Laboratory Physics for Sixth Semester BSc Physics
Pondicherry University

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Contents

1 Dispersive Power of a plane Diffraction Grating

Aim

To determine the dispersive power of a plane diffraction grating arranged for normal incidence

Apparatus

Spectrometer, plane diffraction grating, mercury vapour lamp

Principle

Plane diffraction grating consists of a number of parallel and equidistant lines ruled on an optically plane and parallel glass plate by a fine diamond point. Each ruled line behaves as an opaque line while the transparent portion between two consecutive ruled lines behaves as a slit. The width of each slit is a and opaque spacing between two consecutive slits is b. Then $(a + b)$ is called grating element or grating constant. The dispersive power of a grating is defined the ratio of the difference in angle of diffraction of any two neighbouring spectral lines to the diffraction in the wavelength between the two spectral lines. Let two wavelengths λ and $\lambda + d\lambda$ be diffracted through θ and $\theta + d\theta$ respectively. Then the dispersive power of the grating is expressed as $\frac{d\theta}{d\lambda}$.
We know, for a plane diffraction grating arranged for normal incidence

$$(a + b) \sin\theta = n\lambda$$

Differentiating with respect to λ

$$(a + b) \cos\theta \frac{d\theta}{d\lambda} = n$$

Dispersive power

$$\frac{d\theta}{d\lambda} = \frac{n}{(a + b) \cos\theta}$$

We have

$$N = \frac{1}{a + b}$$

N is the number of lines per unit length of the grating. n is the order of the spectrum. λ is the wavelength of the light.

So we get, dispersive power

$$\boxed{\frac{d\theta}{d\lambda} = \frac{nN}{\cos\theta}}$$

Higher is the order n, greater is the dispersive power. Smaller is the grating element $(a+b)$, more widely spread is the spectrum. If the value of θ is large, $\cos\theta$ will be small and therefore dispersive power will be more.

We know $\lambda_{(Red)} > \lambda_{(Violet)}$. Therefore angle of diffraction for Red light is greater than Violet in a given order spectrum, therefore the dispersion in the red region is greater than that in violet region.

Procedure

The **preliminary adjustments** (eye-piece, collimator and telescope adjustments) of the spectrometer are made. The spectrometer is now set up for **normal incidence** of light from a mercury lamp.

1. Telescope is brought in a line with collimator to observe the direct image. Now it is turned to either side of the direct image to observe the diffracted spectrum in the first order. The vertical cross-wire is adjusted to coincide with the line violet I, violet II, blue, bluish green, green, yellow I and yellow II successively on the left side. The readings for each line both in vernier I and vernier II are noted.

2. Now the telescope is turned in to the right side of the direct image and the vertical cross-sire is adjusted to coincide with the lines successively. The readings for each line both in vernier I and vernier II are noted.

3. The difference between the readings in corresponding verniers on the left and the right side gives 2θ. Mean angle of diffraction θ for each line is calculated.

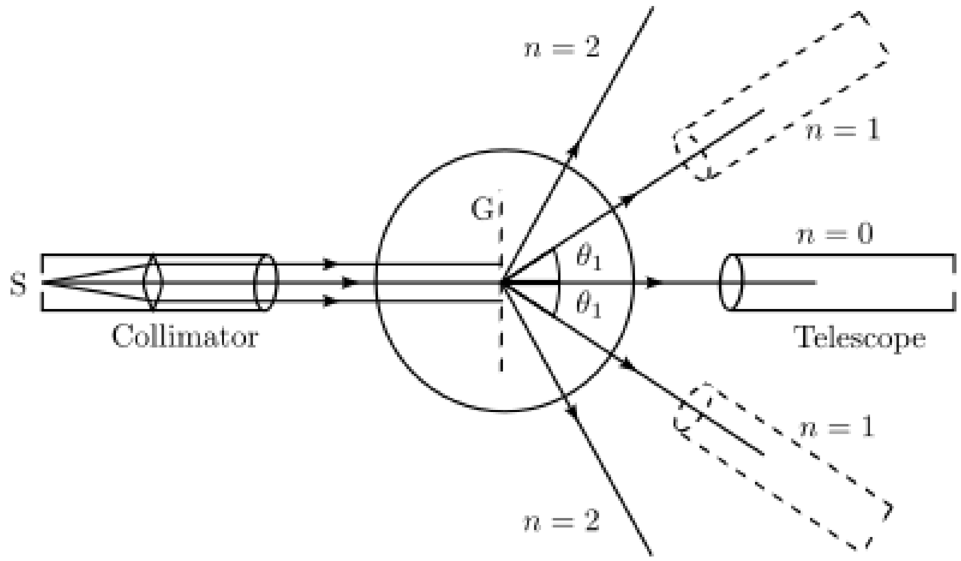
4. The grating is standardised (N is found out) using the angle of diffraction obtained for green θ_{green} and assuming wavelength of mercury green as $\lambda_{green} = 546.1 \times 10^{-9}\ m$

$$N = \frac{\sin\theta_{green}}{n\lambda_{green}}$$

5. Using this value of N, wavelength of other lines are calculated

$$\lambda = \frac{\sin\theta}{nN}$$

6. Grating Spectrum for different orders



Grating Spectrum for different orders

7. Calculation of dispersive power in the blue-green region

$$d\theta = \theta_{green} - \theta_{blue}$$
$$d\lambda = \lambda_{green} - \lambda_{blue}$$
$$\theta = \frac{\theta_{green} + \theta_{blue}}{2}$$

8. Dispersive power is calculated using $\frac{d\theta}{d\lambda}$ and also by $\frac{nN}{\cos\theta}$. the mean dispersive power of the two values is found out.

9. Dispersive power for other pairs of colors are also found out.

Observations

Adjustments for normal incidence

	vernier I	vernier II
Direct reading	...	...
Reading when telescope is turned through 90^0	...	...
Reading when telescope is turned through 45^0	...	...

