EXPERIMENT No.1

Aim: Implement Kirchhoff's Voltage Law and Current Law.

Learning Objective: To use ammeter and voltmeter and verify implementation of KVL and KCL.

Apparatus required:

S. No.	Items	Specifications	Quantity
1	DC Voltage source	0-20V	01
2	Resistors	330 ohms	05
3	Ammeter	Digital/Analog	01
4	Voltmeter	Digital/Analog	01
5	Connecting wires	As per requirements	

1. **Kirchhoff's Voltage Law** states that the algebraic sum of all the voltages around any closed path (loop or mesh) is zero.

   Applying Kirchhoff's voltage law to the first (loop with voltage source) and the second loops (without voltage source) in the circuit of **Figure 1:**

   Loop 1: $-V_s + V_1 + V_2 + V_5 = 0$ (1),

   Let I_1 is loop-1 current and I_2 is loop-2 current in clockwise direction, Vs=5V

   $\Rightarrow -5+I_1R_1+(I_1-I_2)R_2+I_1R_5=0; \Rightarrow I_1*330+(I_1-I_2)*330+I_1*330$—(2)

   $\Rightarrow 990I_1-330I_2=5$ ------- (3)

   Loop 2: $V_2 + V_3 + V_4 = 0$ (4)

   $\Rightarrow (I_2-I_1)R_2+I_2R_3+I_2R_4=0; \Rightarrow (I_2-I_1)*330+I_2*330+I_2*330$---(5)

   $\Rightarrow -330I_1-990I_2=0$ ------- (6)

   $\Rightarrow I_1=15/2640A=5.7mA$ A, $I_2=1.9mA$ using these values of current =>
   LOOP1 equation (2) becomes -5+ 5.7m*330+ (5.7-1.9)m*330+ 5.7m*330= -5 + 1.881 + 1.254 +1.881= -5+5.016 ≈ 0, hence KVL verified theoretically.
   LOOP2 equation (5) becomes (1.9-5.7) m*330+1.9m*330+ 1.9m*330= -1.254+0.627+0.627≈ 0. hence KVL verified theoretically.

2. **Kirchhoff's Current Law** states that the algebraic sum of all the currents at any node is zero.

   Applying Kirchhoff's current law to the first four nodes in the circuit shown in **Figure 2** yields the following equations; In Figure 2 Clockwise Current: through voltage source is Iv, through R1 is I_1, through R2 is I_2, through R3 is I_3, Current through R4 is I_4, and Current through R5 is I_5, Let's consider that node **e** is a reference node and is chosen as GND. V_a, V_b, V_c, V_d are node voltages at points **a, b, c** and **d** respectively.

   Node a: $-I_s + I_1 = 0 \Rightarrow V_s = 5V = Va$
   Node b: $I_1 = I_2 + I_3 \Rightarrow (V_b-5)/R_1 = (V_b - V_a)/R_3 + (V_b-V_d)/R_2 \Rightarrow$
   Node c: $I_3 = I_4$
   Node d: $I_2 + I_4 = I_5$

   Let e as reference point or ground.

   ⇨ Va = 5V----(1)

   At node b: $I_1 = I_2 + I_3$

   $(5 - Vb)/R_1 = (Vb - Vd)/R_2 + (Vb - Vc)/R_3$
   After putting values of Resistence, we get
   3Vb -Vc-Vd = 5 ----(2)

   At node C : $I_3 = I_4$

   $(Vb - Vc)/R_3 = (Vc - Vd)/R_4$
   $(Vb - Vc) = (Vc - Vd)$

$2Vc - Vb - Vd = 0$ ------(3)

At node D: $I_5 = I_2 + I_4$

$(Vd - 0)/R_5 = (Vb - Vd)/R_2 + (Vc - Vd)/R_4$

$Vc - Vd + Vc - Vd = Vd$

$Vb + Vc - 3Vd = 0$ -----(4)

Now simplify equation 2, 3 and 4.

Add equation (2) and [(3) × 3], we get

$5Vc - 4Vd = 5$-----(5)

Add equation (3) and (4), we get

$Vc = 4Vd/3$ ------(6)

Put equation (6) in equation (5), we get

$Vd = 15/8$ V -------(7)

Put equation (7) in equation (6), we get

$Vc = 2.5V$ ----(8)

Put equation (7) ad (8) in equation (3), we get

$Vb = 25/8$ -----(9)

Now to find I_1, I_2, I_3, I_4 and I_5 put the value of Va, Vb, Vc and Vd in

$I_1 = (5 - Vb)/R_1$

$I_2 = (Vb - Vd)/R_2$

$I_3 = (Vb - Vc)/R_3$

$I_4 = (Vc - Vd)/R_4$

$I_5 = (Vd - 0)/R_5$

We get, $I_1 = 15/(8\times330)$ A, $I_2 = 10/(8\times330)$ A, $I_3 = 5/(8\times330)$ A, $I_4 = 5/(8\times330)$ A and $I_5 = 15/(8\times330)$ A

Hence Equations below at nodes a, b , c and d are verified theoretically

$-I_5 + I_1 = 0$

$I_1 = I_2 + I_3$

$I_3 = I_4$

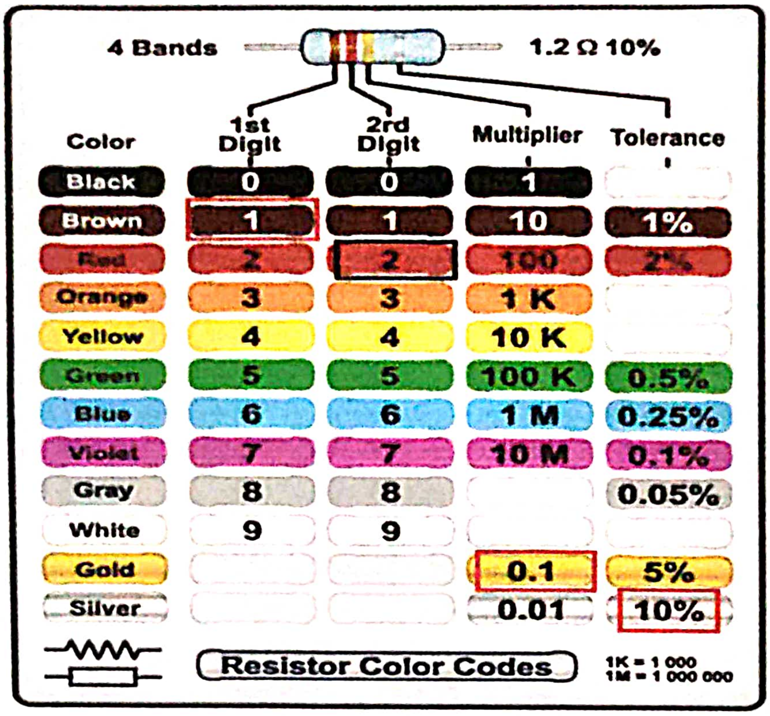
$I_2 + I_4 = I_5$

3. **Reading Resistor with color code:**

The color code is used to specify the resistance value, the tolerance value, and sometimes the reliability or failure rate. The number of bands varies from three to six. At a minimum, two bands indicate the resistance value and one band serves as multiplier.

The four-band color code is the most common variation. These resistors have two bands for the resistance value, one multiplier and one tolerance band. In the example shown here, the 4 bands are green, blue, red and gold. By using the color code chart, one finds that green stands for 5 and blue for 6. The third band is the multiplier, with red representing a multiplier value of 2 (10^2). Therefore, the value of this resistor is $56\text{x}10^2 = 56\text{x}100 = 5600\ \Omega$. The gold band means that the resistor has a tolerance of 5%. The resistance value lies therefore between 5320 and 5880 Ω (5560 ± 5%). If the tolerance band is left blank, the result is a 3-band resistor. This means that the resistance value remains the same, but the tolerance is 20%. **For 5 band resistor**, the first three bands indicate the significant digits, the fourth band is the multiplication factor, and the fifth band represents the tolerance. Let us consider another example (say); brown (1), yellow (4), violet (7), black ($\text{x}10^0 = \text{x}1$), green (0.5%) represents a resistor of 147 Ω with a tolerance of 0.5%. The tolerance represents deviation from the normal value. It is measured at 25 ^{0}C with no load applied and is generally expressed as ±%.

Resistance Value of 330ohm as Band1: Orange, Band2: Orange, Band3: Brown=> 33x10=330∓ tolerance (5% Gold, 10% Silver)



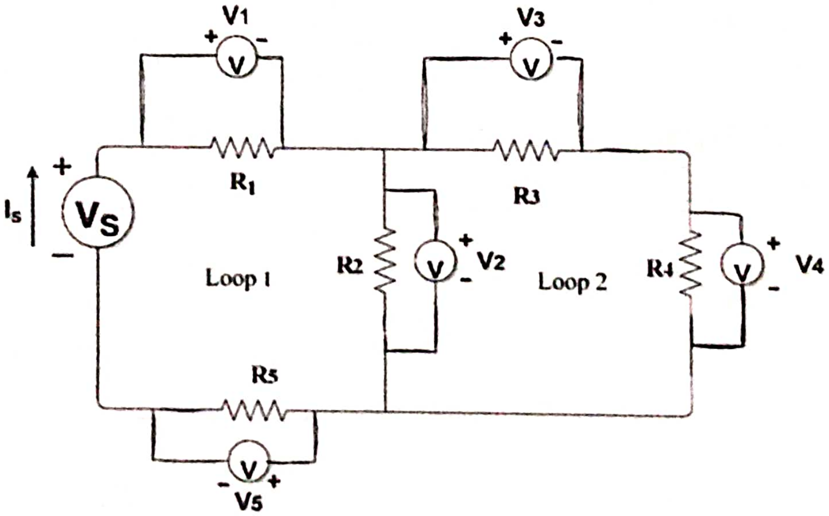


Figure 1 Voltage measurement across circuit elements

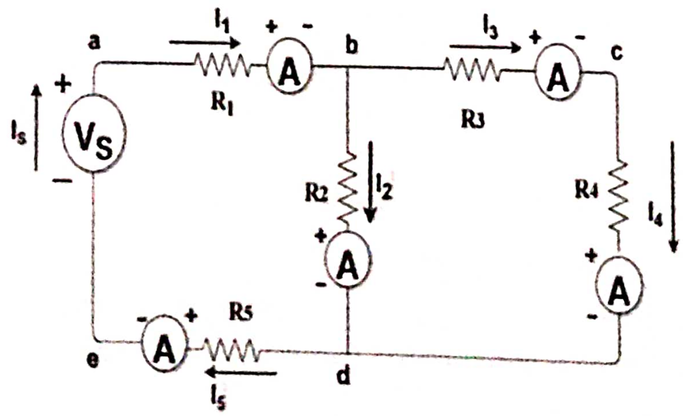


Figure 2 Current Measurement across circuit elements

4. **Least count of Voltmeter and Ammeter:-**

In the given figure 3 below, total range is up to 3V for voltmeter and 1000 mA for ammeter.

