KLE Technological University
Creating Value
Leveraging Knowledge

2021 – 2022

DEPARTMENT OF PHYSICS

LABORATORY MANUAL

LABORATORY MANUAL

Name of the Student :

College Roll No. :

USN No. :

Semester : I (Electrical Stream)

Title of the Laboratory : Applied Physics Lab.

Course Code : 21EPHP102

Maximum Marks

Internal Marks : 80

Practical Examination : 20

Batch No.

Instructions to Students

Introduction

Experiments provide a way of scientific enquiry and probing nature through observations. A physics laboratory course should ideally give exposure to this. Physics experiments have also led to important technological applications. Therefore any educational program in science and technology can't be complete without a good experience in laboratory work.

As a technologist you will deal with instruments and apparatus of various kinds throughout your carrier. You will be greatly benefited from the beginning if you take a enthusiastic attitude towards experimental work. There is no substitute for the experience that you gain by conducting even simple laboratory measurements.

In addition to improve understanding of Physics, a laboratory course certainly exposes you to the technology of measurements, use of basic instruments and methodology of data analyses and the scientific documentations. Moreover it offers the student a unique opportunity of learning science by doing rather than by reading.

Specific Instructions: (should follow in the laboratory course)

1. Assessment in the course is based on

i) Your performance in the laboratory class
ii) Your laboratory report,
iii) The semester examination and
iv) Regular attendance.

2. A prior study about the experiment is essential for good performance in the class. Read the instruction manual carefully before coming to the lab. If you come unprepared to the lab; your performance would be accordingly affected.

3. You are expected to perform the experiment, complete the calculations and get the results corrected for every experiment on the same day within the laboratory slot assigned for it and also the experiment has to be submitted through e- journal on the same day after concerned faculty authentication

4. You must bring with you the following material to the lab: Observation book, writing materials, graph sheets and calculator and tablet provided by the college.

5. At least one set of observations to be corrected by the faculty.

6. Each graph should be well documented; abscissa and ordinate along with the units should be mentioned clearly. The title of the graph should be stated on the top of each graph paper & roll number, experiment no.

Scheme of Evaluation

In semester Assessment (ISA)	-	80 marks
End Semester Assessment (ESA)	-	20 marks

Allotment of marks for the lab examination **(Write up of two experiments and performing one experiment**).

a) Write up
b) Apparatus
c) Formula with units
d) Circuit/Ray /Block diagram.
e) Observations& tabular columns (self explanatory)
f) Nature of graph
g) Calculations and result

Conducting Practicals

Write up	03+03 = 06 marks
Performance	03+03 = 06 marks
Calculations, graphs, results	02+02 = 04 marks
Viva-voce	02+02 = 04 marks
	10+10 = 20 marks

LIST OF EXPERIMENTS FOR 1ST SEMESTER 2021-22

Electrical Stream

1ST SET

SL. NO	NAME OF THE EXPERIMENT
1.	ENERGY BAND GAP OF A SEMICONDUCTOR
2.	SELECTIVITY OF TUNED CIRCUITS FREQUENCY RESPONSE
3.	MEASUREMENT OF DIELECTRIC CONSTANT OF A CAPACITOR
4.	TRANSISTOR CHARACTERISITICS
5.	V–I CHARACTERISTICS OF PN JUNCTION DIODE

2ND SET

6.	USE OF MEASURING INSTRUMENTS: FUNCTION GENERATOR, REGULATED POWER SUPPLY AND CALIBRATION OF CATHODE RAY OSCILLOSCOPE
7.	VERIFICATION OF KVL & KCL
8.	REALIZATION OF SINGLE-PHASE RECTIFIER
9.	LOGIC DESIGN USING BASIC GATES (IC'S) (FULL ADDER & HALF ADDER)
10.	ZENER DIODE CHARACTERISTICS, VOLTAGE REGULATION USING ZENER DIODE

OPEN-ENDED

1.	REALIZATION OF A ±5/12V REGULATED POWER SUPPLY

EXPERIMENT NO. 01	ENERGY BAND GAP OF A SEMICONDUCTOR

AIM: *To study the effect of temperature on electrical resistivity of a semiconductor and hence determine the energy gap of given semiconductor using four probe method.*

APPARATUS: Four probe arrangement, semiconductor specimen, oven, constant current Source, thermometer etc.

THEORY: The properties of bulk material used for the fabrication of transistor and other semiconductor devices are essential in determining the characteristics of the completed devices. Resistivity measurement is an important parameter to determine suitability of semiconductor crystal. The resistivity must be measured accurately since its value is critical in many devices. The value of some transistor parameters, like the equivalent base resistance, is linearly related to resistivity.

The electrical properties of semiconductors involve the motion of charged particles within them. Therefore, we must have an understanding of the forces which controls the motion of these particles. It is of course, the physical structure of the solid which exerts their control. Atoms, of which a solid is composed, consist of positively charged nuclei with electrons orbiting around them. An electron in an atom has only discrete values of energy. There is a forbidden energy region in between two consecutive allowed energy levels. In solid atoms are very closely packed. Hence each atom interacts with a large number of surrounding atoms. As a result, each energy level splits in to many number of energy level. Hence each discrete energy level of an atom transforms in to an energy band for the solid.

The highest energy band which is completely filled at zero Kelvin is called valence band. The next higher band which may be partially filled or completely empty is called conduction band. The difference between the highest energy in a given band and the lowest energy in the next higher band is called the band gap between the two bands. On the basis of energy band structure solids are classified as conductors, semiconductors and insulators.

At absolute zero, semiconductors are pure insulators. As the temperature is increased thermal energy create vibrations in crystal lattice and few electrons, which acquire sufficient Vibrational energy, break their covalent bond, become free, and move to the conduction band. The energy required to rupture the covalent bond is designated as energy gap '$\mathbf{E_g}$'. The energy less than E_g is not acceptable or one cannot have partially ruptured covalent bond, hence this energy is also called as forbidden energy gap. As the temperature increases above room temperature more and more covalent bonds are broken and conduction increases rapidly and resistivity falls. We have, at temperature T > 0K,

$$\rho(T) = \rho_0 \exp\left(\frac{E_g}{2k_B T}\right)$$

Where, ρ (T) is resistivity at temperature T.

ρ_0 is resistivity at absolute zero

E_g is forbidden energy gap of a semiconductor

K is Boltzmann constant.

FOUR PROBE METHOD

High resistance or rectification appears fairly often in electrical contacts to semiconductors and in fact is one of the major problems. Soldered probe contacts may disturb the current flow and affect the

sample properties. Many conventional methods for measuring resistivity are unsatisfactory for semiconductors because of metal –semiconductor contacts are usually rectifying in nature. Also there is generally minority carrier injection by the current carrying contacts. An excess concentration of minority carriers will affect the potential of other contacts and modulate the resistance of the materials.

The four probe method overcomes the difficulties mentioned above and also offers several other advantages. It permits measurements of resistivity in samples having a wide variety of shapes, including the resistivity of small volumes within bigger pieces of semiconductor. In this manner the resistivity on both sides of p-n junction can be determined with more accuracy before the material is cut into bars for making devices. This method of measurement is also applicable for elemental as we as compound semiconductor materials.

The basic model for the measurement of resistivity is shown below. Four sharp probes are placed on the flat surface of the material to be measured, current is passed

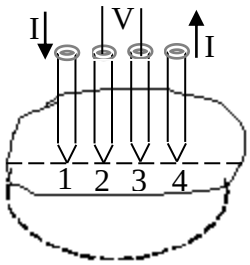


Figure : A

Through the outer probes and the potential is measured across the inner probes. A nominal value of probe spacing which has been found satisfactory is an equal distance of 1.5 mm between adjacent probes. This permits measurement with reasonable resistivity of n- and p- type semiconductor from 0.001 to 50 ohm-cm.

In order to use this method in semiconductor crystals or slices it is necessary to assume that:

a. The resistivity of the material is uniform in the area of measurement.
b. The surface on which the probe rests is flat with no surface leakage.
c. The four probes used for resistivity measurement contact the surface that lie in a straight line.
d. The diameter of the contact between the metallic probes and the semiconductor should be negligibly small compared with the distance between the probes.
e. The surfaces of the crystal may be either conducting or non-conducting.

For such an arrangement, the floating potential V_f a distance r from the electrode (probe) carrying current I in a material of resistivity ρ_0 is given by,

$$V_f = \frac{\rho_0 I}{2\pi r} \qquad \textbf{(1)}$$

In this model there are two current carrying electrodes, numbered 1 and 4 (Fig. A), and the floating potential V_f at any point in the semiconductor is the difference between the potential induced by each of the electrodes. Since they carry currents of equal magnitude but in opposite directions thus:

$$V_f = \frac{\rho_0 I}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_4}\right), \qquad \textbf{(2)}$$

where r_1 and r_4 are the distance from probe 1 and 4 respectively.
The floating potentials at probe (2) V_{f2} and at probe (3) V_{f3} can be calculated from Eq. (2) by substituting the proper distances as follows;

$$V_{f2} = \frac{\rho_0 I}{2\pi}\left(\frac{1}{S_1} - \frac{1}{S_2 + S_3}\right) \quad \textbf{(3)}$$

$$V_{f3} = \frac{\rho_0 I}{2\pi}\left(\frac{1}{S_1 + S_2} - \frac{1}{S_3}\right) \quad \textbf{(4)}$$

The potential difference V between probes is then,

$V = V_{f2} - V_{f3}$

$$V = \frac{\rho_0 I}{2\pi}\left(\frac{1}{S_1} + \frac{1}{S_3} - \frac{1}{S_1 + S_3} - \frac{1}{S_1 + S_2}\right) \quad \textbf{(5)}$$

and the resistivity ρ_0 is computed as (From Eq.1)

$$\rho_0 = \frac{V}{I}\frac{2\pi}{\left(\frac{1}{S_1} + \frac{1}{S_3} - \frac{1}{S_1 + S_3} - \frac{1}{S_1 + S_2}\right)} \quad \textbf{(6)}$$

If the spacing between the probes are equal; ($S_1=S_2=S_3= S$)

$$\rho_0 = \frac{V}{I} 2\pi S \quad \textbf{(7)}$$

The correction factor for the slice kept on non-conducting surface has to be included to get the correct resistivity of the sample. The correction factor is denoted by f (w/s) which depends on the probe distance and the thickness of the sample; it decreases as W/S increases (for sample kept on conducting surface f (W/S) increases with W/S). For the sample with W = 1 mm and probe spacing S = 1.5 mm f (w/s) = 2.34.

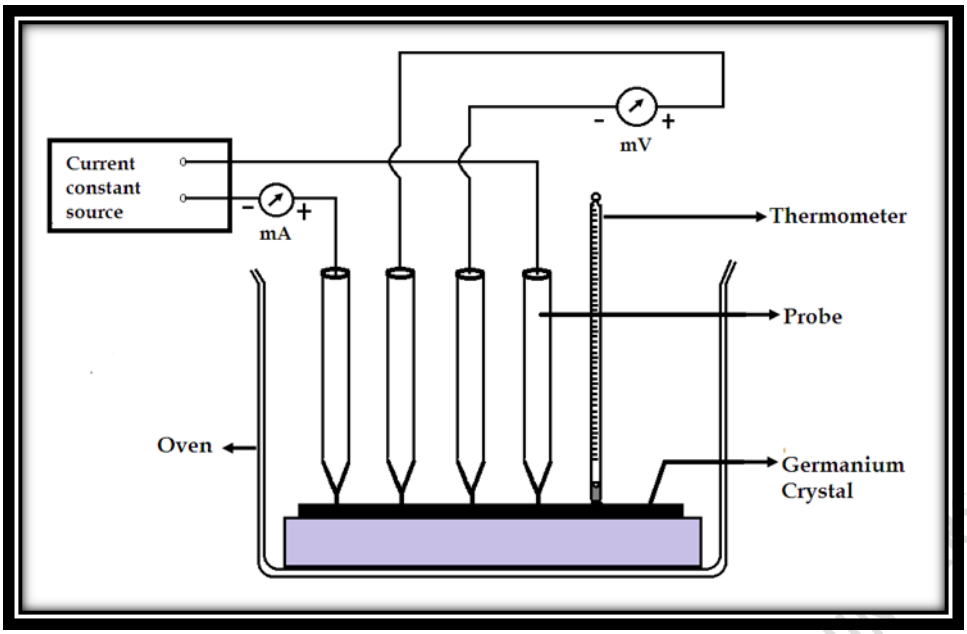
$$\rho = \frac{\rho_0}{f(w/s)} \quad \textbf{(8)}$$

which is purely the resistivity of the sample.

PROCEDURE

- Connect the outer pair of probes to the constant power supply and the inner pair of probes to the voltage terminals.
- Place the four probe arrangement in the oven and fix the thermometer in the oven through the hole provided.
- Switch on the constant current power supply and adjust the desired value (Say 0.5mA)
- Connect the oven power supply and heat it up to 130 ^{0}C. Rate of heating may be selected with the help of band switch of the oven power supply.
- Measure the inner probe voltage for various decreasing temperatures (by 10 ^{0}C).
- Plot a graph of ln ρ as a function of 1/T.
- Calculate the energy gap of a given semiconductor using a formula :$E_g = 2k_B$ x slope.

CIRCUIT DIAGRAM



RECORD OF OBSERVATIONS

1. Distance between the probes(s) = **1.5mm = 0.15 cm**
2. Thickness of the crystal (w) = **1 mm**
3. Current (I) = **0.5 mA** (constant)
4. Correction factor f(w/s) =**2.34**

TABULAR COLUMN

SL. NO.	Temperature		Voltage	ρ_0= (V/I) X 2 π S	$\rho = \frac{\rho_0}{f(w/s)}$	ln ρ	$\frac{1}{T}$
	^{0}C	K	mV	Ohm-cm	Ohm-cm		K^{-1}
1							
2							
3							
4							
5							
.							
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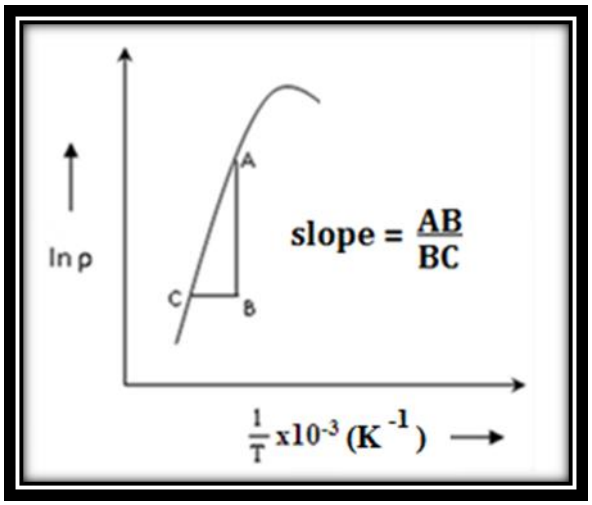
NATURE OF GRAPH



CALCULATION: Given k_B=1.38x10^{-23} J/K

E_g = 2 x k_B x Slope

= _ _ _ _ _ _ _ _ **J**

= _ _ _ _ _ _ _ _ **eV**

VIVA QUESTIONS

1) What is semiconductor?
2) Define energy gap. Is it temperature dependent?
3) What do you mean by conduction band and valence band?
4) Why current decreases with decrease of temperature in case of semiconductor?
5) What is the characteristic difference between metals and semiconductors from the consideration of temperature coefficient of resistivity?
6) Does semiconductor obey Ohm's law?
7) What do you mean by extrinsic and intrinsic semiconductor?
8) What are n-type and p-type semiconductors?
9) Is an extrinsic semiconductor electrically neutral?
10) What are the advantages of four probe method?
11) What is the order of resistivity of semiconductor?

Experiment. NO. : 02	SELECTIVITY OF TUNED CIRCUITS FREQUENCY RESPONSE

AIM: *To calculate the resonance frequency, quality factor and band width of a given LCR circuits which are connected in series/parallel.*

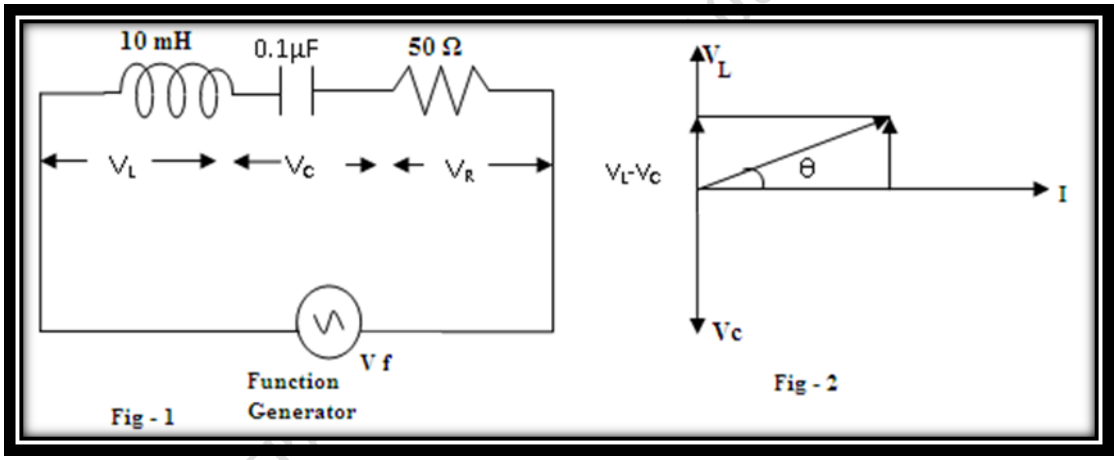
Compare the theoretically calculated resonance frequency and experimentally calculated resonance frequency and comment on the result.

