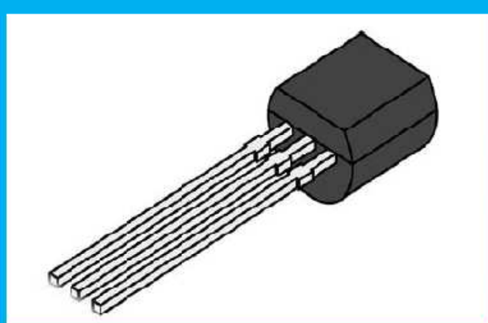
MSCPH510

M. Sc. IInd Semester

PRACTICAL PHYSICS




DEPARTMENT OF PHYSICS

SCHOOL OF SCIENCES

UTTARAKHAND OPEN UNIVERSITY

Board of Studies

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Course Title and Code : **Practical Physics (MSCPH 510)**
ISBN :
Copyright : **Uttarakhand Open University**
Edition : **2022**
Published By : **Uttarakhand Open University, Haldwani, Nainital- 263139**
Printed By :

MSCPH510

Practical Physics

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Contents

Course: Practical Physics **Course code: MSCPH510**

Credit: 3

EXPERIMENT 1

PNP (or NPN) TRANSISTOR CHARACTERISTICS

OBJECTIVE:

To draw characteristics of a PNP junction transistor in common base and common emitter arrangement

APPARATUS:

PNP transistor, batteries, voltmeter, millivoltmeter, milli and micro ammeters

THEORY:

(A) In common base arrangement we draw:

1. I_c/V_c characteristics – We plot collector current versus collector voltage for various values of constant emitter current.
2. I_c/I_e characteristics – We plot collector current versus emitter current for various values of constant collector voltage.

(B) In common emitter arrangement we draw:

1. I_c/I_b characteristics – We plot collector current versus base current for a constant collector voltage.
2. I_c/V_c characteristics – We plot collector current versus collector voltage for various values of constant base current.

***Note**: If we have been supplied by a NPN transistor in place of PNP transistor, just keep the circuit (as discussed ahead) same with input biasing as forward bias and output circuit as reversed bias accordingly.*

PROCEDURE:

(A) Common Base Arrangement:

1. I_c/V_c characteristics:

(i) Make the electrical connections as shown in figure 1 (next page).

(ii) Adjust the emitter current to 1 mA and keep it constant by adjusting variable resistor R_1.

(iii) Adjust collector voltage to – 5V with the help of resistor R_2.

(iv) Now increase collector voltage in steps on 1 Volt and note the corresponding collector current. If emitter current changes then readjust it to 1mA.

(v) Now reverse the polarity of the collector voltage (exchange terminals of battery between collector and base) and adjust to 0.1 volt. Note down the collector current.

(vi) Increase collector voltage in steps of 0.1 volt and take the readings of collector current until it becomes zero.

(vii) Repeat the whole procedure (point i to vi) for other constant values of emitter current.

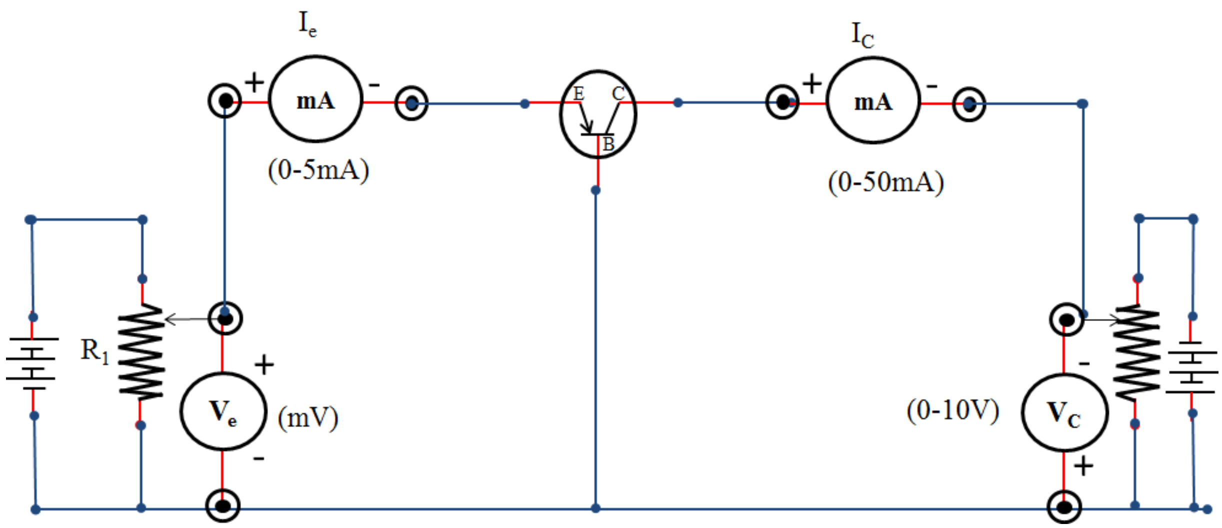


Figure 1. Circuit diagram for common base arrangement

(viii) Draw the characteristics as shown in figure 2.

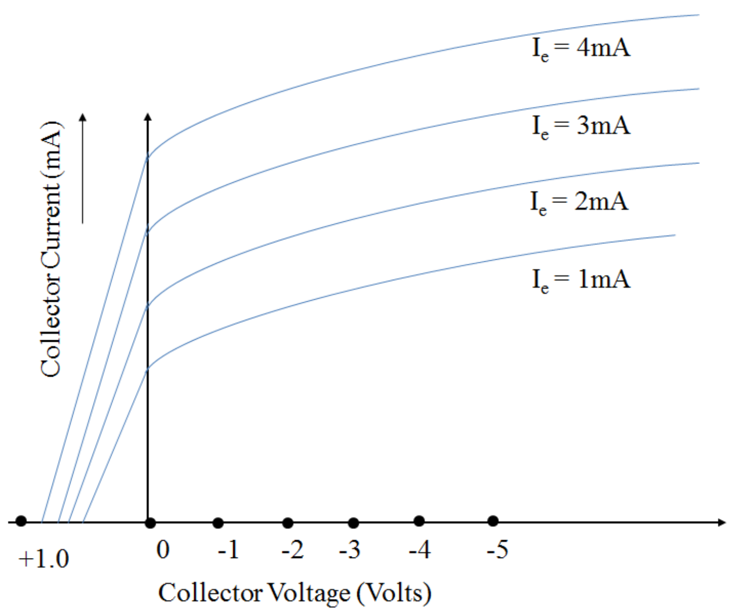


Figure 2. Output characteristics of collector current versus collector voltage

2. I_c/I_e characteristics:

(i) Keep the collector voltage fixed at – 5V.

(ii) Adjust emiiter current 100μA (0.1 mA) and note the corresponding collector current.

(iii) Increase emitter current in steps and note the collector current each time.

(iv) Draw the characteristics as shown in figure 3.

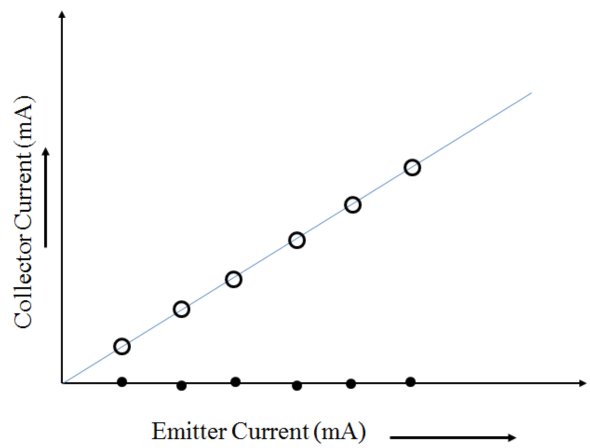


Figure 3. Characteristics of collector current versus emitter current

(B) Common Emitter Arrangement:

1. I_c/I_b characteristics:

(i) Make the connections as shown in figure 4.

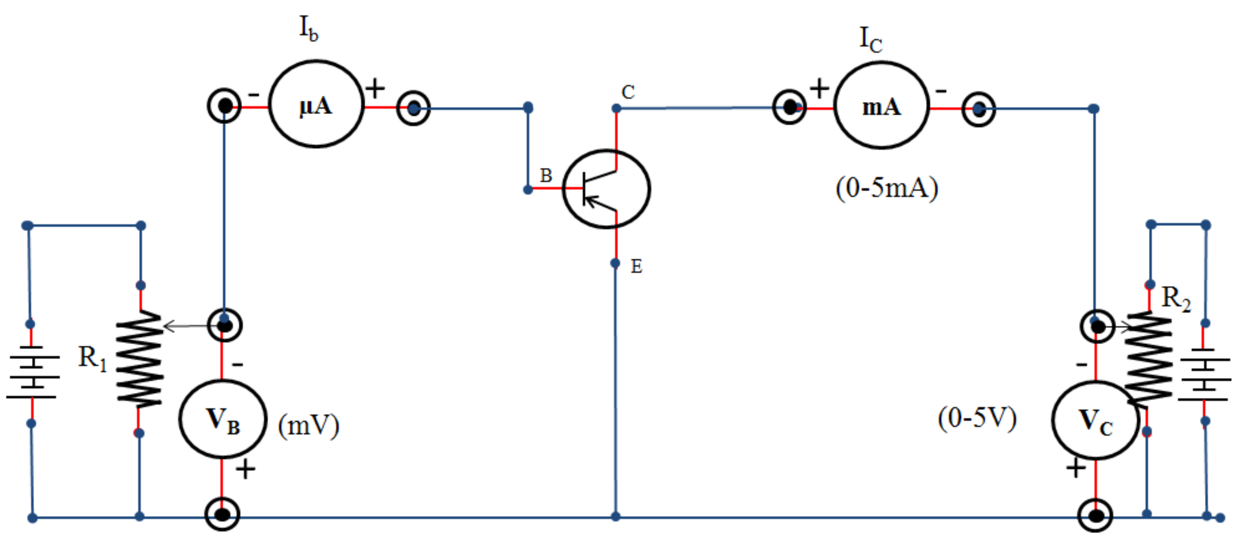


Figure 4. Circuit diagram for common emitterarrangement

(ii) Adjust the collector voltage – 2V by means of R_2 and keep it fix for the whole experiment.

(iii) Adjust the base current to 20μA by means of R_1 and note the corresponding collector current.

(iv) Increase base current in steps and note the corresponding collector current till the latter reaches, say about 4 mA. If collector voltage changes then readjust it to –2V.

(v) Plot collector current against base current as shown in figure 5.

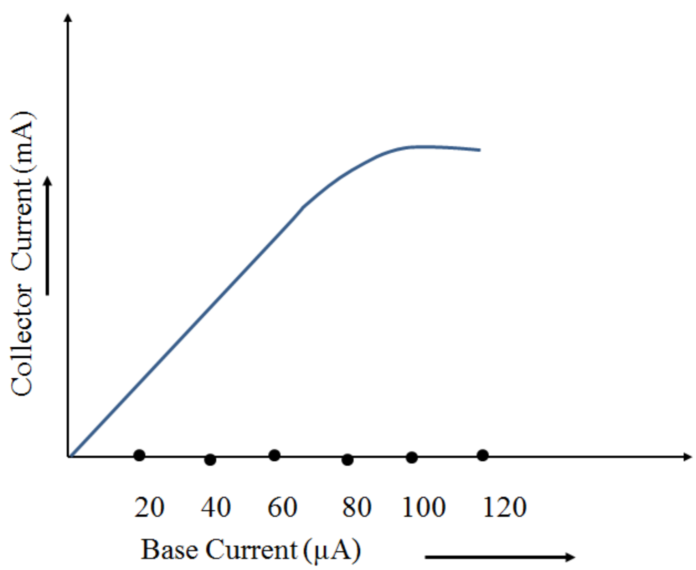


Figure 5. Output characteristics of collector current versus base current

2. I_c/V_c characteristics:

(i) Adjust base current to 20 μA by means of R_1.

(ii) Increase collector voltage in steps of 1 volt by means of R_2 and note the corresponding collector current.

(iii) The base current is now adjusted to 40 μA, 60 20 μA, etc. and with every value of base current; procedure of point (ii) is repeated.

(iv) Plot curves between collector current and collector voltage as shown in figure 6.

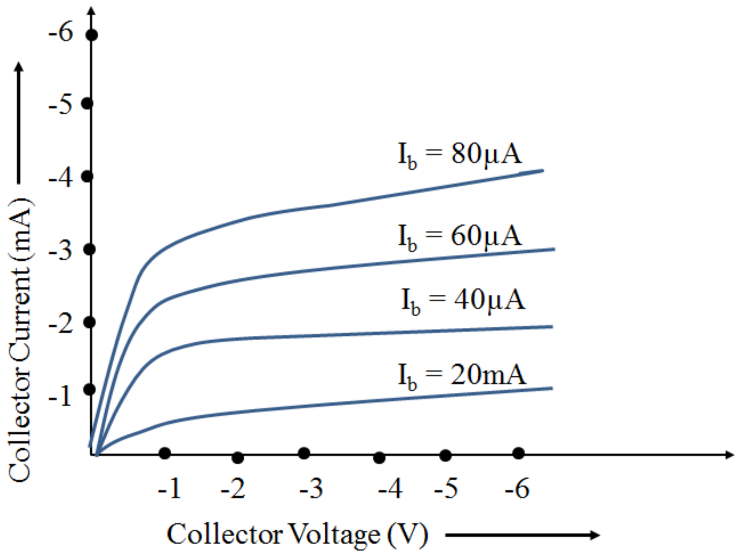


Figure 6. Output characteristics of collector current versus collector voltage

OBSERVATIONS:

(A) For Common Base Arrangement:

1. I_c/V_c characteristics:

S.No	Collector Voltage, V_c, In volt	Collector current I_c in mA for emitter current			
		$I_e = 1$ mA	$I_e = 2$ mA	$I_e = 3$ mA	$I_e = 4$ mA
1	-5V	…	…	…	…
2	-4V	…	…	…	…
3	-3V	…	…	…	…
4	-2V	…	…	…	…
5	-1V	…	…	…	…
6	0.1V	…	…	…	…
7	0.2V	…	…	…	…
…	…	…	…	…	…
…	1.0V	…	…	…	…

2. I_c/ I_e characteristics:
Collector voltage = - 5 V

S.No	Emitter Current, I_e , in mA	Collector Current, I_c, in mA
1	…	…
2	…	…
3	…	…
4	…	…
5	…	…
6	…	…

(B) For Common Emitter Arrangement:

1. I_c/ I_b characteristics:
Collector Voltage = -2V

S.No	Base current, I_b , in mA	Collector Current, I_c, in mA
1	…	…
2	…	…
3	…	…
4	…	…
5	…	…
6	…	…

2. I_c/V_c characteristics:

S.No	Collector Voltage, V_c, in volts	Collector Current I_c, in mA for base current			
		I_b = 20 μA	I_b = 40 μA	I_b =60μA	I_b = 80 μA
1	…	…	…	…	…
2	…	…	…	…	…

3	…	…	…	…	…
4	…	…	…	…	…
5	…	…	…	…	…
6	…	…	…	…	…

RESULTS:

Characteristics of PNP transistor in common base and common emitter arrangement have been plotted.

Sources of Error and Precautions:

1. Student should not, in hurry by mistake, connect the transistor directly to the a.c. switch. Battery, with correct polarity, is to be used.
2. Voltages applied between the different leads should not exceed the recommended value.
3. Overheating of the transistor should be avoided.

QUESTIONS FOR VIVA VOCE

Q.1. What is triode transistor?

Ans. It can be regarded as a combination of two junction PN diodes, one biased in the low impedance direction and other in high impedance direction, e.g. in a PNP transistor, emitter is biased in the forward direction while the collector is biased in the reverse direction.

Q.2.What is PNP transistor?

Ans. A junction transistor can be formed by growing a germanium or silicon crystal with two N – regions separated by very thin P region (called NPN arrangement) or with two P regions fused on to a very thin N region (called PNP arrangement).

Q.3. What is emitter, collector and base?

Ans. In PNP or NPN arrangement, the central region is called base one of the outer layers as emitter and the other as collector.

Q.4. Why is it called a transistor?

Ans. A transistor is basically a resistor that amplifies electrical impulses as they are transferred through it from its input to its output terminals. The name transistor is derived from the words transfer and resistor.

Q.5. Whatare the basic materialsused for making transistor?

Ans. Semiconductor germanium or silicon is used.

Q.6. What is peculiar about a semiconductor?

Ans. Its resistivity depends upon temperature and decreases with the rise in temperature.

Q.7. What is the difference between a transistor and vacuum tube?

Ans. (i) transistor is current operated device while tube is a voltage operated device.
(ii) in transistor, output and input circuits are not isolated.
(iii) in transistor, input and output impedances widely differ.

Q.8. What are the advantages of a transistor over a vacuum tube?

Ans. (i) small size, light weight,
(ii) long operating life and more mechanical strength,
(iii) low current requirement.

Q.9. How the current is conducted in a PNP transistor?

Ans. Holes in emitter P region (emitter is biased positively) are repelled to base region. But base region is thin and lightly doped so the holes drift across the base, N, without meeting electrons to combine with. Thus holes reach the collector P region (biased negatively). For each hole, an electron is emitted from negative terminal of the battery and neutralises the hole. For each hole lost by combination, a covalent bond near emitter electrode breaks and a liberated electron from there – enters the positive terminal of the battery while the new holes move towards the collector. This process continues. Thus holes move inside the material from the emitter to collector while electrons move in the outer circuit from emitter to base. The current in outer emitter – base circuit is called emitter current I_e and the current in the outer collector base circuit is called collector current, I_c.

Q.10. Which region in a transistor are heavily doped?

Ans. Emitter region is heavily doped while the base region is lightly doped.

Q.11. How a PNP or NPN' transistor is biased?

Ans. The emitter – base junction is forward biased while the collector base junction is reverse biased.

Q.12. What is the fundamental relation between the currents in a bipolar transistor?

Ans. In the external circuit, the magnitudes of the emitter current, Ie, the base current, I_b and the collector current, I_c, are given by

$$I_e = I_b + I_c$$

Base current is of the order of μA where $I_e \approx I_c$ of mA order.

Q.13. Why common emitter amplifier is most widely used?

Ans. (i) it has good current and voltage gains.
(ii) it has the highest power gain.
(iii) The difference between its input and output impedances is not very large. Therefore, common emitter circuits can be connected in cascade directly without using transformers for matching purposes.

Q.14. Define static current amplification factors.

Ans. (i) α_{dc}, the static current amplification factor for a transistor in common base connection is the ratio of static (dc) collector current, I_c, to the static emitter current, I_e, at a constant collector voltage with respect to the emitter. That is

$$\alpha_{dc} = \frac{I_c}{I_e}, \text{ at constant } V_{cb}$$

(ii) β_{dc}, the static current amplification factor for a transistor in the common – emitter connection, is the ratio of static (d.c) collector current, I_c, to the static base current, I_b, at a constant collector voltage with respect to the emitter. That is

$$\beta_{dc} = \frac{I_c}{I_b}, \text{ at constant } V_{ce}$$

Normally the value of α_{dc} is greater than 0.9 and less than 1. Value of β_{dc} depending on the design, may be about 600. Its value (β_{dc}) highly depends upon the position of operating point, and it determines the quality of a transistor.

Q.15. What are small signal current – amplification factor (a.c current gains).

Ans. For a transistor in CB configuration

$$\alpha = \left(\frac{\partial I_c}{\partial I_e}\right)_{V_{cb}}$$

For a transistor in CE configuration

$$\beta = \left(\frac{\partial I_c}{\partial I_b}\right)_{V_{ce}}$$

In h- parameters, α is written as h_{fb} and β as h_{fe} as they are also called as small signal forward current transfer ratio. They are related as

$$\beta = \frac{\alpha}{1-\alpha}$$

EXPERIMENT 2A

STUDY OF RC COUPLED AMPLIFIER

OBJECTIVE: To design and study amplifying characteristics of a single stage RC coupled amplifier.

APPARATUS: A valve 6J5; Two load resistors (R_L = 30 KΩ and 47 KΩ), coupling condensers (C_c = 0.01 μF, 0.02μF, 0.04 μF), Cathode biasing arrangement (R_K = 3 KΩ, C_K = 25 μF), Grid leak resistors (0.47 MΩ, 0.1 MΩ), input capacitor (0.1μF), Vacuum Tube Voltmeter (V.T.V.M) or CRO, High tension (0 – 250 Volts), A.F. Generator (0 – 50 kc/s).

FORMULA USED: At a particular frequency,

$$Voltage\ Amplificaiton = \frac{Output\ Voltage}{Input\ Voltage}$$

CIRCUIT DESIGN: The plate is connected to positive of high tension through a load resistor, R_L. The cathode is connected to negative of high tension through a cathode resistor R_K (=3KΩ) having a capacitor C_K (=25μF) across it.

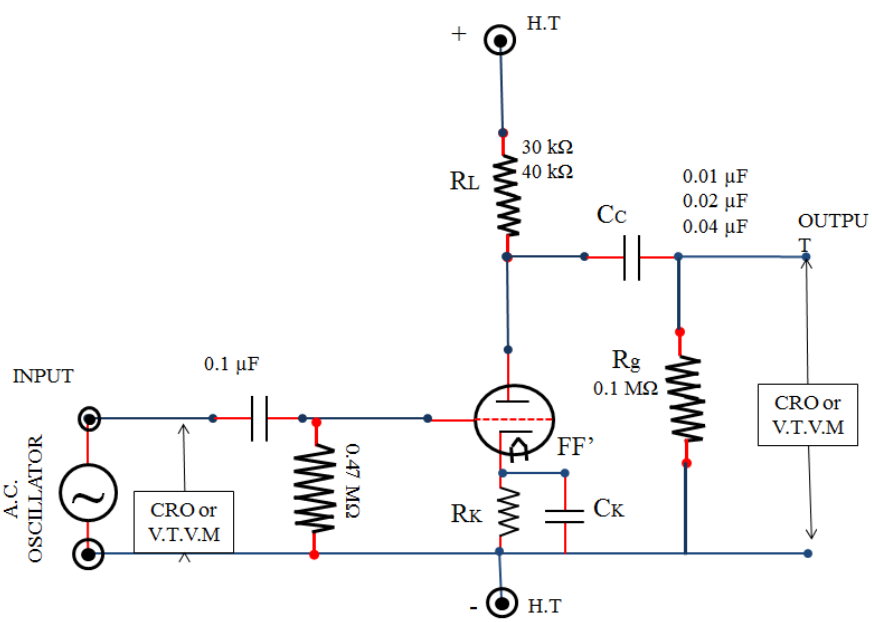


Figure 1. Single stage RC coupled amplifier

RC COUPLED AMPLIFIER: An input is connected to an audio frequency oscillator. Input and Output voltages are measured by V.T.V.M or CRO. C_C is the coupling condenser and R_g is grid leak resistor of next stage. Circuit is shown in Figure 1.

PROCEDURE:

1. Wire the circuit as shown in figure 1.
2. Set R_L= 30 KΩ, C_c = 0.01 μF
   Keep the input voltage (output of oscillator) constant, equal to 1V. Vary the oscillator frequency from 10 c/s to 50 kc/s and note the output voltage at various frequencies.
3. With R_L= 30 KΩ, C_c = 0.02 μF, repeat the step 2.
4. With R_L= 30 KΩ, C_c = 0.04 μF, repeat the step 2.
5. Now set R_L= 47 KΩ and then repeat the step 2 for C_c = 0.01, 0.02 and 0.04 μF, respectively.

OBSERVATIONS:

Input Voltage = 1.0 Volt

Frequency c/s	**Output Voltage, Volt**	**Voltage Amplification**
10	17	17
50	…	…
100	…	…
500	…	…
1000	…	…
3000	…	…
5000	…	…
10,000	…	…
20,000	…	…
30,000	…	…
40,000	…	…
50,000	…	…

RESULT: Graph is plotted between voltage amplification and frequency for various values of load resistor (R_L = 30 KΩ and 47 KΩ) and coupling capacitor (C_c = 0.01, 0.02, 0.04 μF). It is observed in Figure 2 that voltage amplification is not constant at low and high frequencies but remains fairly constant at mid frequencies. At higher load values, length of flat portion of the response curve decreases.

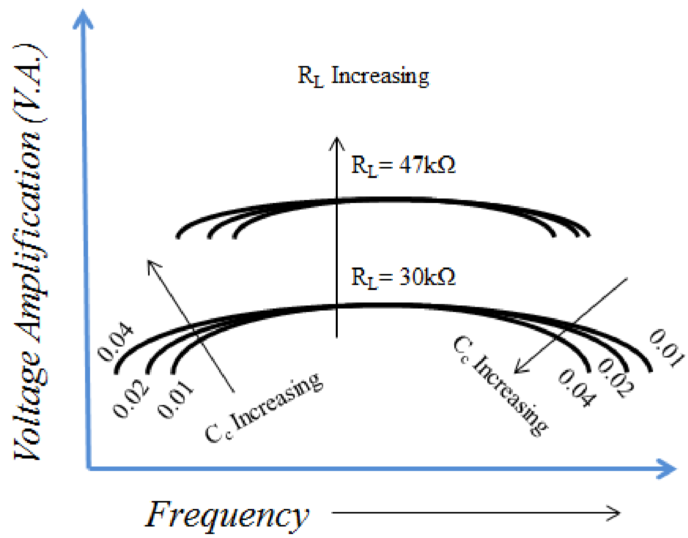


Figure 2: Frequency response curve of RC coupled amplifier

Source of Error and Precautions:

1. Values of circuit elements should be chosen carefully.
2. Various voltages developed and applied in the circuit should correspond to circuit voltage requirements and tube limitations.
3. Prior to using V.T.V.M its suitable range should be chosen first and then zero adjustment should be done.

EXPERIMENT 2B

STUDY OF RC COUPLED TRANSFORMER COUPLED AMPLIFIER

Objective: to design and study amplifying characteristics of a single stage coupled amplifier.

Apparatus: Circuit elements and their values are indicated in the figure (1) Digital Mutimeter, Audio frequency Oscillator (0-50 kc/s), two output transformers (one high grade and other low grade.

Circiut:

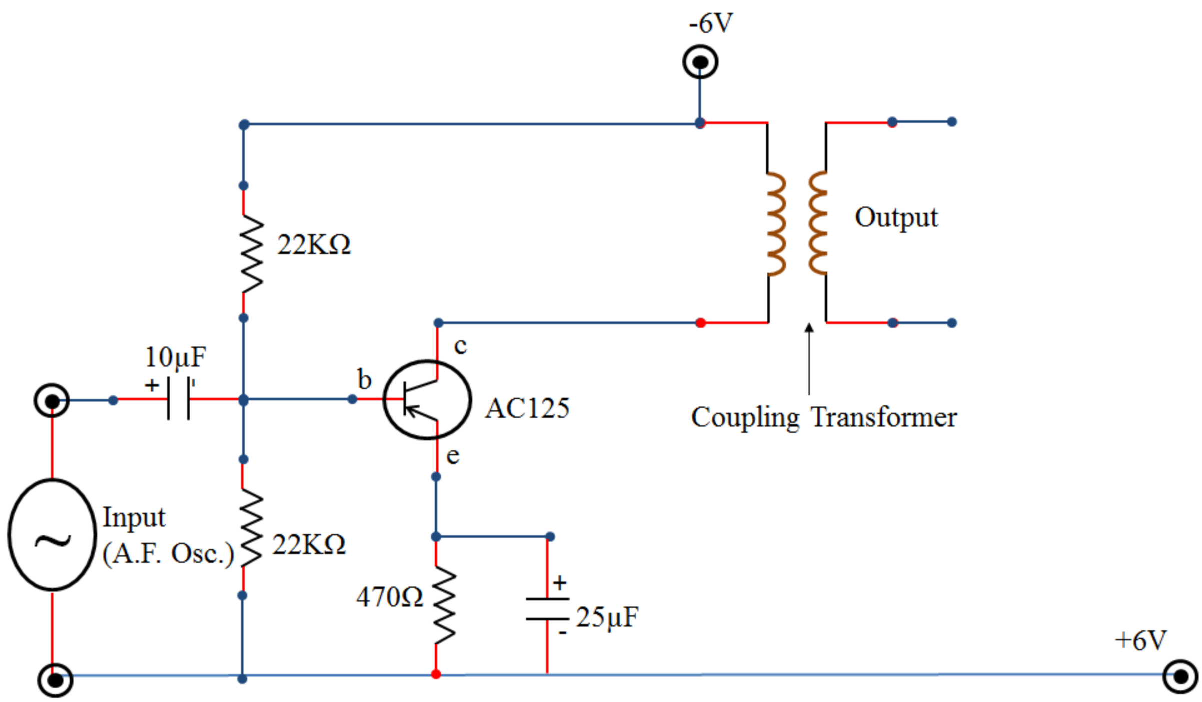


Figure 1. Circuit diagram of single stage transformer coupled amplifier.

Procedure:

(1) First use high grade transformer for coupling. Keep input at 10 mV (this is output of audio oscillator connected at the input terminals). It is kept constant throughout the experiment. Now vary oscillator frequency from 10 kc/s to 50 kc/s. Note output voltage at each frequency applied.
(2) Repeat the procedure
(3) With a low grade transformer.

Observations:

Input voltage = 10 mV

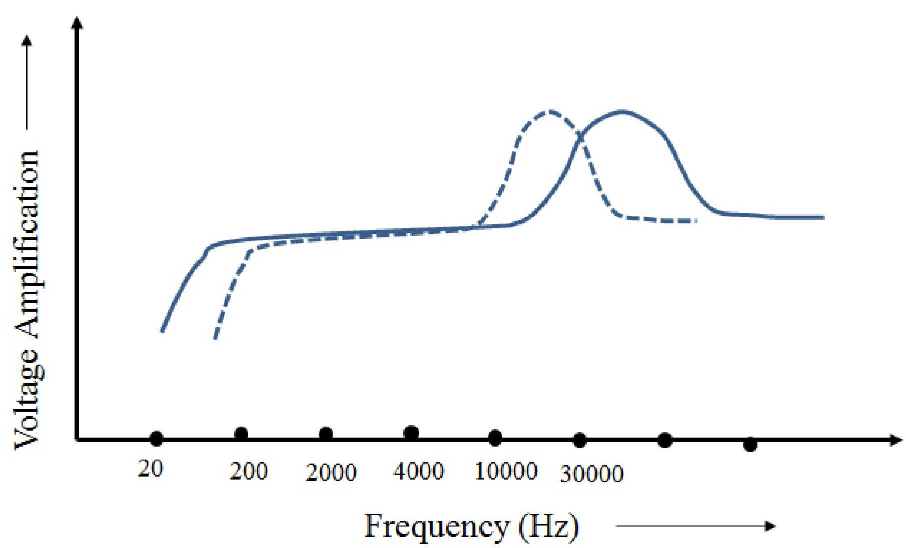
Freq in c/s	High grade transformer		Low grade transformer	
	Output volt	Voltage amplification	Output volt	Voltage amplification
10				
50				
100				

Calculations:

For each observation find:

Voltage amplification = Output voltage/ Input voltage

Result: Plot graphs as figure for the two types of transformers in voltage amplification and frequency



We note that the frequency response curve for high grade transformer (a transformer having high inductance with negligible distributed capacitance) is fairly uniform.

Precautions and sources of errors:

1. Input voltage should be checked at every frequency. It should remain constant at all applied frequencies.
2. Use proper range of digital milliammeter for input and output voltage measurements.

Vive-Voce

1. What is voltage amplification?
   Ans: It is the ratio of output voltage to the input voltage.
2. Does it change with input voltage frequency?
   Ans: Yes, we observe from frequency response curve that low and high frequencies are reduced.
3. What are shunt capacitors?
   Ans: They include plate – cathode inter – electrode capacitance of the tube and also stray wiring capacity to the left and right sides of the coupling capacitors.
4. Explain fully C_C and R_g coupling?
   Ans: Coupling capacitor C_c prevents the high voltage, applied to the plate of the valve, from the grid of next stage valve. Function of resistor, R_g, is to provide a path for the leakage of electrons that would otherwise be collected at the grid side of C_c and then will bias the tube cut off.

EXPERIMENT 3

CATHODE RAY OSCILLOSCOPE

OBJECTIVE: To study the working of Cathode Ray Oscilloscope

APPARATUS REQUIRED: CRO, frequency generator, digital multi-meter, tracing paper

THEORY:

Cathode Ray Oscillograph utilises the property of cathode rays of getting deflected in the presence of magnetic or electric fields as well as shows scintillations on a fluorescent screen. This Cathode Ray Oscillograph traces the oscillation graphs and the first Oscillograph appeared as an electromagnetic vibrator associated with a moving coil attached with a mirror. This Oscillograph worked on the principle that includes the deflection of a spot of light on to a scale when converged on a mirror. The fluctuating current that streams through it, it oscillates the vibrator which further displaces the spot of light over the scale in the oscillatory path corresponding to the oscillation of the vibrator. Due to its inertia, this set up follows only small current fluctuations. To overcome this problem, cathode ray tube was developed which worked efficiently that in contrary utilised an electric beam. The cathode rays generate a spot of light that falls on the fluorescent screen and can follow high rate of changes in the voltage as well as current due to small inertia produced by the electronic beam.

Since the cathode ray tube can ease the movement of spot in two mutually perpendicular direction at a single time, this property can be utilised for various purposes like that to elucidate the waveforms of the oscillations as well as to consider different numbers of phenomenon in television and radio- techniques.

DESCRIPTION:

It was 1897, when Braun constructed an elementary form of cathode ray oscillograph, which was then known as ‘Braun Tube’. In original discharge tube, cathode rays narrows to a thin beam while passing through the slit of the anode then travels the length of the tube and strike the fluorescent screen at the other end of the tube, thus giving a bright spot of light. The electric field (in the perpendicular direction to the tube axis) of very high potential difference is applied between two metal plates. The spot moves up and down in straight line when the field is applied. The requirement of the high voltage for the operation of Braun tube was the major drawback as it was dependant on the electron emissions from the cold cathode.

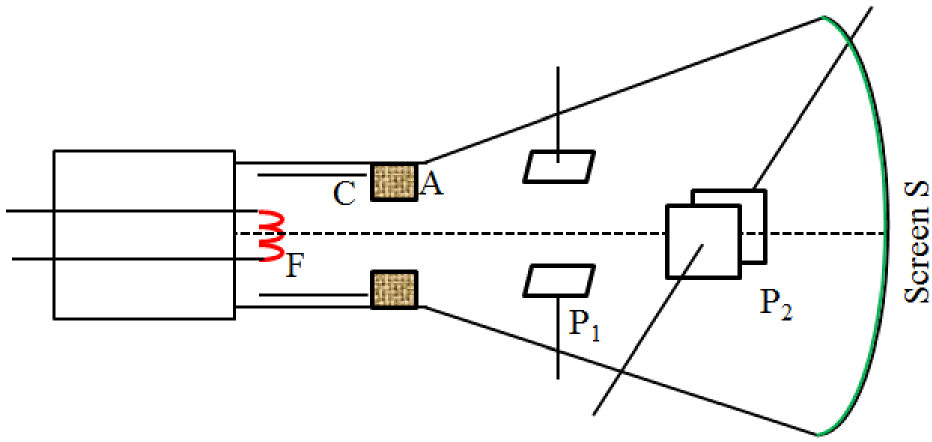


Figure 1. Cathode Ray Tube showing X and Y plates

Mode efficient Cathode Ray Oscillograph was devised with major improvements that utilised low voltage. In this evolved type, the tungsten filament F, served as cathode, laminated with oxides of alkaline earth produced thermionic electrons. The high potential difference of 500 to 2000 volts speed up the electrons from the filament upto the anode A (disc shaped with a hole in the centre). The electron comes out of the hole of anode (also called 'anode – gun'), strikes the fluorescent screen S, after the cathode ray travels the length of the tube in a straight line, thus producing the spot of bright light on the screen. The magnetic fields present outside the tube or the two pairs of plates P1 and P2 are placed in mutually perpendicular directions, deviate the beam ray through its electrostatic fields, vertically as well as horizontally while travelling to the screen. The tube is quite sensitive and can identify the transition even of shortest time. Moreover, the periodic changes of 200 million/ second frequency can be well recognised and responded by the cathode ray Oscillograph.

OPERATION OF CATHODE RAY OSCILLOGRAPH:

These include:

1. **Focusing**: Focusing refers to the concentration of large number of electrons by the device, in form of thin pencil that hits the other side of the screen. Due to this focussing there is a bright, sharp and defined spot achieved on the screen. *Wehnelt cylinder* C, also termed as shield, being a metal cylinder that surrounds the filament and serves the purpose, by maintaining the negative potential. The negative potential repels the electron coming from cathode; diverge it and then focuses the electron stream on the central axial line, such that concentrated beam of electrons is shot out of the anode gun. This can be done through two different principles: Gas focussing (soft tube) and Electrostatic focussing (hard tube).

   The gas focussing system utilises an inert gas like helium or argon which gets ionised due to collision with the electrons. The negatively charged electron flows through the stream

while the positive ions move slowly to form the core of the beam. The positive core attracts the electrons in order to replenish the lost ones, and thus form a concentrating effect. The advantage of this system is that it can work at low levels of voltage (300 to 500 V) and it is highly sensitive. Disadvantages include that the focus depends on the beam intensity. This means that a slight variation in the current of the beam due to any means, like altering the shield potential, loses the focus of the system. Thus, it seems impossible for its application in television. Another problem is its limited lifespan of cathode, as it gets bombarded by heavy slow moving positive ions, thus restricting the multiple usage of the tube.
Another system, that is the electrostatic focussing system, utilises number of anodes at increasing potentials.

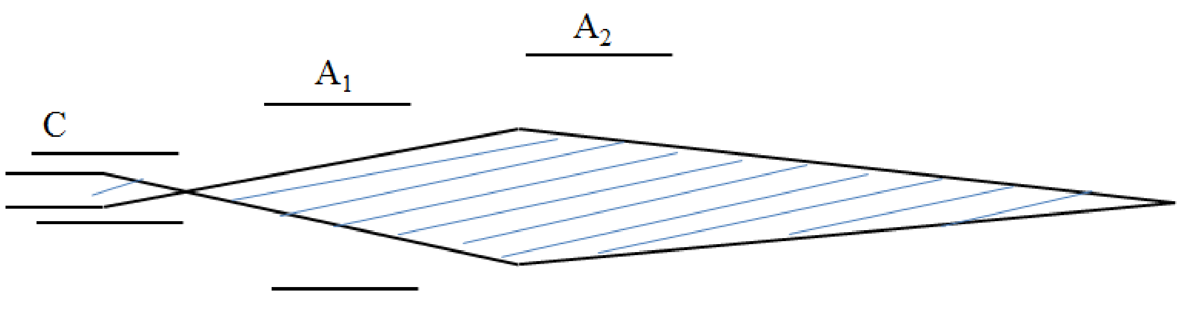


Figure 2. Arrangements showing the electrostatic focusing system

The potential of the anode is kept in such a manner that the field causes the electron to focus or converge. It is just like focussing of rays of light through use of lenses, thus the system arrangement is also called as Electron gun. The relative voltage of the anodes controls the level of focussing. The first Anode A1 is kept fixed with respect to the second anode A2, and is at one fourth distance of the latter. This increases the lifespan of cathode tube as no damage occurs to the cathode. Advantages include: 1 – It focuses good even at high deflecting fields as no heavy ion containing residual gas is there. 2 – The spot can be controlled independently to the focus, since voltage of the focus depends upon the second anode while the beam current depends on the first, thus controlling the brightness/ sharpness of the spot. The major disadvantage is that it requires high anode voltage (700 to 1200 V), which also reduces the sensitivity of the tube. Moreover, the spot does not remain focussed throughout the screen though; these problems have been reduced in the improvised and modern cathode ray tubes. A method, known as magnetic focussing is also used where the coil which is placed outside the tube, produces the magnetic field. This arrangement has the advantage over the electrostatic focussing, in achieving a better focus that cannot be lost at the sides of the screen. This can be applied in television, which requires focus throughout the screen.