Least count = $\frac{Total\ range\ of\ meter}{Total\ number\ of\ division}$

Least count of voltmeter = 3/30 = 0.1 V

Least count of ammeter = 1/50 = 0.02 A

Reading of Voltmeter = Number of divisions scaled by the pointer * Least count of voltmeter = 21*0.1=2.1V

Reading of Ammeter = Number of divisions scaled by the pointer * Least count of Ammeter= 15 *0.02A=0.3A=30mA

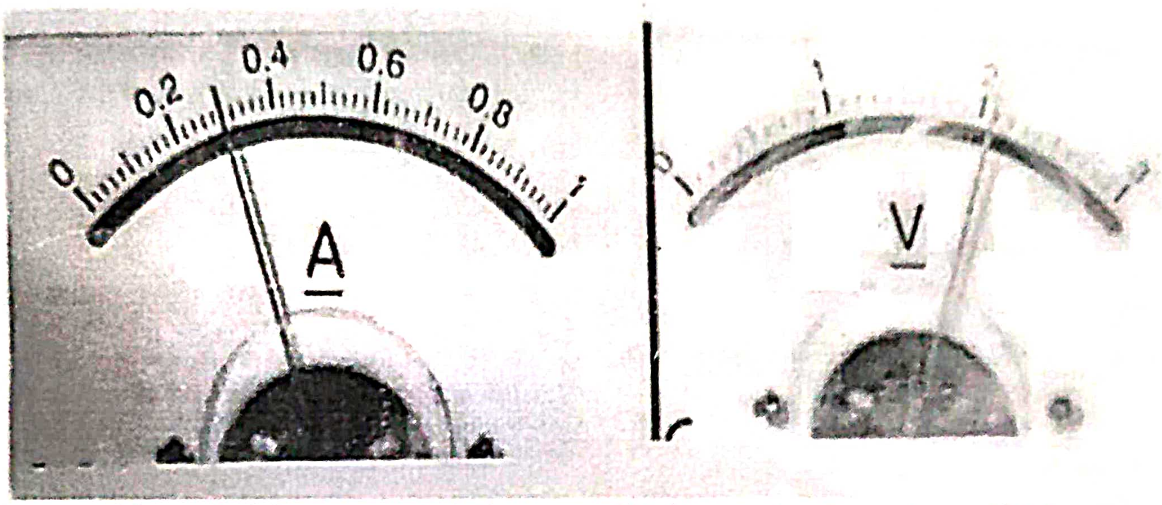


Figure 3: Measurement of Current and Voltage using Ammeter and Voltmeter

5. **Half-Breadboard for circuit implementation:**

	Internally connected
W column	Hole 1 to 25, vertically
X Column	Hole 1 to 25, vertically
Y Column	Hole 1 to 25, vertically
Z Column	Hole 1 to 25, vertically
	Internally connected
Row-1	Holes A B C D & E, horizontally
Row -1	Holes F G H I & J, horizontally
Row-2	Holes A B C D & E, horizontally
Row -2	Holes F G H I & J, horizontally
And so on till 30th row	

Table 1: Internal connection of holes through a metal strip on backside of Half Breadboard

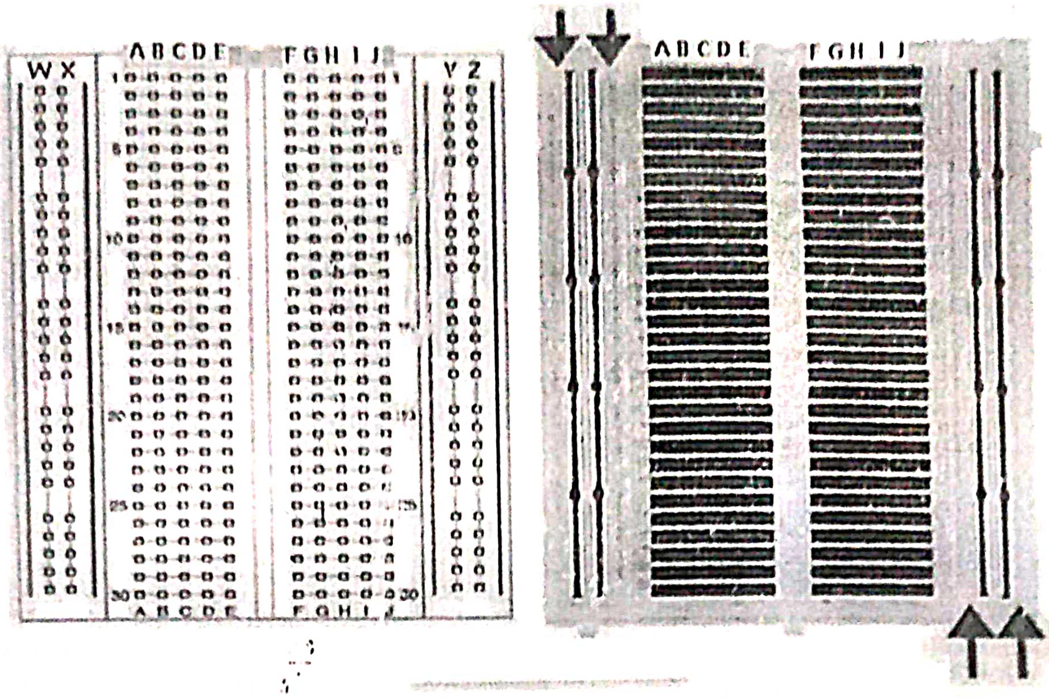


Figure 4: Front view and Back view of Half Breadboard

Procedure:

1. Construct the circuit shown in Figure using the values below: R1 = 330 Ω R2 = 330 Ω R3 = 330 Ω R4 = 330 Ω R5 = 330 Ω,
2. Set the Variable Power Supply (Vs) to 5 Volts.
3. Accurately measure all voltages and currents in the circuit using the Digital/Analog Meter.
4. Record the measurements in the observation and calculation table containing the measured voltage and currentvalues.
5. Verify KVL for the loops in the circuit using equations of Results and Discussion section.
6. Verify KCL for the loops in the circuit using equations of Results and Discussion section.
7. $\%age\ Error = ([V\_Calculated - V\_Measured)/V\_Calculated]x100$

Observation and Calculation: Vs=5V, R=330ohm

Resistance	*Theoretical Value using KVL and KCL Equations*		*Practical value using Ammeter and Voltmeter*			
	Voltage across R	Current in R	Voltage across R	%age error	Current in R	%age error
R_1	1.881V	15 (8×330) A=5.7mA	1.6 v	14.9 %	9.01mA	58.07%
R_2	1.254V	10 (8×330) A= 3.8mA	1.0V	20.2%	2.99mA	95.26%
R_3	0.627V	5 (8×330) A=1.9mA	0.4V	36.2 %	7.42mA	57.36%
R_4	0.627V	5 (8×330) A=1.9mA	0.4v	36.2%	2.99mA	57.36%
R_5	1.881V	5/ (8×330) A= 5.7mA	1.6V	14.9%	8.04mA	58.59%

Results and Discussion:

1. Verify the KVL principle using measured values for the equations below:

   LOOP-1: $-V_S + V_1 + V_2 + V_5 = 0$,

   LOOP-2: $V_2 + V_3 + V_4 = 0$

Check 29/12

loop 1 → $-5 + 1.6 + 1 + 1.6 \Rightarrow -0.8 \neq 0$

loop 2 → $-1 + 0.4 + 0.4 \Rightarrow -0.2 \neq 0$

2. Verify the KCL principle using measured values for the equations below:

Node b: $I_1 = I_2 + I_3$ $\Rightarrow 2.99 + 7.42 \Rightarrow 10.41 \neq 9.01$

Node c: $I_3 = I_4$ $\Rightarrow 2.99 = 2.99$

Node d: $I_2 + I_4 = I_5$ $\Rightarrow 2.99 + 7.42 \Rightarrow 10.41 \neq 9.02$

Precautions:

1. All the connections should be perfectly tight.
2. Always connect ammeter in series and voltmeter in parallel
3. Use safety guards while working on live parts
4. Don't touch the bare conductor when supply is ON.
5. Supply should not be switched ON until and unless the connections are checked by the Faculty/Lab Instructor
6. Use proper wire for connections

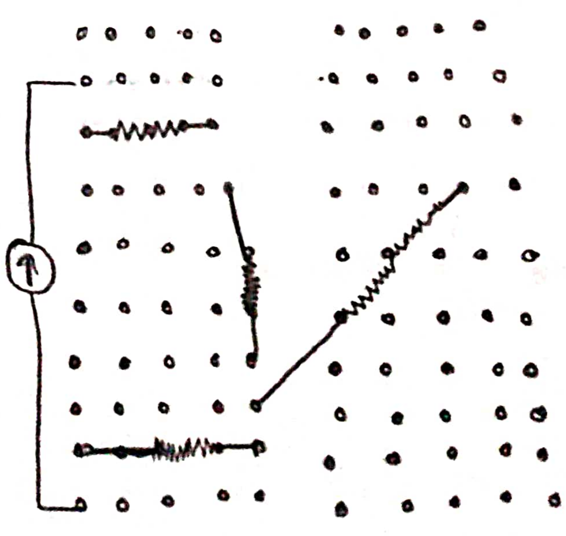
Learning Outcome (expected):

1. Able to connect circuit on the breadboard.
2. Use voltmeter and ammeter on the breadboard and finding least count.
3. Read resistance values using formula "BB ROY of Great Britain Having Very Good Wife".
4. Calculate I and V across any circuit element.

Learning Outcome (what I have learnt):

* sum of all voltage across a loop is zero
* setting wire and resistor on breadboard.

Breadboard Circuit Diagram:



EXPERIMENT No.2

Aim: Apply Thevenin's theorem on DC circuits.

Learning Objective:

1. To implement the circuit on the breadboard and verify Thevenin's theorem.
2. To identify different sources of error in this practical.

Apparatus/Components required:

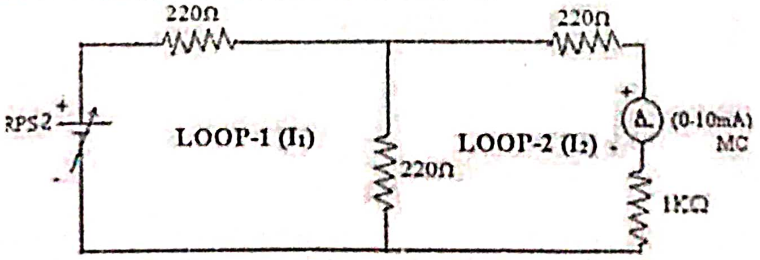
S No	Apparatus	Range	Quantity
1	Regulated Power Supply	(0-30V)	2
2	Ammeter	(0-10mA)	1
3	Resistor	1Kohm,220ohm. 330ohm	1,3,1
4	Bread Board	--	1
5	Voltmeter	(0-30V)	1
6	Digital Multimeter	--	1

Statement: If we wish to find I or V across any element (load resistance) in the linear bilateral circuit, then we go for Thevenin's theorem. Any complex circuit can be broken down to only three elements such as V_{TH}, R_{TH}, and load resistance (R_L) using Thevenin's theorem. In this practical we will find I across 1Kohm Load resistance of **Circuit-1** using Thevenin's equivalent **Circuit-4.** We will prove that I_L of Circuit-1 and Circuit-4 are same.