To find least count

Value of 1 main scale division 1 m.s.d	......
Number of divisions on the vernier scale, VSD	......
Least count $= \frac{1\ msd}{VSD}$	......

Total reading = main sale reading + vernier scale reading × Least Count

To standardise grating

Order of the spectrum, n	......
Angle of diffraction for green , θ_{green}	......
Wavelength of mercury green, λ_{green}	$546.1 \times 10^{-9}\ m$
Number of lines per meter of grating $N = \frac{\sin\theta_{green}}{n\lambda_{green}}$	...... lines/meter

To determine the wavelength of spectral lines

Order $n = \ldots$

Spectral Line	Vernier	Diffracted reading						**Difference** 2θ	Mean θ	$\lambda = \frac{\sin\theta}{nN}$ **m**
		Left			Right					
		MSR	VSR	Total	MSR	VSR	Total			
violet I	Vernier I									
	Vernier II									
violet II	Vernier I									
	Vernier II									
Blue	Vernier I									
	Vernier II									
Bluish Green	Vernier I									
	Vernier II									
Green	Vernier I									546.1 $\times 10^{-9}$
	Vernier II									
Yellow I	Vernier I									
	Vernier II									
Yellow II	Vernier I									
	Vernier II									

Calculations

Dispersive power in blue-green region

Dispersive power in yellow I - yellow II region

Results

The given plane diffraction is standardised by taking green line of mercury spectrum, using spectrometer. The number of lines per meter of the grating $N = \ldots\ldots$

The wavelengths of prominent lines of mercury spectrum are found out, after arranging the grating for normal incidence. The dispersive power of the grating in two sets of color regions are found out.

Dispersive power of the grating in blue-green region = ... degree/meter

Dispersive power of the grating in yellow I - yellow II region = ... degree/meter

2 Air wedge - Diameter of a thin wire

Aim

To determine the diameter of a thin wire by measuring the width of the interference bands formed by the air-wedge arrangement

Apparatus

Sodium vapour lamp, travelling microscope, the given wire, two optically plane glass plates

Principle

A thin film having zero thickness at one end and progressively increasing to a particular thickness at the other end is called a wedge. A thin wedge of air film can be formed by two glasses slides on each other at one edge and separated by a thin spacer at the opposite edge.

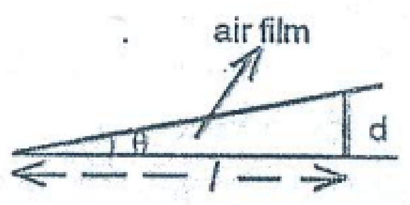
The diameter of the wire used to form the air wedge is given by

$$d = \frac{l\lambda}{2\beta}$$

where l is the distance of the wire from the edge at which the plates are in contact (tight edge), λ is the wavelength of the light used and β is the width of the interference band formed.

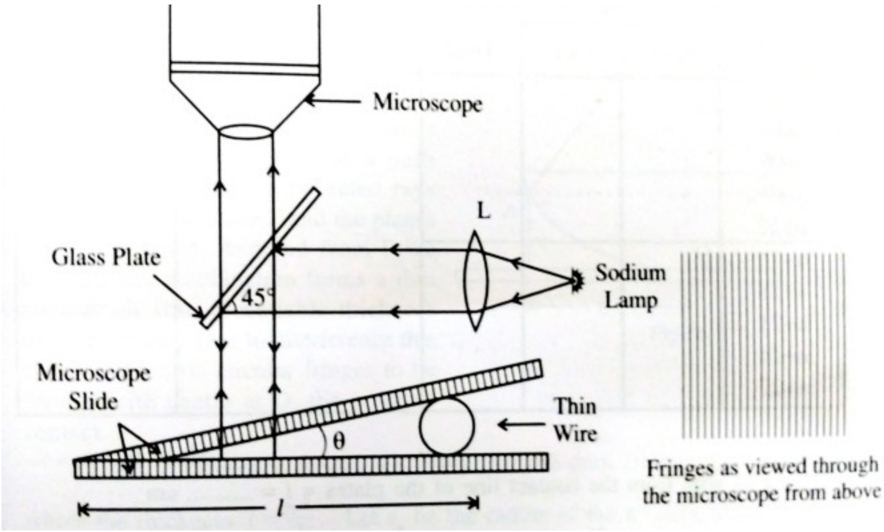
Procedure

Air wedge is formed by placing two optically plane glass plates one above the other and keeping in the wire in between the plates. One end of the plates is held tight by a rubber band so that it becomes the line of contact and put another rubber band loosely on the other end so that it forms the open edge. Interference bands are formed from the top and bottom surfaces of air film enclosed between the two glass plates of the air wedge.



Air Wedge

Light from a sodium lamp is rendered parallel by a short focus convex lens (the lamp should be placed at a large distance) and is allowed to fall on a glass plate inclined at 45^0 to the horizontal. Place the air wedge such that the light reflected from the glass plate B is incident normally on the air wedge.



Air Wedge - Experimental arrangement

Adjust the travelling microscope which is placed vertically above the glass plate B to view clearly the interference bands. Using the tangential screw of the microscope, one of the cross wires is made to coincide with a dark and count the number of clear bands obtained (above 20) so that the tangential screw is free to move on either side. Make the cross wire to coincide with a dark band (say n^{th} either on extreme right or extreme left and the horizontal scale reading is taken. The cross wire is moved to $n+2^{th}, n+4^{th}, \cdots\cdots, n+18^{th}$ bands and the readings are taken. From these readings width of 10 bands and hence width of one band β is found out.

The distance l between the wire and the line of contacts of the plates is measured. The value of sodium yellow is taken to be 589.3 nm. Using the formula, the diameter of the wire is calculated.

Observations

To find the least count of the microscope

Value of 1 main scale division 1 m.s.d	......
Number of divisions on the vernier scale, VSD	......
Least count $= \dfrac{1\ msd}{VSD}$	......