2. **Deflection system**: Deflection system includes two pair of plates that deflect the beam in the vertical or horizontal direction. One pair which is placed vertically introduces the horizontal deviation in the beam and is termed as Horizontal or X – plates. Similarly, the other pair of plates placed horizontally and causes displacement in the vertical direction, are called as Vertical or Y – plates. The position of cathode tube affects the direction in which the spot moves. Therefore, the tube is placed in such a way that it can be rotated to achieve a properly aligned deflection. The sensitivity of the tube depends upon the position of the deflector plates. Closer the plates to the beam, greater will be the deflection. Though the plates should not be too close such that the beam strikes the plate and did not reach the screen at all to produce the spot.
3. **Electromagnetic Deflectors**: This is a system which includes the electromagnetic deflection of the spot unlike the one described above (the electrostatic mode of deflection). In this system, the coils are placed outside the tube and consist of similar two pair of plates to cause horizontal and vertical displacement. The magnetic field need to be uniform throughout as the defection of the beam depends on the actual strength of the field. Difference in the field for a constant current through the coil, affects the sensitivity to the greater extent.
4. **Tube Dimensions**: The cathode ray tube is glass conical tube with the screen at the wider end of the tube. So as to attain, perfect sensitivity and brightness of the spot, the diameter of the screen and the tube length is adjusted accordingly. The sensitivity can be increased by increasing the length of the tube. But in practice the situations are different. Longer the tube, greater will be the diameter of the screen due to the shape of the tube, but greater the screen's diameter, higher will be the anode voltage. This has been known that increased anode voltage, reduces the sensitivity of the tube. It is interesting to see that the sharpness and brightness of the spot also depends upon the colour of the spot as there are certain colours which have more sensitivity towards the eyes than the others. The tubes are made of variable sizes; generally the tube length is two or three times the diameter of the screen while for the televisions, larger as well as longer tubes are considered. Moreover, Zinc Silicate is used as the fluorescent material for coating inside the screen, thus giving brighter green spot with the maximum colour sensitivity of the human eye.

TIME BASE:

Variation of a quantity with respect to time can be studied by using cathode ray oscillograph. Hence, the movement of screen with respect to time in horizontal (usually) direction gives the liner time base arrangement. The circuit diagram given below illustrates the simplest time-base circuit (Figure 3).

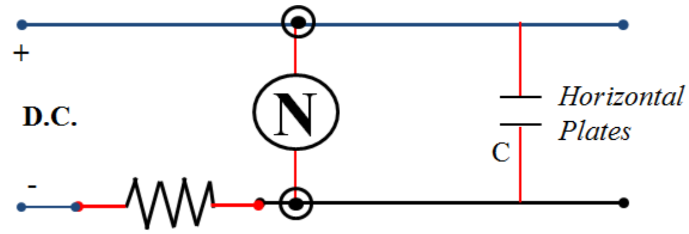


Figure 3. A block diagram showing the basic time-base circuit.

The condenser is placed across the terminals of a neon lamp N. The condenser is charged and discharged via resistance R from DC mains and neon lamp respectively. The condenser is charged via resistance R on turning the DC supply until and unless a peak value of voltage corresponding to Neon lamp is achieved. It is of the order of 150olts. The condenser gets short circuited as the neon lamp glows. This process discharges the condenser via lamp. Every time the process gets repeated the neon lamp flashes. The flash rate depends upon the product of capacitance and resistance. If their product is large, the flashing rate remains low. A horizontal movement of the spot is observed on screen with charge build up in the condenser. The spot keeps moving till the condenser is completely charged up. As soon as the condenser discharges due to flashing of neon lamp, the spot suddenly moves to its starting position. With every flashing of neon lamp, the point is instantaneously sweeped to the initial point. This offers the evaluation of frequency from the time base. It can be evaluated as follows:

Let us assume the charging is linear and voltage supplied by DC mains is E so that the charging current becomes $i=E/R$. Thus, the condenser acquires the charge $Q=it$, where t is the charging time. The voltage across the condenser is $V=Q/C$ (same as that of striking voltage of neon lamp). Therefore,

$$t = \frac{Q}{t}$$

$$t = \frac{VCR}{E}$$

And frequency $f = \frac{1}{t}$

$$f = \frac{E}{VCR}$$

From the above relation, it can be inferred that the frequency can changed by varying the values of R and C.

In radio-techniques, where the frequencies used are very high, therefore the time-based frequencies must be synchronised with the frequencies used. When they get superimposed, trace the coincided wave and impressions of stationary waves are obtained.

USES OF CATHODE RAY TUBE:

1. The elucidation of the amplitude of variable quantities, like sound vibrations, oscillatory voltage, oscillatory current or mechanical vibrations, etc. For this, only one pair that is either X – plates or Y – plates are used. Variation in the voltage that corresponds to the variables under examination, when subjected to X – or Y – plates, causes the spot on the screen to move either horizontal or vertical. The line and the spot movement appear to be traced due to vision persistence. The distance between both, that is spot as well as the trace is known as the amplitude of the vibration.
2. Detecting the actual wave form like, alternating current or voltage, sound, etc. Let us consider that the wave form of voltage oscillations is to be traced as shown in Figure 4.

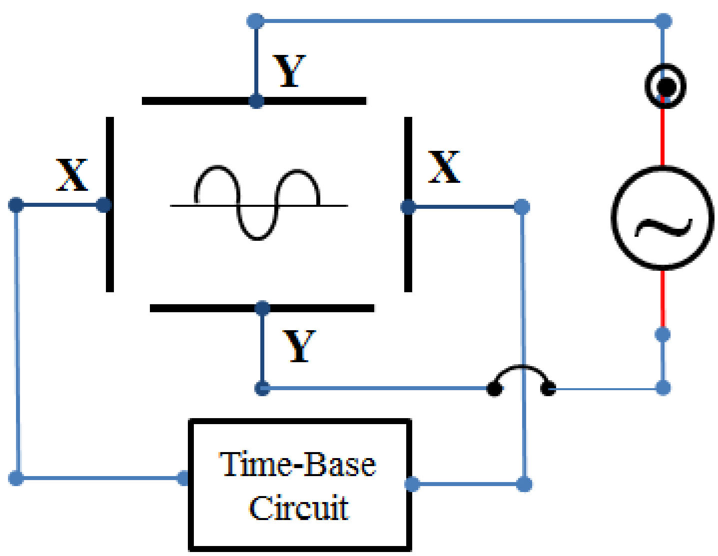


Figure 4. Block diagram showing the Time-base circuit with X and Y plates, respectively

For this, the voltage is connected to the Y – or vertical plates. On the other hand a time base circuit of known value of frequency is applied to the X – or the horizontal plates. If the circuit is considered alone, it produces a spot which lines the screen horizontally. Similarly, if voltage is applied alone, the spot traces a line on the vertical plane. When both are applied simultaneously, the combination causes synchronisation of the trace to take a stationary position which provides the actual wave form. Through the known frequency of the time base, frequency of oscillatory circuit is obtained.

3. The phase differences between the current and voltage can be studied by constructing each of the two quantities such that it performs on only one pair of the deflecting plates.
4. The determination of an unknown frequency using the value of a known frequency
5. Tracing the hysteresis curve: The Cathode Ray Tube (CRT) can be used to trace the Hysteresis loop for any specimen say iron, over a complete cycle of magnetisation. For this purpose, following circuit diagram should be considered.

The magnetising force H is measured by alternating current that magnetizes the specimen. Therefore, proportionality should be maintained with the horizontal deflection of the cathode ray. For this, a resistance (R1) in series is introduced in the circuit (Figure 5).

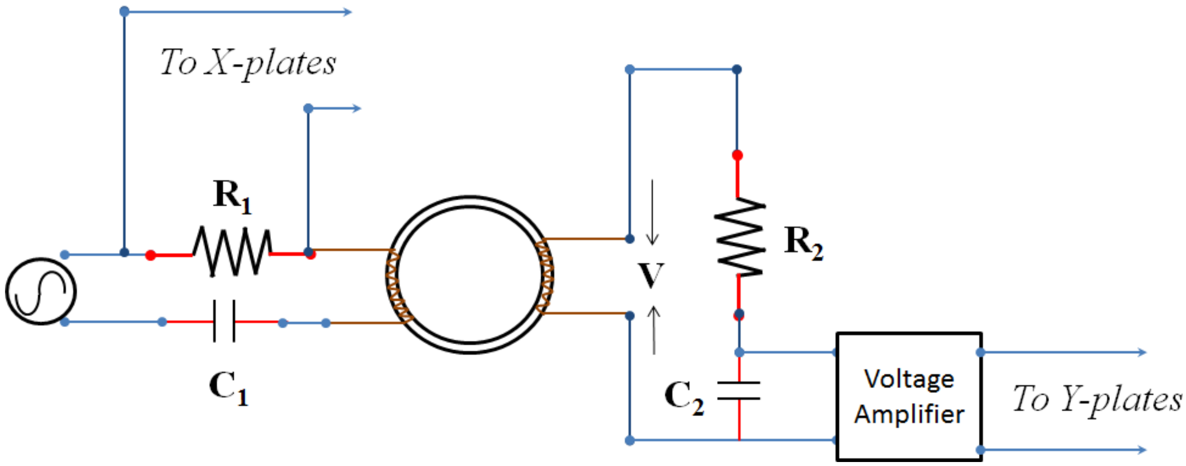


Figure 5. Circuit diagram for tracing the B-H curve

Across the horizontal X – plates a potential drop across the resistance is applied. The induced alternating voltage V in the secondary windings gives the measure of change in magnetic induction B. In order to obtain precise readings, it should be ensured that the secondary windings are small and is kept outside the magnetising flux. This ensures that the induction B is only due to the specimen itself. To get the deflection proportional to B, the rate of change of induction with respect to the voltage must be integrated. Further, in order to make the induced emf in phase with magnetising coil, a condenser C_2 and a large resistance R_2 is employed with secondary winding of the circuit. The voltage across the condenser C2 is being amplified and thereafter applied to the vertical Y-plates. Then the spot traces the B-H curve which shows the Hysteresis effect in the form of a loop. As a precautionary note, the magnetising curve should be enough to saturate the iron specimen or else a distorted ellipse will be seen instead of a normal hysteresis loop.

6. Other applications include plotting of the response curve of circuits with low and high frequencies; study of transformer magnetization, comparison of output and input voltages of an amplifier; vibrations in machinery; heights measurements of Kennelly Heaviside E layer and Appleton F layer which affect the propagation of radio waves and cause fading in radar systems; microwave spectrometer; defects in motors and generators during its operation; elucidation of nervous reactions and heart rhythms, etc.

Thus, the Cathode Ray Oscillograph is of great usage to the engineers, physicist or medical persons as well as used in research laboratories.

DISCRIPTION:

Figure 6. Actual image of a CRO

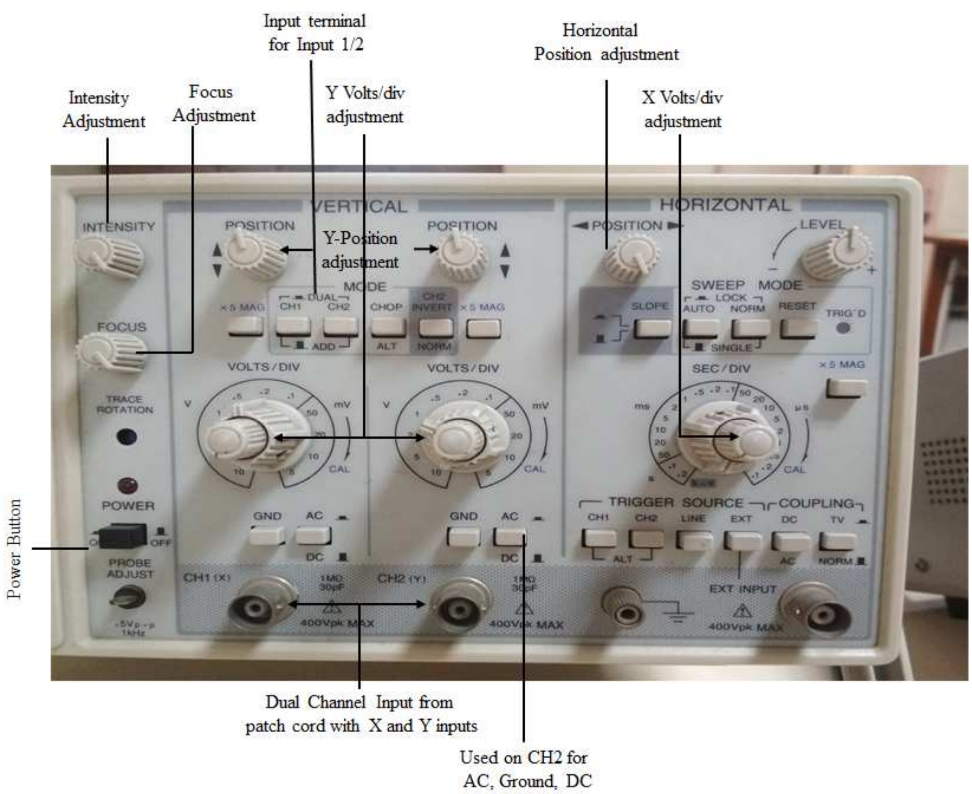


Figure 7. Some useful functions for tracing a curve on CRO

CONTROLLER FUNCTIONS: Use the CRO Instruction manual for complete description of model specific points and their functions. Here, for reference we have used a 20MHz Dual Trace Oscilloscope.

OPERATION:

1) Measuring voltage and time period

The trace on an oscilloscope screen is a graph of voltage against time. The shape of this graph is determined by the nature of the input signal either supplied by the patch cords, or any other setup.

Amplitude is the maximum value of voltage reached by the signal. It is measured in volts.

- Peak voltage is also known as amplitude.
- Voltage (Peak-peak) or $V_{P-P}$is twice the peak ac voltage (amplitude) measured between maximum and minimum value of peaks. When reading an oscilloscope trace it is usual to measure peak-peak voltage.
- **Time period** is defined as the time taken for the signal to complete one wave of cycle. It is measured in seconds (s), but time periods tend to be short so milliseconds (ms) and microseconds (μs) are often used. 1ms = 0.001s and 1μs = 0.000001s.
- **Frequency** is defined as the number of cycles per second. It is measured in hertz (Hz), but frequencies tend to be high so kilohertz (kHz) and megahertz (MHz) are often used. $1kHz = 10^3Hz$ and $1MHz = 10^6Hz$.

  $F = 1/T$

(A) **Voltage**:

a) Ac voltage measurement: Voltage is will be shown on the vertical y-axis and the scale is determined by the Y (VOLTS/div) control. Usually peak-peak voltage is measured because it can be read correctly even if the position of 0V is not known. The amplitude is half of the peak-peak voltage given by the relation:

   $V_{p-p} = V/DIV \times H(DIV)$

   $V_{effect} = V_{p-p}/2\sqrt{2}$

   If the probe is magnified by 10 times, then the value calculated should be times 10.

b) DC Voltage measuring: If the DC part of a signal is measured, first set Y Coupling mode to GND and Y position to make the sweep baseline to be a proper position, then set Y Coupling mode to DC to adjust LEVEL to synchronize the waveforms. With the vertical distance from the waveform to the basic sweep baseline, read out each voltage value of the signal on CRO.

(B) **Time period**: When the signal cycle or the time factor between two points, operate as mentioned above. After the waveform is synchronized, time the value indicated by SEC/DIV using the horizontal distance between two points or the signal cycle. If one part of the signal is measured, pull out MAG knob to magnify 5. Adjust 'X' position to move the waveform to the proper position for observation. Then the value measured should be divided 5.

Calculate the time intervals by the following formulae:

Time interval (S) = [Distance between two points (DIV) × Sweep time factor (TIME/DIV)]/ Magnification factor horizontally

(C) **Frequency Measurement**: As to the frequency measurement of the repeated signals, first measure out the signal cycle, then work it out as following:

f (Hz) = 1/T (S)

If the frequency of the measured signal is very high, even if SEC/DIV is set to the fastest step, the displayed waveform is still very close. Calculate the value with the cycles displaced in 10 DIV on X – axis for higher accuracy:

f (Hz) = N (Cycles)/ Values on SEC/DIV × 10

Result: The study of CRO is complete.

Precaution:

1) Never switch on the CRO while all its full controls on maximum mode. Reduce the knobs to minimum value.
2) Do not play with the knobs unnecessarily as they get loose with times and these effects the efficiency of CRO in future.
3) Always connect a CRO on Uninterrupted Power Supply (UPS) line. This helps to plots the graphs with reduced ripples and better signal to noise ratio.

EXPERIMENT 4A

STUDY OF DIFFERENT OSCILLATOR

OBJECTIVE:

To design a Wien bridge oscillator and to measure the frequency of oscillations generated.

APPARATUS:

2 SB 75 PNP transistors (or equivalent available), capacitances and resistances of the values shown in the circuit (Figure 1).

Wien Bridge Oscillator

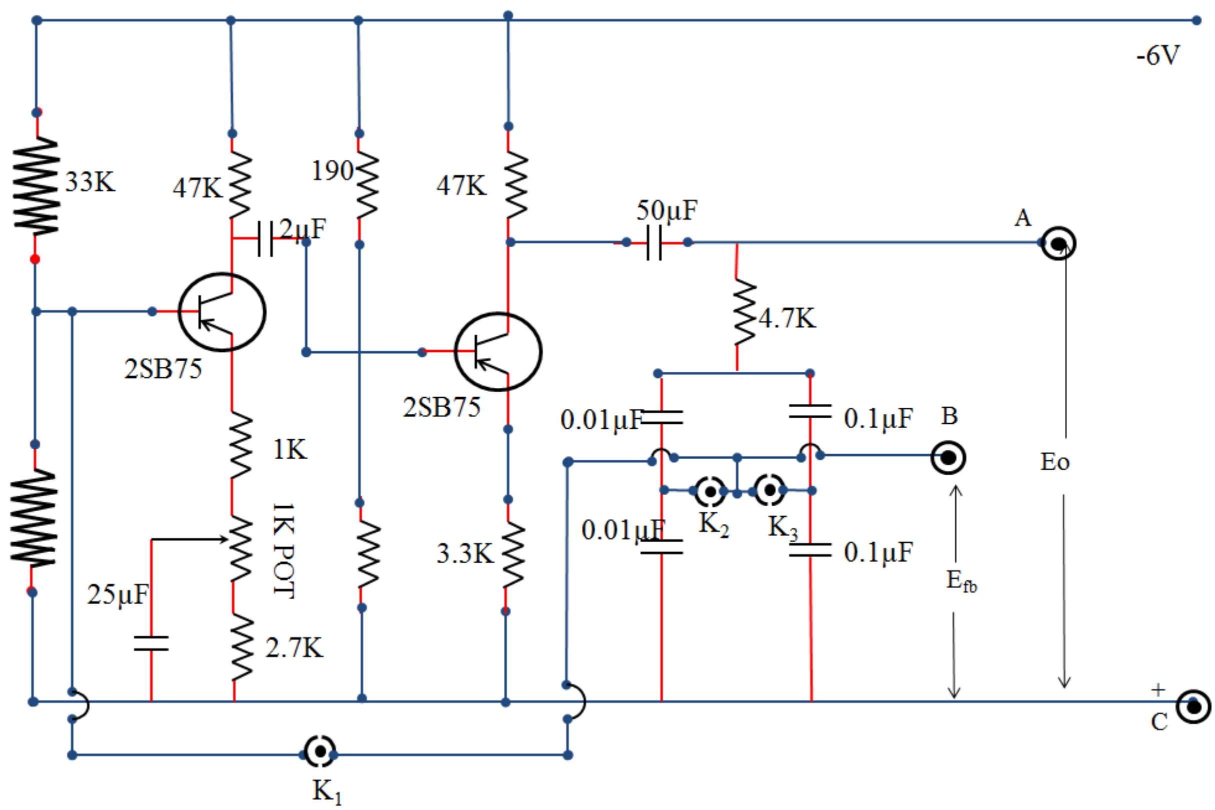


Figure 1: Circuit diagram of a Wien Bridge Oscillator

Three switches K1, K2 and K3, one C.R.O, one audio frequency oscillator, V.T.V.M. or CRO, and a 6V DC supply.

CIRCUIT DESIGN:

Various circuit element values are shown in the figure. There are two RC combinations. When K_2 is closed (K_3 is open) then R = 4.7KΩ and C = 0.01μF so that frequency of the oscillator will be

$$f = \frac{1}{2\pi RC} = \frac{1}{2 \times 3.14 \times 4{,}7 \times 10^3 \times 0.01 \times 10^{-6}}$$

= 3387.99 c/s = 3388 c/s

But when K_3 is closed (K_2 is open) then R = 4.7 KΩ and C = 0.1 μf so that

$$f = \frac{1}{2\pi RC} = \frac{1}{2 \times 3.14 \times 4{,}7 \times 10^3 \times 0.01 \times 10^{-6}}$$

= 338.8 c/s = 339 c/s

For the circuit to work as an oscillator, switch K_1 should be closed so that positive feedback exists and the circuit oscillates. If $K_1$is opened, the circuit works as amplifier. When an a.f. oscillator (keep input low 10 mV) is connected at A and C, we can measure output voltages, E_0, with the help of V.T.V.M. between A and C terminals and voltage feedback, E_{fb}, between B and C terminals at various input frequencies. If we then plot a graph in E_{fb}/E_0 with frequency then it will have its maximum at f = 3388 c/s (for R = 4.7 KΩ and C = 0.01 μf) or f = 338.8 c/s (for R = 4.7 KΩ and C = 0.1 μf).

FORMULA USED:

$$f = \frac{1}{2\pi RC}\ \text{c/s}$$

PROCEDURE:

1. **With R = 4.7 KΩ and C = 0.01 μf: Close K_2 and K_1 (Open K_3):**
   Connect terminal B to Y input of C.R.O and terminal, C, to ground of C.R.O. Use internal synchronisation and form wave pattern on the screen. Suppose 3 waves are formed. Then disconnect B and C from C.R.O. Instead connect an audio oscillator frequency (Internal synchronizing frequency of C.R.O should not be disturbed this time. It should remain exactly at the value at which it was set for Wien Bridge oscillator waveformon C.R.O screen) make the same number of waves (3 waves as formed with Wien bridge oscillator, say) on the C.R.O screen. This frequency of audio oscillator, at

which these same waves are obtained, gives the frequency of Wien bridge oscillator. Compare this value with the calculated value of the frequency.

2. **With R = 4.7 KΩ and C = 0.1 μf: Close K_3 and K_1 (Open K_2):**
   Proceed as detailed above as in step 1.
3. Disconnect supply to the circuit. Connect K_2, open K_3. Connect audio frequency oscillator at A and C terminals. Keep its output 10 mV. Vary oscillator frequency and note E_0 and E_{fb} at every frequency with the help of V.T.V.M or CRO.
4. Connect K_3, open K_2.
   Proceed as detailed above in step 3.

OBSERVATIONS:

1. Oscillator frequency
   With R = 4.7 KΩ, C = 0.1 μf = c/s
2. Oscillator frequency
   With R = 4.7 KΩ, C = 0.01 μf = c/s
3. Remove supply to circuit.

Oscillator Frequency c/s	With K_2 close			With K_3 close		
	E_{fb}	E_0	E_{fb}/ E_0	E_{fb}	E_0	E_{fb}/ E_0
10 c/s	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
50 k c/s	…	…	…	…	…	…

CALCULATIONS:

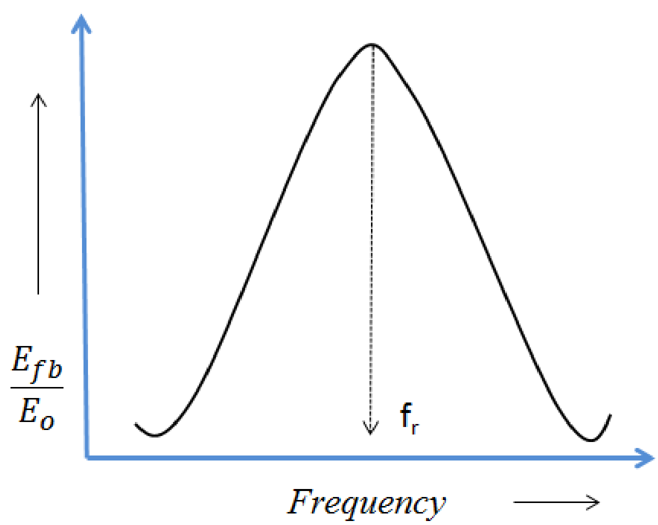
$$f_r = \frac{1}{2\pi RC_1} = \cdots c/s$$

$$f_r = \frac{1}{2\pi RC_2} = \cdots c/s$$

RESULTS:

RC Values	Exp. value of frequency	Theoretical value of frequency	Frequency values from graph
R = 4.7 KΩ and C = 0.1 μf	….	….	….
R = 4.7 KΩ and C = 0.01 μf	….	….	….

Plot graph in E_{fb}/E_0 with oscillator frequency as shown in figure.



Find frequency, at which this ratio is maximum (as marked by dotted line). It gives frequency corresponding to the combination used.

Sources of Error and Precautions:

1. Polarities of the supply should be connected properly.
2. Zero adjustment should be done for every range of V.T.V.M. selected for use.

VIVA – VOCE

Q.1. What is the advantage of using phase shift oscillator?

Ans. R.C. oscillators can be used for very low frequencies where L.C resonant circuits would be too bulky and expensive.

Q.2. What is phase shift network in your circuit?

Ans. It is a lead – lag network consisting of a series RC and a parallel RC combination. At low frequencies, the phase angle is positive and the circuit acts like a lead network. On the other hand, at very high frequencies, the phase angle is negative and the circuit acts like a lag network. In between, there is a resonant frequency at which phase shift equals 0˚, f_r is given by

$$f_r = \frac{1}{2\pi RC'}$$

At which frequency feedback fraction (E_{fb}/ E_0) reaches a maximum value of 1/3.

Q.3. The circuit of Wien bridge oscillator works like a two stage RC coupled amplifier?

Ans. Yes, it is a two stage RC coupled amplifier in which a fraction of output voltage is fed back to the input terminals.

Q.4. What are its advantages?

Ans. It has low distortion and good frequency stability.

EXPERIMENT 4B

STUDY OF HARTLEY OSCILLATOR

OBJECTIVE:

To design a Hartley oscillator and to calibrate the dial of its tank circuit capacitor in terms of frequency and to find the dielectric constant of a liquid, say kerosene oil.

APPARATUS:

A NPN transistor 2N3055, one R.F.Choke (R.F.C. which it is a coil of high inductance used to prevent high frequency oscillations from reaching the supply say of 30mH), Capacitors of values 0.02 μf, 0.05 μf, 0.05 μf, 25 μf. Resistors of values 33K, 10K and 4.7K. Variable air capacitor (0 – 1000 pf) and an inductive coil (of mH order) with various tappings to serve as tank circuit of the oscillator (they are C and L in the circuit). A 20V D.C. supply, an air capacitor in which liquid can be filled and closed, a CRO. The complete circuit is shown below for your convenience.

CIRCUIT DESIGN:

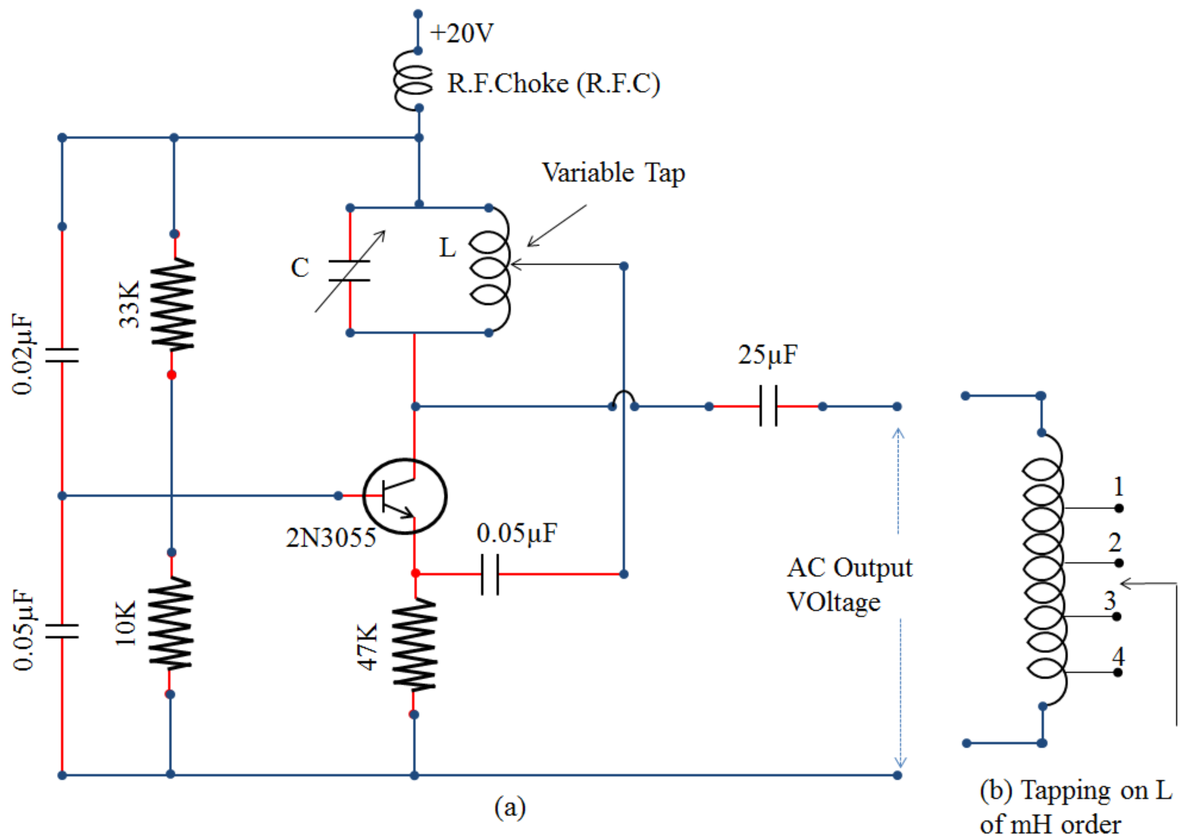


Figure 1. Circuit diagram of Hartley oscillator

The voltage developed across the tank circuit (LC circuit) is fed back to the base emitter junction through 0.02 *µf* capacitor and the variable tap on the coil. Resistors of 33 K and 10 K bias the circuit into class C operation, where C is a variable air capacity (0 – 1000 *pf*) as shown in Figure 1(a). A dial marked in degree, say from 0˚C to 90˚C, is attached to its slow motion handle. Coil L of order of mH is wound on a former and various tapping terminals say after every 5 turns are provided. The variable tap wire can be connected as shown in Figure 1(b) to any of the tapping terminals 1, 2, 3, ….etc.

(A) For Calibration of air capacitor or tank capacitor:

PROCEDURE:

1. Keep C at some value say its dial pointer on 10˚. Now connect variable tap from base end with tapping terminals 1, 2, 3, … towards collector end. For each tap, note the a.c. output voltage (for it keep V.T.V.M. or CRO on some suitable a.c. range and adjust zero of scale). For any particular tapping, output voltage will be maximum. Note this tapping. Fix the variable tap in this tapping terminal for calibrating dial of capacitor as described in step 2.
   Plot a graph in the output voltage with number of tappings.

2. Using coil of appropriate frequency range (in which the frequency of tank circuit is expected to lie) in frequency meter (wavemeter) start calibrating the dial of variable air capacitor. Keep dial pointer on 10˚ and then adjust frequency meter for maximum deflection. Read this frequency. Next keep dial pointer on 20˚ and obtain *maximum deflection* in frequency meter. Read this frequency. Continue likewise till the whole capacitor range is covered. Thus the variable air capacitor is calibrated.

(B) For the measurement of dielectric constant:

1. Keep the variable air capacitor at some dial reading (say at 40˚) and note frequency, f_0, from the table as measured in point 2 of part A.
2. Now connect another cylindrical condenser (with air in between the plates) in parallel with variable air capacitor and again measure the frequency of the circuit with the help of wavemeter. Let it be f_a.
3. Fill the cylindrical condenser with dielectric and again measure the frequency of the circuit. Let it be f_d.

OBSERVATIONS:

1. Variable tapping readings with CRO or V.T.V.M.

No. of tappings	Output voltage, Volt
1	…
2	…
3	…
4	…
…	…

2. Calibration of capacitor:

Dial Division	Frequency, c/s
10˚	…
20˚	…
30˚	…

…	…
…	…
90˚	…

3. For dielectric constant measurement.

Dial reading	Frequency f_0 in c/s	Frequency f_a in c/s	Frequency f_d in c/s
	…	…	…

CALCULATIONS:

Dielectric constant is given by the formula

$$k = \frac{f_a^{\,2}(f_0^{\,2} - f_d^{\,2})}{f_d^{\,2}\,(f_0^{\,2} - f_a^{\,2})}$$

RESULTS:

1. Plot a graph in output voltage (V.T.V.M) reading with number of tappings.
2. Draw a calibration curve in dial divisions and corresponding frequency.
3. Dielectric constant of the liquid, k =……

PRECAUTIONS:

1. Power ratings of power transistor 2N 3055 should be kept in mind while performing the experiment.
2. It is better to use heat sink with 2N3055.
3. Inductive coil may be of order of μH and variable air capacitor of value (0 – 500 *pf*).

VIVA VOCE

Q.1. What is the function of 33 K, 10 K and 4.7 K resistors?

Ans. They provide necessary bias conditions,

Q.2. Through which path voltage is fed back from tank circuit?

Ans. The voltage developed across tank circuit is fed back to the base emitter junction through 0.02 μf capacitor and variable tap on the coil.

Q.3. What is the function of R.F.C?

Ans. It is a radio frequency choke of large reactance (mH order) at the oscillation frequency. Its function is to prevent r.f. curremt from reaching the d.c. supply.

Q.4. What is the mathematical relation for frequency of oscillation here?

Ans. It is $\boldsymbol{f = \frac{1}{2\pi\sqrt{(LC)}}}$, where L is the total inductance of the coil.

EXPERIMENT 4C

STUDY OF COLPITT OSCILLATOR

OBJECTIVE:

To study the Colpitt's oscillator and hence find the feedback fraction.

APPARATUS:

A NPN transistor 2N3055, one R.F.Choke (R.F.C. which it is a coil of high inductance used to prevent high frequency oscillations from reaching the supply say of 30mH), Capacitors of values 0.02 μf, 0.05 μf, 0.05 μf, 25 μf. Resistors of values 33K, 10K and 4.7K. Variable air capacitor (0 – 1000 *pf*) and an inductive coil (of mH order) with various tappings to serve as tank circuit of the oscillator (they are C and L in the circuit). A 20V D.C. supply, an air capacitor in which liquid can be filled and closed, a CRO.

THEORY:

The circuitcomprises of two capacitors C_1, C_2 and inductor L. The Colpitt's oscillator has two capacitors that are placed across a common inductor L and the centre of these two capacitors is tapped. The frequency of the oscillations is determined by the magnitude value of C_1, C_2 and L.

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

where, $C_T = \frac{C_1 C_2}{C_1 + C_2}$

$C_1 - C_2 - L$is also the feedback circuit that produces a phase shift of 180˚.

OPERATION:

When the circuit is turned on, the capacitors C_1 and C_2 are charged. The capacitors discharge through L, setting up oscillations of frequency determined by above equation. The output voltage of the amplifier appears across C1 and feedback voltage is developed across C_2. The voltage across 180˚ out of phase with the voltage developed across C_1(V_{out}). The voltage feedback (voltage across C_2) to the transistor provides positive feedback. A phase shift of 180˚ is produced by transistor and a further phase shift of 180˚ is produced by C_1 – C_2 voltage divider. In this way, the feedback is properly phased to produce continuous undamped oscillations.

Feedback fraction (m_v): The amount of feedback voltage depends upon feedback fraction m_v.

Feedback fraction $m_v = \frac{V_f}{V_i} = \frac{X_{C_2}}{X_{C_1}} = \frac{C_1}{C_2}$

$$m_v = \frac{C_1}{C_2}$$

CIRCUIT DESIGN:

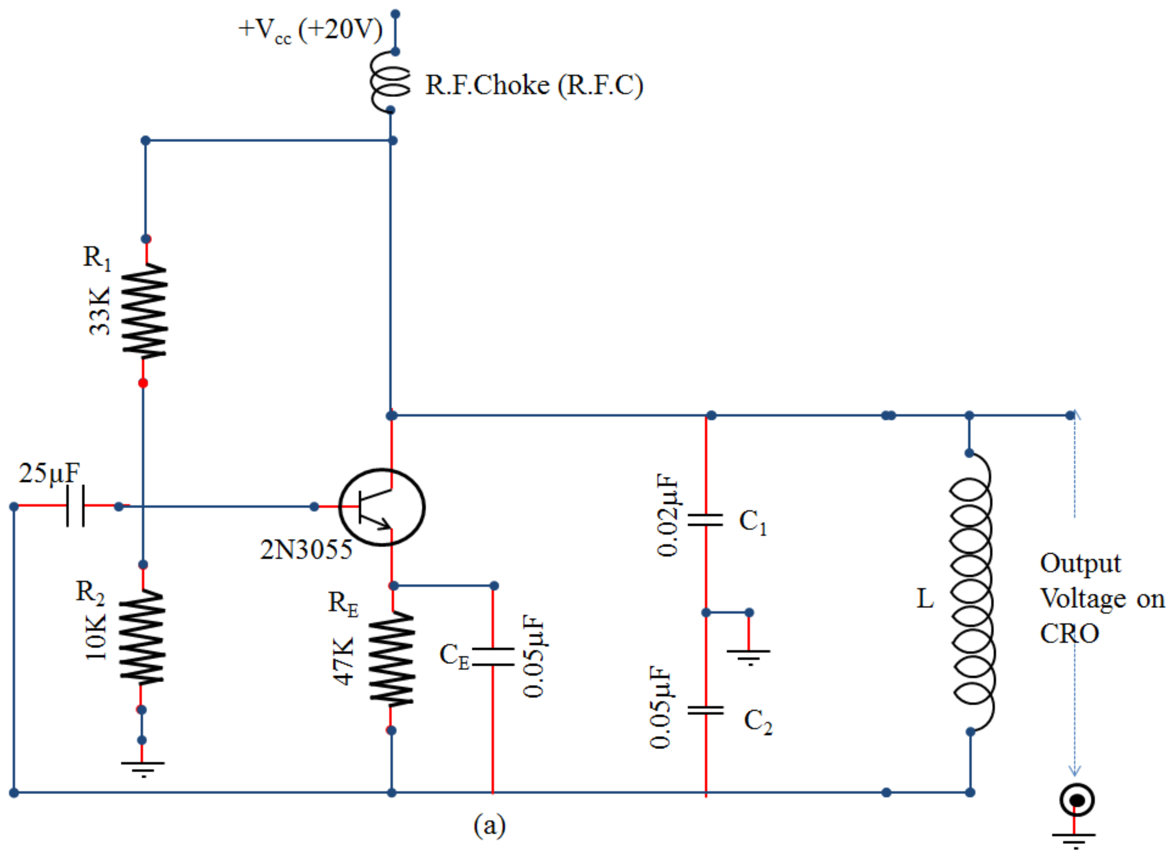
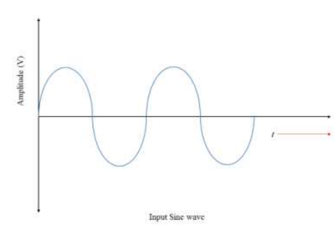


Figure 1. Circuit Diagram of Colpitt's Oscillator

Procedure

- Hook up the circuit as shown in the circuitdiagram.
- Switch on the powersupply.
- Slight modification in value of C_1, C_2can be made to get perfect sine waveoutput.
- Observe the output waveform inCRO.