Procedure:

1. Connections are given as per the circuit diagram.
2. Set 5Vvalue of voltage using RPS and note down the correspondingammeter readings as per **Circuit-1.**
3. **To find V_{TH}** : Remove the load resistance and measure the open circuit voltage using multimeter (VTH) as per **Circuit-2.**
4. **To find R_{TH}** : Remove the RPS and short circuit it and find the RTH using **multimeter in Circuit -3.**
5. Give the connections for equivalent circuit and set VTH and RTH and note the corresponding Ammeter reading in **Circuit -4.**
6. Verify Thevenin's theorem for theoretical and practical values using observation table and identify sources of error (if any).
7. Also find percentage error.

Circuit Diagrams: Circuit - 1: To find load current

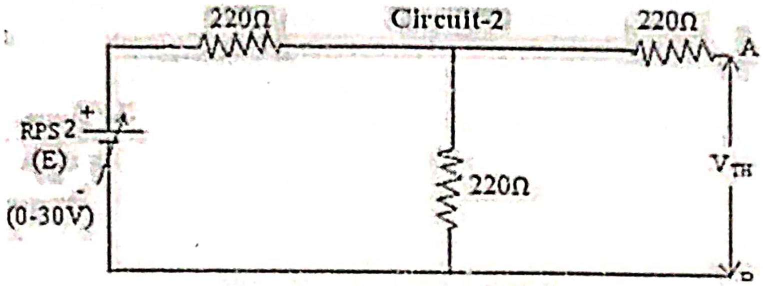


Supply Voltage =5V, I_1 and I_2 are in clockwise direction, $I_2 = I_L$

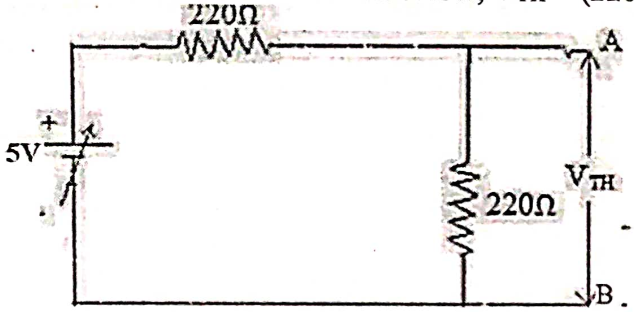
$5 = 220\ I_1 + 220\ (I_1 - I_2) \Rightarrow\ 440\ I_1 - 220\ I_2$ ------------(1)

$0 = 220\ I_2 + 1000\ I_2\ + 220\ (I_2 - I_1); \Rightarrow -220\ I_1 + 1440\ I_2$ ------------(2) => **I_2= 1.879mA= I_L**

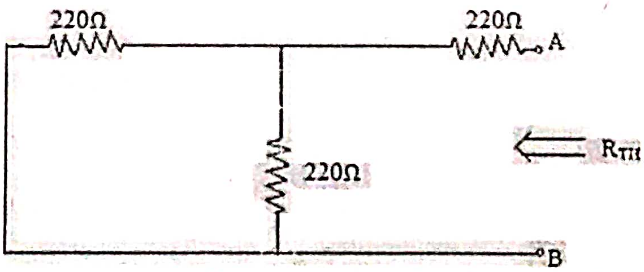
Circuit 2: To find V_{TH}



Since no current is passed through the resistance connected to point A, so it will not contribute to V_{TH} value, so using potential divider law in the circuit below, V_{TH} = (220*5V)/440 =2.5V

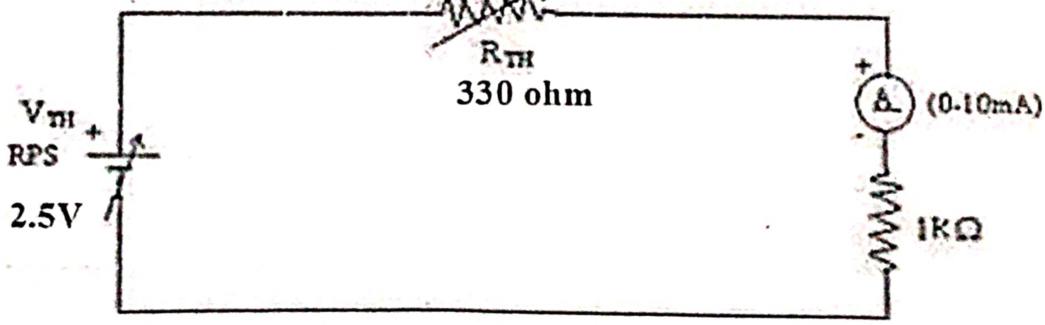


Circuit 3: To find R_{TH}



R_{TH} = 220 ohm connected to point A + Parallel combination of other two resistances
Parallel combination of other two resistances = (220*220)/(220+220)=220*220/440=110ohm
⇨ **R_{TH} =220+110=330ohm**

Circuit-4: Thevenin's Equivalent Circuit:



Current flowing through 1Kohm, **I_L= 2.5/(330+1000)= 1.879mA**

Precautions:

1. All the connections should be perfectly tight.
2. Always connect ammeter in series and voltmeter in parallel
3. Use safety guards while working on live parts
4. Don't touch the bare conductor when supply is ON.
5. Supply should not be switched ON until and unless the connections are checked by theFaculty/Lab Instructor
6. Use proper wire for connections

Worksheet of the student

Observation table: for Input Voltage =5V

	Power supply Voltage	Thevenin's Voltage V_{TH} Circuit-2	Thevenin's Resistance R_{TH} Circuit-3	Load Current I_L (mA) Circuit -1	Load Current I_L (mA) Thevenin's equivalent Circuit-4
Calculated value	5V	2.5V	330 ohm	1.879mA	1.879mA
Measured value	5v	2.1V	330Ω	1.27	2.68

$$\%age\ Error\ for\ V = ([V\_Calculated - V\_Measured)/V\_Calculated]X100$$

Calculation of %age Error:

1. %age Error for V_{TH}= $\frac{2.5-2.1}{2.5} \times 100 = 16\%$

2. %age Error for R_{TH}=

$\frac{330-330}{330} \times 100 = 0\%$

3. %age Error for I_L =

circuit 1 → $\frac{1.879-1.27}{1.879} \times 100 \Rightarrow 32.41\%$

circuit 4 → $\frac{1.879-2.68}{1.879} \times 100 \Rightarrow -42.62\%$

Results and Discussion:

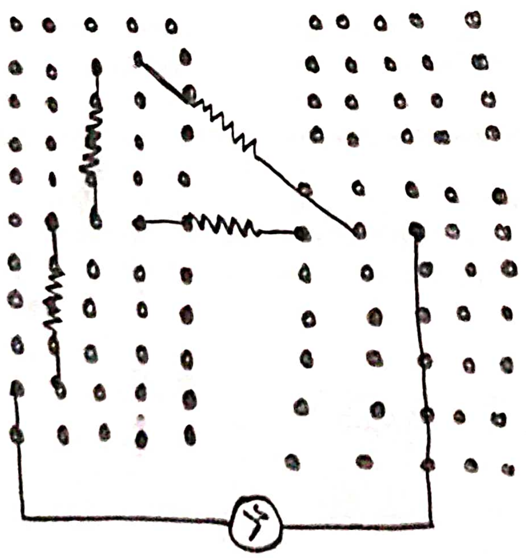
Learning Outcomes (expected):

1. Measure the values of Thevenin's voltage and resistance.
2. Able to use ammeter and voltmeter
3. Identify different sources of error in this practical.

Learning Outcomes (what I have learnt):

* about the Thevenin's theorm.
* use of ammeter and voltmeter
* Finding voltage and resistance along any resistor.

Bread Board Circuit Diagram/ Connection Diagram



EXPERIMENT No. 3

Aim: Analysis of V-I characteristics of PN Junction diode.

Learning Objective(s):

1. To identify sources of error in this practical.
2. To measure diode current in forward biased condition.
3. To test the diode for functioning.

Instruments/Components: A p-n junction diode, 30V DC power supply, 1Kohm, 0-30V voltmeter, 0–100mA ammeter and connecting wires.

Sr. No.	Components/Instruments	Range	Quantity
1.	PN Junction Diode Number : IN 4007		1
2.	Regulated DC Variable Power Supply	0-30V	1
3.	DC Voltmeter	0-1V/0-20V	1
4.	DC Ammeter	0-30mA	1
5.	Resistance * as per calculation	470 ohm*	1
6.	One Bread Board and Connecting Wires Single Strand 8-10 number		

Theory: A semiconductor PN junction diode is a two terminal electronic device (Di-electrode → Diode). The metal contacts taken out from p-region and n-region are called anode and cathode respectively. There are three possible biasing conditions and two operating regions for the typical PN-Junction Diode, they are: zero bias, forward bias and reverse bias.When no voltage is applied across the PN junction diode then the electrons will diffuse to P-side and holes will diffuse to N-side through the junction and they combine with each other. Therefore,the acceptor atom close to the P-type and donor atom near to the N-side are left unutilized. An electronic field is generated by these charge carriers. This opposes further diffusion of charge carriers. Thus, no movement of the region is known as ***depletion region*** or space charge. Figure 1 shows the symbol diagram of diode with its real appearance.

