

Practical Workbook

CS-220

Digital Logic Design



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Roll No :	<hr/> <hr/>	
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Teacher :	<hr/> <hr/>	
Department:	<hr/> <hr/>	

**Department of Computer & Information Systems
Engineering
NED University of Engineering & Technology**

Practical Workbook

CS-220

Digital Logic Design



Prepared by:

Ms. Anita Ali

Revised in:

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**Department of Computer & Information Systems Engineering
NED University of Engineering & Technology**

INTRODUCTION

Digital Logic Design is the one of the fundamental courses taught in CIS Department. The digital logic design area covers the digital building blocks, tools, and techniques in the design of computers and other digital systems. It is one of the areas that differentiate computer engineers from electrical engineers and computer scientists. It covers a variety of basic topics, including switching theory, combinational and sequential logic circuits, and memory elements.

The course profile of CS-220 Digital Logic Design lays down the following Course Learning Outcome:

“Practice designing and testing digital logic circuit of MSI (medium scale integration)

level

(P3, PLO-3)”

All lab sessions of this workbook have been designed to assist the achievement of the above CLO. A rubric to evaluate student performance has been provided at the end of the workbook. In this Practical Workbook, laboratory sessions based on both combinational and sequential logic are covered. The lab sessions fall into two categories:

1. Hardware implementation and IC testing. It covers combinational and sequential circuit building on a bread board or logic trainer board, and testing of various MSI ICs including registers and different types of counters.
2. Logic circuit simulation on CAD software – Electronics Workbench (EWB). EWB is excellent simulation software for beginners, where circuits can be designed and tested before physical implementation. Various laboratory sessions of this workbook provide activities and exercises on EWB.

All laboratory sessions of this workbook incorporate brief theoretical backgrounds, as details may be covered in the respective theory classes. Exercises / activities are included with all the sessions for the students to practice.

Three appendices are also included in this workbook. The first one provides pin diagrams for all the ICs required for the laboratory work provided in this workbook. It will help the students in preparing the pin diagrams for the circuits. Second appendix covers hardware equipment /components other than ICs that are commonly required in building circuits / mini projects. Third appendix discusses generation of square wave via 555 timer IC and a hardware debouncing circuit for mechanical switches as such switches are extensively used for input purpose in logic circuits.

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Lab Session 01

Practice logic circuits simulation

ELECTRONICS WORKBENCH – EWB

Electronics Workbench is a computer aided design tool that provides you with all the components and instruments necessary to create board-level designs. It has complete mixed analog and digital simulation and graphical waveform analysis, allowing you to design your circuit and then analyze it using different simulated instruments and analysis options. It is fully integrated and interactive, thus you can change your circuits quickly, allowing fast and repeated what-if analysis.

Electronics Workbench provides the following kind of components:

- Sources parts bin (*AC voltage source, Vcc source, ground, battery, etc*)
- Basic parts bin (*resistors, capacitors, transformers, switches, etc*)
- Diodes parts bin
- Transistors parts bin
- Analog ICs parts bin (*op-amps, etc*)
- Mixed ICs parts bin (*ADCs, DACs, 555 timers, etc*)
- Digital ICs parts bin (*AND, OR, adders, multiplexers, etc*)
- Indicators parts bin (*voltmeter, ammeter, probe, displays, etc*)
- Controls parts bin (*voltage differentiator, multiplier, etc*)
- Instruments parts bin (*multimeter, oscilloscope, function generator, etc*)
- Miscellaneous parts bin (*write data, textbox, etc*)
 - *Write data*: This component allows you to save simulation results as an ASCII file.
 - *Text Box*: Use this to add descriptive text anywhere in a circuit.

DESIGNING LOGIC CIRCUIT FOR A GIVEN LOGIC EXPRESSION

Given Logic Expression: $F = \overline{A} \cdot B + A \cdot \overline{B} \cdot C$

Procedure

1. From *Logic Gates Parts Bin*, drag and drop the required logic gates on the design area. Use *Component Properties* dialog box to customize these gates.
2. Connect the terminal of these gates according to the given expression. Use additional connectors from the *Basic Parts Bin* if more than one wire needs to be connected at a single node.
3. Drag and drop a *probe* from *Indicators Parts Bin*. Use *Component Properties* dialog box to customize the color and other properties of the probe. Connect this probe at the output terminal of the circuit to indicate results.
4. Select four *switches* from *Basic Parts Bin*. Specify the key that controls the switch by typing its name in the *Value* tab of the *Component Properties* dialog box. For example, if you want the switch to close or open when digit ‘1’ is pressed, type 1 in the *Value* tab, then click *OK*. Assign different keys to all the switches.
5. Connect the output terminals of the switches to each of the circuit inputs A, B, and C.
6. Drag and drop *Vcc* and *Ground* form the *Sources Parts Bin*.
7. Connect *Vcc* terminal to one end and *Ground* terminal to the other end of all the switches.
8. Label the circuit properly using *text boxes* found in the *miscellaneous parts bin*.
9. Run the circuit using the *Activate Simulation* switch. Use the keys you have assigned to the switches to toggle them between *Vcc* and *Ground* connections, thus providing 1 or 0 respectively to the

inputs. Record the results as indicated by the probe for all possible combinations of 1s and 0s at the inputs.

EWB Circuit

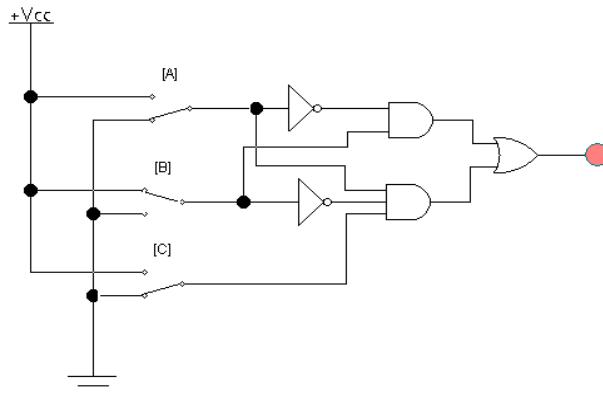


Figure 1.1: Designed circuit on EWB

Observations

A	B	C	Expected Output	Observed Output
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

USING LOGIC CONVERTER

Logic converter can be used to derive truth table and logic expression for a given logic circuit or vice versa, i.e. if a logic circuit is expressed in any one of the three ways, other two can be directly obtained using the logic converter.

From the Instruments Parts Bin, drag and drop Logic Converter on the design area. Double click the Logic Converter to reveal Logic Converter dialog box. This dialog box shows various conversion options between truth table, logic expression and logic circuit.

Finding truth table and logic expression for a given logic circuit

1. Create any arbitrary logic circuit on the design area.
2. Attach the input terminals of the logic converter to the input points in the circuit.
3. Connect the single output of the circuit to the output terminal on the logic converter icon.
4. Click the Circuit to Truth Table button. The truth table appears in the logic converter's display.
5. To convert this truth table to a Boolean expression, click the Truth Table to Boolean Expression button. The Boolean expression will be displayed at the bottom of the logic converter.

Creating logic circuit and truth table for a given logic expression

1. Enter the given logic expression in the edit box found at the end of the Logic converter dialog box. Use ‘ to represent invert of a variable. For example, \bar{A} is written as A’.
2. Click the Boolean Expression to Truth Table button. The truth table appears in the logic converter's display.
3. Now click the Boolean Expression to Circuit button. This creates the logic circuit for the given expression in the design area. Label the diagram if needed.

Creating logic circuit and finding logic expression for a given truth table

1. Click desired number of input channels from A to H, across the top of the logic converter. The display area below the terminals fills up with the necessary combinations of ones and zeros to fulfill the input conditions. The values in the output column on the right are initially set to 0.
2. Edit the output column to specify the desired output for each input condition. To change an output value, select it and type a new value: 1, 0 or x. An x indicates a don't care condition.
3. To convert this truth table to a Boolean expression, click the Truth Table to Boolean Expression button. The Boolean expression will be displayed at the bottom of the logic converter.
4. Simplify the expression by clicking the Simplify button.
5. Now click the Boolean Expression to Circuit button. This creates the logic circuit for the given expression in the design area.

EXERCISE

1. (a) Use Electronics Workbench or any other simulation tool to develop a logic circuit diagram for the logic expression $F = \bar{A}\bar{B} + \bar{A}\bar{C}$

<i>A</i>	<i>B</i>	<i>C</i>	<i>Expected Output</i>						<i>Observed Output</i>
			\bar{A}	\bar{B}	\bar{C}	$A\bar{B}$	$\bar{A}\bar{C}$	F	
0	0	0							
0	0	1							
0	1	0							
0	1	1							
1	0	0							
1	0	1							
1	1	0							
1	1	1							

Paste logic circuit diagram here

(b) Create a neat pin diagram using TTL ICs and paste the hardcopy of the same in the given space.



Lab Session 02

Practice logic expression implementation in hardware

COMPONENTS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 7404 hex inverter
 - 7408 quad 2 input AND gate
 - 7432 quad 2 input OR gate
 - 7411 triple 3 input AND gate

GIVEN LOGIC EXPRESSION

$$F(X, Y, Z) = \bar{X}YZ + \bar{X}Y\bar{Z} + XZ + \bar{X}Z$$

PROCEDURE

Part A:

1. Draw a logic circuit diagram for the given logic expression.
2. Implement the logic circuit using digital ICs on a bread board/ logic trainer (refer to appendix A for IC pin configurations)
3. Now record the observations in Table 1.

LOGIC CIRCUIT DIAGRAM

(Draw your circuit logic diagram)

Paste snapshot of your designed circuit here

Part B:

1. Use Boolean algebra or K-map to reduce the given logic expression.
2. Draw the circuit diagram for the obtained reduced function.
3. Implement the reduced circuit using digital ICs on a bread board/logic trainer (refer to appendix A for IC pin configurations).
4. Now record the observations in Table 2.1 .

REDUCTION OF LOGIC EXPRESSION

Reduced logic expression comes out to be: _____

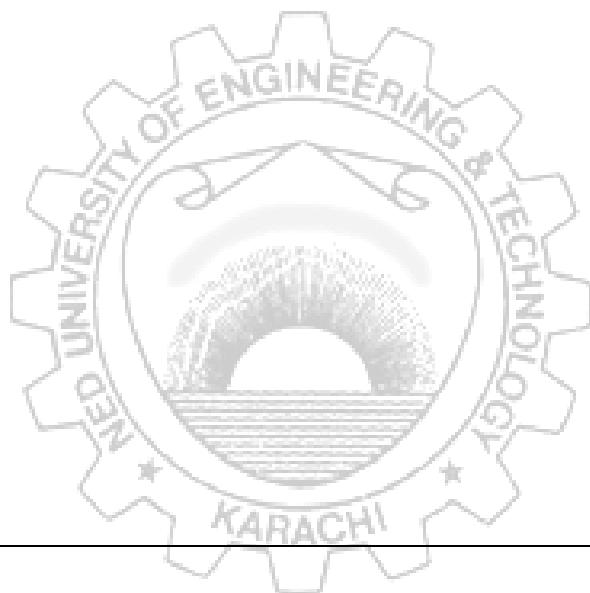
LOGIC DIAGRAM (REDUCED FORM)*Draw your reduced circuit logic diagram**Paste snapshot of your designed reduced circuit here***OBSERVATIONS**

Table 2.1:

X	Y	Z	<i>Observed Output</i>	
			<i>For given expression</i>	<i>For simplified expression</i>
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

EXERCISE

1. Conduct a comparison between the design process of both given and simplified circuit and tick as appropriate in the given chart.

Comparison Metric	Given logic expression		Simplified logic expression	
• Design time	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more
• Number of logic components	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more
• Chip area needed	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more
• Power consumption	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more
• Heat dissipation	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more
• Cooling requirement	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more
• Design cost	<input type="checkbox"/> less	<input type="checkbox"/> more	<input type="checkbox"/> less	<input type="checkbox"/> more

2. Comment on the significance of reduction of logic circuits.

Lab Session 03

Practice to implement half and full adder circuits

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 7408 Quad 2-input AND Gate
 - 7432 Quad 2-input OR Gate
 - 7486 Quad 2-input XOR Gate

Half Adder

Half adder is a combination circuit that performs the addition of two bits without accounting for the previous carry is called half adder. It needs two binary inputs and two binary outputs. The input variables designate the augend and addend bits. The output variables produce the sum and carry. The simplified, sum of product expressions for a half adder are:

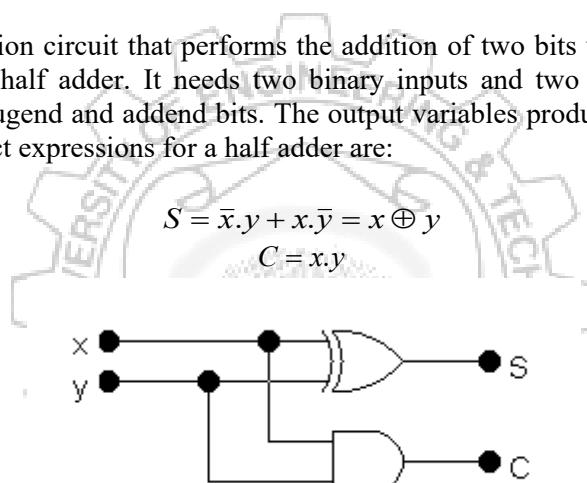


Figure 3.1: Logic circuit for Half Adder

Full Adder

Full adder is a combinational circuit that performs the addition of three input bits. It consists of three inputs and two outputs. Two of the input variables, represent the two significant bits to be added. The third input, represents the carry from the previous lower significant position. The output variables produce the sum and carry. The simplified, sum of product expressions for a full adder are

$$S = \bar{X} \bar{Y} \text{Cin} + \bar{X} Y \bar{\text{Cin}} + X \bar{Y} \bar{\text{Cin}} + X Y \text{Cin} = X \oplus Y \oplus \text{Cin}$$

$$C = X Y + X \text{Cin} + Y \text{Cin} = (X \oplus Y) \text{Cin} + X Y$$

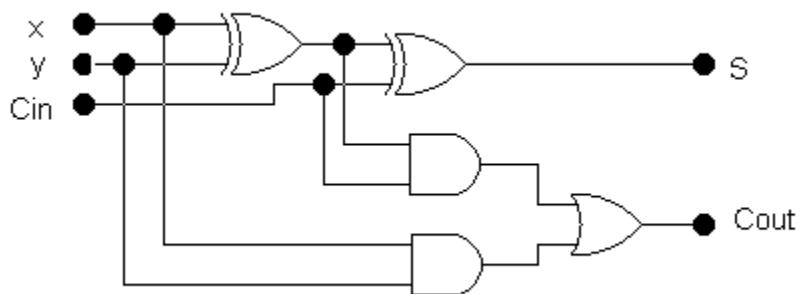


Figure 3.2: Circuit diagram for Full Adder

HARDWARE IMPLEMENTATION AND OBSERVATIONS

Implement the half adder and full adder circuits in hardware (refer to appendix A for IC pin configurations) and record the observations in the following tables:

Table 1: Half Adder

Inputs		Outputs	
X	Y	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Table 2: Full Adder

Inputs		Outputs		
X	Y	Cin	Cout	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Paste snapshot of your designed circuit here

EXERCISE

1. (a) Design a full subtractor circuit and simulate it using Electronic Workbench or any other simulation tool.

