the 2 to 4 decoder is shown in Figure-3.

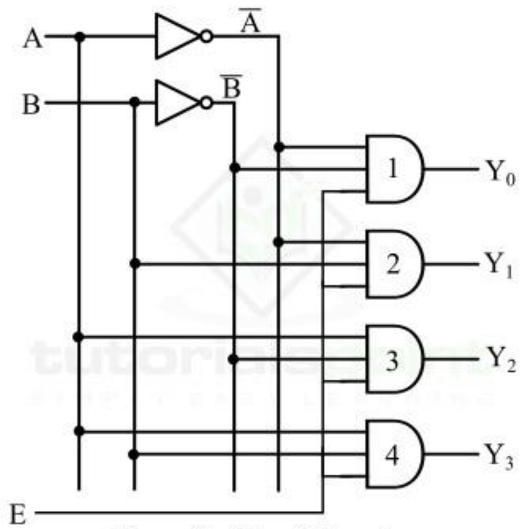


Figure 3 - 2 to 4 Decoder

Operation

The operation of logic circuit of the 2 to 4 decoder is described as follows −

- When enable input (E) is inactive, i.e. set to 0, none of the AND gates will function.
- When enable input (E) is made active by setting it to 1, then the circuit works as explained below.
- When A = 0 and B = 0, the AND gate 1 becomes active and produces output Y_0.
- When A = 0 and B = 1, the AND gate 2 becomes active and produces output Y_1.
- When A = 1 and B = 0, the AND gate 3 becomes active and produces output Y_2.
- When A = 1 and B = 1, the AND gate 4 becomes active and produces output Y_3.

3 to 8 Decoder

The 3 to 8 decoder is one that has 3 input lines and 8 (2^3) output lines. The functional block diagram of the 3 to 8 decoder is shown in Figure-4.

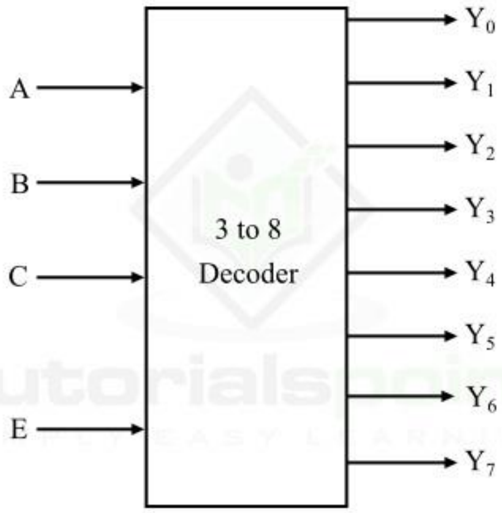


Figure 4 - 3 to 8 Decoder

When this decoder is enabled with the help of enable input E, then it's one of the eight outputs will be active for each combination of inputs. The operation of this 3-line to 8-line decoder can be analyzed with the help of its function table which is given below.

Inputs				**Outputs**							
E	**A**	**B**	**C**	**Y_7**	**Y_6**	**Y_5**	**Y_4**	**Y_3**	**Y_2**	**Y_1**	**Y_0**
0	X	X	X	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	1
1	0	0	1	0	0	0	0	0	0	1	0
1	0	1	0	0	0	0	0	0	1	0	0
1	0	1	1	0	0	0	0	1	0	0	0
1	1	0	0	0	0	0	1	0	0	0	0
1	1	0	1	0	0	1	0	0	0	0	0
1	1	1	0	0	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0

Using this function table, we can derive the Boolean expression for each output as follows −

$$Y_0=E\bar{A}\bar{B}\bar{C}$$

$$Y_1 = E\bar{A}\bar{B}C$$

$$Y_2 = E\bar{A}B\bar{C}$$

$$Y_3 = E\bar{A}BC$$

$$Y_4 = EA\bar{B}\bar{C}$$

$$Y_5 = EA\bar{B}C$$

$$Y_6 = EAB\bar{C}$$

$$Y_7 = EABC$$

As we can see, each output term contains products of input variables, hence they can be implemented with the help of AND gates. Therefore, the logic circuit diagram of the 3 to 8 decoder is shown in Figure-5.