Total reading = main sale reading + vernier scale reading × Least Count

Number of bands	**Microscope readings**			**Width of 10 bands**	**Mean width of 10 bands**	**bandwidth β metre**
	MSR	VSR	Total			
n			x_0	$x_{10} - x_0$		
n+2			x_2	$x_{12} - x_2$		
n+4			x_4	$x_{14} - x_4$		
n+6			x_6	$x_{16} - x_6$		
n+8			x_8	$x_{18} - x_8$		
n+10			x_{10}			
n+12			x_{12}			
n+14			x_{14}			
n+16			x_{16}			
n+18			x_{18}			

Distance of the wire from the line of contact of the plates, $l = \ldots\ldots\ m$

Wavelength of the sodium light, $\lambda = 589.3 \times 10^{-9} m$

Diameter of the wire, $d = \frac{l\lambda}{2\beta} = \ldots\ldots\ldots\ m$

Angle of the wedge, $\theta = \frac{\lambda}{2\beta} = \ldots\ldots\ldots\ rad$

Result

The diameter of the given thin wire is found out by forming interference fringes using air wedge.

Diameter of the wire, $d = \ldots\ldots\ m$

Angle of the wedge, $\theta = \ldots\ldots\ rad$

3 Solar Cell characteristics

Aim

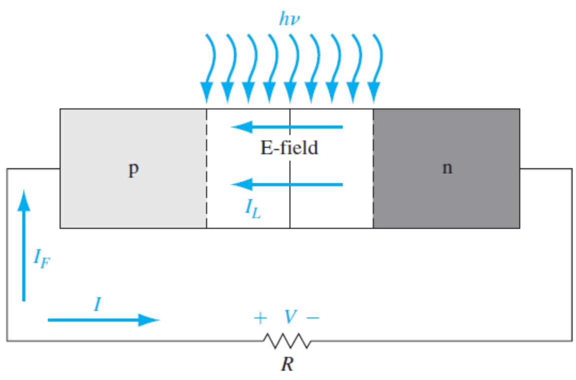
To study the V-I characteristics of a solar cell

Apparatus

Solar cell and lamp arrangement, solar cell trainer kit

Theory

A solar cell is a pn junction device with no voltage directly applied across the junction. A solar cell is nothing but a P-N junction diode under light illumination with a very large surface area. When solar radiation is absorbed in a P-N junction diode, electron–hole pairs are generated. The solar cell converts photon power into electrical power and delivers this power to a load.



A pn junction solar cell with resistive load.

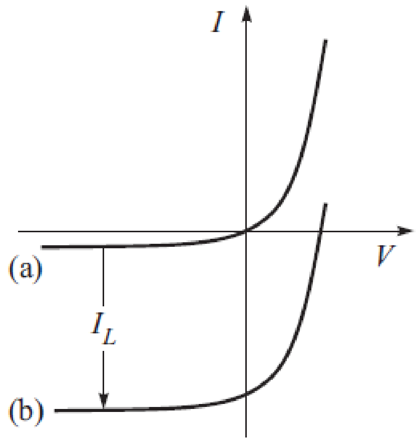
Thus, when light shines on a solar cell, the current flows in the opposite direction to that of the generated voltage. Overall effect of light shining is to shift the I-V curve of the diode downwards in the current–voltage axis as shown in the first figure. In the fourth quadrant of this curve, voltage is positive and current is negative, resulting in negative power. The negative power implies that the power can be extracted from the device. Therefore, a solar cell generates power rather than consuming power like the other electronic devices, where power is positive.

The I-V equation for the solar cell is

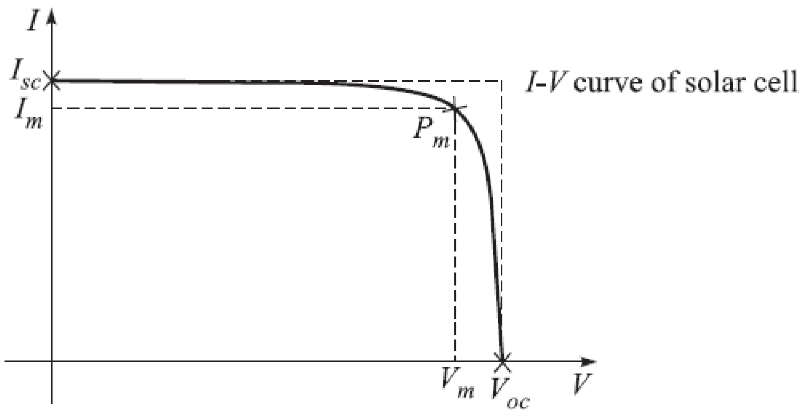
$$I = I_o[e^{qV/kT} - 1] - I_L$$

where I_L is the light generated current and the remaining part is the pn junction diode equation. Solar cells are characterized and compared with each other with four parameters: short circuit current I_{sc}, open circuit voltage V_{oc}, fill factor FF and efficiency η. These parameters can be represented using the following figure.

The I-V curve drawn in the second figure is same as the illuminated curve shown in the first figure, but negative current axis is shown as positive, which is done only for the sake of convenience. The solar cell I-V curve in most occasions is plotted like second figure; with the current axis is actually a negative axis.



Downward shifting of dark *I-V* curve (a) when light shines on a *P-N* junction diode and curve (b) is illuminated *I-V* curve.



Typical plot of a solar cell *I-V* curve and its parameters.

Short circuit current I_{sc}

This is the maximum current that flows in a solar cell when its terminals at P-side and N-side are shorted with each other, i.e., V = 0.

Open circuit voltage V_{oc}

: As the name suggests, it is the maximum voltage generated across the terminals of a solar cell when they are kept open, i.e., I = 0.

Fill factor FF

It is the ratio of maximum power that can be extracted from a solar cell to the ideal power

$$FF = \frac{P_m}{P_{ideal}}$$

$$FF = \frac{I_m V_m}{I_{sc} V_{oc}}$$

The FF represents the squareness of the solar cell I-V curve. It is represented in terms of percentage.