Interpret the variation in the output in response to the variation in frequency, using graph

APPARATUS: Audio frequency oscillator, a. c. millimeters (0-20 mA) or millimeter, Inductance, resistor and capacitor of known values, connecting cords.

THEORY

Resistance, Inductance and Capacitance in series AC circuit. Consider a circuit containing inductance L, capacitor C and resistor R in series as shown in fig.1. When an alternate e.m.f. V ($=V_{max}$ sinωt) is applied to the circuit an alternate current flows in the circuit. Let 'I' be the current, at any instant. Let voltage drop across resistance R be V_R in phase with current, voltage drop across inductance L be V_L leading the current by 90^o and voltage drop across capacitance C be V_C lagging the current by 90^o. The resultant of V_L and V_C, (V_L- V_C) leads the current by 90^0, provided (V_L-V_C) and will lag current by 90^0 if $V_C > V_L$ (fig 2)



V_R = IR in phase with current

V_L = IX_L leading the current by 90^0

V_C = IX_C lagging by 90^0

The applied potential difference will be given by

$V^2 = V_R^2 + (V_L - V_C)^2$

$V^2 = (IX_L - IX_C)^2 + (IR)^2$ as $V_L = IX_L$, $V_C = IX_C$ & $V_R = IR$

$= I^2 (X_L - X_C)^2 + I^2R^2$

$= I^2 ((X_L - X_C)^2 + R^2)$

There force $I = V/((X_L - X_C)^2 + R^2))^{1/2}$

Where 'Z' is the impedance of the circuit

Or $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Where X_L---- inductive reactance and X_C---- capacitive reactance

SERIES AND RESONANCE CIRCUIT

In a circuit containing R, L and C connected in series the impedance is given by

$Z=\sqrt{R^2+(X_L-X_C)^2}$ Or $Z=\sqrt{R^2+(\omega L-\frac{1}{\omega C})^2}$

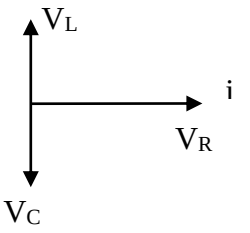
The effective reactance is inductive or capacitive depending upon $X_L>X_C$ or $X_L<X_C$. The inductive reactance X_L is directly proportional to the frequency and increases as the frequency increases from zero onwards. The capacitive reactance is inversely proportional to the frequency, decreases from an infinite value downwards. At certain frequency both reactances become equal and this frequency is called resonant frequency (f_r). At resonant frequency the two reactances are equal.

i.e., $X_L = X_C$ (or) $X_L - X_C = 0$. Then $V_L = V_C$ (fig3)

$\therefore \omega L = 1/\omega C$ Therefore $2\pi f_r L = 1/2\ \pi f_r C$ because $\omega = 2\pi f$

$$\mathbf{f_r} = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}\ \mathbf{Hz}$$

Therefore



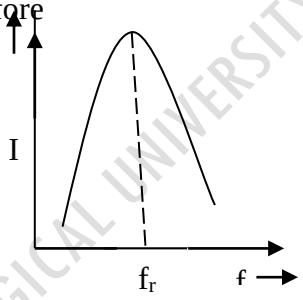


Fig -3a Where $V_L = V_C$ net voltage = V_R **Fig: 3b**

When $X_L = X_C$ at resonant Frequency the impedance is minimum and equal to the resistance. i.e., Z = R. In an Ac circuit containing R, Land C the supply voltage is magnified at resonant frequency as V_C reaches a value far excess of the supply voltage. The ratio of V_L or V_C with applied voltage at resonant frequency is called voltage magnification and denoted by Q factor i.e., quality factor

$Q = V_L / V = iX_L / iR$ (as Z = R)

Or $Q = 2\pi f_r (L / R)$

As fr = $\frac{1}{2\pi}\sqrt{\frac{1}{LC}}$

$Q = 2\pi\frac{1}{2\pi}\frac{L}{R}\sqrt{\frac{1}{LC}}$

$$Q=\frac{1}{R}\sqrt{\frac{L}{C}}$$

PARALLEL RESONANT CIRCUIT

A parallel resonance circuit is shown in fig-4. It is assumed that the resistance of the inductance coil is negligible. The current in the inductance I_L will lag in phase by 90^0 to the applied Voltage V. while the current in the capacitor I_C will lead in phase by 90^0 the applied voltage V. These currents being out of phase can be considered equivalent to an AC. If the supply current is "I" then

$I = I_L + I_C$ If I_C is greater than I_L at a particular frequency, then

$I = I_C - I_L = V/X_C - V/X_L$

Since I leads by 90^o on V in this case the circuit is 'net capacitive.'

If I_L is greater than I_C at a particular frequency, then

$I = I_L - I_C = V/X_L - V/X_C$

Since I lags by 90^o on V in this case the circuit is 'net inductive'.

Suppose V, L, C are kept constant & frequency f of supply is varied from low to high , the magnitude of I varies according to the relative magnitudes of $X_L(2\pi fL)$ & $X_C (1/2\pi fC)$.A special case occurs when $X_L = X_C$, then $I_L = I_C$ & so, I=0 at a particular frequency called resonant frequency f_r.

$$2\pi f_r L = 1/ 2\pi f_r C$$

Therefore $f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$

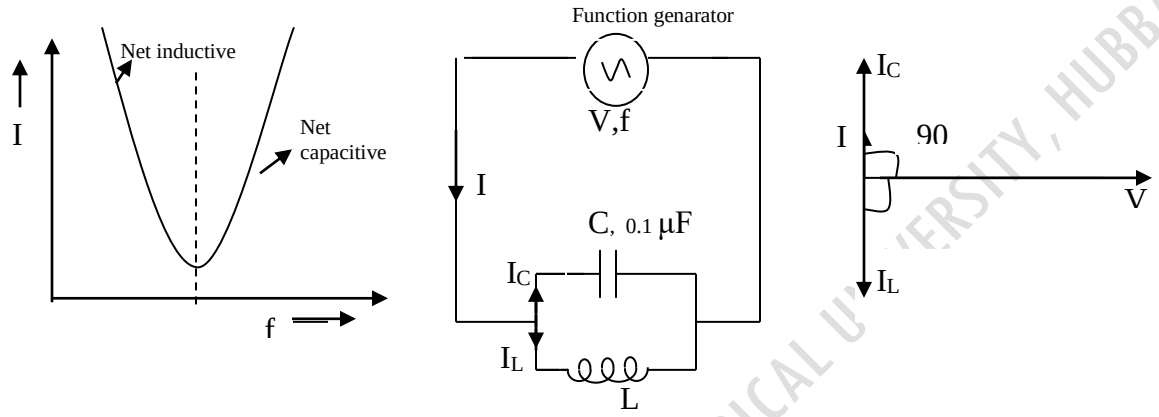


Fig:4a For L,C in parallel **Fig: 4b** Variation of I with 'f'

Since Z=V/I and I is zero at f_r , it follows that Z=infinity at f_r for a parallel inductor-capacitor circuit.

In practice when resistance R is taken in series with L, a similar variation of Z with f is obtained. But the maximum value of Z is finite now. & Z=L/CR. In this case also the resonant frequency is practically still given by

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \text{ Hz}$$

PROCEDURE

SERIES RESONANCE

The circuit connection is made as shown in the fig 5(a). The supplied points are switched on, and the output of the oscillator is adjusted suitably, which is kept constant throughout the experiment. The frequency 'f' is increased in appropriate steps and the corresponding readings of the current 'I' in mA as read from the milliammeter are entered in tabular column 1 under series resonance. The frequency for which current reaches its maximum value (I_{max}) is called resonant frequency (f_r). The readings including f_r and I_{max} are plotted with frequency in Hz along X-axis and the current in mA along the Y-axis. A resonance curve as shown in fig 6(a) will be obtained in which f_r and I_{max} are marked. The value of R, C, L and f_r are entered in tab. column 2 against Series resonance. The quality factor Q of the circuit is evaluated by using the equation,

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$Q_{\text{graphically}} = (f_r/\Delta f)$ where,

$\Delta f = (f_b - f_a)$ is the bandwidth

PARALLEL RESONANCE

The circuit connection is made as shown in the fig 5(b). The frequency f is varied and the corresponding circuit currents are noted. The readings are entered in tab. column 1 under parallel resonance. In this case the resonance frequency 'f_r' corresponds to the minimum value of current (Imin) in the circuit. The readings are plotted as earlier, and resonance curve as shown in fig 6(b) will be obtained. f_r and I_{min} are marked. The values of R, C, f_r and L are entered in tab. column 2 against parallel resonance and the Quality factor is determined.

CIRCUIT DIAGRAM

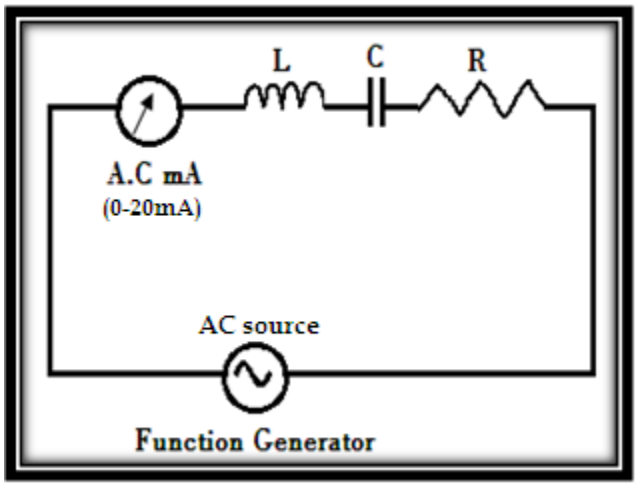


Fig: 5a Series resonance circuit

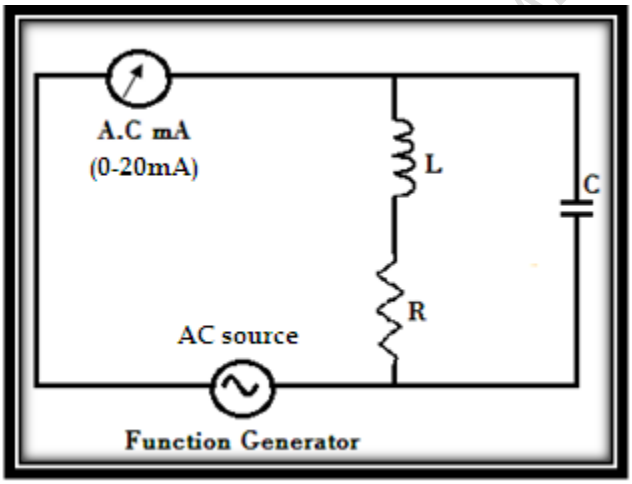


Fig: 5b Parallel resonance circuit

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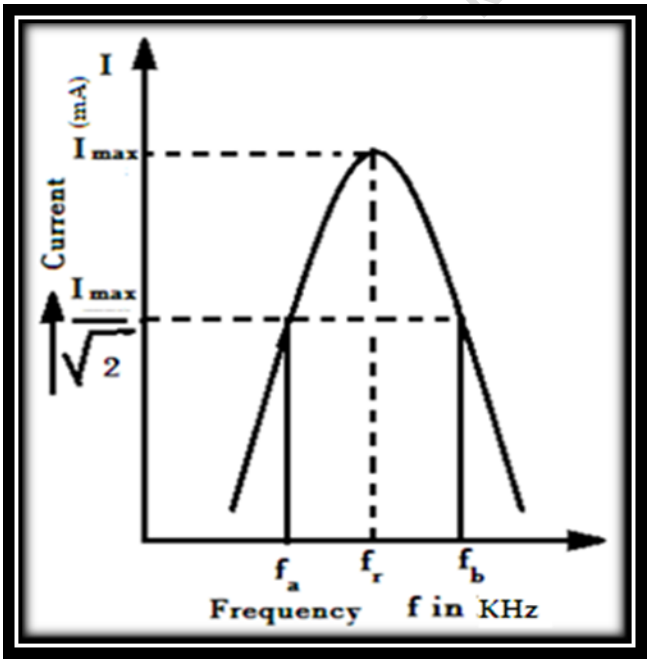
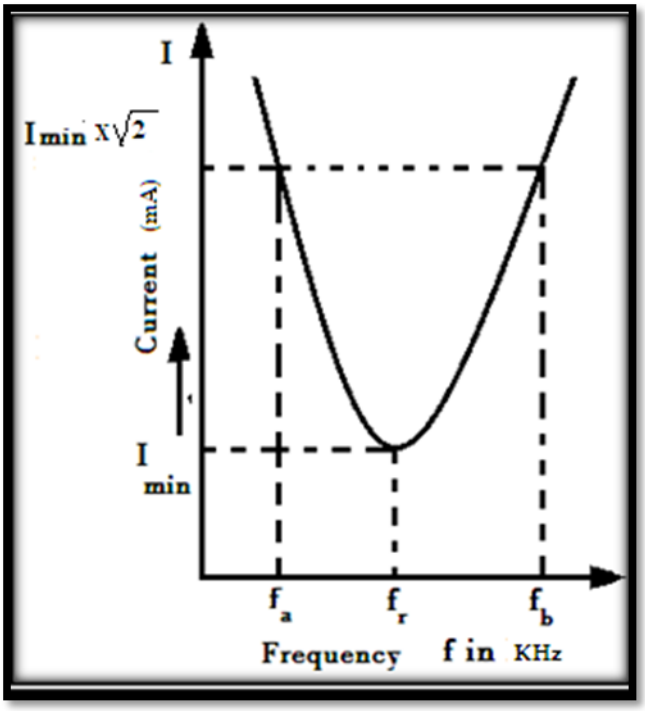


Series resonance frequency f_r = ...KHz.

Fig: 6a For Series Resonance



Parallel resonance frequency f_r = ...KHz

Fig: 6b for Parallel Resonance

RECORD OF OBSERVATIONS

Resistance = R =. ……. Ω
Capacitance =C =……. μF
Inductance= L= …….. mH

SUBSITUTE & CALCULATE

1. $f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$
   = ... Hz

2. $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

TABULATION 1

Series Circuit

Sl.No	Frequency 'f ' in kHz.	Current 'I' in mA.

Parallel Circuit

Sl.No	Frequency 'f ' in kHz.	Current 'I' in mA.

RESULTS

Type of Resonance	R in Ω	L in mH	C in μF	f_r (Experimental) In KHz	$Q_{expt} = (f_r / \Delta f)$	$\Delta f = (f_b - f_a)$
Series Resonance						
Parallel Resonance						

CONCLUSION:

VIVA QUESTIONS

1) What is Resonance?
2) How the resonance takes place in LCR circuit?
3) How do we identify the resonance in LCR circuit?
4) Why the series resonance circuit is called an acceptor circuit and the parallel resonance circuit is called rejector circuit?
5) What is the potential difference across L and C at resonance?
6) What is the role of resistance in LCR circuit?
7) What is reactance?
8) What is impedance?
9) What is meant by band width?
10) What is quality factor?
11) What is the impedance of the LCR series circuit at resonance frequency?
12) How do you change the resonance frequency in LCR circuit?
13) What is the difference between Impedance & Résistance?

Experiment. No. : 03	MEASUREMENT OF DIELECTRIC CONSTANT OF A CAPACITOR

AIM: *To study the charging and discharging of a given capacitor.*
To determine dielectric constant of a given dielectric material in an electrolytic capacitor

APPARATUS: capacitor, resistor, dc power supply, digital voltmeter, charging and discharging key, stop clock etc.

THEORY: A capacitor is a device for storing charge. The most common capacitor consists of two parallel plates. The ratio of the charge on either plate to the potential difference between the plates is called capacitance 'C' of the capacitor.

$$C = Q/V \quad \textbf{(1)}$$

And according to Gauss law the field between the two plates is

$$E = \frac{Q}{\varepsilon_0 A} \Rightarrow Ed = V = \frac{Q.d}{\varepsilon_0 A} \quad \textbf{(2)}$$

Now equating eqn. (1) and eqn. (2) we get the capacitance in terms of area of the plates 'A' and their separation 'd' as

$$C = \frac{\varepsilon_0 A}{d} \quad \textbf{(3)}$$

If a dielectric is inserted between the plates then above equation becomes

$$C = \frac{K\varepsilon_0 A}{d}$$

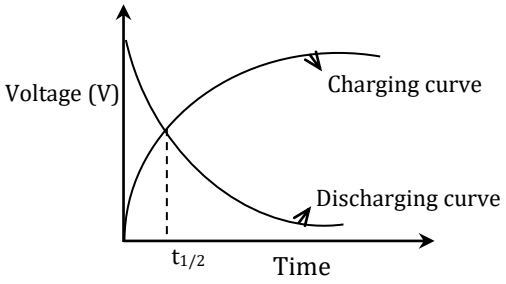
where K is referred as the dielectric constant of the material. The ratio of the capacitance with dielectric to capacitance without the dielectric between the plates is called the dielectric constant of the material used. i.e.,

$$\frac{C}{C_0} = K \quad \textbf{(4)}$$

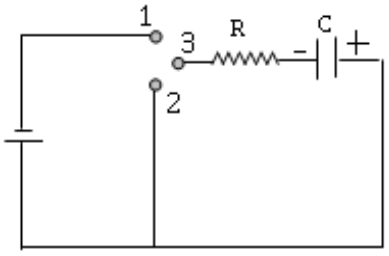
All materials have 'K' value greater than unity, thus capacitance can be increased by inserting a dielectric.