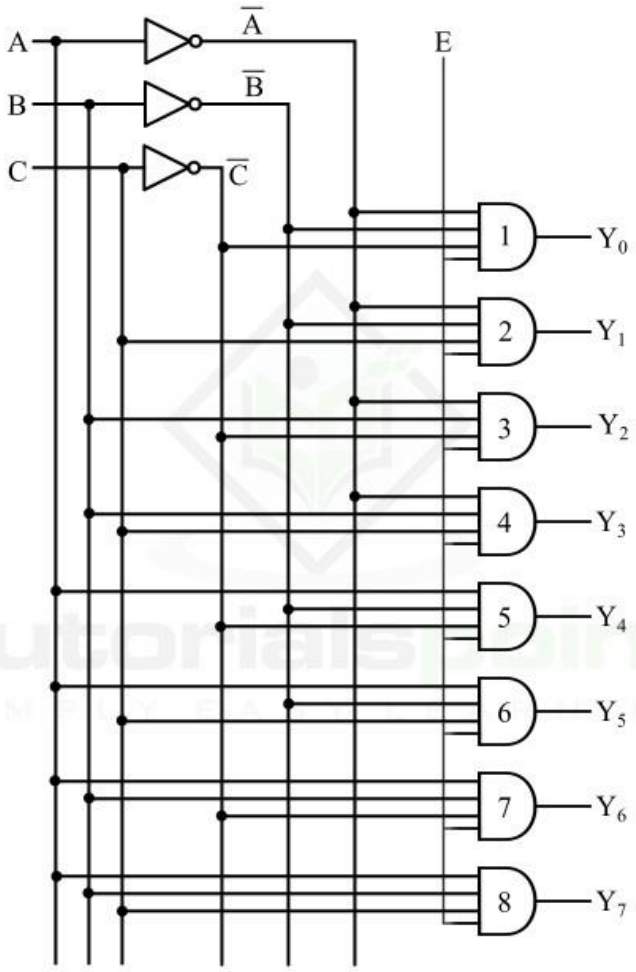


Figure 5 - 3 to 8 Decoder

Operation

The operation of logic circuit of the 3 to 8 decoder is described as follows −

- When enable input (E) is inactive, i.e. set to 0, none of the AND gates will function.
- When enable input (E) is made active by setting it to 1, then the circuit works as described below.
- When A = 0, B = 0, and C = 0, the AND gate 1 becomes active and produces output Y_0.
- When A = 0, B = 0, and C = 1, the AND gate 2 becomes active and produces output Y_1.
- When A = 0, B = 1, and C = 0, the AND gate 3 becomes active and produces output Y_2.
- When A = 0, B = 1, and C = 1, the AND gate 4 becomes active and produces output Y_3.
- When A = 1, B = 0, and C = 0, the AND gate 5 becomes active and produces output Y_4.
- When A = 1, B = 0, and C = 1, the AND gate 6 becomes active and produces output Y_5.
- When A = 1, B = 1, and C = 0, the AND gate 7 becomes active and produces output Y_6.
- When A = 1, B = 1, and C = 1, the AND gate 8 becomes active and produces output Y_7.

4 to 16 Decoder

The 4 to 16 decoder is the type of decoder which has 4 input lines and 16 (2^{14}) output lines. The functional block diagram of the 4 to 16 decoder is shown in Figure-6.

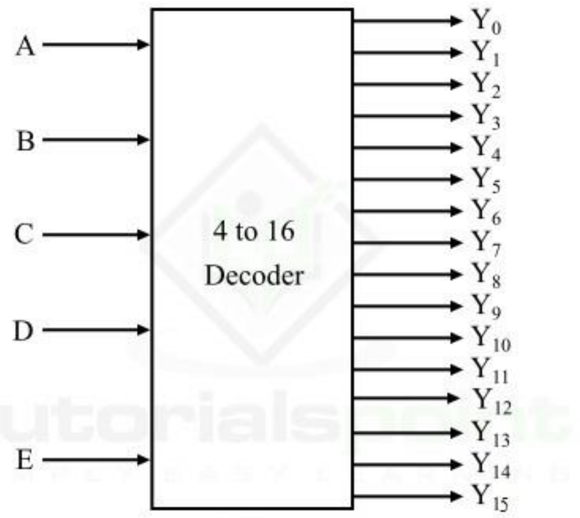


Figure 6 - 4 to 16 Decoder

When this decoder is enabled with the help of enable input E, it's one of the sixteen outputs will be active for each combination of inputs. The operation of the 4-line to 16-line decoder can be analyzed with the help of its function table which is given below.