Efficiency η

It is defined as the ratio of the power output to power input. The power output is the maximum power point P_m of a solar cell, and input power is the power of solar radiation P_{rad}. According to the international standard for characterization of solar cells, P_{rad} is equal to 1000 W/m^2

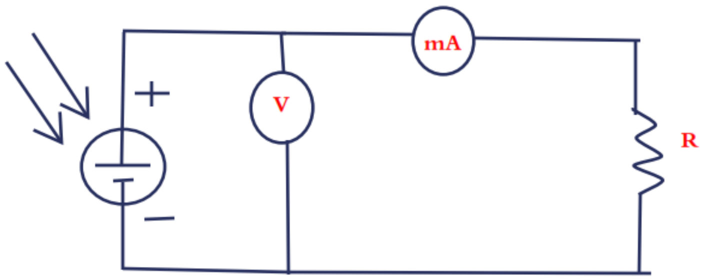
$$\eta = \frac{P_m}{P_{rad}}$$

$$\eta = \frac{I_m V_m}{P_{rad}}$$

$$\eta = \frac{I_{sc} V_{oc} FF}{P_{rad}}$$

Procedure

1. Make the connections in the solar cell characteristics trainer kit as as shown in figure



Solar Cell trainer kit circuit diagram

2. The incandescent lamp with solar cell is connected to the the trainer kit through the cable provided

3. The intensity of the light from the lamp is fixed by the knob/potentiometer connected with. The distance from the lamp to the solar cell is also fixed.

4. The load resistance is varied by using the knob provided, and for each load, voltages and currents shown in the trainer kit are noted. By removing the connections at the load, the open circuit voltage V_{oc} and by shorting the load, the short circuit current I_{sc} are also found out.

5. By varying the intensity of the lamp, the experiment is repeated for different intensities of the lamp

6. For each intensity, I-V curves are plotted and Fill factor and efficiency are found out

Observations and calculations

Load Resistance	Intensity I		Intensity II		Intensity III	
	V (volts)	I (mA)	V (volts)	I (mA)	V (volts)	I (mA)
$R_L = \infty$ or $R_L = 0$	$V_{oc} =$	$I_{sc} =$	$V_{oc} =$	$I_{sc} =$	$V_{oc} =$	$I_{sc} =$

Result

The I-V characteristics of the solar cell is studied and the curves are plotted for three different incident light intensities. Fill-factor and efficiencies of the solar cell are calculated in each case.

4 Determination of Planck's constant

Aim

To determine the Planck constant using LED's of known wavelength

Apparatus

0-10 V power supply, a one way key, a rheostat, a digital milliammeter, a digital voltmeter, a 1 K resistor and different known wavelength LED's (Light-Emitting Diodes).

Theory

Planck's constant (h), a physical constant was introduced by German physicist named Max Planck in 1900. The significance of Planck's constant is that *quanta* (small packets of energy) can be determined by frequency of radiation and Planck's constant. It describes the behavior of particle and waves at atomic level as well as the particle nature of light.

An LED is a two terminal semiconductor light source. In the unbiased condition a potential barrier is developed across the p-n junction of the LED. When we connect the LED to an external voltage in the forward biased direction, the height of potential barrier across the p-n junction is reduced. At a particular voltage the height of potential barrier becomes very low and the LED starts glowing, i.e., in the forward biased condition electrons crossing the junction are excited, and when they return to their normal state, energy is emitted. This particular voltage is called the knee voltage or the threshold voltage. Once the knee voltage is reached, the current may increase but the voltage does not change.

The light energy emitted during forward biasing is given as,

$$E = \frac{hc}{\lambda}$$

If V is the forward voltage applied across the LED when it begins to emit light (the knee voltage), the energy given to electrons crossing the junction is,

$$E = eV$$

Equating the above two equations, we get

$$eV = \frac{hc}{\lambda}$$

The knee voltage V can be measured for LED's with different values of wavelength of light λ.

$$V = \frac{hc}{e}\frac{1}{\lambda}$$

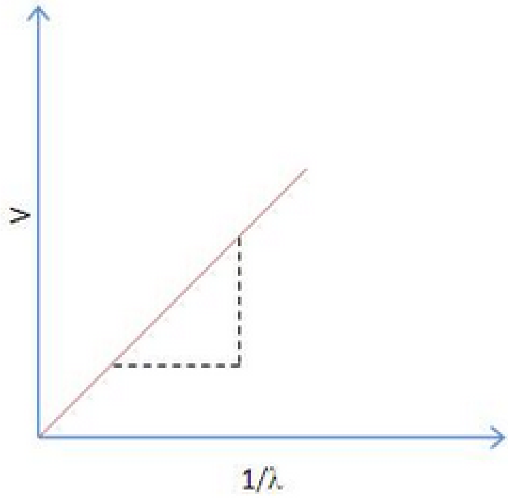
From the above equation, the slope of a graph of V on the vertical axis vs. $1/\lambda$ on the horizontal axis is

$$slope = \frac{hc}{e}$$

Using the known value of

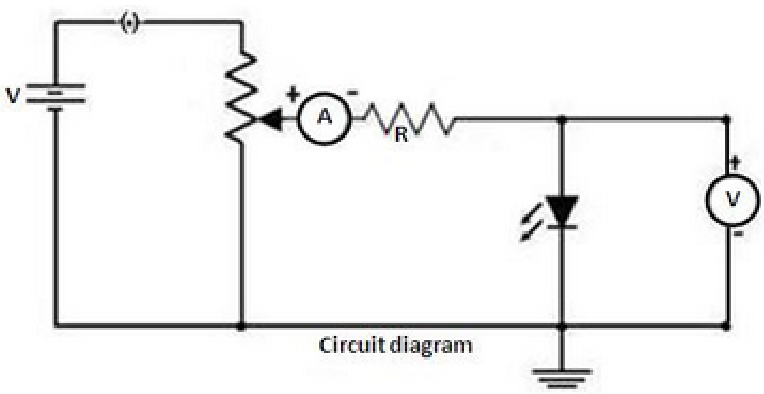
$$\frac{e}{c} = 5.33 \times 10^{-28} \ \ Cs/m$$

the value of Planck's constant h can be calculated



Procedure

1. Connections are made as shown in circuit diagram.



2. Insert key to start the experiment.
3. Adjust the rheostat value till the LED starts glowing, or in the case of the IR diode, whose light is not visible, until the ammeter indicates that current has begun to increase.
4. Corresponding voltage across the LED is measured using a voltmeter, which is the knee voltage.
5. Repeat, by changing the LED and note down the corresponding knee voltage.
6. Using the formula given,find the value of the Planck's constant.