Table 3: Half Subtractor

Inputs		Outputs	
X	Y	Borrow	Difference
0	0	0	0
0	1	1	1
1	0	0	1
1	1	0	0

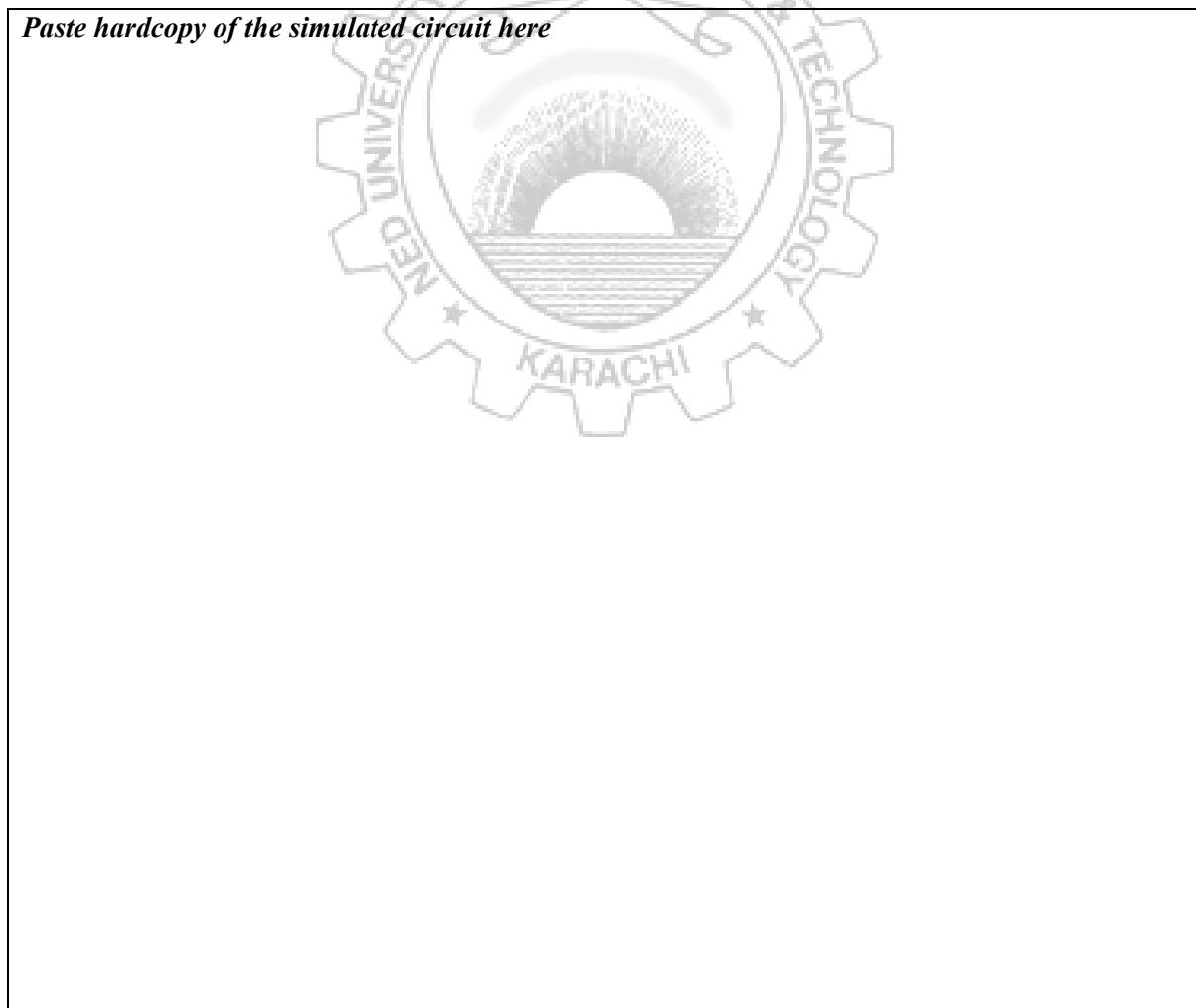
Table 4: Full Subtractor

Inputs			Outputs	
X	Y	B_{out}	B_{in}	Difference
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

Logic Expression for *Difference* bit:

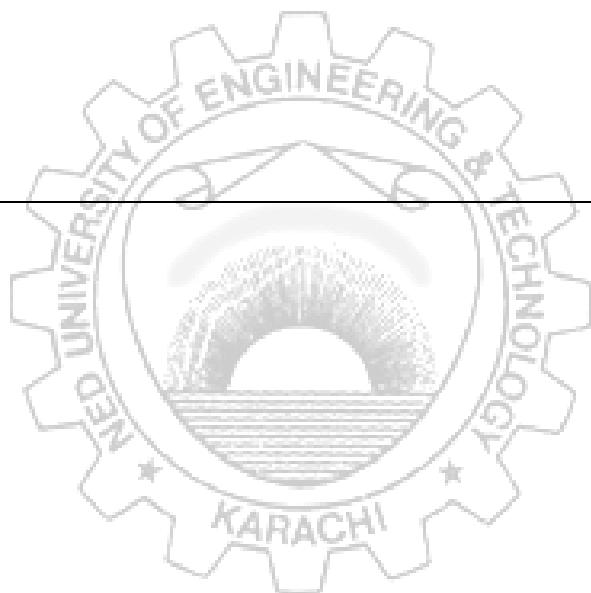
Logic Expression for *Borrow* bit:

Paste hardcopy of the simulated circuit here



(b) Generate NAND equivalent of circuit generated in part (a) using Logic Converter tool.

Paste snapshot of the NAND equivalent here



Lab Session 04

Practice to simulate a 4-bit parallel adder

4-Bit Parallel Adder

A 4-bit parallel adder can add two 4-bit values. One way of constructing such an adder is to simply cascade four full adders as shown in figure 4.1. Here $A_3A_2A_1A_0$ and $B_3B_2B_1B_0$ are two 4-bit values to be added. FA3, FA2, FA1 and FA0 are the four full adders that are cascaded in parallel to provide the desired result. $S_3S_2S_1S_0$ is the final 4-bit sum. C_0 is the external carry input (if any) to the circuit and C_4 is the final carry generated by the 4-bit addition.

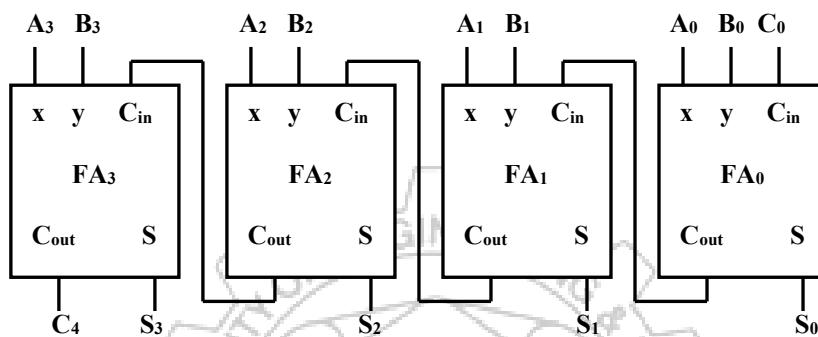


Figure 4.1: 4-bit Parallel Adder

Creating Subcircuits in Electronic Workbench

Creating a subcircuit allows you to reuse the circuit multiple times in a design and in future designs. Subcircuits may contain basic circuit elements or other subcircuit definitions. To create a subcircuit in Electronics Workbench:

1. First you have to design the circuit that you want to implement. Let's say you want to create a half-adder, so you simply draw a circuit with a XOR and AND gate (XOR is SUM and AND is Carry Out).
2. Select all components of the design that needs to be included in the subcircuit.
3. From the menu *Circuit*, select *Create Subcircuit*. Type a name and choose appropriate options. This will open a subwindow on the main design area containing the initially selected components.
4. Drag the input and output lines towards the edges to make input and output ports/terminals in the subcircuit.
5. Now click anywhere in the outer design area, this will close the internal structure of the subcircuit. The subcircuit will appear as a block on the main design area with assigned input and output lines. Now this block can be replicated (copy-pasted) where ever required or can be saved for future reuse.

PROCEDURE

1. Create a subcircuit for a full adder unit. Refer to lab session 3 for the gate level circuit of a full adder. This subcircuit should have three inputs namely x , y , C_{in} and two outputs namely C_{out} and S .
2. Replicate the subcircuit to make a total of four full adder subcircuits namely FA3, FA2, FA1 and FA0.
3. Make connections among these full adders as shown in figure 4.1.

4. Again create a subcircuit containing all these four full adders to make a single unit of a 4-bit parallel adder. This new subcircuit should have nine inputs (C_0 , A₃, A₂, A₁, A₀, B₃, B₂, B₁, B₀) and five outputs (C₄, S₃, S₂, S₁, S₀).
5. Connect the inputs to switches and outputs to indicators. Apply various combinations of 1s and 0s at inputs and check the binary values at the outputs.

EXERCISE

1. Find the sum and output carry for the addition of following two 4-bit numbers if the input carry (C_0) is 0

a. A₃A₂A₁A₀ = **1100** B₃B₂B₁B₀ = **1101**

C ₄	S ₃	S ₂	S ₁	S ₀

b. A₃A₂A₁A₀ = **1011** B₃B₂B₁B₀ = **1010**

C ₄	S ₃	S ₂	S ₁	S ₀

2. Paste a screenshot of your simulation in the given space.



Lab Session 05

OBJECTIVE

Practice to implement logic circuits with digital decoder IC.

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 74138 - 3 x 8 Line Decoder / Demultiplexer

DECODER

A Decoder is a combinational circuit that converts binary information from n input lines to a maximum of 2^n unique output lines. In practical applications, decoders are often used for selecting one of several devices.

DEMULTIPLEXER

A Demultiplexer (DMUX) is a circuit that receives information on a single line and transmits this information on one of 2^n possible output lines. The selection of a specific output line is controlled by the bit values of n selection lines. A decoder with an enable input can function as a Demultiplexer (DMUX).

74138 - 3 X 8 LINE DECODER / DEMULTIPLEXER

The 74138 IC has three inputs and eight output lines. It has three enable inputs and for the IC to function all three inputs need to be enabled. Refer to appendix A for IC pin configuration. Function of various pins of this IC is described below:

- ***Y0 through Y7:*** Active low data outputs
- ***A, B, C:*** Active high input / select lines with C being the MSB
- ***G1:*** Active high enable Input
- ***G2A' and G2B':*** Active low enable Inputs
- ***VCC and GND:*** Supply connections lines

TESTING PROCEDURE AND OBSERVATIONS

- Make Vcc and Gnd supply connections.
- Connect the three inputs A(LSB), B and C (MSB) to switches.
- Set appropriate values at enable inputs to activate the IC.
- Apply different combinations of 1s and 0s at data inputs.
- Observe the output and record your observations in the following table.

C	B	A	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7
0	0	0								
0	0	1								
0	1	0								
0	1	1								
1	0	0								
1	0	1								
1	1	0								
1	1	1								

EXERCISES

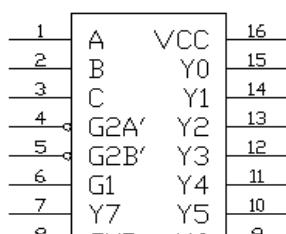
1. What will be the binary values at the outputs, Y0 through Y7, of 74138 if:
- All three enable pins are connected to ground?

 - What can be the possible reason for above observation?

 - All three enable pins are connected to VCC?

 - What did you deduce from your observation in part c?

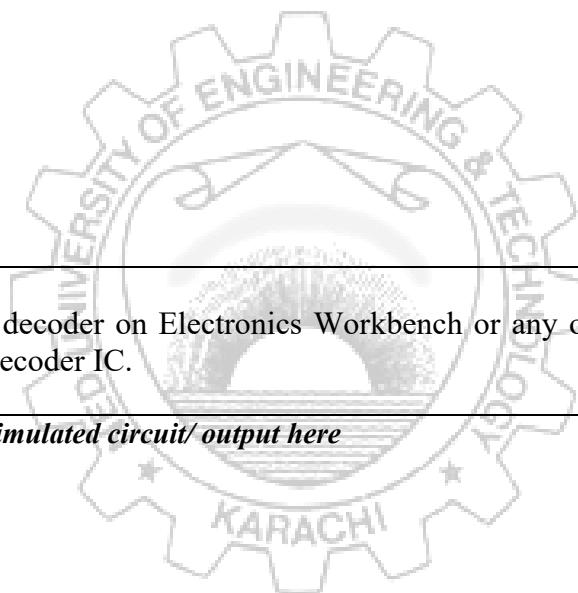
2. A number of logic functions can be implemented using digital decoders considering the constraint of Fan-In index of decoder IC.
- Use given pin diagram and add necessary connection/gates to implement a full adder circuit.
 $S = \bar{X} \bar{Y} \text{ Cin} + \bar{X} Y \overline{\text{Cin}} + X \bar{Y} \overline{\text{Cin}} + X Y \text{ Cin} = \sum \underline{\hspace{1cm}}$
 $C = X Y + X \text{Cin} + Y \text{Cin} = \sum \underline{\hspace{1cm}}$



74138

(b) Realize the circuit in hardware.

Paste snapshot of logic circuit here



3. Simulate a 3x8 line decoder on Electronics Workbench or any other simulation software using 74139 2x4 dual decoder IC.

Paste hardcopy of the simulated circuit/ output here

Lab Session 06

Practice to implement logic circuits using digital multiplexer IC in cascaded mode

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 74150 - 16 x 1 Multiplexer

MULTIPLEXERS

A digital data Multiplexer (MUX) is a combinational circuit having several data inputs and a single output. A set of *data-select* inputs is used to control which of the data inputs is routed to the single output. A multiplexer is also called a *data selector* because of this ability to select which data input is connected to the output. Normally there are 2^n input lines and n selection lines whose bit combination determine which input is selected.

74150 - 16 X 1 MULTIPLEXER

The 74150 IC has sixteen data inputs and four data-selection lines. It also contains an active low enable and an active low output line. Refer to appendix A for IC pin configuration. Function of various pins of this IC is described below:

- **E0 through E15:** Active high data input lines
- **A, B, C, D:** Active high data select lines with D being the MSB
- **W:** Active low output line
- **G':** Active low enable line
- **VCC and GND:** Supply connections lines

TESTING PROCEDURE AND OBSERVATIONS

1. Make Vcc and Gnd supply connections.
 2. Connect the data select inputs A, B, C and D to switches.
 3. Set appropriate values at enable inputs to activate the IC.
 4. Connect the data inputs E0 through E15 to switches. For simplicity just two or three data inputs can be connected to switches at a time. Remaining inputs will draw 1 by default (float high characteristic of TTL ICs).
- [Note: EWB considers a zero value at unconnected pins]**
5. Now select any data input with the help of data selectors A, B, C, and D. Apply following data at data inputs lines.
Data = **0xWXYZ** [where WX is the two digit year code and YZ is last two digits of your roll number, for instance if roll number is 128 and year is 2019 then data = 0x1928]
 6. Now express above in binary form and apply on data lines from E0 to E15

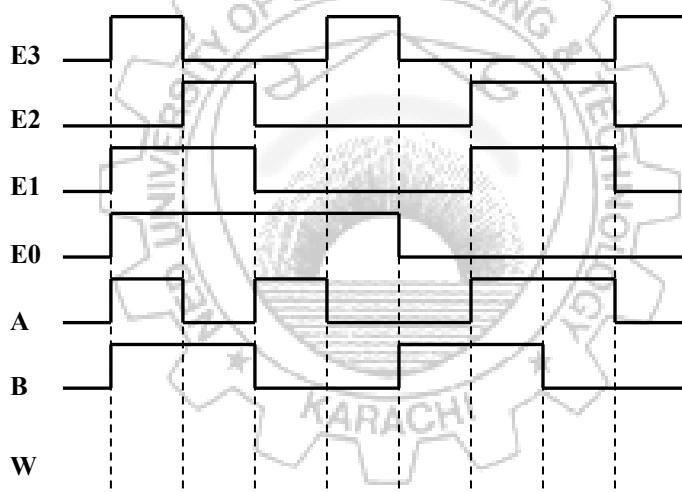
E ₁₅	E ₁₄	E ₁₃	E ₁₂	E ₁₁	E ₁₀	E ₉	E ₈	E ₇	E ₆	E ₅	E ₄	E ₃	E ₂	E ₁	E ₀

7. Observe the output. The invert of the value applied at the selected data input will appear at the output.
 8. Record your observations for the input configurations given in the following table.

G'	D	C	B	A	Value at data input	W	G'	D	C	B	A	Value at data input	W
0	0	0	0	0			0	1	0	0	1		
0	0	0	0	1			0	1	0	1	0		
0	0	0	1	0			0	1	0	1	1		
0	0	0	1	1			0	1	1	0	0		
0	0	1	0	0			0	1	1	0	1		
0	0	1	0	1			0	1	1	1	0		
0	0	1	1	0			0	1	1	1	1		
0	0	1	1	1			1	0	1	0	1		
0	1	0	0	0			1	1	0	1	0		

EXERCISE

1. Consider 4x1 Multiplexer. Draw the output wave-form for the following data inputs (E_0, E_1, E_2, E_3) and select lines A, B (B being the MSB). Output is W.



2. Consider the function; $F(D, C, B, A) = \sum(1, 3, 5, 6, 9, 13, 15)$

Implement the circuit in hardware using TWO 74150 IC. [Carefully cascade ICs to obtain desired output]. Observe output in given cases;

Select Line				Output
D	C	B	A	W
1	1	0	0	
1	0	0	1	

Paste snapshot of logic circuit here

3. Simulate the above circuit on Electronics Workbench or any other simulation software using 74151 – 8-line-to-1-line multiplexer IC.

Paste hardcopy of the simulated circuit/output here

Lab Session 07

*Operate logic trainer board under supervision
for experimenting with encoder and seven segment display driver ICs*

COMPONENTS & APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Seven Segment Display (Common Anode Type) with resistor
5. Following ICs and their datasheets or pin configurations:
 - 74148 Octal to Binary Priority Encoder
 - 7447 BCD to Seven Segment Driver
 - 7404 hex inverter

ENCODER

An Encoder is a digital function that produces a reverse operation from that of a decoder. An Encoder has 2^n (or less) input lines and n output lines. The output lines generate the binary code for the 2^n input variables.

PRIORITY ENCODER

A simple encoder may produce an erroneous output if more than one of its inputs is high. A Priority Encoder is one that responds to just one input among those that may be simultaneously high, in accordance with some priority system. The most common priority system is based on the relative magnitudes of the inputs: whichever decimal input is largest is the one that is encoded.