Inputs					**Output**
E	**A**	**B**	**C**	**D**	
0	X	X	X	X	0
1	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	1	0	1	0	Y_{10}
1	1	0	1	1	Y_{11}
1	1	1	0	0	Y_{12}
1	1	1	0	1	Y_{13}
1	1	1	1	0	Y_{14}
1	1	1	1	1	Y_{15}

From this function table, we can directly write the Boolean expression for each output as follows −

$$Y_0=E\bar{A}\bar{B}\bar{C}\bar{D}$$

$$Y_1=E\bar{A}\bar{B}\bar{C}D$$

$$Y_2=E\bar{A}\bar{B}C\bar{D}$$

$$Y_3=E\bar{A}\bar{B}CD$$

$$Y_4=E\bar{A}B\bar{C}\bar{D}$$

$$Y_5=E\bar{A}B\bar{C}D$$

$$Y_6=E\bar{A}BC\bar{D}$$

$$Y_7=E\bar{A}BCD$$

$$Y_8=EA\bar{B}\bar{C}\bar{D}$$

$$Y_9=EA\bar{B}\bar{C}D$$

$$Y_{10}=EA\bar{B}C\bar{D}$$

$$Y_{11}=EA\bar{B}CD$$

$$Y_{12}=EAB\bar{C}\bar{D}$$

$$Y_{13}=EAB\bar{C}D$$

$$Y_{14}=EABC\bar{D}$$

$$Y_{15}=EABCD$$

We can implement these output expression in the same way as we done for the 2 to 4 decoder and 3 to 8 decoder.

Applications of Decoders

Decoders are used in the cases where an output or a collection of outputs is to be activated only on the occurrence of a particular combination of input codes. Some important applications of decoders are listed below −

- Decoders are used for code conversions.
- Decoders are extensively used in memory systems of computers.
- Decoders are also used for de-multiplexing or data distribution.
- Decoders are also used in data routing applications where very short propagation delay is required.
- Decoder may also be used for timing or sequencing purposes.
- Decoders are also utilized to turn on and off digital devices at a specific time.

What is an Encoder?

An **encoder** is a digital combinational circuit that converts a human friendly information into a coded format for processing using machines. In simple words, an encoder converts a piece of information normal form to coded form. This process is called encoding.

Encoders are crucial components in various digital electronics applications such as data transmission, controlling and automation, communication, signal processing, etc.

An encoder consists of a certain number of input and output lines. Where, an encoder can have maximum of "2^n" input lines whereas "n" output lines. Hence, an encoder encodes information represented by "2^n" input lines with "n" bits.

The **block diagram of an encoder** is shown in the following figure −

Let us now discuss different types of encoders commonly used in digital electronic applications.

Types of Encoders

Some of the commonly used types of encoders in digital electronics −

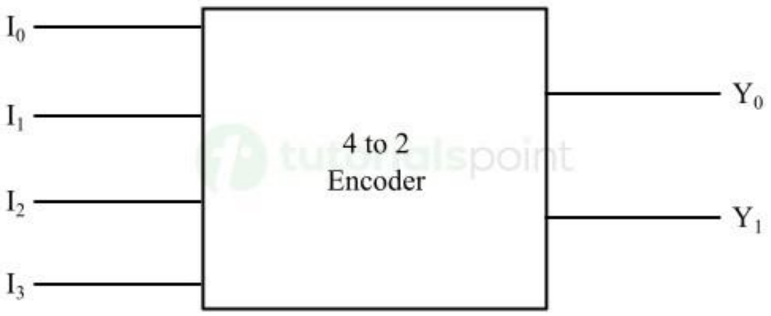
- 4 to 2 Encoder
- 8 to 3 Encoder (Octal Encoder)
- Decimal to BCD Encoder

Let us now discuss these three types of most commonly used encoders in detail.

4 to 2 Encoder

A 4 to 2 Encoder is a type of encoder which has 4 (2^2) input lines and 2 output lines. It produces an output code (i.e., convert input information in a 2-bit format) depending on the combination of input lines.

The block diagram of a 4 to 2 Encoder is shown in the following figure.



The working of a 4 to 2 Encoder for different input combinations is described in the following truth table −

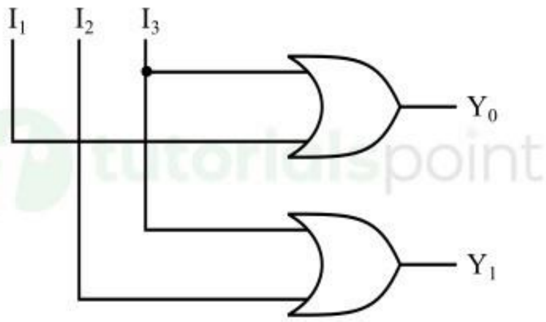
Inputs				Outputs	
I_3	**I_2**	**I_1**	**I_0**	**Y_1**	**Y_0**
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1

From this truth table, we can derive the Boolean expression for each output of the 4 to 2 Encoder as follows −

$$Y_0=I_1+I_3$$

$$Y_1=I_2+I_3$$

It is clear that we can implement the logic circuit of the 4 to 2 Encoder using two OR gates. The following figure depicts the logic diagram of the 4 to 2 Encoder.