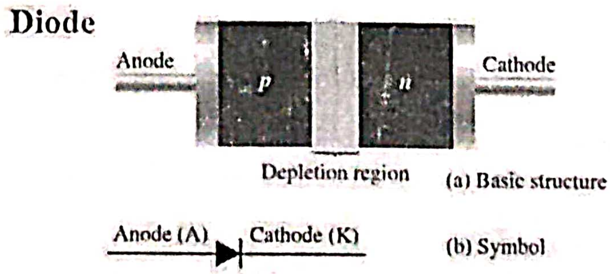


Fig. 1: Symbol of PN Diode

Zero Biased PN Junction Diode

Unbiased pn Junction: As the pn junction is formed, holes from p-region diffuse across the junction and recombine with the electrons in the n-region near the junction resulting in formation of positive ions in the n-region near the junction. Similarly, electrons from n-region diffuse across the junction and recombine with the holes in p-region near the junction to form negative ions. Thus there exists a narrow region extended in both the regions, that does not have any mobile charge carriers (neither holes nor electrons) is called depletion region, the region depleted of charge carriers. After generating a depletion region a equilibrium state reaches in whichAt equilibrium, these two currents are equal and opposite i. e. $I_D = I_S$. This condition is maintained by barrier potential. The built-in potential across the junction is given by,

$$V_O = V_T \ In\left(\frac{N_A N_D}{n_i^2}\right)$$

where, $V_T = kT/q$, called thermal voltage, N_A, N_D are doping concentrations of p side and n side. Typically the value of V0 at room temperature ranges between 0.6 to 0.8V

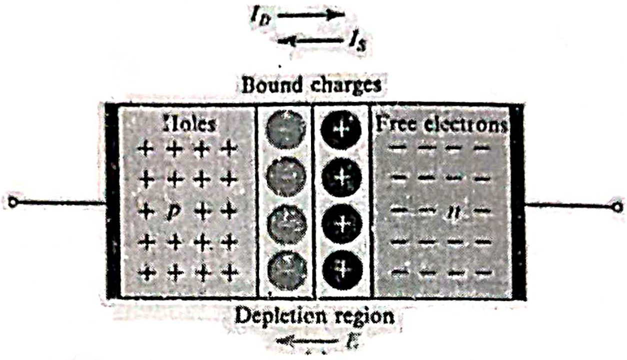


Figure 2: Unbiased Diode current direction

Forward Bias Condition: On forward biasing, initially no current flows due to barrier potential. As the applied potential exceeds the barrier potential the charge carriers gain sufficient energy to cross the potential barrier and hence enter the other region. The holes, which are majority carriers in the P-region, become minority carriers on entering the N-regions, and electrons, which are the majority carriers in the N-region, become minority carriers on entering the P-region. This injection of minority carriers results in the current flow, opposite to the direction of electron movement. **(Resistance RS calculation for maximum current flow through the diode i.e. at maximum DC supply 20 V/ 30V and maximum forward current 50 mA given)**

$R_S = V/I = 20 / 50$ mA (Supply 20 V) or 30 /50 mA (supply 30 V)
Thus R = 400 to 600 ohm

What happens inside the pn junction diode when forward biased?

When we apply voltage to the terminals of diode, the width of depletion region slowly starts decreasing. The reason for this is, in forward bias we apply voltage in a direction opposite to that of barrier potential. So the electrons in n-side get pushed towards the junction (by force of repulsion) and the holes in p-side get pushed towards the junction. As the applied voltage increases from 0 volts to 0.7 volts, the depletion region width reduces to zero. This means depletion region vanishes at 0.7 volts of applied voltage.

Procedure:

1. Before connection of the diode in the circuit test that diode is working, for that connect the diode the anode terminal with +ve probe of multimeter and cathode with –Ve probe and adjust the multimeter knob at Diode symbol as sown in figure 3. If value on multimeter is zero then diode is working fine and if lower voltage present in the diode it is due to charged capacitor.

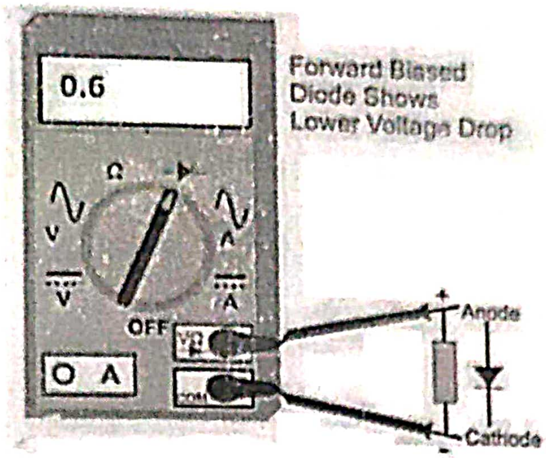


Fig: 3 Diode testing with multimeter.

1. Connect the circuit as shown in figure 4 using PN Junction diode
2. Before switch 'On' the supply, rotate power supply potentiometer fully in CCW (counter clockwise direction) to start experiment from Zero voltage otherwise excessive voltage can damage the diode and multimeter.
3. Connect Ammeter in series of Power supply positive terminal and anode of Diode to measure diode current ID (mA)
4. Connect Voltmeter across diode to measure diode voltage VD.
5. Initially vary the Regulated Power Supply voltage, Vs from zero in steps of 0.1 V. Once the current starts increasing vary Vs in steps of 0.5 V, Vary the DC power supply till the value of diode voltage V_F from 0 to 1V, (0.83V) in steps and Measure the corresponding values of diode Forward Current I_F in mA and note down in the Observation Table.
6. Plot a curve between diode voltage V_F and diode current I_F as shown in figure 5 (First quadrant) using suitable scale, with the help of Observation Table. This curve is the required forward characteristics of Si diode.
7. After complete the experiment, Switch 'Off' the supply with doing DC power supply to zero volts.

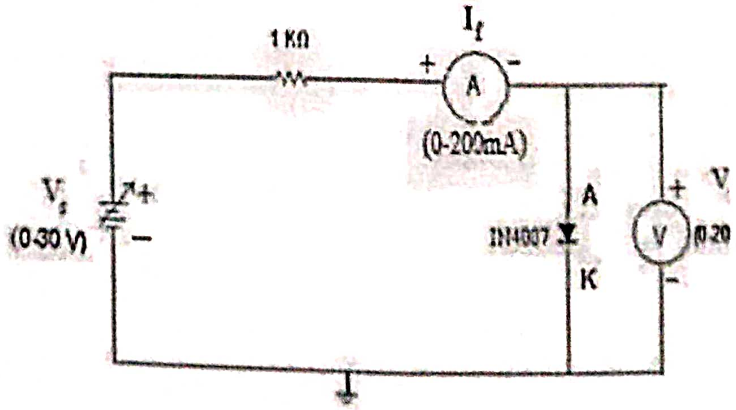
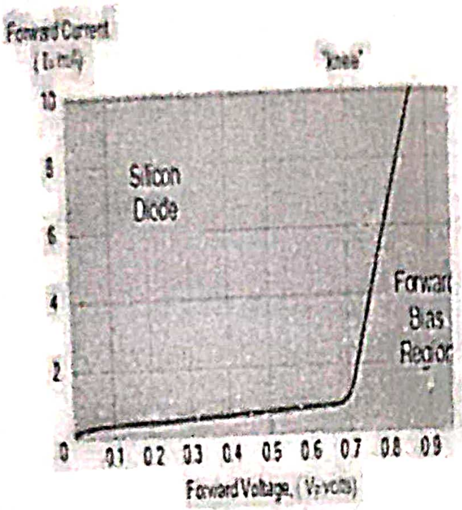


Fig. 4: Circuit diagram of Forward Bias diode.



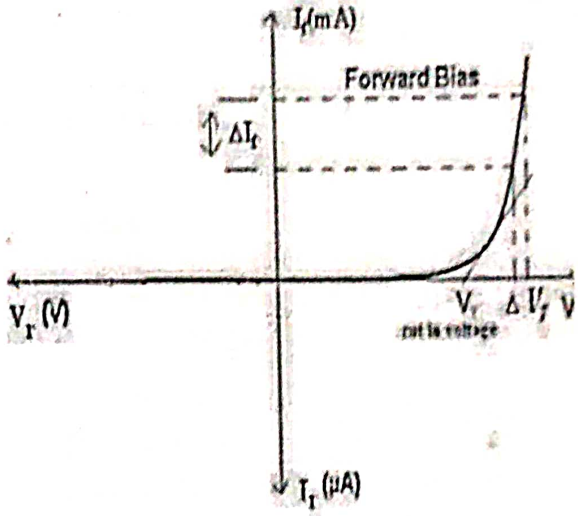


Fig. 5: VI characteristic of Forward Bias diode.

Precautions:

Do not press the IC on breadboard until pins are aligned with pours.

1. Make connection properly.
2. There should not any short circuit in the circuit. Avoid the heating of IC. Provide proper clock pulse.

Calculations from Graph: Cut in Voltage V (It is observed that Ge diode has smaller cut in voltage when compared to Si diode. The reverse saturation current in Ge diode is larger in magnitude when compared to Si diode)

Static forward Resistance $R_{DC} = V_f / I_f\,\Omega$
Dynamic Forward Resistance $r_{ac} = \Delta V_f / \Delta I_f\,\Omega$

In the above diode current equation, defines an exponential relationship between the diode current (the dependent variable) and the diode voltage (the independent variable). This equation holds over at least seven orders of magnitude of current and is truly valuable in defining the behaviors of semiconductor diodes. Where I is the forward current, V is the forward voltage, IO is the reverse saturation current, and $V_T = kT/q$ is the thermal Voltage. $V_T = T/11600$, 26 mV at room temperature, k is Boltzmann's constant (1.38 x 10-23 j/°K, T is the absolute temperature in degree Kelvin (°K = 273 + the temperature in °C) and q indicates the fundamental charge of electron (1.60 x 10-19 Coulombs (C=J/V). η is dependent on material, diode construction and operational considerations and unless otherwise explicitly stated, the standard simplification of $\eta = 1$ for Ge and 2 for Si will be used for all examples and may be made for all analyses. Initially, the V vs I graph is linear but then after reaching breakdown, it becomes exponential.

Worksheet of the Students

Observation Table:

η is the emission coefficient which is 1 for Ge and 2 for Si

Value of reverse saturation current (I_0) varies with temperature, since forward current varies between 1mA to 10mA at V_F=0.7V for Si and 0.3 V for Ge so approximate range of reverse saturation current (**Io**) for Si is 1.22nA to 12.2nA, Ge is 8.52nA to 85.2nA. You can find the correct value from this range.

Thermal Voltage V_T= 298.15/11600= 0.0257V at room temp.