MODEL GRAPH:



TABULATION:

Amplitude (Volts)	Time(ms)	Frequency (KHz)

CALCULATIONS:

Feedback fraction m_v: $\frac{C_1}{C_2}$

Equivalent Output Circuit:

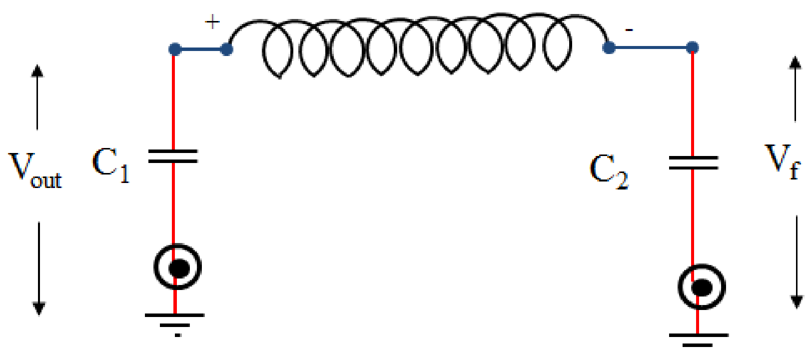


Figure 2: Equivalent Feedback Circuit diagram of Colpitt's Oscillator

RESULT: Thus, the Colpitts oscillator was designed and its output waveform was verified.

PRECAUTIONS:

1. Never connect the input with high frequencies at the beginning of the experiment.
2. Before connecting the CRO, check the output for noise in the input signal. This may help to remove the noise factor.
3. Make the circuit diagram properly.

VIVA-VOCE

1. What is sinusoidal oscillator?
   Ans. An electronic device that generates sinusoidal oscillations of desired frequencies is known as a sinusoidal oscillator.
2. What are the advantages of electronic oscillators over mechanical oscillators?
   Ans. An electronic oscillator is a non-rotating device, which produce a little wear and tear and therefore, these have longer life. Without any moving parts like those of mechanical oscillators, these are much silent in operations.

3. What are the types of sinusoidal oscillations?
   And. There are two types of oscillation:
   a) Damped Oscillations
   b) Undamped Oscillations.
4. What is a tank circuit?
   And A circuit which produces electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit.
5. Define frequency of oscillations and what is its mathematical formula?
   Ans. Frequency of oscillation of a tank circuit is determined by L and C constants of the components. The actual frequency of oscillation is the resonant frequency given by: $f_r = \frac{1}{2\pi\sqrt{LC}}$

EXPERIMENT 5

STUDY OF ELECTRONICALLY REGULATED POWER SUPPLY

OBJECTIVE: To study the electronically regulated power supply

APPARATUS: Breadboard, 3 Voltmeter (0-30V), digital multimeter, one ammeter (0-100mA), resistance 220Ω, 1kΩ, 130Ω, 100Ω, a frequency generatoras a voltage source (0-30V), a npn transistor (in CB and CE mode), connecting wires, patch cords for CRO, clips.

THEORY: The regulated power supply comprises of three circuits, namely - a zener diode as a voltage regulator, the bridge rectifier and the filter via capacitor.
In general the two types of voltage regulators are:
(i) Series Voltage Regulator
(ii) Shunt Voltage Regulator

In Shunt regulator the load is kept in parallel connection while in the series regulator the load is connected in parallel.

Transistor Series Voltage Regulator

Some active devices such as a transistor, zener or a combination of both is employed as per the requirement, in a voltage regulated power supply. The circuit diagram of a Series Voltage Regulator is shown below:

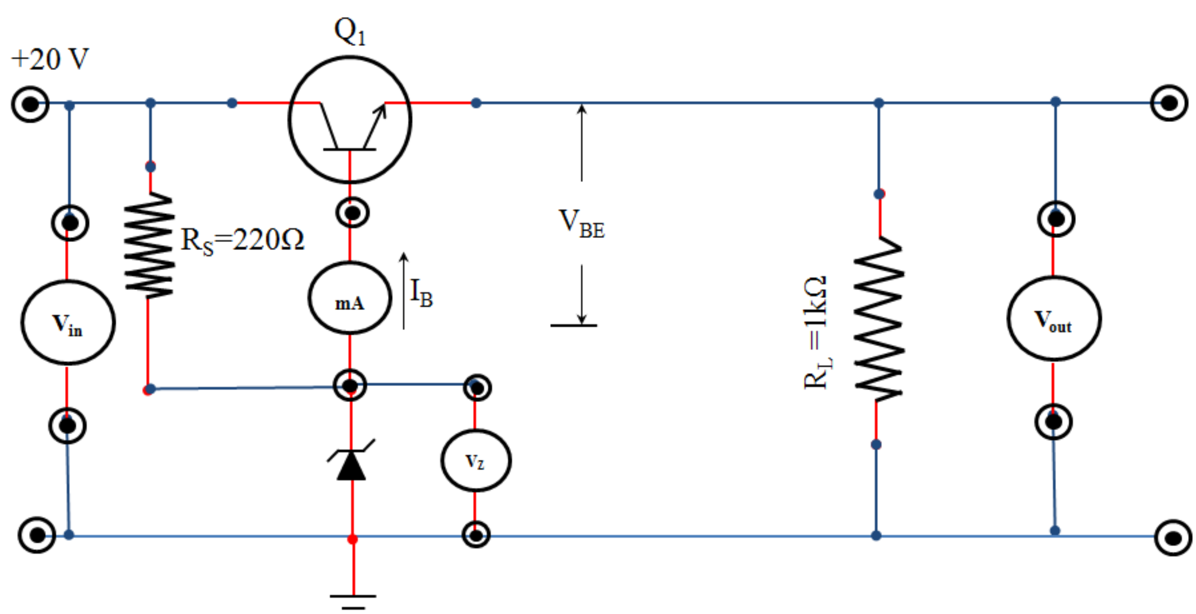


Figure 1. Circuit diagram for a transistorized series voltage regulator

The load current passes through the series transistor and hence it is called as a series voltage regulator. However, the excessive load current may destroy the transistor. The unregulated d.c. supply is fed to input terminals and the regulated output is obtained across the load. The zener diode provides the reference voltage.

The base voltage of transistor is held relatively constant voltage across the zener diode.

$V_{out} = V_z - V_{BE}$

If the output voltage decreases, the increased base-emitter voltage causes the transistor to conduct more, thereby raising the output voltage. On the other hand, if the output voltage is increased, the decreased base-emitter voltage causes the transistor to conduct less. Therefore, the output voltage remains regulated in both the instances.

The limitations of this circuit are:

a) Although the changes in Zener current are reduced a lot, yet the output is not constant. This is due to decrease in both V_{BE} and V_Z as the room temperature increases.
b) The output voltage cannot be changed easily as no such means is provided.

Transistor Shunt Voltage Regulator

A shunt voltage regulator provides regulation by shunting current away from the load to regulate the output voltage. The circuit diagram of shunt voltage regulator is shown below.

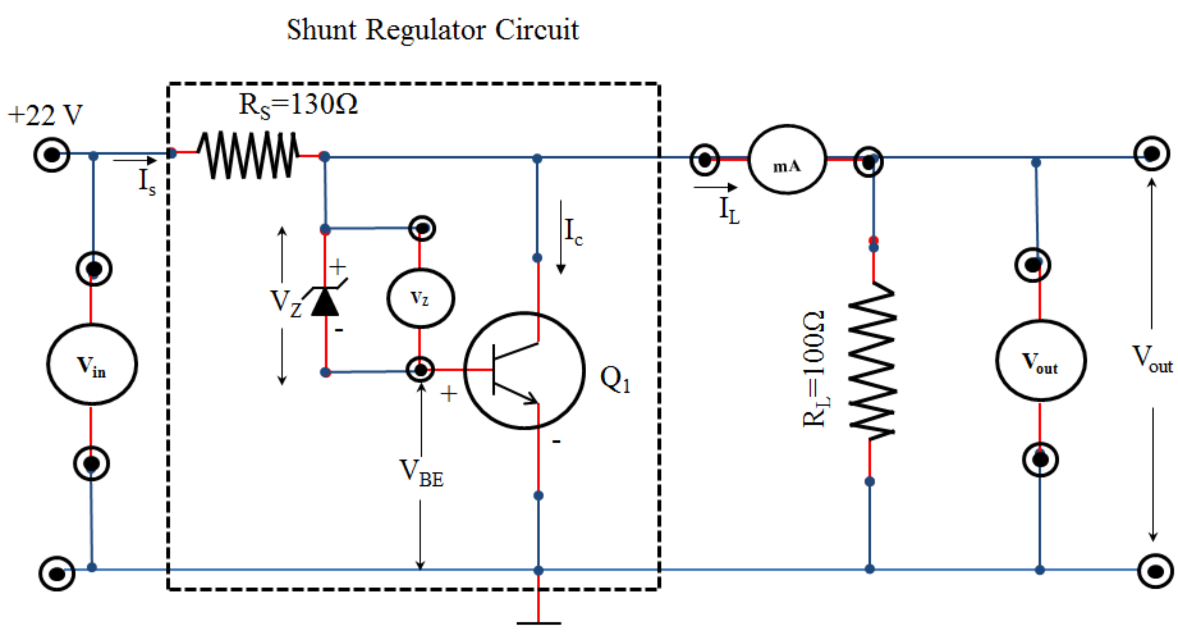


Figure 2. Circuit diagram for a transistorized shunt voltage regulator

The voltage drop across series resistance depends upon the current supplied to the load R_L. The output voltage is equal to sum of zener voltage (V_z) and transistor base-emitter voltage (V_{BE})

$V_{out} = V_z + V_{BE}$

If the load resistance decreases, the current through base of transistor decreases. As, a result, less collector current is shunted. Therefore, the load current becomes larger, thereby maintaining the regulated voltage across the load.

PROCEDURE:

1. Connect the circuit as shown in the figure 1 and 2, respectively.
2. Connect the frequency generator at the input of the circuit at specified voltages (see figure).
3. Keep the voltage below the zener breakdown voltage.
4. By variying the voltage in steps of 0.1 to 1V, note down the changes in load resistance.

Table:

S. No.	**Input Voltage (V_{in})**	**Output Voltage(V_{out})**
1	0.1	
2	0.2	
3	0.3	
4	.	
5	.	
6	.	
.	.	
.	.	
.	.	
10.	1	

RESULT: The transistor series and shunt voltage regulators have been studied.

PRECAUTIONS:

1. Make the connections properly.
2. Never cross the zener breakdown voltage.
3. Keep a check on the β parameter of the transistor for calculating the I_c and I_b, if required for calculations.

EXPERIMENT No. 6A

STUDY OF TRANSISTOR

You have to design specifically on breadboard using different components (passive and active) for the comparative study of Common Emitter (CE), Common Base (CB) and Common Collector (CC) Transistor Amplifiers. These practical transistor amplifier configurations are evaluated in respect of their main parameters and results are compared with theoretical calculations. Practical experience on this board carries great educative value for Science and Engineering Students.

OBJECTIVE:

1. Study of Common Emitter (CE) transistor amplifier circuit and evaluation of its input and output resistance, voltage gain and power gain.
2. Study of Common Base (CB) transistor amplifier circuit and evaluation of its input and output resistance, voltage gain, current gain and power gain.
3. Study of Common Collector (CC) transistor amplifier circuit and evaluation of its input and output resistance, voltage gain, current gain and power gain.

FEATURES:

The circuit consists of following built – in parts:

1. ± 9V DC at 100mA, IC Regulated Power Supply internally connected.
2. All the three circuits i.e. CE, CB and CC are built separately.
3. Adequate number of other electronic components.
4. Sine Wave Signal Generator of 1 KHz, with variable level, low distortion, based on IC.
5. Mains ON/OFF switch, Fuse and Jewel light.
6. The unit is operative on 230 V ± 10% at 50 Hz AC Mains.
7. Adequate number of patch cords stackable from rear both ends 4 mm spring loaded plug length 0.5 meter.
8. Good quality, reliable terminal / sockets are provided at appropriate places on panel for connections / observation of waveforms.

OTHER APPARATUS REQUIRED:

1. Cathode Ray Oscilloscope 20 MHz
2. A.C Millivoltmeter OMEGA TYPE ACV – 25

PANEL DESCRIPTION:

Keep a 1 KHz sine wave signal source with adjustable level. In the breadboard, draw three transistor amplifiers of common emitter, common base and common collector configurations respectively.

THEORY:

Three Basic Transistor Configurations

A transistor has three electrodes (terminals) i.e., Emitter, Base and Collector. In whatever way a transistor is connected in a circuit it must have two input leads and two output leads. Since a transistor has only three leads this follows that one lead will be common to both input and output. The common lead gives the name to that transistor configuration viz. Common emitter, Common base and Common collector. The common collector configuration is also called emitter follower.

Very often the common lead is used as a reference point for the entire circuit and is thus connected to chassis or ground. Hence the three configurations can also be called as grounded emitter, grounded base and grounded collector. These three basic transistor configurations are shown in Figure 1.

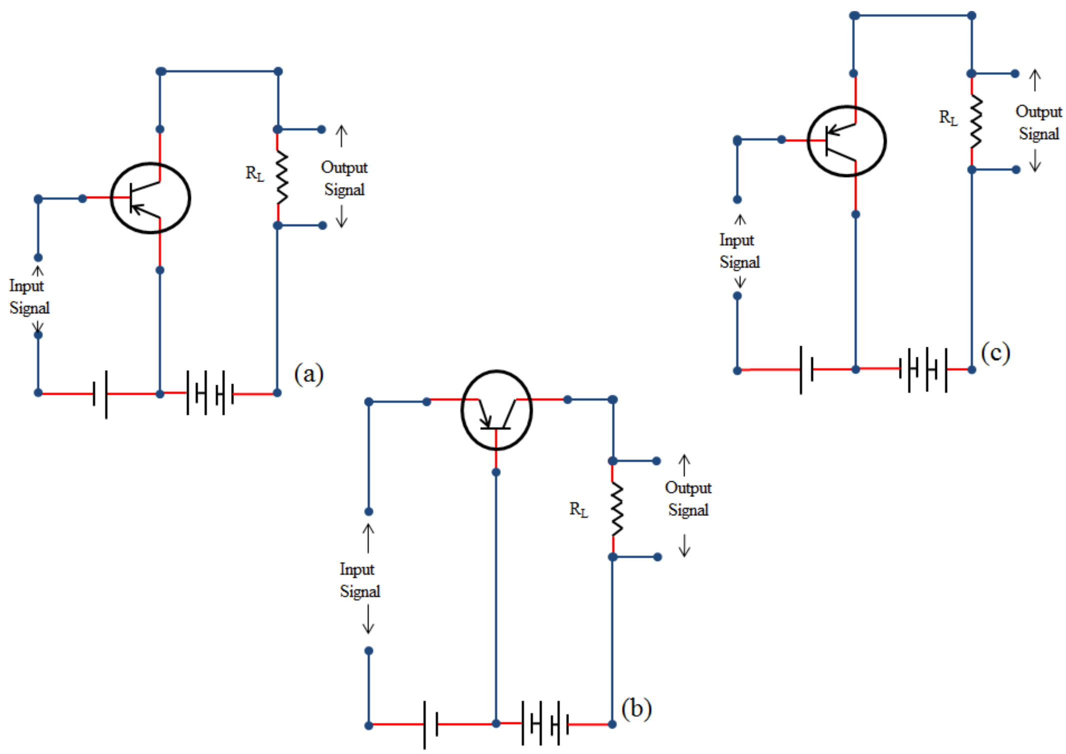


Figure 1(a) Common Emitter Collector (b) Common Base (c) Common Collector circuit diagrams

Each configuration has specific characteristics that make it useful in different circumstances. Their characteristics are compared in table 1.

Table 1:

Parameters / Configuration	Input Resistance (R_{in})	Output Resistance (R_{out})	Voltage Gain (A_v)	Current Gain (A_i)	Power Gain (A_p)	Where Used
Common Emitter	Around 1K	Around 20 K	Around 100	Around 100	Around 10,000	General Purpose Amplification
Common Base	Around 100 E	Around 500 K	Around 100	Less than 1	Around 50	Very high frequency circuits
Common Collector	Around 300 K	Around 200 E	Less than 1	Around 100	Around 50	Buffer circuits

Note: In practical circuits this is approximately equal to the value of collector resistance.

The parameters given in Table 1 are only for comparison purpose. The actual values in practical circuits are subject to particular device and circuit design.

1. COMMON EMITTER:

In the common emitter circuit, the input and output voltage are 180° out of phase. In this configuration the current gain is called Beta (β).

The voltage gain A_v, the current gain A_i and input and output resistance may be calculated from the following relation:

$$A_v = -\frac{h_{fe} R_c}{h_{ie}}$$

$$A_i = -h_{fe}$$

$$A_p = A_v \cdot A_i$$

$$R_{in} = h_{ie} - \frac{h_{re}h_{fe}R_c}{1 + h_{oe}R_c}$$

Or

$$R_{in} = h_{ie}$$

Or

$$R_o = {}^{1}\Big/\left(h_{oe} - \left[\frac{h_{re}h_{fe}}{h_{ie}R_s}\right]\right)$$

$$R_o = {}^{1}/_{h_{oe}}$$

The current gain in common emitter configuration is mentioned as

$$\text{Beta } (\beta) = \frac{\Delta\, l_c}{\Delta l_b} = \frac{Change\ in\ collector\ current}{Change\ in\ base\ current}$$

The *h* parameter of the transistor used in this training board i.e, BC 177 (PNP) from the data book are as follows:

At 3 mA collector current

$$h_{ie} = 2K2$$

$$h_{fe} = 100$$

$$h_{oe} = 50\,\mu\, mho$$

Note: The above parameters are not measured parameters for the particular transistor used. The actual parameters of the particular transistor may differ from these figures.

Substituting these in the relation for voltage, current gain & input and output resistances we get:

$$A_v = -\frac{100\ \times 2K2}{2K2} = -100$$

$$A_i = -h_{fe} = -100$$

$$A_p = 100\ \times 100 = 10{,}000$$

$$R_{in} = h_{je} = 2\text{K}2$$

$$R_o = \frac{1}{h_{oe}} = \frac{1}{50\ \times\ 10^{-6}} = 20K$$

2. COMMON BASE:

In this configuration the emitter base circuit is forward biased whereas the collector base circuit is reverse biased. In the common base circuit the input and output voltages are in phase. The current gain of this configuration is termed as alpha (α).

The relation between alpha and beta is given below:

$$\beta = \frac{\alpha}{1-\alpha}$$

Where β = current gain of common emitter configuration

This circuit is used for VHF and UHF amplification, as well as to match low impedence to high impedence. Here,

$$A_v = \frac{i_c}{i_e} \cdot \frac{R_L}{r_{in}}$$

$$A_i = {}^{i_c}/_{i_e}$$

$$r_{in} = \frac{V_{be}}{i_e} - R_s$$

$$r_o = \frac{\Delta V_{cb}}{\Delta i_c}$$

For the given circuit these parameters are:

$$A_v = 50$$

$$A_i = 0.96$$

$$A_p = 48$$

$$r_{in} = 100\ E$$

$$r_o = 2K$$

3. COMMON COLLECTOR:

In this configuration also the input and output voltages are in phase. This circuit is quite different from the two previous circuits. The input resistance of this configuration is high due to the high resistance of the base collector circuit. The output resistance is low due to the low resistance of the emitter collector circuit. The circuit makes an excellent isolation network between a high impedence and a low impedence circuit. The voltage and current gain & input and output resistances can be calculated using the following relations:

$$A_v = 1 - \left({h_{ie}}/{R_{in}} \right)$$

$$A_i = 1 + h_{fe}$$

$$A_p = A_v \, . A_i$$

$$R_{in} = h_{ie} + \left(1 + h_{fe}\right) R_E$$

$$R_o = {h_{ie}}/{1 + h_{fe}}$$

Using the above formulae we get:

$$A_v = 0.99$$

$$A_i = 101$$

$$A_p = 99.99$$

$$R_{in} = 335.5K$$

$$R_o = 22\ E$$

OBJECTIVE 1: STUDY OF COMMON EMITTER (CE) TRANSISTOR AMPLIFIER CIRCUIT AND EVALUATION OF ITS INPUT AND OUTPUT RESISTANCE, VOLTAGE GAIN, CURRENT GAIN AND POWER GAIN

PROCEDURE:

1. Turn the knob marked level of 1 KHz sine wave generator to fully anti clockwise direction and using connecting leads connect the output of sine wave generator to the input of common emitter transistor amplifier. Also connect 4K7 resistor as load to the output. Refer to Figure 2.

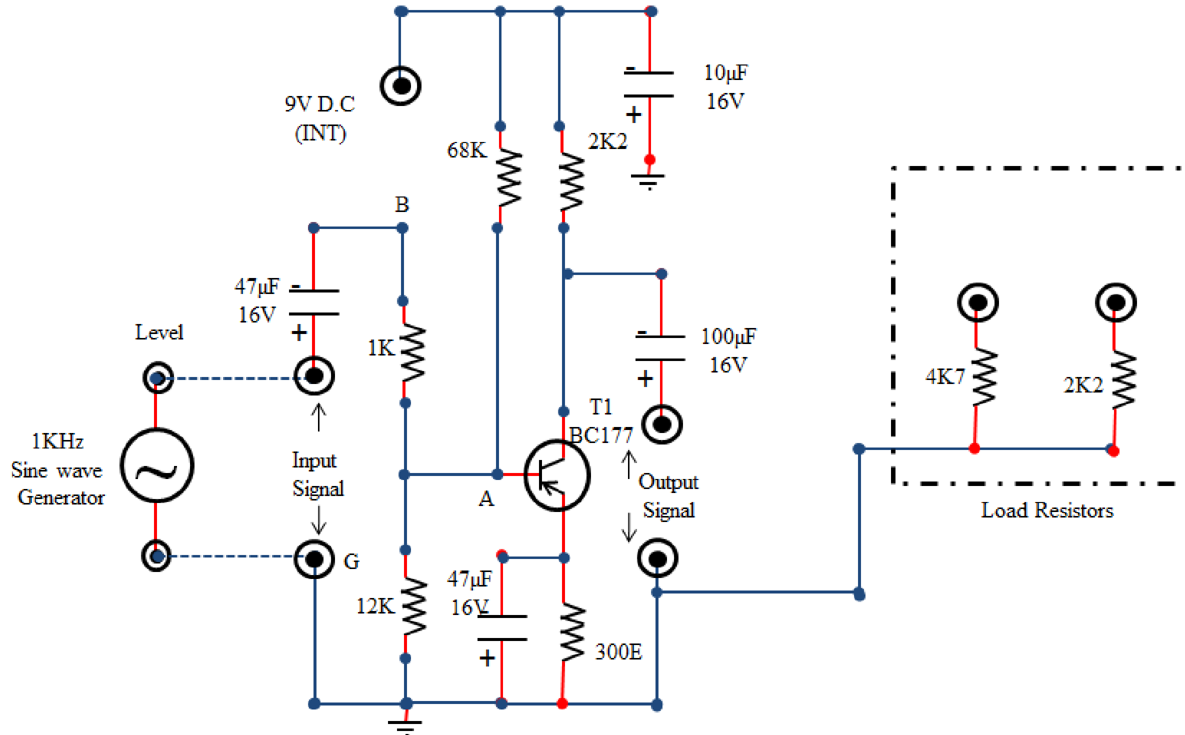


Figure 2. Study of common emitter transistor amplifier

2. Switch on the mains power to the training board.
3. Now connect the CRO probe to output sockets of CE amplifier. Increase the level of sine wave generator till the output as seen on the CRO is a clean & undistorted sine wave of about 3V peak to peak.
4. Now using a calibrated CRO or A.C millivoltmeter record the A.C voltages at the sockets marked 'A' and 'B' (These voltages are measured with respect to ground socket marked G) these are V_{AG} and V_{BG}, respectively.
5. Now connect the CRO probe to the output sockets of CE amplifier. Disconnect the 4K7 resistor across the output sockets and now connect the 2K2 resistor in its place. Note the level of output signal on CRO, it should have reduced to approximately half the original value.

   Record the reading below:

   R_i = 1 Kohm (connected between A and B)

   R_L = 4K7

   V_o =________

   V_{AG} = ________

   V_{BG} = ___________

   Now calculate various parameters using the following formulae:

$$A_v = {}^{V_o}/_{V_{AG}}$$

$$A_i = \frac{V_o R_i}{R_L(V_{BG} - V_{AG})}$$

$$A_p = A_v . A_i$$

$$R_{in} = {V_{AG} R_i}/{(V_{BG} - V_{AG})}$$

R_o = Value of resistance connected across the output at which the output level falls to half the original level

= 2K2 (as demonstrated above)

Now compare these results with the theoretical results as shown earlier in theory section.

OBJECTIVE 2: STUDY OF COMMON BASE (CB) TRANSISTOR AMPLIFIER CIRCUIT AND EVALUATION OF ITS INPUT AND OUTPUT RESISTANCE, VOLTAGE GAIN, CURRENT GAIN AND POWER GAIN

PROCEDURE:

1. Turn the knob of 1 KHz sine wave generator to fully anti clockwise direction and using connecting leads connect the output of sine wave generator to the input of common base transistor amplifier. Also connect 4K7 resistor as load to the output Ref. to Figure 3
2. Switch on the mains power to the training board.
3. Now connect the CRO probe to the output sockets of CB amplifier. Increase the level of sine wave generator till the output as seen on the CRO is a clean undistorted sine wave of about 0.3 volt peak to peak.
4. Now using a calibrated CRO or A.C millivoltmeter record the A.C voltages at the sockets marked 'A' and 'B' (These voltages are measured with respect to ground socket marked 'G') these are V_{AG} and V_{BG}, respectively.

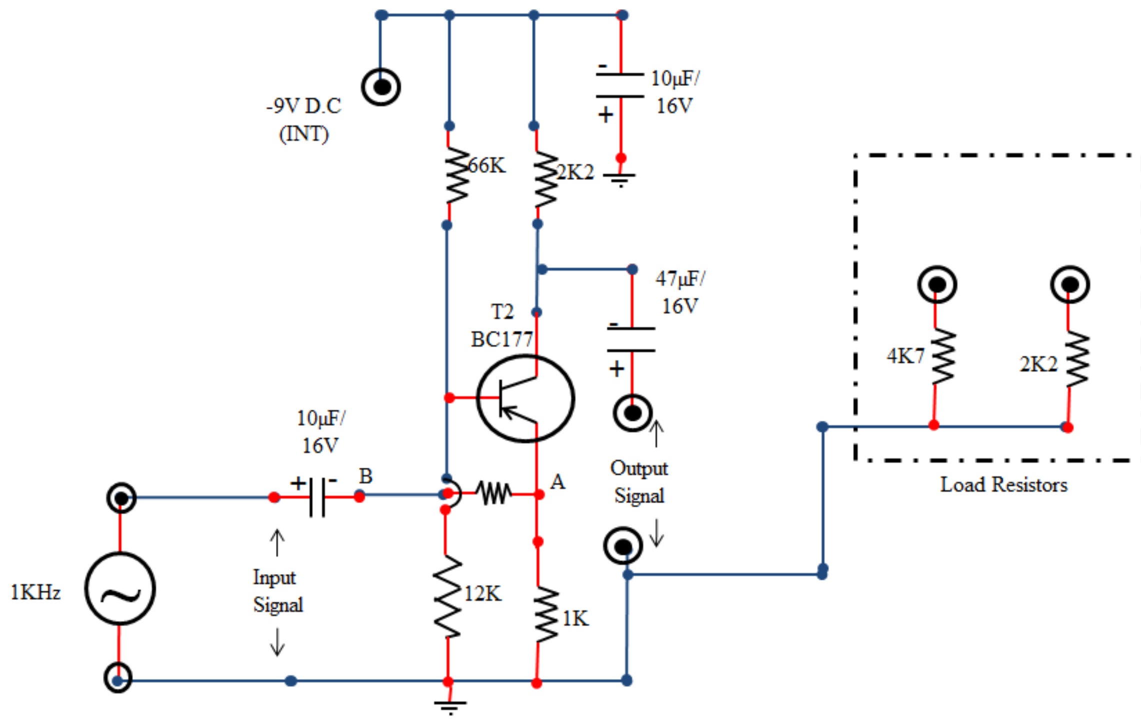


Figure 3. Study of common base transistor amplifier circuit

5. Now connect the CRO probe to the output sockets of CB amplifier. Disconnect the 4K7 resistor across the output sockets and connect the 2K2 resistor in its place. Note down the level of output signal on CRO it should have reduced to approximately half the original value.
   Record the reading below:
   R_i = 1 K ohm (connected between 'A' and 'B')
   R_L= 4K7
   V_{AG} =
   V_{BG} =
   Now calculate various parameters using the following formulae:

$$A_v = {}^{V_o}/_{V_{AG}}$$

$$A_i = {}^{V_o R_i}/_{R_L (V_{BG} - V_{AG})}$$

$$A_p = A_v . A_i$$

$$R_{in} = {}^{V_{AG} R_i}/_{(V_{BG} - V_{AG})}$$

R_o = value of resistance connected across the output at which the output level falls to half the original level = 2K2 (as demonstrated above)

Now compare these results with the theoretical results as shown earlier in theory section.

OBJECTIVE 3: STUDY OF COMMON COLLECTOR (CC) TRANSISTOR AMPLIFIER CIRCUIT AND EVALUATION OF ITS INPUT AND OUTPUT RESISTANCE, VOLTAGE GAIN, CURRENT GAIN AND POWER GAIN

PROCEDURE:

1. Turn the knob of 1 KHz sine wave generator to fully anti – clockwise direction and using connecting leads connect the output of sine wave generator to the input of common collector transistor amplifier. Also connect 1K resistor as load to the output as shown in Figure 4.

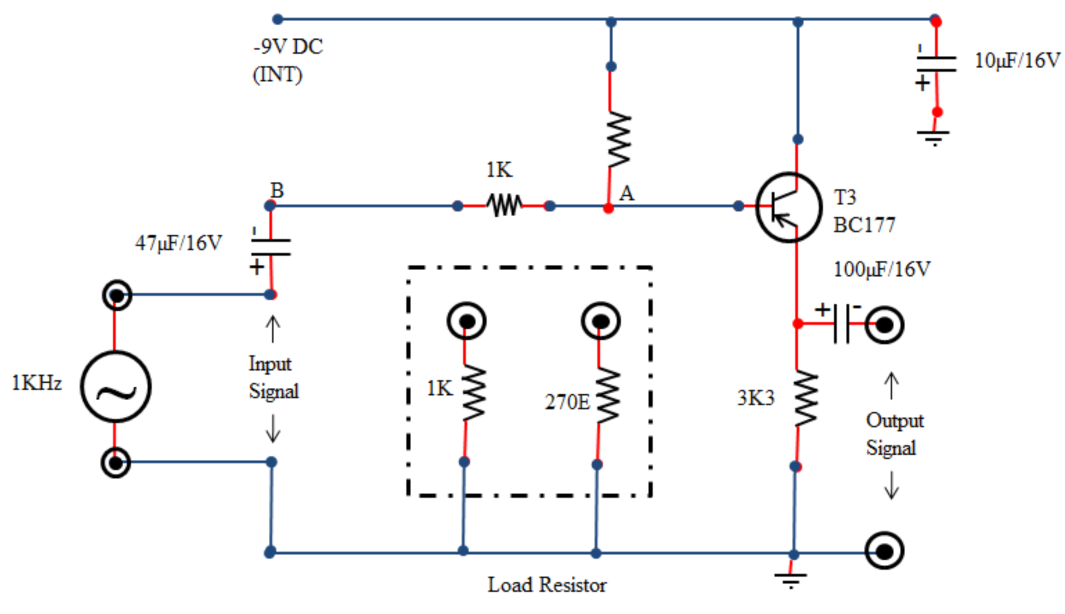


Figure 4. Study of Common Collector Amplifier circuit

2. Switch on the mains power to the training board.
3. Now connect the CRO probe to the output sockets of CC amplifier. Increase the level of sine wave generator till the output as seen on the CRO is clean undistorted sine wave of about 3V peak to peak.
4. Now using a calibrated CRO or A.C millivoltmeter, record the A.C voltages at the sockets marked 'A' and 'B' (These voltages are measured with respect to ground socket marked 'G') these are V_{AG} and V_{BG}, respectively.

5. Now connect the CRO probe to the output sockets of CC amplifier. Disconnect the 1K resistor across the output sockets and connect the 270E resistor in its place. Note down the level of output signal on CRO, it should have reduced to approximately half the original value.
   Record the reading below:
   R_i = 1K ohm (connected between 'A' and 'B')
   R_L= 1K
   V_{AG} =______
   V_{BG} =______
   Now calculate various parameters using the following formulae:

$$A_v = {V_o}/{V_{AG}}$$

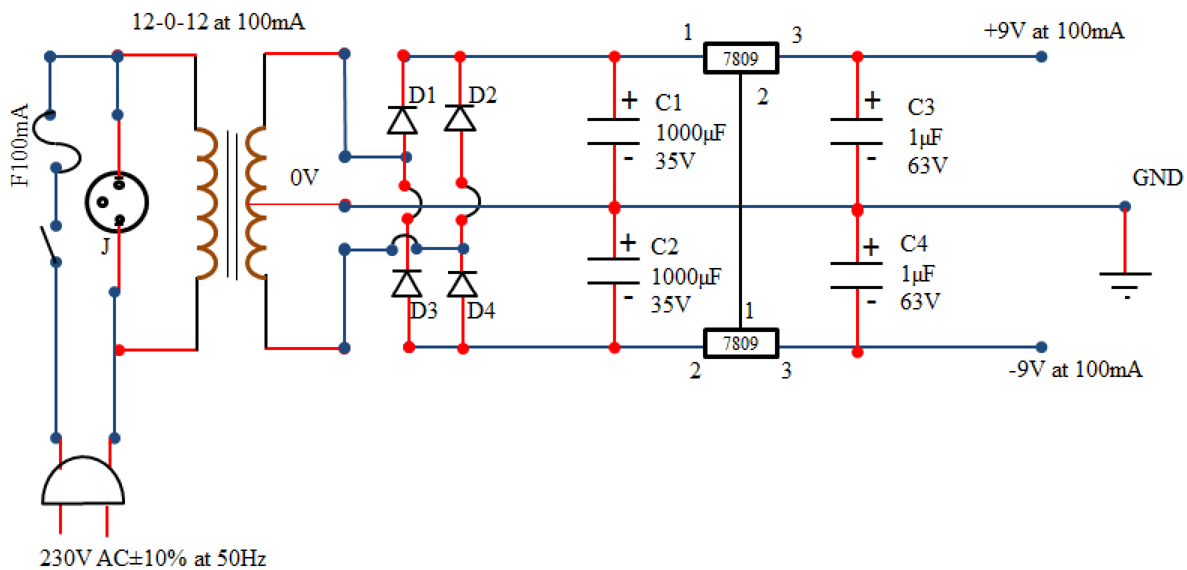
$$A_i = {V_o R_i}/{R_L(V_{BG} - V_{AG})}$$

$$A_p = A_v . A_i$$

$$R_{in} = {V_{AG} R_i}/{(V_{BG} - V_{AG})}$$

   R_o = the value of resistance connected across the output at which the output level falls to half the original level.
   = 270E (as demonstrated above)
   Now compare these results with the theoretical results as shown earlier in the theory section.

BREADBORD CIRCUIT:



VIVA-VOCE

1. Explain why the input and output signals in common emitter amplifiers are out of phase?
2. Which configuration has the highest power gain?
3. If the current gain (A_i) of a common emitter amplifier is 100, what can you state regarding its h_{fe}?

EXPERIMENT 6B

STUDY OF TRANSISTOR AS FEEDBACK AMPLIFIERS

SINGLE STAGE COMMON EMITTER AMPLIFIER

OBJECTIVE: To study response characteristics of a transistorised RC coupled amplifier with and without negative current feedback.

APPARATUS REQUIRED: PNP transistor 2SB 77, or AC 125, Resistances of values shown in the circuit (2K, 3K, 5K, 22K, 5.1K, 470Ω), Capacitances shown in the circuit (100 µF, 100 µF, 50 µF, 50 µF). Audio frequency generator (0 – 50 kc/s), V.T.V.M. as output meter, High frequency (a.c.) millivoltmeter (0 – 500 mV), 6V d.c. supply.

CIRCUIT DESIGN:

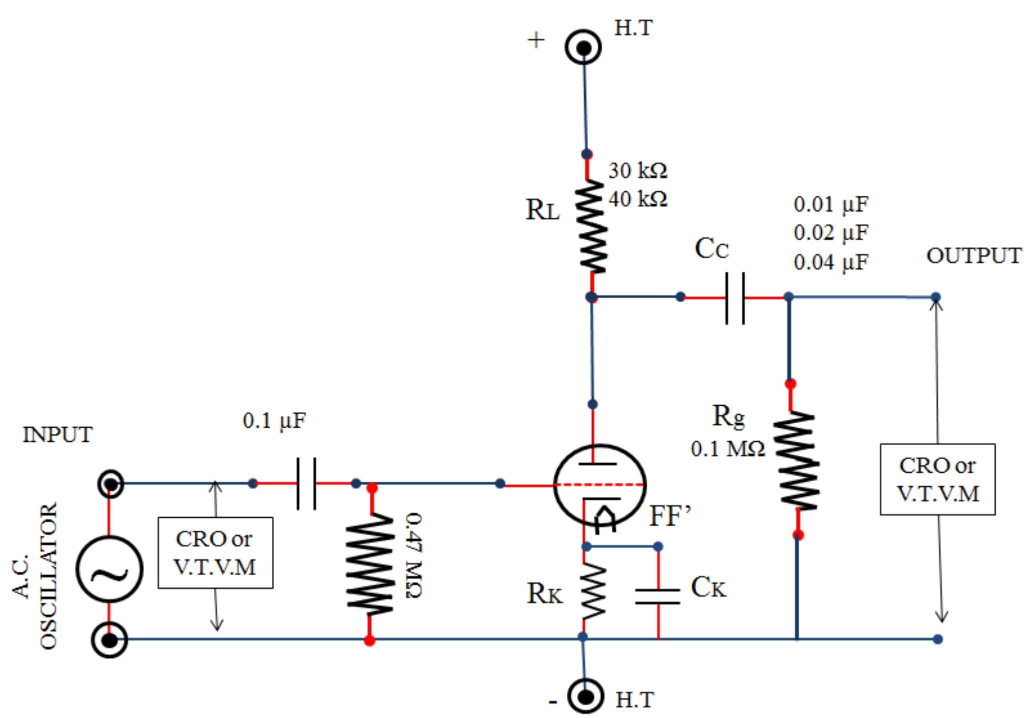


Figure1. Single RC stage coupled amplifier. For current feedback switch K should be open

PROCEDURE: Refer to Figure 1.