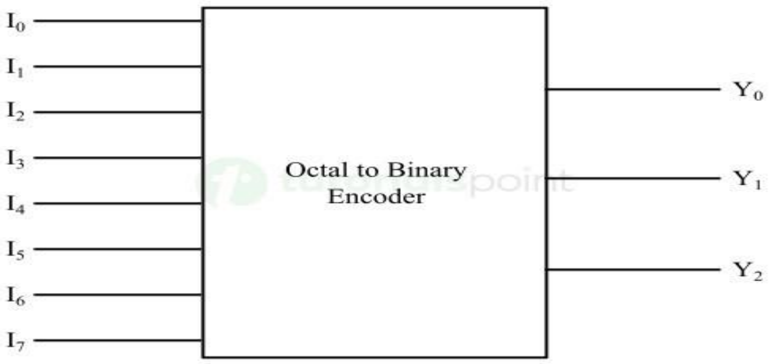
Applications of 4 to 2 Encoder

The 4 to 2 Encoder is widely used in the following applications: Data multiplexing, Generating digital control signals, Address decoding applications, Encoding data in digital systems, etc.

Octal to Binary Encoder

The octal to binary encoder is a type of encoder that converts an octal code into binary code. It accepts 8 input lines and produces a 3-bit output depending on the combination of input lines. Therefore, it is also known as **8 to 3 Encoder**.

The **block diagram of an octal to binary encoder** is shown in the following figure −



The following truth table describes the working of an octal to binary encoder −

Inputs								Outputs		
I_7	I_6	I_5	I_4	I_3	I_2	I_1	I_0	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	1	0	0	0

0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	1
0	0	0	1	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	0	0	1	1	0
1	0	0	0	0	0	0	0	1	1	1

From this truth table, we can write the Boolean expression for the outputs of the octal to binary encoder as follows.

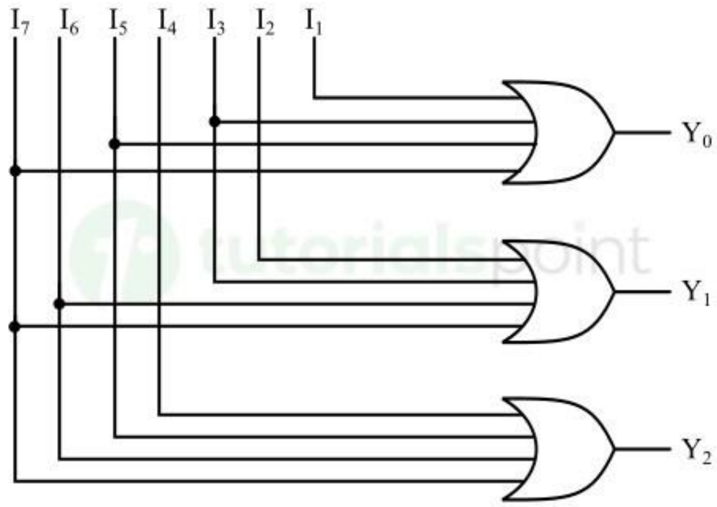
$$Y_0=I_1+I_3+I_5+I_7$$

$$Y_1=I_2+I_3+I_6+I_7$$

$$Y_2=I_4+I_5+I_6+I_7$$

From these expressions, it is clear that the implementation of an octal to binary encoder requires 3 OR gates.

The logic circuit diagram of the octal to binary encoder is shown in the following figure −



Applications of Octal to Binary Encoder

The octal to binary encoder is used in the following applications −

- Data conversion in digital systems.
- Conversion of octal memory addresses into binary memory addresses.
- In microprocessors and microcontrollers, to convert octal instructions into binary format.
- In communication systems, to encode octal data into binary form for transmission, etc.