Forward Bias					
Sr. No.	V_F	I_Calculated Si diode $I=Io[e^{(\frac{V}{\eta V_T})}-1]$ (A) 0.53	I_Calculated)Ge diode $I=Io[e^{(\frac{V}{\eta V_T})}-1]$ (A)	I (Measured) Using ammeter	%age Error
1.	0.1	$I= Io[e^{(\frac{0.1}{2*0.0257})}-1=$	$I= Io\ [e^{(\frac{0.1}{1*0.0257})}-1]=$	0	
2.	0.2	$I= Io\ [e^{(\frac{0.2}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{0.2}{1*0.0257})}-1]=$	0.1mA	
3.	0.3	$I= Io\ [e^{(\frac{0.3}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{0.3}{1*0.0257})}-1]=$	0.2mA	
4.	0.4	$I= Io\ [e^{(\frac{0.5}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{0.4}{1*0.0257})}-1]=$	0.4mA	
5.	0.5	$I= Io\ [e^{(\frac{0.5}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{0.5}{1*0.0257})}-1]=$	0.6 mA	
6.	0.6	$I= Io\ [e^{(\frac{0.6}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{0.6}{1*0.0257})}-1]=$	8mA	
7.	0.7	$I= Io\ [e^{(\frac{0.7}{2*0.0257})}-1] =$	$I= Io\ [e^{(\frac{0.7}{1*0.0257})}-1]=$	4.5mA	
8.	0.8	$I= Io\ [e^{(\frac{0.7}{2*0.0257})}-1] =$	$I= Io\ [e^{(\frac{0.8}{1*0.0257})}-1]=$	3.9mA	
9.	0.9	$I= Io\ [e^{(\frac{0.9}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{0.9}{1*0.0257})}-1]=$		
10.	1	$I= Io\ [e^{(\frac{1.0}{2*0.0257})}-1]=$	$I= Io\ [e^{(\frac{1.0}{1*0.0257})}-1]=$		

Calculations:

Find optimal value of Io, for which measured diode current is equal to theoretical value of current, and using that optimal value find theoretical diode current, and hence calculate

$$\%age\ Error\ I = ([I\_Calculated - I\_Measured)/I\_Calculated]x100$$

Results and Discussion on Sources or Error:

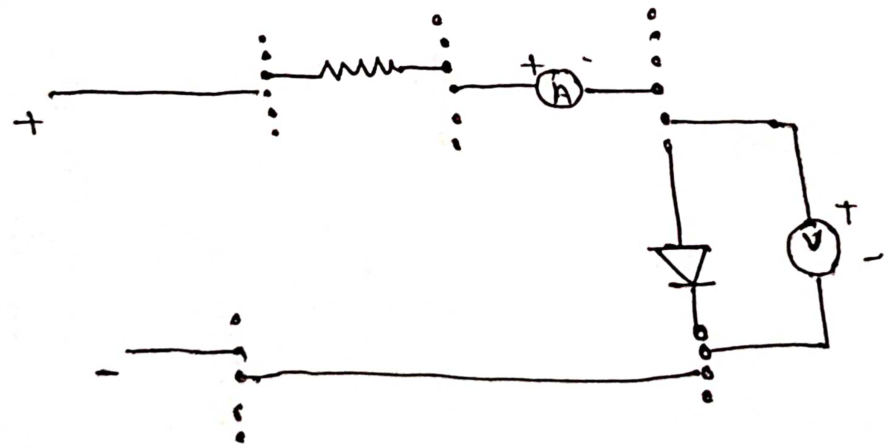
Learning Outcomes (expected):

1. Leant to forward bias a diode
2. Know the minimum bias voltage for Si and Ge diode?
3. Identify sources of error in this practical

Learning Outcomes (what I have learnt):

* masure Diode current in forward Bias
* understand diode functionning

Breadboard Connection Diagram:



EXPERIMENT No.4

Aim: Understanding the truth table of Logic Gates and implement these gates using Universal gates.

Learning Objectives: 1. To verify the functionality of Logic Gates

2. To implement Basic Logic gates using Universal gates and verify their function.

Instruments/Components required: IC-7404,7408,7432, 7400,7402, 7486, Digital Trainer module,

Theory and verification

1. NOT GATE 7404

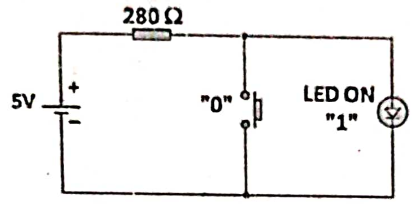
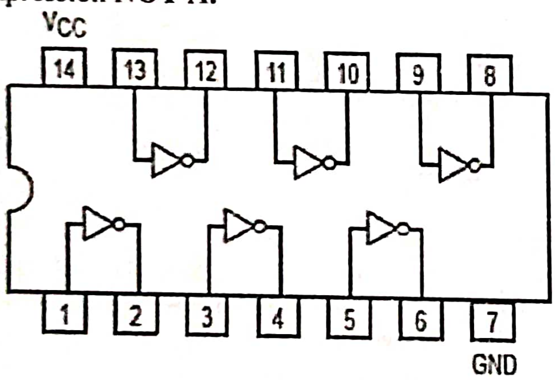


Figure1: NOT gate using a SWITCH

The NOT gate, also known as **an inverter**, produces the complement of its input. If **the input** is high, the output is low, and vice versa. It can be represented by the Boolean expression **NOT A.**



Input	Output
0	1(LED GLOW)
1	0 (LED OFF)

Figure 2: IC diagram of 7404 and Truth Table

Truth Table		Outputs taken at					
Input	Output	PIN2(Y1)	PIN4(Y2)	PIN6(Y3)	PIN8(Y4)	PIN10(Y5)	PIN12(Y6)
0	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0

Table 1: Observation table for NOT gate (7404)

2. AND GATE 7408

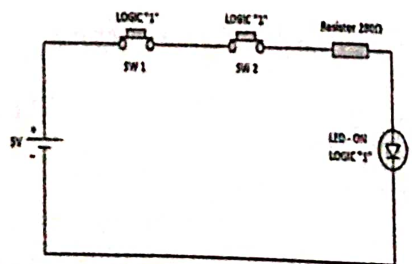
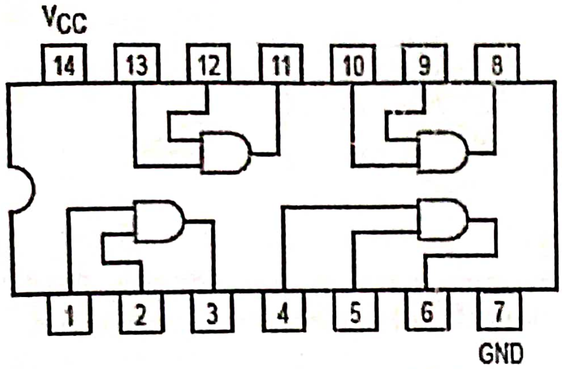


Figure 3: AND Gate using switches

The AND gate produces a high output only when all of its inputs are high. It can be represented by the Boolean expression A AND B, where A and B are the inputs.



Input1	Input2	Output
0	0	0
0	1	0
1	0	0
1	1	1

Figure 4: IC diagram of 7408 and Truth Table

Input	Output	PIN3, Y1	PIN6, Y2	PIN8, Y3	PIN11, Y4
0	0	0	0	0	0
0	1	0	0	0	0
1	0	0	0	0	0
1	1	1	1	1	1

Table 2: Observation table for AND gate (7408)

3. OR GATE 7432

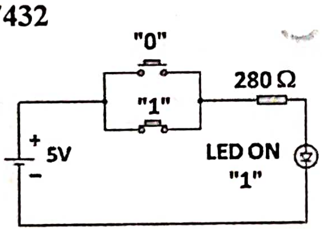
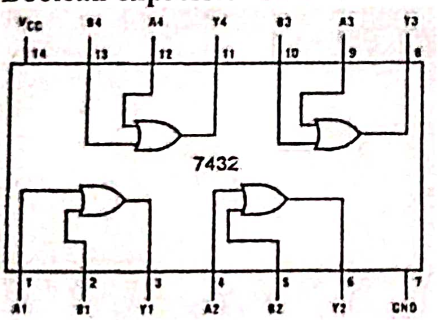


Figure 5: OR gate using a SWITCH

The OR gate produces a high output if any of its inputs are high. It can be represented by **the Boolean expression** A OR B.



Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Figure 6: IC diagram of 7432 and Truth Table

Input	Output	PIN3, Y1	PIN6, Y2	PIN8, Y3	PIN11, Y4
0	0	0	0	0	0
0	1	1	1	1	1
1	0	1	1	1	1
1	1	1	1	1	1

Table 3: Observation table for OR gate (7432)

4. NOR Gate 7402

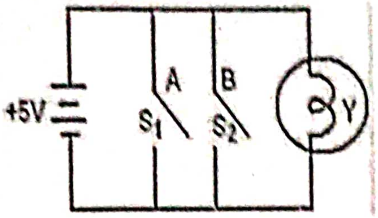
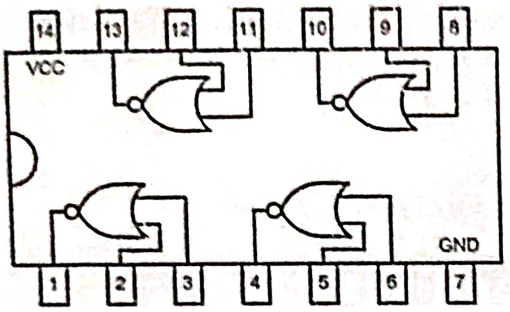


Figure 7: NOR gate using a SWITCH

NOR gate: The NOR gate is a combination of an OR gate followed by a NOT gate. It produces the complement of the OR gate output. It can be represented by the Boolean expression NOT (**A OR B**).



Input A	Input B	Output
0	0	1
0	1	0
1	0	0
1	1	0

Figure 8: IC diagram of 7402 and Truth Table

Input	Output	PIN1, Y1	PIN4, Y2	PIN10, Y3	PIN13, Y4
0	0	1	1	1	1
0	1	0	0	0	0
1	0	0	0	0	0
1	1	0	0	0	0

Table 4: Observation table for NOR gate (7402)

5. NAND Gate 7400

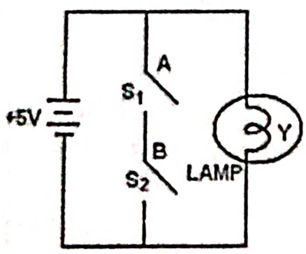
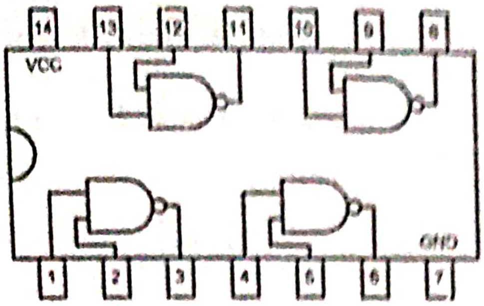


Figure 9: NAND gate using a SWITCH

The **NAND gate** is a combination of an **AND gate** followed by a **NOT gate.** It produces the complement of the **AND gate** output. It can be represented by the Boolean expression NOT (A AND B).