Observations and Calculations

From graph, slope = ...

$$h = \frac{e}{c}\, slope = \ldots\ldots\ldots$$

Sl. No.	LED Colour	Wavelength λ m	Knee Voltage V volts	$h = \frac{e\lambda V}{c}$ J.s

Mean value of $h = \ldots\ldots$

Result

The value of Planck's constant is determined using the LED's of known wavelength. The value obtained is $h = \ldots\ldots\ldots\ldots$ J.s

5 Potentiometer - Temperature Coefficient of Resistance

Aim

To find the temperature coefficient of resistance of the material of the given wire using potentiometer

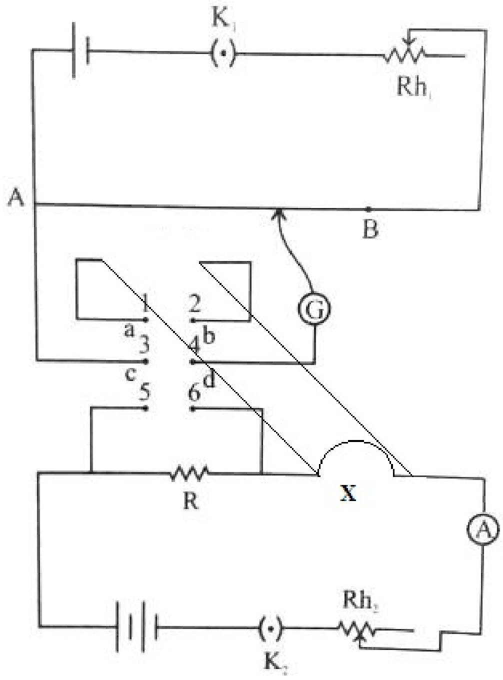
Apparatus

Potentiometer, given wire, power supply, key, standard resistance, galvanometer, high resistance etc

Theory

Potentiometer is a device used to measure the internal resistance of a cell, to compare the e.m.f. of two cells and potential difference across a resistor. It consists of a long wire of uniform cross sectional area and of 10 m in length. The material of wire should have a high resistivity and low temperature coefficient. The wires are stretched parallel to each other on a wooden board. The wires are joined in series by using thick copper strips. A metre scale is also attached on the wooden board.

It works on the principle that when a constant current flows through a wire of uniform cross sectional area, potential difference between its two points is directly proportional to the length of the wire between the two points.



Let the known resistance R and the unknown resistance X (of the given wire) are in series in the secondary circuit of the potentiometer. Then the same current I flows through both. Let l_1 be the balancing length when R is introduced in the potentiometer and l_2 when X is introduced in the potentiometer.

$$IR \propto l_1$$

and

$$IX \propto l_2$$

Or

$$\frac{X}{R} = \frac{l_2}{l_1}$$

The resistance of the wire,

$$X = (\frac{l_2}{l_1})R$$

The electrical resistance of every substance changes with change in its temperature. Temperature coefficient of resistance is the measure of change in electrical resistance of any substance per degree of temperature change. In metals if the temperature increases, the random motion of free electrons and interatomic vibration inside the metal increase which result in more collisions. More collisions resist the smooth flow of electrons through the metal, hence the resistance of the metal increases with the rise in temperature. So, we consider the temperature coefficient of resistance as **positive** for metal.

Let X_{ref} be the resistance of the given wire at $T^0_{ref}C$. Then resistance $X_T$of the wire at any temperature $T^0C(> T_{ref})$

$$X_T = X_{ref}\left[1 + \alpha(T - T_{ref})\right]$$

where α is called the temperature coefficient of resistance of the material of the given wire.

Let $T_{ref} = 0^0C$, and then $X_{ref} = X_0$. Let X_1 and X_2 be the resistance of the wire at temperatures T_1 and T_2 respectively. Then

$$X_1 = X_0\left[1 + \alpha(T_1 - 0)\right] = X_0\left[1 + \alpha T_1\right]$$

and

$$X_2 = X_0\left[1 + \alpha(T_2 - 0)\right] = X_0\left[1 + \alpha T_2\right]$$

From the above two equations, the temperature coefficient of resistance

$$\alpha = \frac{X_2 - X_1}{X_1T_2 - X_2T_1}$$

The resistance values of the given wire is found out using potentiometer at any two temperatures using which α can be calculated.

Procedure

1. The primary and secondary connections of the potentiometer are made as shown in figure.
2. The wire whose resistance is to be found out is kept in room temperature. The room temperature is also noted.
3. Using six way key, the standard resistance R is introduced in the potentiometer and circuit is checked for opposite deflection in galvanometer. Then the balancing length l_1 for R is found out.
4. Then the unknown resistance X (wire) is introduced in the potentiometer and its balancing length l_2 is found similarly.
5. The experiment is repeated with the wire at 0^0C, $100^0C, 80^0C, \ldots\ldots$, by keeping it in ice, boiled water and hot water at different temperatures respectively.
6. A graph is drawn between resistance and temperature
7. Taking any two X values and their corresponding temperatures, α is determined. Mean value of α is found out.