74148 8 X 3 Octal to Binary Priority Encoder

The 74148 is a priority encoder with active-low inputs for decimal digits. There are nine inputs lines (including an enable input) and five output lines, of which three represents the binary code for the octal digit. Refer to appendix A for IC pin configuration. Function of various pins of this IC is described below:

- **0 through 7:** Active low data inputs representing the octal digits
- **A₂, A₁, A₀:** Active low output lines representing the binary code
- **E_I:** Active low enable Input
- **E_O:** Active low output indicating none of the inputs is high
- **G_S:** Active low output indicating any of the inputs is high
- **V_{CC} and G_ND:** Supply connections lines

Considering above characteristics of 74148 IC, complete the given table.

key	Inputs									Outputs				o/p on 7 segments	
	E1	0	1	2	3	4	5	6	7	A3	A2	A1	Eo	Gs	
0	0	0	1	1	1	1	1	1	1						
1	0	X	0	1	1	1	1	1	1						
2	0	X	X	0	1	1	1	1	1						
3	0	X	X	X	0	1	1	1	1						
4	0	X	X	X	X	0	1	1	1						
5	0	X	X	X	X	X	0	1	1						
6	0	X	X	X	X	X	X	0	1						
7	0	X	X	X	X	X	X	X	0						
-	0	1	1	1	1	1	1	1	1						
X	1	X	X	X	X	X	X	X	X						

7447 BCD TO SEVEN SEGMENT DRIVER

7447 IC is particularly used to drive common-anode Seven Segment displays. Its input is a BCD number and output drives a seven segment display. Refer to appendix A for IC pin configuration. Function of various pins of these ICs is described below:

- **A, B, C, D:** Active high inputs representing BCD digits (D being the MSB).
- **OA through OG:** Active low outputs to drive segments *a* through *g* of the display.
- **LT:** Lamp Test input. Tests whether all segments are working or not. Illuminates all segments if kept low, provided that BI is kept high. Should be kept high otherwise.
- **RBI:** Ripple Blanking Input. Turns off all the segments if kept low (i.e. it blanks decimal 0), provided that LT is kept high and all other inputs (A, B, C, D, BI) are kept low. Should be kept high otherwise. RBI is used in multi-digit display and should be connected to the RBO of the previous digit (the digit to the left). In this way, you may avoid showing trailing “0”. (e.g. 00123 will be shown as “ 123”). This trick was in use when digital circuits were not so intelligent
- **BI / RBO:** Wire-AND logic serving as a Blanking Input and / or Ripple Blanking Output.
 - **BI:** Turns off all the segments if low.
 - **RBO:** Goes to a low level (response condition) along with other outputs, when RBI and inputs A, B, C, and D are low with LT input at high level.
- **VCC and GND:** Supply connections lines

SEVEN SEGMENT DISPLAYS

A Seven Segment Display consists of seven light-emitting segments. The segments are designated by letters *a* through *g* (see figure 9.1). By illuminating various combinations of segments, the numerals 0 through 9 can be displayed. Seven Segment Displays are commonly constructed with light-emitting diodes (LEDs) and with liquid-crystal displays (LCDs). LEDs generally provide greater illumination levels but require much greater power than LCDs.

An LED display can be a common-anode type or common cathode type. In common anode type, a high voltage is applied at the *common* terminal of the display and low voltage is applied at a segment's terminal for illumination. In the common-cathode type, a low voltage is applied at the *common* terminal of the display and high voltage is applied at a segment's terminal for illumination.

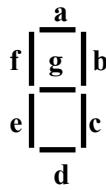


Figure 7.1: Seven Segment Display

IMPLEMENTATION & OBSERVATIONS

You are required to display the outputs of a 74148 encoder IC on a seven segment display. The circuit is given in figure 7.2.

- 1 Make connections as shown in figure 7.2. (refer to appendix A for IC pin configurations).
- 2 Select any input from 74148 IC and observe the corresponding decimal code being displayed on the seven segment.

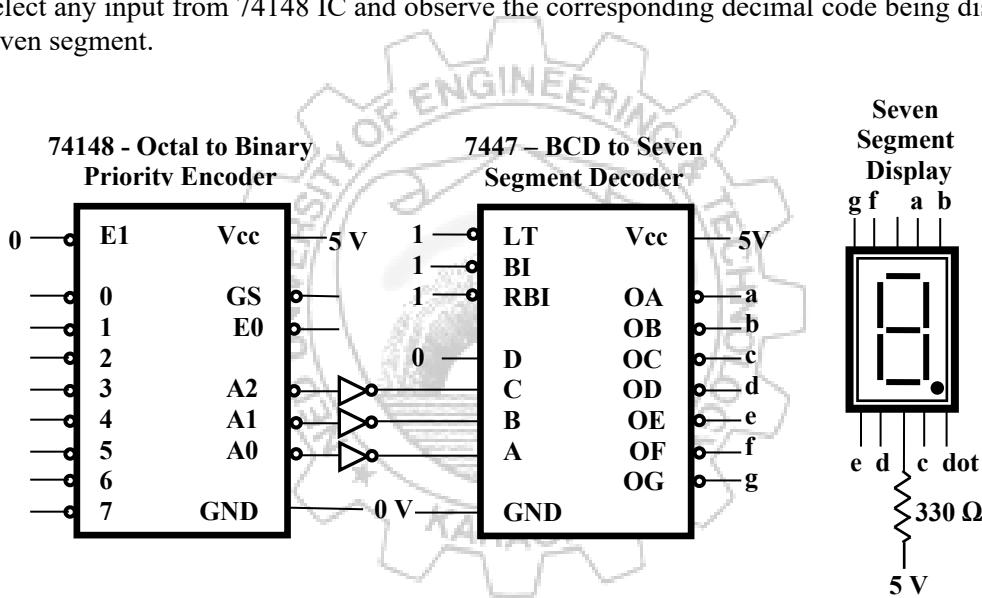


Figure 7.2: Circuit for displaying encoders output on 7-segment display

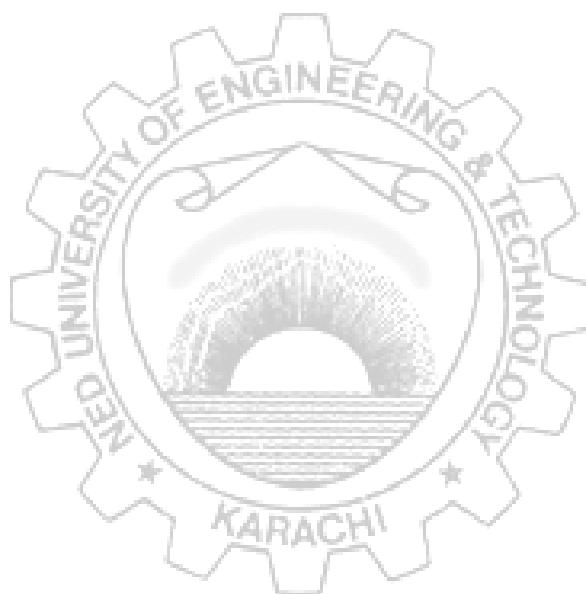
EXERCISE

1. Perform the Lamp Test for the designed circuit and write your observations.

2. How can you use 7447 IC to drive a common-cathode display?
-
-
-

3. Paste a snapshot of the working circuit when input pins 1, 3 & 6 are being activated simultaneously.

Paste snapshot here



Lab Session 08

Practice to implement a modulo-4 asynchronous up-counter using JK flip flops

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 7473 / 7476 JK Flip-Flop

FLIP-FLOP

A flip-flop circuit can maintain a binary state indefinitely (as long as the power is delivered to the circuit) until directed by an input signal to switch states. The major differences among various types of flip-flops are in the number of inputs they possess and in the manner in which the inputs affect the binary state.

JK Flip-Flop

JK flip flop is an edge triggered device. A typical JK flip flop has three inputs: J, K and a clock input. The flip-flop can be either positive or negative edge triggered. The output Q is available in complemented form as well.

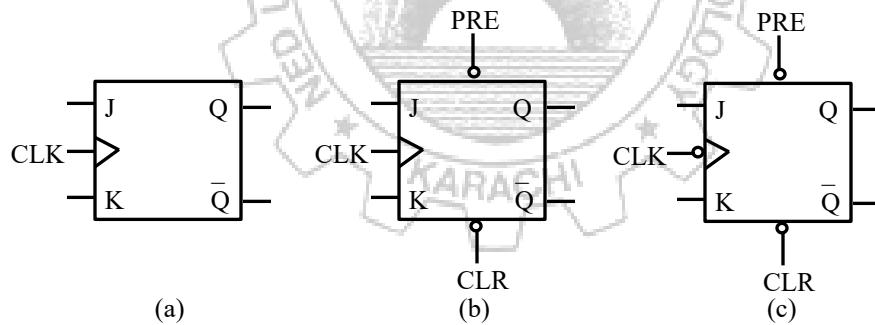


Figure 8.1: Symbol for JK flip-flop.

(a) Positive-edge triggering.

(b) Active low Preset (PRE) and Clear (CLR) with positive-edge triggering.

(c) Active low Preset (PRE) and Clear (CLR) with negative-edge triggering

Besides the usual inputs and output, most of the flip-flop IC also possess two asynchronous inputs, namely *Preset* and *Clear*. These inputs are usually active low. If used, *Preset* and *Clear* inputs keep the flip-flop in set and reset state respectively, irrespective of the other inputs. Both of these inputs cannot be used simultaneously, otherwise they will bring the flip-flop in unstable state.

7473 / 7476 Dual JK Flip Flop

Both the ICs 7473 and 7476 are similar in functionality except for one difference. The flip-flops in 7473 have only one type of active low asynchronous input, which is the *Clear* input, whereas the flip-flops in 7476 have both *Preset* and *Clear* inputs. Both these ICs have negative edge triggered flip-flops. Refer to appendix A for IC pin configuration Function of various pins of this IC is described below:

- ***1CLK, 2CLK***: Negative edge triggered clock inputs for FF1 and FF2 respectively.
- ***IPRE, 2PRE(for 7476 only)***: Active low preset inputs for FF1 and FF2 respectively.
- ***ICLR, 2CLR***: Active low clear inputs for FF1 and FF2 respectively.
- ***IJ, 2J***: Active high J inputs for FF1 and FF2 respectively.
- ***IK, 2K***: Active high K inputs for FF1 and FF2 respectively.
- ***IQ, 2Q***: Active high outputs for FF1 and FF2 respectively.
- ***IQ', 2Q'***: Active low outputs for FF1 and FF2 respectively.
- ***VCC and GND***: Supply connections lines

DIGITAL COUNTERS

A digital counter is a set of flip-flops whose states change in response to pulses applied at the input to the counter. Every counter resets after a certain number of clock pulses. Thus, as it name implies, a counter is used to count pulses. An n stage counter can count up to a maximum of 2^n states. n is equal to the number of flip-flops required for the construction of counter.

Modulus Counters

The number of input pulses that causes a counter to reset to its initial count is called the *modulus* of the counter. Thus, the modulus equals to total number of distinct *states* (counts), including zero that a counter can store. A binary counter with n stages is a *modulo- 2^n* (or *MOD- 2^n*) counter. The largest count a *mod-N* counter can achieve is $N-1$, i.e. a *mod-N* counter never reaches the binary number equal to its modulus. N is always equal to or less than 2^n .

Counters can be classified as:

- ***Synchronous Counters***, which are clock driven. All the flip-flops are driven by a single clock.
- ***Asynchronous Counters***, which are event driven. Clock input is given to the first flip-flop only. Rest of the flip-flops are driven by their preceding flip-flops.

Mod-4 Asynchronous Up Counter

The number of flip-flops required to construct a mod-4 counter is 4. This counter will count from 0 to 3, a total of 4 distinct states.

TESTING PROCEDURE AND OBSERVATIONS

7473 / 7476 Dual JK Flip Flop

- 1 Make Vcc and Gnd supply connections.
- 2 Connect the CLK input to some clock source or a switch.
- 3 Apply different combinations of 1s and 0s at inputs J, K, Preset and Clear.
- 4 Observe the output and record your observations in the following table.

<i>CLK</i>	<i>PRE*</i>	<i>CLR</i>	<i>J</i>	<i>K</i>	<i>Q</i>
↓	1	1	0	0	
↓	1	1	0	1	
↓	1	1	1	0	
↓	1	0	1	1	
↓	0	1	1	1	
1	1	1	1	1	
↓	1	1	1	1	

*ignore if 7473 IC is being used

MOD-4 Asynchronous Counter

1. Make connections as shown in figure 8.2. (refer to appendix A for IC pin configurations).
2. Observe the binary values at the outputs of the two flip flops with the incoming clock pulses.

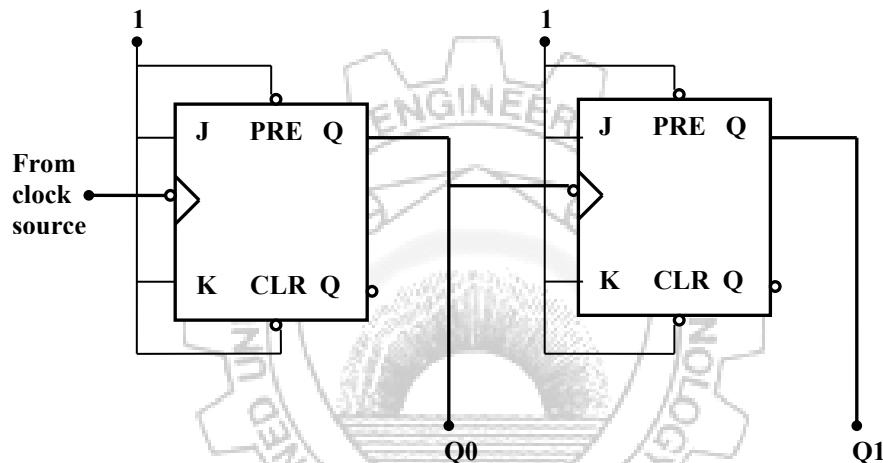
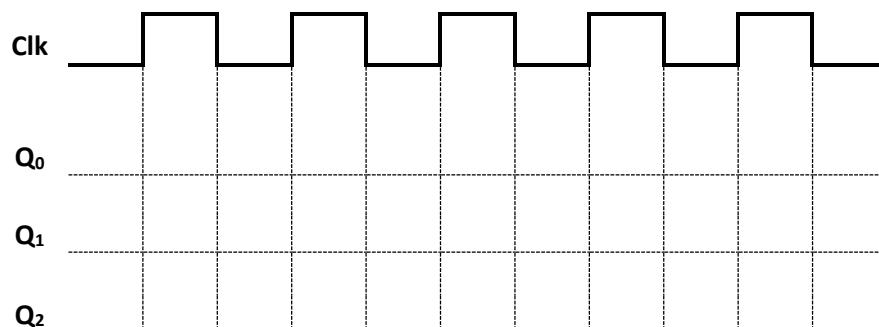


Figure 8.2: MOD-4 Asynchronous Counter

EXERCISE

1. Draw the timing diagram for MOD-4 counter designed in this laboratory session.



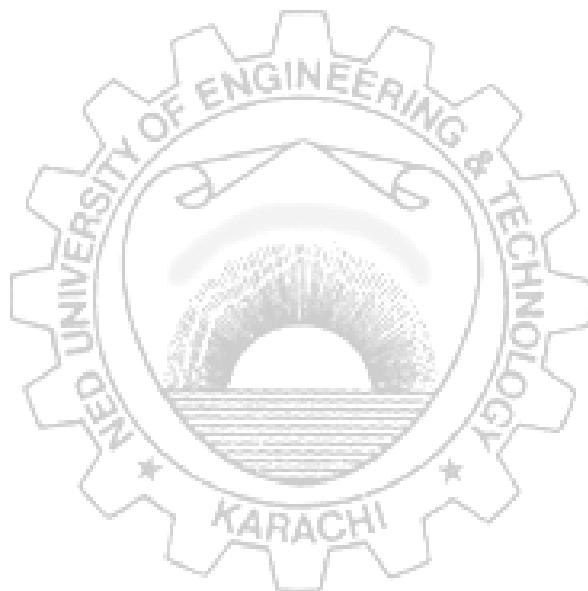
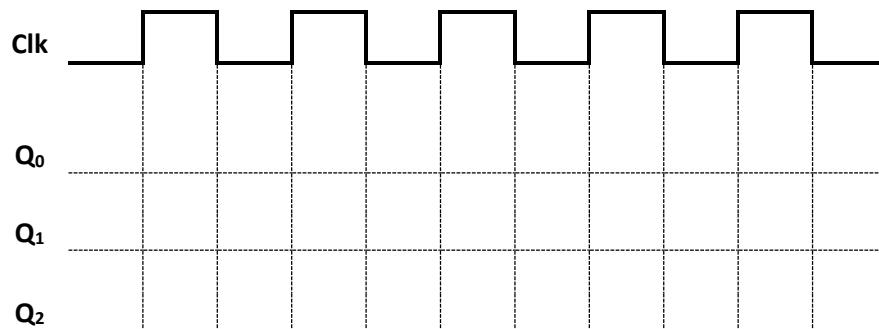
2. Use JK FF as a building block and add necessary connection/gates to construct a MOD-5 counter.
[Hint: The number of flip-flops required to construct a MOD-5 counter is 3. This counter will count from 0 to 4, a total of 5 distinct states. Since a 3-stage counter can count up to 8 states at maximum, a NAND gate is used to reset it after 5 clock pulses.]

Draw logic diagram here

3. Simulate MOD-5 asynchronous counter using Electronic Workbench or any other simulation tool.

Paste hardcopy of the simulated circuit here

4. Draw the timing diagram for MOD-5 counter, as simulated in exercise 3. Clearly show the glitch.



Lab Session 09

Practice digital clock implementation with decade counter IC

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 7490 decade counter

7490 Decade Counter

7490 decade counter can generate the following two sequences:

1. BCD sequence: In this case output QA is connected to input B, external clock is applied to input A
2. Bi-quinary sequence: In this case output QD is connected to input A, external clock is applied to input B

Refer to appendix A for IC pin configuration. Function of various pins of this IC is described below:

- **Input A, Input B:** Negative edge triggered clock inputs.
- **QA, QB, QC and QD:** Active high outputs.
- **R91, R92, R01, R02:** Active high reset inputs. These resets are activated as follows:
- **VCC and GND:** Supply connections lines.

Reset Inputs				Output			
R01	R02	R91	R92	QD	QC	QB	QA
H	H	L	X	L	L	L	L
H	H	X	L	L	L	L	L
X	X	H	H	H	L	L	H
X	L	X	L	COUNT			
L	X	L	X	COUNT			
L	X	X	L	COUNT			
X	L	L	X	COUNT			

TESTING PROCEDURE AND OBSERVATIONS

1. Make Vcc and Gnd supply connections.
2. Disable all RESET inputs.
3. Connect input A and input B according to the connections indicated in Fig. 9.1 & 9.2 to generate BCD count and bi-quinary count respectively.
4. Observe the output in each case and record your observations given in the following table.