Charging and discharging of capacitor in a RC circuit:

When we connect a capacitor to a battery, electrons flow from the negative terminal of the battery on to the plate 'B' of the capacitor connected to it. At the same time the positive terminal of the battery extracts electrons from the plate 'A'. As electrons accumulate on plate 'B' and others depart from the plate 'A', a difference of potential develops across the capacitor. As the capacitor continues to charge, the voltage across the capacitor rises until it is equal to the source voltage. Once the emf developed across the capacitor equals the source voltage then the capacitor is fully charged



Charging and discharging curves



RC- charging and discharging circuit

To discharge a capacitor, the charges on the two plates must be neutralized. This is accomplished by providing a conducting path between the two plates, so that the excess electrons on the plate 'B' can flow to the plate 'A' and neutralize its charge. Thus the capacitor discharges through the resistance 'R'.

It is seen from the charging and discharging curves that variation is exponential in nature. The variation of voltage in the charging mode is given by

$$V = V_0(1 - e^{-t_{1/2}/RC}) \quad \textbf{(5)}$$

Similarly in the discharging mode the voltage variation is given by

$$V = V_0 e^{-t_{1/2}/RC} \quad \textbf{(6)}$$

The charging–discharging curves intersect at a point at the time $t_{1/2}$. at this instant of time $t_{1/2}$ the voltage across the capacitor is the same during charging and discharging process. Therefore, we have

$$V_0(1 - e^{-t_{1/2}/RC}) = V_0 e^{-t_{1/2}/RC}$$

$$V_0 - V_0 e^{-t_{1/2}/RC} = V_0 e^{-t_{1/2}/RC}$$

$$V_0 = 2V_0 e^{-t_{1/2}/RC}$$

$$\frac{1}{2} = e^{-t_{1/2}/RC} \quad \textbf{(7)}$$

$$\ln\left(\frac{1}{2}\right) = -t_{1/2}/RC$$

$$\therefore t_{1/2} = \ln 2RC$$

$$C = \frac{t_{1/2}}{R \ln 2}$$

Also $C = \dfrac{\varepsilon_0 \varepsilon_r A}{d}$

Equate

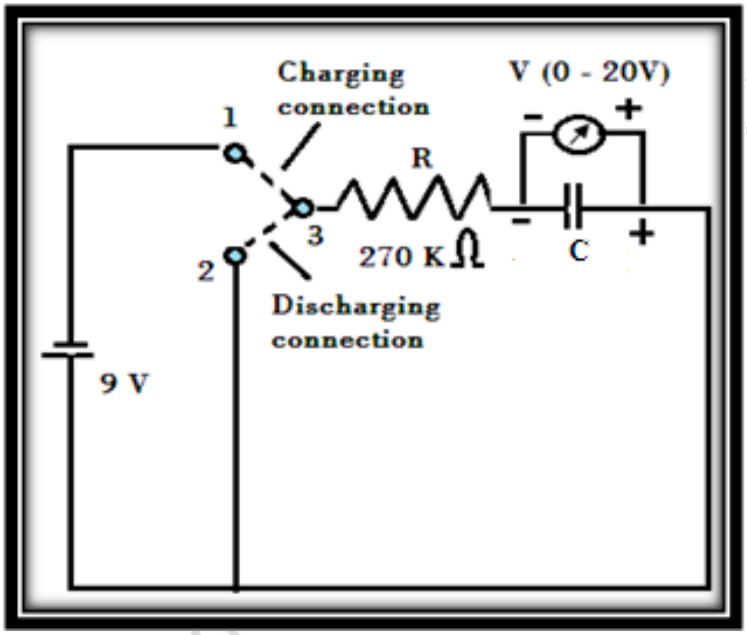
$$\varepsilon_r = \frac{d t_{1/2} 10^{-6}}{0.693 \varepsilon_0 A R}$$

At $t_{1/2}$ the instantaneous voltage across the capacitor is half of its initial voltage.

PROCEDURE

- Make the connections as shown in the circuit diagram.
- Set some voltage in the battery.(say around 9V)
- For charging the capacitor, connect 1 and 3 terminals of the key.
- Immediately start noting down the voltage across capacitor at every 15 seconds interval using a stop clock, until the voltage becomes constant.
- Once the capacitor is fully charged then connect the 2 and 3 terminals of the key to discharge the capacitor.
- Again note down the voltage reading at every 15 seconds until voltage becomes constant.
- The charging and discharging curves are to be drawn by plotting 't' along x-axis and 'V along y-axis
- By noting the values of t1/2 from graph (where charging and discharging curves meet) calculate 'K' the dielectric constant of the given material.
- Repeat the same procedure for another value of capacitor.

CIRCUIT DIAGRAM



RECORD OF OBSERVATIONS

C = 100 μF or C = 220 μF, R = 270 KΩ, Battery voltage (V_0) = --------Volt

DIMENSIONS OF THE CAPACITOR AND THICKNESS OF THE DIELECTRIC MEDIUM

CAPACITOR	C= 100μ F	C= 220μ F
Length(l)	50 mm	120 mm
Width(w)	6 mm	6 mm
Thickness of the dielectric material(d)	0.10 mm	0.10 mm

TABULAR COLUMN

Capacitance = C = 100μF or C=220μF

Obs. No.	Time 'T' In Sec	Voltage 'V' In Volt Charging	Voltage 'V' In Volt Discharging
1.	0		
2.	10		
3.	20		
4.	30		
5.	40		
6.	50		
7.	60		
8.	70		
9.	80		
10.	90		
11.	100		
12.	110		
13.	120		
14.	130		
15.	140		
16.	150		
17.	160		
18.	170		
19.	180		
20.	.		
21.	.		
22.	.		

NATURE OF GRAPH

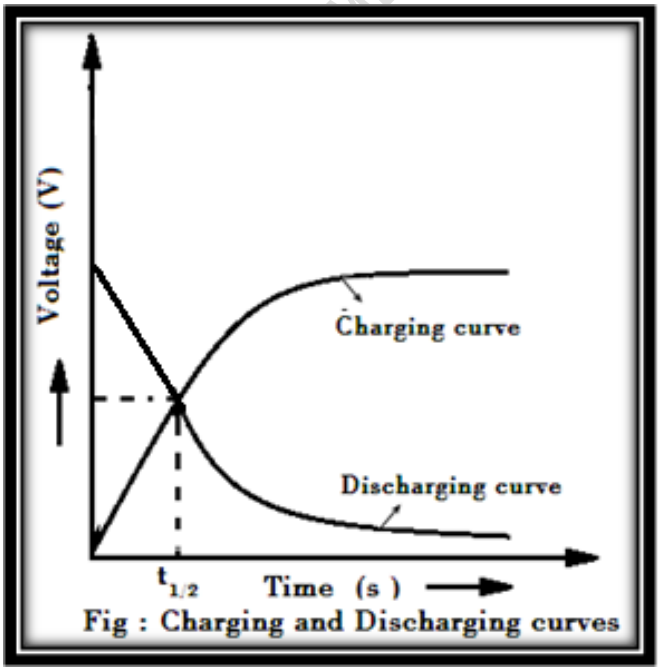


Fig : Charging and Discharging curves

CALCULATIONS

For Capacitor C =……μF

1) Theoretically $t_{1/2} = RC_1\ ln2$

=……..**sec**

2) Dielectric constant= ε_r=K = $\frac{d\ t_{1/2} \mathbf{X}\ 10^{-6}}{0.693\ \ \varepsilon_0\ A\ R}$

=……

Where
K is dielectric constant of the given material
$t_{1/2}$ is the time required to get charged / discharged to 50% of the capacitance.

d and A are the thickness and area of the dielectric material, and
A is given by: A = length (l) x width (w)
R is the resistance in the circuit.
ε_0= 8.85x10^{-12} F/m is the permittivity of the free space.

RESULT:

Capacitance	**$t_{1/2}$ in sec (Theoretically)**	**$t_{1/2}$ in sec (Graphically)**	**Dielectric constant K (Theoretically)**	**Dielectric constant K (Graphically)**
100µF				
220 µF				

CONCLUSIONS:

VIVA QUESTIONS:

1) What is capacitor?
2) What is dielectric? What is its role in capacitor?
3) Why are dielectrics?
4) What is dielectric constant?
5) What is charging and discharging of a capacitor?
6) What is the role of resistance in charging and discharging circuit?
7) What is dipole?
8) Derive the equation K = $\frac{d\ \mathbf{X}\ t_{1/2} \mathbf{X}\ 10^{-6}}{0.693\ \mathbf{X}\ \varepsilon_0 \mathbf{X}\ A\ \mathbf{X}\ R}$
9) Applications of dielectrics.
10) Capacitance of a capacitor depends on what factors?

EXPERIMENT NO. 04	TRANSISTOR CHARACTERISITICS

AIM: *To study*

i) the V-I characteristics of a transistor

ii) Input and Output characteristics of transistor for CE configuration

iii) Determine the current amplification factor β from the graph of I_C vs I_B.

APPARATUS: Transistor, Micro ammeter, Millimeter, Voltmeter, & connecting wires, etc**.**

THEORY: The transistor was invented by John Bardeen and Walter Brattain in the year 1948 and was improved by William Shockley in 1951. The three of them received the Nobel Prize for Physics in 1956 for the invention of transistor. Transistors form the basis of almost all modern electronic devices. A transistor consists of two P-N junctions formed by sand witching either a P-type or N-type semiconductor material between a pair of opposite type of semiconductor materials. Hence two types of transistors (i) PNP and (ii) NPN transistors are possible [figure 3.1(a) & figure 3.1(b)]. Their symbols are also shown in the figure.

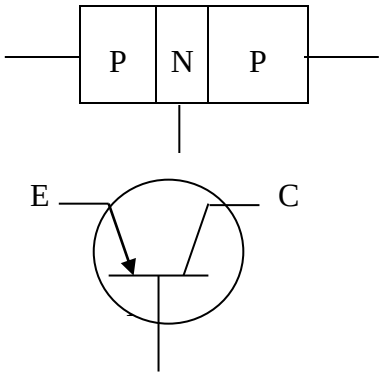


Figure3. 1(a)

E – Emitter

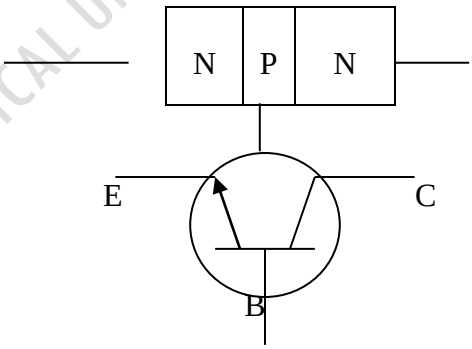


Figure 3.1(b)

B – Base

C – Collector

Terminals of Transistor: A transistor may be regarded as made up of two P-N junctions connected back to back. The middle section of the transistor is known as **'Base'**. The section on one side of the base which supplies the free charges is known as **'Emitter'** and the section on the other side which collects these charges is known as **'Collector'**. The junction between the emitter and base is known as **emitter-base junction** or simply emitter junction. The junction between collector and base is known as **collector-base junction** or simply collector junction. In schematic symbols of transistor an arrow is shown for emitter to indicate the direction of the conventional current.

Transistor action: For normal operation of the transistor the emitter junction must be forward biased and the collector junction must be reverse biased [Figure 3. 2(a) and (b)]. The forward biased emitter junction offers very low resistance to the current flow and the reverse biased collector junction offers high resistance to the flow of current. A weak signal is introduced at the low resistance emitter side and the output is taken from the high resistance collector side. A transistor, therefore, transfers signal from low resistance side to high resistance side. Hence the name transistor is derived from the two words **TRANSfer resISTOR.**

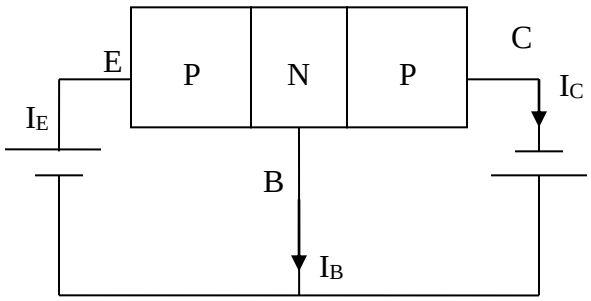


Figure 3. 2(a)

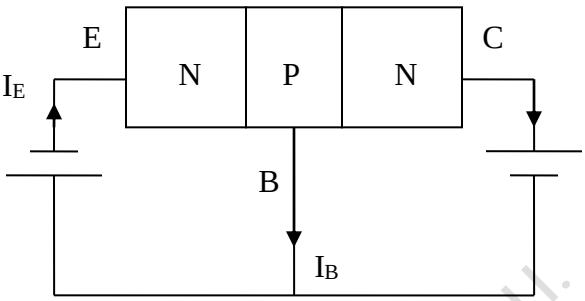


Figure 3. 2(b)

The current flow in the emitter base junction has to primarily carry out by the majority carriers in the emitter region. The flow of majority carriers from the base to the emitter does not contribute to the collector current. Hence **in a transistor the emitter region is heavily doped, the base is lightly doped.** The collector is doped to a level greater than that of the base and less than that of the emitter. For efficient working of a transistor, collector current must be a large fraction of the emitter current. This is possible only if emitter current is entirely due to the flow of the majority carriers from the emitter and the loss of majority carriers from emitter in base is kept a minimum. This is possible only if the emitter is heavily doped and the base is made very thin.

The area of the collector junction is generally made considerably larger than that of the emitter junction. This is necessary because the majority carriers from the emitter diffuse through the base in forward direction and as well as sideways. A large area of the collector junction prevents excess recombination of holes and electrons in the base region.

Transistor configurations: The transistor is a three terminal device. A transistor is normally used as an amplifier. For an amplifier there should be two terminals for input and two terminals for output. Since the transistor has only three terminals, one of the terminals is used as a common terminal to both the input and the output. Accordingly, a transistor can be connected in the following three different configurations:

(1) Common -- Base (CB) configuration
(2) Common – Emitter (CE) configuration.
(3) Common – Collector (CC) configuration.

Regardless of the type of connection, the emitter-base junction is always forward biased and collector-base junction is reverse biased, when used as an amplifier. Each of these circuit connections has specific advantages and disadvantages. The common-emitter configuration has a specific feature that its high gain which is due to the fact that the changes in base current affect the collector current more than changes in emitter current for common-base circuit.

A bipolar transistor is usually regarded as a current amplifier, and its characteristics are usually described in term of current. In each configuration, the transistor has two characteristics, viz. (i) Input characteristics, and (ii) Output characteristics.

Current Gain: Since the input controls the output current the gain in the transistor is characterized by current gain or current amplification factor.

In general current amplification is defined as the ratio of the output current to the input current.

The Beta factor (β): It is the property of the common-emitter circuits. It is the ratio of collector current (I_C) to the base current (I_B) at constant collector to emitter potential (V_{CE}).

$$\beta_{dc} = \left(\frac{I_C}{I_B}\right)_{V_{CE}} \quad ----(2)$$

In Junction transistors, β reaches the value of 40 and even 100 in some units. The reason for this is that I_B is very small as compared to I_C.

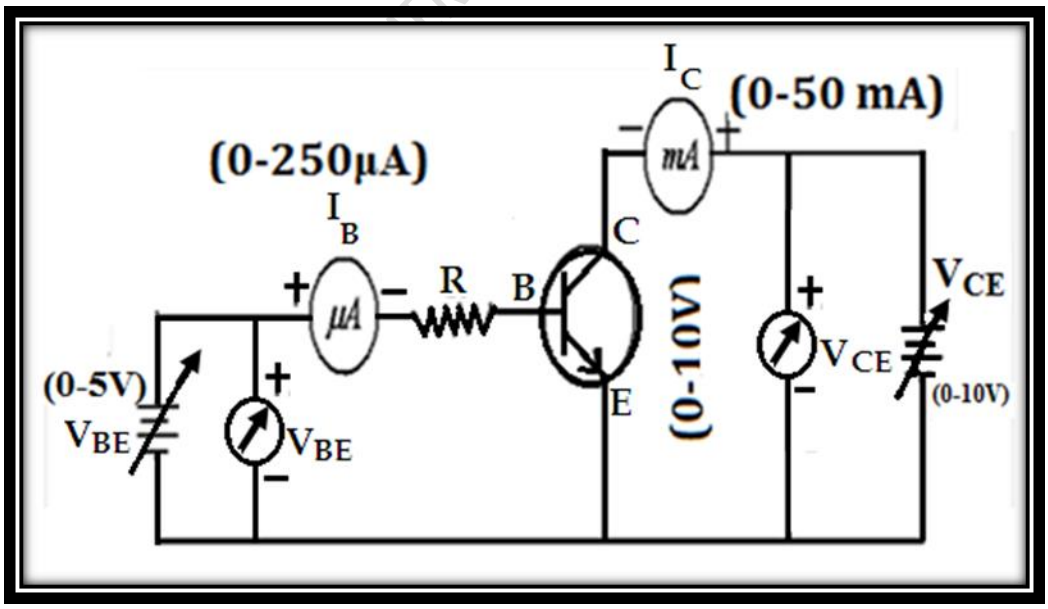
PROCEDURE: ***INPUT CHARACTERISTICS***

- Connect the circuit as per the circuit diagram.
- For plotting the input characteristics the output voltage V_{CE} is kept constant at 1V and for different values of V_{BE}. Note down the values of I_C
- Repeat the above step by keeping V_{CE} at 2V and 3V.
- Tabulate all the readings.
- plot the graph between V_{BE} and I_B for constant V_{CE}

PROCEDURE: ***OUTPUT CHARACTERISTICS***

- The given transistor is connected in CE configuration as shown in circuit diagram.
- First, the base current 'I_B' is fixed for certain value. Then V_{CE} is varied in steps and corresponding collector current I_c is noted down till you get a constant collector current.
- Step 2 is repeated for different fixed values of I_B.
- A graph of I_C v/s V_{CE} for various fixed I_B is plotted.
- Note down Steady Value of I_C for various fixed I_B value in table 2.
- Another graph is plotted for I_C v/s I_B.
- Finally the current amplification factor 'β' is calculated from the graph.