Observation and Calculations

Room temperature = ...^0C

Temperature in ^0C	Resistance R in Ω	Balancing length for R, l_1	Balancing length for X, l_2	Resistance of the wire $X = R(l_2/l_1)$
Room Temp.				
0^0C				
100				
80				
60				
40				

Result

The temperature coefficient of resistance of the material of the given wire α is found using potentiometer.
$\alpha = \ldots\ldots\Omega/^0C$

6 Cauchy's constants of a prism

Aim

To determine the Cauchy's constants of the given prism

Apparatus

Spectrometer, prism, prism clamp, Magnifying glass, mercury vapor lamp, etc.

Principle

Cauchy's equation is an empirical relationship between the refractive index and wavelength of light for a particular transparent material. It is named for the mathematician Augustin-Louis Cauchy, who defined it in 1836.

The most general form of Cauchy's equation is

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \ldots$$

where n is the refractive index of the material, λ is the wavelength, B, C, D, etc., are coefficients that can be determined for a material by fitting the equation to measured refractive indices at known wavelengths. The above equation is only valid for regions of normal dispersion in the visible wavelength region. In the infrared, the equation becomes inaccurate, and it cannot represent regions of anomalous dispersion.

Approximating the equations to first two terms, the refractive index n of the material of the prism for a wavelength λ is given by

$$n(\lambda) = A + \frac{B}{\lambda^2}$$

Where **A** and **B** are called **Cauchy's constants** for the prism. If the refractive indices n_1 and n_2 for any two known wavelength λ_1 and λ_2 are determined by a spectrometer, the Cauchy's constants A and B can be calculated from the above equation.

Procedure

Preliminary adjustments

1. Turn the telescope towards the white wall or screen and looking through eye-piece, adjust its position till the cross wires are clearly seen.
2. Turn the telescope towards window, focus the telescope to a long distant object.
3. Place the telescope parallel to collimator.
4. Place the collimator directed towards sodium vapour lamb. Switch on the lamp.
5. Focus collimator slit using collimator focusing adjustment.
6. Adjust the collimator slit width.
7. Place prism table, note that the surface of the table is just below the level of telescope and collimator.
8. Place spirit level on prism table. Adjust the base levelling screw till the bubble come at the centre of spirit level.

9. Clamp the prism holder.
10. Clamp the prism in which the sharp edge is facing towards the collimator, and base of the prism is at the clamp.

To find least count

Value of 1 main scale division 1 m.s.d	......
Number of divisions on the vernier scale, VSD	......
Least count $= \frac{1\ msd}{VSD}$	......

Total reading = main sale reading + vernier scale reading × Least Count

To determine the angle of the Prism

1. Prism table is rotated in which the sharp edge of the prism is facing towards the collimator.
2. Rotate the telescope in one direction up to which the reflected ray is shown through the telescope.
3. Note corresponding main scale and vernier scale reading in both vernier (vernier I and vernier II).
4. Rotate the telescope in opposite direction to view the reflected image of the collimator from the second face of prism.
5. Note corresponding main scale and vernier scale reading in both vernier(vernier I and vernier II).
6. Find the difference between two readings, i.e. θ
7. Angle of prism, A=$\theta/2$

To determine the Cauchy's constants for the prism

The angle of the prism A and the angle of minimum deviation D for different wave length are determined. From this the refractive index n for these colours are calculated. Taking the value of λ from the mathematical table, the Cauchy's constants **A** and **B** are calculated for different pairs of spectral colours using the equation. The Cauchy's constants can also be determined graphically. A graph is drawn with n along the y-axis and $\frac{1}{\lambda^2}$ along x-axis with zero as the origin for both axes. The graph is a straight line. The *Y intercept gives A and the slope gives B.*

Rotate the vernier table so as to fall the light from the collimator to one face of the prism and emerged through another face.

1. The emerged ray has different colors.
2. Turn the telescope to each color, and note the readings for different colors.
3. Remove the prism, hence note direct ray reading.

4. Find the angle of minimum deviation for different color.(Say ,violet, blue, green, yellow).
5. Find the refractive index for these colors.
6. Draw the graph with n along the y-axis and $\frac{1}{\lambda^2}$ along x-axis with zero as the origin for both axes.

Observations and Calculations

Angle of the prism A

Reading of reflected ray from	Vernier I			Vernier II		
	MSR	VSR	Total	MSR	VSR	Total
Face I (a)						
Face II (b)						
Difference(a-b=2A)						

Mean $(a - b) = 2A = \ldots\ldots$

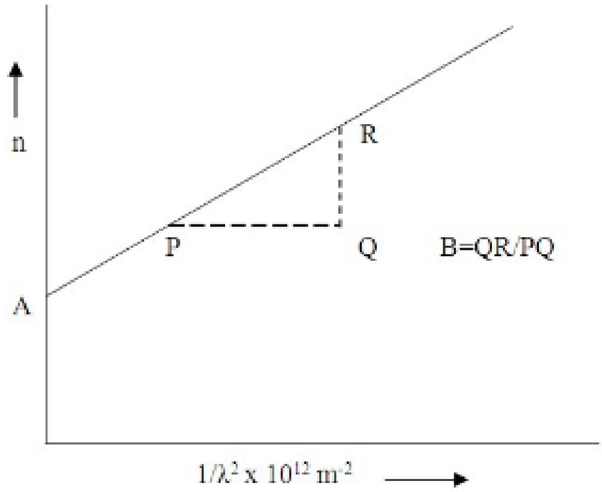
Angle of the prism $A = \ldots\ldots$ degree $\ldots\ldots$ minutes

To calculate A and B

Pair of colours	λ_1	λ_2	n_1	n_1	A	B
Yellow 1 & Blue						
Gree n & Violet						

To find A and B graphically

Colour	λ	$\frac{1}{\lambda^2}$	n
Yellow	579.1 nm		
Green	546.1 nm		
Blue	435.8 nm		
Violet 2	404.7 nm		



Results

The Cauchy's constants of the given prism are found using spectrometer. The values are

A = ...