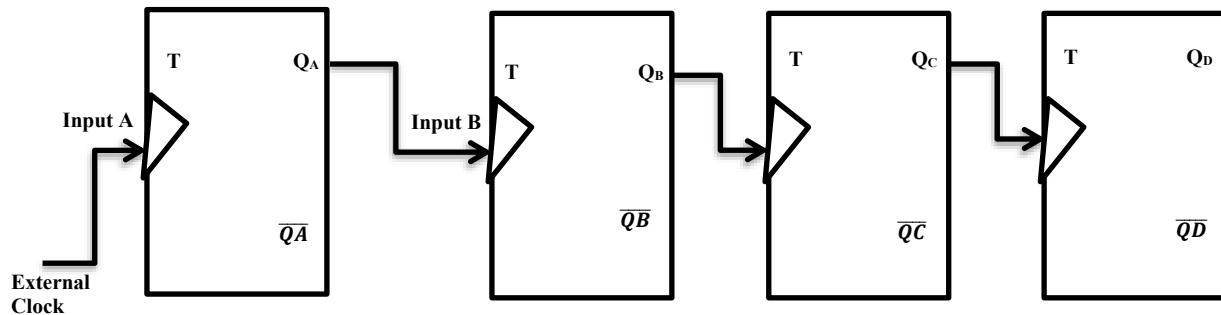


Fig 9.1: Connections for BCD Count

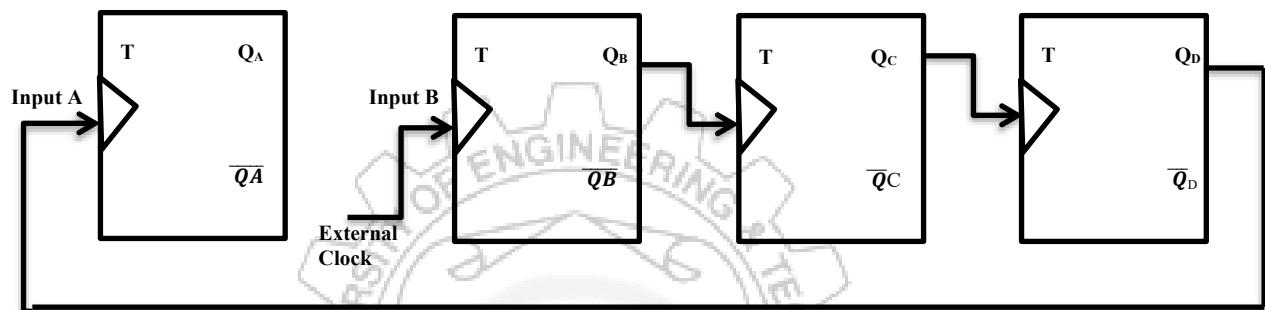


Fig 9.2: Connections for Bi-quinary Count

BCD Count				
Clock Pulse	QD	QC	QB	QA
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Bi-quinary Count				
Clock Pulse	QD	QC	QB	QA
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

5. Now write your observation in the following situations;

Situation	Observation
Enable the RESET inputs R01 and R02 (keeping R91 and R92 disabled)	
Enable the RESET inputs R91 and R92 (keeping R01 and R02 disabled)	
Enable all the RESET inputs R01, R02, R91 and R92	

Digital Clock

A digital clock is a time keeping circuit that displays seconds, minutes and hours. For seconds' section of a digital clock, a MOD-60 counter needs to be designed. A simple way to do this is to design MOD-10 and MOD-6 counters separately and then cascade them.

Generating Clock Signals for Sequential Circuits in EWB

Most sequential circuits require trigger/pulse for the functioning of their memory elements. This trigger is merely a 0 to 1 or 1 to 0 signal transition at the input where it needs to be applied. This can be achieved by simply connecting a switch which can toggle between 0 and 1.

For continuous pulse generation a proper clock source is needed. In EWB, this can be achieved via function generator (in *Instruments Parts Bin*) or more easily as follows:

1. From the *Sources Parts Bin*, drag and drop *Clock* on the design area. Double click the *Clock* to reveal the properties dialog box, where frequency, duty cycle and voltage of the signal can be chosen.
2. Connect the negative end of the component to the ground.
3. Positive end can be connected to the point where the clock signal needs to be applied. You can connect an indicator here to view the generated signal.

PROCEDURE

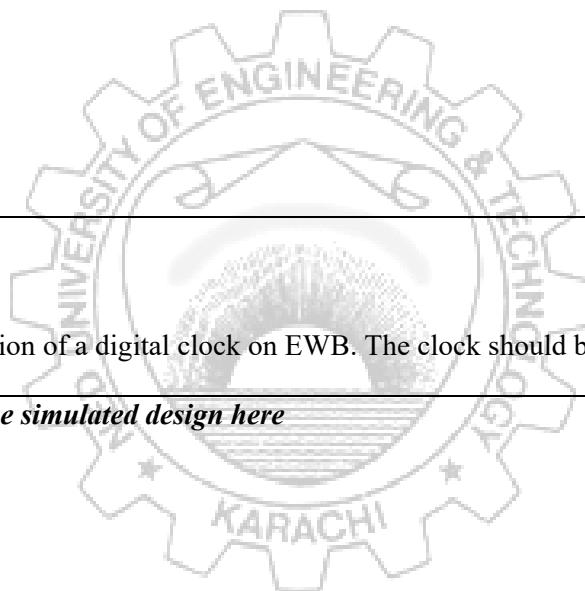
In this lab session we will use two 7490 ICs to design MOD-10 and MOD-6 counters.

1. For MOD-10 counter, connect a 7490 IC in BCD count mode. Disable all RESET inputs and apply clock at input A as illustrated in the previous section. Set the frequency of the clock to 1 Hz.
2. Connect another 7490 IC in BCD mode. To convert it to MOD-6 counter, connect R01 to QB and R02 to QC. This will activate the resets of 7490 when it reaches the count of 6. Disable the other two RESET inputs R91 and R92. Now connect QD of the MOD-10 counter created in the last step to the clock input (input A) of this IC. QD is the MSB of the MOD-10 count and it goes from 1 to 0 only when the counter resets after 9, thus providing the negative edge to increment the MOD-6 counter. Here also a seven segment display can be connected to view the outputs. Now collectively this circuit works as a MOD-60 counter.

Note:

The same circuit can be simulated on Electronic workbench, where the output of this circuit can be viewed on seven segment displays. Two kinds of 7 segment displays are available in Electronic workbench B. One takes four BCD inputs directly and the other one takes seven inputs for the seven segments. The later one is connected via a BCD to seven segment converter. For our application the former one is simpler to use as it provides the BCD to seven segment conversion internally.

Paste snapshot of the designed logic circuit here



EXERCISE

1. Design the hours' section of a digital clock on EWB. The clock should be a 24 hour clock.

Paste hardcopy of the simulated design here

Lab Session 10

Practice with bidirectional universal shift register IC for serial & parallel data loading

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 74194 4-bit bidirectional universal shift register

Shift Registers

A Register is a set of flip-flops used to store binary data. A register, which is capable of shifting its binary information either to the right or left, is called a shift register. The logical configuration of a register consists of a chain of flip-flops connected in cascade, with the output of one flip-flop connected to the input of next flip-flop. All flip-flops receive a common clock pulse, which causes the shift from one stage to the next.

Universal Bidirectional Shift Registers

A bi-directional shift register is one whose bits can be shifted from left to right or from right to left. A universal shift register is a bi-directional register whose input can be in either serial or parallel form and whose output can be in either serial or parallel form.

74194 4-Bit Bidirectional Universal Shift Register

The 74194 register provides parallel as well as serial loading in both directions. A, B, C, and D are inputs for parallel loading, whereas SR and SL are inputs for serial loading with right or left shifting respectively. S1 and S0 are used to select the loading mode. Refer to appendix A for IC pin configuration. Function of various pins of this IC is described below:

- **A, B, C and D:** Active high inputs for parallel loading.
- **QA, QB, QC and QD:** Active high outputs.
- **S0 and S1:** Active high mode control inputs. The following table shows combinations of S1 and S0 to enable various modes.

S1	S0	Clock	Action
0	0	x	No change
0	1	↑	Shift right
1	0	↑	Shift left
1	1	↑	Parallel load

- **SR:** Active high serial input for right shifting.
- **SL:** Active high serial input for left shifting.
- **CLR:** Active low clear input.

- **CLK:** Positive edger triggered clock input.
- **VCC and GND:** Supply connections lines.

TESTING PROCEDURE AND OBSERVATIONS

- 1 Make Vcc and Gnd supply connections.
- 2 Connect the CLK input to some clock source or a switch.
- 3 Disable CLR input.
- 4 Apply different combinations of 1s and 0s at inputs A, B, C & D.
- 5 Observe the output and record your observations given in the following table.

S1	S0	SL	SR	A	B	C	D	QA	QB	QC	QD
1	1	1	1	1	1	0	0				
0	0	0	1	0	0	0	0				
0	1	1	0	0	0	0	1				
1	0	0	0	0	0	1	0				
1	1	0	0	0	0	1	1				
0	0	1	1	0	1	0	0				
0	1	1	1	0	1	0	1				
1	0	1	0	0	1	1	0				
1	1	1	0	0	1	1	1				
1	1	0	0	1	1	1	1				

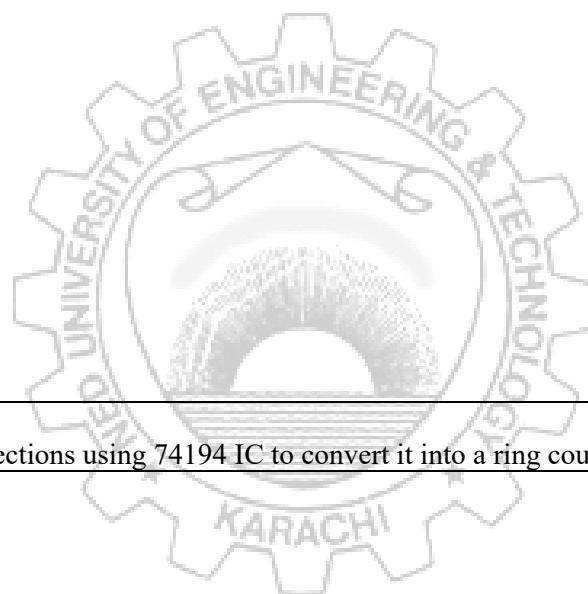
EXERCISES

1. Simulate using Electronic Workbench or any other simulation tool to show that how *serial data 0111* can be loaded into 74194 with *shift left mode*. Take snapshot of your circuit after 4 clock pulses and Paste in the provided space.

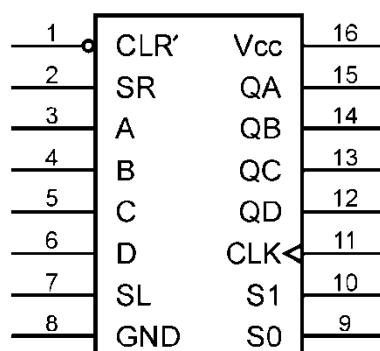
Paste hardcopy of the simulated design here

2. Simulate using Electronic Workbench or any other simulation tool to show that how data **1011** can be loaded in *parallel* into 74194.

Paste hardcopy of the simulated design here



3. Show necessary connections using 74194 IC to convert it into a ring counter with right shifting.



74194

Lab Session 11

Practice to design and implement a 3-bit even sequence synchronous up counter using T flip flops

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - 7473 / 7476 JK Flip-Flop

PROCEDURE

As mentioned in Lab session 08, synchronous counters are clock driven counters. It is a sequential circuit, the design of which involves the following steps:

1. Generate a state diagram and/or a state table from the statement of the problem.
2. Select the type of flip-flop for the circuit and generate the flip flop input equations needed for the required state transitions
3. Derive logic equations for generation of the output from the inputs and current state.
4. Generate a logic diagram of the circuit using ANDs, ORs, inverters, and flip flops.

3-bit Even Sequence Synchronous Up Counter

A 3-bit even sequence synchronous up counter will count through the following sequence: 0, 2, 4, 6 and repeat. The number of flip-flops required to construct such a counter is 3. The state of the flip flops is the final output of the circuit, therefore no explicit output equations need to be generated.

T Flip-Flop

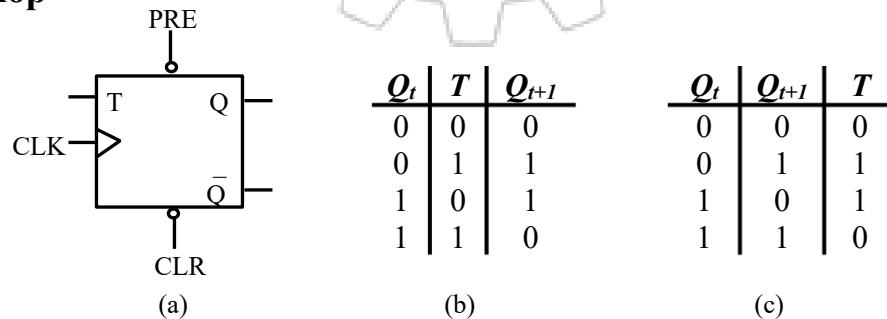


Figure 11.1: T Flip Flop. (a) Graphical symbol. (b) Characteristic table. (c) Excitation table

T flip-flop (toggle flip flop) has a single input T. If the T input is high, the T flip-flop changes state (toggles) whenever the clock input strobes. If the T input is low, the flip-flop holds the previous value. This behavior is described by the characteristic table and transition table given in figure 12.1.

Characteristic equation of T flip-flop is: $Q_{(t+1)} = T \oplus Q_t$

DESIGNING THE COUNTER

State Diagram

State Table

The design requires three flip flops: FF-0, FF-1 and FF-2.

<i>Present State</i>			<i>Next State</i>			<i>Flip flop inputs</i>		
Q_{2t}	Q_{1t}	Q_{0t}	$Q_{2(t+1)}$	$Q_{1(t+1)}$	$Q_{0(t+1)}$	$FF-2, T_2$	$FF-1, T_1$	$FF-0, T_0$
0	0	0						
0	0	1						
0	1	0						
0	1	1						
1	0	0						
1	0	1						
1	1	0						
1	1	1						

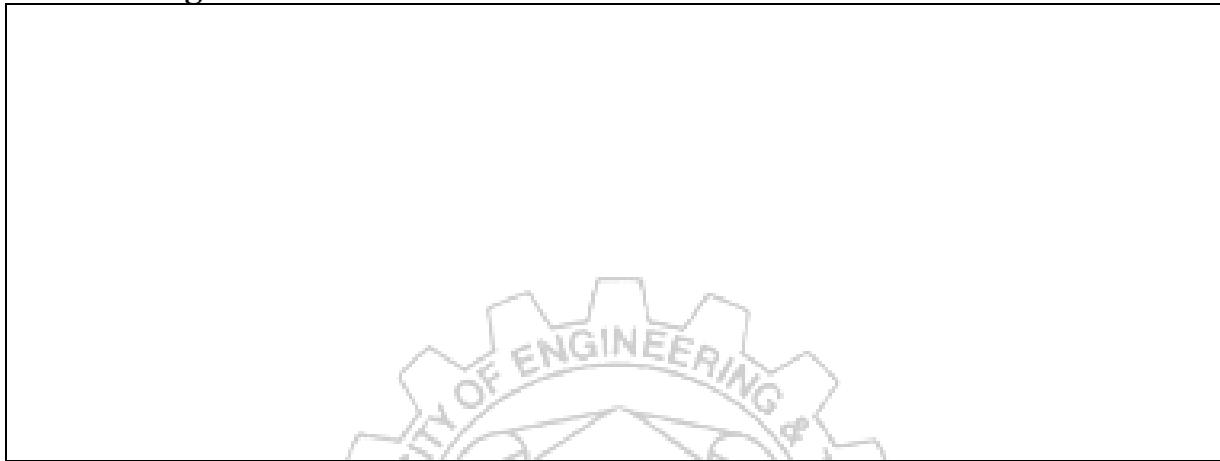
Input Equations

Work out to find logic expressions for T_2 , T_1 & T_0 .

T₂ = _____

T₁ = _____

T₀ = _____

Circuit Diagram**IMPLEMENTATION PROCEDURE AND OBSERVATIONS**

1. Implement the circuit using digital ICs on a bread board (refer to appendix A for IC pin configurations). T flip flop can be obtained by connecting together the two inputs J and K, of JK flip flop.
2. Make Vcc and Gnd supply connections.
3. Connect the CLK input to some clock source or a switch.
4. Observe the output even value sequence of the circuit.

Paste snapshot of the designed logic circuit here

Lab Session 12

Practice to implement synchronous sequential circuit for the given state diagram

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, LEDs with Resistors, Switches
2. Logic probe
3. Connecting wires
4. Following ICs and their datasheets or pin configurations:
 - Any Flip-Flop (In this lab session 7474 D Flip-Flop is being used)
 - 7408 Quad 2-input AND Gate
 - 7432 Quad 2-input OR Gate
 - 7404 Hex Inverter

Sequential Circuits

In *Sequential Circuits*, the output not only depends on the present inputs, but also on previous states of the circuit. These circuits use memory elements (latches, flip-flops) and the binary information stored in the memory elements at any given time defines the state of the sequential circuit.