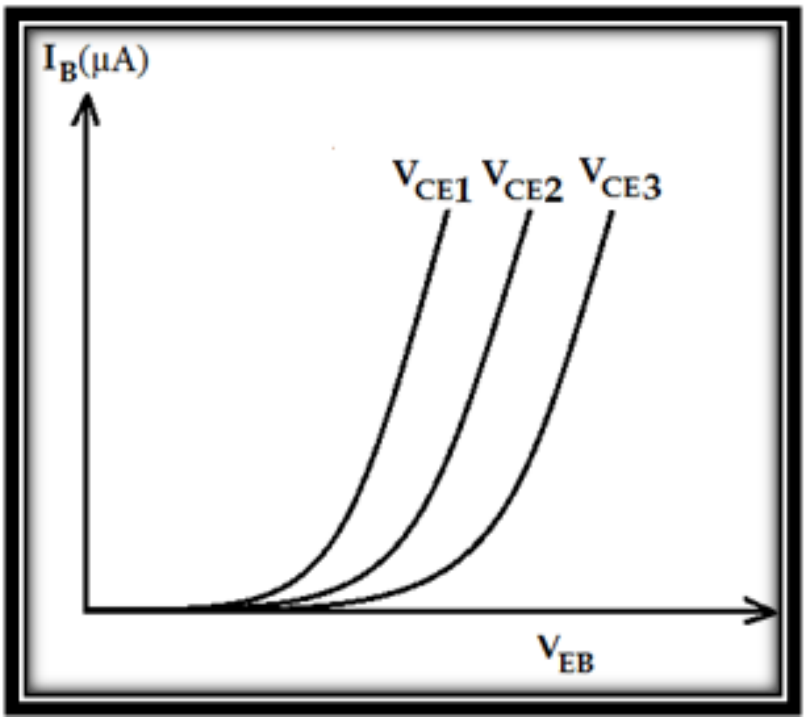
CIRCUIT DIAGRAM



TABULAR COLUMN 1:
INPUT CHARACTERISTICS:

Sl. NO.	V_{CE}=_ _ _ _ _ _V		V_{CE}= _ _ _ _ _ _V		V_{CE}= _ _ _ _ _ _V	
	V_{BE} in V	I_B in µA	V_{BE} in V	I_B in µA	V_{BE} in V	I_B in µA

NATURE OF GRAPH: INPUT CHARACTERSTICS



TABULAR COLUMN 2: Variation of collector current with base current

Sl. No	I_B =_____ µA		I_B =____µA		I_B =____ µA		I_B =____ µA		I_B =____ µA	
	V_{CE} in (V)	I_C in (mA)	V_{CE} in (V)	I_C In(mA)	V_{CE} in (V)	I_C In(mA)	V_{CE} in (V)	I_C In(mA)	V_{CE} in (V)	I_C In(mA)

NATURE OF GRAPH 2

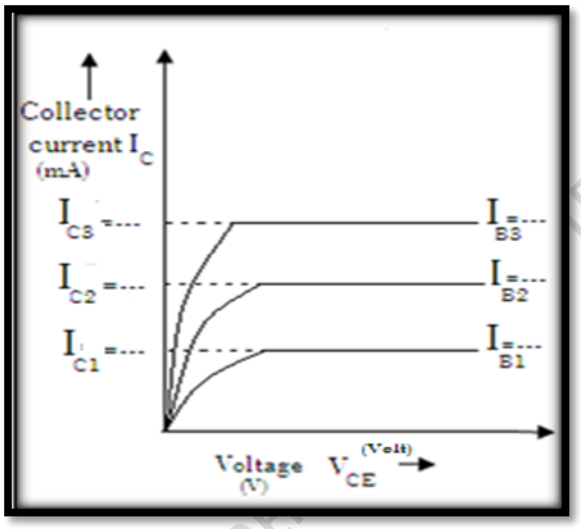


Figure: 2

TABULAR COLUMN 3: Saturated collector current with base current

Base Current I_B in (µA)	Collector Current I_C in(mA)

NATURE OF GRAPH 3:

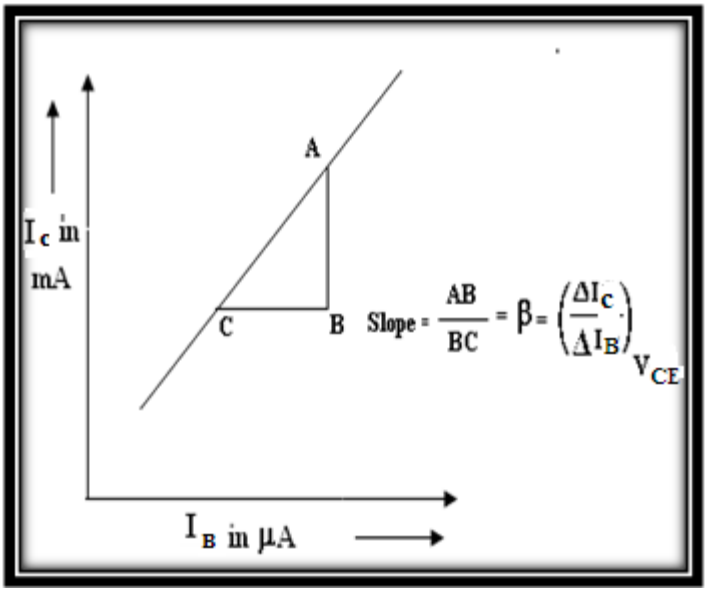


Figure: 3

RESULTS

The current amplification factor $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}} =$ …… from graph (Figure 2)

CONCLUSIONS:

VIVA QUESTIONS:

1. Why it is called as a transistor?
2. What are other modes of operation of a transistor?
3. Under normal use of transistors, how they are biased?
4. What is meant by input characteristics of a transistor?
5. What is gain?
6. Which configuration gives more current gain and voltage gain (more than unity)?
7. On what a factor does the characteristic of a transistor depends?
8. What are the advantages of common emitter configuration?
9. What are the applications of transistor?
10. Explain different configurations of transistor.
11. What is amplification?

EXPERIMENT NO. 05	V – I CHARACTERISTICS OF PN JUNCTION DIODE

AIM: *To determine the following:*

i) V-I characteristics of PN junction diode.

ii) DC load line and the Q point.

iii) Static and Dynamic resistance.

COMPONENTS

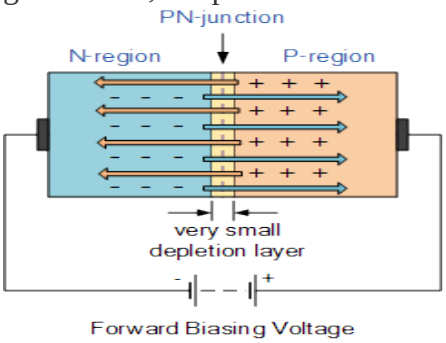
List of Components/Equipment/Instruments with specifications:

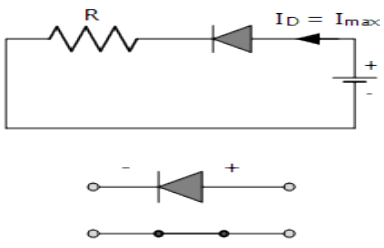
Sl.No	Name of the component	Specification	Quantity
1.	Bread Board	-	1
2.	Diode	IN4007	1
3.	Resistor	1KΩ	1
4.	Multimeter	-	2
5.	Regulated Power Supply	(0 – 30) V	1
6.	Wires	Single stranded	

THEORETICAL BACKGROUND (CIRCUIT DIAGRAM AND DESIGN):

FORWORD BIAS

When a diode is connected in a Forward Bias condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material. If this external voltage becomes greater than the value of the potential barrier, approx. 0.7 volts for silicon and 0.3 volts for germanium, the potential barriers opposition will be overcome and current will start to flow.



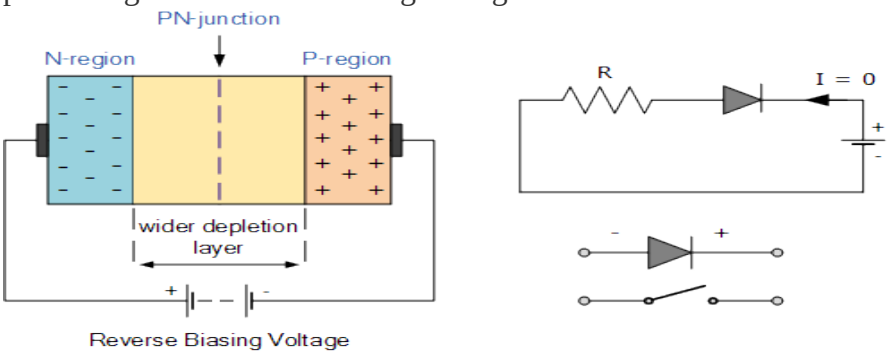


REVERSE BIAS

When a diode is connected in a **Reverse Bias** condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material.

The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode.

The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator. The result is that a high potential barrier is created thus preventing current from flowing through the semiconductor material.



V-I CHARACTERISTICS OF DIODE

A *PN Junction Diode* is one of the simplest Semiconductor Devices around, and which has the characteristic of passing current in only one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage (I-V) relationship and therefore we cannot described its operation by simply using an equation such as Ohm's law.

The diode is the non ohmic device, the V-I characteristics of the diode is understood by the equation

$$I = I_o\left(e^{\frac{eV}{KT}} - 1\right)$$

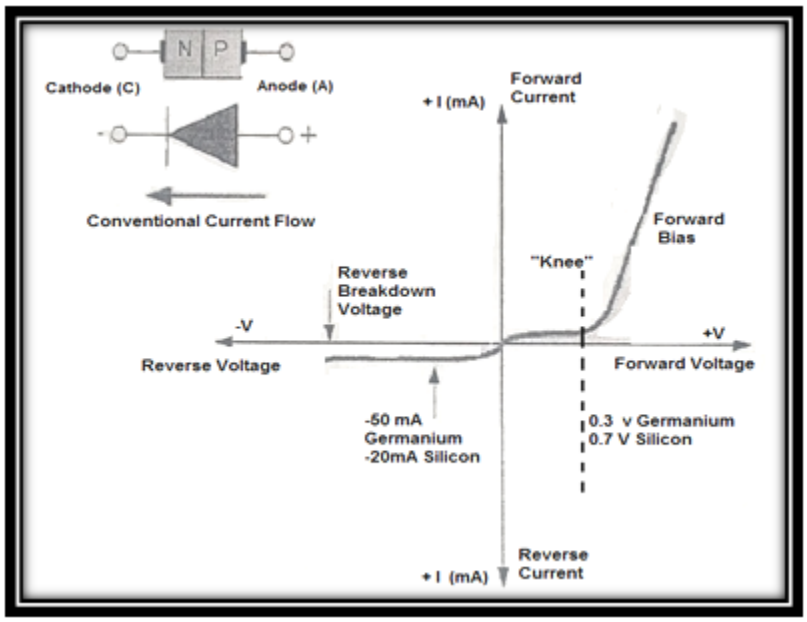
When the diode is forward biased, V is +ve and therefore the forward current increases exponentially as soon as the applied voltage exceeds the barrier voltage.

Forward current is given by

$I_f = I_o e^{\frac{eV}{KT}}$ K - Boltzmann constant

When the diode is reversing biased the, the voltage is –ve, the reverse saturation current is given by

$I_r = - I_o$



PROCEDURE

FORWARD BIAS

- Connect the circuit as per the diagram on bread board. Vary the applied voltage V in steps of 0.1V for forward bias.
- Note down the corresponding Ammeter readings I_f. Plot a graph between V_f & I_f.
- Obtain the DC load line using the equation $E= I_fR_1+ V_f$ and obtain the value of Q point.

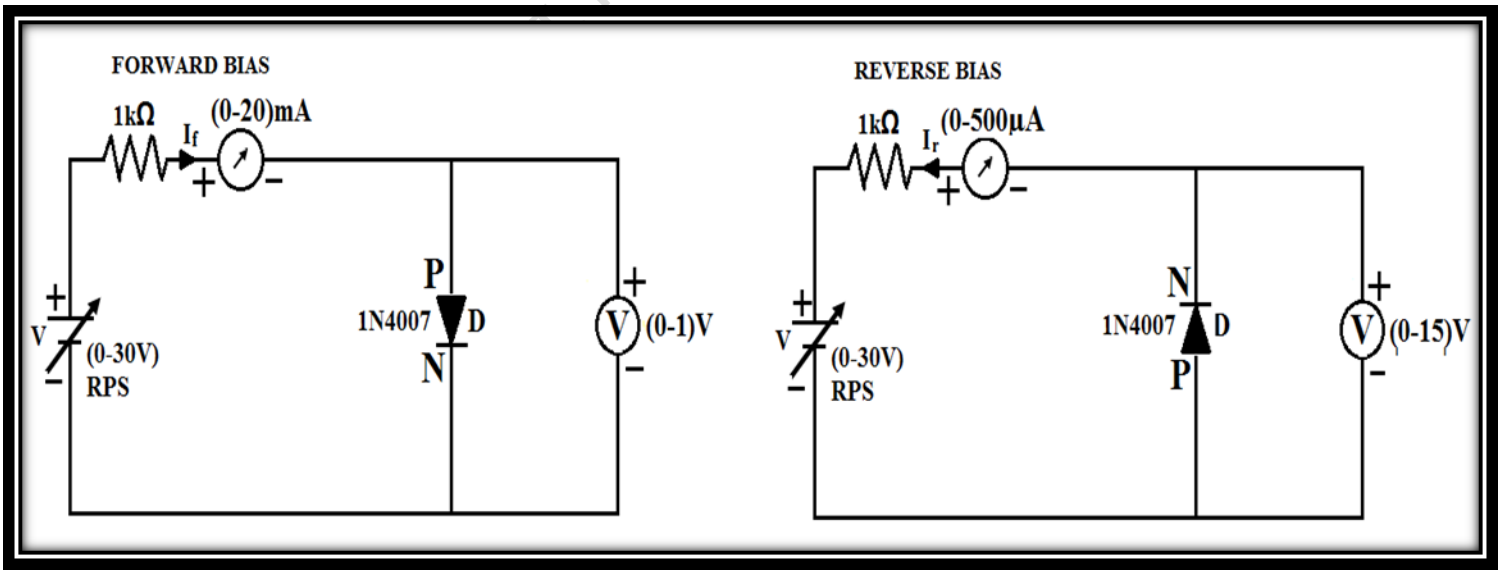
REVERSE BIAS

- Connect the circuit as per the diagram on bread board. Vary the applied voltage V in steps of 1V in Reverse bias respectively.
- Note down the corresponding Ammeter readings I_r. Plot a graph between V_r & I_r.

TO FIND STATIC AND DYNAMIC RESISTANCES

- Static Resistance = V/I Ω It is found by plotting a point on forward characteristics curve and traverse across I and V axis and note down the values. Ratio of V / I gives static resistance.
- Dynamic Resistance = Δ Vd / Δ Id. It is found by drawing a tangent at Q point and then a right angle to it. Traverse the points across I and V axis and find the difference in voltage and current values. Ratio of this change in voltage by change in current gives the dynamic resistance.