Input A	Input B	Output
0	0	1
0	1	1
1	0	1
1	1	0

Figure 10: IC diagram of 7400 and Truth Table

Input	Output	PIN3, Y1	PIN6, Y2	PIN8, Y3	PIN11, Y4
0	0	1	1	1	1
0	1	1	1	1	1
1	0	1	1	1	1
1	1	0	0	0	0

Table 5: Observation table for NAND gate (7400)

6. XOR Gate 7486

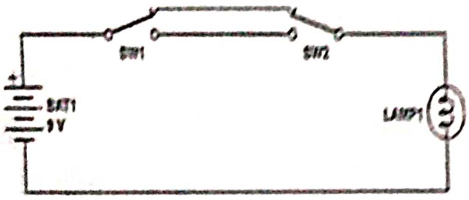
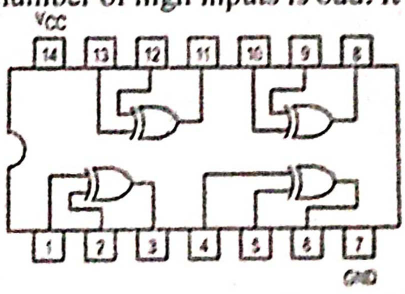


Figure 11: XOR gate using a SWITCH

XOR gate: The XOR gate, also known as an exclusive OR gate, produces a high output if the number of high inputs is odd. It can be represented by the Boolean expression A



Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	0

xor B

Figure 12: IC diagram of 7486 and Truth Table

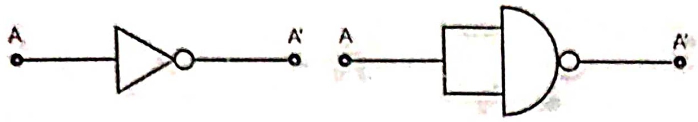
Input	Output	PIN3, Y1	PIN6, Y2	PIN8, Y3	PIN11, Y4
0	0	0	0	0	0
0	1	1	1	1	1
1	0	0	0	0	0
1	1	1	1	1	1

Table 6: Observation table for XOR gate (7486)

7. Implementation using Universal gates

7.1 Using NAND Gate:

NAND Gate as NOT Gate:



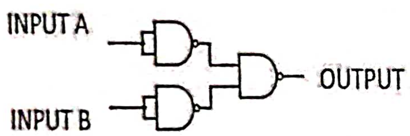
Input	Output
0	1
1	0

Figure 13: NOT gate using NAND Gate and Truth table

Truth Table		Outputs taken at			
Input	Output	PIN3, Y1	PIN6, Y2	PIN8, Y3	PIN11, Y4
0	1	1	1	1	1
1	0	0	0	0	0

Table 7: Observation table for NOT gate using NAND Gate

NAND Gate as OR Gate:



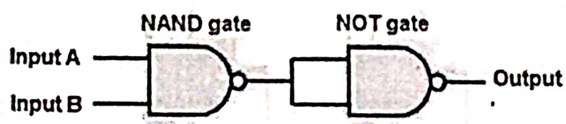
Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Figure 14: OR gate using NAND Gate and Truth table

Truth Table			**Output taken at**
Input-1	**Input-2**	**Output**	**PIN6, Y1**
0	0	1	1
0	1	1	1
1	0	1	1
1	1	0	0

Table 8: Observation table for OR Gate using NAND Universal gate

NAND Gate as AND Gate:



Input1	**Input2**	**Output**
0	0	0
0	1	0
1	0	0
1	1	1

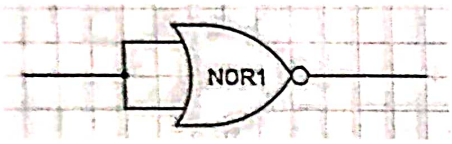
Figure 15: AND gate using NAND Gate and Truth table

Truth Table			Output taken at
Input-1	Input-2	Output	PIN6, Y1
0	0	1	1
0	1	1	1
1	0	1	1
1	1	0	0

Table 9: Observation table for AND Gate using NAND Universal gate

7.2 Using NOR Gate:

NOR Gate as NOT Gate:



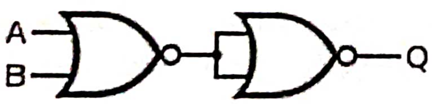
Input	Output
0	1
1	0

Figure 16: NOT gate using NOR Gate and Truth table

Truth Table		Outputs taken at			
Input	Output	PIN3, Y1	PIN6, Y2	PIN8, Y3	PIN11, Y4
0	1	1	1	1	1
1	0	0	0	0	0

Table 10: Observation table for NOT gate using NOR Gate

NOR Gate as OR Gate:



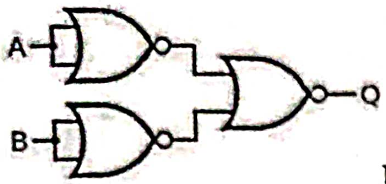
Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Figure 17: OR gate using NOR Gate and Truth table

Truth Table			Output taken at
Input-1	Input-2	Output	PIN6, Y1
0	0	0	0
0	1	1	1
1	0	1	1
1	1	1	1

Table 11: Observation table for OR Gate using NOR Universal gate

NOR Gate as AND Gate:



Input1	Input2	Output
0	0	0
0	1	0
1	0	0
1	1	1

Figure 18:
AND gate using NOR Gate and Truth table

Truth Table			Output taken at
Input-1	**Input-2**	**Output**	**PIN6, Y1**
0	0	1	1
0	1	1	1
1	0	1	1
1	1	0	0

Table 12: Observation table for AND Gate using NOR Universal gate

Procedure:
1. Place the IC on the breadboard of digital trainer module.
2. Identify VCC and GND terminals of the trainer module and connect them to VCC and GND pins of the IC.
3. Identify toggle switches on the trainer module and connect them as inputs to the IC.
4. Identify output LEDs on the trainer module. Connect output pins of the IC to those LEDs.
5. Apply various combinations of inputs according to the truth table and observe behavior of the logic gates of the IC.
6. Disconnect the inputs and outputs of the IC and replace this IC with a new one and go to step 1.
7. Got to step 1, till all ICs are tested/verified.
8. Now implement NOT, OR, AND using NOR, NAND respectively and verify the functionality of NOT, OR, AND Gates.

Precautions:
1. All the connections should be perfectly tight.
2. Always connect ammeter in series and voltmeter in parallel.
3. Use safety guards while working on live parts.
4. Don't touch the bare conductor when supply is ON.
5. Supply should not be switched ON until and unless the connections are checked by the Faculty/Lab Instructor.
6. Use proper wire for connections.

Viva Questions:
1. Define gates?
2. Define IC?
3. What is DE Morgan's law?
4. (A+A) A =?

5. Define Universal gates and draw their internal and external Pin Diagram.
6. Write the Boolean expression of the 2 inputs AND gate.
7. How many no. of input variables can a NOT Gate have?
8. Under what conditions the output of a two input AND gate is one?
9. Calculate 1+0 =?
10. When will the output of a NAND Gate be 0?

Learning Outcome (expected):

1. Understanding the breadboard and its usage.
2. Able to understand logic gates and universal gates.
3. Understand pin diagrams of Logic Gate IC's.
4. Able to implement AND, OR, NOT, XOR gates using Universal gates.

Learning Outcome (what I have learnt):

* Able to understand logic gates and universal gates.
* Pin diagram of Logic gat

IC Connection Diagram:

Practical No: 05

Aim: Understanding the combinational logic by implementing the Boolean function using a multiplexer.

Learning Objective: 1. To implement FA and FS using 4:1 MUX.

2. To verify the working of FA and FS using MUX.

Instruments/Components: 74153 IC, 7404 IC, Digital Trainer module, connecting probes

Theory: Multiplexer (MUX) is a device that connects one of the input lines to the output line depending upon control signal as shown in **Figure 1.** Same is explained through a control switch and internal circuit of 2:1 MUX.

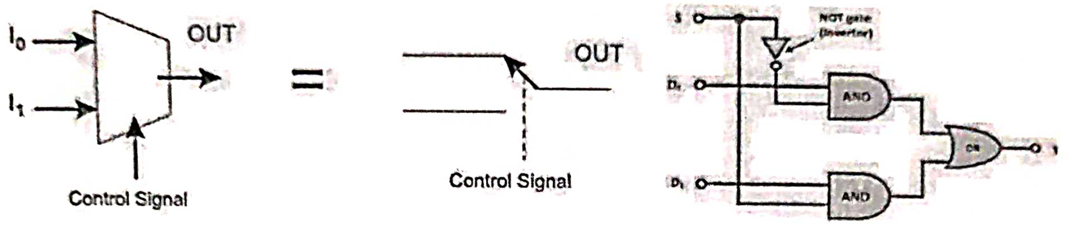


Figure 1: Block diagram of 2:1Mux, 2:1 Mux implementation using control switch, Internal circuit of 2:1 MUX

In case of 4:1 Mux, there are four input lines, I0, I1, I2 and I3, which are to be multiplexed on a single line output line (Y). The four input lines are also known as the Data Inputs. Since there are four inputs, there is need of two additional inputs to the multiplexer, known as the Select Inputs. The purpose of select inputs is to select, which of the inputs is reflected at the output. Call these select lines S1(A) and S0(B). The pin diagram of IC74153, which is dual 4:1 Multiplexer IC is shown below in **Figure 2.**

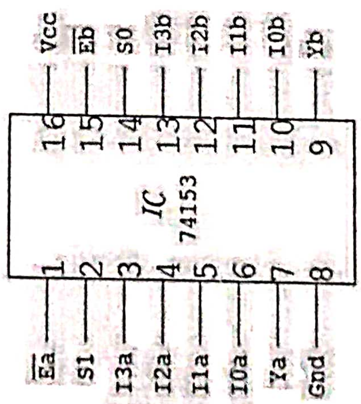


Figure 2: Pin diagram of IC 74153

Implementation of a Full Adder using 4:1 mux:

The full adder has three inputs and 2 outputs i.e. Sum and Carry. In order to realize full adder 2 multiplexers are required, one for implementation of Sum and another of realization of Carry. The Sum (S_n) and Carry (C_n) are expressed following Boolean functions:

$Sum(A, B, C_{in}) = \sum m(1,2,4,7)$---------1

$Carry(A, B, C_{in}) = \sum m(3,5,6,7)$-------2

The given function has three variables, but 4:1 MUX can have only two select lines, so one of the variables will be taken at the input. In this case we are taking C_{n-1} as 3[rd] variable that will be connected to input line of MUX. Table "Mux Map for SUM" and "Mux Map for Carry" helps to identify input data line connections using equations 1 and 2, wherein bracketed values in the table below indicate values of equation 1 and 2 respectively.

Mux map for Sum

Inputs	I0	I1	I2	I3
$\overline{C}_{n-1}$	0	(2)	(4)	6
C_{n-1}	(1)	3	5	(7)
	C_{n-1}	$\overline{C}_{n-1}$	$\overline{C}_{n-1}$	C_{n-1}

Mux map for Carry

Inputs	I0	I1	I2	I3
$\overline{C}_{n-1}$	0	2	4	(6)
C_{n-1}	1	(3)	(5)	(7)
	0→ GND	C_{n-1}	C_{n-1}	1→ Vcc

MUX map for SUM is implemented in A part of MUX IC & MUX map for Carry is implemented in B part of MUX IC, A & B are select lines as indicated in **Figure** 3:

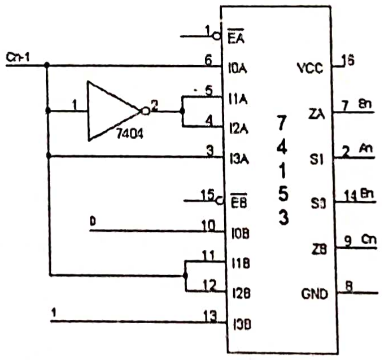


Figure 3: Connection diagram of Full Adder using 74153

Implementation of a Full Subtractor using 4:1 mux:

The full subtractor has three inputs and 2 outputs i.e. Difference and Borrow. In order to realize full subtractor, 2 multiplexers are required, one for implementation of Difference and another of realization of Borrow. The Difference (D_n) and Borrow (B_n) are expressed following Boolean functions:

$Difference\ (A, B, B_{n-1}) = \sum m(1,2,4,7)$--------3

$Borrow(A, B, B_{n-1}) = \sum m(1,2,3,7)$--------------4

The given function has three variables, but 4:1 MUX can have only two select lines, so one of the variables will be taken at the input. In this case we are taking B_{n-1} as 3[rd] variable that will be connected to input line of MUX. Table "Mux Map for Difference" and "Mux Map for Borrow" helps to identify input data line connections using equations 1 and 2, wherein bracketed values in the table below indicate values of equation

3 and 4 respectively.