Decimal to BCD Encoder

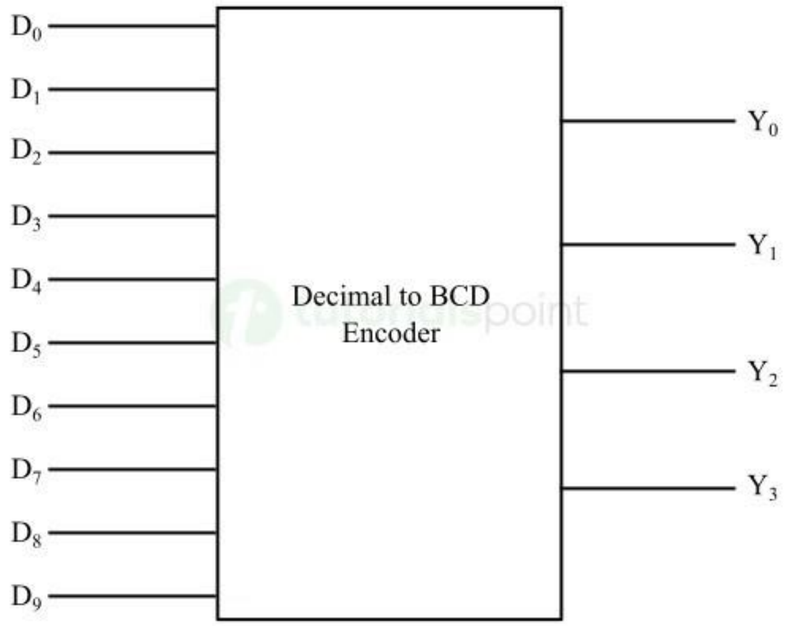
A type of encoder that can convert a decimal number or information represented using decimal number into its equivalent binary-coded decimal (BCD) format is known as a decimal to BCD encoder.

In the BCD encoding scheme, each decimal digit can be converted into a 4-bit binary representation. The following table shows the BCD equivalents of decimal digital from 0 to 9.

Decimal Digit	**BCD Code**			
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

The decimal to BCD encoder accepts 10 input lines and produces a 4-bit BCD output depending on the combination of input lines. Therefore, sometimes it is also called a 10 to 4 encoder.

The following illustration depicts the block diagram of a decimal to BCD encoder.



The truth table describing the working of the decimal to BCD encoder is given blow −

Inputs										Outputs			
D_9	D_8	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	0	1	0	1
0	0	0	1	0	0	0	0	0	0	0	1	1	0
0	0	1	0	0	0	0	0	0	0	0	1	1	1
0	1	0	0	0	0	0	0	0	0	1	0	0	0
1	0	0	0	0	0	0	0	0	0	1	0	0	1

From this truth table, we can write the Boolean expression of the decimal to BCD encoder as follows.

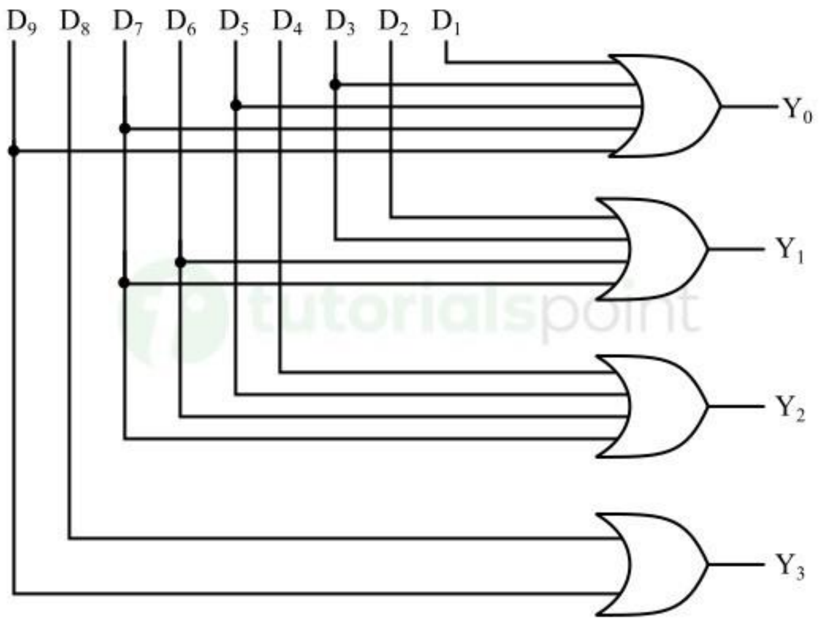
$Y_0 = D_1 + D_3 + D_5 + D_7 + D_9$

$Y_1 = D_2 + D_3 + D_6 + D_7$

$Y_2 = D_4 + D_5 + D_6 + D_7$

$Y_3 = D_8 + D_9$

The **logic circuit of the decimal to BCD encoder** can be implemented using four OR gates which is shown in the following figure −



Applications of Decimal to BCD Encoder

Decimal to BCD encoders find their application in digital clocks and timers, data processing devices and storage systems, calculators, measuring instruments, display devices, microprocessors, microcontrollers, embedded systems, etc.