Refer to lab session 12 for the steps involved in the design of synchronous sequential circuit.

D Flip-Flop

D flip-flop is also called transparent flip-flop as it simply transfers the input data to the output. This behavior is described by the characteristic table and transition table given in figure 13.2.

Characteristic equation of D flip-flop is: $Q_{(t+1)} = D$

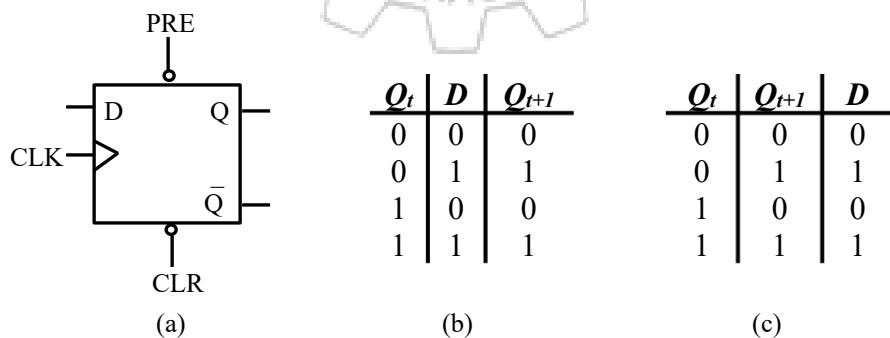


Figure 12.1: D Flip Flop. (a) Graphical symbol. (b) Characteristic table. (c) Excitation table

DESIGNING SYNCHRONOUS SEQUENTIAL CIRCUIT

STATE DIAGRAM (Given)

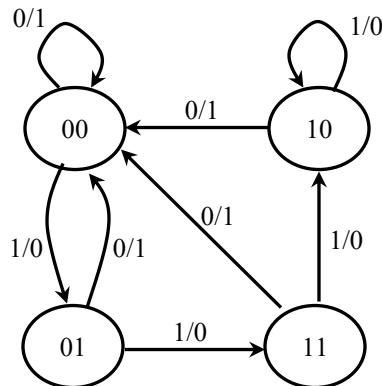


Figure 12.2: State Diagram

State Table

The given state diagram has four states, so two D flip-flops (FF-0, FF-1) will be required.

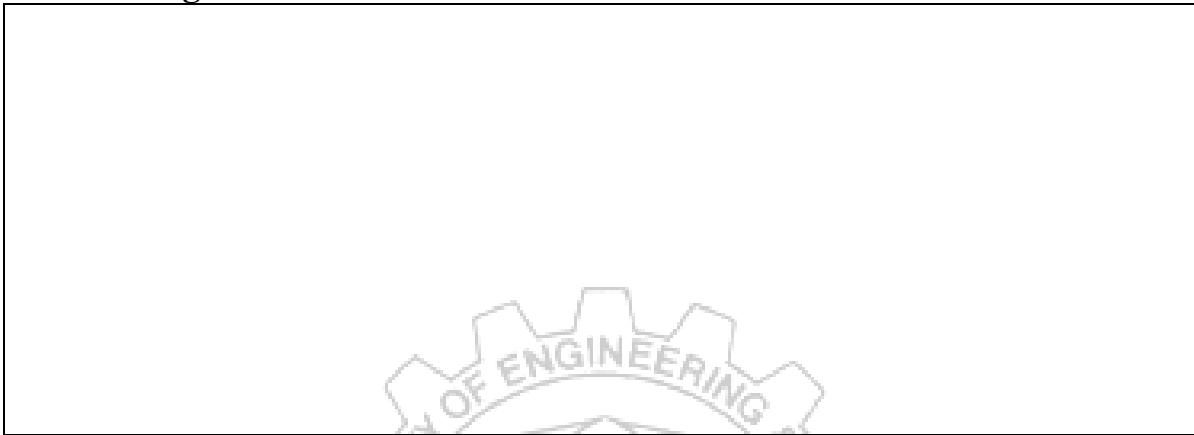
<i>Present State</i>		<i>Input</i>	<i>Next State</i>		<i>Output</i>	<i>Flip flop inputs</i>	
Q_{I_t}	Q_{0t}	X	$Q_{I(t+1)}$	$Q_{0(t+1)}$	Z	$FF-I, D_I$	$FF-0, D_0$
0	0	0					
0	0	1					
0	1	0					
0	1	1					
1	0	0					
1	0	1					
1	1	0					
1	1	1					

Input and Output Equations

Work out to find logic expressions for D_1 , D_0 & Z .

D₁ = _____D₀ = _____

Z = _____

Circuit Diagram**IMPLEMENTATION PROCEDURE AND OBSERVATIONS**

1. Implement the circuit using digital ICs on a bread board (refer to appendix A for IC pin configurations).
2. Make Vcc and Gnd supply connections.
3. Connect the CLK and the CLR inputs to input switches (preferably push buttons).
4. Apply 0 to the input x.
5. Enable CLR input momentarily to clear all the flip flops.
6. Apply CLK through the switch and record your observations in the following table.
7. Apply 1 to the input x.
8. Enable CLR input momentarily to clear all the flip flops.
9. Apply CLK through the switch and record your observations in the following table.

<i>X = 0</i>				<i>X = 1</i>			
<i>Clock Pulse #</i>	<i>Q₁</i>	<i>Q₀</i>	<i>Output Z</i>	<i>Clock Pulse #</i>	<i>Q₁</i>	<i>Q₀</i>	<i>Output Z</i>
Initial value	0	0		Initial value	0	0	
1				1			
2				2			
3				3			
4				4			
5				5			

Alternatively, connect the CLK input to a continuous clock source. Now output will change continuously. These outputs can be viewed using an oscilloscope.

Paste snapshot of the designed logic circuit here

EXERCISE

1. Use Electronic Workbench or any other simulation tool to simulate above sequential circuit.

Paste screenshot of the simulated design here

Lab Session 13

Operate IC Programmer under supervision to program EEPROM as a hex to seven-segment driver.

COMPONENTS AND APPARATUS REQUIRED

1. Digital logic trainer board or the following components:
Bread board, 5 V - Power Supply, Multimeter, Switches
2. Logic probe
3. Connecting wires
4. Seven Segment Display (Common Anode Type) with resistor
5. Universal IC programmer
6. Any EEPROM IC with datasheet or pin configuration

PROGRAMMING ICs

A large number of fixed function ICs are available from a variety of manufacturers at reasonably low cost. However, some designs are too complex to be implemented using fixed function ICs. Programmable logic devices (PLDs) are frequently used in such scenarios. A PLD is an IC that is user configurable and is capable of implementing logic functions. Some commonly used simple PLDs are ROMs (read only memories), PAL (programmable logic array) devices and PLA (programmable logic array) devices. When used for implementing logic functions, PLDs are actually working as lookup tables for code conversions and logic functions. The ‘memory addresses’ in such applications are actually the binary input to the logic function and the logic outputs are stored at the corresponding memory locations.

A seven-segment display consists of seven light-emitting segments. The segments are designated by letters *a* through *g*. By illuminating various combinations of segments, the numerals ‘0’ through ‘F’ (hex) can be displayed. For details on segment labels and types refer to lab session 07.

When an EEPROM IC is used as a hex to seven-segment driver, the IC addresses represent the binary-coded hex values (logic input) and the output (data) lines drive the seven-segment display. Table 15.1 shows a function table for such a decoder, based on the illuminated segments as shown in figure 15.1.



Figure 13.1: Illumination of hex numerals 0 through F, on a seven segment display

PROCEDURE

1. Place memory chip at the bottom most position of Universal IC programmer & lock it (See figure 13.2) before starting the writing procedure.
2. Start IC Programmer software (see fig.) and click on tab **List → EEPROM → vendor** (ATMEL, Intel, TI etc.).



Figure 13.2 (a): Incorrect way of IC placement



Figure 13.2 (b): Correct way of IC placement

3. Now mention **IC number** (e.g. AT2816) or select the particular vendor (e.g. ATMEL) from the list and then look for IC number, you are using then press **Ok**. (See figure 13.3)

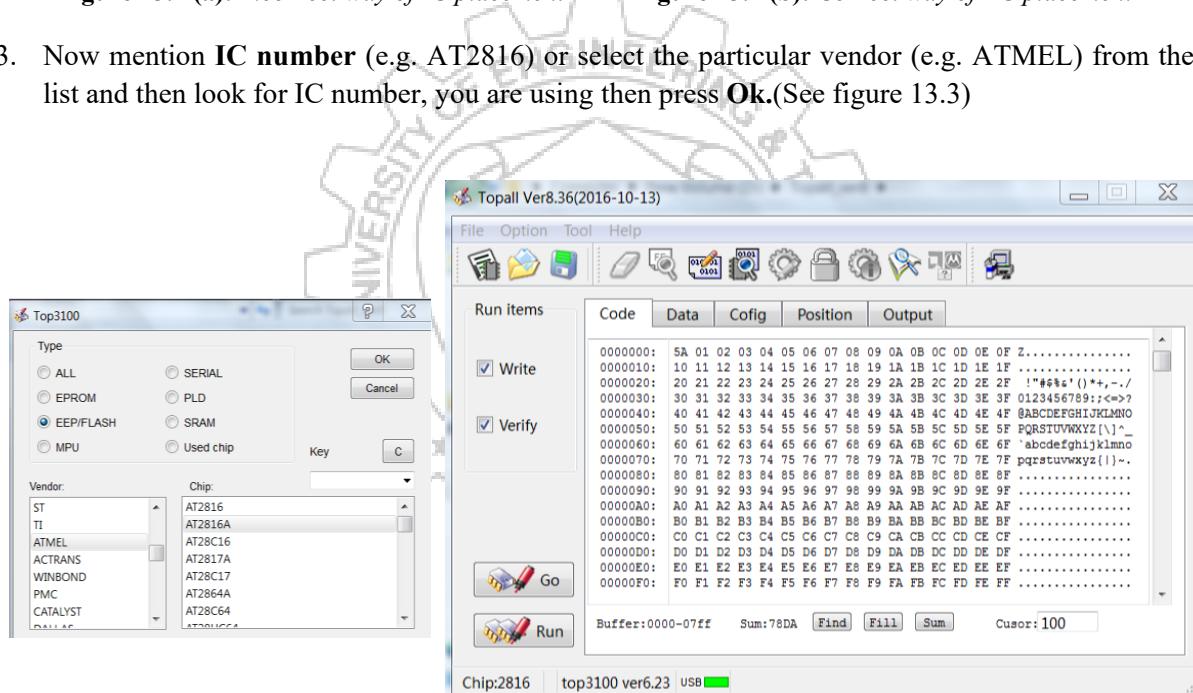


Figure 13.3: Writing to Memory Chip

4. In the editor window (called buffer zone) left most column represents “addresses”, middle one represents “contents in hex” & right most shows the character whose ASCII is in the middle.
5. Now enter your desired contents (see Table 15.1) in the middle and Press **write**. Within few seconds, programmer will write this data to your memory chip. Now remove this chip from the programmer.
6. Now place this memory chip on the breadboard of logic trainer board and make supply connections of this IC.
7. Connect the least significant four address (input) lines of the memory chip to the input switches and ground the remaining address lines; otherwise float high property of TTL IC may lead with unexpected output.

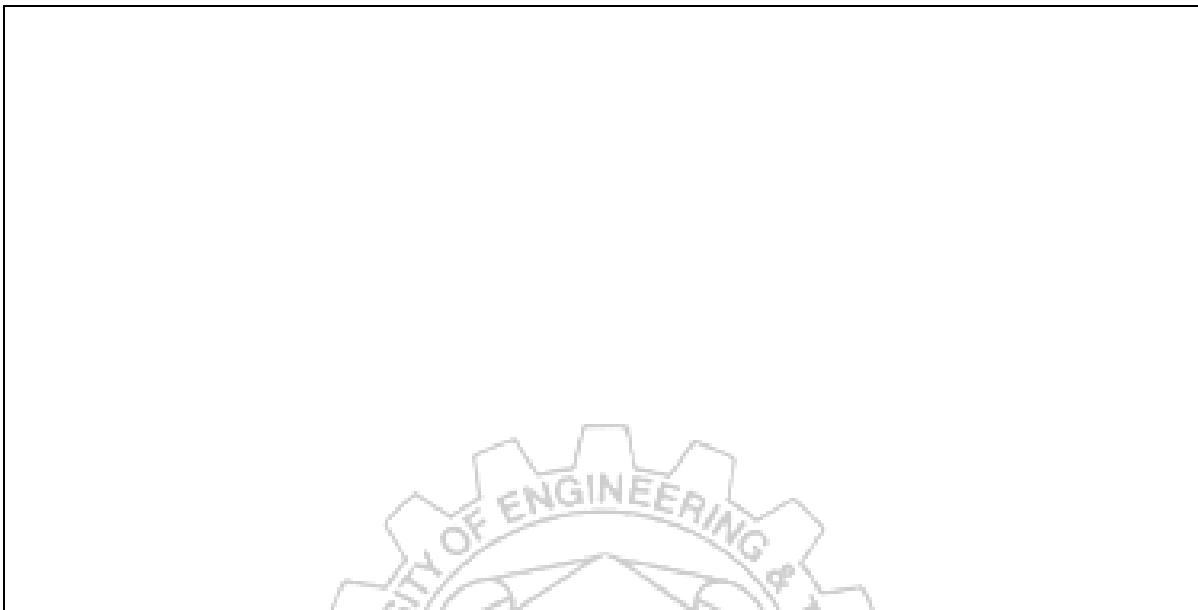
8. Connect the least significant 7 data (output) lines (DQ0 to DQ6) to the segments **a** through **g** of the seven segment display.
9. Other common pins found in memory chips are OE (output enable), CE (chip enable) and WE (write enable). Of these pins WE is kept OFF (disabled), remaining two are enabled.
10. Apply address form 0H to FH through the switch and observe the output on the seven-segment display.

Table 13.1

Hex digit	Address lines of the EPROM				Seven segments							Contents to be stored in EPROM (in hex)
	A_3	A_2	A_1	A_0	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	
0	0	0	0	0	1	1	1	1	1	1	0	7E
1	0	0	0	1	0	1	1	0	0	0	0	30
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								
A	1	0	1	0								
B	1	0	1	1								
C	1	1	0	0								
D	1	1	0	1								
E	1	1	1	0								
F	1	1	1	1								

EXERCISE

1. Paste a snapshot of the working hardware when an input, same as last digit of your roll number, is applied to the circuit.



Lab Session 14

Complex Engineering Activity

PROBLEM STATEMENT

Design and implement a finite state machine for a real-world scenario as given by the lab instructor.

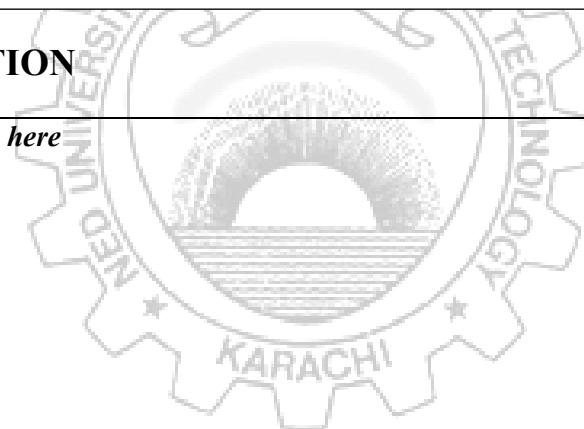
COMPLEX PROBLEM SOLVING ATTRIBUTES COVERED

Assigned complex engineering activity covers following attributes.

- **Range of resources:** Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).
- **Level of interaction:** Require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues.
- **Innovation:** Involve creative use of engineering principles and research-based knowledge in novel ways.
- **Familiarity:** Can extend beyond previous experiences by applying principles-based approaches.

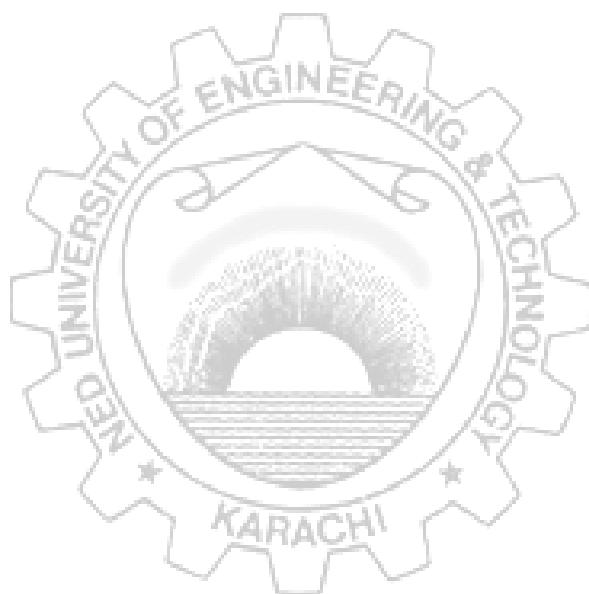
TASK DESCRIPTION

Paste Task Description here



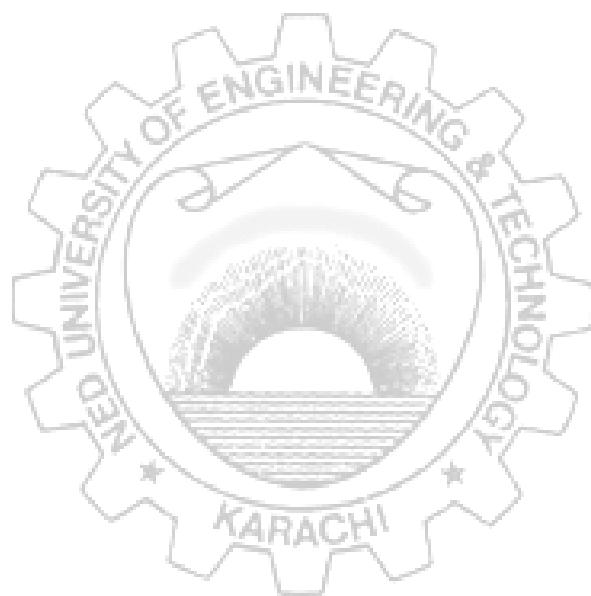
DELIVERABLES

- Hardware circuit, based on the simulated model, either on Bread board or Vero board. Implementation on PCB or microcontroller is not allowed.
- Working simulation for the circuit using any appropriate simulation software (Electronic workbench, Proteus, Multisim, etc.).