Mux map for Difference

Inputs	I0	I1	I2	I3
$\overline{B}_{n-1}$	0	(2)	(4)	6
B_{n-1}	(1)	3	5	(7)
	B_{n-1}	$\overline{B}_{n-1}$	$\overline{B}_{n-1}$	B_{n-1}

MUX map for Borrow

Inputs	I0	I1	I2	I3
$\overline{B}_{n-1}$	0	(2)	4	6
B_{n-1}	(1)	(3)	5	(7)
	B_{n-1}	1→ Vcc	0→ GND	B_{n-1}

MUX map for Difference is implemented in A part of MUX IC & MUX map for Borrow is implemented in B part of MUX IC, A & B are select lines as indicated in **Figure** 4:

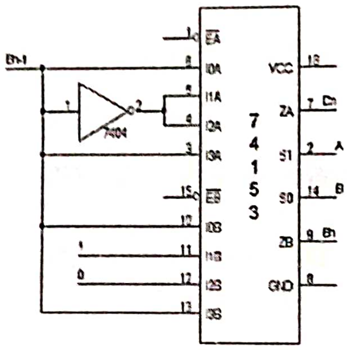


Figure 4: Connection diagram of Full Subtractor using 74153

Procedure:

1. **Power ON the IC:** Connect Vcc *to* Pin [16] and GND to Pin [8].
2. **Enable the IC-74153:** Initialize MUX 'A' and MUX 'B' by connecting *EA*, *EB* to GND.
3. **Select Lines:** The inputs 'A' and 'B' are applied to Pin [2] and input Pin [14] as select lines, respectively.
4. **Data line inputs for FA:** Make use of 7404 and create input connections to MUX-A and MUX-B part of IC-74153 as shown in Figure 3
5. In full adder the outputs S_n and C_n are taken from pins [7] and [9], respectively. Now, complete the observation Table.
6. **Data line inputs for FS:** Make use of 7404 and create input connections to MUX-A and MUX-B part of IC-74153 as shown in Figure 4.
7. In full subtractor the outputs D_n and B_n are taken from pins [7] and [9],

respectively, Now, complete the observation Table.

Precautions:

1. Do not press the IC on breadboard until pins are aligned with pours.
2. Make connection properly.
3. There should not any short circuit in the circuit. Avoid the heating of IC.

Observation Table:

Full Adder

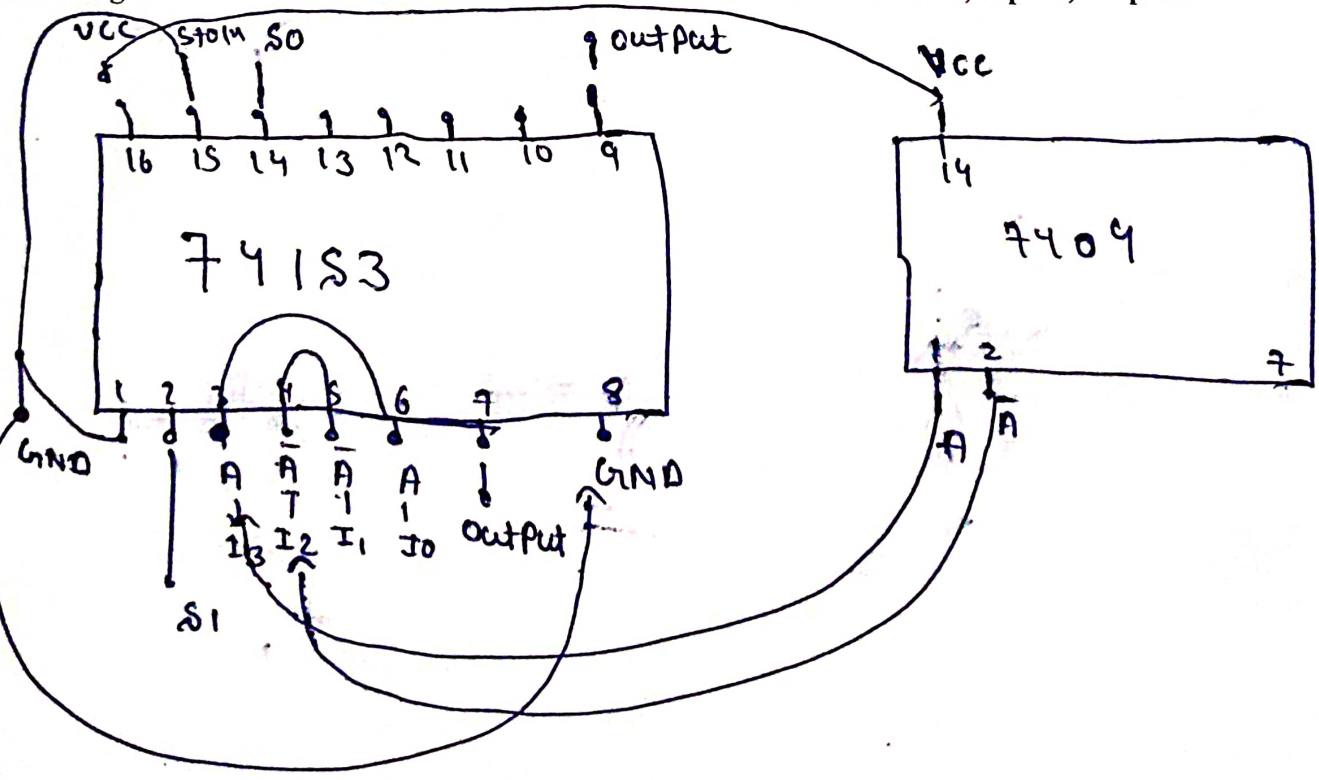
Inputs			Outputs	
A	B	C_{n-1}	S_n	C_n
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Full Subtractor

Inputs			Outputs	
A	B	B_{n-1}	D_n	B_n
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

Worksheet of the student

PIN diagram of IC-74153 with other external connections such as 7404, inputs, outputs



Boolen ? $F(ABC) = \Sigma_m(1,2,4,7)$

Carry: $F(A,B,C) = \Sigma m(3,5,6,7)$

D - $F(A,B,C) = \Sigma m(1,2,4,7)$

B - $F(A,B,C) = \Sigma(1,2,3,7)$

Learning Outcomes (Expected):

1. Could differentiate between adder is HA and FA?
2. Able to connect the circuit diagram using breadboard.
3. Understand provision of input carry and Borrow in FA, FS respectively

Learning Outcomes (What I have learnt):

Viva Questions:

1. How many select lines are there in 4:1 mux?
2. How can you implement a function with multiplexer?
3. IC 74153 is which type of the IC?
4. In 74153 what is the purpose of Strobe pin?
5. In 74153 how many multiplexers are present?
6. Which pin is active low pin in 74153 IC.

EXPERIMENT No. 6

Aim: Virtual Integration of IR sensor using Arduino.

Learning Objective (s):

1. To write a program code on Arduino for integration of IR sensor
2. To verify the working of the experiment using a circuit simulator.

Instruments/Components Required:

S.No.	Items	Quantity
1	Arduino Uno	1
2	LED-GREEN (or any color)	1
3	Analog Primitive Resistor (220-ohm)	1
4	Virtual Terminal	1
5	Logic Toggle	1
6	IR Obstacle Sensor	1
7	Battery (Cell)	1

Theory:

An object can be detected with an infrared system consisting of an infrared transmitter and a receiver. More in detail an IR transmitter, also known as IR LED, sends an infrared signal with a certain frequency compatible with an IR receiver which has the task to detect it. There are different kind of IR sensors for different type of application. In this practical, IR technology is used as a proximity sensor to detect a near object.

IR sensor principle of operation with/without object: The IR transmitter sends an infrared signal that, in case of a reflecting surface (e.g., white color), bounces off in some directions including that of the IR receiver that captures the signal detecting the object. When the surface is absorbent (e.g., black color) the IR signal isn't reflected and the object cannot be detected by the sensor. Same result would occur with object absent.

IR transmitter and IR receiver:

The IR transmitter is a particular LED that emits radiation in the frequency range of infrared, invisible to the naked eye as shown in **Figure 1.** An infrared LED just works as a simple LED with a voltage of 3V DC and a current consumption of about 20mA. The IR receiver, such as a photodiode or a phototransistor, is capable of detect infrared radiation emitted from the IR transmitter. Aesthetically it is similar to a LED but the external capsule can be wrapped by a dark color film.