B = ... m^2

7 Field along the axis of a circular coil – Determination of B_H using Searle's vibration magnetometer

Aim

To determine the horizontal component of the earth's magnetic flux density at the place B_H using the field along the axis of a coil apparatus and Searle's vibration magnetometer

Apparatus

Field along the axis of a coil apparatus, Searle's vibration magnetometer, Stop watch etc

Theory

The period of oscillation of a vibration magnetometer in earth's magnetic field is

$$T_0 = 2\pi \frac{I}{mB_H}$$

where I is the moment of inertia of the magnetic needle of the vibration magnetometer.
If n_0 is the frequency of oscillations, then $n_0^2 \propto B_H$.

If the flux density of earth B_H and the flux density due to the current in circular coil are acting in the same direction and if n is the frequency of oscillations in the combined field (both the fields in the same direction) $B + B_H$, we get

$$\begin{aligned} n_0^2 &\propto B_H \\ n^2 &\propto (B + B_H) \\ \frac{n_0^2}{n^2 - n_0^2} &= \tfrac{B_H}{B} \\ B_H &= B\tfrac{n_0^2}{n^2 - n_0^2} \end{aligned}$$

But the flux density at an axial distance x from the center due to the coil of radius a and N turns carrying current I

$$B = \frac{\mu_0 N I a^2}{2(a^2 + x^2)^{3/2}}$$

Therefore, the horizontal component of the earth's magnetic field at the place is

$$B_H = \left(\frac{\mu_0 N I a^2}{2(a^2 + x^2)^{3/2}}\right)\left[\frac{n_0^2}{n^2 - n_0^2}\right]$$

Procedure

1. The magnetic meridian is drawn on the table using a compass box. Place the vibration magnetometer in the meridian. It is forced to oscillate using a small bar magnet and the magnet is moved away. The time period and hence frequency of oscillations n_0 is found out

2. The circular coil is set with its plane perpendicular to the magnetic meridian

3. The vibration magnetometer is arranged along the axis of the coil in such a way that the center of the coil is in the same plane of the suspended needle of the magnetometer.

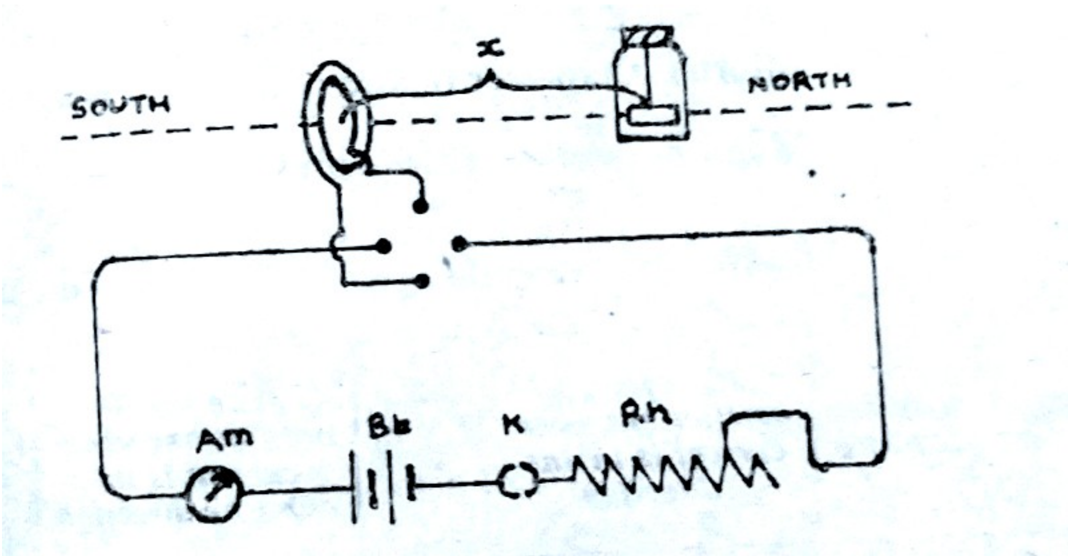
4. The distance x from the center of the coil to the center of the suspended needle is measured

5. Suitable current is passed through the coil by closing the key. Oscillations are noted and rough time period is measured

6. Current is reversed and and again oscillations are noted and rough time period is measured

7. **If both the fields (field due to coil and earth's field) are in same direction, time period of oscillation will be less and frequency will be high**. In this arrangement the time period of oscillations are measured and n is calculated.

8. The experiment is repeated for different currents and distances and also with magnetometer on northern and southern side of the coil.



Observations and Calculations

Time for 10 Oscillations			Mean t seconds	$n_0 = 10/t$, Hz
1 (seconds)	2 (seconds)	3 (seconds)		

To find n_0

Number of turns of the coil, $N = \ldots\ldots$

Circumference of the coil $= \ldots\ldots$

Radius of the coil, $a = \ldots\ldots$

Distance x in	**Current I in A**	**Time for 10 Oscillation**				**Mean time t in seconds**	$n = 10/t$	B_H
		Northern side		Souther side				
		1 (sec)	2 (sec)	1 (sec)	2 (sec)			

To find n and hence B_H

Results

The horizontal component of the earth's magnetic field at the place is found out using field along the axis of a coil apparatus and Searle's vibration magnetometer. The value obtained is
$B_H = \ldots\ldots\ \ Tesla$