(A) Without Current Feedback: Switch K is closed:

1. Connect CA and CE.
   Keep input voltage (10 mV) constant. Vary oscillator frequency from 10 c/s to 50 kc/s and note the output voltage at various frequencies.
2. Connect CB and CE.
   Repeat the procedure written in step 1.
3. Take similar set of observations by connecting CD and CE, CA and CF, CB and CF, CD and CF.

(B) With Current Feedback: Switch K is open:

Repeat the whole procedure detailed in above method (A).

OBSERVATIONS:

(A) Without Current Feedback:

Frequency c/s	**Output in Volts**					
	C = 50 μF with CA CB CD			**C= 100 μF with CA CB CD**		
	2k	**3k**	**5k**	**2k**	**3k**	**5k**
10	…	…	…	…	…	…
50	…	…	…	…	…	…
100	…	…	…	…	…	…
…..	…	…	…	…	…	…
…..	…	…	…	…	…	…
50,000	…	…	…	…	…	…

(B) With Current Feedback:

Prepare same table as in (A).

RESULTS:

Find the voltage amplification at various frequencies by

$$Voltage\ Amplification = \frac{Output\ Voltage}{Input\ Voltage}$$

And then plot graphs in voltage amplification and corresponding frequencies. Do it for both the cases – with and without current feedback. Without feedback, curves will show rapid fall in gain at low and high frequencies but not so with feedback.

Sources of Error and Precautions:

1. Input Voltage should be kept low.
2. Take precautions about the polarities while connecting the supply.
3. Zero adjustment for every range of V.T.V.M selected should be done.

EXPERIMENT 6C

INSTRUCTION MANUAL FOR STUDY OF CLASS 'A', 'B', 'AB' AND PUSH PULL AMPLIFIER

Class 'A', 'B', 'AB' and Push Pull Amplifier Circuits has been designed to study the output again and frequency response of these amplifiers.

The instrument comprises of the following built – in parts:

1. DC Regulated power supply of ± 12V and +5V.
2. Four PNP and four NPN Transistors are mounted on the front panel.
3. Four driver transformers are also mounted on the front panel to perform class B and Push Pull experiments.
4. Circuit diagram is printed and components are mounted on the front panel.

THEORY:

A practical amplifier always consists of a number of stages that amplify a weak signal until sufficient power is available to operate a loudspeaker or other output device. The first few stages in this multistage amplifier have the function of only voltage amplification. However, the last stage is designed to provide maximum power. This final stage is known as power stage. The term audio means the range of frequencies that we can hear. The range of human hearing extends from 20 Hz to 20 kHz. Therefore, audio amplifiers amplify electrical signals that have a frequency range corresponding to the range of human hearing, that is, 20 Hz to 20 kHz. Figure 1 shows the block diagram of an audio power amplifier. The early stages built up the voltage level of the signal while the last stage built up power to a level sufficient to operate the loudspeaker.

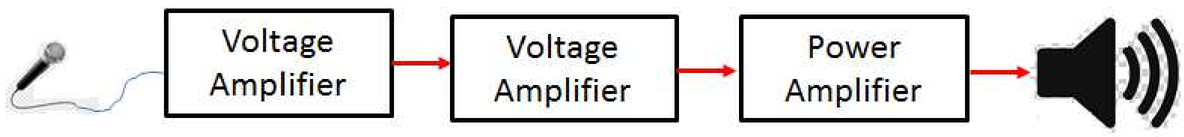
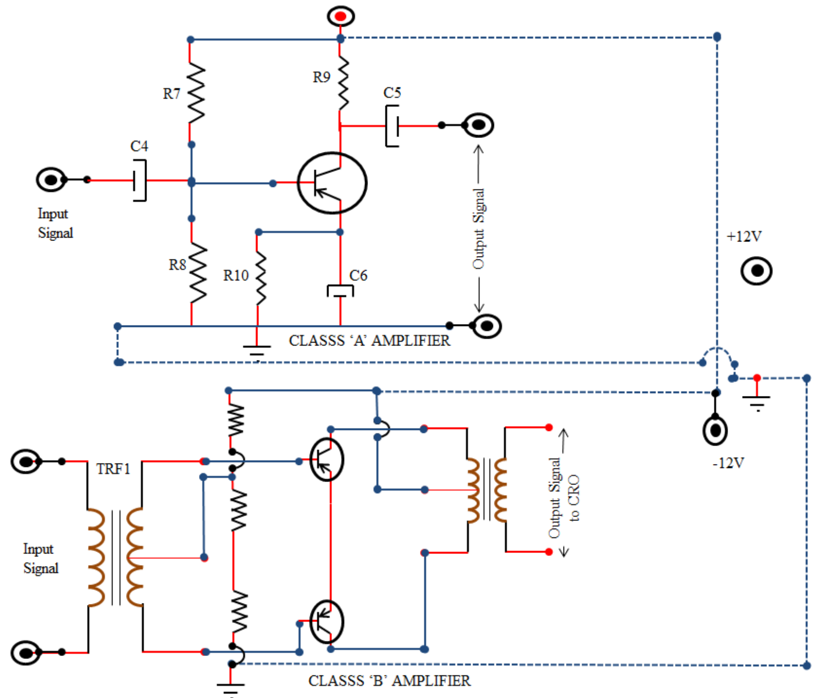


Figure 1. Block diagram of Audio Amplifier showing its various stages

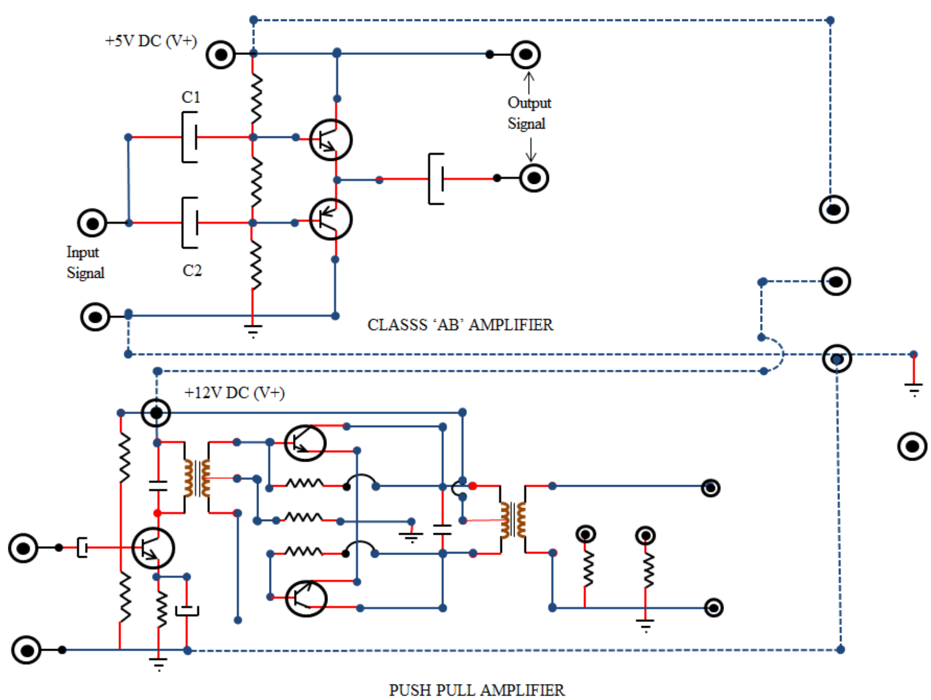
A transistor amplifier which raises the power level of the signals that have audio frequency is known as transistor audio power amplifier. In general, the last stage of a multistage amplifier is the power stage; the amplifier differs from all the previous stages in that here a concentrated effort is made to obtain maximum output power. A transistor that is suitable for power amplification is generally called a power transistor. A power amplifier is required to deliver a large amount of power and such it has to handle large current. In order to achieve high power amplification, transformer coupling is used for impedence matching. If the collector current flows at all times during the full cycle of the signal the power amplifier is known as Class ‘A’ power amplifier. A basic class ‘A’ power amplifier normally consists of a signal transistor, wired in the common emitter mode with the speaker acting as its collector load. The essential feature of this type of amplifier is that its input (Base) is biased so that the collector current takes up a quiescent value roughly halfway between the desired maximum and minimum swings of output current, so that maximum undistorted output signal swings can be obtained.

The Class ‘A’ amplifier is simple and produces excellent low distortion audio signal. Its major disadvantages are that it consumes a high quiescent current and is relatively inefficient. A basic Class ‘B’ amplifier normally consists of a pair of transistors driven in anti-phase but driving a common output load. In this particular design the two transistors are wired in common emitter mode and driven the speaker via Push Pull transformer. The major advantages of the Class ‘B’ amplifier are that it consumes near zero quiescent current and has a very high efficiency under all operating conditions. Its major disadvantages are that it produces high levels of signal distortion. The crossover distortion of the Class ‘B’ amplifier can be virtually eliminated by applying slight forward bias to the base of each transistor, so that each transistor passes as a modest quiescent current. Such a circuit is known as a Class ‘AB’ amplifier. Circuits of this type were widely used in early transistor power amplifier systems. The Push Pull amplifier is a power amplifier and is frequency employed in output stages of electronic circuits. It is used whenever high output power at high efficiency is required. Two transistors placed back to back are employed. Both transistors are operated in Class ‘B’ operation, i.e., collector current is nearly zero in the absence of the signal. The centre tapped secondary of driver transformer applies equal and opposite voltage to the base circuits of two transistors. The output transformer has the centre tapped primary winding. The supply voltage V_{cc} is connected across the secondary of this centre tap. The loudspeaker is connected across the secondary of this transformer.

CIRCUIT DIAGRAM:



(a)



(b)

Figure 1. (a) Circuit diagram of Class A and Class B amplifier and (b) Class AB and Push pull amplifier

PROCEDURE:

For Class 'A' Amplifier:

1. Connect -12 V DC power supply across power supply sockets through patch cords as shown by dotted lines in the circuit diagram of Class 'A' amplifier.

Table 1:

Sr. No	Frequency	Input Signal	Output Signal	Gain Output/ Input
1				
2				
3				
4				
5				

2. Connect Audio Frequency Function Generator across input sockets and set it at sine wave signal of 30 mV peak to peak amplitude, 100 Hz frequency.
3. Connect CRO across output sockets.
4. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
5. Observe the amplitude output on CRO. Note down the output amplitude.
6. Calculate the voltage gain of the amplifier, using formula

$$A_v = V_{Out} / V_{In}$$

7. Increase the frequency of the signal towards 100 KHz in small steps and note down the voltage gain at different frequencies.
8. Note down the observation in table no. 1 and plot a graph between Voltage Gain vs Frequency as shown in Figure 2.

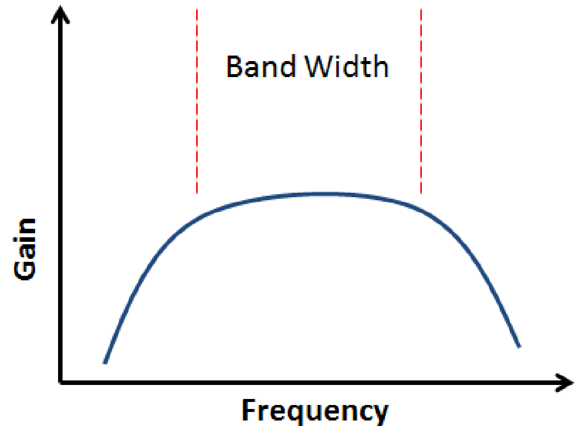


Figure 2. Plot a graph between Voltage Gain vs Frequency

For Class ‘B’ Amplifier:

1. Connect -12 V DC power supply across power supply sockets through patchcords as shown by dotted lines in the circuit diagram of Class ‘B’ amplifier.

Table 2:

Sr. No	Frequency	Input Signal	Output Signal	Gain Output/ Input
1				
2				
3				
4				
5				

2. Connect Audio Frequency Function Generator across input sockets. Set the Audio Frequency Function generator output to 50 mV peak to peak, 10 kHz sine wave signal.
3. Connect CRO across output sockets.
4. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
5. Observe the amplitude output on CRO. Note down the output amplitude.
6. Calculate the voltage gain of the amplifier, using formula

$$A_v = V_{Out} / V_{In}$$

7. Increase the frequency of the signal towards 100 KHz in small steps and note down the voltage gain at different frequencies.
8. Note down the observation in table no. 2 and plot a graph between Voltage Gain vs Frequency as shown in Figure 3.

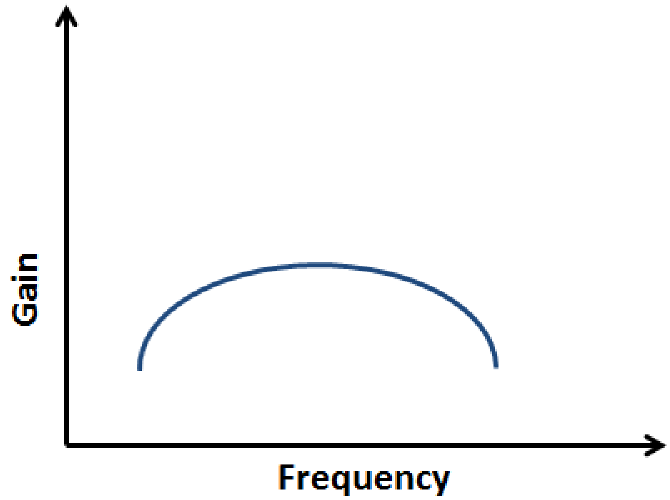


Figure 3. Plot a graph between Voltage Gain vs Frequency

For Class 'AB' Amplifier:

Class 'AB' amplifier is basically a power amplifier, it handles large signal. It amplifies the power level of the signal and does not amplify the voltage level.

1. Connect +5V DC power supply across power supply sockets through patch cords as shown by dotted lines in the circuit diagram of Class 'AB' amplifier.

Table 3:

Sr. No	**Frequency**	**Input Signal**	**Output Signal**	**Gain Output/ Input**
1				
2				
3				
4				
5				

2. Connect Audio Frequency Function Generator across input sockets and set it at sine wave signal of 2V peak to peak amplitude, 10 Hz frequency.
3. Connect CRO across output sockets.
4. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
5. Observe the output on CRO. Note down the output amplitude.
6. Calculate the voltage gain of the amplifier, using formula

$$\mathbf{A_v = V_{Out} / V_{In}}$$

7. Increase the frequency of the signal towards 100 KHz in small steps and note down the voltage gain at different frequencies.
8. Note down the observation in table no. 3 and plot a graph between Voltage Gain vs Frequency as shown in Figure 4.

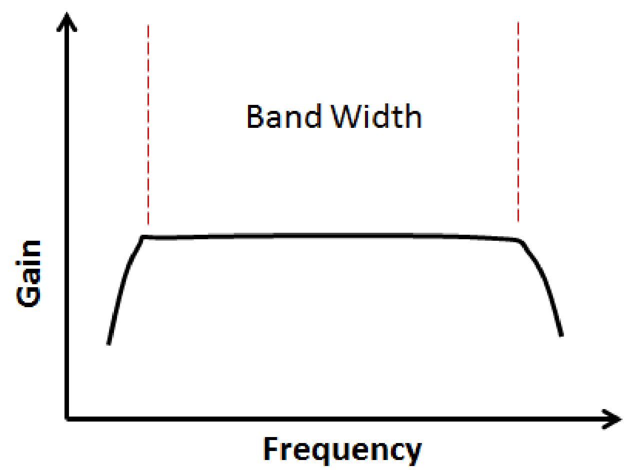


Figure 4: Graph of voltage gain vs frequency

9. We will observe this amplifier does not amplify the voltage level of the input signal but only the power level of the signal amplifies. If we will connect the loudspeaker load across output socket, the amplifier will drive the loudspeaker.

For Push Pull Amplifier:

1. Connect +12V DC power supply across power supply sockets through patchcords as shown by dotted lines in the circuit diagram of Push Pull amplifier.

Table 4:

Sr. No	Frequency	Input Signal	Output Signal	Gain Output/ Input
1				
2				
3				
4				
5				

2. Connect Audio Frequency Function Generator across input sockets and set it at sine wave signal of 50mV – 100mV peak to peak amplitude, 1.5 KHz frequency.
3. Connect CRO across output sockets.
4. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
5. Observe the amplified output on CRO. Note down the output amplitude.
6. Calculate the voltage gain of the amplifier, using formula

$$A_v = V_{Out} / V_{In}$$

7. Increase the frequency of the signal in small steps and note down the voltage gain at different frequencies.
8. Note down the observation in table no. 4 and plot a graph between Voltage Gain vs Frequency.

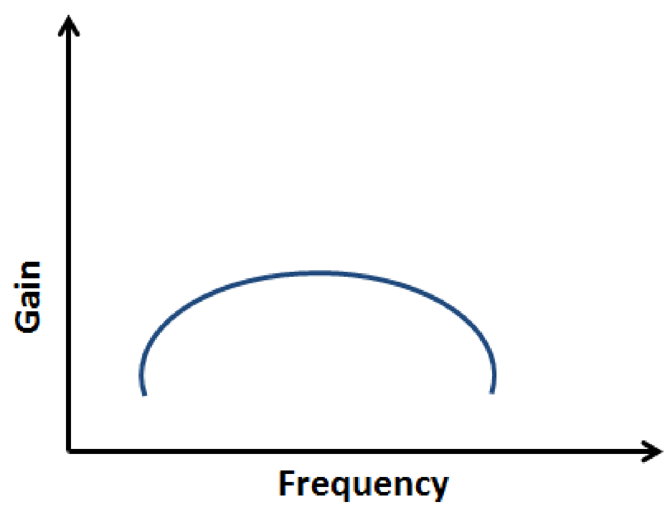


Figure 5. Plot a graph between Voltage Gain vs Frequency.

9. Connect the load resistance (R17 or R18) across output sockets and calculate the output power by using the formula;

$$P = V^2/R \text{ (V is the RMS value of the output signal)}$$

EXPERIMENT 7A

STUDY OF DIFFERENT TYPES OF RESISTORS

OBJECTIVE: To study about different types of resistors and its colour coding.

APPARATUS:

Different types of resistors

THEORY:

This is the most common component in electronics. It is used mainly to control current and voltage within the circuit. Its function is to reduce the flow of electric current. Its value is designated in units called the 'Ohm'. A 1000 ohm resistor is typically known as 1 K=Ohm. It is an electrical component with known specified value of resistance. The opposition to the flow of electric current is known as resistance. The resistance of resistor is given by

$$R = V/I$$

Where, R=Resistance, V= Voltage, I = Current

Types of Resistors: There are two types of resistors;

1. Fixed Resistor
2. Variable Resistor

Fixed Resistor is one whose value remains stable within the limits of its specification. Variable resistors are the resistor whose resistance can be changed from zero to a certain maximum value.

There are two types of fixed resistors; 1) Linear and 2) Non Linear. In linear resistor, there is linear relationship between resistance and temperature while in non linear resistor, there is non – linear relationship between resistance and temperature.

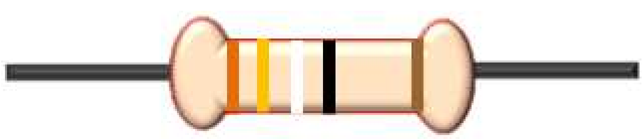


Figure 1. Symbol of a resistor

There are five types of linear resistors as under:

1. Carbon composition
2. Metal film

3. Carbon film
4. Wire wound
5. Cernet

Specification of Resistors: The electrical specifications of resistor are its resistance value, tolerance, wattage, voltage and temperature coefficient.

The value of the resistor can be verified by the colour coding scheme. The tolerance is the deviation from the real or actual value of resistance. For example, if the resistance value of a resistor indicates 10 K Ohm ± 10% then the tolerance will indicate that the resistance value of the resistor lies between 9 K Ohm to 11 K Ohm.

Based on the tolerance value the resistors can be classified as general purpose resistors (±5%, ±10%, ±20%), semi – precision resistor (±5% to ±10%), or precision resistors (±0.01 to 10%). Wattage rating is the maximum power in watts that the resistor can safely dissipate at ambient temperature (i.e. without excessive heat). Since it is the current which produces heat power ratings indicate the maximum current rating a resistor can safely carry. If the current exceeds this value more heat will be produced than that can be carried safely and the resistor will eventually burn out. For a given value of resistance, greater the physical size, higher is the power rating.

Colour Coding Scheme of Resistor: There are two methods to find value of resistance.

1. **Using Colour band**
   There are two common ways to know the value of a resistor, by measuring it using an Ohmmeter, or by reading the colour code printed on it, which is much faster, when you get used to do it. The colour coding method is explained as below.

   Three band resistors – They represent the value as per the colour code. Absence of fourth band means a resistance tolerance ± 20%.
   Four band resistors – Four band types is the most commonly used colour coding scheme on resistors. It consists of four coloured bands that are painted around the body of the resistor. The first two bands encode the first two significant digits of the resistance value, the third is a power of ten multiplier or number of zeros, and the fourth is the tolerance accuracy, or acceptable error, of the value. The first three bands are equally spaced along the resistor; the spacing to the fourth is wider.

   The table given below s the numerical meaning, and multiplication factor:

Colour	Numerical meaning 1st and 2nd	Multiplying factor	Percent tolerance

	figures		
Black	0	1 or 10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold	-	0.1 or 10^{-1}	±5%
Silver	-	0.01 or 10^{-2}	±10%
No colour	-	-	±20%

The mnemonics of learning the position number & multiplication factor is:
BB ROY Great **B**ritain **V**ery **G**ood **W**ife

For example:

(a) Green-Blue-Yellow-Red is $56 \times 10^3 = 560\ k\Omega \pm 2\%$.
(b) Yellow-Red-Orange-Gold is $42\times10^3\Omega\pm5\%$.

Five band resistors – It is used for higher precision (lower tolerance) resistors (1%, 0.5%) to specify a third significant digit. The first three bands represent the significant digits, the fourth is multiplier, and the fifth is the tolerance. Five – band resistor with a gold or silver 4^{th} band is sometimes encountered, generally on older or specialized resistors. The fourth band is tolerance and the 5^{th}, the temperature coefficient.

Using Character: Here, characters (E, K, M) are used for indication. When characters come between two decimal numbers, it acts as a decimal point.

E means – Ohm

K means – Kilo Ohm

M means – Mega Ohm

For example,

2E5 – 2.5Ω

3K9 – 3.9 kΩ

2M7 – 2.7 MΩ

CONCLUSION: The study of various resistors was done.

PRECAUTIONS:

1. Never bend the resistor wire to many times. It may damage the ceramic resistor structure.
2. Switch off the Digital multimeter when not in use. This may save the draining the battery, when not in use.

EXPERIMENT 7B

STUDY OF DIFFERENT TYPES OF DIODES

Objective: (a)To study VI characteristics and determine the forward and reverse resistance of pn Junction Diode (b)To study the voltage regulating characteristic of a Zener diode.

Apparatus: A junction diode, rheostat, zener diode, variable d. c. Power supply (2-20 Volts), two d.c. voltmeter (0-2 V; 0-10V), d.c. milliammeter (0-100mA), d.c. microammeter (0-100μA).

P-N Junction diode:

Theory:

A *p-n* junction diode is known as a semi-conductor or a crystal diode. When a *p*-type semiconductor is suitably joined to *n* – type semiconductor, the contact surface is called pn junction. The *n* type material has high concentration of free electrons whereas *p*-type has high concentration of holes. Therefore, at the junction, there is tendency for free electrons to diffuse over the *p* side and holes to the *n* – side. This process is called diffusion. As the free electrons move across the junction from *n* – type to *p* – type, they neutralize the holes and a junction devoid of any charge carriers is formed. Hence a positive charge is built on the *n*-side of the junction and a negative charge is developed on the *p* – side of the junction. This further repels the majority charge carriers on both the sides. Therefore, a potion barrier gets formed at the junction. As the layer is deployed of free electrons and holes, it is often called as depletion layer.

The potential difference can be applied across the pn junction in two ways:

1. **Forward Bias**:
   The external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting the current flow, it is called forward biasing. To apply forward bias, connect positive terminal of the battery to *p* type and negative terminal to n type as shown in figure 1.

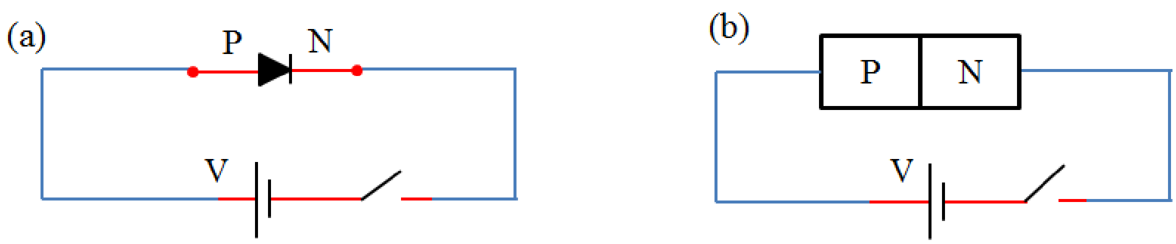


Figure 1. (a) Symbolic representation of a forward bias *pn* junction diode (b) A representation of *p* type and *n* type wafers sandwiched together in a forward bias mode.

The applied forward potential establishes an electric field which acts against the field due to potential barrier. Therefore, the resultant field is weakened and the barrier height is reduced at the junction. As the potential barrier voltage is very small, therefore a small forward voltage is sufficient enough to completely eliminate the barrier. Once the potential barrier is eliminated by the forward voltage, junction resistance becomes almost zero and a low resistance path is established for the entire circuit. Therefore, current flows in the circuit. This is called forward current. With forward bias to pn junction, we note the following points:

1. The potential barrier is reduced and at some forward voltage (~ 0.3 Volts), it is eliminated all together.
2. The junction offers low resistance called forward resistance (R_f) to current flow.
3. The magnitude of current depends upon the applied forward voltage.

2. **Reverse Bias**:
   When the external voltage applied to the junction is in such a direction that the potential barrier is increased, it is called reverse biasing. To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type as shown in Figure 2.

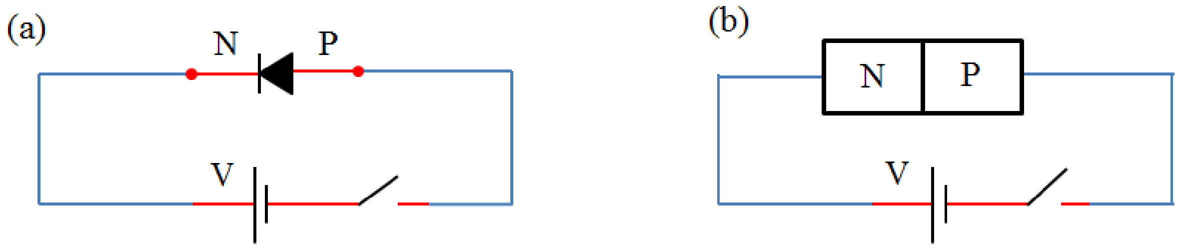


Figure 2. (a) Symbolic representation of a forward bias *pn* junction diode (b) A representation of *p* type and *n* type wafers sandwiched together in a forward bias mode.

It is clear that applied reverse voltage establishes an electric field which acts in the same direction as the field due to potential barrier. Therefore, the resultant field at the junction is strengthened and the barrier height is increased. The increased potential barrier prevents the flow of charge carriers across the junction. Thus, a high resistance path is established for the entire circuit and hence the current doesn't flow. With reverse bias to pn junction, the following observations are noted:

1. The potential barrier is increased.
2. The junction offers very high resistance called reverse resistance R_r.
3. No current flows in the circuit due to the high resistance path.

Procedure:

1. **Forward – Bias Characteristics**:

- Connect the junction diodes in forward bias mode as shown in Figure 3.

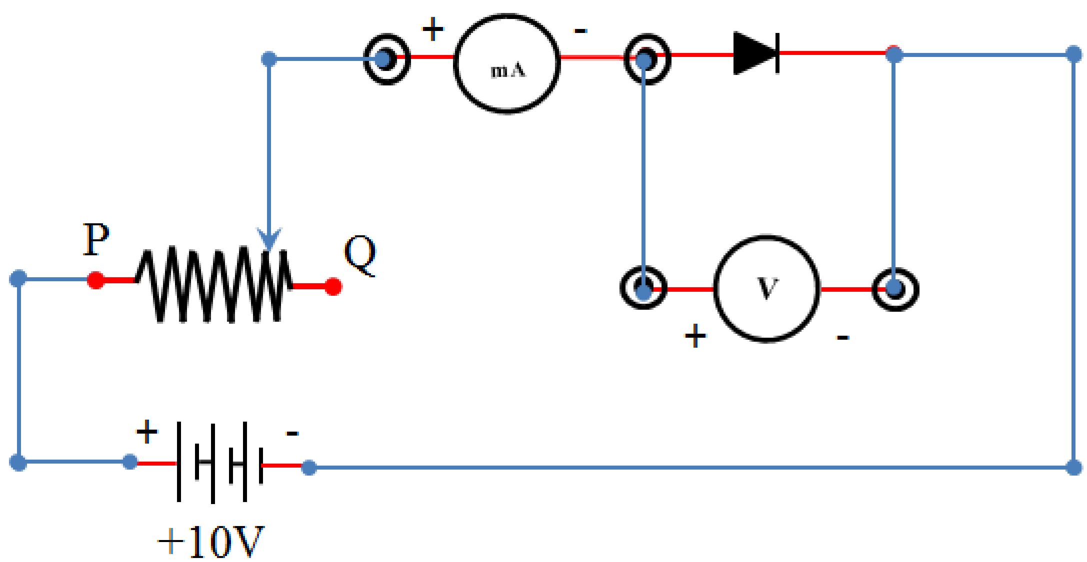


Figure 3. Circuit diagram of forward bias *p-n* junction diode

- Keeping the sliding contact of the rheostat towards Q, switch on the power supply. The voltmeter will show zero.
- Increase the voltage in steps of 0.1 V by moving the sliding contact of the rheostat and record the voltmeter and milliammeter readings. Take observations till the milliammeter reads about 100 mA.

3. **Reverse – Bias Characteristics**:
    - Connect the junction diode in the reverse bias mode as shown in figure.

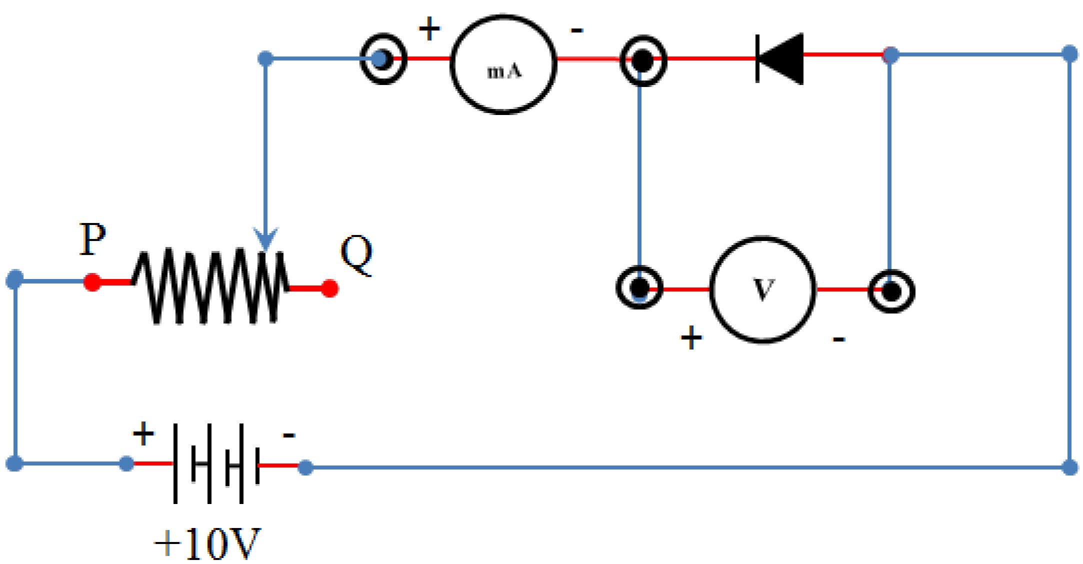


Figure 4. Circuit diagram of reverse bias *p-n* junction diode

- Keeping the sliding contact of the rheostat towards Q, switch on the power supply. Increase the voltage across the diode in steps of one volt by moving the sliding contact of the rheostat and record the voltmeter and micro ammeter readings.
- Draw the forward voltage and current respectively along the + X and +Y axis choosing a suitable scale. Also draw on the same graph paper, the reverse voltage and current respectively along –X and –Y axes choosing another suitable scale.

Note: If you have a variable power supply, then rheostat and fixed supply can be replaced in the circuit.

Observations and Calculations:

Sr. No.	**Forward Bias**		**Reverse Bias**	
	Voltage (V)	**Current (mA)**	**Voltage (V)**	**Current (μA)**
1				
2				
3				

Determine the Forward/Reverse Resistance = $\frac{\Delta V}{\Delta I}$ from the linear region of the graph.

Result: The forward bias and reverse bias characteristic curves are shown in Figure 5 and the for Forward/Reverse Resistance = $\frac{\Delta V}{\Delta I}$ are determined for the given Junction diode

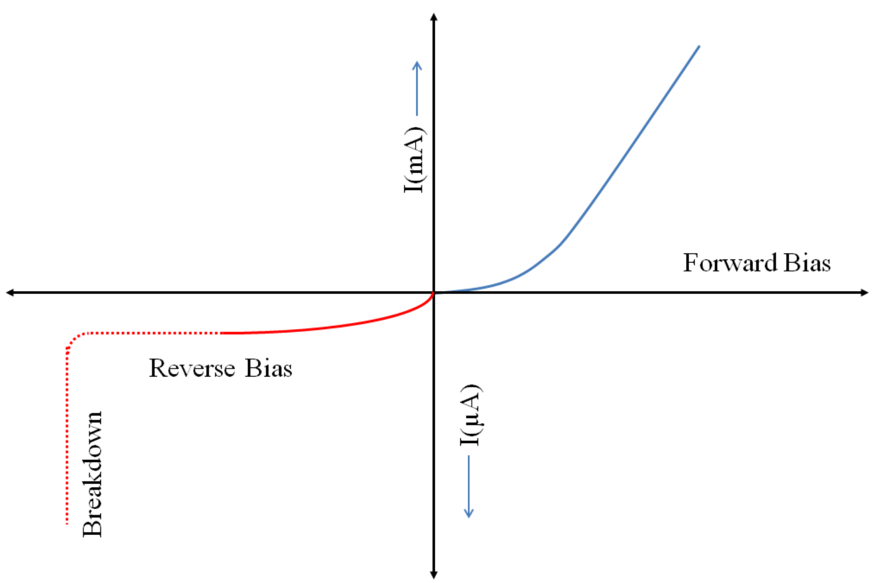


Figure 5. Characteristic curves of forward bias and reverse bias circuit.

Precautions and sources of error:

1. In both forward and reverse bias the sliding contact of the rheostat should be capped so as to give minimum voltage before switching on the power supply
2. The reverse bias voltage should be kept below the breakdown voltage of the diode.
3. In forward bias mode the voltage should be increased in steps of 0.1 volts and a milli ammeter should read the current. In reverse bias mode the voltage should be increased in steps of 1 volt and a micro ammeter should read the current

Zener Diode

Objective: To study the voltage regulating characteristic of a Zener diode

Apparatus: Same as above

Theory:
A zener diode is highly doped pn junction diode. Due to heavy doping on both p and n side, the junction is relatively narrow as compared to the normal diode.

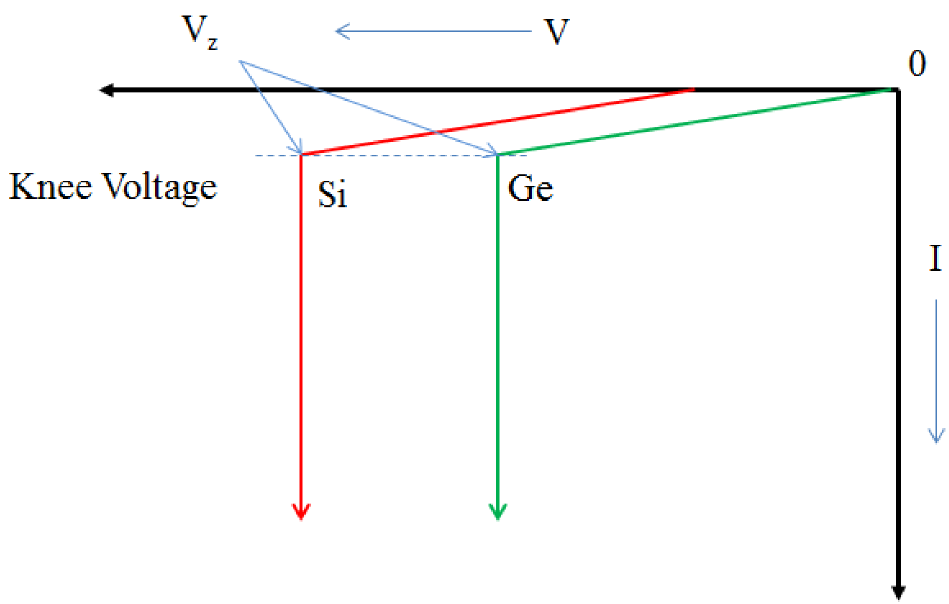


Figure 1. Reverse current in zener diodes made through Si and Ge material

As seen from figure 1 , when a reverse bias is applied, a very small current flows through it due to the minority charge carriers. However, at some reverse voltage (Vz), the reverse current in the junction increases rapidly. The current through the device increases while the voltage remains essentially constant, i.e., the reverse resistance decreases. In this condition the diode is said to have reached the 'breakdown'.

There are two possible mechanisms for such a breakdown. Here, due to heavy doping, the depletion layer is very thin and hence the electric field becomes large even for a small reverse bias voltage. Electrons are excited directly from the valence band of p side to the conduction band of n – side by the high electric field across the junction. A very sharp increase in the current is observed causing the breakdown of the junction. The value of the reverse voltage at which breakdown occurs is called as the break down voltage or zener voltage.