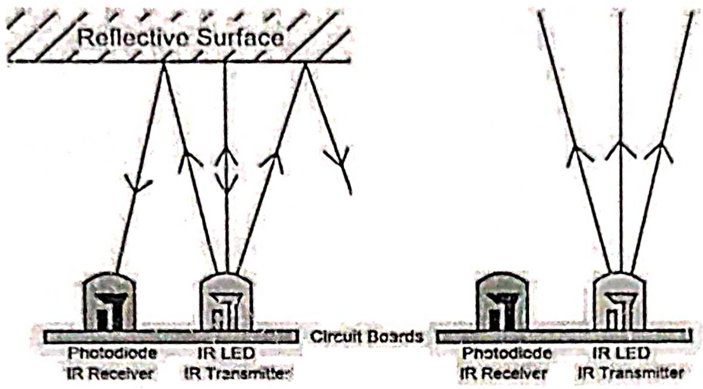


Figure 1: working of IR transmitter Receive module

Circuit Diagram for IR sensor connected at pin no 2 and output led connected at pin no 13:

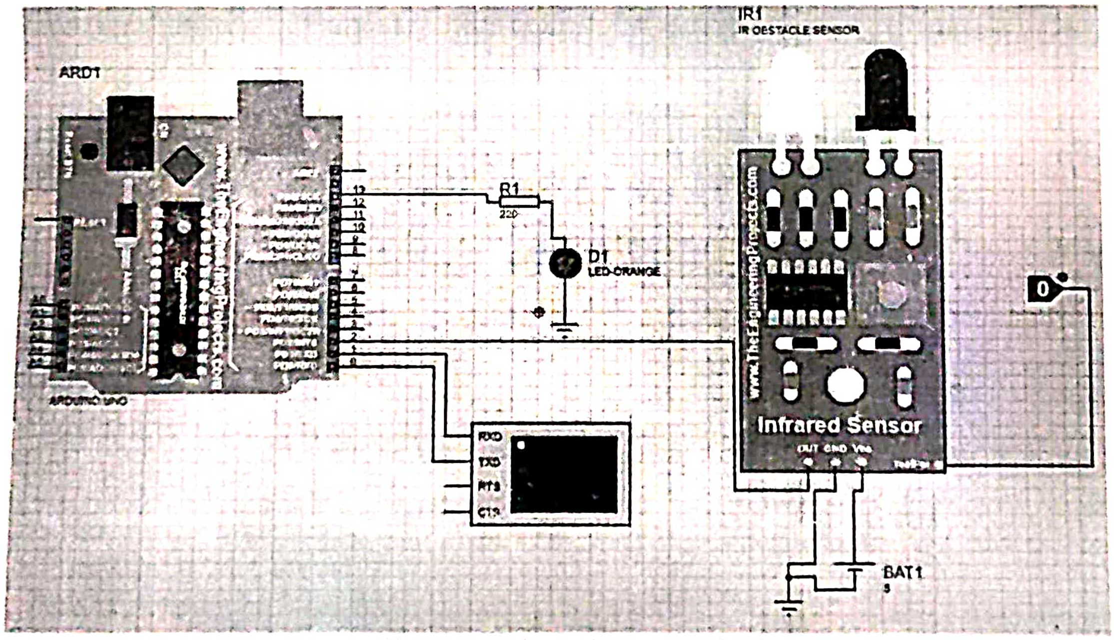


Figure 2: Connection Diagram of the Practical

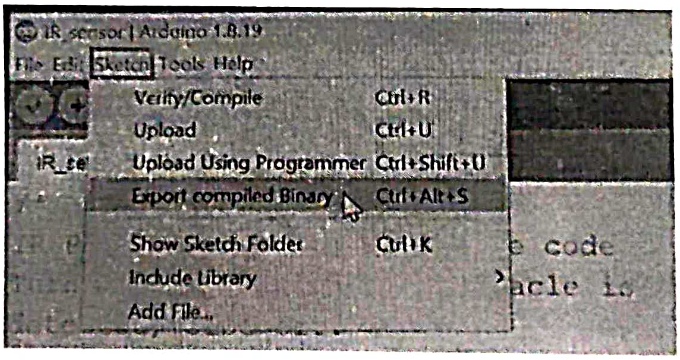
Program File for IR sensor connected at pin no 2 and output led connected at pin no 13:

```
void setup() {
 pinMode(13, OUTPUT);
 pinMode(2, INPUT);
 //Serial.begin(9600);
```

```
}
void loop() {
 int SensorValue = digitalRead(2);
 //Serial.print("SensorPin Value: ");
 //Serial.println(SensorValue);
 delay(100);
  if (SensorValue==LOW){ // LOW MEANS Object Detected
   digitalWrite(13, HIGH);
  }
  else
  {
   digitalWrite(13, LOW);
  }
 }
```

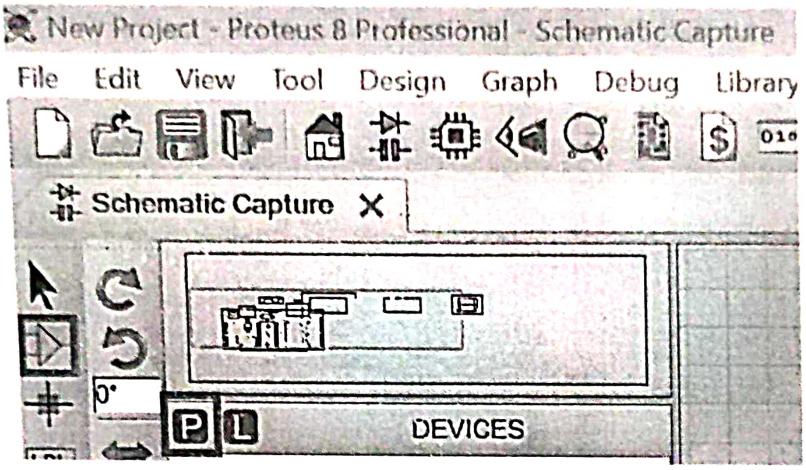
Procedure:

1. At first, write the program (code) as given above on Arduino Uno 1.8.19. Verify the code and save it. Secondly, Go to Sketch → export compiled binary, and click on it to get IR_sensor.ino.standard.hex, and IR_sensor.ino.with_bootloader.standard.hex in your folder where Arduino program is saved.

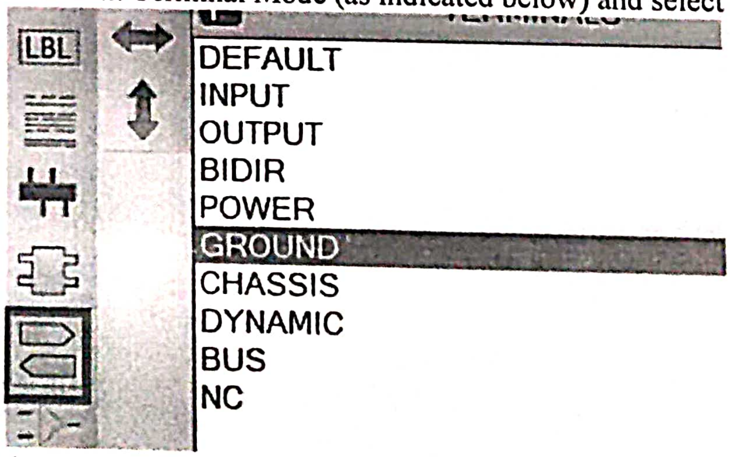


2. For circuit simulation, Open simulation window and follow the path: File → Project Name→ Create a schematic from Templates (Select Default) → Do not create a PCB layout → No Firmware Project→ Schematic→ Press "finish".
3. Double click on Arduino board (at simulation window) and place compiled binary files IR_sensor.ino.standard.hex, and IR_sensor.ino.with_bootloader.standard.hex file at the location of circuit simulator file.
4. Ensure that following library file are available at a place where circuit simulator file is saved: "InfraredSensorsTEP.HEX"
5. If files not available as per step 4, then follow path follow path; C::// → Program files (*86) → lab Centre electronics→ professional→ Data→ library → Copy "InfraredSensorsTEP .HEX" and past at location of circuit simulator file.

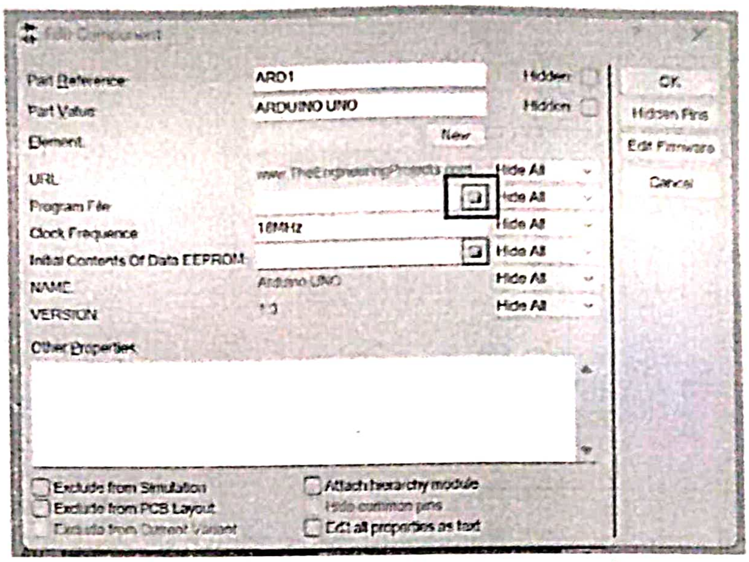
6. Click on component mode (highlighted in red above) → P icon (highlighted in red) → search component names as mentioned in "apparatus required" and place components as per given above diagram with double click on the simulation window.



6.1 Get Arduino Board: Component mode→ P→ Search "Arduino UNO R3 V1.0"
6.2 Get Infrared Sensor: Component mode→ P→ Search "IR Obstacle Sensor"
6.3 Get Toggle Switch: Component mode→ P→ Search "LOGICTOGGLE"
6.4 Get Battery: Component mode→ P→ Search "CELL"→ Battery (single cell). Now edit the value of battery (right click on the icon) and make it 5V.
6.5 Get Resistance: Component mode→ P→ Search "RESISTORS"→ 1K---10Watt. Now edit the value of resistance (right click on the icon) and make it 220 ohm.
6.6 Get LED: Component mode→ P→ Search "LED"→ LED-GREEN
6.7 Get Virtual Terminal: Right click on the circuit creation space→ Place→ Virtual Instrument→ Virtual Terminal.
6.8 Get Ground Terminal: Terminal Mode (as indicated below) and select Ground



7. Now Double click on Arduino board -→ open the folder highlighted in RED→ select the IR_sensor.ino.standard.hex from circuit simulator file folder → Press "OK".



8. Repeat the same exercise IR sensor, Double click on IR Sensor → Open program file folder → select "InfraredSensorsTEP.HEX" from circuit simulator file folder→ press "OK"
9. Once the circuit diagram is completed as indicated in **Figure 2**, press the play button available at bottom left corner of simulation window as shown below (highlighted in red).

Verification of circuit connections

The sensor input is at pin 2 and the output is taken from pin no 13 as per given code. The "glowing LED" will detect the presence of object in the IR radiation path. On changing logic toggle to 0 & 1, the virtual terminal displays the presence or absence of object indicating communication through serial port. The virtual terminal is used to display the content of print statements.

Precautions:

1. Carefully write the program to avoid syntax errors.
2. In the circuit simulator, bin files must be called before running the circuit.

Observation Table:

Proteus circuit		Arduino Program code		Observation
Sensor I/P	Arduino O/P	Sensor I/P	Arduino O/P	
2	13	2	12	
2	13	2	13	
2	13	3	13	

Viva Questions:

1. The function which repeatedly executes in the main program is?
2. How many buttons exist for reset and erase in Arduino Due?
3. What is the Importance Virtual terminal and logic toggle switch?

Learning outcomes (Expected)

1. Write a program on Arduino and simulate it
2. Use the Arduino binary file in circuit simulator
3. Learn to use TEP.HEX file in IR sensor module and its significance.
4. Connect other sensors and repeat the practical (home exercise)

Learning outcomes (what I have learnt)

1. virtual connection b/w arduino and IR

2):- How to use proteus software, and Arduino

(3) writing program on Arduino.

(4)- use of Tep.HEx file in IR sensor module.

(5).. use of arduino and IR sensor.

8/2