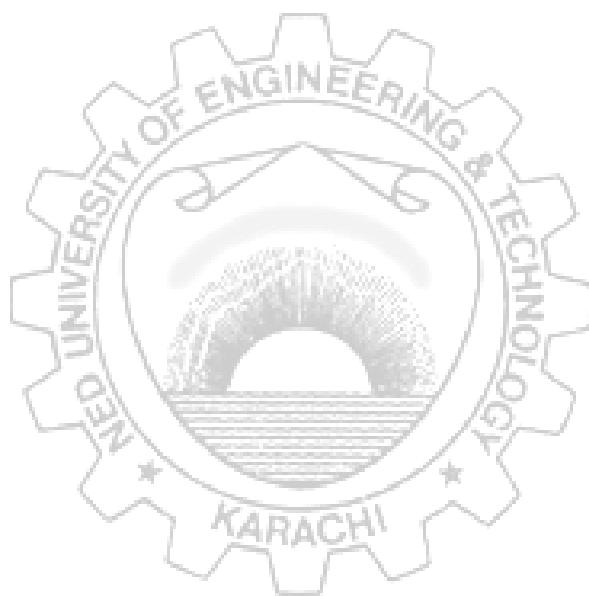
GRADING RUBRIC

FINITE STATE MACHINE DESIGN

continued

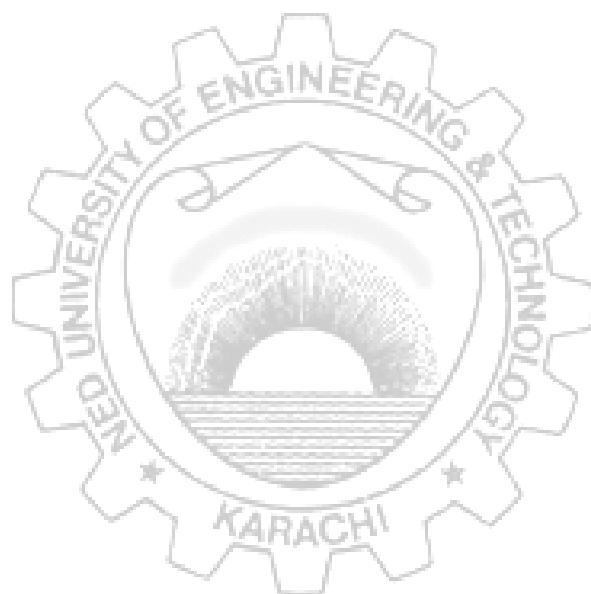


LOGIC CIRCUIT DIGRAM

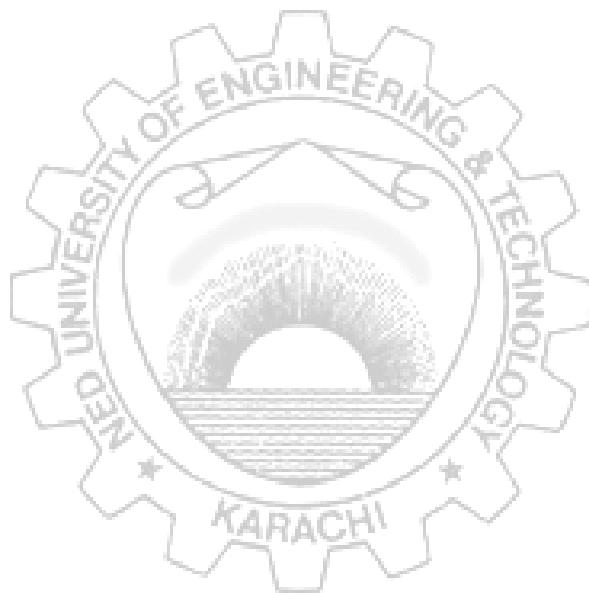


SIMULATION

Paste screenshot of simulation designed here



Paste snapshot of working hardware here

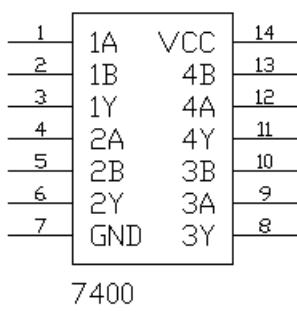
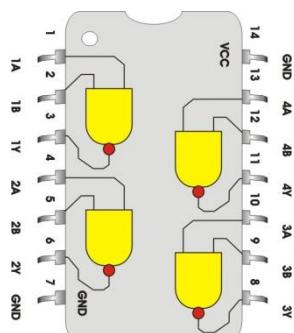


Appendix A

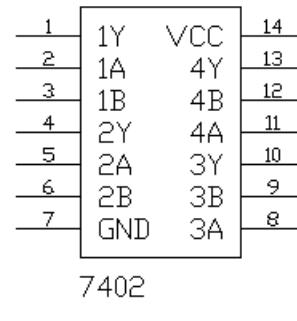
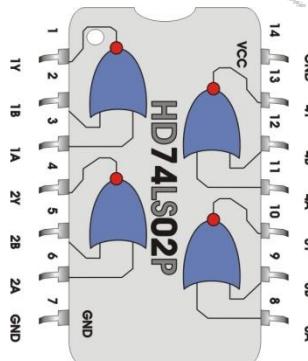
PIN DIAGRAMS OF THE ICS REQUIRED FOR THE LABORATORY SESSIONS

Consult the TTL/IC data book for internal diagrams and electrical characteristics of these ICs.

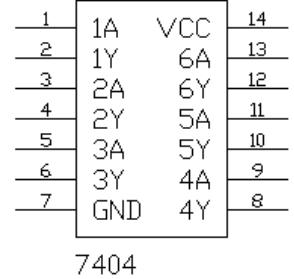
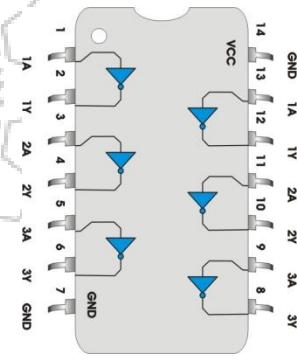
7400 Quad 2-Input NAND

7400 Quad 2-Input NAND
(Internal Diagram)

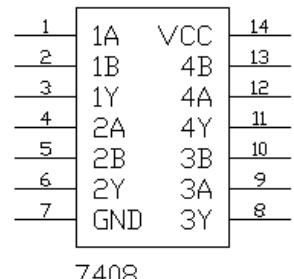
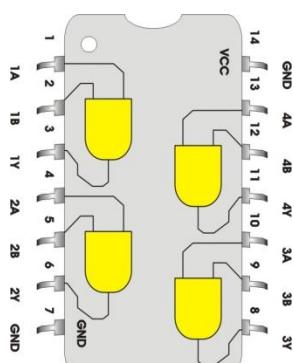
7402 Quad 2-Input NOR

7402 Quad 2-Input NOR
(Internal Diagram)

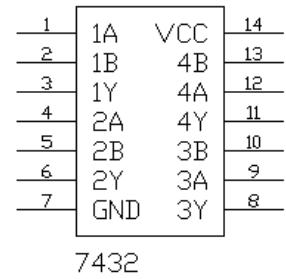
7404 Hex Inverter

7404 Hex Inverter
(Internal Diagram)

7408 Quad 2-Input AND

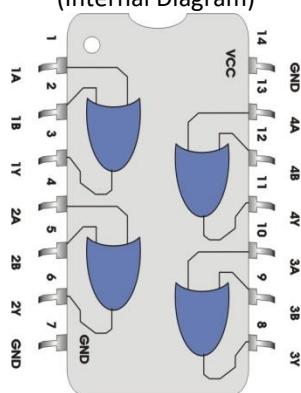
7408 Quad 2-Input AND
(Internal Diagram)

7432 Quad 2-Input OR

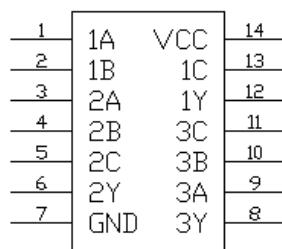


7432 Quad 2-Input OR

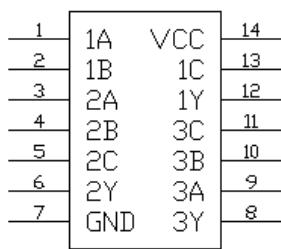
(Internal Diagram)



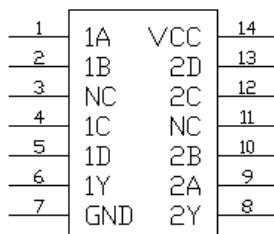
7410 Triple 3-Input NAND



7411 Triple 3-Input AND

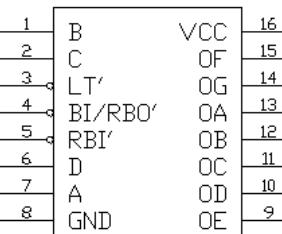


7421 Dual 4-Input AND



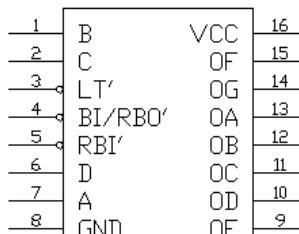
7421

7447 BCD-to-Seven Segment Decoder (15V, O.C.)



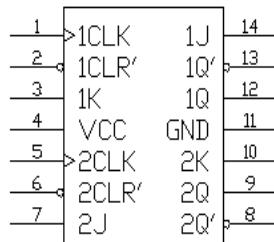
7447

7448 BCD-to-Seven Segment Decoder (2kΩ pull-up output)



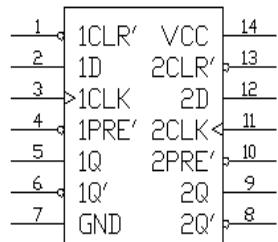
7448

7473 Dual JK Flip-Flop



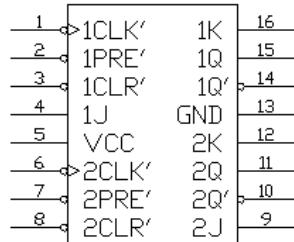
7473

7474 Dual D-Type Flip-Flop



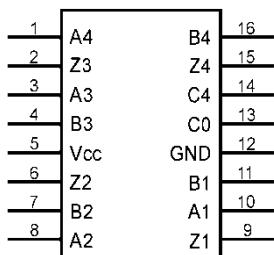
7474

7476 Dual JK Flop-Flop



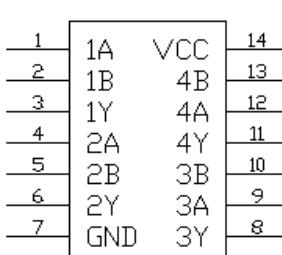
7476

7483 4-Bit Binary Full Adder With fast carry



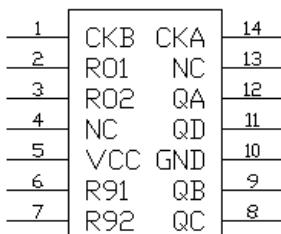
7483

7486 Quad 2-Input Exclusive OR



7486

7490 Decade Counter



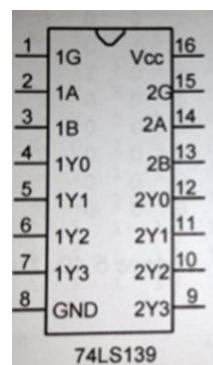
7490

74138 3-to-8 Line Decoder / Demultiplexer

1	A	VCC	16
2	B	Y0	15
3	C	Y1	14
4	G2A'	Y2	13
5	G2B'	Y3	12
6	G1	Y4	11
7	Y7	Y5	10
8	GND	Y6	9

74138

74139 2-to-4 Duo Decoder



74147 10-to-4 Priority Encoder

1	4	VCC	16
2	5	NC	15
3	6	D	14
4	7	3	13
5	8	2	12
6	C	1	11
7	B	10	10
8	GND	A	9

74147

74148 8-to-3 Line Priority Encoder

1	4	VCC	16
2	5	E0	15
3	6	GS	14
4	7	3	13
5	E1	2	12
6	A2	1	11
7	A1	0	10
8	GND	A0	9

74148

74150 16-to-1 Line Data Selector / Multiplexer

1	E7	VCC	24
2	E6	E8	23
3	E5	E9	22
4	E4	E10	21
5	E3	E11	20
6	E2	E12	19
7	E1	E13	18
8	E0	E14	17
9	G'	E15	16
10	W	A	15
11	D	B	14
12	GND	C	13

74150

74157 Quad 2x1 Data Selector / Multiplexer

1	A/B'	VCC	16
2	1A	G'	15
3	1B	4A	14
4	1Y	4B	13
5	2A	4Y	12
6	2B	3A	11
7	2Y	3B	10
8	GND	3Y	9

74157

74194 4-Bit Bidirectional Universal Shift Register

1	CLR'	VCC	16
2	SR	QA	15
3	A	QB	14
4	B	QC	13
5	C	QD	12
6	D	CLK	11
7	SL	S1	10
8	GND	S0	9

74194

74245 Octal Bus Transceivers (3 State)

1	DIR	Vcc	20
2	A1	G'	19
3	A2	B1	18
4	A3	B2	17
5	A4	B3	16
6	A5	B4	15
7	A6	B5	14
8	A7	B6	13
9	A8	B7	12
10	GND	B8	11

74245

Appendix B

COMMON COMPONENTS (BESIDE LOGIC ICS) USED IN BUILDING CIRCUITS

Battery

Battery supplies a voltage which drives an electric *current* round the circuit from the positive (+) terminal of the battery to its negative (-) terminal. Voltage is measured in volts (V) and current in *amperes* (A).

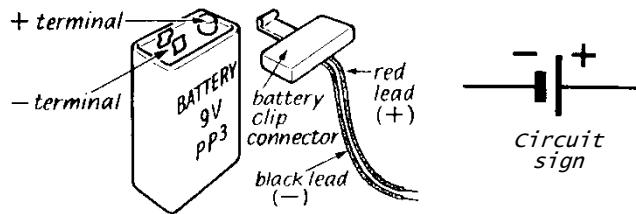


Figure B.1: Battery (9V, type PP3)

Connecting Wires

A connecting wire allows current to flow through it easily because it is made of copper which is a good electrical conductor. Insulators like PVC (polyvinyl chloride - a plastic) and enamel are used to cover connecting wires.

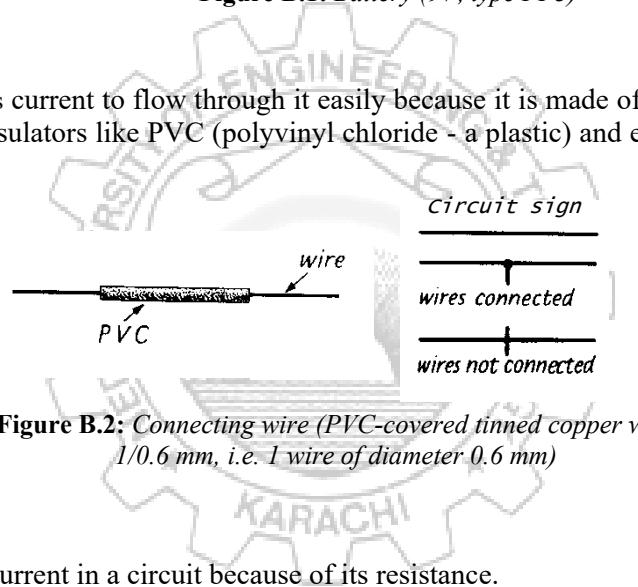


Figure B.2: Connecting wire (PVC-covered tinned copper wire 1/0.6 mm, i.e. 1 wire of diameter 0.6 mm)

Resistors

A resistor reduces the current in a circuit because of its resistance.

Color Coded Resistor

The colored bands give the resistance in ohms.

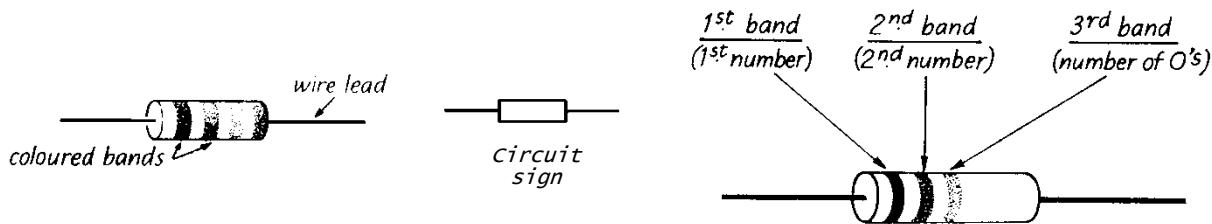


Figure B.3: Color coded resistor (carbon, 1/2 watt)

To distinguish left from right there is a gap between the C and D bands.