CIRCUIT DIAGRAM



RECORD OF OBSERVATIONS:

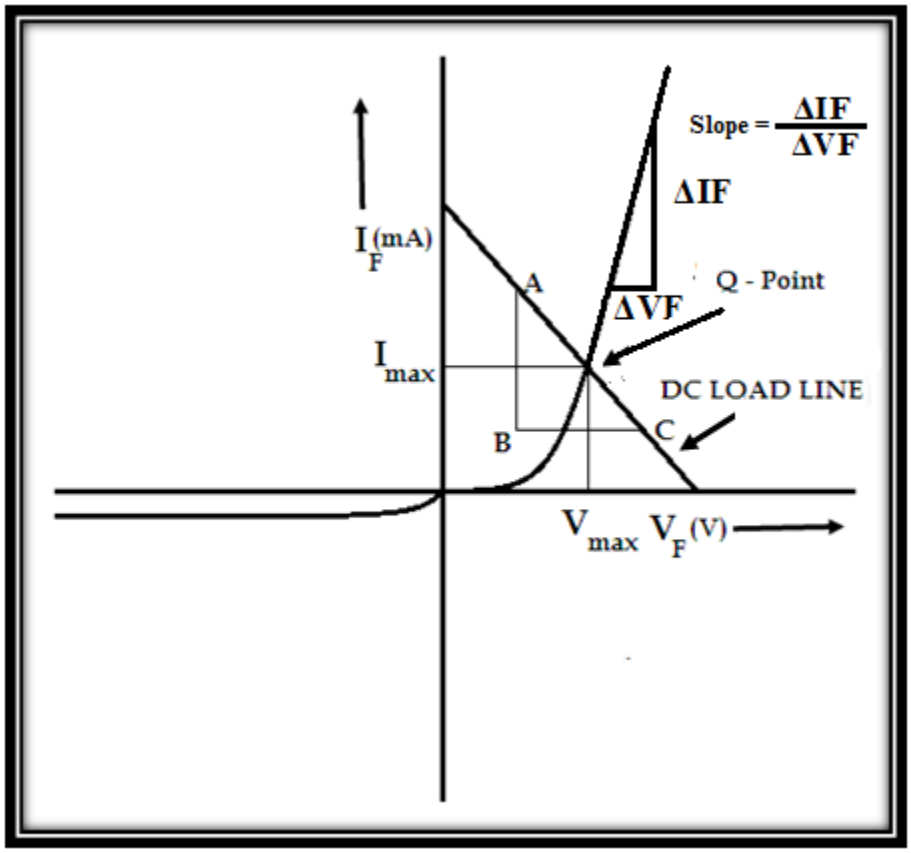
FORWORD BIAS:

Sl.No	V_F (in V)	I_F (in mA)	R_F (In Ω)

REVERSE BIAS:

SL.NO	V_R (in V)	I_R (in µA)	R_R (In Ω)

NATURE OF GRAPH



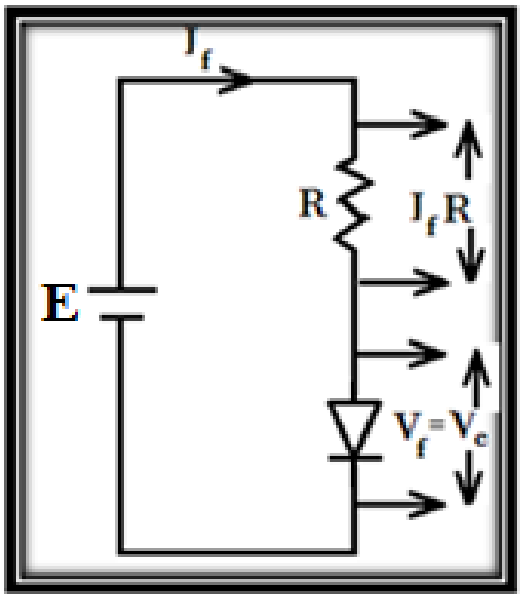
RESULTS:

Cut in voltage V_C= _ _ _ _ _

Dynamic resistance $\mathbf{r_d} = \frac{1}{slope}$ = _ _ _ _ _

Static resistance $r_s = \frac{V_c}{I_f}$

DC LOAD LINE ANALYSIS:



The loop equation is

$E = I_f R + V_f$

Let R = 100 Ω, E =1 volt

If I_f =0, V_f=E= _ _ _ _volts

If V_f = 0, $I_f = \frac{E}{R}$ = _ _ _ mA

RESULTS

1. Maximum forward voltage $\mathbf{V_{f\,max}}$ = _ _ _ _ _ V
2. Maximum forward current $\mathbf{I_{f\,max}}$ = _ _ _ _mA
3. R = Load resistance = $\frac{1}{\text{slope}}$ = _ _ _ _ _ _ _ Ω
4. Reverse saturation current $\mathbf{I_0}$ = =_ _ _ _ _ _ _µA

CONCLUSIONS

VIVA QUESTIONS

1) What is diode?
2) What is meant by biasing? What is forward and reverse biasing?
3) Mention the important difference between ordinary diode and Zener diode?
4) Explain the formation of depletion region in a p-n junction.
5) Mention the application of diode?
6) What is DC load line?
7) What is Q point?
8) What are Dynamic and static forward resistance?
9) What happens when diode is connected to AC source?
10) What is diffusion current?
11) What is drift current?

EXPERIMENT NO. 06	USE OF MEASURING INSTRUMENTS AND CALIBRATION OF CRO

AIM:

i) To study the use of measuring instruments: Digital multimeter and Cathode Ray Oscilloscope

ii) To study Calibration of CRO

iii) DC voltage measurement of Regulated power supply using CRO

iv) AC voltage and frequency measurement using CRO

EQUIPMENTS/APPARATUS REQUIRED:

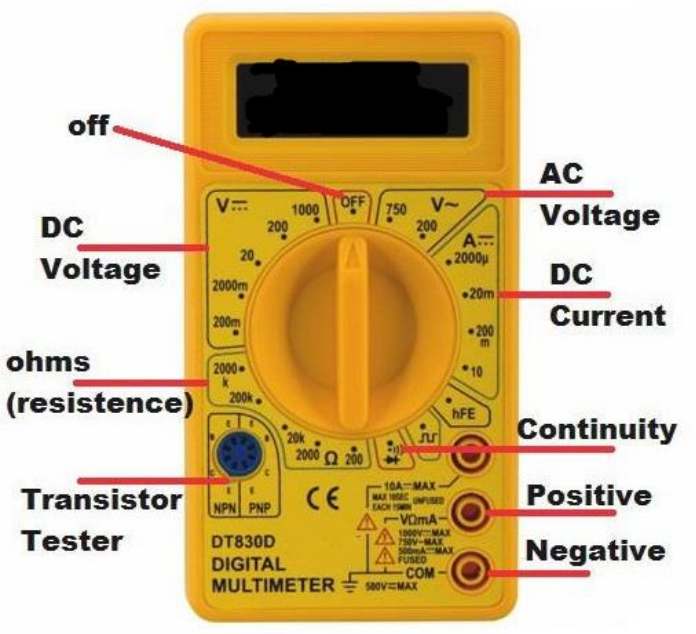
Sl. No.	Particulars	Specifications	Quantity
1.	Oscilloscope	20/30 MHz, Dual trace	01
2.	Digital multimeter	-	01
3.	DC regulated power supply	0 – 15V	01
4.	Function generator/waveform generator	0 – 1 MHz	01

THEORY

Introduction to Measuring Instruments:

1. Digital Multi-meters

A digital multi-meter (DMM) is a multifunctional meter that displays its electrical quantitative values on an LCD screen. A digital multi-meter much like an analog meter, it is able to read voltage, current, and resistance. Digital multi-meter differ from the analog meter as it has the ability to display measured electrical values quickly without any computations. Because of its design, a processor can be built into the meter which allows the user to take measurements of frequency, the inductance of a coil, capacitance of a capacitor, and a host of other high functional electrical measurements.



2. Dc regulated power supply

A regulated power supply (also known usually as a linear power supply) ensures that the output current remains constant, even if the input changes, by converting unregulated AC (alternating current) to a constant DC (direct current).

Common Applications

- Testing Circuits
- Testing mobile phone chargers
- Regulated power supplies in different appliances
- Various oscillators & amplifiers
- Audio visual applications

Regulated power supply

3. Function generator/waveform generator

A Function generator is usually a piece of electronics test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine wave, square wave, triangular wave and saw-tooth shapes.

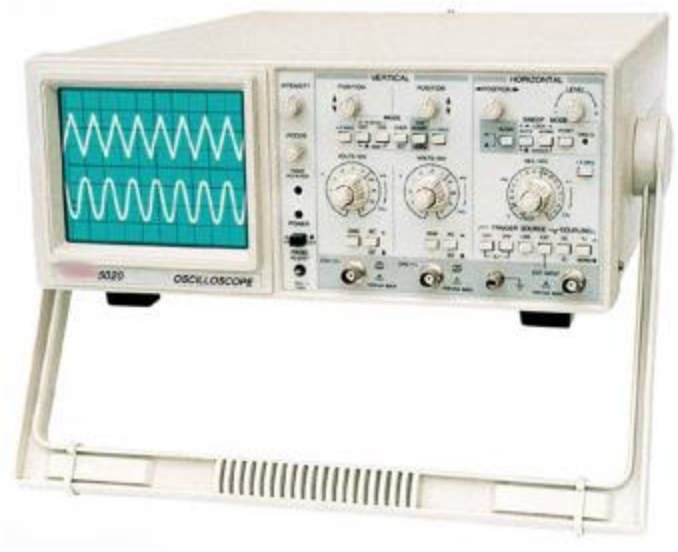
Function generators may typically produce other repetitive waveforms including saw-tooth and triangular waveforms, square waves, and pulses. Another feature included on many function generators is the ability to add a DC offset. Although function generators cover both audio and RF frequencies, they are usually not suitable for applications that need low distortion or stable frequency signals. Function generators are used in the development, test and repair of electronic equipment. For example, they may be used as a signal source to test amplifiers.

4. Cathode ray Oscilloscope

Oscilloscope is a measuring device, which can test, and display voltage signals as waveforms, visual representations of the variation of voltage over time. The signals are plotted on a graph, which shows how the signal changes. The vertical (Y) access represents the voltage measurement and the horizontal (X) axis represents time

The graph on an oscilloscope can show:

- Voltage signal shape
- Current signal shape
- Signal anomalies
- Amplitude modulation of an oscillating signal and any variations in frequency
- Whether a signal includes noise and changes to the noise



Cathode Ray Oscilloscope

The basic oscilloscope, as shown in the illustration, is typically divided into four sections: the display, vertical controls, horizontal controls and trigger controls. The display is usually a CRT or LCD panel which is laid out with both horizontal and vertical reference lines referred to as the graticule. In addition to the screen, most display sections are equipped with three basic controls, a focus knob, an intensity knob and a beam finder button.

The vertical section controls the amplitude of the displayed signal. This section carries a Volts-per-Division (Volts/Div) selector knob, an AC/DC/Ground selector switch and the vertical (primary) input for the instrument. Additionally, this section is typically equipped with the vertical beam position knob**.**

The horizontal section controls the time base or "sweep" of the instrument. The primary control is the Seconds-per-Division (Sec/Div) selector switch. Also included is a horizontal input for plotting dual X-Y axis signals. The horizontal beam position knob is generally located in this section.

The trigger section controls the start event of the sweep. The trigger can be set to automatically restart after each sweep or it can be configured to respond to an internal or external event. The principal controls of this section will be the source and coupling selector switches. An external trigger input (EXT Input) and level adjustment will also be included

In addition to the basic instrument, most oscilloscopes are supplied with a probe as shown. The probe will connect to any input on the instrument and typically has a resistor of ten times the oscilloscope's input impedance. This results in a .1 (-10X) attenuation factor, but helps to isolate the capacitive load presented by the probe cable from the signal being measured. Some probes have a switch allowing the operator to bypass the resistor when appropriate.

PROCEDURE:

i) Calibration of CRO

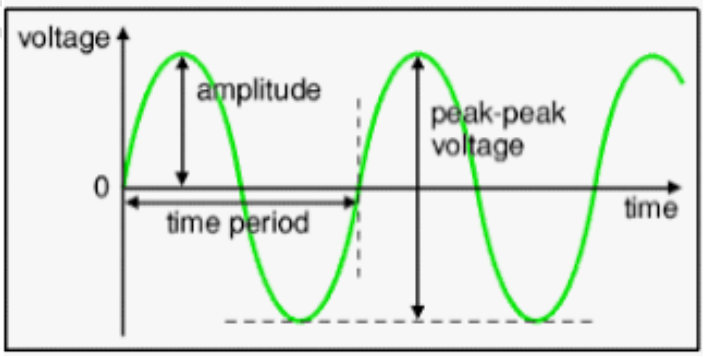
1. Verify that all the CRO controls are in released position off mode then put on CRO.
2. Adjust y-displacement knob to see horizontal line of channel 1
3. Adjust intensity and focus knob for proper visibility and sharpness
4. Connect BNC wire to channel 1
5. Positive of the BNC wire is connected to calibration point and observe the displacement on the screen
6. Record the y-displacement in tabular column and verify calibration voltage and CRO voltage are same

ii) DC voltage measurement of Regulated power supply using CRO

1. Adjust the horizontal line to x-axis using y-position knob.
2. Connect regulated DC power supply to Channel 1 or channel 2.
3. Set some voltage in DC power supply
4. Observe the shift of horizontal line from x-axis to above
5. Record the shift from x-axis in divisions and verify that CRO voltage and supply voltage are same.

iii) AC voltage measurement of using CRO

1. Connect regulated Function generator to Channel 1 or channel 2.
2. Adjust Time/div and volts/div knobs to get fine oscillating wave on the screen
3. Record peak height from screen in terms of divisions in tabular column
4. Signal voltage is measured by CRO
5. Repeat the same for more voltages of AC signal



iv) AC frequency measurement of Function generator using CRO

1. Continue with the previous setting and for the existing waveform measure the peak-to- peak distance
2. Record the peak-to-peak distance and time/div in tabular column to find frequency of the waveform
3. Compare the frequency measured by CRO with frequency displayed in function generator
4. Repeat the experiment for more input frequencies

RECORD OF OBSERVATIONS:

i) Calibration of CRO

Sl.No	Calibration voltage	Y-displacement	Volts/div	CRO voltage
1	0.2V			
2	2V			

ii) DC voltage measurement of Regulated power supply using CRO

Sl.No	Supply voltage	Y-displacement	Volts/div	CRO voltage
1	2V			
2	4V			
3	6V			
4	10V			

iii) AC frequency measurement of Function generator using CRO

Sl. No	Frequency in Function generator KHz	Peak-to-peak distance	time/div	Time period T= Peak-to-peak distance x time/div	Frequency signal f = 1 / T
1	**1**				
2	**2**				
3	**3**				
4	**4**				

RESULTS:

CONCLUSIONS:

EXPERIMENT NO. 07	VERIFICATION OF KIRCHOFF's LAW (DC circuits)

AIM: *To verify Kirchhoff's voltage law and Kirchhoff's current law.*

APPARATUS: Resistors (100 Ω, 220 Ω and 1kΩ), Power supply, Multimeter

Note: Resistors used are of quarter watt, so students are advised not to give supply voltage more than 2V

THEORY

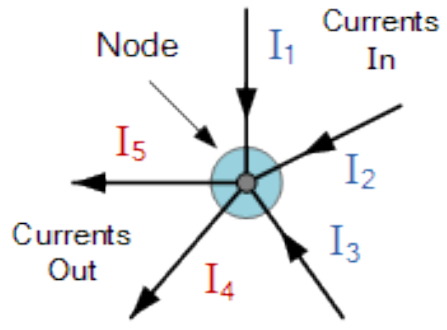
Kirchhoff's laws are important in describing the transfer of energy through electrical circuits; they give us a better understanding of the connections in the circuit, they quantify current flows, and they explain how voltage varies around the loop. In 1845, a German physicist, **Gustav Kirchhoff** developed a pair or set of rules or laws which deal with the conservation of current and energy within electrical circuits. These two rules are commonly known as: *Kirchhoffs Circuit Laws* with one of Kirchhoffs laws dealing with the current flowing around a closed circuit, **Kirchhoff's Current Law, (KCL)** while the other law deals with the voltage sources present in a closed circuit, **Kirchhoff's Voltage Law, (KVL)**.

Kirchhoffs First Law – The Current Law, (KCL)

Kirchhoffs Current Law or KCL, states that the "*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, $I_{(exiting)} + I_{(entering)} = 0$. This idea by Kirchhoff is commonly known as the **Conservation of Charge**.

Kirchhoff's Current Law

Currents Entering the Node
Equals
Currents Leaving the Node



$$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$$

Here, the three currents entering the node, I_1, I_2, I_3 are all positive in value and the two currents leaving the node, I_4 and I_5 are negative in value. Then this means we can also rewrite the equation as;

$$I_1 + I_2 + I_3 – I_4 – I_5 = 0$$

The term **Node** in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components. Also for current to flow either in or out of a node a closed circuit path must exist. We can use Kirchhoff's current law when analysing parallel circuits.

Kirchhoff's Voltage Law, (KVL)

Kirchhoff's Voltage Law or KVL, states that "*in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop*" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the **Conservation of Energy**.

Starting at any point in the loop continue in the **same direction** noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero. We can use Kirchhoff's voltage law when analysing series circuits.

