Experiment (6)

Decoders / Encoders

8.1 Objectives :

- To study the basic operation and design of both decoder and encoder circuits.
- To describe the concept of active –low and active-high logic signals.
- To learn how to use the n-to-2^n type decoders to implement a given Boolean function.
- To learn how to use 7-segment LED display along with a seven-segment decoder to create decimal digits.

8.2 Background Information :

Decoders :

A decoder is a combinational circuit that converts coded inputs to another coded outputs. The famous examples of decoders are binary n-to-2^n decoders and seven-segment decoders.

A binary decoder has n inputs and a maximum of 2^n outputs. As we know, an n-bit binary number provides 2^n minterms or maxterms. This type of decoder produces one of the 2^n minterms or maxterms at the outputs based on the input combinations.

Lets take the 2-to-4 decoder as an example, the block diagram and the truth table of this decoder is shown in Figure 8.1 and Table 8.1 respectively.

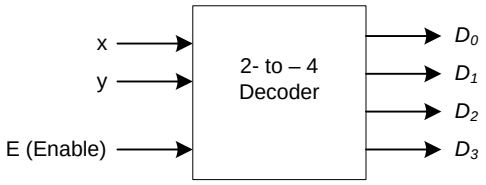

Figure 8.1 Block Diagram of 2-to-4 Decoder

E	x	y	D_0	D_1	D_2	D_3
0	X	X	0	0	0	0
1	0	0	1	0	0	0
1	0	1	0	1	0	0
1	1	0	0	0	1	0
1	1	1	0	0	0	1

Table 8.1 Truth table of 2-to-4 Decoder

From the truth table, you can observe the basic operation of n-to-2^n decoders, there is only one active output (minterm) for each input combination. The Boolean expression of the output signals are :

$$D_0 = E\,x'\,y',\ D_1 = E\,x'\,y,\ D_2 = E\,x\,y' \text{ and } D_3 = E\,x\,y$$

Now, the logic diagram for the 2-to-4 decoder can obtained as shown in Figure 8.2.

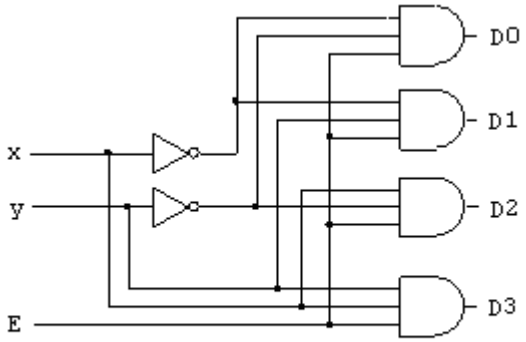

Figure8.2 Logic Diagram for the 2-to-4 Decoder

In the same way, we can obtained the logic diagram for any n-to-2^n type decoder.

The commercially available decoders are normally built using NAND gates instead of using AND gates because they are easy and less expensive to build. An example of a commercial n-to-2^n line decoder is the 74139 chip. This chip has two 2-to-4 decoders with active low enable for each , They constructed using the NAND gates (see its pinout diagram and Function Table)

Because any Boolean function can be expressed as a sum of products (minterms) or a product of sums (maxterms), we can use a decoder to implement any Boolean function. For example, consider the full-adder circuit illustrated in figure 4.6. The Boolean expressions for the outputs S and C are :

$$S = x'y'z + x'yz' + xy'z' + xyz$$
$$C = x'yz + xy'z + xyz' + xyz$$

The above expressions can be implemented by ORING the appropriate combination of output minterms of a 3-to-8 decoder :

$$S = D_1 + D_2 + D_4 + D_7$$
$$C = D_3 + D_5 + D_6 + D_7$$

Seven-Segment Display

Another common type of decoder is the **seven-segment decoder**. This decoder is used along with seven-segment LED display to create a decimal or hexadecimal digits. The Seven-segment LED display is commonly used for numerical display as in multimeters and calculators, it contains seven independent LEDs arranged as shown in Figure 8.3.

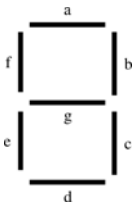

Figure 8.3 A Seven-Segment Display

There are two main types of seven-segment LEDs, the common cathode (CC) and the common anode (CA). In the CC type, the cathodes for all segments are joined in a single node. On the other hand in CA type, the anodes are joined together in a single node. (see Figure 8.4)