Another mechanism responsible for breakdown of a normal pn junction is avalanche multiplication. It occurs when a large reverse voltage applied causes a large electric field and number of covalent bonds are broken with consequent increase in current. Further, the highly accelerated carriers collide with the ions and release many more mobile charges and the process is multiplicative in nature and results in avalanche discharge. This type of breakdown of the junction is called as avalanche breakdown.

Study of Zener diode as a voltage regulator

A zener dioof input de is also used as a voltage regulator to provide a constant voltage from a source whose voltage may vary over a wide range. Zener Diode is preferred over a normal p-n diode for voltage regulation, as the Zener breakdown occurs below 0.8V and even much below depending on the amounts of doping and the method of production. Avalanche breakdown in a normal *p-n* junction diode occurs at much higher voltages.

The basis circuit of Zener diode as DC voltage regulating circuit is shown in the figure 2. The Zener diode with breakdown voltage V_z is reverse biased and is connected in parallel with the load resistance R_L across which a constant output voltage is desired.

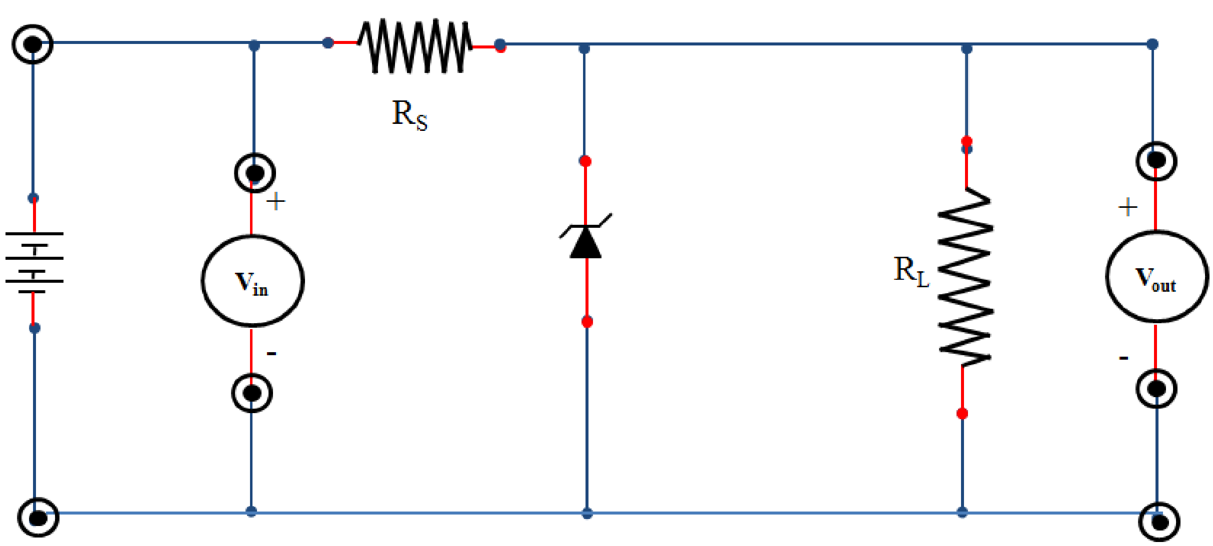


Figure 2. Circuit diagram for voltage regulation using zener diode

For an input voltage V_i greater than the Zener voltage V_z, the Zener diode will maintain a constant output voltage $V_o=V_z$ across the load resistance R_L. When the input voltage is increased slowly, a very small current flows through the Zener diode. It offers a very high resistance to the current and the whole of the input appears across the output terminals. Consequently, in this range, the output voltage increases linearly with the input voltage. Once the input voltage is greater than V_z, the Zener diode offers a very small resistance to the current. Consequently, a large current flow in the circuit and the voltage drops across the R_s increases thus maintaining the voltage drop across R_L at constant value $V_o=V_Z$. Similarly, when the input voltage is fixed at a value greater than the breakdown voltage V_Z, any change in R_L will not affect the output voltage which remains constant at V_Z. The value of R_S and R_L to be in the voltage regulation circuit can be calculated as:

$$(R_s)_{min.} = \frac{V_i - V_Z}{I_{Zm}}$$

This gives the minimum value of Rs to be connected in the circuit . V_Z and I_{ZM} are respectively the breakdown voltage and the maximum allowable current through the Zener diode and are specified by the manufacturer.

Besides,

$$(R_L)_{min.} = \frac{V_Z}{I_{Zm}}$$

where $(R_L)_{min.}$ is the minimum value of R_L for the firing of the Zener diode. So, R_L to be connected in the circuit should be more than $(R_L)_{min.}$ Usually, taking R_S=100Ω and R_L=1KΩ works well. Now, let us study about the procedure.

Procedure:

1. Make the connections as shown in figure 2.
2. Choose a series resistance R_S=100Ω and load resistance R_L=1KΩ.
3. Now, increase the V_i in small steps and note down the corresponding output V_o.
4. Take the readings till V_i is well above V_Z and V_O remains constant.
5. Plot a graph between V_i (on x-axis) and V_o (on y-axis).
6. For observing the effect of load resistance, always keep $V_i>V_Z$.
7. Keep R_S same as before and increase R_L in small steps starting from a value of about 50Ω. Now, note down the corresponding output voltage.
8. Plot a graph between R_L (on x-axis) and V_o (on y-axis).

Observations:

For output versus input characteristics:

Connected Series resistance R_S=100Ω, load resistance R_L=1KΩ

Sr.No.	**Input voltage V_i (Volts)**	**Output voltage V_o (Volts)**
1		
2		
3		
.		
.		
.		

For output versus load resistance characteristics:

Connected Series resistance R_S=100Ω, Input voltage V_i=10 volts (Vi> Vz)

S.No.	Load resistance R_L (ohms)	Output voltage V_o (Volts)
1	50	
2	100	
3	150	
.	200	
.	.	
.	.	
	.	

Result:

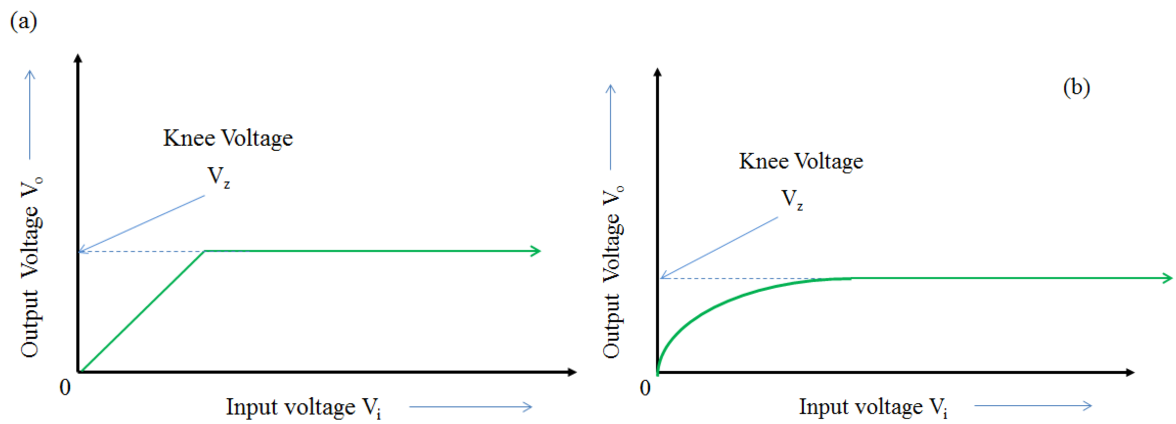


Figure 3 (a). Plot showing the the output voltage as a function of input voltage (b) Plot showing the output voltage as a function of load resistance.

1. Plot 1 in Figure 3(a) shows the output voltage as a function of input voltage. The output voltage varies linearly for $V_i \leq V_z$ and becomes constant for $V_i \geq V_Z$.
2. Plot 2 in Figure 3(b)showsthe output voltage as a function of load resistance. For load resistance greater than some minimum value $(R_L)_{min}$, the output voltage remains constant even hen the load resistance changes.

Precautions and Sources of error:

1. Zener diode must always be connected in reverse bias conditions.
2. The series resistance Rs should be so chosen that it limits the current at breakdown.
3. While studying the effect of input voltage on the output voltage
    a. Load resistance R_L should be kept much above its maximum calculated value.
    b. The input voltage must be increased in small steps upto a point well above the breakdown voltage V_Z.
4. While studying the effect of load resistance on the output resistance on the output voltage, the input voltage must be kept above the Zener voltage.

QUESTIONS FOR VIVA-VOCE

p-n junction diode:

1. How does the potential barrier form in a p-n junction diode?
2. What is the depletion region?
3. What happens to the potential barrier when (a) forward bias is applied, and (b) reverse-bias is applied?
4. Explain the VI characteristics of a p-n junction diode in forward and reverse bias mode, respectively?

5. What do you understand by knee voltage?
   Ans. Knee voltage is the forward voltage beyond which the current through the junction starts increasing rapidly with the voltage showing the linear variation. Knee voltage is 0.3V for Ge and 0.7V for Si.
6. What will happen is the reverse bias of a p-n junction is gradually increased?
7. What is the reverse saturation current?
   Ans. The maximum current that flows in a reverse biased p-n junction at a specific temperature before the breakdown. It is due to the majority carriers.
8. How and why the reverse saturation current varies with temperature?
   Ans. The reverse saturation current increases with increase in temperature according to the current equation $I_s \propto e^{-E_g/kT}$. This happen because of the increased current density of carriers.
9. What is the approximate increase in the reverse saturation current for every 10°C increase in temperature?
   Ans. It becomes double for every 10°C increase in temperature.
10. Why Ge diode is preferred in the experiment to find out the band gap?
    Ans. This is so because the reverse saturation current of Ge is about 1000 times higher than that of Si diodes.

Zener Diode

1. What is Zener diode?
   Ans. Zener diode is a p-n junction diode with heavily doped p and n regions. It is specially designed for operation in its breakdown region in reverse bias condition and is normally used as a voltage regulator.
2. What is Zener voltage? What is the range of available Zener voltage?
   Ans. The reverse bias voltage at which the reverse current increases rapidly is called the reverse breakdown voltage or Zener voltage. Zener diodes are available in the Zener voltage range of 2.4V to 200V.
3. What causes reverse breakdown?
   Ans. The rupture of covalent bonds due to the high electric field across the thin junction causes reverse breakdown.
4. Is the reverse breakdown reversible?
   Ans. Yes, the decrease of reverse bias voltage restores the condition. The broken bonds are reassembled.
5. On what factors does the reverse breakdown voltage or Zener voltage depend?
6. Ans. It depends upon the level of doping of n type and p type sections of the diode. Ordinary p-n junction diodes have lightly doped n and p sections and hence have high value of reverse breakdown voltage. Zener diodes have heavily doped p- and n- sections and hence have low value of breakdown voltage.
7. How does a Zener voltage of Ge and Si Zener diodes differ?

Ans. For same order of doping it is less for Ge and more for Si.

8. Why is Si preferred for manufacturing Zener diodes?

   Ans. Si is preferred over Ge because of higher operating temperature and current capacity. The knee point is also sharpened in case of Si diodes.

9. What is the role of the resistor R_s in series with the Zener?

   Ans. It is the current limiting resistor and avoids any accidental burn out of the diode.

10. Will the Zener diode fire for any value of load resistance R_L?

    Ans. No, a minimum value of R_L is required.

11. How does the Zener diodes act as voltage regulator?

    Ans. Refer to the working of circuit as explained in theory section.

12. What happens to the series current, load current and Zener current when the DC input voltage of a Zener regulator increases?

    Ans. Zener current and series current increase while the load current remains unchanged.

EXPERIMENT 8

e/m BY ZEEMAN EFFECT

OBJECTIVE: To determine the e/m ratio using Zeeman Effect

APPARATUS: Electromagnetic on rotating stand for axial or transverse mode observation

Lamp fitted on the top of the high current capacity 1 Tesla electromagnet, Hall Probe, Image J software, constant current poser supply, probe holders.

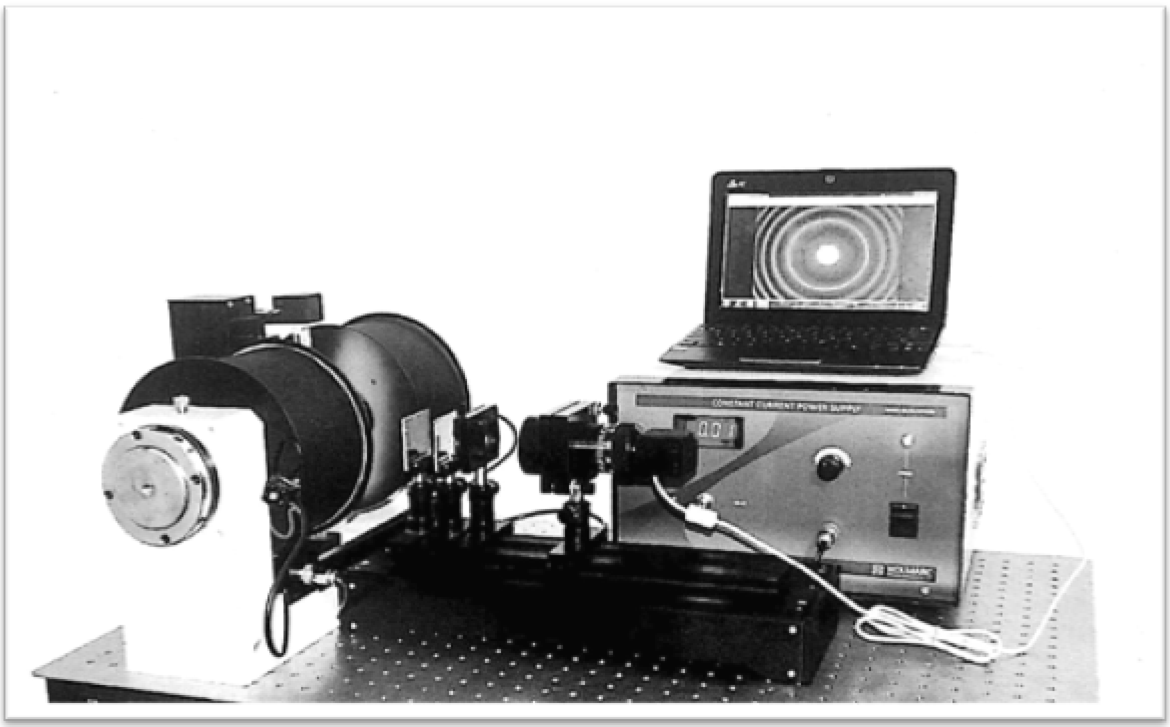


Figure 1: A setup of the Zeeman Effect on a vibration less table

THEORY: In evolving quantum theory, Zeeman Effect played a vital role. It exhibited the quantization of space in terms of angular momentum $\vec{L}$ with different orientations in presence of external magnetic field $\vec{B}$. From the Bohr's theory, we know that the electron's magnetic dipole moment is

$$\mu = IA$$

Where, $A = \pi R^2$(Area enclosed in an orbit with radius R)

I = Current due to movement of the electron

Also for a steady current,

$$I = \frac{dq}{dt} = -\frac{e}{t}$$

Where e = Electronic charge of an electron

T = Time period of the orbiting electron

Hence,

$$T = \frac{2\pi R}{v}$$

Where, v = velocity of the moving electron

The magnitude of $\vec{L}$ is given as

$$L = pR = mvR = \frac{hl}{2\pi}$$

Where, l = Azimuthal Quantum

Therefore,

$$I = \frac{ev}{2\pi R}$$

And $v = \frac{hl}{2\pi mR}$

$$\mu = IA = \frac{ev}{2\pi R}\,\pi R^2$$

$$\mu = \frac{e\,\cancel{R}\,h\,l}{2\times 2\pi\cancel{R}\,m}$$

$$= \frac{e\,h\,l}{2\times 2\pi\,m}$$

$$= \frac{e\,\hbar\,l}{2m}$$

$\boxed{\mu = \mu_o l}$--------(1)

Where, $\mu_o = \frac{e\hbar}{2m}$, is called as Bohr magneton

If the total spin contributed by all the electrons is zero for an atom then equation 1, holds to be true. The μ can be written in terms of spin and orbital angular momentum as

$$\mu = \frac{\mu_o}{\hbar}(L + 2S)$$

Note: For details, please study reference number 1.

The total angular momentum J is given as

$$J = L + S$$

If the total electron spin –S = 0, then reference is given to normal Zeeman Effect and if S ≠ 0, then it is associated with anomalous Zeeman Effect. During normal Zeeman Effect, for equation 1, holds true J = L.

We would consider magnetic field to be weak because under strong magnetic field the internal coupling between spin and orbital angular momentum gets destroyed and results in Paschen – Back Effect. In Paschen Back Effect, the splitting is disproportional, and the splitting distance does not correspond linearly with the strength of magnetic field. Therefore, for normal Zeeman Effect, a weak field is employed for internal L-S coupling. If the magnetic field is strong the Zeeman Effect develops in Paschen Back Effect.

The internal magnetic field associated with an electron of an atom is ≈ 1 Tesla and hence, we consider here the magnetic field of order 0.8 or below is weak and higher than 1.5 is strong.

In the present experiment, the external magnetic field is kept below 0.8 Tesla.

The applied magnetic field exerts a torque on the atom

$$\tau = \mu \times B$$

$$= -\frac{\mu_o}{\hbar} L \times B$$ (L is l as we are considering Azimuthal component only)

The torque is perpendicular to both B and L. Under this affect the tip of $\vec{L}$ vector process in circular motion about the external magnetic field B (Figure 2).

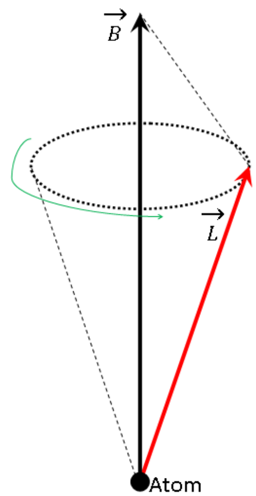


Figure 2. Representation of vector orbital angular momentum **L** précising about the external magnetic field **B.**

The interaction energy ΔE between the external magnetic field B and magnetic moment of the atom is given as:

$$\Delta E = -\mu . B = +\frac{\mu_0}{\hbar} L.B \qquad \ldots(2)$$

If we take the direction of magnetic field in Z direction, then B = B_z and L = L_z.

Therefore,

$$\Delta E = \frac{\mu_o}{\hbar} B.L_z$$

Where, L_z = z component of orbital angular momentum

$$L_z = m_e \hbar$$

Where m_e = magnetic quantum number and varies as

$$m_e = -e \; to + e$$

Therefore, the energy levels obtained are

$$\Delta E = \mu_o \, B \, m_e \qquad \ldots(3)$$

This further infers that the energy level splits up into 2l + 1 sub levels (Fiure 3).

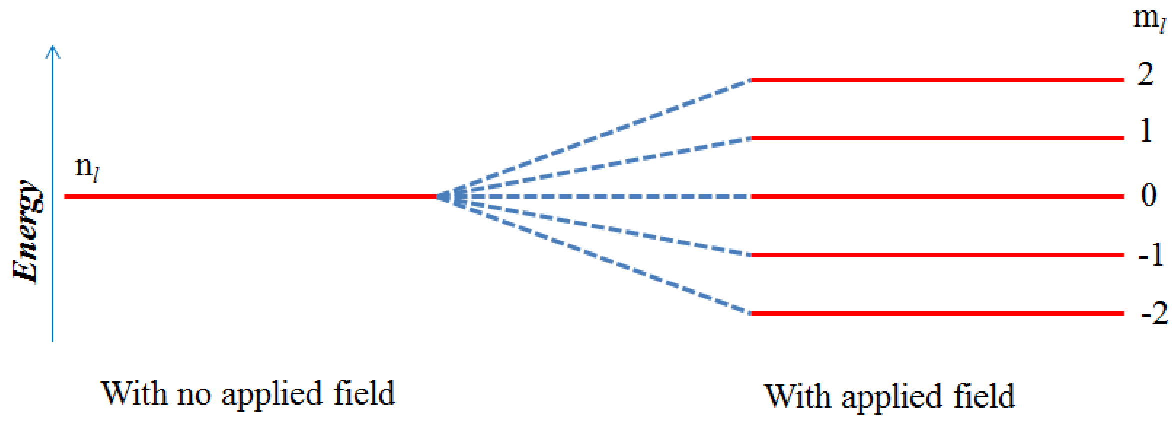


Figure 2. Splitting of energy level in presence of magnetic field.

Conventionally, the l associated with different orbital angular momenta for an atom is given as:

States		**Orbital Angular Momenta**		
s	=	l	=	0
p	=	l	=	1
d	=	l	=	2
f	=	l	=	3
g	=	l	=	4

And so on.

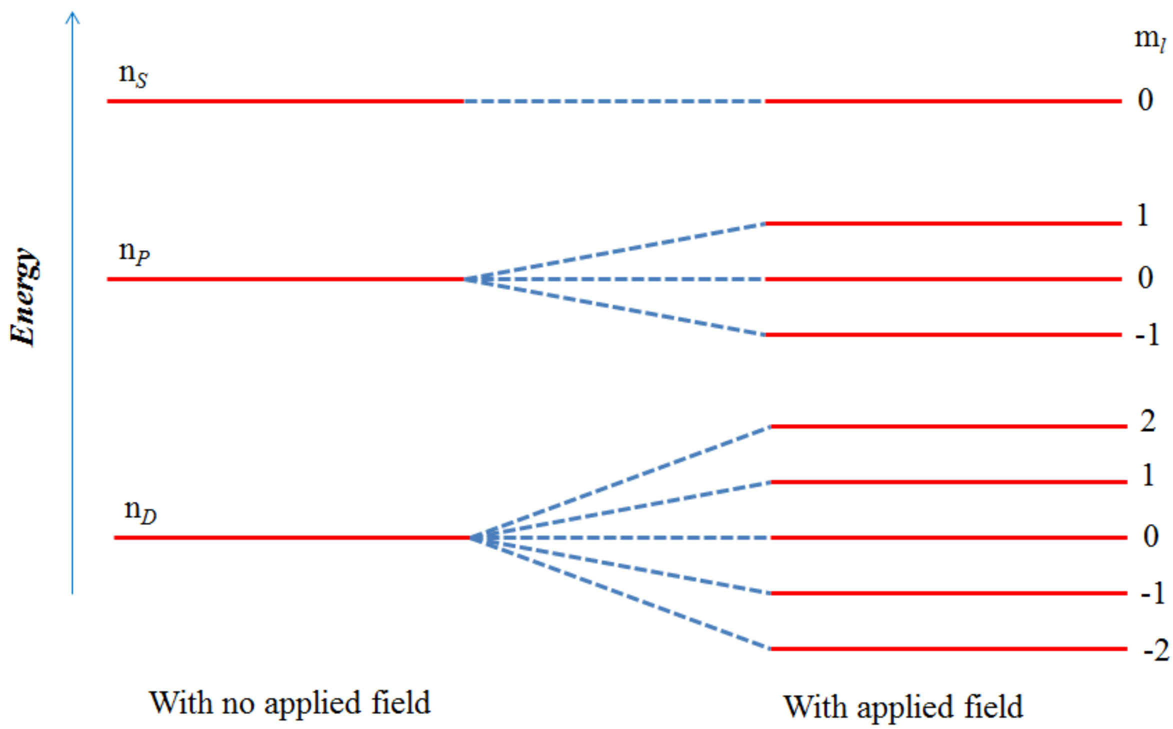


Figure 3. Splitting of energy levels associated with different orbitals.

In the presence of external magnetic field, three transitions with frequencies $v = v_o, v = v_o + \mu_o B$ and $v = v_o - \mu_o B$are obtained. When $\Delta m = -1$ and +1, we get light that is circularly polarised in the direction along with the field B. A linearly polarised light is obtained when $\Delta m = 0$ in direction along the field B. Electric field (E_w) and magnetic field (B_w) are associated with a travelling electromagnetic wave. Therefore, the right and left circularly polarised light corresponding to frequencies $v = v_o + \mu_o B$ and $v = v_o - \mu_o B$ are seen and no wave is seen for $v = v_o$, when viewed along the magnetic field B respectively.

Considering the second orientation that is direction of magnetic field is perpendicular, then linearly polarised light is seen for $v = v_o$ with $E_w \parallel$ to B_w and $E_w \perp$ to B_w for $v = v_o \pm \mu_o B$, respectively.

We would study the Zeeman Splitting in Cadmium (^{112}Cd) red spectral lines. The red line is obtained when an electron makes a transition from 5^1D_2 state to 5^1P_1 state in the presence of external weak magnetic field. When the electromagnet produces a uniform magnetic field of around 0.8Tesla, normal Zeeman effect is observed.

Hall probe is used to measure the magnetic field B. A Hg-Cd discharge lamp is placed between the poles. For parallel and perpendicular orientations the whole magnetic assembly can be rotated as per the requirement.

A red filter is placed in front of the Q water wave plate for removal of other than red extra emission lines of the spectra. Depending upon the orientation of polarizer and observation direction, each red spectral line splits into two or three lines when placed in weak magnetic field lines. This splitting ΔS can be measured with respect to spacing between successive spectral lines (ΔA) when the field is off.

It should be noted that ΔS is ½ of the spacing between two splitting spectral lines. We shall determine an expression for relationship between frequency shift and magnetic field causing it. We know that

$$\Delta E = h\boldsymbol{\nu} = 2\pi\hbar\delta v$$

By equating the equations 3 and above equation, we get

$$\delta v = \frac{\mu_o \, m_l B}{2\pi\hbar}$$

$$= \frac{m_l B}{4\pi}\frac{e}{m}$$

As per the selection rule, m_l = -1, 0, +1

Therefore,

$$\delta v = 0, \pm\frac{B}{4\pi}\frac{e}{m} \qquad \ldots(4)$$

Now, we shall evaluate frequency shift (Δv) by using wavelength shift ($\Delta\lambda$) as per the Lummer – Gehrke plate method. The details can be seen in reference number 2.

$$\Delta\lambda = \frac{\lambda^2\sqrt{\eta^2-1}}{2d\left(\eta^2-1-\eta\lambda\frac{d\eta}{d\lambda}\right)} \qquad \ldots(5)$$

Where λ= 643.8 nm for the red line in cadmium, d = 4.04 mm is the thickness of the Lummer plate, and η = 1.4567 is the refractive index of quartz glass of the Lummer plate. From Cauchy's equation fro refractive index

$$\eta(\lambda) = B + \frac{C}{\lambda^2} + \frac{D}{\lambda^4} + \cdots$$

We see that, to first non – constant order

$$\frac{d\eta}{d\lambda} = -\frac{2C}{\lambda^3}$$

And so the last term in the denominator of equation 4 is

$$\eta\lambda\frac{d\eta}{d\lambda} = -\frac{2\eta C}{\lambda^3}$$

Usually, the numbers C are around 0.005 μm^2 – after everything is factored in, the term still small enough compared to 1 to be neglected. Thus we obtain,

$$\Delta\lambda = \frac{\lambda^2}{2d}\frac{1}{\sqrt{\eta^2-1}} \qquad \ldots(6)$$

Now we can measure the spitting ΔS relative to the distance between adjacent spectral ΔA. Since both these quantities will be small, we may use an approximation:

$$\frac{\delta\lambda}{\Delta\lambda} \approx \frac{\Delta S}{\Delta\lambda}$$

where by ΔS we denote the displacement of the split lines, as before. Using the expression for $\Delta\lambda$

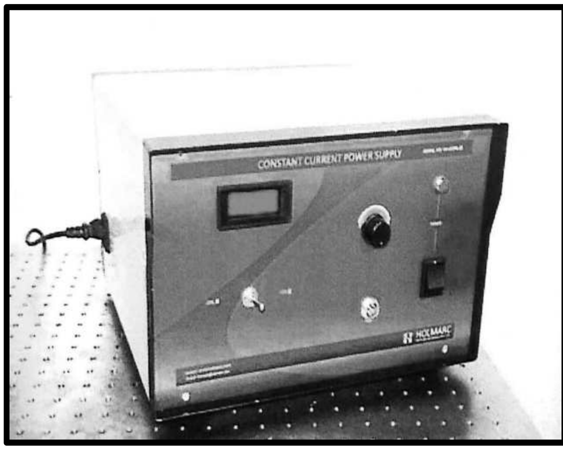
$$\delta v = \frac{\Delta S}{\Delta \mathrm{A}}\frac{\lambda^2}{2d}\frac{1}{\sqrt{\eta^2-1}} \qquad \ldots(7)$$

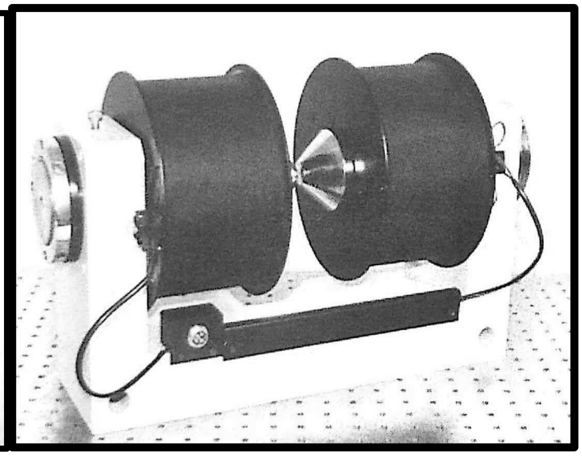
The spectral line separation ratio, ${}^{\Delta S}/_{\Delta A}$ vs magnetic field B is fit linearly using equation 7. This is used to deduce the value of charge by mass ratio for an electron.

The charge to mass ratio of an electron is determined by curve fit (linear) method for equation 7. The fit is between the separation ratio (${}^{\Delta S}/_{\Delta A}$) of the spectral line and magnetic field B. It is observed that the discrete nature as exhibited by Cd atom (vector model in the influence of magnetic field) is in fair agreement with the experimental results. The quantization of space is also confirmed further in this experiment. The polarisation by three Cd lines in the presence of magnetic field in perpendicular and parallel directions to B is measured using quarter wave plate and polarised.

PROCEDURE:

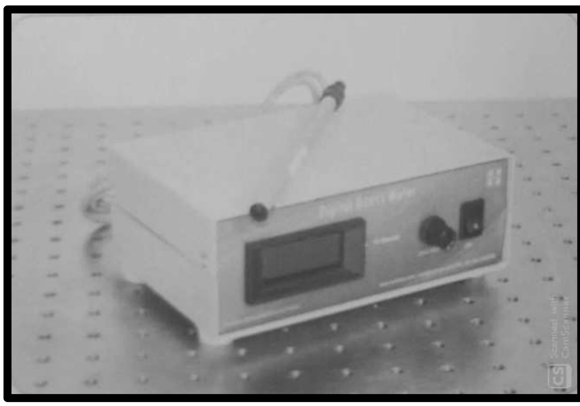
1. **Set the power source supply:**
   The current and voltage knobs (two sets) on the power supply can be used for coarse and fine controls. The current and voltage knobs should be used simultaneously to obtain a particular value of current. The voltage knob is the principal knob to set the current as it controls the current and voltage of the electromagnet.





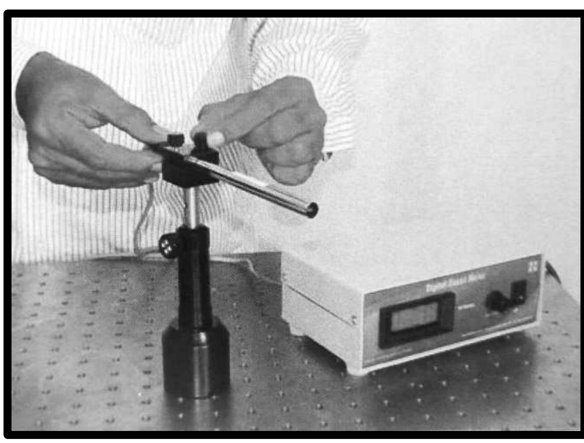
The constant power supply

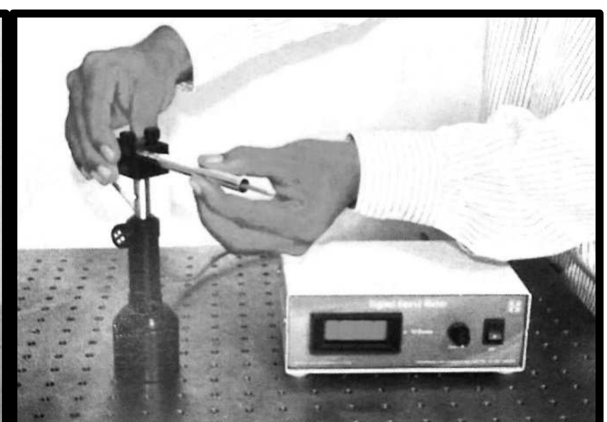
The electromagnet



The Gauss meter

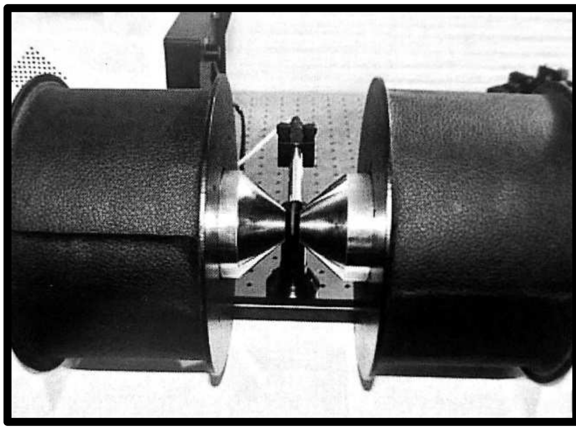
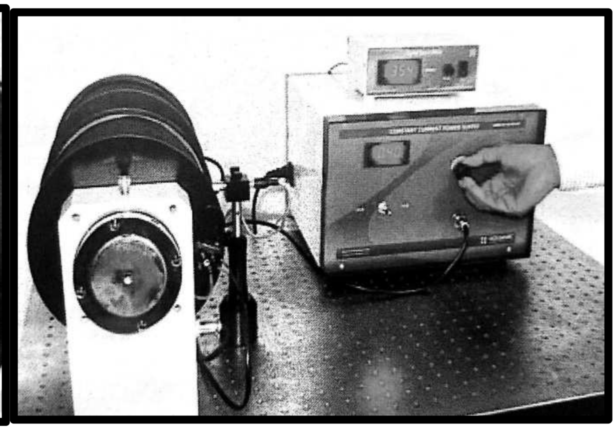
Hall Probe Holder





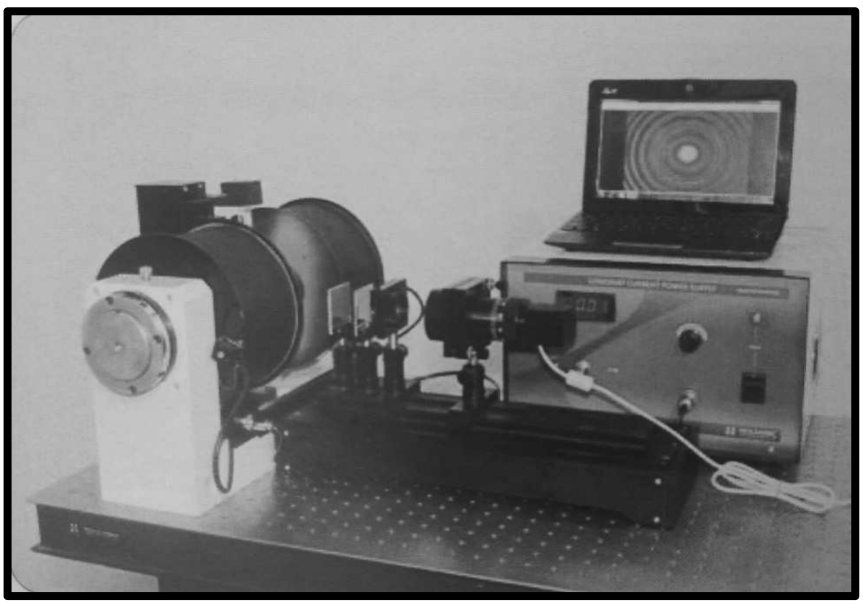
Setting up the Hall Probe with gauuss meter.

Bring out the Hall Probe ith Gauss meter

Placement of Hall Probe   Connect the Power supply to electromagnet

After placing the filters on the optical bench and connecting the laser, and after installing the camera with the computer, we have the complete setup as shown below.



2. The presence of magnetic field when after turning off the current shows the presence of residual magnetic field stored from previous experiments. Thus, it is essential to degauss the electromagnetic before taking any measurements.

   For degaussing, the power supply is turned on and the current is increased to 9A. Then it is reduced to bring the value of current as zero. Thereafter, the power supply should be turned off, reverse the polarity and turn the power supply. Now increase the current till -8A. Thereafter, reduce the current to zero and turn it off. Repeat the process by decreasing the value of current by 1A during each cycle until 1A current. This eliminates the stray magnetism left in the instrument.

3. The value of magnetic field can be measured by using Hall Probe. However, it becomes quite inconvenient to measure directly using the Hall Probe, when lamp is clamped in between. Thus, before taking the separation measurements, calibration curve is determined. This curve is associated with the value of current as measured by multimeter for a given value of magnetic field as measured by Hall Probe.

S. No.	Current I (A)	Magnetic Field Increasing (Gauss)	Magnetic Field Decreasing (Gauss)	Average B
1	1			
2	2			
3	3			
4	4			
.	.			
.	.			
.	.			
.	.			
10	10			

The current is changed and the corresponding magnetic field is measured as shown in table above. The values of current and corresponding magnetic field are plotted and curve fitting is done in it. The fitted curve is then capable of predicting the magnetic field values for given set of current values. The reliability and reproducibility of the calibration curve is checked. This is done by first maximising the current and then decreasing it to zero. The current is increased and then decreased in steps of 1A. The curve gives the relationship between B and I, therefore the Gaussmeter is not required now.