- Band A is the first significant figure of component value (left side)
- Band B is the second significant figure

- Band C is the decimal multiplier
- Band D if present, indicates tolerance of value in percent (no color means 20%)

The values are interpreted as given in table B.1.

Color	Significant figures	Multiplier	Tolerance
Black	0	$\times 10^0$	-
Brown	1	$\times 10^1$	$\pm 1\%$
Red	2	$\times 10^2$	$\pm 2\%$
Orange	3	$\times 10^3$	-
Yellow	4	$\times 10^4$	-
Green	5	$\times 10^5$	$\pm 0.5\%$
Blue	6	$\times 10^6$	$\pm 0.25\%$
Violet	7	$\times 10^7$	$\pm 0.1\%$
Gray	8	$\times 10^8$	$\pm 0.05\%$
White	9	$\times 10^9$	-
Gold	-	$\times 10^{-1}$	5%
Silver	-	$\times 10^{-2}$	10%
None	-	-	20%

Table B.1: Standard color codes

For example, a resistor with bands of yellow, violet, red and gold will have first digit 4, second digit 7, followed by 2 zeros: 4700 ohms. Gold signifies that the tolerance is $\pm 5\%$, so the resistance could lie anywhere between 4465 and 4935 ohms.

Variable Resistor

Variable resistors are used when it is necessary to dynamically change the resistance in order to control the current in a circuit, and may also be used when a voltage divider is needed. For example, they are used to control the volume in a radio or the brightness of a lamp.

Variable resistors consist of a resistance track with connections at both ends and a wiper which moves along the track as you turn the spindle (see figure B.4). The track may be made from carbon, cermet (ceramic and metal mixture) or a coil of wire (for low resistances). The track is usually rotary but straight track versions, usually called sliders, are also available.

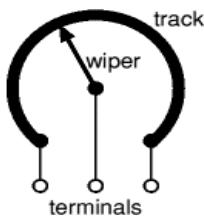


Figure B.4: Variable resistor

They are specified by their maximum resistance, linear or logarithmic track, and their physical size. The standard spindle diameter is 6mm. The resistance and type of track are marked on the body (for example: 4K7 LIN means 4.7 k Ω linear track ; 1M LOG means 1 M Ω logarithmic track). Linear (LIN) track means that the resistance changes at a constant rate as you move the wiper. This is the standard arrangement which is assumed if a project does not specify the type of track. Logarithmic (LOG) track means that the resistance changes slowly at one end of the track and rapidly at the other end, so halfway along the track is not half the total resistance. This arrangement is used for volume (loudness) controls because the human ear has a logarithmic response to loudness so fine control (slow change) is required

at low volumes and coarser control (rapid change) at high volumes. It is important to connect the ends of the track the correct way round, if turning the spindle increases the volume rapidly followed by little further change you should swap the connections to the ends of the track.

Variable resistors may be used as a rheostat with two connections (the wiper and just one end of the track) or as a potentiometer with all three connections in use. Miniature versions called presets are made for setting up circuits which will not require further adjustment.

The terminal in the middle is the *wiper*. When a potentiometer is used as a voltage divider, all three terminals are wired separately. But when a potentiometer is used strictly as a rheostat, only need two connections are needed. Either side of the variable resistor may be attached to the circuit board, with the remaining side unattached or grounded, but it is important to always connect the wiper. The wiper must be grounded or affixed to the voltage source. For example, the left terminal of the pot may be attached to the voltage source and the wiper to ground, or the right terminal may be substituted for the left. Changing the connection to a different side alters the direction the knob must be turned in order to achieve maximum resistance. The unused side of the variable resistor may be left unconnected, wired to an unused portion of the breadboard, or wired to ground.

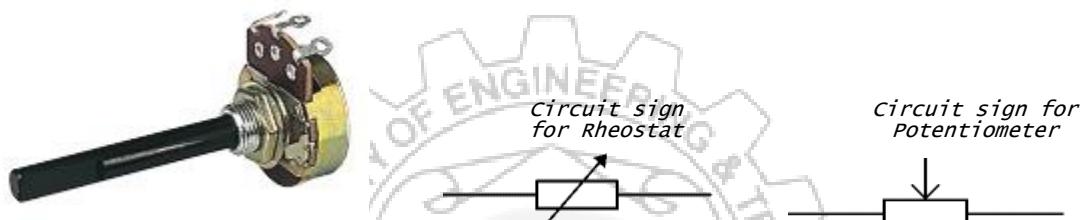


Figure B.5: Potentiometer and Rheostat

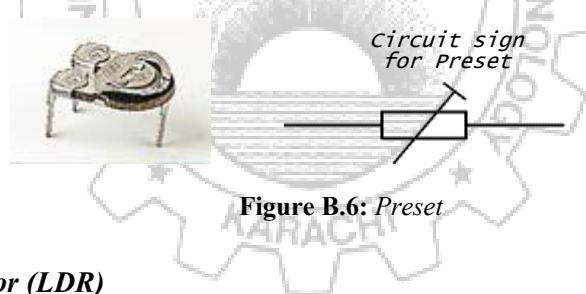


Figure B.6: Preset

Light Dependent Resistor (LDR)

When light falls on it, its resistance becomes small; in the dark resistance is high.

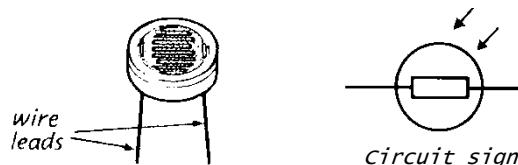


Figure B.7: Photocell or light dependent resistor (LDR)

Capacitors

A capacitor stores electricity; the greater the capacitance the more does it store. Capacitance values are measured in microfarads shortened to μF or, less correctly, to mfd. On a capacitor, $0.1 \mu\text{F}$ may be marked as .1 mfd and $0.01 \mu\text{F}$ as 10n. The greatest voltage it can stand is also shown, e.g. 30V.

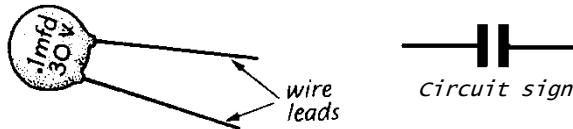


Figure B.8: Capacitor (disc ceramic type)

Electrolytic Capacitor

Electrolytic capacitor stores electricity: values usually larger than $1 \mu\text{F}$. Greatest voltage marked on it. Must be connected the correct way round.

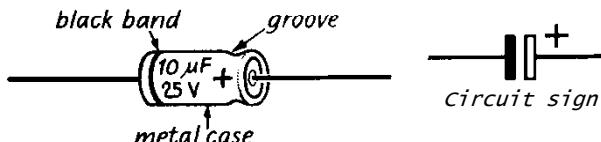


Figure B.9: Electrolytic Capacitor

Variable Capacitor

It varies the capacitance in a circuit by moving one set of metal plates in or out of a fixed set when the spindle is rotated. The sets of plates are separated by sheets of an insulator (also called a dielectric).

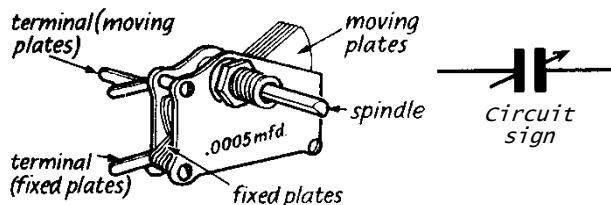
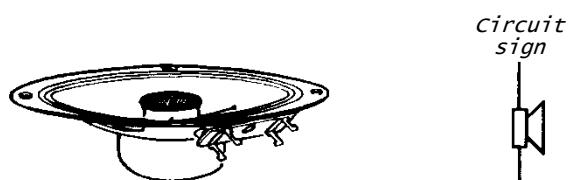


Figure B.10: Variable Capacitor (0.0005 microfarads)

Loud Speaker

It changes electric currents into sound.



Aerial

Changes radio waves into electric currents.

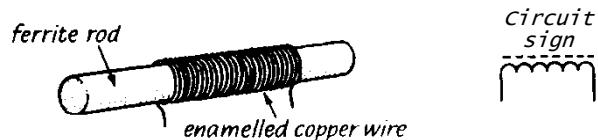


Figure B.12: Ferrite rod aerial

Light Emitting Diode (LED)

An LED lets current flow in one direction but not in the other. When it conducts, light is emitted. Must have a current limiting resistor in series with it. The cathode lead is nearest the ‘flat’ and may be shorter than the anode lead (but not always).

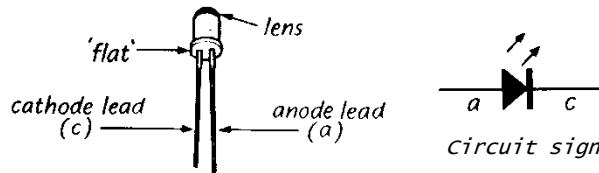


Figure B.13: LED (light emitting diode)

Transistor

Transistor amplifies small currents into much larger copies. It acts as a very fast switch. It must be correctly connected with a positive voltage to the collector

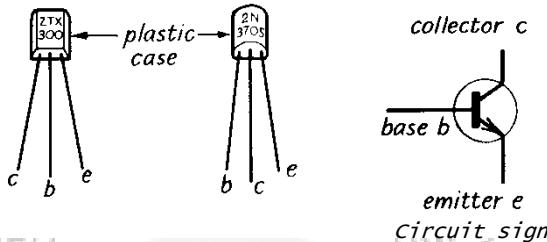


Figure B.14: Transistor (npn)
(e.g. ZTX300 or 2N3705)

Switches

A switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another.

SPDT Switch

Connects terminal A to terminal B or C, i.e. it is a change-over switch.

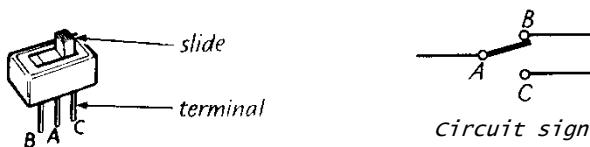


Figure B.15: Miniature slide switch SPDT (single pole double throw)

DIP Switch

A DIP switches are manual electric switches that are packaged in a group in a standard dual in-line package (DIP) (the whole package unit may also be referred to as a DIP switch in the singular). It provides an easy way of inputting values to a digital circuit. The Dip Switch requires a Resistor Network Pack for its operation.

The connection configuration is shown in figure B.17. Resistor Network Pack has a pin configuration that must be followed. The side of the resistor pack with the print is the “front.” At the far left end of the component there is a black circle. This pin must be connected to the power supply. The other pins do not required to be connected to power. Once the dipswitch and resistor pack is placed on the board,

the next thing that needs to be done is to connect wires from all the columns connected to the dip-switch to the ground rail. This way one side of the dip-switch is “tied” to ground.



Figure B.16: (a) Resistor Network Pack, (b) DIP Switch

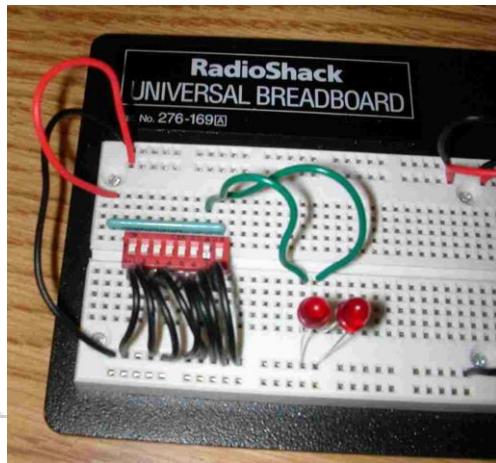


Figure B.17: Circuit Connections of DIP switch with resistor network pack

The dip-switch can now be used to “input” values. When the switch is pushed to one side it disconnects the top column from the bottom column on the breadboard. Voltage appears on the column due to the pin of the resistor pack pin connected to that column. When switch is pushed to the other side, the dip-switch connects the top column to the bottom column. Since the top column along with the pin of the resistor pack is “tied” to ground, no voltage appears on the top column. The idea of the dip-switch is that when the dip switch is open, or there is no connection between the top and bottom column, current flows from the resistor pack to the electrical component. However, when the dip-switch is closed, or the top and bottom column are tied together, current flows from the resistor pack to ground rather than to the electrical component. This resistor-pack/dip-switch circuit should be placed as far to the left side of the breadboard as possible to leave space for other components.

Push Button

A Push Switch or Push to make switch, allows electricity to flow between its two contacts when held in. When the button is released, the circuit is broken. Other forms are push to break which, does the opposite.

Relay

A relay is an electrically operated switch. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. These devices use a solenoid to control a heavy-duty switch. The wiring for the solenoid may require only 0.5 amps to activate, while the switch it controls carries 10 to 30 amps.

A Solid State Relay (SSR) is an electronic switch that works without moving parts. Here the low current control and a high current load are isolated optically or with transformers. They are activated by AC control signals or DC control signals from Programmable logic controller (PLCs), PCs,

Transistor-transistor logic (TTL) sources, or other microprocessor and microcontroller controls. Since relays are switches, the terminology applied to switches is also applied to relays. A relay will switch one or more *poles*, each of whose contacts can be *thrown* by energizing the coil in one of three ways:

- Normally-open (NO) contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.
- Normally-closed (NC) contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.
- Change-over (CO), or double-throw (DT), contacts control two circuits: one normally-open contact and one normally-closed contact with a common terminal.

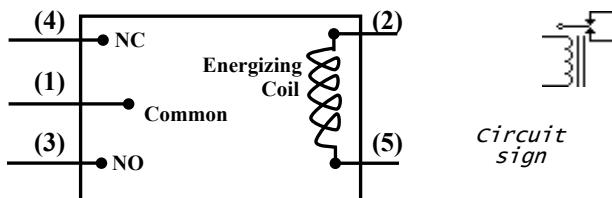


Figure B.18: Relay

For circuit connections, consider figure B.18, pins 2 and 5 seem to go to the coil. Pin 1 is the common pin. Pin 4 is the NC (normally closed) pin and pin 3 is the NO (normally open) pin. Connect the control device to the two solenoid pins (pins 2 and 5) of the relay. Supplying a small voltage to these two pins will turn the relay switch on or off. The lower the better until you are sure what voltage the relay can take (can start from 3V or 5V). When the relay is not energized, there should be continuity between pins 1 and 4. When the relay is energized, there should be continuity between pins 1 and 3. Connect the negative terminal of the battery to pin 1. This pin brings the power into the relay for powering the external device, which could be the electric motor of a fan or light. If the external device should only be on when the relay is energized, connect a wire from the negative terminal of the external device to pin 3 of the relay. If the external device should be on at all times except when the relay is energized, connect to pin 4 instead of pin 3. Complete the circuit by connecting a wire from the positive terminal of the external device to the positive terminal of the battery.

Integrated Circuits (ICs)

Transistors, diodes, resistors and capacitors are connected together on a tiny ‘chip’ of silicon (sand is mostly silicon oxide) to give any desired circuit, e.g. a multistage amplifier; an astable, bistable or monostable multivibrator; a counter; a logic gate for a computer; several stages of a TRF (tuned radio frequency) radio.

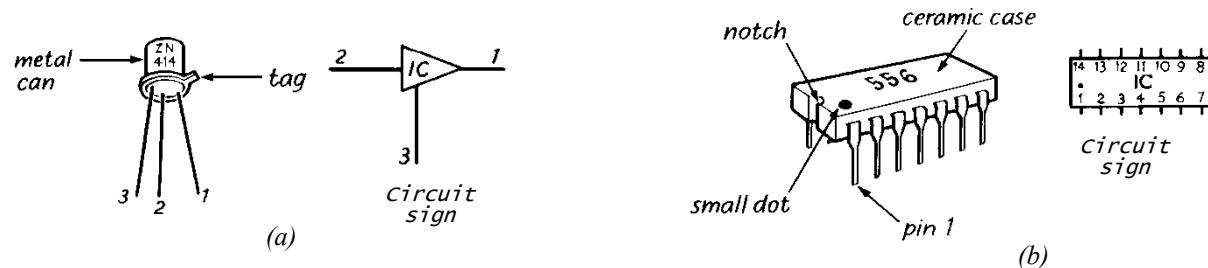


Figure B.19: Integrated circuits ('chips')
(a) Can type (b) Dual in line (d.i.l.) type (14 or 16 pins)

They must be correctly connected. Pin 1 is next to the ‘tag’ in the can type and on the d.i.l. type it is identified from the ‘notch’ or ‘small dot’ on the case. TTL and CMOS are two technologies in which

logic gate ICs are available. CMOS ‘chips’ (standing for Complementary Metal Oxide Semiconductors and pronounced ‘see-moss’) need special care.

CMOS (4000 series) General Characteristics

- Supply: 3 to 15V, small fluctuations are tolerated.
- Inputs have very high impedance (resistance), this is good because it means they will not affect the part of the circuit where they are connected. However, it also means that unconnected inputs can easily pick up electrical noise and rapidly change between high and low states in an unpredictable way. This is likely to make the chip behave erratically and it will significantly increase the supply current. To prevent problems all unused inputs MUST be connected to the supply (either +Vs or 0V), this applies even if that part of the chip is not being used in the circuit.
- Outputs can sink and source only about 1mA if you wish to maintain the correct output voltage to drive CMOS inputs. If there is no need to drive any inputs the maximum current is about 5mA with a 6V supply, or 10mA with a 9V supply (just enough to light an LED). To switch larger currents you can connect a transistor.
- Fan-out: one output can drive up to 50 inputs.
- Gate propagation time: typically 30ns for a signal to travel through a gate with a 9V supply, it takes a longer time at lower supply voltages.
- Frequency: up to 1MHz, above that the 74 series is a better choice.
- Power consumption (of the chip itself) is very low, a few μW . It is much greater at high frequencies, a few mW at 1MHz for example.
- Damage occurs if static charges build up on input pins when, for example, they touch insulating materials (e.g. clothes, plastic pen) in warm, dry conditions.
 1. Keep the IC in the carrier in which it is supplied until it is inserted in the circuit.
 2. Do not finger the pins or hold them in contact with an insulator.
 3. Connect all unused inputs of the IC to either the positive or the negative of the battery, depending on the circuit.