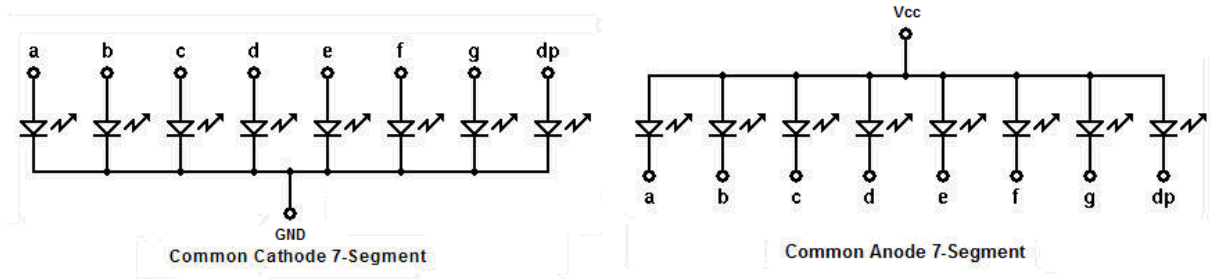

Figure 8.4 Types of 7-Segment Display

All decimal or hexadecimal numbers can be displayed by controlling the state of the appropriate segments ON or OFF. This can be done using a seven-segment decoder, a seven-segment decoder accepts four binary inputs and provides seven outputs that determines which of the segments on a seven-segment LED display should be on or off to create a decimal or hexadecimal digits.

As an example of the commercial 7-segment decoder is the 7447 chip, This is a BCD to seven-segment decoder which used for displaying the numbers from 0 trough 9 based on the corresponding input BCD number. This chip is design for use with to a common anode seven segment display. It has active-low outputs (see Pin-Out Diagram and Function Table).

The circuit for the BCD to 7-Segment is shown in Figure 8.5

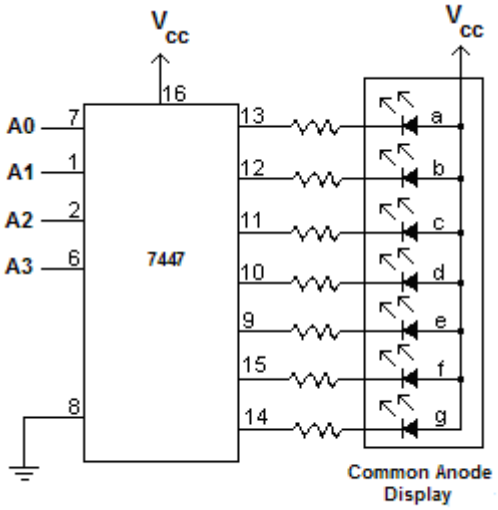

Figure8.5 BCD to Seven-Segm ent

Encoders:

The encoder is a combinational circuit that performs the reverse operation of the decoder. The encoder has a maximum of 2^n inputs and n outputs. The block diagram and the truth table of a 4-to-2 encoder are shown in Figure8.6 and Table8.2 respectively.

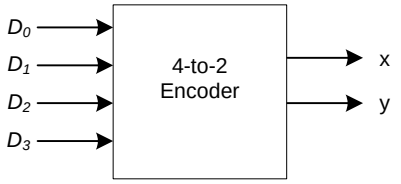

Figure 8.6 Block Diagram of 4-to-2 Encoder

D_0	D_1	D_2	D_3	x	y
1	0	0	0	0	0
0	1	0	0	0	1
0	0	1	0	1	0
0	0	0	1	1	1

Table 8.2 truth table For the 4-to-2 encoder

From the truth table, we can expressed the outputs as :

$$x = D_2 + D_3$$
$$y = D_1 + D_3$$

Therefore, the logic diagram for the 4-to-2 Encoder can be obtained as shown in Figure 8.7.

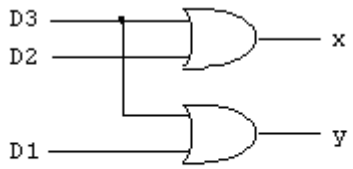

Figure8.7 Logic Diagram of the 2-to-4 Encoder

8.3 Equipments Required :

Universal Breadboard
Jumper wire kit
2x 7411 TRIPLE 3-INPUT AND
1x 7404 HEX INVERTERS
1x 7447 BCD-TO-SEVEN SEGMENT DECODERS/DRIVERS
1x Common Anode (CA) Seven-Segment LED Display (MAN72A)
4x Toggle Switches
7x Carbon-film Resistors (470Ω)
4x LEDs

8.4 Procedure :

Step 1 :

1. Construct the logic circuit of 2-to-4 Decoder that shown in Figure 8.2.
2. Try all input combinations and fill in the following truth table :

E	x	y	D_0	D_1	D_2	D_3
0	X	X				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

Step 2 :

1. Construct the circuit of BCD to 7-segment LED display.
2. Verify the function of the circuit by applying different BCD numbers and monitoring the corresponding decimal digits on the 7-segment LED display,
3. Complete the following table by filling in the segments.

A_3	A_2	A_1	A_0	Fill in Seg's
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	

A_3	A_2	A_1	A_0	Fill in Seg's
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	

Questions :

1. Design a 3-to-8 decoder with active low enable input E. When E is low, the decoder will function normally, when E is high, all outputs should be high regardless of the inputs.
2. Derive the simplified Boolean expressions for the seven outputs (a,b,c,d,e,f & g) of the 7447 decoder. (Remember, the selected outputs are LOW signals in this decoder)
3. Implement the following Boolean functions using a decoder and external gates:

$$F_1(A,B,C) = A'B'C' + AB'C + AB'$$
$$F_2(A,B,C) = ABC + ABC'$$

4. Give summary of the points you have learned from the experiment.