# **EXPERIMENT #7: DECODERS AND CODE CONVERTERS**

#### **OBJECTIVES:**

- Implement circuits with multiple outputs
- Design and implement a code converter
- Implement a BCD-to-Seven-Segment decoder

## **Equipment and ICs:**

- Mini-Lab ML-2001 lab station
- 1 IC 7493 4-bit Ripple Counter
- 1 IC 7446 BCD-to-Seven-Segment decoder
- 2 IC 7400 Quad 2-input NAND gates
- 1 IC 7410 Triple 3-input NAND gates
- 1 IC 7420 Dual 4-input NAND gates
- 2 IC 7408 Quad 2-input AND gates
- 2 IC 7411 Triple 3-input AND gates
- 2 IC 74138 3 x 8 Decoder

## Introduction:

#### Decoders

A decoder is a combinational circuit that converts binary information from n input lines to a maximum of  $2^n$  output lines. Logic circuit implementation with basic logic gates involves obtaining simplified Boolean expressions for each output. Implementation with MSI decoders is very simple and straightforward and may require a few external gates.

The implementation of functions  $F = \Sigma (1, 2, 3)$  and  $G = \Sigma (5, 6, 7, 8, 9)$  using a 4 x 16 decoder is shown below. Since a decoder generates minterms at its outputs we need only to sum the minterms for which F and G are 1. Hence, we require OR gates to produce F and G.



If the decoder is constructed using NAND gates, then it has active low outputs. In this case, NAND and/or AND gates could be used to sum the minterms of F and G.



#### **Code Converters**

A code converter is a circuit that makes two digital systems using different codes for the same information compatible even though each uses a different code. To convert from binary code A to binary code B, the input lines must supply the bit combination of elements as specified by code A and the output lines must generate the corresponding bit combination of code B.

The circuit for this code converter can be implemented using basic logic gates or with available MSI devices such as Decoders, and Multiplexers. The unused input combinations can be treated as don't cares. The truth table of Gray code to binary code converter is shown here.

Decimal	Gray	Binary			
0	0000	0000			
1	0001	0001			
2	0011	0010			
3	0010	0011			
4	0110	0100			
5	0111	0101			
6	0101	0110			
7	0100	0111			
8	1100	1000			
9	1101	1001			
10	1111	1010			
11	1110	1011			
12	1010	1100			
13	1011	1101			
14	1001	1110			
15	1000	1111			

В

С

#### Seven-Segment LED Display:

A light emitting Diode (LED) is a PN junction diode. When the diode is forward biased, a current flows through the junction and the light is emitted.



A seven segment LED display contains 7 LEDs. Each LED is called a segment and they are identified as (a, b, c, d, e, f, g) segments. Digits (0 - F) represented by the 7 segments are shown below:



The display has 7 inputs each connected to an LED segment. Seven-Segment displays are of two types – Common Anode and Common Cathode. When all anodes of LEDs are tied together and joined to 5 volts this type is called common anode type, and when all cathodes of LEDs are tied together and connected to ground this type is called common cathode type. For further information and pin connections, consult the specification sheet for decoder and 7-segment units. A limiting resistance network must be used at the inputs to protect the 7-segment from overloading.

For example, to represent digit zero: **a b c d e f g** = **0 0 0 0 0 1** for Common Anode type **a b c d e f g** = **1 1 1 1 1 1 0** for Common Cathode type

#### Part 1: Code Converter

Design a circuit for BCD to 631(-1) code converter using two 3 x 8 decoders and external NAND and/or AND gates.

	BI	DC		6 3 1 (-1)
Α	B	С	D	WXYZ
0	0	0	0	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	
0	1	1	1	
1	0	0	0	
1	0	0	1	1 1 0 0

**Pre-lab Work:** (All Pre-lab work must be shown in the Pre-lab report)

1. Complete the above truth table for the code converter with inputs A, B, C, D and outputs W, X, Y, Z.



- 2. Obtain the simplified Boolean expressions for the four outputs using K-map method.
- 3. Draw the logic diagram of a 4 x 16 decoder using two 3 x 8 decoders constructed with NAND gates (active LOW outputs).
- 4. Implement outputs W, X, Y, Z using the 4 x 16 decoder constructed in Step 3 and NAND and/or AND gates. You may use **only**: (2-input, 3-input, and 4-input NAND gates), and (2-input, and 3-input AND gates).
- 5. Draw and simulate your circuit in LogicWorks. Include your LogicWorks drawing in the pre-lab report.

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Lab Work: (All Lab work must be shown in the Lab report)

- 1. Implement the logic diagram of the Code Converter on the proto-board using two 3 x 8 decoders (IC 74LS138) and NAND and/or AND gates. You may use **only**: (2-input, 3-input, and 4-input NAND gates), and (2-input, and 3-input AND gates).
  - a. Connect IC 7493 as a binary counter.
  - b. Connect the 4 outputs of IC 7493 to inputs A, B, C, and D.
  - c. Connect the four outputs to four LEDs or indicator lamps as shown below.



- 2. Apply all 16 combinations (0000-1111) of 4 inputs to your circuit through IC 7493 by pushing the Pulser-button as many times. You can observe the input sequence on the 4 indicator lamps connected with the outputs of IC 7493.
- 3. Observe the four outputs for all combinations of inputs (switches). Record your observations in a truth table.
- 4. Compare the truth table above with the truth table obtained in Step 1 of Pre-Lab work and verify the operation of the circuit.
- 5. Compute the cost of the circuit in terms of gates and ICs.

#### **OBSERVATIONS**:

	BI	DC		6 3 1 (-1)
Α	B	С	D	WXYZ
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	
0	1	1	1	
1	0	0	0	
1	0	0	1	

## Part 2: Seven-Segment Decoder

Implement the following BCD-to-Seven-Segment decoder circuit using (IC 7447).



**Pre-lab Work:** (All Pre-lab work must be shown in the Pre-lab report)

1. Complete the truth table below for the BCD-to-Seven-Segment decoder with inputs A, B, C, D and outputs a, b, c, d, e, f, g for common anode Seven-Segment display.

Dec.	BCD			Outputs							
	Α	В	С	D	a	b	С	d	e	f	g
0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	1							
2	0	0	0	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	0	0	0	0	1	0	0

Lab Work: (All Lab work must be shown in the Lab report)

- 1. Implement the logic diagram of the Code Converter on the proto-board.
  - a. Connect IC 7493 as a BCD counter
  - b. Connect the 4 outputs of IC 7493 to inputs A, B, C, and D.
  - c. Connect the 4 outputs of IC 7493 to four LED's.
  - d. Connect the seven outputs of IC 7447 to the Seven-Segment LED display as shown below.





- 2. Apply all 10 combinations (0000-1001) of inputs to your circuit through IC 7493 by pushing the Pulser-button as many times. You can observe the input sequence on the 4 indicator lamps connected with the outputs of IC 7493.
- 3. Verify that the Seven-Segment display shows the Decimal value corresponding to the 4-bit BCD input.
- 4. Now connect IC 7493 as a 4-bit binary counter.
  - Disconnect pin 2 from pin 9 and pin 3 from pin 11.
  - Connect pin 2 and 3 to ground.
  - Do not change any other connections in your circuit.

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- 5. Apply all 16 combinations (0000-1111) of inputs to your circuit through IC 7493 by pushing the Pulser-button as many times.
- 6. What do you observe on the Seven-Segment display when the input exceeds 9 (1001)?
- 7. Comment on the circuit design if you see invalid digits on the Seven-Segment display.

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