4. Now download the Image J software to measuring the separation between the lines.

5. The separations between the unsplit and split spectral lines are measured with the help of cross – wire.

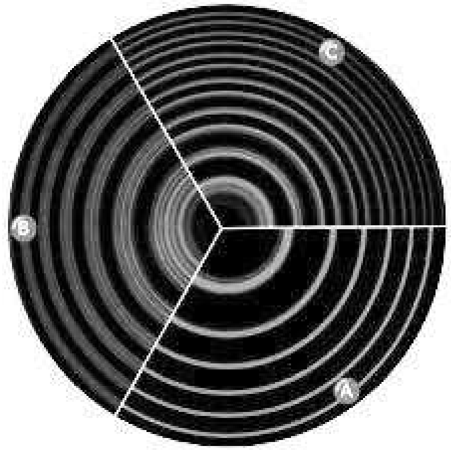
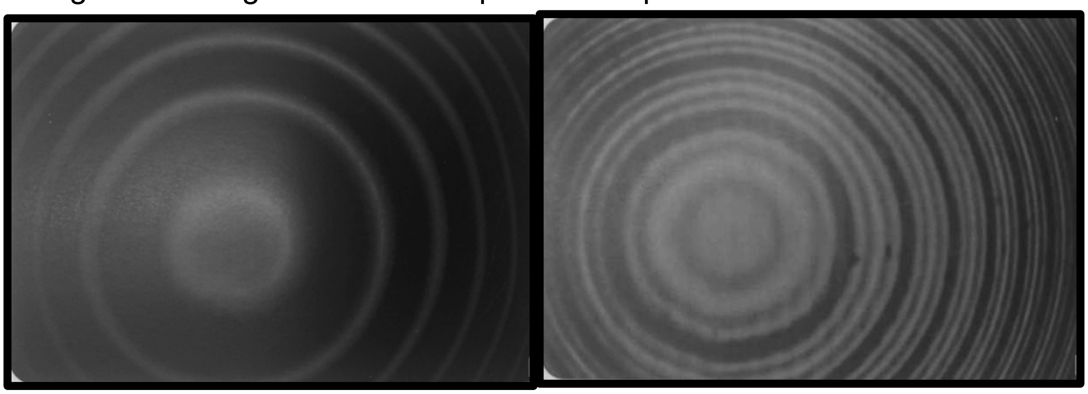


Figure showing the collective split and unsplit lines for better understanding.



The same set of split (right) and unsplit (original-left image) spectral lines should be chosen carefully. The set should be such that the separation between them is wide, bright and sharp. Take three sets of readings by choosing one above and one below the first one. Thereafter average ratios are determined.

A Table for measuring the difference between splitting and unsplit lines is given below. For your reference, you can use the below mentioned images for better understanding.

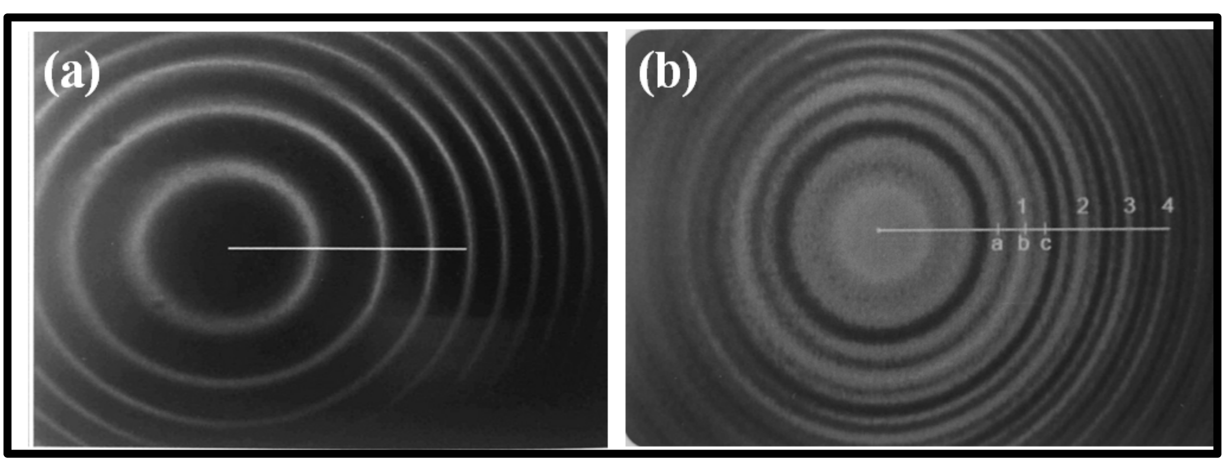


Figure for measuring (a) ΔA and (b) ΔS

Table for measuring ΔA:

S. No.	Ring number from center	Distance from Center to n^{th} ring (right)	Distance from Center to n^{th} ring (left)	Mean ΔA
1	1			
2	2			
3	3			
.	.			
.	.			

Table for measuring ΔS:

S. No.	Ring number from center		Distance from Center to n^{th} ring (right)	Distance from Center to n^{th} ring (left)	(b-a)	(c-a)	Mean ΔS=[(b-a)+(c-b)]/2
1	1	a					
		b					
		c					
2	2	a					
		b					
		c					
3	3	a					
		b					
		c					

4	4	a					
		b					
		c					
5	5	a					
		b					
		c					
6	6	a					
		b					
		c					

Putting these values in equation 7, i.e.

$$\delta v = \frac{\Delta S}{\Delta A}\frac{\lambda^2}{2d}\frac{1}{\sqrt{\eta^2-1}}$$

One can calculate the e/m ratio.

6. The quarter wave plate is used to determine the polarisation of spectral lines. The polarisation of the light gets changed after passing through the quarter wave plate. These are made up of birefringent materials. The birefringent materials differ in refractive index in accordance with the direction of the propagating light. These crystals have an optical axis and the light passing through them gets doubly refracted. This produces, two rays E ray (Extraordinary ray, perpendicular to the original direction) and O ray (ordinary, parallel to original direction) that travel with different speeds.
   Due to the birefringent properties, the refractive indices of E ray –η_E and O ray –η_O are also different. There will be a path difference between E and O ray. If d is the total distance travelled by the beams, then the path difference

$$\Delta = r_E - r_O = d(\eta_E - \eta_O)$$

Therefore,

$$\delta = \frac{2\pi}{\lambda}\, d\,(\eta_E - \eta_O)$$

For a phase difference of $\lambda/_4$ or 90˚, the resulting polarised beams are at right angles to each other. Due to this, the electric vectors oscillate perpendicular to each other. This theory is used for circulatory polarised light. Due to the property of reversibility of light, a circularly polarised light when incident on the quarter wave plate gets linearly polarised and vice versa. Thus these optical devices are used to get desired polarisation.

PRECAUTION:

1. Make all connections tight.
2. Handle the gauss-meter probe with care.
3. Be careful with the setup as it contains sophisticated Cd tube, He-Neon Laser (once exposed to eye, may damage it completely) and strong magnetic field.
4. If the temperature of electromagnet goes too high then turn off the power supply and allow it to cool.
5. Do not change the voltage / current supply very quickly.

REFERENCE:

1. David J. Grifith, Introduction to Electrodynamics, Prentise Hall, 1999.
2. F. Simeon, “The Lummer-Gehrcke Parallel Plate Interferometer”, J. of Sci. Instrum., **1.10**, 296-304, 1994.

Experiment 9: Study of characteristics of FET & MOSFET

Structure

9.1 Object:

After performing this experiment, you should be able to

- What are FET and MOSFET?
- What are bipolar and unipolar devices.
- How the operation of FET/MOSFET are different from NPN and PNP transistor.
- Uses of FET/MOSFET

9.2 Introduction:

After the advance of semiconductor technology, because of small size, low operation voltage and low noise many semiconductor devices are manufactured and used. Among these all, FET and MOSFET have important and used in amplification. FET/MOSFET are field effect transistors in which electric field controls the flow of current. As we know that P and N type semiconductor are made by doping trivalent and pentavalent impurity in intrinsic semiconductor respectively. FET is a three terminals device and is a semiconductor bar (either P or N type semiconductor) on which two PN junction is made on opposite sides in middle parts. The terminals from either side of bar along the bar are called drain and source terminals and terminal from PN junction is called gate. The FET/MOSFET is called unipolar device as current inside the bar is due to movements of only one type of charge carrier (i.e. holes or electrons). The symbolic diagram of FET is presented in figure 1.

MOSFET as shown in figure 2 is Metal-Oxide-Semiconductor-Field effect-Transistor. This works in enhancement and depletion modes. The MOSFET has much higher input impedance than FET. It is a four terminals device having source(S), gate (G), drain (D) and substrate or body (B).The channel (N-N) of N channel MOSFET is made of heavily doped N type semiconductor (N^+) splitted by P type semiconductor as substrate (body). Two terminal for source and drain are made on two end of channel. There is insulating thin layer of silicon di oxide (SiO_2) between gate and channel. Similary p channel MOSFET is made. The symbolic diagram of MOSFET is presented in figure 2.

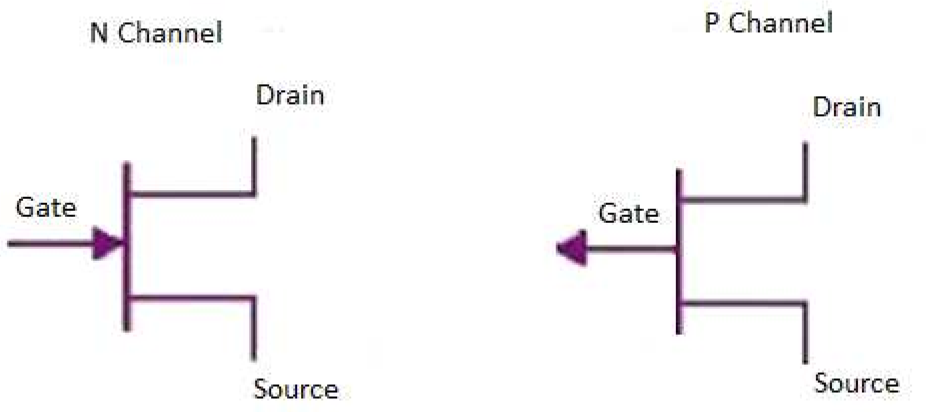


Figure 1

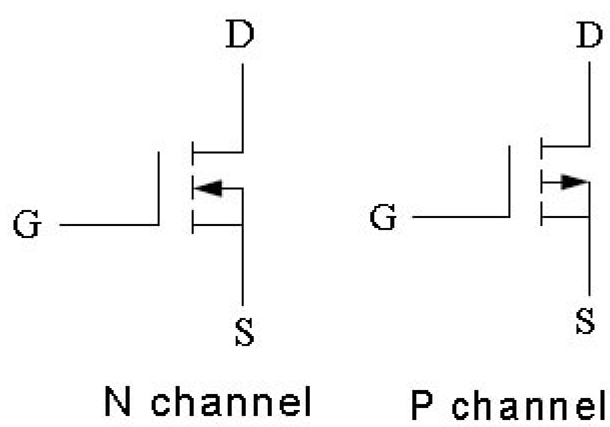


Figure 2

9.3 Apparatus Used:

Experimental board of FET/MOSFET, connection wires.

9.4 Theory :

The field effect transistor is a semiconductor device in which the controlled by electric field. The two PN junctions at the two sides of bar of conduction channel (either N or P type material) form depletion layers. The current flows through N channel bar is by electrons and in P channel bar is by holes. The width and hence resistance of channel can be controlled by changing the input voltage between gate and source V_{GS}. The greater reverse voltage V_{GS} will narrow the channel as the depletion layer of PN junction become wider.

The FET operate on the principle that the drain current through channel can be change by changing reverse gate source voltage V_{GS}. The working of FET is as

(A) When is drain kept at positive voltage (V_{DS}) with respect to source at zero gate potential, the drain current flows in channel of the FET. On increasing V_{DS} drain current increases and becomes saturated after a fixed voltage called pinch of voltage (V_P).

(B) When a reverse voltage V_{GS} is applied between gate and source, the depletion layers on the two sides of bar become wider and hence drain current decreases. The drain current I_p decreases on increasing reverse voltage V_{GS} and at some fixed reverse voltage the channel become completely cut off i.e. the drain current become zero. This reverse gate source voltage is called cut off voltage.

The working of **MOSFET** depends on the electrical variations happening in the channel width along with the flow of carriers (either holes or electrons). The charge carriers enter into the channel through the source terminal and exit via the drain.The width of the channel is controlled by the voltage on an electrode which is called the gate and it is located in between the source and the drain. Gate is insulated from the channel by metal oxide(SiO_2) form parallel plate capacitor with dielectric SiO_2.MOSFET work in two following mode

(A) Enhancement mode: When gate (G) is positive with respect to source in N channel MOSFET, the +ve gate induces –ve charge on the channel side of this capacitor and makes channel continuous to conduct between source and drain for a positive drain source voltage V_{DS}. For P channel MOSFET, polarity of Gate voltage (V_{GG}) and Drain source voltage (V_{DS}) is reversed.

(B) Depletion mode: When there is no voltage on the gate, the channel exhibits its maximum conductance. As the voltage on the gate increases (either positive or negative, depending on whether the channel is made of P-type or N-type semiconductor material), the channel conductivity decreases.

The MOSFET characteristics are studied by noting the variation of current I_D with voltage V_{GS} and V_{DS}. The variation of current I_D with and V_{DS}at constant voltage V_{GS} is called drain characteristics. The mutual characteristics is curve between I_D and V_{GS} at constant V_{DS}. The drain resistance (r_d), mutual conductance (g_m) and amplification factor (μ) are evaluated using characteristics of MOSFET. The characteristics for Enhancement mode and Depletion mode will plotted in same way.

9.5 About apparatus:

The apparatus in the experiment is circuit for a N channel field effect transistor (N channel FET) as shown in figure 3. The drain is kept at positive voltage with respect to source by the battery (0-30V) and gate is kept at negative voltage with the source by the battery (0-10V). For the measurement of drain current milliammeter is used in circuit.

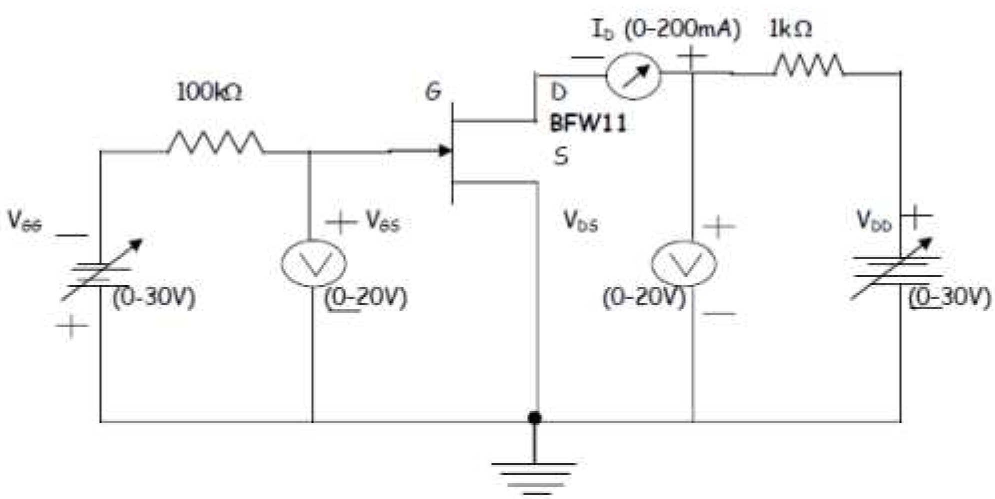


Figure 3

The circuit diagram for N channel metal oxide field effect transistor (N channel MOSFET) is shown in figure 4.

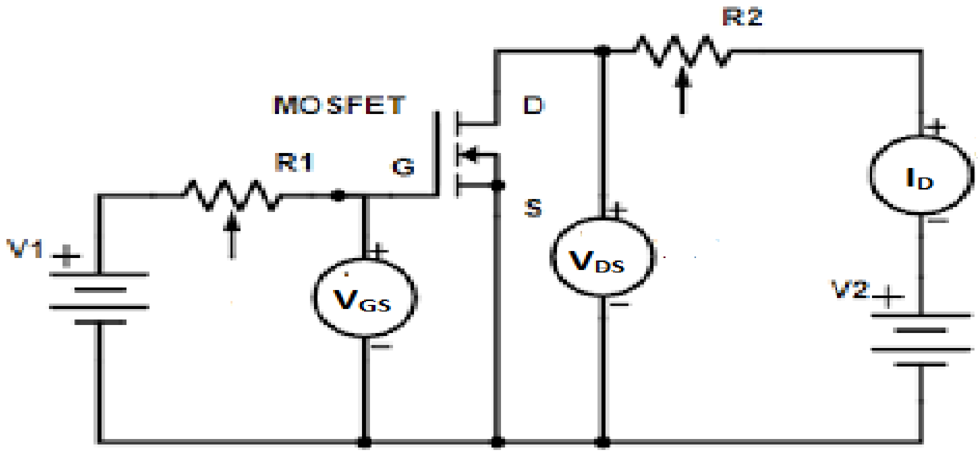


Figure 4

9.6 Procedure:

For FET, let us perform the experiment in following steps.

1. Make connection as shown in figure 2.
2. Adjust reverse gate voltage say at 1V by means of R_1.
3. Increase drain voltage in step of 1 volt by changing R_2 and note the corresponding drain current.
4. Now note drain current with changing drain voltage for constant reverse gate voltage say for 1V, 2V, 3V and 4Vetc.
5. Plot curve between drain voltage and drain current for constant reverse gate voltage.
6. Obtain the pinch off voltage from the graph between drain voltage and drain current.
7. Repeat the observation of drain current with drain voltage for different V_{GS} say1V,2V,3V and 4V and find the pinch off voltage.

For MOSFET, let us perform the experiment in following steps.

(A) Drain characteristics (For N –Channel MOSFET)

1. Make connection as shown in figure 4.
2. Switch on the power supply.
3. Keep V_{GS} fixed, record drain current (I_D) with varying drain voltage (V_{DS}).

4. Repeat the observation of drain current with drain voltage for different V_{GS} say 4V, 5V, 6V and 7V and find the pinch off voltage.
5. Tabulate the observation and plot graph.
6. Record the pinch off voltage (V_P) and corresponding current (I_P) for each value of (V_{GS}) from characteristics or table. Calculate drain resistance (r_d).

Ohmic drain resistance $r_d = \frac{V_P(V)}{I_P(mA)} = \cdots \ldots\ldots \Omega$

(B) Mutual characteristics (For N –Channel MOSFET)

1. Make connection as shown in figure 4.
2. Switch on the power supply.
3. Keep V_{DS} fixed, record drain current (I_D) with varying gate voltage (V_{GS}).
4. Repeat the observation for different V_{DS} say 10V, 12V, 14V and 16V.
5. Tabulate the observation and plot graph.
6. From above plotted graph mutual conductance (g_m) is evaluated as

Mutual conductance $g_m = \frac{\Delta I_D(mA)}{\Delta V_{GS}(V)} = \cdots \ldots\ldots milli\ mho$

9.7 Observation:

Table 1 for FET for Output characteristics (I_d/V_{DS})

S.N.	Drain Voltage V_{DS} (In volt)	Drain current I_d (mA)			
		V_{GS}=1V	V_{GS}=2V	V_{GS}=3V	V_{GS}=4V
1					
2					
3					
4					

5					
6					

Table 2 for MOSFET for Drain characteristics (I_d/V_{DS})

S.N.	Drain Voltage V_{DS} (In volt)	Drain current I_d (mA) for base current			
		V_{GS}=4V	V_{GS}=5V	V_{GS}=6V	V_{GS}=7V
1					
2					
3					
4					
5					
6					

Table 3 for MOSFET for Values of V_P , I_P with V_{GS}.

S.N.	V_{GS}	Values of $V_P I_P$ and r_d	**S.N.**	V_{GS}	Values of $V_P I_P$ and r_d
1	3V	V_P	4	7V	V_P

		I_P r_d			I_P r_d
2	4V	V_P I_P r_d	5	8V	V_P I_P r_d
3	5V	V_P I_P r_d	6	9V	V_P I_P r_d

Table 4 for MOSFET for Output characteristics (I_d/V_{DS})

S.N.	Gate Voltage V_{GS} (In volt)	Drain current I_d (mA)			
		$V_{GS}=$	$V_{GS}=$	$V_{GS}=$	$V_{GS}=$
1					
2					
3					
4					
5					
6					

7					
8					
9					
10					

9.8 Result:

1. For FET the graph between drain voltage with drain current at constant gate source reverse voltage V_{GS} are plotted in the graphs and pinch off voltage V_P are ………....
2. For MOSFET, the **Mutual characteristics and drain characteristics are plotted and following constants for MOSFET are calculated**

   (a) Drain resistance r_d in ohmic region =

   (b) Mutual conductance g_m in pinch off region =

   (c) The value of amplification factor (μ)in pinch off region =

9.9 Precaution and source of error:

1. FET/MOSFET should handle carefully.
2. Sensitive voltmeter and sensitive ammeter sould be used.
3. There should be proper biasing i.e. gate is netaive and drain is positive with respect ro source.
4. Voltge should not exceeds the rated value of FET/MOSFET.
5. There should be not be fluctuation of power.

9.10 Summary:

1. FET/MOSFET are three terminal unipolar device.

2. Three terminals in FET/MOSFET are called source, gate and drain.

3. While operating with FET drain is always kept positive with respect to source, while gate is negative with respect to source.

4. While operating with MOSFET drain is always kept positive with respect to source, gate is negative (depletion mode) and positive (enhancement mode) with respect to source.

4. Drain and source terminals are interchangeable.

5. The drain voltage for which drain current become saturate is called pinch off voltage.

9.11 Glossary:

Semiconductor: Material whose conductivity lies between conductor and insulator.

Intrinsic semiconductor: Si and Ge in their pure form.

Amplifier: A device which raises the strength of weak signal.

Unipolar device: The semiconductor inside which the conduction is by either (holes or electrons) charge carriers

Pinch off voltage: The drain voltage for the drain current becomes saturated is called pinch off voltage.

9.12 References:

1. C. L. Arora,B.Sc. Practical Physics, S. Chand publication, Delhi.
2. V.K. Mehta & Rohit Mehta, Principles of Electronics, S. Chand publication, Delhi.
3. B. L. Thereja, Basic electronics, S. Chand publication, Delhi.
4. S.L.Gupta, V.Kumar, Practical Physics, Pragati prakashan, Meerut.
5. https://en.wikipedia.org.

9.13 Viva-voce questions:

Question1.How a FET is different from npn/pnp transistor?

Answer: In FET current conduction is either by holes or electrons and is controlled by means by electric field while in npn/pnp transistor input current controls output current and conduction is due to both holes & electrons.

Question2. Define pinch off voltage?

Answer: It is drain-source voltage at which the drain current becomes constant.

Question3.What are use of FET& MOSFET?

Answer. FET& MOSFET are used as amplifier

Question4. **What is advantages of MOSFET over FET.**

Answer: In MOSFET has, the gate is insulated electrically from the channel, no current flows between the gate and the channel, no matter what the gate voltage (as long as it does not become so great that it causes physical breakdown of the metallic oxide layer). Thus, the MOSFET has practically infinite impedance.

Experiment 10: Study of lattice dynamic kit

Structure

10.1 Objective:

After performing this experiment, you should be able to understand

- What is Lattice and lattice vibration?
- What are the mono-atomic and di-atomic lattices.
- Dispersion relation of mono-atomic lattice and comparison with theory.
- Determination of Cut off frequency of mono-atomic lattice.
- Dispersion relation of di-atomic lattice – optical mode and acoustical mode energy gap and comparison with theory.

10.2 Introduction:

Matter in nature exists in three states viz. solid, liquid and gas by chemical composition of one or more elements. Atoms in matter are attached to each other with force of attraction. In solids, strong force of attraction maintains their shape and volume. Solids are broadly classified as crystalline and non-crystalline depending upon the arrangement of atoms or molecules.

The crystalline state of solids is characterized by regular or periodic arrangement of atoms and molecules. As the energy released in formation of ordered state is less than the disordered state, the crystalline state (low energy state) thus preferred by most of the solids. The non-crystalline or amorphous solids are characterized by completely random arrangement of atoms or molecules.

The atomic arrangement in a crystal is called crystal lattice. In the perfect crystal, there is regular or periodic arrangement of atoms and periodicity varies in different directions. It is always convenient to imagine points in space that have definite relationship with the atom or molecules of solids. The arrangement of such imaginary points in space that have definite relationship with the atom or molecules of solids is called lattice.

10.3 Apparatus Used:

Lattice dynamic kit, CRO and connection wire.

10.4 Theory :

A lattice is a regular arrangement of atoms which are joined together by electrostatic force of attraction and may be regarded as joined by elastic spring. A two dimension lattice is shown in figure 1 and it is obvious that the motion of single atom will be shared by all the atoms i.e.

motion of atom is coupled. Due to internal energy in lattice, the lattice may vibrate in normal mode and it may vibrate in forced vibration (under effect of mechanical or electromagnetic external force). The vibration in normal mode results to information regarding thermal conductivity & specific heat. The forced vibrations are associated with the optical properties of solids. Let's discuss the lattice vibration for monoatomic and diatomic lattice as following

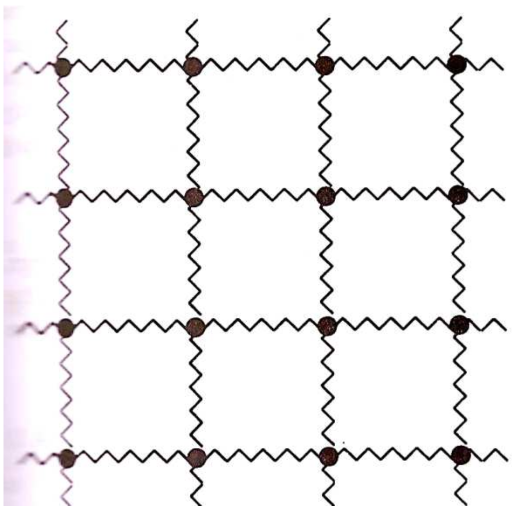


Figure 1: One dimensional lattice

10.4.1 Vibrations of one –dimensional monoatomic lattice

Let consider aone –dimensional monoatomic lattice where atoms of mass 'm' are attach by massless springs as shown in figure 2.

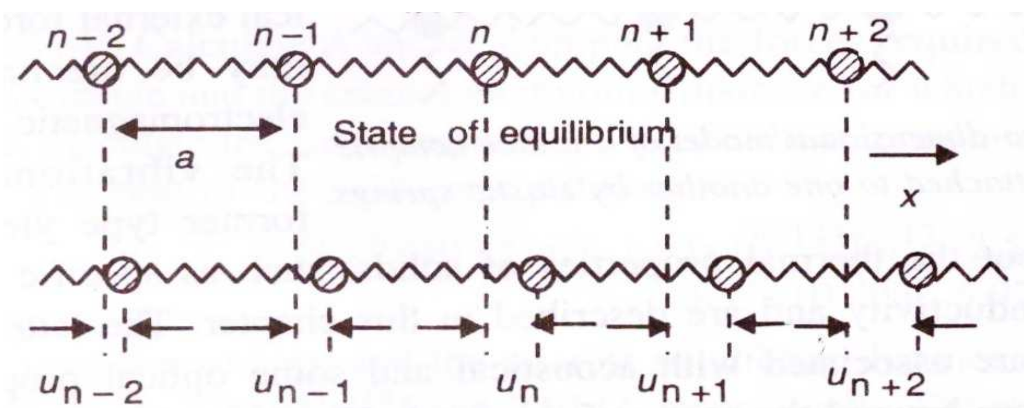


Figure 2: one dimensional monoatomic lattice

The atoms are placed in x-axis with interatomic spacing 'a'. The coordinate of atoms will be ……,(n-1)a, na, (n+1)a,…….In the state of vibration along x axis, the atoms will have periodic motion about their equilibrium positions and become the source of elastic wave that propagates through the medium. Let at any instant of time, the displacement of……,(n-1)th, nth, (n+1)th,……atoms are ….. u_{n-1}, u_n, u_{n+1}……. and β is force constant of spring. As nth atom is attached to (n-1)th and (n+1)th atoms by two springs, so the net force on nth atoms will be given as following

$$F = \beta(u_{n+1} - u_n) - \beta(u_n - u_{n-1})$$

$$F = \beta(u_{n+1} + u_{n-1} - 2u_n)$$

$$m\frac{d^2u_n}{dt^2} = \beta(u_{n+1} + u_{n-1} - 2u_n) \qquad 10.1$$

(where, $\frac{d^2u_n}{dt^2}$ is acceleration of nth atom)

The solution of equation 1.1 is

$$u_n = u_0 \exp i(\omega t - Kna) \qquad 10.2$$

(where, na is x coordinate of nth atom , K$\left(=\frac{2\pi}{\lambda}\right)$is propagation vector and ω is angular frequency of wave)

Similarly for (n+1)th and (n-1)th atoms, the solution will be

$$u_{n+1} = u_0 \exp i[\omega t - K(n+1)a] \qquad 10.3$$

$$u_{n-1} = u_0 \exp i[\omega t - K(n-1)a] \qquad 10.4$$

Putting values from equations 10.2, 10.3 & 10.4 to 10.1, we will get

$$-m\omega^2 = \beta(e^{iKa} - 2 + e^{-iKa}) \qquad 10.5$$

$$-m\omega^2 = \beta(e^{iKa/2} - e^{-iKa/2})^2$$

$$-m\omega^2 = 4\beta i^2\left(\frac{e^{iKa/2} - e^{-iKa/2}}{2i}\right)^2$$

$$-m\omega^2 = -4\beta\sin^2\left(\frac{Ka}{2}\right)$$

$$\omega = \pm\sqrt{\frac{4\beta}{m}}\sin\frac{Ka}{2} \qquad 10.6$$

The relation (10.6) is called dispersion relation and is plotted in figure 3.

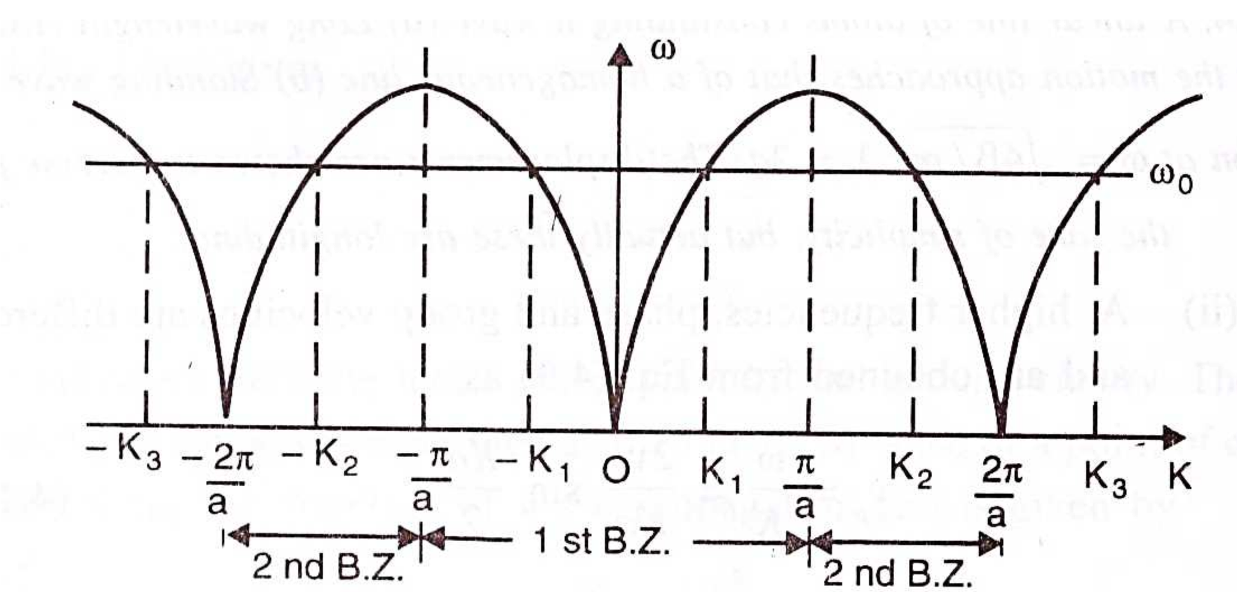


Figure 3: Dispersion relation

(i) **At low frequencies**, $K \to 0$

$$\sin\frac{Ka}{2} \to \frac{Ka}{2}$$

$$\omega = \pm\sqrt{\frac{4\beta}{m}}\frac{Ka}{2} \qquad 10.7$$

The phase velocity $v_p = \omega/K$ and group velocity $v_g = d\omega/dK$ are same.

(ii) **At higher frequency**, the group velocity $v_p = \omega/K$, group velocity $v_g = d\omega/dK$ are different and given by

$$v_p = \frac{\omega}{K} = \pm\sqrt{\frac{4\beta}{m}}\frac{1}{K}\sin\frac{Ka}{2} \qquad 10.8$$

$$v_g = \frac{d\omega}{dK} = \pm\sqrt{\frac{4\beta}{m}}\cos\frac{Ka}{2} \qquad 10.9$$

Thusgroup velocity v_p and group velocity v_g are different and functions of frequency. This phenomenon is called dispersion and medium is called dispersive medium.

(iii) At frequency $\omega = \pm\sqrt{\frac{4\beta}{m}}$ is maximum angular frequency of vibration, $K = \pi/a$ or $\lambda = 2a$.

$$v_p = \frac{\omega}{K} = \pm\sqrt{\frac{4\beta}{m}}\frac{a}{\pi} \quad , \quad v_p = 0 \qquad 10.10$$

It follows that there is no transfer of signal or energy corresponding to this frequency limit and hence the wave behaves like standing wave.

From above discussion that vibrations frequency $\omega\langle\sqrt{\frac{4\beta}{m}}$ can propagate through the lattice, **so the lattice behave like as low-pass filter.**

Dispersion relation 10.6 shows that numbers of K values are associated with same frequency ω, which lattice can propagates numbers of wavelength corresponding same frequency and K range $-\frac{\pi}{a}\langle K\langle\frac{\pi}{a}$. The region of K values where $-\frac{\pi}{a}\langle K\langle\frac{\pi}{a}$ called first Brillouin zone, region of K values $-\frac{2\pi}{a}\langle K\langle\frac{2\pi}{a}$ is called second Brillouin zone and so on. As right half of Brillouin zone is same to left half, the periodic arrangement of atoms can be explained verified.

10.4.2 Vibrations of one –dimensional diatomic lattice

Let consider adi –dimensional monoatomic lattice with two atoms of mass ‘m’ and ‘M’ are attach alternatively by massless springs as shown in figure 4.

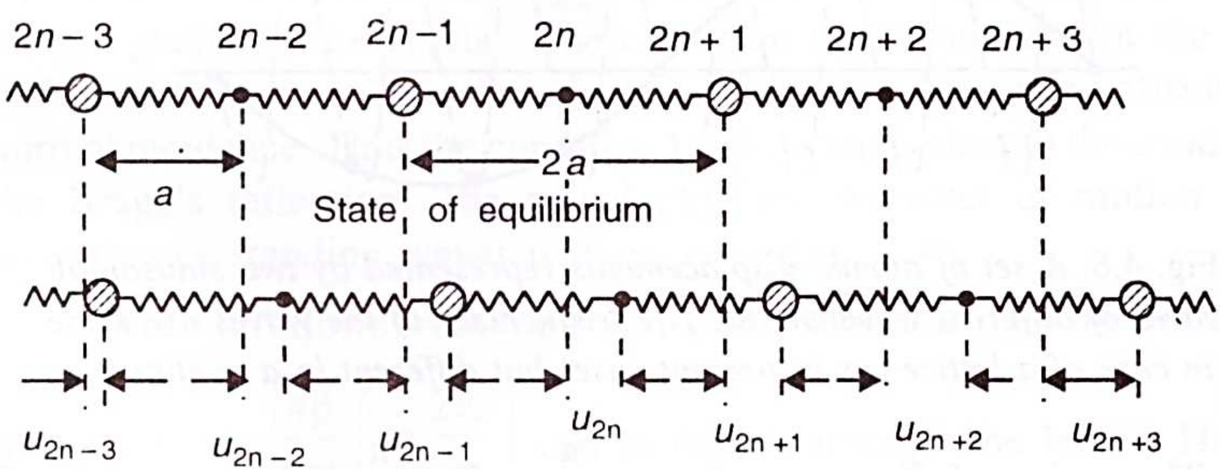


Figure 4: One –dimensional diatomic lattice

The atoms are placed in x-axis with interatomic spacing ‘a’. In the state of equilibrium, location of atoms of masses ‘m’ let represented by ……,(2n-2), 2n, (2n+2),……. Let β is force constant of spring and u_{2n} be displacement of atom at 2nth site. So we will get following differential equation

$$F_{2n} = m\frac{d^2u_{2n}}{dt^2} = \beta\left(u_{2n+1} + u_{2n-1} - 2u_{2n}\right) \qquad 10.11$$

$$F_{2n+1} = M\,\frac{d^2u_{2n+2}}{dt^2} = \beta\left(u_{2n+2} + u_{2n} - 2u_{2n+1}\right) \qquad 10.12$$

Solutions of equations 10.11 & 10.12 are

$$u_{2n} = A\exp i\left(\omega t - 2Kna\right) \qquad 10.13$$

$$u_{2n+1} = B\exp i\left[\omega t - (2n+1)Ka\right] \qquad 10.14$$

Here K is wave vector of particular mode of vibration. The vibration frequency of both atoms is same as both participate in same motion. The similar expressions for u_{2n-1}& u_{2n+2} are

$$u_{2n-1} = B\exp i[\omega t - (2n-1)Ka] \tag{10.15}$$

$$u_{2n+2} = A\exp i[\omega t - (2n+2)Ka] \tag{10.16}$$

Putting values from equations 10.13, 10.14, 10.15and 10.16 to 10.11&10.12, we will get

$$-m\omega^2 A = \beta B\left(e^{iKa} + e^{-iKa}\right) - 2\beta A \Rightarrow \ (2\beta - m\omega^2)A - (2\beta\cos Ka)B = 0 \tag{10.17}$$

$$-M\omega^2 B = \beta A\left(e^{iKa} + e^{-iKa}\right) - 2\beta B \Rightarrow \ -(2\beta\cos Ka)A + (2\beta - M\omega^2)B = 0 \tag{10.18}$$

The above sets of homogeneous linear equations give to non-zero solutions for A & B for

$$\omega^2 = \beta\left(\frac{1}{m} + \frac{1}{M}\right) \pm \beta\sqrt{\left(\frac{1}{m} + \frac{1}{M}\right)^2 - \frac{4\sin^2 Ka}{mM}} \tag{10.19}$$

So, the allowed frequency range in diatomic lattice split into two branches, an upper branch is called optical branch and lower branch is called acoustical branch and there exists band of frequencies between these branches in which wave like solution is not possible is called forbidden band. In monoatomic lattice optical branch and acoustic branch coincide at $K = \pm \pi/2a$ and forbidden band disappears.

The vibrations of acoustical branch can be excited by force which makes atoms in crystal move in same direction. Such effects may produce sound waves on surface of the crystal and therefore called acoustical vibrations.

The vibrations of optical branch can be excited by force which makes atoms in crystal move in opposite direction. Optical radiation can make such effects and therefore called optical vibrations.

10.5 About apparatus:

The lattice dynamic kit consist of following parts

(a) Audio oscillator with amplitude control and frequency varying facilities.

(b) Lattice dynamic kit consists of electrical circuit which stimulates one dimensional monoatomic and diatomic lattice. The kit has switches for monoatomic and diatomic lattice.

The electrical analog of monoatomic and diatomic lattice as shown in figure 2&3 is chained LC circuit resented in figure 4&5.