EXPERIMENTAL PART

I. To verify KVL

Let us choose, $R_1 = 100\ \Omega$. $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$

For V = 2V, $R_{eff} = R_1 + R_2 + R_3$

$I = V/R_{eff}$ = ----- mA

CIRCUIT DIAGRAM

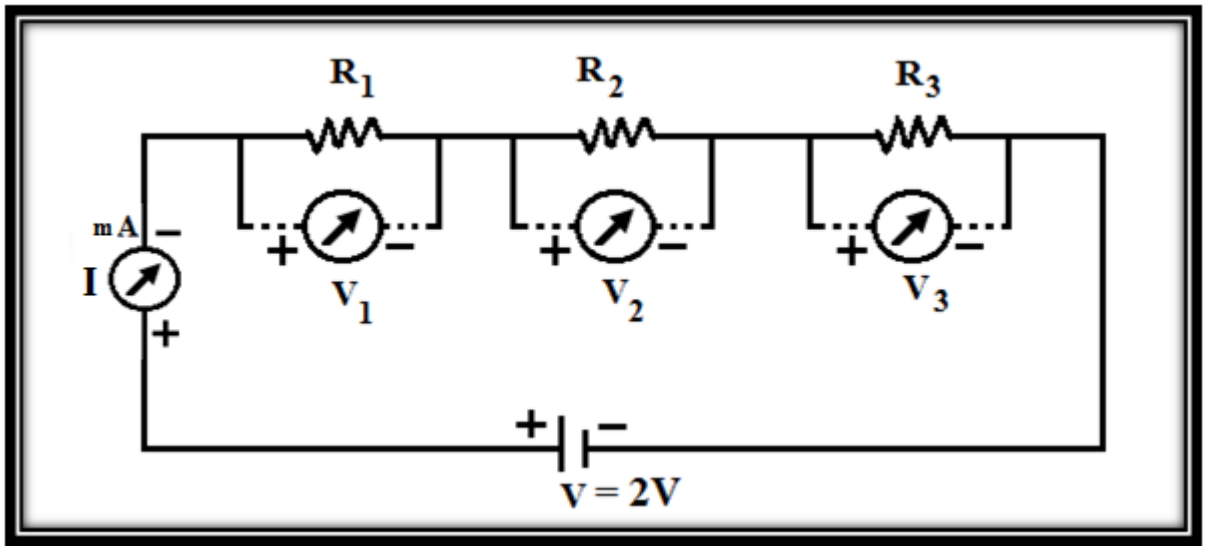


FIGURE 01

TABLE 01

For V = 2V,

Theoretical Calculations			Experimentally measured		
$V_1 = R_1I$,	$V_2 = R_2I$	$V_3 = R_3 I$	V_1(V)	V_2(V)	V_3(V)

Verify $V = V_1 + V_2 + V_3$

II. To verify KCL,

Let us chose, $R_1 = 100\ \Omega$. $R_2 = 220\ \Omega$, $R_3 = 1k\ \Omega$

For V = 2V, $1/ R_{eff} = (1/R_1 + 1/R_2 + 1/R_3)$

$I = V/R_{eff}$ = ----- mA

CIRCUIT DIAGRAM

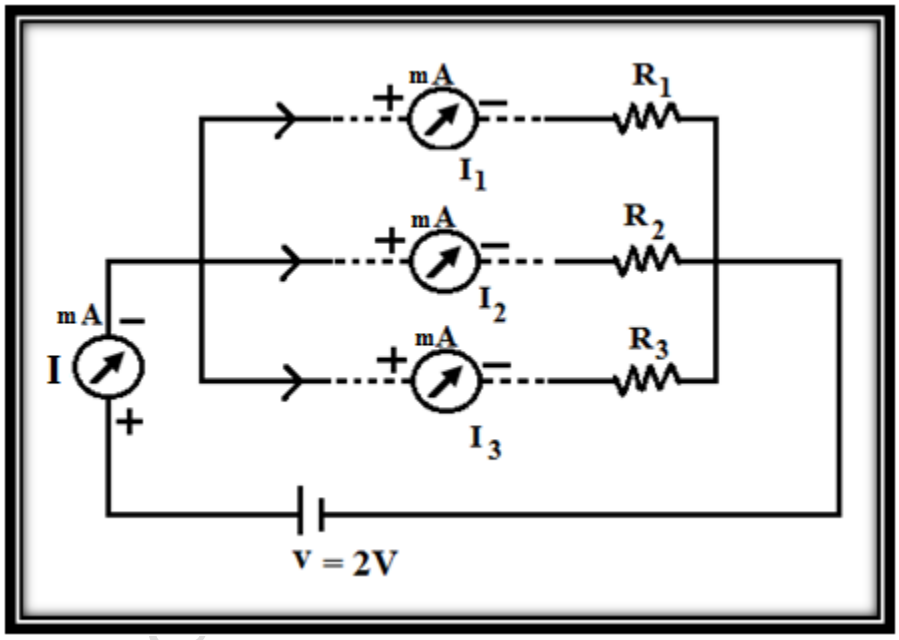


FIGURE 02

TABLE 02

For V = 2V

Theoretical Calculations			Experimental Measurements		
$I_1 = V/R_1$	$I_2 = V/R_2$	$I_3 = V/R_3$	I_1 (mA)	I_2 (mA)	I_3 (mA)

Verify $I = I_1 + I_2 + I_3$

CIRCUIT DIAGRAM

III. To verify KVL and KCL for series-parallel resistive circuit

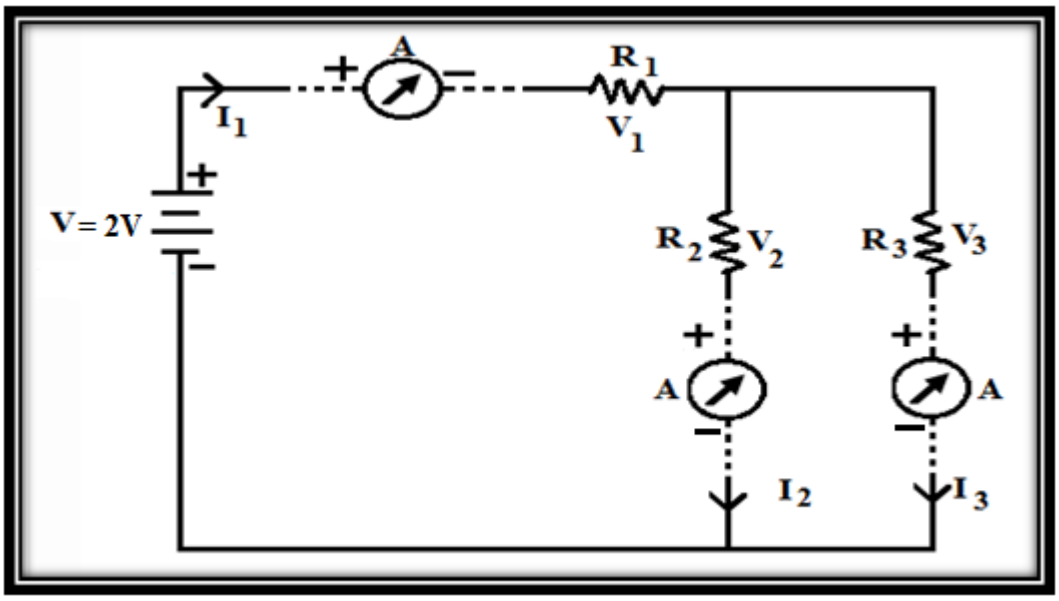


FIGURE 03

TABLE 03

For V = 2V, experimentally measure the following,

I_1 (mA)	I_2 (mA)	I_3 (mA)	V_1(V)	V_2(V)	V_3(V)

Verify, $I_1 = I_2 + I_3$ and $V = V_1 + V_2$

PROCEDURE

- Circuit connections are made as shown in figure
- A supply voltage of 2 V is chosen
- KVL is verified for the series circuit (Figure a), $V = V_1 + V_2 + V_3$ and compared with the theoretical values
- KCL is verified for the parallel circuit (Figure b), $I = I_1 + I_2 + I_3$ and compared with theoretical values
- For the series-parallel resistive circuit (Figure c), KCL and KVL are verified.

RESULTS:

CONCLUSIONS:

EXPERIMENT NO. 08	REALIZATION OF SINGLE-PHASE RECTIFIER CIRCUIT (HALF-WAVE, FULL-WAVE AND FULL-WAVE BRIDGE) WITH FILTER

AIM: *To study the characteristics of half wave, full wave and bridge rectifier with and without filter and find its performance parameters.*

LIST OF COMPONENTS/EQUIPMENT/INSTRUMENTS WITH SPECIFICATIONS:

Sl.No	Name of the component	Specification	Quantity
01	Resistors	1K	03
02	Diodes	1N4001	04
03	Capacitors	100uF	03
04	Transformer	230/6-0-6V, 230/6V	01 each
05	Breadboard	--	01
06	CRO	--	01
07	BNC Connector	--	02

Theoretical Background (Circuit diagram and Design):

Half Wave Rectifier The main power supply is applied at the primary of the step-down transformer. All the positive half cycles of the stepped down AC supply pass through the diode and all the negative half cycles get eliminated. The peak value of the output voltage is less than the peak value of the input voltage by 0.6V because of the voltage drop across the diode.

Full Wave Rectifier: During the positive half cycle of the transformer secondary voltage, the diode is forward biased and is reverse biased. So, a current flow through the diode, load resistor and upper half of the transformer winding. During the negative half-cycle, the diode becomes forward biased and becomes reverse biased. The current then flows through the diode, load resistor and lower half of the transformer winding. Current flows through the load resistor in the same direction during both the half cycles. The peak value of the output voltage is less than the peak value of the input voltage by 0.6V because of the voltage drop across the diode

Bridge Rectifier: During the positive half cycle of the secondary voltage, diodes and are forward biased and diodes and are reverse biased. Therefore, current flows through the secondary winding, diode, load resistor and diode. During the negative half-cycle, and are forward biased and diodes and are reverse biased. Therefore, current flows through the secondary winding, diode and Load resistor. During both the half-cycles, the current flows through the load resistor in the same direction. The peak value of the output voltage is less than the peak value of the input voltage by 1.2V due to the voltage drop across two diodes. The ripple factor of the bridge rectifier is the same as that of a fullwave rectifier.

Rectifiers with Filter: All rectifier outputs contain a considerable amount of ripple in addition to the DC component. To avoid AC components, a filter is connected at the output of the rectifier. Capacitor input filter, choke input filter, RC, CRC, LC, and CLC filters are the usually used filters. The capacitor input filter is the simplest and cheapest. A high-value capacitor C is connected in shunt with the load resistor. Capacitor charges to peak voltage when the half-cycle appears at the output. After the peak value is passed, the capacitor discharges through the load resistor slowly since

the diode is reverse biased by the capacitor voltage. Before the capacitor voltage drops substantially, the next output cycle arrives and the capacitor recharges to peak

Design: Select 230V/6V-0-6V, 100 mA centre-tapped transformer and diodes 1N4001

DESIGN OF LOAD RESISTOR R_L: Load resistor RL should be high enough to make the capacitor discharge slowly. Same time it should limit the current through the diodes. Assume a current of 5 mA to flow through the diodes.
Then $R_L = (6\sqrt{2} - 1.4)/0.005 = 920\Omega$
Because voltage drop across the two diodes together is 1.4V.
Select $R_L = 1k\Omega$.

DESIGN OF CAPACITANCE C:
The required ripple factor of the capacitor input filter is 3%. The theoretical value of r = 1⁄4√3fRLC

PROCEDURE:
Step 1: Wire up the half-wave rectifier circuit without a capacitor after testing all the components.
Step 2: Switch on the main supply. Observe the transformer secondary voltage waveform and output voltage waveform across the load resistor, simultaneously on the CRO screen.
Step 3: Connect the capacitor filter and observe the waveforms
Step 4: Repeat the above steps for full-wave and bridge rectifiers.

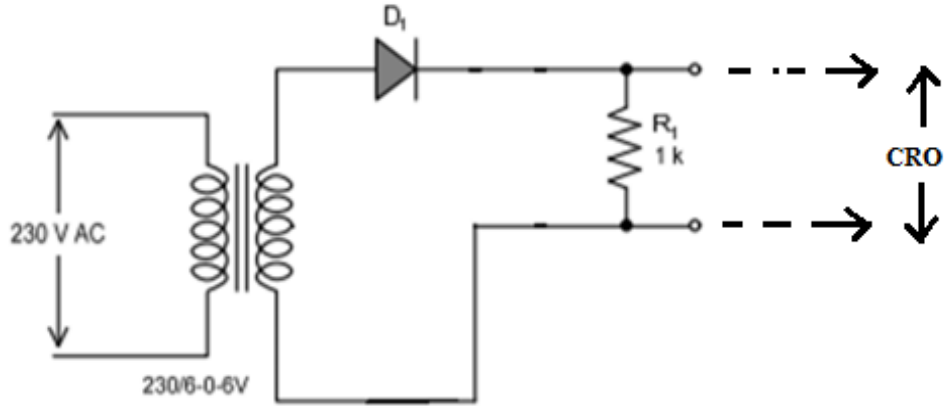


Figure 1: Half-wave Rectifier without filter

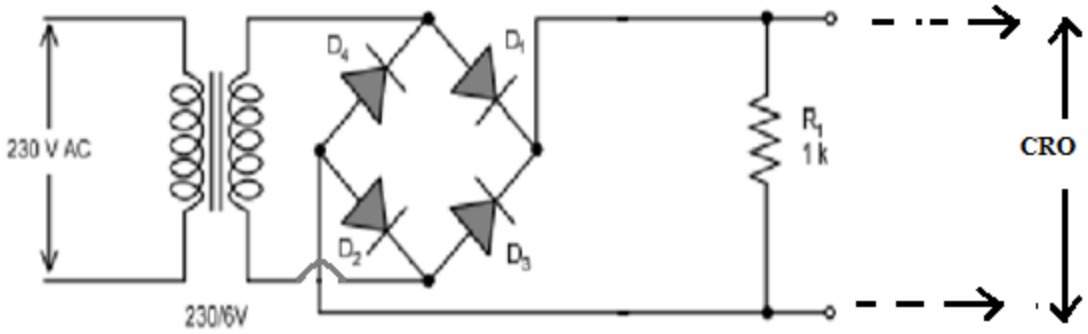


Figure 3: Full-wave Bridge Rectifier without filter

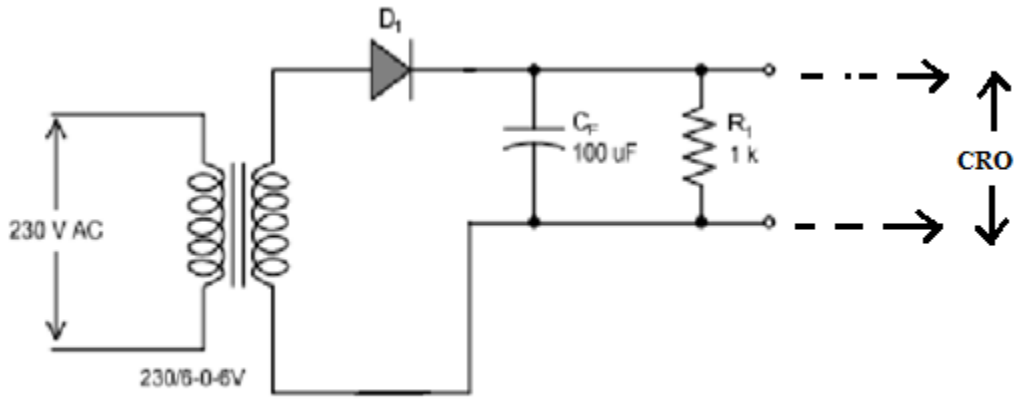


Figure 4: Half-wave Rectifier with filter

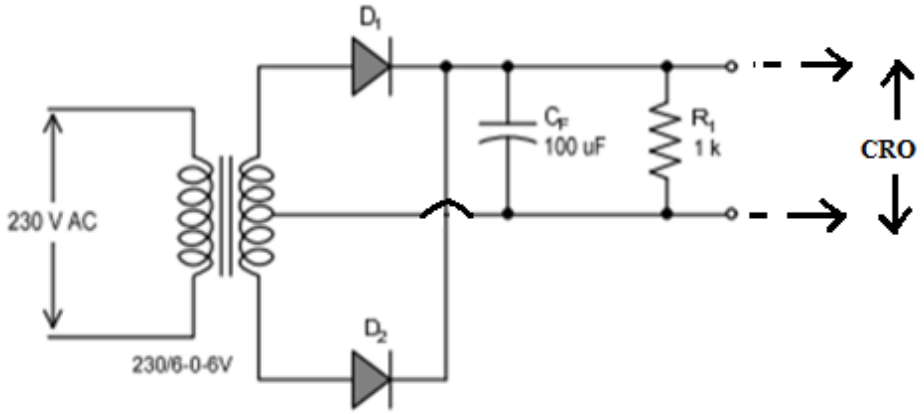


Figure 5: Full-wave Rectifier with filter

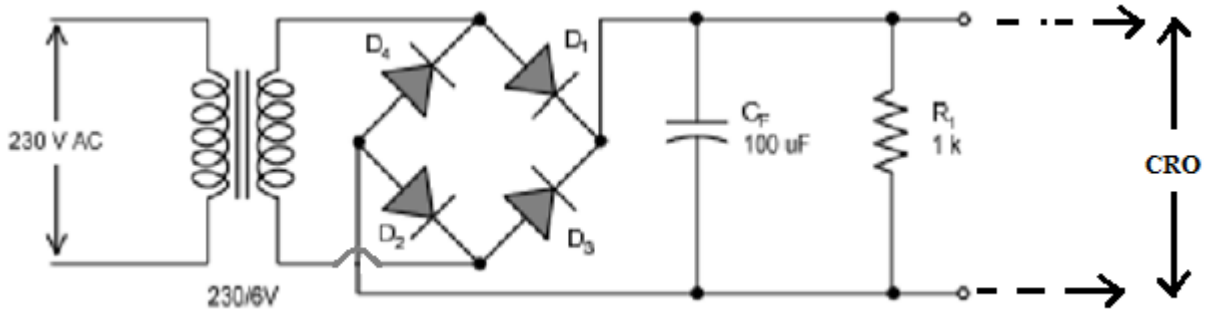


Figure 6: Full-wave Bridge Rectifier with filter

Expected Waveforms:

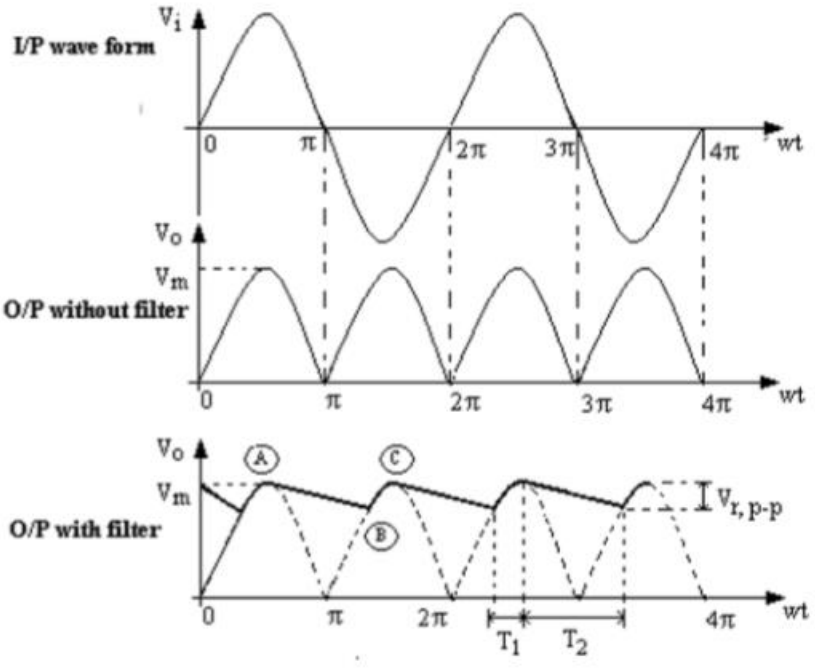


Figure 7: Expected Waveforms for Full Wave Rectifier

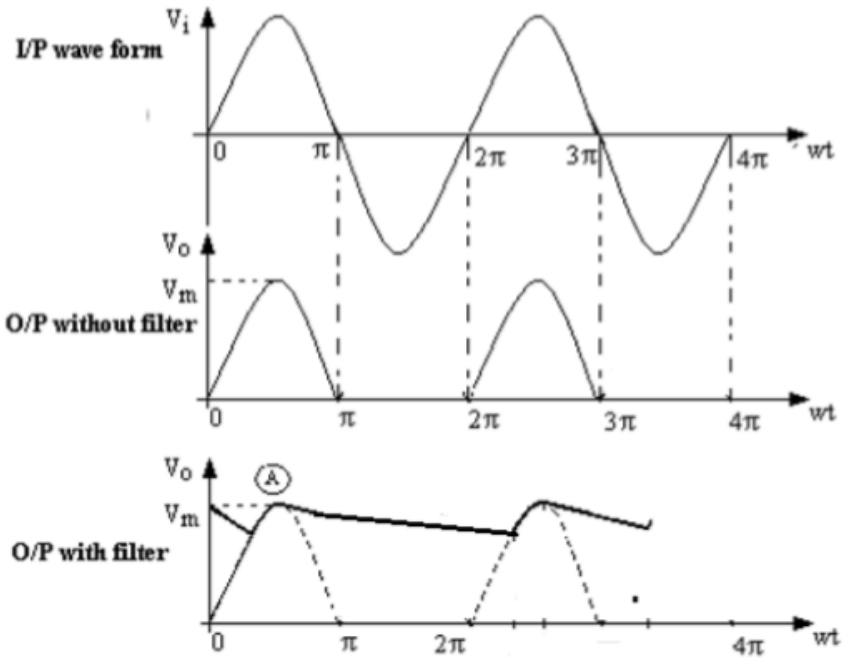


Figure 8: Expected Waveforms for Half Wave Rectifier

Figure 9: Expected Waveforms for Full Wave Bridge Rectifier

Table of Observation:

Table 1: Rectifier without filter

HWR	V_m	$V_{rms} = V_m/2$	$V_{dc} = V_m/\pi$	$r = \sqrt{(V_{rms}/V_{dc})^2 - 1}$	Efficiency = $(V^2_{dc} / V^2_{rms}) \times 100$
FWR	V_m	$V_{rms} = V_m/\sqrt{2}$	$V_{dc} = 2V_m/\pi$	$r = \sqrt{(V_{rms}/V_{dc})^2 - 1}$	Efficiency = $(V^2_{dc} / V^2_{rms}) \times 100$
BR	V_m	$V_{rms} = V_m/\sqrt{2}$	$V_{dc} = 2V_m/\pi$	$r = \sqrt{(V_{rms}/V_{dc})^2 - 1}$	Efficiency = $(V^2_{dc} / V^2_{rms}) \times 100$

CONCLUSION: Rectifiers of different types are realized and their performance is compared with and without the filter.

Table 2: Rectifier with capacitor filter

HWR	V_m	V_{rpp}	$V_{r,rms} = V_{rpp}/2\sqrt{3}$	$V_{dc} = V_m - V_{rpp}/2$	$r = V_{r,rms}/V_{dc}$
FWR	V_m	V_{rpp}	$V_{r,rms} = V_{rpp}/2\sqrt{3}$	$V_{dc} = V_m - V_{rpp}/2$	$r = V_{r,rms}/V_{dc}$
BR	V_m	V_{rpp}	$V_{r,rms} = V_{rpp}/2\sqrt{3}$	$V_{dc} = V_m - V_{rpp}/2$	$r = V_{r,rms}/V_{dc}$

EXPERIMENT NO. 09	LOGIC DESIGN USING BASIC GATES (IC's) AND REALIZATION OF HALF ADDER AND FULL ADDER

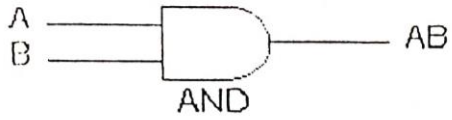
AIM:
1. *Verification of truth tables of basic gates using ICs.*
2. *To study and verify the Truth Table of Half Adder and Full Adder using basic ICs.*

List of Components/Equipment/Instruments with specifications:

Sl.No	Name of the component	Specification	Quantity
01	NOT Gate	7404	1
02	AND Gate	7408, 7411	1, 2
03	OR Gate	7432, 4072	1, 1
04	wires	Single strand red, black & yellow	1 small roll each
05	Breadboard	---	1
06	LEDs	Red/green	5
07	Small screw driver,wire cutter	----	1

Theoretical Background (Circuit diagram and Design)

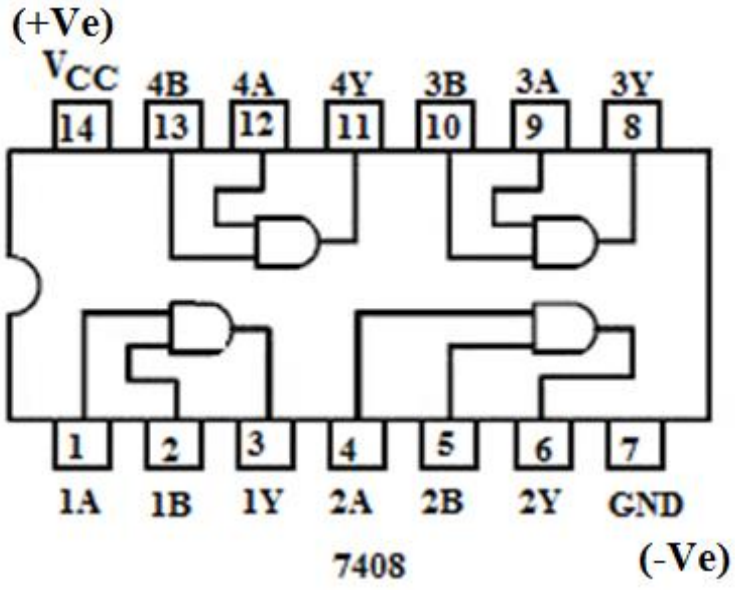
AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

The AND gate is an electronic circuit that gives a **high** output (1) only if **all** its inputs are high. A dot (.) is used to show the AND operation i.e. A.B. Bear in mind that this dot is sometimes omitted i.e. AB

PIN DIAGRAM OF AND GATE 7408 (IC)

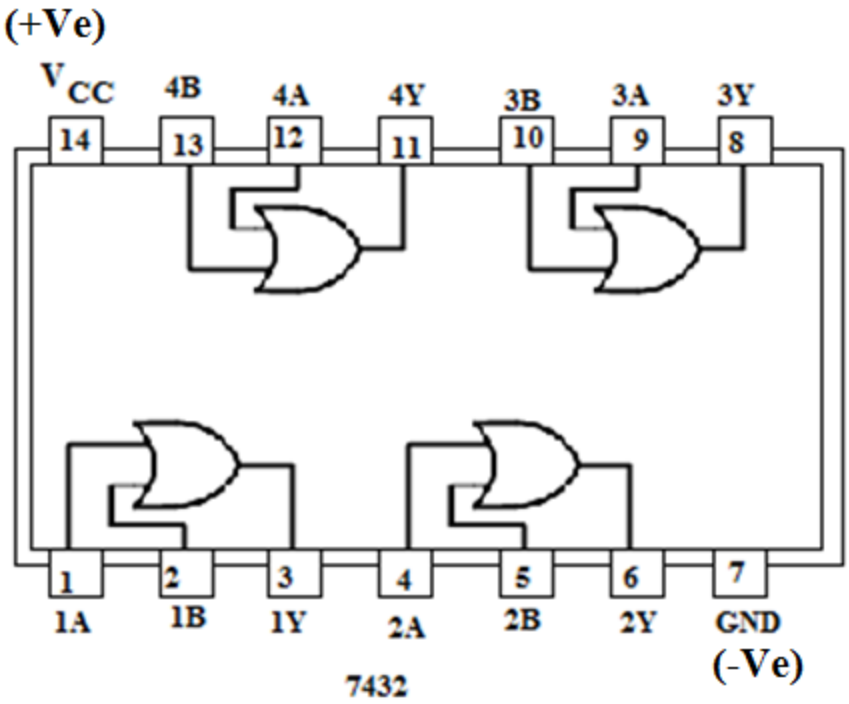


2) OR gate

2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

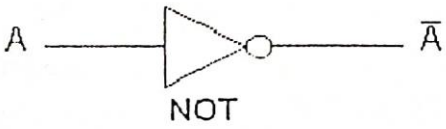
The OR gate is an electronic circuit that gives a high output (1) if **one or more** of its inputs are high. A plus (+) is used to show the OR operation.

PIN DIAGRAM OF OR GATE 7432 (IC)



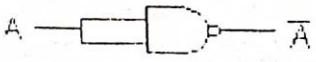
3)

NOT gate

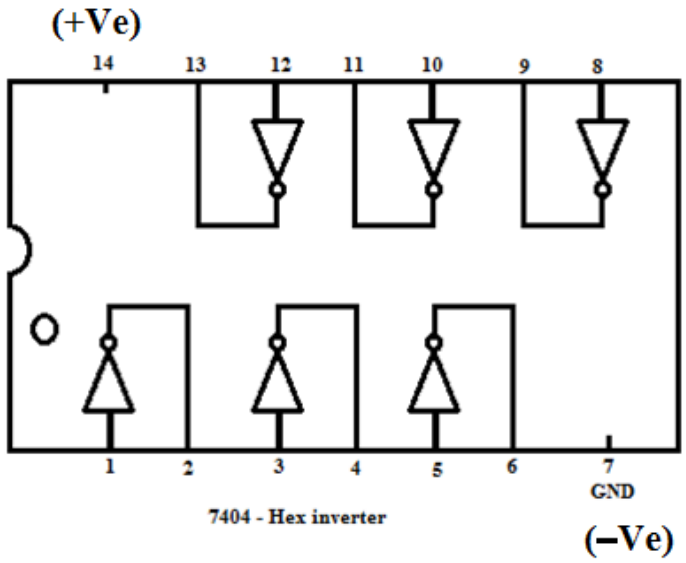


NOT gate	
A	Ā
0	1
1	0

The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an *inverter*. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs. The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.

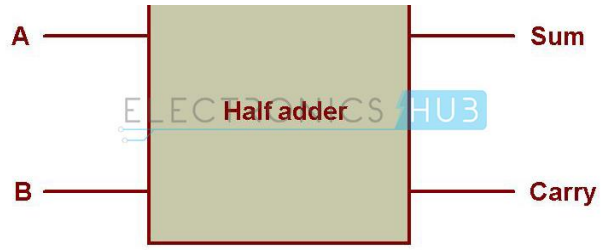


PIN DIAGRAM OF NOT GATE 7404 (IC)



Half Adder

Half adder is a combinational circuit that performs simple addition of two single bit binary numbers and produces a 2-bit number. The LSB of the result is the Sum and the MSB is the Carry.
The block diagram of a half adder is shown below.



Here, 'A' and 'B' represents the input two bits that must be added and outputs are 'Sum' and 'Carry'.

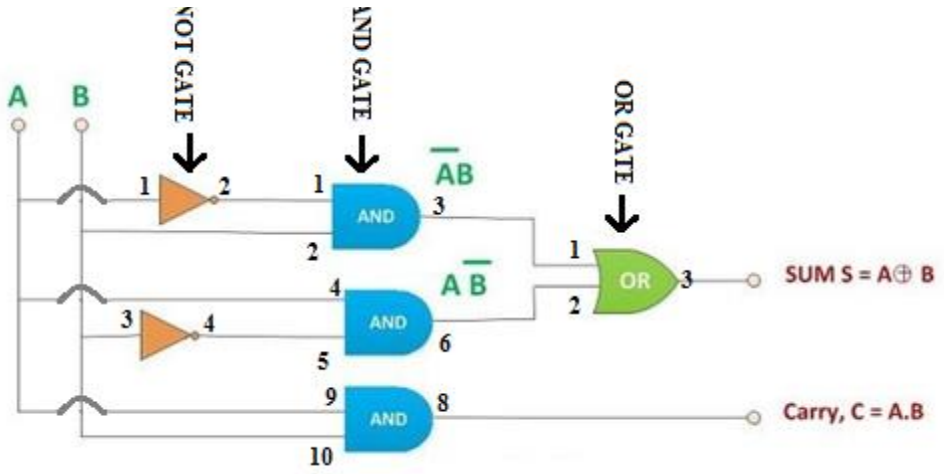
Half Adder Truth Table

If we assume A and B as the two bits whose addition is to be performed, a truth table for half adder with A, B as inputs and Sum, Carry as outputs can be tabulated as follows.

INPUT		OUTPUT	
A	**B**	**Sum**	**Carry**
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Design: Sum = $\overline{AB}+\overline{AB}$ (1)

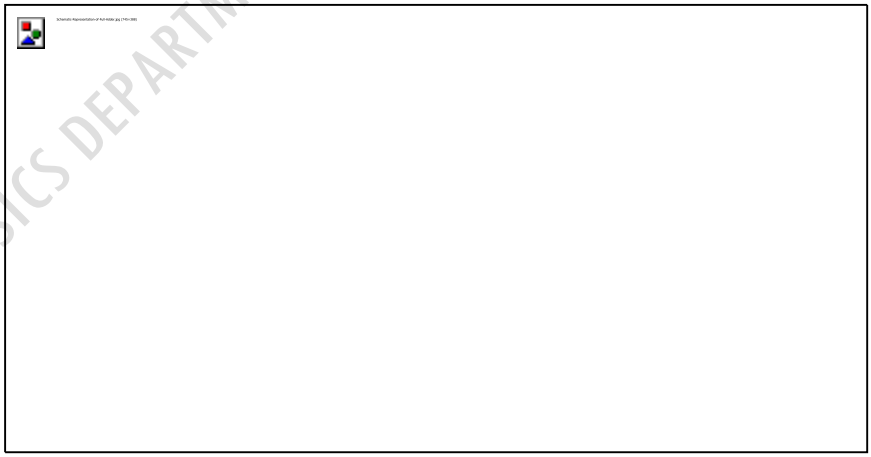
Carry = A B (2)



Full Adder

A Full Adder is a Combinational Logic Circuit which performs binary addition on two-digit numbers. Full adder is a digital circuit used to calculate the sum of three binary bits, which is the main difference between this and half adder. Two of the three bits are same as before which are A, the addend bit and B, the addend bit. The additional third bit is carry bit from the previous stage and is called Carry–in, generally represented by C_{IN}. It calculates the sum of three bits along including the carry. The output carry is called Carry–out and is represented by C_{OUT}.

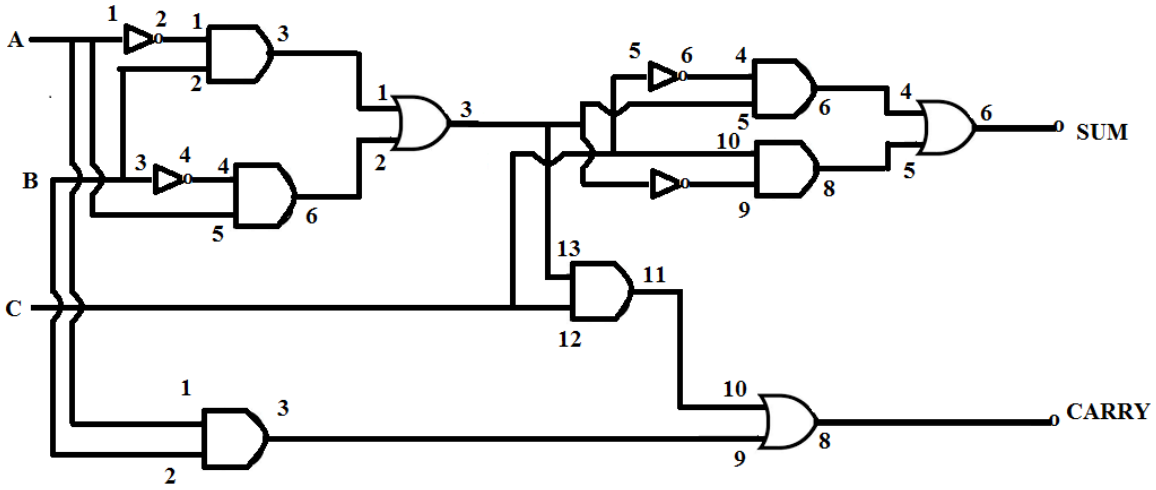
The block diagram of a full adder with A, B and CIN as inputs and S, COUT as outputs is shown below



Sum = A⊕ B ⊕ C (3)

Carry = AB + C (A⊕B) (4)

Full Adder Truth Table



PROCEDURE:

- Check the components for their working.
- Insert the appropriate IC into the IC base (Breadboard).
- Make connections as shown in the circuit diagram.
- Switch on Vcc and apply various combinations of input according to the truth table and verify.
- Provide the input data via the input switches and observe the output on output LEDs.