74LS series TTL Characteristics

- Supply: $5\text{V} \pm 0.25\text{V}$, it must be very smooth, a regulated supply is best. In addition to the normal supply smoothing, a $0.1\mu\text{F}$ capacitor should be connected across the supply near the chip to remove the ‘spikes’ generated as it switches state, one capacitor is needed for every 4 chips.
- Inputs ‘float’ high to logic 1 if unconnected, but do not rely on this in a permanent (soldered) circuit because the inputs may pick up electrical noise. 1mA must be drawn out to hold inputs at logic 0. In a permanent circuit it is wise to connect any unused inputs to +Vs to ensure good immunity to noise.
- Outputs can sink up to 16mA (enough to light an LED), but they can source only about 2mA. To switch larger currents you can connect a transistor.
- Fan-out: one output can drive up to 10 74LS inputs, but many more 74HCT inputs.
- Gate propagation time: about 10ns for a signal to travel through a gate.
- Frequency: up to about 35MHz (under the right conditions).
- Power consumption (of the chip itself) is a few mW.

Building Circuits

The circuit board shown in figure B.20 accepts ICs as well as separate components. It has 47 rows of 5 interconnected sockets on each side of a central channel across which d.i.l. ICs can be fitted. A wire inserted in a socket in a certain row becomes connected to wires in any of the other 4 sockets in that row by a metal strip under the board. For example, wires in sockets B5, C5, D5, E5 and F5 are all joined. Metal strips under the board connect the sockets.

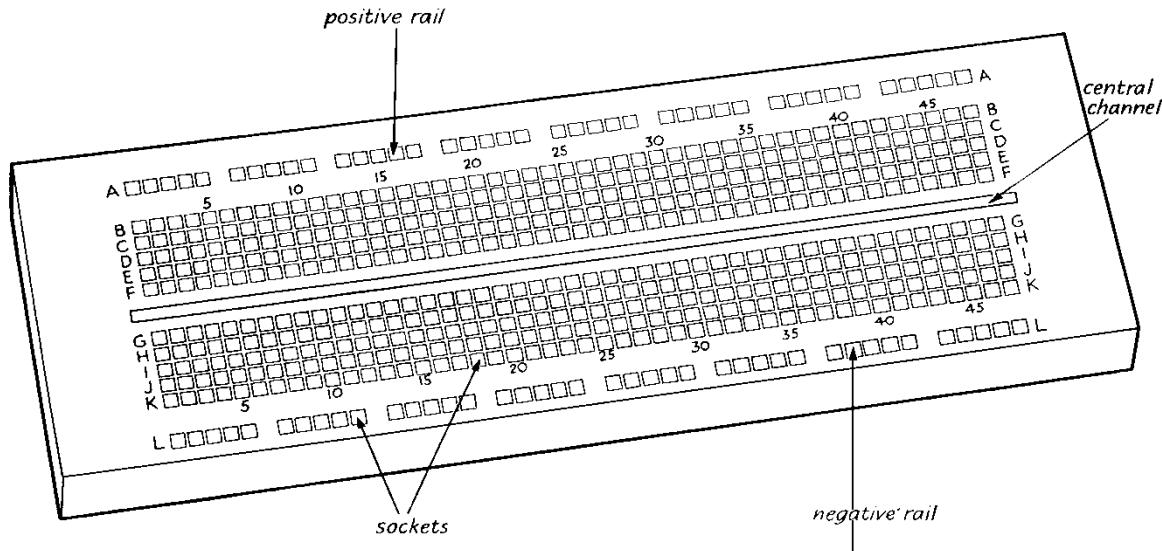


Figure B.20: Circuit board

The circuit board shown above accepts ICs as well as separate components. It has 47 rows of 5 interconnected sockets on each side of a central channel across which d.i.l. ICs can be fitted. A wire inserted in a socket in a certain row becomes connected to wires in any of the other 4 sockets in that row by a metal strip under the board. For example, wires in sockets B5, C5, D5, E5 and F5 are all joined. Metal strips under the board connect the sockets. There is a row of 40 interconnected sockets along the top of the board and a similar row along the bottom act as the positive and negative power supply rails (called ‘bus bars’). Various makes of circuit board are available, some with vertically mounting removable panels for supporting controls.

To make a connection push about 1 cm of the bare end of a wire (0.25 to 0.85 mm diameter) straight into the socket (not at an angle) so that it is gripped by the metal strip under the board. Do not use wires that are dirty or have kinked ends. Only put one wire in each socket. Bend leads on resistors etc., as shown in figure B.21 before inserting them in the board.

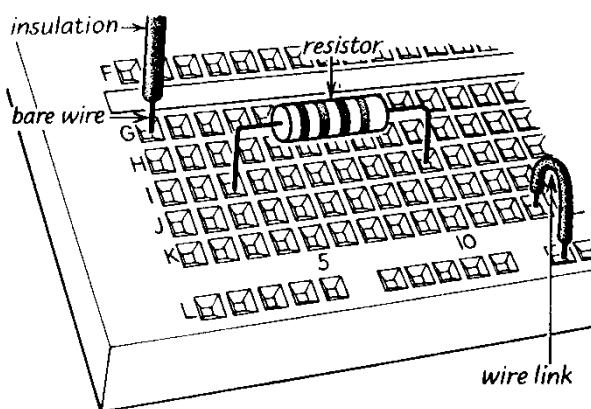


Figure B.21: Placing various components on the circuit board

Bare the ends of connecting wire (PVC-covered tinned copper wire 0.6 mm diameter) by removing the insulation (PVC) either with wire strippers or using a pair of blunt-nosed pliers and a pair of side cutters as shown in figure B.22. With practice you should be able to judge just how much the side cutters have to be squeezed and pulled to remove the insulation without cutting the wire.

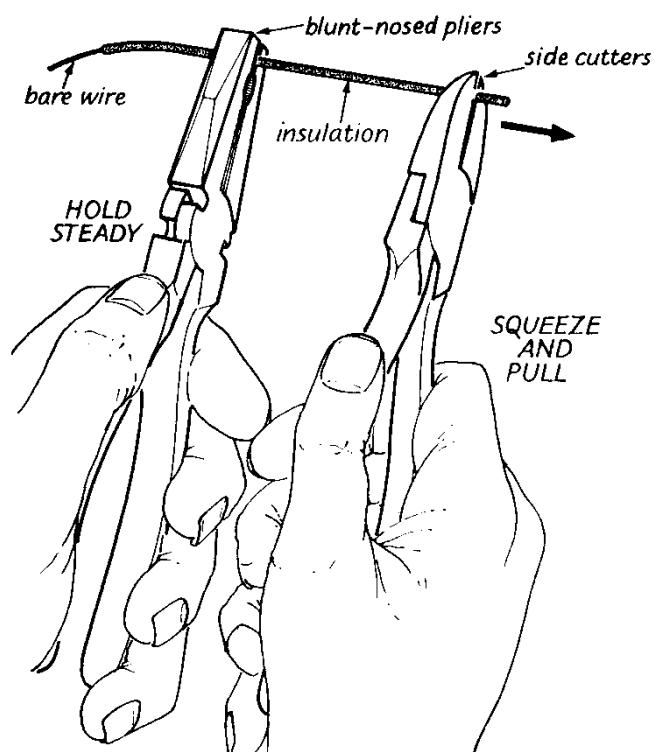


Figure B.22: Stripping wire



Appendix C

C.1 CLOCK GENERATION USING 555 TIMER IC

The 555 timer is a versatile and widely used device which can be used effectively without understanding the function of each pin in detail. It can be configured in two different modes as either a *monostable multivibrator (one-shot)* or as an *astable multivibrator (oscillator)*. An astable multivibrator has no stable state and therefore changes back and forth (oscillates) between two unstable states without any external triggering, hence can be used for clock generation of desired frequency and duty cycle. The circuit given in figure C.1 shows the connections of 555 timer in astable mode.

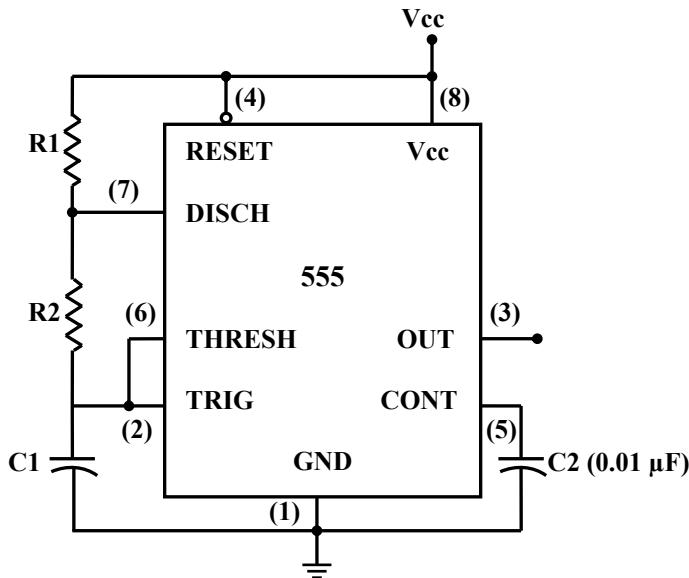


Figure C.1: Connections of 555 timer IC in astable mode

The frequency, or repetition rate, of the output pulses is determined by the values of two resistors, R1 and R2 and by the timing capacitor, C1. The design formula for various parameters are as follows:

1. Frequency , $f = \frac{1.44}{(R1 + 2R2) \times C1}$
2. Period , $t = \frac{1}{f} = 0.69 (R1 + 2R2) \times C1$
3. HIGH time = $0.69 (R1 + R2) \times C1$
4. LOW time = $0.69 (R2 \times C1)$
5. Duty Cycle = $\frac{\text{HIGH time}}{\text{period}}$

Before calculating a frequency, it is usual to make $R_1=1\text{ k}\Omega$ because this helps to give the output pulses a duty cycle close to 50%, that is, the HIGH and LOW times of the pulses are approximately equal. By selecting $C_1 = 10\mu\text{F}$ and $R_2 = 140\text{k}\Omega$, output pulses having approximately 1Hz frequency can be generated. Another usual practice is to replace R_2 with a potentiometer (usually $500\text{k}\Omega$) so that the output frequency can be changed at runtime.

C.2 DEBOUNCING CIRCUITRY FOR MECHANICAL SWITCHES

Mechanical switches form the interface between human beings and computers or other digital systems. For example, a keyboard is a matrix of switches used to supply alphanumeric data to a computer. Whatever the switch design, it is a potential source of problems due to contact bounce. The contact bounce creates a sense of narrow pulses when a switch is opened or closed. An example of device whose operation would be adversely affected by contact bounce is a digital counter used to count the number of times a switch is depressed. Eliminating the effects of contact bounce is called *debouncing*.

When data is entered into a computer via a keyboard, a *software debounce* is often used. This type of debouncing is a program that causes the computer to sample the switch terminal (i.e., to input data from it) many times in succession during the interval of time that contact bounce occurs. If the data is sensed to be 1s (or 0s) for a specific number of consecutive samples, then it is assumed that contact bounce has ended and the last value sensed is valid.

Hardware debouncing is the use of electronic circuitry to eliminate the effects of contact bounce. There are numerous versions of such circuitry, including those that use monostable multivibrators (one-shots), but the most straightforward is simply an RS latch. Figure C.1 shows the circuit. When the switch is in position 1, $R = 0$ and $S = 1$, so the latch is set and the output (Q) is 1. When the switch is in position 0, $R = 1$ and $S = 0$, so the latch is reset and the output is 0. When the switch is moved from one position to the other, the latch changes state and bouncing occurs at either the R or the S input. The bouncing does not affect the latch after it has change state. An RS latch will remain set, for example, when its R input is 0 and its S input is alternately changed from 1 to 0.

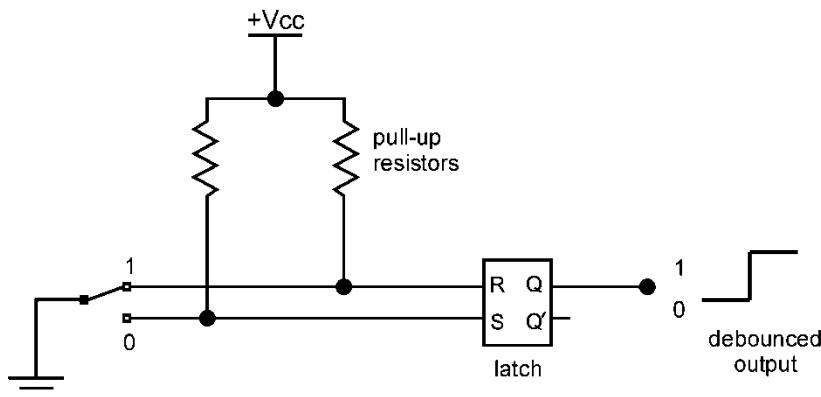


Figure C.1: Use of RS latch to debounce a mechanical switch

GUIDELINES

The students are advised to carefully read and follow the guidelines given below:

Session Code

1. Please **fill-in the session code** given in the page footer against each lab session. Your session code is in format ‘A-B’. Ask your lab teacher for the value of A, and here B is the sum of your 3-digit roll number and lab session number.

For instance: If A=F20, your roll number is CS-100, and lab session number is 5, then the session code will become:

Session Code# F20 – 105

Exercise

2. **Answer to all the questions** in an exercise to consider the lab session as complete.
3. **Handwrite all your answers** to the exercises where printouts are not required.
4. **Neatly paste the printouts** with the glue, no stapling or loose paper is allowed.
5. Printouts must be of size enough to read and understand. Strictly **avoid micro-size printouts**.
6. **Properly label your printouts** with the question / part number.

Submission

7. Submission of any lab session exercise will only be accepted subject to **your presence and performance** of the particular lab. In case if you are casually absent, you must perform your lab in the **same week by or before Friday**.
8. The workbook manual submission may be asked randomly on any date.
9. Individual lab sessions once completed, will be required for **online submission by Friday in the next week** or on specific date if separately announced.
10. **No grade on incomplete exercises or late submissions.**
11. Procedure for the online submission:
 - a. Verify that you have defined the session code on all pages of the lab session.
 - b. With your mobile phone, scan only the pages in exercise of the required lab session (exclude theoretical procedure). You may use any professional scanner app for this.
 - c. Export or combine images in one single pdf file against each lab session. **Rename your pdf file** as your session code. For instance, **F20-105.pdf** can be the filename against example session code as given above.
 - d. Kindly note that only a **single pdf file will be required** to be submitted online against each lab.



Course Code and Title: CS-220 Digital Logic Design

Laboratory Session No. _____

Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to <i>identify</i> equipment and/or its component for a lab work.	Not able to identify the equipment.	--	--	--	Able to identify equipment as well as its components.
Equipment Use Sensory skills to <i>demonstrate</i> the use of the equipment for the lab work.	Doesn't demonstrate the use of equipment.	Slightly demonstrates the use of equipment.	Somewhat demonstrates the use of equipment.	Moderately demonstrates the use of equipment.	Fully demonstrates the use of equipment.
Procedural Skills <i>Displays</i> skills to act upon sequence of steps in lab work.	Not able to either learn or perform lab work procedure.	Able to slightly understand lab work procedure and perform lab work.	Able to somewhat understand lab work procedure and perform lab work.	Able to moderately understand lab work procedure and perform lab work.	Able to fully understand lab work procedure and perform lab work.
Response Ability to <i>imitate</i> the lab work on his/her own.	Not able to imitate the lab work.	Able to slightly imitate the lab work.	Able to somewhat imitate the lab work.	Able to moderately imitate the lab work.	Able to fully imitate the lab work.
Observation's Use <i>Displays</i> skills to use the observations from lab work for experimental verifications and illustrations.	Not able to use the observations from lab work for experimental verifications and illustrations.	Slightly able to use the observations from lab work for experimental verifications and illustrations.	Somewhat able to use the observations from lab work for experimental verifications and illustrations.	Moderately able to use the observations from lab work for experimental verifications and illustrations.	Fully able to use the observations from lab work for experimental verifications and illustrations.
Safety Adherence Adherence to <i>safety</i> procedures.	Doesn't adhere to safety procedures.	Slightly adheres to safety procedures.	Somewhat adheres to safety procedures.	Moderately adheres to safety procedures.	Fully adheres to safety procedures.
Equipment Handling <i>Equipment care</i> during the use.	Doesn't handle equipment with required care.	Rarely handles equipment with required care.	Occasionally handles equipment with required care.	Often handles equipment with required care.	Handles equipment with required care.
Group Work <i>Contributes</i> in a group based lab work.	Doesn't participate and contribute.	Slightly participates and contributes.	Somewhat participates and contributes.	Moderately participates and contributes.	Fully participates and contributes.
Weighted CLO (Psychomotor Score)					
Remarks					
Instructor's Signature with Date:					



Course Code and Title: CS-220 Digital Logic Design

Laboratory Session No. _____

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Psychomotor Domain Assessment Rubric-Level P3

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Weighted CLO (Psychomotor Score)					
Remarks					
Instructor's Signature with Date:					