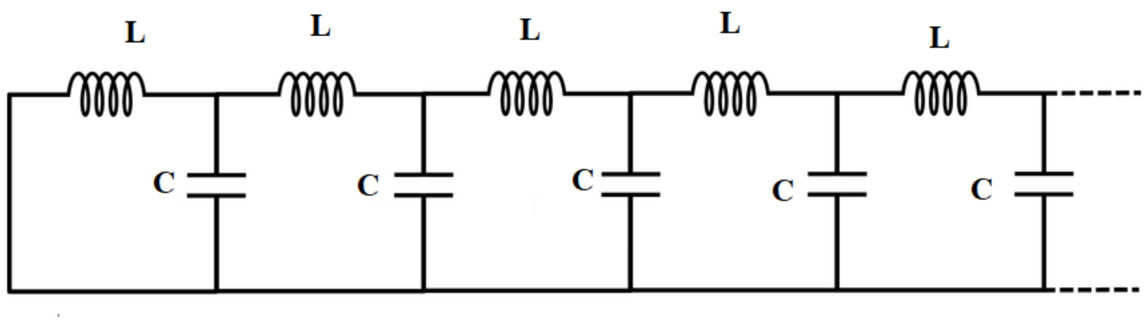


Figure 4: Electrical analog of one dimensional monoatomic lattice

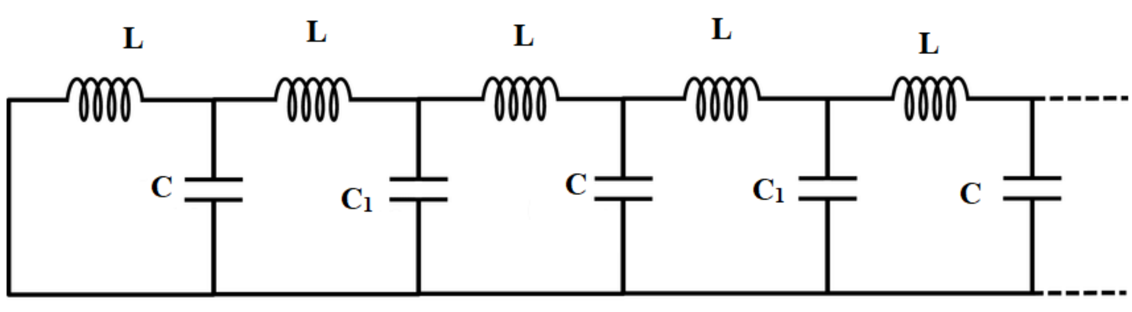


Figure 5: Electrical analog of one dimensional diatomic lattice

The dispersion relation for circuit in figure 4 (monoatomic lattice) is given by

$$\omega^2 = \frac{2}{LC}(1-\cos\theta) \qquad 10.20$$

Where 'θ' is phase change introduce by each section (unit cell) of filter with $C \leftrightarrow m$ and $\frac{1}{L} \leftrightarrow \beta$

(as compares to dispersion relation in equation 10.6 we have $\omega^2 = \frac{4\beta}{m}\sin^2\frac{Ka}{2} = \frac{2\beta}{m}(1-\cos Ka)$

So, by measuring phase difference between input and output voltage will verify dispersion relation for monoatomic lattice.

Similarly the dispersion relation for circuit in figure 5 (diatomic lattice) is

$$\omega^2 = \beta\left(\frac{1}{C_1}+\frac{1}{C}\right) \pm \beta\sqrt{\left(\frac{1}{C_1}+\frac{1}{C}\right)^2 - \frac{4\sin^2\theta}{CC_1}}$$

Which is as in equation 10.19

$$\omega^2 = \beta\left(\frac{1}{m}+\frac{1}{M}\right) \pm \beta\sqrt{\left(\frac{1}{m}+\frac{1}{M}\right)^2 - \frac{4\sin^2 Ka}{mM}}$$

With $C \leftrightarrow m$, $C_1 \leftrightarrow M$ and $\frac{1}{L} \leftrightarrow \beta$

In diatomic lattice there are two frequencies corresponding to K with gap. Plot of θ with two frequencies will give acoustical branches (ω_+) and optical branch (ω_-).

10.6 **Procedure**:

Let us perform the experiment in following steps.

For monoatomic lattice

1. Connect the kit to mains and switch on.
2. Keep amplitude R_1, R_2 nob at maximum. Keep the toggle switch to Lo.
3. Connect the output of kit with the CRO and switch CRO to XY mode.
4. Keep both switches to monoatomic side, let the circuit consist of ten section (LC circuit called unit cell) given by constant source (audio oscillator with series R_1). With the help of R_2 , set the output on CRO to Lissajous figure nearly circle.
5. Starting with low frequency, vary the frequency of audio oscillator with help of TPP and note the frequencies for which Lissajous figure is circle or ellipse i.e. phase difference is $\frac{n\pi}{2}$. An elliptical shape can be made circular with adjusting R_2.
6. At circular shape phase difference 'θ' is 90^0, so phase difference is 9^0 per unit cell. Note the reading.

7. Repeat the observation with changing frequency.
8. Tabulate the frequency and phase difference 'θ'.
9. Plot the graph.
10. Find the maximum frequency and compare the result with theoretical value $\frac{1}{\pi}\sqrt{\frac{L}{C}}$.

For diatomic lattice

1. Keep both switches to diatomic side.
2. Note the value of C & C_1.
3. Take observation as taken for monoatomic lattice.
4. Tabulate the frequency and phase difference 'θ' and Plot the graph.
5. Note the energy gap.

10.7 Observation:

Table 1 for frequency (KHz) and phase difference for monoatomic lattice kit.

SN	Frequency(KHz)	Shape	Phase difference
1		Circle/ellipse	9^0
2		Circle/ellipse	18^0
3		Circle/ellipse	27^0
4		Circle/ellipse	89^0
5		Circle/ellipse	45^0
6		Circle/ellipse	54^0
7		Circle/ellipse	63^0
8		Circle/ellipse	72^0
9		Circle/ellipse	81^0

10		Circle/ellipse	90^0

Table 2 for frequency (KHz) and phase difference for diatomic lattice kit.

SN	Frequency(KHz)	Shape	Phase difference
1		Circle/ellipse	9^0
2		Circle/ellipse	18^0
3		Circle/ellipse	27^0
4		Circle/ellipse	89^0
5		Circle/ellipse	45^0
6		Circle/ellipse	54^0
7		Circle/ellipse	63^0
8		Circle/ellipse	72^0
9		Circle/ellipse	81^0
10		Circle/ellipse	90^0

10.8 Result:

(a)The dispersion relation of mono-atomic lattice is plotted and presented in graph 1 which correctly agreed with theory. The cut off frequency of mono-atomic lattice is found........Hz.

(b) Dispersion relation of di-atomic lattice is plotted and presented in graph 2 whichagreed with theory. The energy gap between optical branch and acoustic branch is ....

10.9 Precaution and source of error:

1. Instruction given in manual should be strictly followed.
2. Frequency measurement should be taken carefully.
3. There should be no fluctuation of power.
4. Graph should draw smoothly.

10.10 Summary:

1. Atoms/molecules of lattice vibrate due to internal energy and external force imposed on lattice.
2. Due to lattice vibration, there is transfer of energy.
3. Dispersion relation is the relation between frequency and wave vector for mono-atomic di-atomic lattice.
4. The energy from lattice cannot transfer above certain value of frequency called cut off frequency. This is electrically same as case of low pass filter.
5. In di-atomic lattice, energy can transfers from lattice in two mode – optical mode and acoustical mode with energy gap.

10.11 Glossary:

Lattice: A periodic arrangement of imaginary points in space in place of atoms/molecules of crystal

Lattice dynamic kit: A device to study monoatomic and diatomic lattice. It consists of chain of LC circuit.

Dispersive relation: It is the relation between frequency and wave.

Cut off frequency: Above certain value of frequency,the energy from lattice do not transfer is called cut off frequency. This is electrically same as case of low pass filter.

10.12 References:

1. R.K.puri andV.K.Babbar, Solid State Physics and electronics,S. Chand publication, Delhi.

2. S.O. Pillai, Solid State Physics, New Age Publcation, New Delhi.

3. C.Kittle, Introduction to Physics, Wiley India Edition.

5. Practical manual, Mittal Enterprises, Patel Nagar, New Delhi.

4.*https://en.wikipedia.org.*

10.13 Viva-voce questions:

Question1. What do you understand by lattice?

Answer: The regular or periodic arrangement of infinite numbers of imaginary points (having relationship with atoms/molecules of crystal) in three dimensional space with each points having identical surroundings is called lattice. Lattice form a actual framework of a crystals.

Question2. Define dispersion relation of monoatomic and diatomic lattice.

Answer: Due to internal or external energy, the crystal vibrates and there is no transfer of signal or energy. The frequency of wave of signal related to wavelength is given by

$$\omega = \pm\sqrt{\frac{4\beta}{m}}\sin\frac{Ka}{2}$$ in a monoatomic lattice and

$$\omega^2 = \beta\left(\frac{1}{m}+\frac{1}{M}\right) \pm \beta\sqrt{\left(\frac{1}{m}+\frac{1}{M}\right)^2 - \frac{4\sin^2 Ka}{mM}}$$ in a diatomic lattice

The above relations are called dispersion relations.

Question3. Define Brillouin zone

Answer: Plot of frequency and wave vector K shows that numbers of K values are associated with same frequency ω. So lattice can propagate numbers of wavelength corresponding same frequency, which physically verify the periodicity of crystal. The regions in which K range as '$-\frac{\pi}{a}\langle K \langle \frac{\pi}{a}$' is called first Brillouin zone. Similarly the region of K values $-\frac{2\pi}{a}\langle K \langle \frac{2\pi}{a}$ is called second Brillouin zone and so on.

Question4. What do you understand by optical branch and acoustical branch? Also define forbidden frequency

Answer: The allowed frequency range in diatomic lattice split into two branches, an upper branch is called optical branch and lower branch is called acoustical branch and forbidden band. The vibrations of acoustical branch can be excited by force which makes atoms in crystal move in same direction. Such effects may produce sound waves on surface of the crystal and therefore called acoustical vibrations. The vibrations of optical branch can be excited by force which makes atoms in crystal move in opposite direction. Optical radiation can make such effects and therefore called optical vibrations.

Question5. How you understand lattice practically?

Answer: The frequency response of lattice is that it does not transfer energy after certain frequency limit. So it has same working as low pass electrical filter having chain of units, and in which one unit is equivalent to LC circuit. In case of diatomic lattice there are two capacitances C and C_1. Hence study of chain of LC circuit (electrical analog of lattice), we can understand lattice practically.

Experiment 11: Study of logic gates

Structure

11.1 Objective:

After performing this experiment, you should be able to understand

Types of logic gates

Use of logic gates

Half adder and Full adder

11.2 Introduction:

All digital electronic circuits and microprocessor based on hardware elements are called Digital Logic gates. Logic gates performs the logical operations of AND, OR and NOT on binary numbers. There are two voltage levels or states allowed in digital logic circuits and these states are generally referred to as Logic 1 (HIGH) or Logic 0 (LOW). Boolean algebra is used for binary operation in logical circuits. TRUE or FALSE and ON or OFF can be understood as logical level. In term of voltage level, one common logic is logic 1 (5V i.e. HIGH) and logic 0 (0V i.e. LOW).

Simple digital logic gates can be made by combining transistors, diodes and resistors as discrete components. Such circuits can be made using Diode-Resistor Logic (DRL), Diode-Transistor Logic (DTL) and Transistor-Transistor Logic (TTL). Integrated circuit are available in 74 series for logical gates families.

11.3 Apparatus Used:

Experimental board with slotted ICs for all gates, connection wires.

11.4 Theory :

Figure 1 represents the symbols of all gates. Working of digital logic gates are AND, OR, NOT, NAND and NOR are as following

(A) **AND gate:** The AND gate is a basic digital logical gate whose output is at high state when all the input are in high sate. If one of the input is at low state, the output will be low.

(B) **OR gate:** The OR gate is a basic digital logical gate whose output is at high state (1) when one of the input is high state (1).

(C) NOT gate: The output state is at low state (0) when input is high (1) and vice versa.

(D) NAND: It is combination of NOT and AND gate.

(E) **NOR:** It is combination of NOT and OR gate.

(F) **XOR:** Its out put is in high state (1) when odd numbers of input are at high state(1).

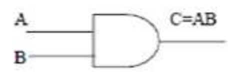
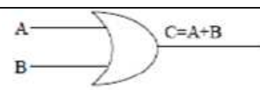
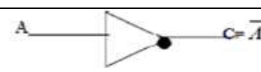
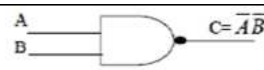
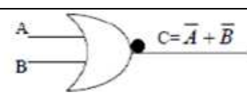
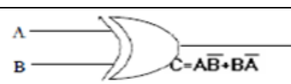
Gate	Symbol
AND	
OR	
NOT	
NAND	
NOR	
XOR	

Figure 1

11.5 About apparatus:

The apparatus is board contains different circuits (ICs) for the logical gates.

(A) **Integrated circuits (ICs) for all above said logical gates are as following**

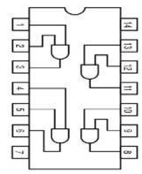
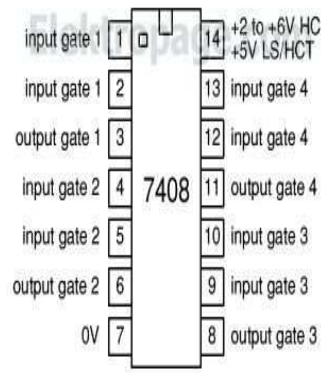
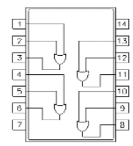
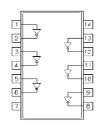
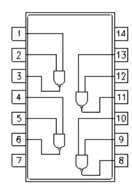
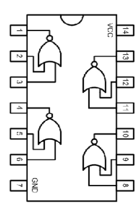
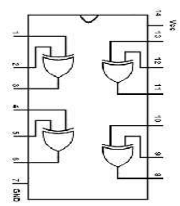
Gate	IC	PIN diagram	PIN diagram description
AND	7408, quad, 2-input IC		
OR	7432, quad, 2-input IC		
NOT	7404, quad, 1-input IC		
NAND	7400, quad, 2-input IC		
NOR	7402, quad, 2-input IC		
XOR	7486, quad, 2-input IC		

Figure 2

(B) Circuit for half adder

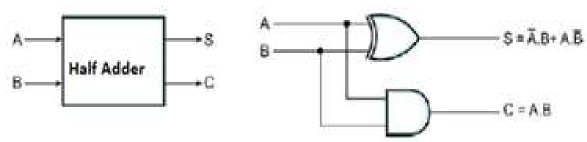


Figure 3

(C) **Circuit of full adder**

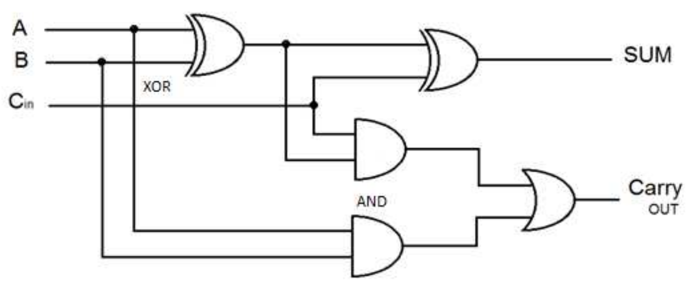


Figure 4

11.6 **Procedure**:

Let us perform the experiment in following steps.

(A) For digital gates

1. For AND gate, connect wire to input to give all possible combinations of high and low state (low state'0' and high state '1'.
2. Observe output from LED indicator.
3. Present results in truth table.
4. Perform the observation for all logical gates.

(B) For half adder

1. Connect circuit as in figure 3.
2. Set input (all possible combinations of high and low state (low state'0' and high state '1').
3. Observe sum and carry.

(C) For full adder

1. Connect circuit as in figure 4.
2. Set input (all possible combinations of high and low state (low state'0' and high state '1').
3. Observe sum and carry.

11.7 Observation:

(A) Table for truth table 1 for all gate

Gate	Truth table		
	Input A	Input B	Output
AND	0 0 1 1	0 1 0 1	
OR			
NOT			
NAND			
NOR			
XOR			

(B) Table 2 for half adder

INPUTS		SUM	CARRY
A	B	S	C
0	0		
1	0		
0	1		
1	1		

(C) Table 3 for full adder

INPUTS			SUM	CARRY
A	B	C_{in}	S	C
0	0			
1	0			
0	1			
1	1			

11.8 Result:

1. The truth tables of all logical gates are presented in tables.
2. The truth tables for half adder and full adder are presented in table 2 and 3 respectively.

11.9 Precaution and source of error:

1. Avoid direct contact with any power source. Turn off all power sources when not needed.
2. Before making changes in a circuit, turn off or disconnect the power first.
3. Know that the circuit and connections are correct before applying power to the circuit.
4. ICs should handle and pined properly in mounting board.

11.10 Summary:

6. Output of logical circuits are either high (logical 1) or low state (logical 0).
7. Output of AND logical circuits is high, when both the inputs are at high.
8. Output of OR logical circuits is high, when either of the inputs are at high.
9. Output of not logical circuits is revert of input.
10. Logical circuits are basic unit of microprocessor.

11.11 Glossary:

IC: Integrated Circuit
DRL: Diode-resistor logic
DTL: Diode-Transistor Logic
Boolean algebra: Used in digital operation
High & Low state: Digital circuit works on two state of voltage i.e. high state (digitally 1) and low state (digitally low)

11.12 References:

1. C. L. Arora,B.Sc. Practical Physics, S. Chand publication, Delhi.
2. V.K. Mehta & Rohit Mehta, Principles of Electronics, S. Chand publication, Delhi.
3. B. L. Thereja, Basic electronics, S. Chand publication, Delhi.
4. S. L. Gupta, V. Kumar, Practical Physics, Pragati prakashan, Meerut.
5. https://en.wikipedia.org.
6. *Gupta & Kumar, Hand book of electronics,* Pragati prakashan, Meerut.

11.13 Viva-voce questions:

Question1. What are DIGITAL gates?

Answer: Digital gates are basically electronic components which are used for switching and manipulating binary data

Question2. What do you mean by universal gate?

Answer: The universal gates are those gate from which we can make any gate by using them. The universal gates are NAND & NOR gates.

Question3.**What are a half-adder and full adder?**

Answer:A logic circuit, that can add two 1-bit numbers and produce outputs for sum and carry, is called a half-adder.

A binary adder, which can add two 1-bit binary numbers along with a carry bit and produces outputs for sum and carry is called a full-adder.

Question4. **Explain what is a flip-flop?**

Answer: A flip-flop is a basic memory element that is made of an assembly of logic gates and is used to store 1-bit of information.

Experiment 12: Detection efficiency of diodes

Structure

12.1 Objective:

After performing this experiment, you should be able to

What is modulation and demodulation?

Type of modulation.

How diode can be used as detector or demodulator.

12.2 Introduction:

The diode detector is the simplest and most basic form of amplitude modulation(AM), AM signal detector and it detects the envelope of the AM signal.

The AM diode detector can be built from just a diode and a few other components and as a result it is a very low cost circuit block within an overall receiver. In the early days of radio, these signal detectors were made using discrete components, but modern radios will use integrated circuits with inbuilt detectors.

12.3 Apparatus Used:

Step down transformer, PN junction diode, micro ac & dc ammeter/milli ammeter, rheostat, load resistance, capacitor, battery.

12.4 Theory :

Modulation is the process of mixing of radio waves with carrier wave. A carrier wave is wave of high energy wave. Modulation is usually applied to electromagnetic signals i.e. radio waves, lasers/optics and computer networks. The common modulation methods includes Amplitude modulation (AM), Frequency modulation (FM), Phase modulation (PM), Polarization modulation, Pulse-code modulation and Quadrature amplitude modulation (QAM). The modulation is used to send electromagnetic signal to distant apart. At the other end, the signal is extract from the modulated signal. This process of extracting original signal from modulated signal is called demodulation.

The diode is useful in demodulation and therefor called AM diode detector.

AM diode detection process

The PN junction diode rectify the RF signal and provides an output equivalent to the envelope of one half of the signal.In view of the operation of the diode detector, it may sometimes be referred to as an envelope detector.

The incoming amplitude modulated RF signal consists of a waveform of both positive and negative going voltages as shown. Any audio transducer would not respond to this.

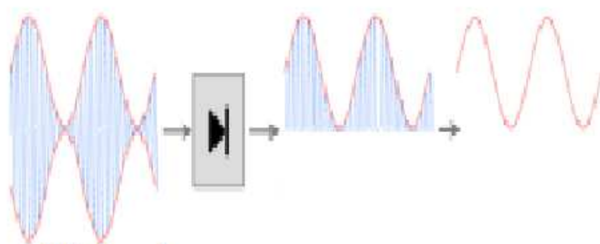


Figure 1

The high frequency element of this is then filtered out by a capacitor. The capacitor act as low pass filter and thus effectively filter the high frequency elements.

The efficiency of diode i.e. detection efficiency is given by the formula

$$\eta\% = \frac{Output\ Voltage}{Input\ Voltage} \times 100$$

$$\eta\% = \frac{RI_0}{\sqrt{2}E_r} \times 100$$

Where R is load resistance, I_0 is the current at which the efficiency is evaluated, E_r is the r.m.s. value if input voltage.

Following two methods are employed for the finding efficiency of diode.

1. Direct method and
2. Load line method

12.5 About apparatus:

The apparatus as presented in figure 2 consist of a circuit having following two main element

(1) **Diode / rectifier:** The diode in the detector serves to that enhances one half of the received signal over the other.

(2) **Low pass filter:** The low pass filter is required to remove the high frequency elements that remain within the signal after detection / demodulation. The filter usually consists of a very simple RC network but in some cases.

The capacitor used in the circuit should be selected so that it is large enough to hold the peak of the RF waveform, but not so large that it attenuates any modulation on the signal, i.e. it should act as a filter for the RF carrier and not the audio modulation.

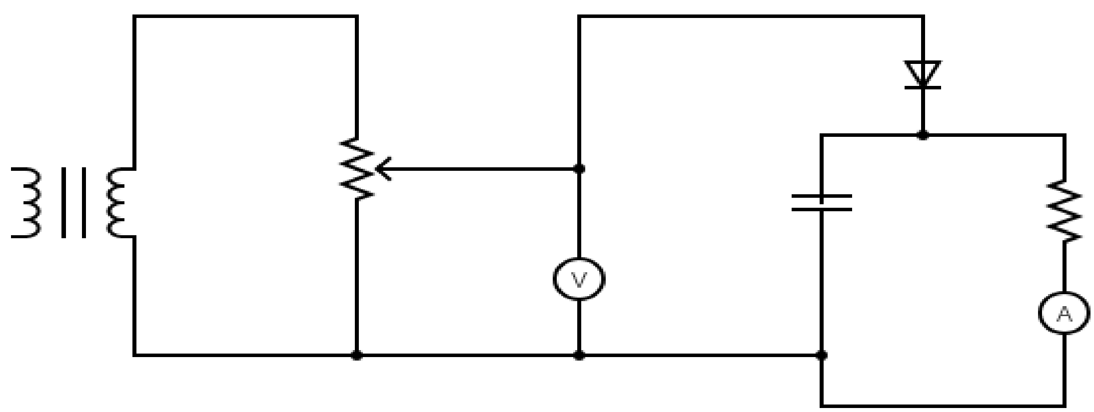


Figure 2

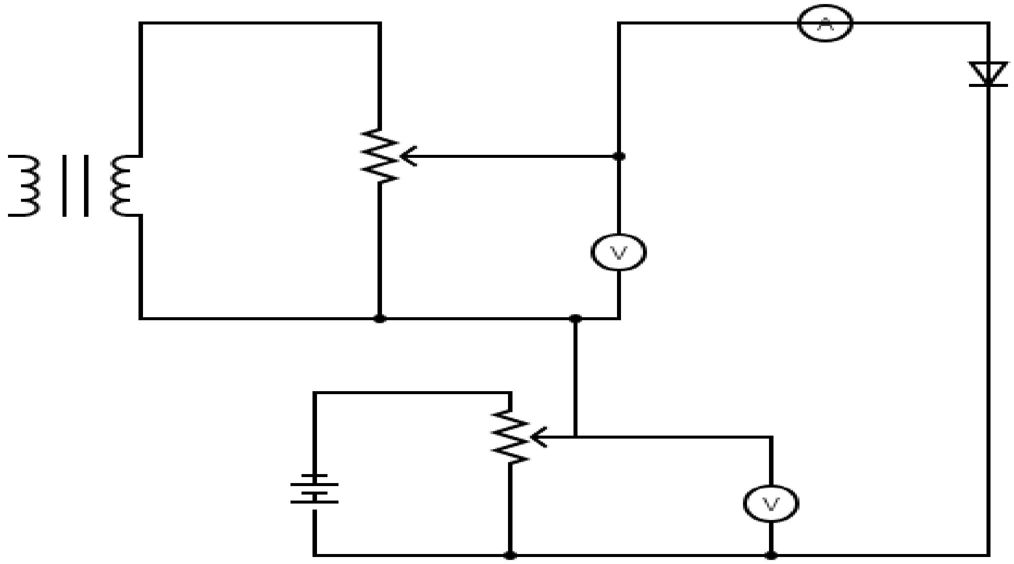


Figure 3

12.6 Procedure:

Let us perform the experiment in following steps.

For Direct method

1. Make connection the circuit as shown in figure 2.
2. Fixed the load resistance say 20 $K\Omega$.
3. For applied input signal voltage, read the output voltage and load current in micrometer.
4. Calculate efficiency by the formula.
5. Repeat the procedure 1-4 for different value of input signal voltage(E_r).

For load line method

1. Make connection the circuit as shown in figure 3.
2. Fixed the input signal voltage(E_r).
3. Read the forward current for different forward voltage of PN junction.
4. Draw the graph betweenforward voltage (V_f) and forward current (I_f).
5. Repeat the procedure 1-4 for different value of input signal voltage(E_r).
6. Draw load line for the load line 20 $K\Omega$.

7. From graph find the forward voltage (V_f) at the input signal voltage(E_r).
8. Calculate the efficiency $\eta\% = \frac{V_f}{\sqrt{2}E_r} \times 100$

12.7 Observation:

Table 1 for Direct method

Load resistance R = …….   Capacitance = ……..

S.N.	Input signal Voltage (E_r)	Micrometer reading I(μA)	Output Voltage (E_r)	$\eta\% = \frac{RI_0}{\sqrt{2}E_r} \times 100$
1				
2				
3				
4				

Table 2 for load line method

Signal voltage =……..

S.N.	Forward voltage (V_f)	Forward current (I_f)	$Output\ Voltage$ From graph for input signal voltage	$\eta\% = \frac{Output\ Voltage}{Input\ Voltage} \times 100$
1				
2				
3				
4				

12.8 Result:

The efficiency calculated by direct method and load line method are presented in table 1 and table 2 respectively.

12.9 Precaution and source of error:

5. Instruction given in manual should be strictly followed.
6. There should be no fluctuation of power.
7. Voltmeter and micrometer reading should taken carefully.
8. Current should not exceed the rating value of PN junction.
9. Graph should draw smoothly.

12.10 Summary:

11. PN junction diode in a simple circuit can be used in detecting the audio signal.

12. The PN junction diode is called envelop detector.

13. Filter circuit is used eliminate high frequency carrier signal from the modulated signal.

12.11 Glossary:

PN junction: Semiconductor device made by diffusion of P and N type semiconductor material.

Rectifier: That covert AC to DC.

Filter: The circuit that allow desire frequency to pass from it.

Efficiency: Capacity of rectification or envelop detection.

12.12 References:

1. C. L. Arora,B.Sc. Practical Physics,   S. Chand publication, Delhi.
2. V.K. Mehta & Rohit Mehta, Principles of Electronics, S. Chand publication, Delhi.
3. B. L. Thereja, Basic electronics, S. Chand publication, Delhi.
4. S.L.Gupta, V.Kumar, Practical Physics, Pragati prakashan Meerut.
5. Gupta & Kumar, Hand book of electronics, Pragati prakashan Meerut.

5.https://en.wikipedia.org

12.13 Viva-voce questions:

Question1. What do you understand by demodulation?

Answer: It the reverse process of modulation. By this process an output wave or signal is obtained having the characteristics of the original modulating wave or signal.

Question2. How the PN junction diode can be used as demodulator or detector.

Answer: Diode detector circuit operates by detecting the envelope of the incoming signal. Current is allowed to flow through the diode in only one direction, giving either the positive or negative half of the envelope at the output. It is the simplest way to demodulate AM. If the detector is to be used only for audio detection it does not matter which half of the envelope is used, it will work equally for both cases.

Question3. Discuss the role of filter circuit in detection

Answer: The filter circuit by pass the high frequency (carrier signal of modulated signal). So it give original modulating signal as output.

Experiment 13: Study of ESR spectra of given sample

Structure

13.1 Objective:

After performing this experiment, you should be able to

What is ESR spectroscopy?
What is g-Lande factor

13.2 Introduction:

In 1944 by E.K. Zavoisky perform magnetic resonance experiment in solids. Electron Spin Resonance (ESR) is a branch of absorption spectroscopy in which radiations having frequency in the microwave region (0.04 – 25 cm) is absorbed by paramagnetic substances. An electron has a spin and due to spin it possessed magnetic moment. The atoms, ions, molecules or molecular fragments which have an odd number of electrons exhibit characteristic magnetic properties due to finite magnetic moment. Such atoms, ions, molecules or molecular fragments absorbs energy and induces transitions between magnetic energy levels of electrons of unpaired spins. It is also known as Electron Magnetic Resonance (EMR) or Electron Paramagnetic Resonance (EPR).

It is a sensitive and informative technique for the investigation of different kinds of paramagnetic species in solid or liquid states and also has great importance in many fields as unpaired electron in semiconductor and organic free radicals, ferro and anti-ferro magnetic material.

13.3 Apparatus Used:

Highly stabilized power supply, Helmholtz coil, sample, RF oscillator, Oscilloscope and connecting wires.

13.4 Theory :

The phenomenon of electron spin resonance (ESR) is based on the fact that an electron is a charged particle. It spins around its axis and this causes it to act like a tiny bar magnet. When a molecule or compound with an unpaired electron is placed in a strong magnetic field The spin of the unpaired electron can align in two different ways creating two spin states ms = ± ½.The alignment can either be along the direction (parellel) to the magnetic field (corresponds to the lower energy state $m_s = -\frac{1}{2}$) or opposite (antiparallel) to the direction of the applied magnetic field (corresponds to the higher energy state $m_s = +\frac{1}{2}$). The two alignments have different energies and this difference in energy lifts the degeneracy of the electron spin states. The energy difference is given by:

$$\Delta E = E_+ - E_- = h\nu = g\mu_0 H$$

Where ν- Resonant frequency, μ_0 -Bohr magnetron=0.927 x 10^{-20} erg/gauss,

h (Planck's constant)= 6.6 x 10^{-27} erg.sec and H_0 – magnetic field at resonance.

Now if the electron has orbital magnetic moment with spin magnetic moment, then total magnetic moment will interact with applied magnetic field. The atoms/molecules having magnetic moment μ, when placed in uniform magnetic fiel 'H' will precess around the field direction with Larmor frequency ω

$$\omega = g\left(\frac{e}{2mc}\right)H$$

Where 'g' is called g - lande factor and its value is '1'for pure orbital motion and '2' for pure spin motion.

13.5 About apparatus:

The block diagram of ESR spectrometer is given in figure 1. The ESR circuit consists of critically adjusted radio frequency oscillator of frequency range 10-17MHz. The sample is kept in tank coil of this oscillator, which placed in the 50Hz magnetic field generated by Helmholtz coil. At the resonance where frequency o oscillation is equal to Larmer's frequency of sample, the oscillator amplitudes will dip at resonance due to absorption of power by the sample. Apparatus contains following parts

(c) Phase shifter to compensate the phase difference which is introduced in amplification stage of ordinary oscilloscope.

(d) The ESR requires a highly stabilized ripple free voltage. It is obtained using integrated circuit regulator.

(e) Helmholtz coil is two exactly alike and parallel circular coil, in which current passes in same direction. There is uniform magnetic field region between two coils in which sample is kept.

(f) R.F. oscillator is used to find resonant frequency.

(g) Oscilloscope is used to trace the two peaks at resonance.

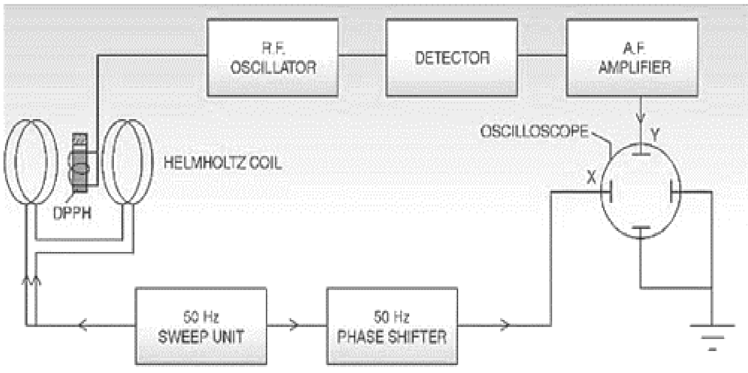


Figure 1

13.6 **Procedure**:

Let us perform the experiment in following steps.

11. Switch on 'Helmholtz coil' power and adjust current at 150mA.
12. Set control panel of ESR spectrometer as

    Frequency – Centre

    Sensitivity – Fully clockwise

    Phase – Centre
13. Observe four peaks in oscilloscope (CRO).
14. Adjust sensitivity & frequency of ESR spectrometer and sensitivity of CRO to get sharp signal.
15. Adjust phase nob of ESR spectrometer to coincide two peaks with the other two.
16. Determine the magnetic field as follows

    First calibrate the X plate of CRO by adjusting X amplifier to maximum deflection (say P division on CRO). Then read current in Helmholtz coil and calculate magnetic field by

$$H = \frac{32\pi n}{10a\sqrt{125}} I$$, H is rms field, peak to peak field is $2\sqrt{2}H$ and if represent'P' division of X plate of CRO. The zero field should be at middle.

n- number of turns in each coil

a-radius of coil

I-current(in amp) flowing in each coil

17. Measure the positions of two peaks (equal distance from middle point) let it be 'Q' division. So its value at resonance will be

$$H_0 = \frac{2H\sqrt{2}}{P} Q$$

18. Using condition of resonance

$$h\nu_1 = g\mu_0 H$$

$$g = \frac{h\nu_1}{\mu_0 H}$$

ν_1- Resonant frequency, μ_0-Bohr magnetron=0.927 x 10^{-20} erg/gauss,

h –Planck's constant=6.6 x 10^{-27} erg.sec and H_0 – magnetic field at resonance.

19. Repeat the experiment for different value of current.

13.7 Observation:

SN	Resonance frequency (MHz) in R.F. oscillator (ν_1)	Current (ampare) in Helmholtz coil (I) at resonance	Magnetic field in gauss at resonance (H0)	'g' lande factor
1				
2				
3				

13.8 Result:

The value of 'g' lande factor for the given sample is …………….

13.9 Precaution and source of error:

10. The experiment should perform in place where there is no mechanical and electric disturbance.

11. Sensitivity of X and Y plate should be adjusted to linear range.

12. Helmholtz current should remains constant during observation.

13. High current should not flow in Helmholtz coil to avoid heating in coil.

14. Two peaks should coincide in X scale. If not, check the sinusoidal form of mains voltage. This may distorted due to other heavy gadgets working on same line.

13.10 Summary:

1. Atoms and molecules with unpaired electron give an ESR signal.
2. ESR involve absorption of electromagnetic radiation.
3. Electrons possess spin angular momentum and an accompanying magnetic moment.
4. The *g*-factor is a dimensionless quantity that characterizes the magnetic moment and angular momentum of an atom, a particle or the nucleus. It is a proportionality constant that relates the observed magnetic moment μ of a particle to its angular momentum.

13.11 Glossary:

ESR: Electron spin resonance spectrometer.

R.F. oscillator: Radio frequency oscillator.

Bohr magnetron: The physical constant, which represents the magnetic moment is called Bohr magnetron. Its value is 9.274×10^{-24}J/T.

Resonance: Phenomena of matching frequency.

Helmholtz coil: Two identical coaxial circular coils in which current flows in same direction. Between these coil, there is uniform magnetic field.

CRO: Cathode ray oscilloscope use to see visual effect of electricity.

13.12 References:

1. Raj Kumar, Atomic and molecular physics. Kedar Nath publication.
2. Element of spectroscopy,Gupta,Kumar&Sharma, Pragati Prakashan,Meerut.
3. Practical manual, SES instrument Pvt.Ltd., Adarsh Nagar, Roorkee.
4. Molecules Spectroscopy, C. N. Banwell, McGraw Hill
5. *https://en.wikipedia.org.*

13.13 Viva-voce questions:

Question1. What is g-lande factor?

Answer: The g-lande is a dimensionless quantity that characterizes the magnetic moment and angular momentum of an atom, a particle or nucleus.

Question2. Which physical phenomenon happens in Electron spin resonance?

Answer: Electron spin resonance involves absorption of electromagnetic radiation.

Question3. Is there any effect by electromagnetic wave on spin of electrons on multi-electrons system?

Answer: Yes. ESR or EPR is commonly used to measure such effect. In this phenomenon, electromagnetic radiation is absorbed and it flips spins from low energy to high energy states. ESR is often measured in systems which not only have many electrons but also where the electrons interact strongly as in ferromagnetic materials.

Question4. How the sensitivity of measurement is enhanced

Answer: By applying high magnetic field

Question5. When the electrons are aligned either parallel or anti-parallel to the direction of the external magnetic field, the electrons will precess about the axis. The frequency of Larmor precession depends on which factors?

Answer: When the electrons are aligned either parallel or anti-parallel to the direction of external magnetic field, the electrons will start to precess about the axis at a frequency that is proportional to both applied magnetic field and electron magnetic moment.

Experiment 14: Study of RCS spectrometer

Structure

14.1 Objective:

After performing this experiment, you should be able to understand

1. Determine GM counter graphs i.e. plateau and optimal operating voltage of a Geiger-Muller counter.
2. Efficiency of GM counter.
3. To find absorption coefficient of absorber.
4. Verify the inverse square relationship between.

14.2 Introduction:

The RCS spectroscopy refer to study of radiation counting spectroscopy. The various instruments used for detecting nuclear particles and radiation are based on the principle of excitation or ionization of the atoms of medium in which subatomic particles pass. The ionization process consists of removing an electron from an initially neutral atom or molecule. Many radiation detectors like ionization chambers, proportional counters, GM counters, spark counters, cloud chambers and emulsion detectors are based on ionization of atoms by charge particles.

The loosely bound electrons of neutral atoms of medium can take energy from radiation and jump to higher excited state. The excited atoms re-emits the energy absorbed in form of visible photon in de-excitation process in very short time (10^{-6}-10^{-9}secs). The counters based on this principle are called scintillation counters.

GM counter is a radiation counter used in this practical.GM counter is a metal cylinder filled with low-pressure gas sealed with a plastic or ceramic window at one end.

14.3 Apparatus Used: GM counting system, GM detector in PVC cylindrical enclosure, source, Source holder, bench and connection wires.

14.4 Theory :

In GM counter, when a large voltage is applied between anode and cathode of counter, a large ion multiplication gas is produced due to secondary collisions of electrons especially in anode region. Very soon the large flux of secondary electron and ions produced in space between anode and cathode. Electrons are lighter and collected in anode in short time (10^{-3}-10^{-4} sec). The counter come back after short time interval. This make pulse in output of counter. The creating a pulse which can be amplified and counted.