TABLE OF OBSERVATION: TRUTH TABLE

Half adder:

INPUT		OUTPUT	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Full adder:

INPUT			OUTPUT	
A	B	Cin	Sum	Carry
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

CONCLUSION:

- Explored the function of the basic logic gate. Implemented them on a bread board with integrated circuits and ensured the results corresponded with the truth table of the logic gate tested.
- Half adder and full adder both performs the addition of the applied input bits.
- Learnt how to implement a Half Adder Circuit, Full Adder Circuit, its Boolean Equations and Logic Circuit.

EXPERIMENT NO.10	ZENER DIODE CHARACTERISTICS AND VOLTAGE REGULATOR

AIM: a. *Obtain the reverse characteristics of a Zener diode and determine reverse break down voltage (Vz) of Zener diode and comment on the results.*
b. To study Zener diode as voltage regulator and determine the line and load regulation.

APPARATUS: Zener diode (V_z = 6.2 V), voltmeter, micro ammeter and connecting wires, Power Supply etc, (Resistors 100 Ω and 1 kΩ are of 1W ratings)

THEORY: A diode is a semiconductor device in which, a p-type semiconductor is suitably joined to n-type semiconductor, and the resulting contact surface is called P-N junction diode.
The voltage across P-N junction diode can be measured in two ways.
1. Forward biasing.
2. Reverse biasing.

Forward biasing: If the positive terminal of the battery is connected to the p-side of the diode and negative terminal to the n-side, then the diode is said to be forward biased. During the forward bias the flow of the current is due to majority charge carriers and the current is of the order of mill amperes.

Reverse biasing: If the positive terminal of the battery is connected to the n-side of the diode and negative terminal to the p-side, then the diode is said to be reverse biased. During the reverse bias the flow of the current is due to minority charge carriers and the current is of the order of microamperes.

Zener diode: A p-n junction diode, which is heavily doped in order to sustain heavy current at breakdown region, is known as Zener diode.A Zener diode is also called a voltage regulator or breakdown diode. Breakdown can be made to occur abruptly and accurately to known values ranging from 2.4V to 200V with different power ratings. The breakdown voltage V_z depends on the amount of doping.

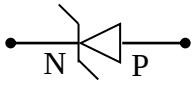
Reverse breakdown: there is a limit to how much reverse voltage a diode can withstand before it is destroyed. There are two mechanisms which give rise to breakdown of p-n junction under reverse condition**.**

- **Avalanche breakdown:** when the reverse voltage increases it forces the minority charge carriers to move quickly, when this minority charge carriers gain enough kinetic energy, they collide with semiconductor atoms in a depletion region and generate electron-hole pairs. These newly generated carriers in turn gain energy due to electric field and produce ionizing collisions. This process of division may continue until an avalanche of electrons is formed. Thus the minority charge carriers get multiplied and the reverse current increases enormously. This process is known as avalanche effect.

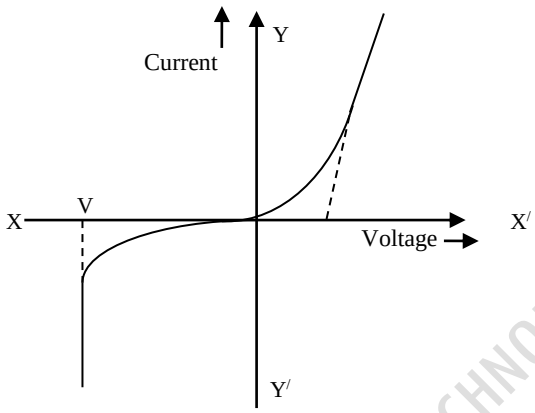
- **Zener breakdown:** When the diode is heavily doped, the depletion region becomes very narrow and there by the electric field in the depletion region increases. When the reverse bias is increased, the electric field at the junction becomes large enough to break the covalent bonds and generate electron-hole pairs. Consequently the reverse current rises abruptly at a particular voltage known as Zener breakdown voltage. This effect is called as Zener effect.

This breakdown can be accurately obtained at known values ranging from 2.4V to 200V. This breakdown depends on the amount of doping. Hence Zener diode is reverse biased, heavily doped p-n junction diode.

The circuit symbol for Zener diode is



V-I CHARACTERISTICS OF ZENER DIODE



The forward characteristic of Zener diode is similar to that of an ordinary forward biased junction diode. When the diode is reverse biased, a small reverse current flows and remains practically constant, until Zener voltage V_z is reached. As soon as the applied voltage equals the Zener voltage of diode the reverse current abruptly increases to a very high value.

From the reverse characteristic of the Zener diode it is clear that as the reverse voltage is increased, the reverse current remains negligibly small up to the knee of the curve and then rapidly increases at V_z. This ability of a diode is called regulation power of the Zener diode.

Zener diode specifications

The Zener diodes are generally specified in terms of Zener voltage V_z , maximum power dissipation, breakdown current I_z and Zener resistance r_z . The Zener resistance is defined as the ratio of change in Zener reverse voltage to corresponding change in Zener current under reverse bias condition,

i.e, Zener resistance $r_z = V_z / I_z$

Zener diode as voltage regulator

A Zener diode can be used as a voltage regulator because it maintains the constant output voltage even though the current through it changes. It is usually used at the output of an unregulated power supply to provide constant output voltage.

Some important points about Zener Diode

- Zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown.
- A Zener diode is always reverse connected.
- It has a sharp breakdown voltage, called Zener voltage.
- When forward biased, its characteristics are just that of ordinary diode
- The Zener diode is not immediately burnt just because it has entered the breakdown region.

Since p and n-type materials are highly doped in Zener diode, the depletion region becomes a very thin layer under a reverse bias of few volts and the field across the junction also becomes very high. Under such conditions of narrow depletion layer, and high field across the junction, the electron can tunnel directly from the valence band on the p-side to the conduction band on the n-side without changing energy

PROCEDURE

a. ZENER DIODE REVERSE CHARACTERISTICS

- Make the connections as shown in fig.
- Bring the reverse voltage V is increased from zero to the breakdown voltage (say 6.2 V). Note the reverse current.
- On further increase in votalge, the current increases but voltage remains constant.
- Increase the reverse voltage in steps and note the corresponding current. Continue till the breakdown occurs. Note the breakdown voltage Vz.
- Draw the graph of reverse voltage versus reverse current.
- Find out the Zener breakdown voltage from the graph.

b. LINE REGULATION

- Connect the circuit as shown in figure
- Keep the load resistance fixed and vary the input voltage.
- Note down the output voltage across R_L.
- Using the given formula, calculate the line regulation of Zener diode.
- Plot graph of V_i vs V_o

c. LOAD REGULATION

- Connect the circuit as shown in figure
- Keep the input voltage constant and vary the load resistance (from no load to full load).
- Note down the output voltage and current.
- Using the given formula, calculate the load regulation of Zener diode.

PART 1 – ZENER DIODE CHARACTERISITICS

CIRCUIT DIAGRAM: REVERSE CHARACTERISITICS

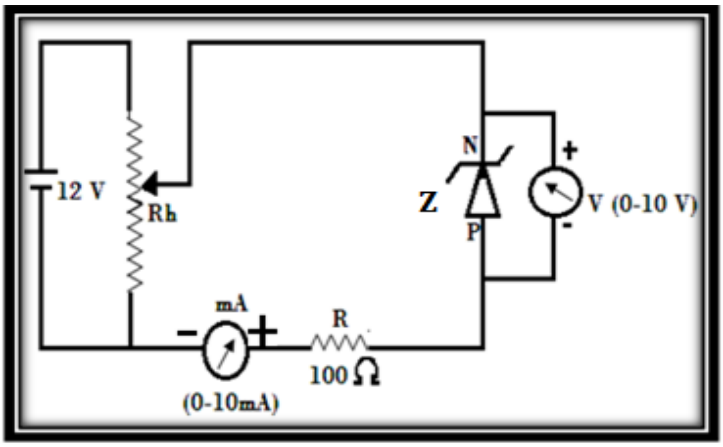
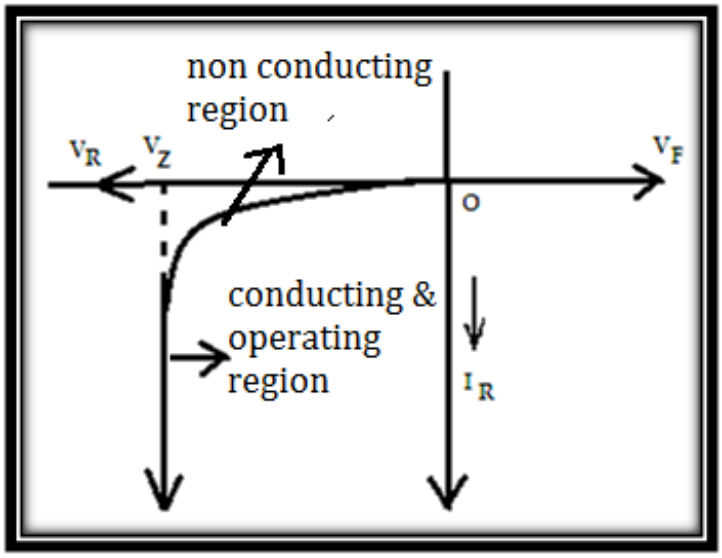


FIGURE 01

TABLE 1
a. FOR REVERSE BIAS CHARACTERISTICS

Sl. No	Voltage 'Vz' (in volt)	Current 'Iz' (in mA)

NATURE OF GRAPH



From graph,
Breakdown voltage V_Z =……..V

PART 2 - ZENER DIODE AS VOLTAGE REGULATOR,

CIRCUIT DIAGRAM

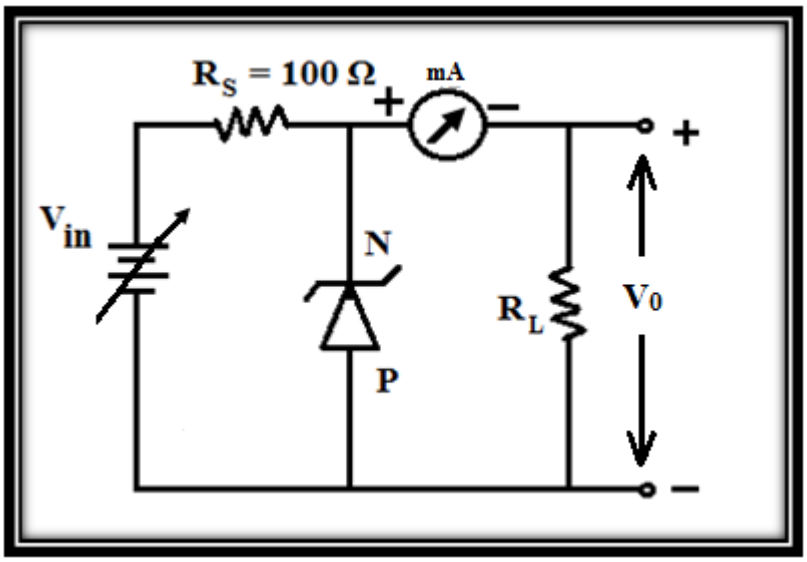


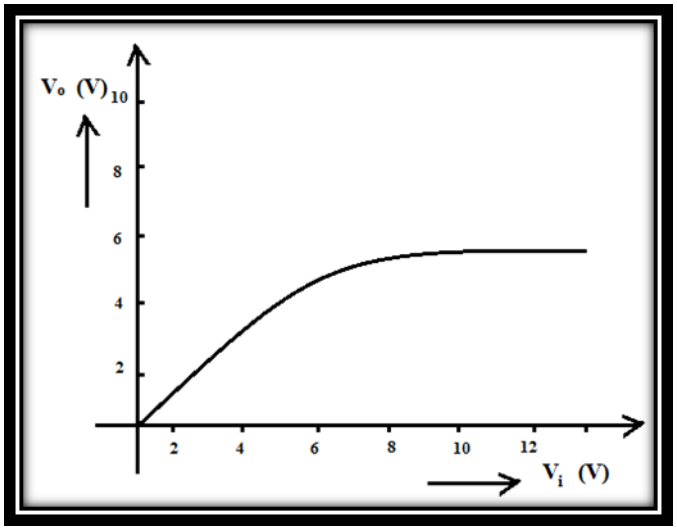
FIGURE 02

TABLE 02
b. LINE REGULATION

R_L = 1 K Ω fixed (Use half watt), R_S = 100 Ω (Use 1W)

Sl. No.	V_i in V	V_0 in V
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		

NATURE OF GRAPH



Suppose V_{in} is varied from 8V - 15V and output voltage changed from ---- V to ----- V

Then, % Line regulation $= \frac{\Delta V_0}{\Delta V_{in}} \times 100$

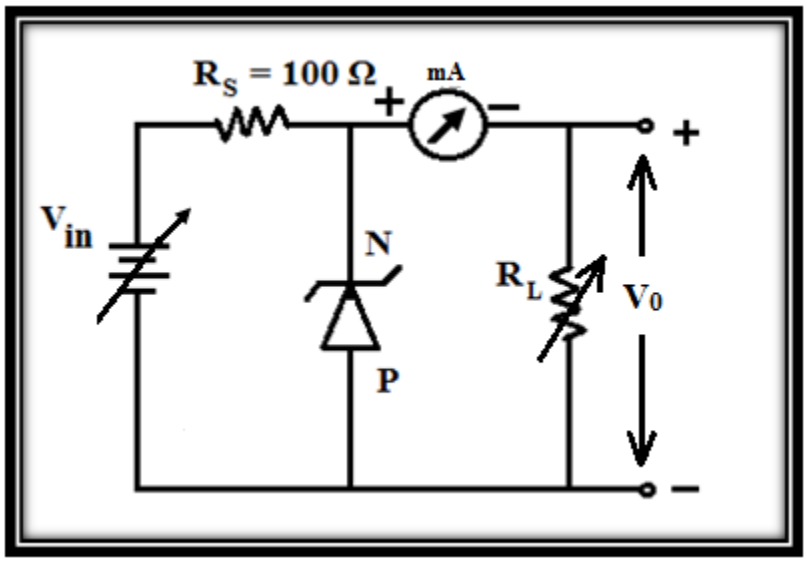


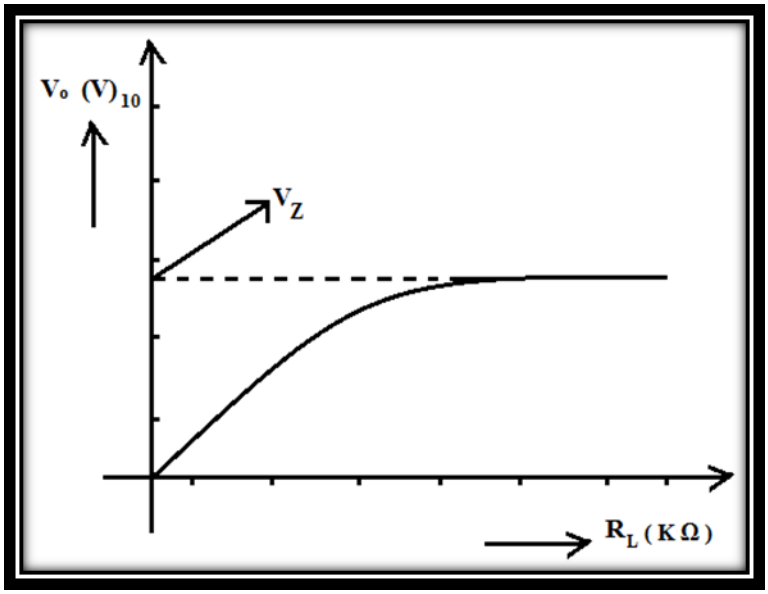
TABLE 03

c. LOAD REGULATION

V_i = 8V fixed, R_L is varied (Resistance box)

Sl. No.	R_L in Ω	V_0 in V
1.	0	(V_{NL})
2.	100	
3.	200	
4.	400	
5.	1000	
6.	2000	
7.	3000	
8.	4000	
9.	5000	
10.	6000	
11.	10000	
12.	20000	
13.	infinity	(V_{FL})

NATURE OF GRAPH



% Load regulation = $\frac{(V_{NL}-V_{FL})}{V_{FL}}$ x 100

As R_L increases, I_L decreases

RESULTS

1. Zener Breakdown Voltage V_Z =……. volt.
2. Line regulation =
3. Load Regulation =

CONCLUSIONS

VIVA QUESTIONS:

1. What is Zener diode?
2. What is meant by biasing? What do you mean by forward and reverse biasing?
3. Mention the important difference between ordinary diode and Zener diode?
4. Explain the formation of depletion region in a p-n junction.
5. What is Zener breakdown? What is the operating region of Zener diode?
6. What is break down voltage? And what is its significance?
7. What is reverse saturation current? Why is it constant?
8. What will be the resistance offered by Zener diode in the breakdown region?
9. If the marking is not done, then how do you identify p and n-side of the diode?
10. Mention the application of Zener diode?
11. Mention the application of Zener diode?
12. Explain breakdown mechanisms in diode?