(A)The plateau region of GM counter

There is a threshold below which the tube doesn't work. After this, the number of pulses is proportional to the voltage. This region is known as proportional region.

If the applied voltage is increased further, then a point will be reached after which the count rate remains constant over a certain region. This region is known as plateau region or Geiger region. This region is used for Geiger Muller operation. Beyond the plateau region the applied electric field is so high that a continuous discharge takes place in the tube and the count rate increases very rapidly.

(B) Efficiency of GM counter

The efficiency of a detector is the ratio of the number of particles of radiation detected to number of particles of radiation emitted. This definition for the efficiency of a detector is also used for our other detectors. In practical, we will measure the efficiency of our Geiger counter system and find that it is quite small. The reason that the efficiency is small for a G-M tube is that a gas is used to absorb the energy. A gas is not very dense, so most of the radiation passes right through the tube. Unless alpha particles are very energetic, they will be absorbed in the cylinder that encloses the gas and never even make it into the G-M tube. If beta particles enter the tube they have the best chance to cause ionization. Gamma particles themselves have a very small chance of ionizing the gas in the tube. Gamma particles are detected when they scatter an electron in the metal cylinder around the gas into the tube. So although the Geiger counter can detect all three types of radiation, it is most efficient for beta particles and not very efficient for gamma particles. The scintillation detectors will prove to be much more efficient for detecting specific radiation.

(C) Absorption coefficient of absorber (Absorption of beta /gamma rays in materials)

While passing through a gaseous medium, nuclear radiations (either charged particles or gamma rays) ionizes atoms/molecules. This ionizing property of a nuclear radiation is utilized for its detection. When a beam of radiation (say γ rays) with an initial intensity I_0 passes through an absorber of thickness x, its intensity will be reduced to a value I(x) given by

$$I(x) = I_0\, e^{-\mu x}$$

where μ is the absorption coefficient.

Intensity is related to the number of particles per unit area per unit time. We will measure the number of counts N for a given time period for a given fixed geometry; in this case the number of counts N is directly proportional to the intensity I, so

$$N = N_0 e^{-\mu x}$$

The number of counts N for a fixed time period clearly depends on the thickness x of the absorber brass. We expect to see an exponential decrease of the number of counts with thickness x.

(D) Inverse square law

As a source is moved away from the detector, the intensity or amount of detected radiation decreases. Inverse square law says is that the intensity of radiation inversely proportional to square of distance. Using the GM counter, the intensity of radiation is take by counted with increasing distances as factor $1/d^2$.

14.5 About apparatus:

Geiger-Muller (GM) are used to detect radioactive particles. It was were invented by H. Geiger and E.W. Muller in 1928. A GM Counter consists of a GM tube having a thin end window, a high voltage supply for the tube, a particle recorder for particles detected by the tube, and a timer to stop recorder action. The sensitivity of the GM tube is such that any particle capable of ionizing a single atom. The collection of the charge produced by ionization formed of a pulse of voltage at the output of the tube. The amplitude of this pulse very low for counting so amplified. The pulse amplitude is largely independent of the properties of the particle detected, so give information about nature of the particle. GM Counter is a versatile device used for counting alpha particles, beta particles, and gamma rays.

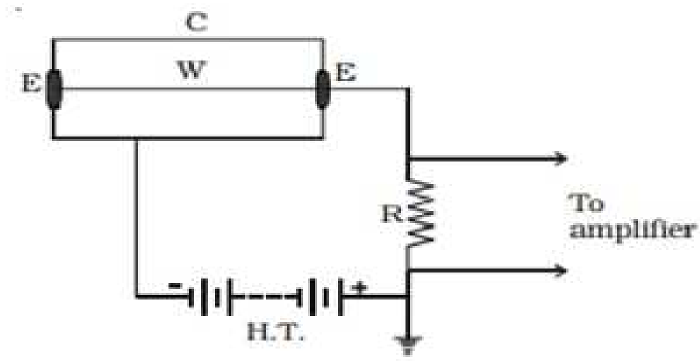


Figure 1

G-M tubes as shown in figure 1 is a gas filled cylindrical tube having two electrodes. The collector electrode (anode) is mounted coaxially and insulated from the outer electrode (cathode). The gases are usually noble gases. G-M tubes require a high voltage. The ion pairs produce in the G-M tube surrounds the anode. Due to high mobility, the free electrons are collected quickly on anode by the strong electric field.

14.6 **Procedure**:

Let us perform the experiment in following steps.

(A) Characteristics curve of GM counter

1. Make connection between GM counting system and GM detector and main chord to main power.
2. Place radiation source (beta or gamma) to window of detector.
3. Press start button and
4. Find the voltage at which the GM tube just starts counting (~400V).
5. Starting from this voltage (just starts counting) take the number of counts n(V) for 30.
6. Find counts per second.

7. Take counts at voltage V in the step of 20 volts.
8. Plot graph between count per second N(V)Voltage applied.

(B) Efficiency of GM counter

1. Convert the disintegrations per minute unit is equivalent to the counts per minute from the GM tube, because each disintegration represents a particle emitted. The conversion factor is 1 Ci = 2.22 × 1012 dpm or 1 μCi = 2.22 ×106 dpm.
2. Multiply this factor by the activity of the source and you have the expected counts per minute of the source.
3. Set the Voltage of the GM tube to its optimal operating voltage, which should be around 900 Volts.
4. Set time to 60 to measure activity in cpm.
5. Observe count without a radioactive source to determine your background level.
6. Next, place one of the radioactive sources (Po-210, Sr-90, Co-60) in close to detector window.
7. Now count with the source
8. Find corrected Counts (counts with source – counts without source).
9. Calculate % Efficiency = r x 100/CK , where r is the measured activity in cpm, C is the expected activity of the source in μCi, and K is the conversion factor.
10. Repeat above for other sources.

(C) Absorption coefficient of absorber (Absorption of beta /gamma rays in materials)

1. Start the GM tube.
2. Set the Voltage of the GM tube to its optimal operating voltage around 900 Volts.
3. Set time to 60 second.
4. Take counts without a radioactive source to determine your background level.
5. Place the radioactive source in the detector window.
6. Place an absorber disk in between source and detector
7. Increase the thickness of absorber by placing two or more similar disc one by one. Now observe counts (N) with increasing thickness.
8. Draw graph between log N and thickness (x). Find the slope.

9. Repeat the experiment for other absorber.

(D) Inverse square relationship between the distance and intensity of radiation

1. Start the GM tube.
2. Set the voltage of the GM tube to its optimal operating voltage around 900 Volts.
3. Observed counts without a radioactive source to determine your background level.
4. Place the radioactive source in source holder.
5. The operating voltage must correspond to the midpoint of flat plateau region of plateau graph.
6. Place the source is 2 cm from the GM tube's actual detector components and note the counts for 60 seconds.
7. Increase the distance between source and detector and take the counts.
8. Plot graph between counts and $1/d^2$.
9. Straight line verify the inverse square law.
10. If the continuous discharge is produced, the voltage should be lowered.

14.7 Observation:

Table 1 for Count Vs applied voltage

S.N.	Voltage (V)	Counts in 60 second	Count rate	S.N.	Voltage (V)	Counts in 60 second	Count rate
1				10			
2				11			
3				12			
4				13			
5				14			

6				15			
7				16			
8				17			
9				18			

Table 2 for Count Vs applied voltage

Source	Counts	Corrected counts	Expected Counts	Efficiency

Table 3 for Count with thickness of absorber applied voltage

Source	Thickness	Counts (N)

Table 4 for Counts Vs varying distance

SN	Distance between source and detector (X) In cm	Counts in 60 seconds
1		
2		
3		
4		
5		

6		
7		

14.8 Result:

1. The characteristics curve is presented in graph.
2. The efficiency of GM counter is
3. The absorption coefficient of different absorbent are tabulated in the table.
4. The Inverse square verified.

14.9 Precaution and source of error:

1. Place the radioactive source closed to detector window.
2. Using the Operating Mode information described above, set the unit up to perform the desired function.
3. Press the COUNT button to start data acquisition, the STOP button to halt data acquisition (providing Preset Time is not being used), and the RESET button to reset the time and data to zero.
4. When the high voltage is on, do not touch the high voltage leads or connectors.
5. Work gently with the radioactive substance.
6. Work with given instruction in operating of GM counter.
7. Do not exceed a photomultiplier voltage of 600 V.

14.10 Summary:

1. The GM counter is used for radiation detector.
2. The GM counter works properly and characteristics curve is as desired.
3. The efficiency of GM counter is low.
4. The square inverse law hold good.
5. The intensity of radiation as counted decreases with thickness of absorber.

14.11 Glossary:

RCS: Radiation counting system

GM counter: Geiger-Muller counter

Efficiency: It is ratio of radiation detected to radiation expacted.

Pulse: It is flux of current produce in short interval

Radioactive activity:The *activity* of a sample of *radioactive* matter is defined by the numbersof disintegrations taking place at its core at any given moment. The ***activity*** also represents the number of radiations emitted.

14.12 References:

1. B.N. Srivastava, Basic Nuclear Physics, Pragati prakashan.
2. The practical manual by Nucleonix system private limited, Hydrabad
3. S.B. Patel, Nuclear physics: An introduction, New age publication.
4. S.N. Ghosal, Nuclear physics, S Chand publication.
4. *https://en.wikipedia.org.*

14.13 Viva-voce questions:

Question1. State principle of GM counter.

Answer: **When nuclear radiations pass through the gaseous medium, gas ionization is produced. This produces the pulse, which is then amplified.**

Question2.What gas is used a G.M. COUNTER, why.

Answer: Argon, It is electrically complete in the outer electron shell, making it Electro – chemically stable.However in the presence of ionizing radiation ,such as gamma or beta, electrons can be "knocked off" the inner wall of the GM tube by the radiation

Question3. What is the dead time of GMtube

Answer: When the beta from the decay product enters the Geiger Muller tube,it collides with an atom ionizing it which in turn releases more electron.This causes the chain reaction of cascading electrons until it hits the electrodes which is measured as one count.After this event, the tube is filled with slow moving positive ions that advance towards the outer walls.

Question4. What is used of GM counter.

Answer: Devices used for detecting and counting individual particles of radiation. The device is a gas filled metal tube with a wire through its axis and a high voltage applied to the wire. As a particle enter the tube, they create a large avalanche of ionization in the gas which than discharges, creating a brief electrical pulse.

Experiment 15: Study of Gamma ray spectrometer

Structure

15.1 **Objective**:

To determine the energy of unknown gamma radiation

To determine the photo-peak efficiency

To determine detector resolution

15.2 **Introduction:**

Gamma spectroscopy is the science of identification and quantification of radionuclides by analysis of the gamma-ray energy spectrum produced in a gamma-ray spectrometer

Gamma radiations are high energy photons that penetrates matter. This is an advantage for the detection of gamma rays, as gamma spectrometry does not need the elimination of the matrix. The disadvantage is that it needs shielding against this radiation. In the Earth, the thorium and uranium nuclides and others are sources for gamma and other radiation. Gamma rays are electromagnetic radiation that have wavelength in range 10^{-7} to 10^{-13} m (Energy range of 0.01–10 MeV). Gamma rays are detected through their interaction with matter.

15.3 **Apparatus Used:**

NaI detector with accessories, Amplifier with ADC and Sources which radiate gamma rays.

15.4 **Theory** :

There are three main processes by which γ ray can interact are photoelectric absorption, Compton scattering and pair production.

Photoelectric absorption: The photoelectric effect occurs when a gamma ray interacts with an electron of an inner shell of an atom and a photoelectron is emitted. This is the most important effect for the detection of gamma rays. The gamma ray loses all its energy to one of the inner tightly bound atomic electrons of an atom and ionizing the atoms of matter.

Compton scattering: The effect of Compton scattering describes the interaction of a gamma ray with matter when some of its energy is transferred to the recoil electron. The energy transmitted is a function of the scattering angle. Therefore, the Compton effect results in a broad range of gamma□ray energies, which gives a continuous background in the gamma spectrum.

Pair production: Pair production is the third effect when a gamma ray is absorbed by matter and loses energy to produce an electron/positron pair. This effect only occurs when gamma rays have more than 1.02 MeV energy i.e. twice the rest mass energy of an electron (0.551 MeV).

15.5 About apparatus:

The components of apparatus are represented in figure 1. It have a source holder, detector with window, and photomultiplier tube.

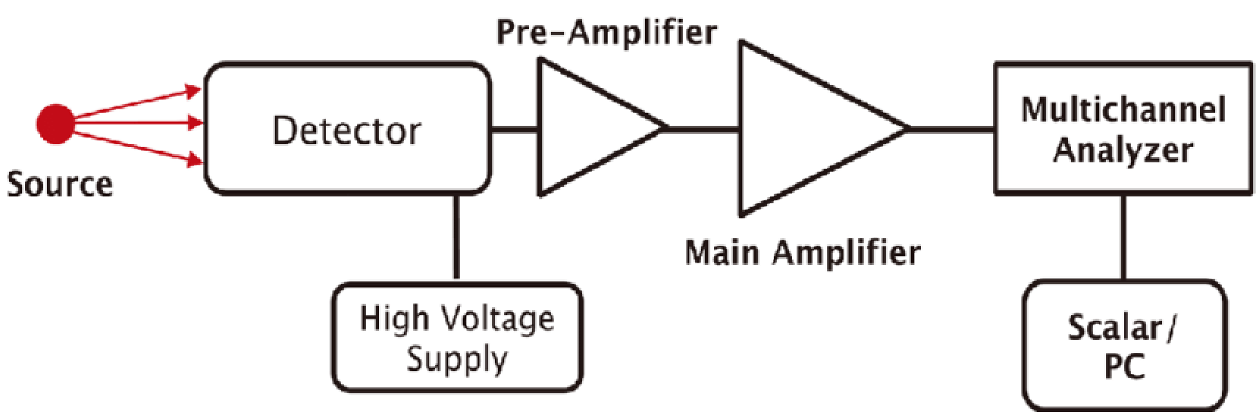


Figure 1

Scintillation Gamma Ray Spectrometer: A spectrometer is an instrument which is used to study the energy or wavelength spectra of radiation. The working of Scintillation gamma ray spectrometer is based on the fact that there are certain substances which emit light flashes (or scintillation) when charged particle, X-rays and γ-rays passes through them. In a scintillation detector these light flashes are allowed to fall on the photocathode of a photo multiplier tube and a pulse is taken out to signal the passage of nuclear radiation in the scintillator. Thallium activated sodium iodide crystal as a scintillator is used in scintillation detector.

Photo multiplier tube (PM tube): It is coupled to the crystal. Here the photons will cause the emission of electrons through the photo-electric effect. The number of electrons emitted from the photo cathode is proportional to the energy of the gamma radiation. The electrons are accelerated in the PM tube towards a structure of metal plates (by many dynodes). The electrons gives rise to an electric pulse, whose amplitude is directly proportional to the amount of light collected on the photo cathode, and thus directly proportional to the energy of the gamma radiation.

Channel: The pulses coming out from the photo-multiplier are fed to the single channel analyzer (SCA) or multi-channel analyzer (MCA).

15.6 Procedure:

Let us perform the experiment in following steps.

(A) Determination of gamma-Ray spectrum

1. Make connection and turn on the system.
2. Adjust high voltage to PMT about 500 to 600V.
3. Put the gamma ray source (^{137}Cs).
4. Adjust the discriminator of the preamplifier such that the Compton distribution should not have very high counts in the initial channels.
5. Keep all the settings undisturbed throughout the experiment.
6. Collect and store the spectrum of a ^{137}Cs source.
7. Identify photo-peak, Compton distribution and Compton edge.

(B) The relation between the channel scale and the energy of the radiation

1. Determine the channel position of the photo peak in the spectrum of ^{137}Cs by using the centroid routine.
2. Find the channel position of the center of mass of the photo peak.
3. Determine the channel position of the photo peak in the spectrum of ^{60}Co spectrum.
4. Note down the number of pulses and the number of pulses per second in the photo peaks of ^{137}Cs &^{60}Co.
5. Draw a diagram of the energies of the two photo peaks as a function of the corresponding channel position, i.e. the energy along the vertical axis and the channel number along the horizontal axis.

(C) Determination of the gamma-ray energies of an unknown gamma source

1. Take a unknown source
2. Determine a gamma-ray spectrum.
3. Calibrate it with known source.
4. Compare the gamma energies obtained with the decay schemes.

(D) Determination of detector resolution and its variation with energy

1. Find pulse height at the peak from spectrum
2. Find full width at half maximum (FWHM).
3. Calculate resolution as given by formula

$$\text{Resolution }\% = \frac{\text{FWHM}}{\text{Pulse height at peak value}} \times 100$$

15.7 Observation:

Table 1: calibration of MCA, determining unknown source and resolution

Source	Energy(MeV)	Channel no.	FWHM	Max. Intensity	Resolution

15.8 Result:

(1) The gamma ray spectrum of different source are presented in graphs.

(2) Full width at half maximum (FWHM),detector resolution are calculated from gamma ray spectrum are calculated and presented in the table 1.

15.9 Precaution and source of error:

1. When the high voltage is on, do not touch the high voltage leads or connectors.
2. Do not hold the sources in your hands longer than necessary, and when not handling the sources, keep them as far from you as practical.
3. The scintillator tube is mechanically fragile. Handle it with care.
4. Do not exceed a photomultiplier voltage of 600 V.

15.10 Summary:

1. Gamma radiation are photon of high energy.
2. Photoelectric effect is main cause of energy loss of gamma radiation with matter, so main peak in gamma ray spectrum comes due photoelectric effect.
3. Due Compton effect the photons a part of energy transfers to electron and the electrons scattered. This energy comes in background of gamma spectrum.
4. The detector resolution is calculated by full width at half maximum (FWHM)andpulse height at photo-peak value.

15.11 Glossary:

PMT: Photomultiplier tube.

FWHM: The energy resolution is measured as the full width at half maximum.

SCA: Single channel analyzer.

MCA: Multi-channel analyzer.

15.12 References:

1. B.N. Srivastava, Basic Nuclear Physics, Pragati prakashan.
2. The practical manual by Nucleonix system private limited, Hydrabad
3. S.B. Patel, Nuclear physics: An introduction, New age publication.
4. S.N. Ghosal, Nuclear physics, S Chand publication.
5. *https://en.wikipedia.org.*

15.13 Viva-voce questions:

Question1. What are gamma radiations?

Answer: *Gamma rays* are the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum. They are produced by the hottest and most energetic objects in the universe, such as neutron stars and pulsars, supernova explosions, and regions around black holes.

Question 2. What is photo-peak.

Answer: The photo-peak refers to the region of the pulse height spectrum caused by the complete photoelectric absorption of Gamma rays by the scintillator crystal.

Question3. Discuss the working of Scintillation Detector

Answer: A scintillation detector is one of several possible methods for detecting ionizing radiation. Scintillation is the process by which some material emits light in response to incident ionizing radiation. In practice, this is used in the form of a single crystal of sodium iodide that is doped with a small amount of thallium, referred to as NaI (Tl). This crystal is coupled to a photomultiplier tube which converts the small flash of light into an electrical signal through the photoelectric effect. This electrical signal can then be detected by a computer.

Question4. What is PMT and its working?

Answer: A photomultiplier tube (PMT) is device that converts light into an electrical signal and amplifies the signal to a useful level by emission of secondary electrons.

Experiment 16: Study of Multivibrator

Structure

16.1 Objective:

After performing this experiment, you should be able to

What are multivibrators

Types of multivibrators

Working of multivibrators

Applications of multivibrators

16.2 Introduction:

An electronic device that produces a non-sinusoidal waveform as its output is known as a **multivibrator**. The generated non-sinusoidal waveforms are basically a square wave, rectangular wave, a triangular wave, or sawtooth wave etc.

It consists of two amplifying device (transistors, vacuum tubes) in which output of one transistor in feedback to input of second and vice versa by resistor or capacitor. There three types of multivibrator as

1. **Astable multivibrator**: It is a circuit whose output is not in stable state. Its output continually changes from one state to the other. It is used as relaxation oscillator.
2. **Monostable multivibrator**: This a circuit having one stable states. A trigger pulse causes the circuit to enter the unstable state. After entering the unstable state, the circuit will return to the stable state after a set time. Such a circuit is useful for creating a timing period of fixed duration in response to some external event.
3. **Bistable multivibrator:** This circuit is in stable in either state. It can be flipped from one state to the other by an external trigger pulse. This circuit is also known as a flip-flop. It can store one bit of information, and is widely used in digital logic and computer memory.

16.3 Apparatus Used:

Experimental board, cathode ray oscilloscope (C.R.O.) & connection wires.

16.4 Theory :

Astable multivibrator: As presented in figure 1, the two transistors Q_1 and Q_2 are connected such a way that output of one transistor is feedback to other and vice versa. The collector of transistor Q_1 is connected to the base of transistor Q_2 through the capacitor C_1 and vice versa. The emitters of both the transistors are connected to the ground. The collector load resistors R_1 and R_4 and the biasing resistors R_2 and R_3 are of equal values. The capacitors C_1 and C_2 are of equal values.

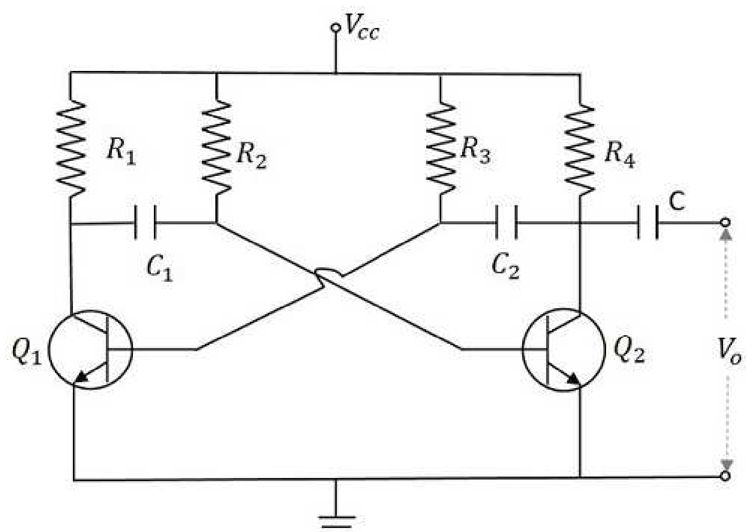


Figure 1

As no transistor characteristics are alike, one of the two transistors say Q_1 has its collector current increase and thus conducts. The collector of Q_1 is applied to the base of Q_2 through C_1. This connection lets the increased negative voltage at the collector of Q_1 to get applied at the base of Q_2 and its collector current decreases. This continuous action makes the collector current of Q_2 to decrease further. This current when applied to the base of Q_1 makes it more negative and with the cumulative actions Q_1 gets into saturation and Q_2 to cut off. Thus the output voltage of Q_1 will be $V_{CE\,(sat)}$ and Q_2 will be equal to V_{CC}.

The capacitor C_1 charges through R_1 and when the voltage across C_1 reaches 0.7 V, the transistor Q_2 turn on to saturation. As this voltage is applied to the base of Q_2, it gets into saturation, decreasing its collector current. This reduction of voltage is applied to the base of transistor Q_1 through C_2 which makes the Q_1 reverse bias.

A series of these actions turn the transistor Q_1 to cut off and transistor Q_2 to saturation (ON).

Hence the output voltage and the output waveform are formed by the alternate switching of the transistors Q_1 and Q_2. The time period of these ON/OFF states depends upon the values of biasing resistors and capacitors used, i.e. on the R_C values used. As both the transistors are operated alternately, the output is a square waveform, with the peak amplitude of V_{CC}.

Monostable multivibrator: Firstly, when the circuit is switched ON, transistor Q_1 will be in OFF state and Q_2 will be in ON state. This is the stable state. As Q_1 is OFF, the collector voltage will be V_{CC} at point A and hence C_1 gets charged. A positive trigger pulse applied at the base of the transistor Q_1 turns the transistor ON. This decreases the collector voltage, which turns OFF the transistor Q_2. The capacitor C_1 starts discharging at this point of time. As the positive voltage from the collector of transistor Q_2 gets applied to transistor Q_1, it remains in ON state. This is the quasi-stable state or Meta-stable state.

The transistor Q_2 remains in OFF state, until the capacitor C_1 discharges completely. After this, the transistor Q_2 turns ON with the voltage applied through the capacitor discharge. This turn ON the transistor Q_1, which is the previous stable state.

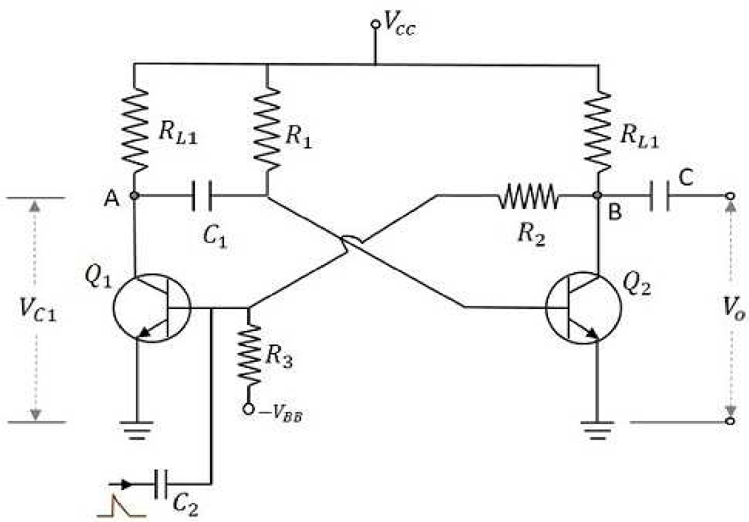


Figure 2

Bistable multivibrator: The circuit for bistable multivibrator is presented in figure 3. When the circuit is switched ON, due to some circuit imbalances as in astable multivibrator, one of the transistors let Q_1 gets saturated (ON state) and the transistor Q_2 gets cut off (OFF state). This is a stable state of the Bistable Multivibrator.

When a negative pulse at the base of transistor Q_1 is applied, the collector voltage increases. This is forward biases the transistor Q_2. The collector current of Q_2 as applied at the base of Q_1, reverse biases Q_1 and this cumulative action, makes the transistor Q_1 to OFF and transistor Q_2 to ON. This is another stable state of the Multivibrator.

Now, if this stable state has to be changed again, then either a negative trigger pulse at transistor Q_2 or a positive trigger pulse at transistor Q_1 is applied.

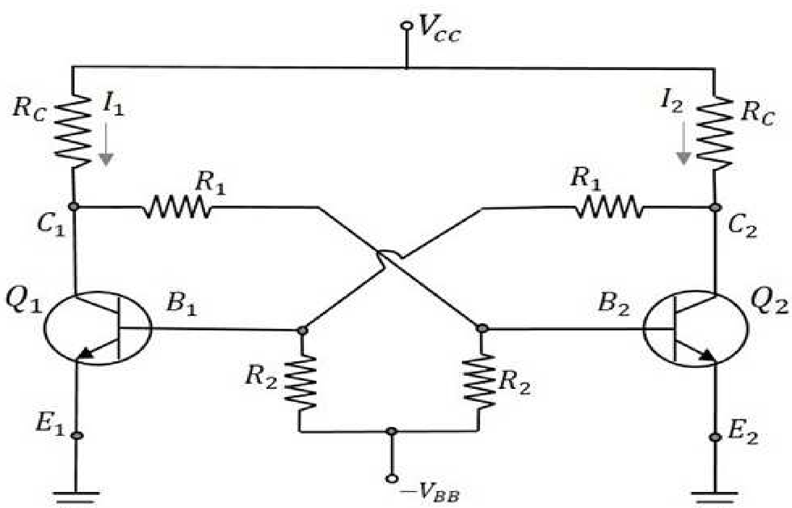


Figure 3

The 555 Timer is a highly stable integrated circuit that can produce accurate time delays and oscillations. The 555 Timer has three operating modes, bistable, monostable and astable mode. As represented in figure 4 (block diagram), it have of 2 comparator, flip flop and voltage divider, a discharge transistor and an output stage. It is 8 pin integrated circuit (IC).

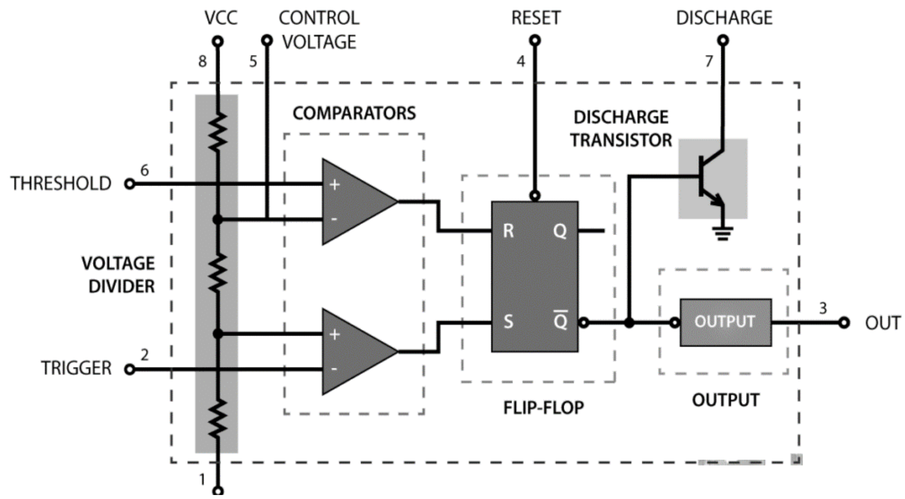


Figure 4

16.5 About apparatus:

The IC 555 timer with external time constant RC circuit is used to study the astable, monostable and bistable multivibrator. The 555 timer is 8 pin IC. The IC 555 timer is shown in figure 5with its pins and time constant RC circuit and pins of IC 555 timer denotes as following.

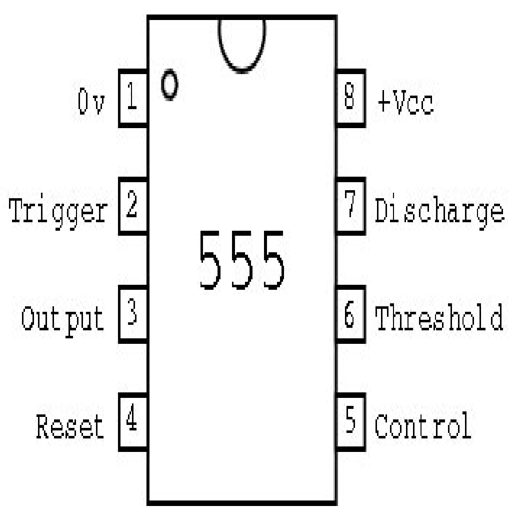


Figure 5

1. Pin 1. – **Ground**, The ground pin connects the 555 timer to the negative (0v) supply rail.
2. Pin 2. – **Trigger**, The negative input to comparator No 1. A negative pulse on this pin "sets" the internal Flip-flop when the voltage drops below 1/3Vcc causing the output to switch from a "LOW" to a "HIGH" state.
3. Pin 3. – **Output**, The output pin can drive any TTL circuit and is capable of sourcing or sinking up to 200mA of current at an output voltage equal to approximately Vcc – 1.5V so small speakers, LEDs or motors can be connected directly to the output.
4. Pin 4. – **Reset**, This pin is used to "reset" the internal Flip-flop controlling the state of the output, pin 3. This is an active-low input and is generally connected to a logic "1" level when not used to prevent any unwanted resetting of the output.
5. Pin 5. – **Control Voltage**, This pin controls the timing of the 555 by overriding the 2/3Vcc level of the voltage divider network. By applying a voltage to this pin the width of the output signal can be varied independently of the RC timing network. When not used it is connected to ground via a 10nF capacitor to eliminate any noise.
6. Pin 6. – **Threshold**, The positive input to comparator No 2. This pin is used to reset the Flip-flop when the voltage applied to it exceeds 2/3Vcc causing the output to switch from "HIGH" to "LOW" state. This pin connects directly to the RC timing circuit.
7. Pin 7. – **Discharge**, The discharge pin is connected directly to the Collector of an internal NPN transistor which is used to "discharge" the timing capacitor to ground when the output at pin 3 switches "LOW".
8. Pin 8. – **Supply +Vcc**, This is the power supply pin and for general purpose TTL 555 timers is between 4.5V and 15V.

16.6 **Procedure**:

Let us perform the experiment in following steps.

For Astable Multivibrator

20. Switch on the power supply.

21. Note down the values of resistor R_1, R_2 and capacitor C.
22. By the values of R_1, R_2 and capacitor Ccalculate the frequency of output wave given by the following formula

$$f_{cal} = \frac{1.44}{(R_1 + 2R_2)C}$$

R in ohm and C in farad to get f_{cal} in Hz.

23. Connect CRO at output terminal (pin 3) and ground terminal (pin 1).
24. Note the experimental values of amplitudes ($V_0 = V_{p\text{-calibration}}$) and frequency ($f_{exp}$) of output wave by calibrated CRO.
25. Trace the output wave.
26. Connect CRO at threshold terminal (pin 6) and ground terminal (pin 1) to record the exponential wave.
27. Note the experimental values of threshold amplitudes ($V_0 = V_{p\text{-calibration}}$) between (pin 6) and ground terminal (pin 1).
28. Trace the exponential wave.
29. Using trace of output rectangular wave determine the value of cycle time (T) corresponding to charge and discharge of capacitor and width (W) corresponds to charging time of capacitor.

T = ……. ms, W = ……. ms

30. Calculate the experimental value of duty cycle D_{exp} by following relation

$$D_{exp} = \frac{W(ms)}{T(ms)} \times 100 = \cdots \ldots .. \%$$

31. Calculate the theoretical value of duty cycle D_{cal} by following relation

$$D_{cal}\% = \frac{D_{exp}}{R_1 + 2R_2} \times 100 = \cdots \ldots .. \%$$

32. Compare the result.
33. Repeat the experiment for another values of R_1, and R_2.

For Monostable Multivibrator

1. Switch on the power supply.
2. Note down the values of resistor R and C in external time base circuit.
3. Connect CRO between pin 2 and pin 1 and measure the amplitude ($V_t = V_{t\text{-calibration}}$) of triggering wave and its frequency (f_t).
4. Trace the trigger wave.
5. Connect CRO at output terminal (pin 3) and ground terminal (pin 1).
6. Note the experimental values of amplitudes ($V_0 = V_{p\text{-calibration}}$) and experimental width (W_{exp}) of output wave by calibrated CRO and width of output wave (W_{exp})
7. Trace the output wave.
8. Connect CRO at threshold terminal (pin 6) and ground terminal (pin 1) to record the exponential wave and measure the threshold voltage ($V_0 = V_{p\text{-calibration}}$).
9. Trace the exponential wave.
10. Calculate the width of output wave (W_{cal}) by the relation.

$$W_{cal} = 1.1RC$$

11. Repeat the experiment for another values of R.

For Bistable Multivibrator

1. Switch on the power supply.
2. Connect CRO at output terminal (pin 3) and ground terminal (pin 1).
3. Set the switch 1 (SW1 in experimental board) and observed the stable state on CRO. Measure the voltage and note that it high state. It will remain in high level until it brought to ground level by pressing switch 2 (SW2).
4. Now reset the switch 2 for the low output. It will be at low output until it is brought to high level by switch 1 (SW1).

16.7 Observation:

Table 1 Astable Multivibrator

$R_1(K\Omega) =$ $R_2(K\Omega) =$			
$C(\mu F)$		$T(mS)$	
$f_{cal}(Hz)$		$W(mS)$	
$f_{exp}(Hz)$		$D_{exp}\%$	
$V_o(Volt)$		$D_{cal}\%$	
$V_o(Volt)Exp$			

Table 2 Monostable Multivibrator

PIN 2→	$V_t(Volt) =$	$f_t(Hz) =$
PIN 3→	$V_o(Volt) =$	$W_{exp}(ms) =$
PIN 6→	$V_{Th}(Volt) =$	

Table 3 Bistable Multivibrator

Switch	Connected to	Output
SW 1	Low (Ground)	
SW 2	High (V_{CC})	

16.8 Result:

(a) The experimental and theoretical values of duty cycle D_{exp} nearly same.

(b) The experimental and theoretical values of frequencies for astable multivibrator are nearly same.

(c) The theoretical and experimental values of duty cycle are nearly same for astable multivibrator.

(d) For monostable multivibrator the theoretical ($C_{alculated}$) and experimental width (W_{exp}) of output are nearly same.

(e) A Bistable multivibrator have two stable state.

16.9 Precaution and source of error:

15. Instruction given in manual should be strictly followed.

16. All the connections should be taken carefully & verify connection before supply.

17. CRO should be calibrated.

18. Observation of wave should be taken correctly.

16.10 Summary:

1. Astable Multivibrators have no stable state, it continuously changes states from low to high and high to low, hence can be used in relaxation oscillator.
2. Bistable multivibrator has two stable state, so it have memory of one bit information.
3. Monostable multivibrator is useful for creating a timing period of fixed duration in response to some external event.
4. Timer 555 is a IC used for astable, monostable and bistable Multivibrators.

16.11 Glossary:

IC: It is a semiconductor *chip* on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated.

IC 555: IC used for multivibrator.

Duty cycle: It is the ratio of time of high output to the time of one cycle.

Threshold voltage: When the input voltage exceeds some voltage, the output makes the change the opposite condition rapidly. This voltage is called "Threshold Input Voltage".

High & Low state: The output of multivibrator is either high voltage (say +5 V) or low voltage (0 V). These voltage states are High & Low state.

16.12 References:

1. C. L. Arora,B.Sc. Practical Physics, S. Chand publication, Delhi.
2. V.K. Mehta & Rohit Mehta, Principles of Electronics, S. Chand publication, Delhi.
3. B. L. Thereja, Basic electronics, S. Chand publication, Delhi.
4. S.L.Gupta, V.Kumar, Practical Physics, Pragati prakashan, Meerut.
5. Practical manual by LMC electronics, Ramnagar Agra.
6. https://en.wikipedia.org.

16.13 Viva-voce questions:

Question1. What is multivibrator?

Answer: A multivibrator is an electronic circuit used to implement a variety of simple two-state systems and two state systems are an oscillator, timer, flip-flop. It produces an output when triggered.

Question2. What is use of Bistable circuit.

Answer: It is basic memory device and has the capability to store 1-bit of information. Like Flip-flop, Bistable circuit also has 2 states.

Question3. State the application of Astable multivibrator.

Answer: Output of Astable multivibrator have no permanent state and it continually switches from one state to the other. So, it can be used as a relaxation oscillator.

Question4. What is duty cycle

Answer: The charging and discharging time constants depends on the values of the resistors R1 and R2. Generally, the charging time constant is more than the discharging time constant. Hence the HIGH output remains longer than the LOW output and therefore the output waveform is not symmetric. Duty cycle is the mathematical parameter that forms a relation between the high output and the low output. Duty Cycle is defined as the ratio of time of HIGH output i.e. the ON time to the total time of a cycle. If T_{ON} is the time for high output and T is the time period of one cycle, then the duty cycle D is given by

$$D = T_{ON} / T$$