8 Synchronous Counters

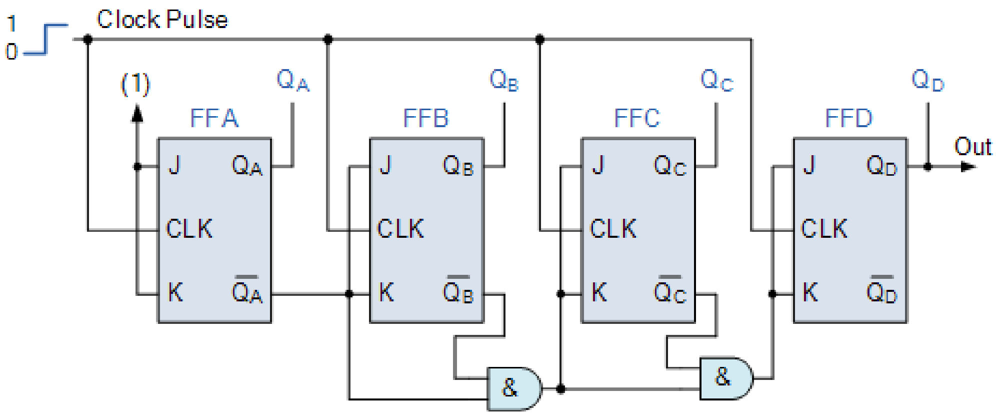
Aim

To construct a 4-bit synchronous up (down) counter using JK Flip-flop and to verify its working

Theory

A Counter is a device which stores the number of times a particular event or process has occurred, often in relationship to a clock signal. Counters are used in digital electronics for counting purpose, they can count specific event happening in the circuit. For example, in UP counter a counter increases count for every rising edge of clock. Synchronous Counters are so called because the clock input of all the individual flip-flops within the counter are all clocked together at the same time by the same clock signal. The result of this synchronisation is that all the individual output bits changing state at exactly the same time in response to the common clock signal with no ripple effect and therefore, no propagation delay.

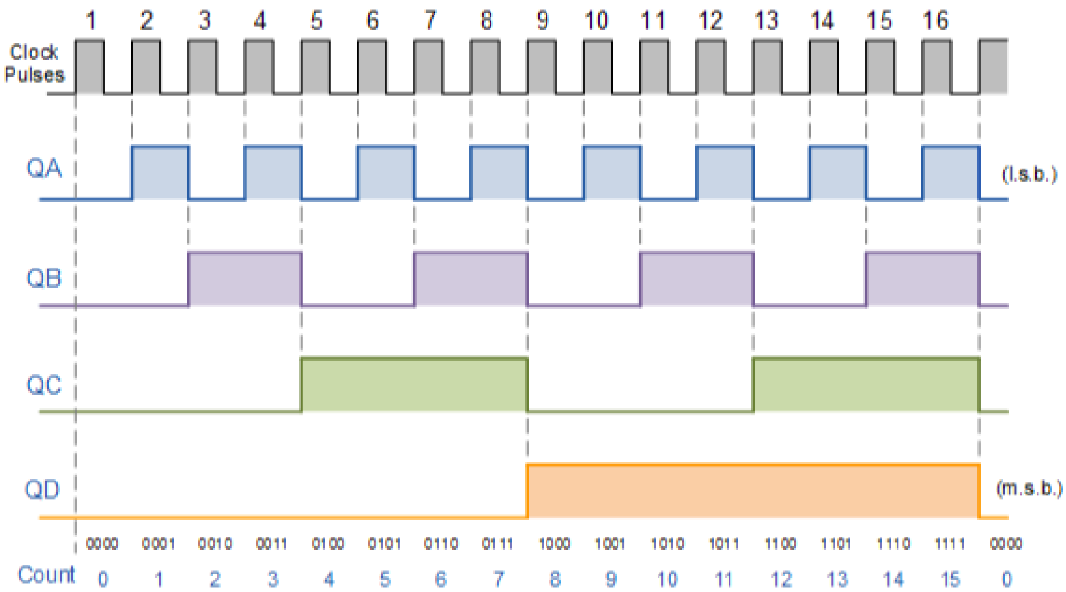
In the Synchronous Counter, the external clock signal is connected to the clock input of every individual flip-flop within the counter so that all of the flip-flops are clocked together simultaneously (in parallel) at the same time giving a fixed time relationship. In other words, changes in the output occur in *synchronisation* with the clock signal.



Synchronous 4 bit up counter

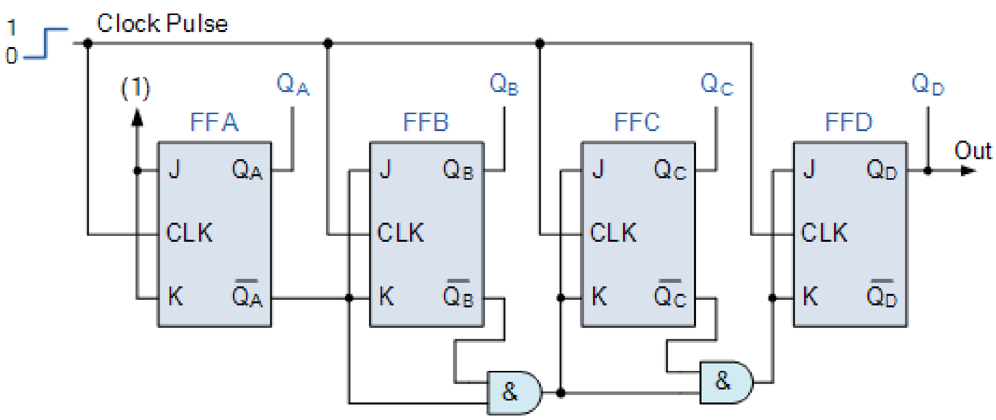
It can be seen above, that the external clock pulses (pulses to be counted) are fed directly to each of the J-K flip-flops in the counter chain and that both the J and K inputs are all tied together in toggle mode, but only in the first flip-flop, flip-flop FFA (LSB) are they connected HIGH, logic 1 allowing the flip-flop to toggle on every clock pulse. Then the synchronous counter follows a predetermined sequence of states in response to the common clock signal, advancing one state for each pulse. The J and K inputs of flip-flop FFB are connected directly to the output QA of flip-flop FFA, but the J and K inputs of flip-flops FFC and FFD are driven from separate AND gates which are also supplied with signals from the input and output of the previous stage. These additional AND gates generate the required logic for the JK inputs of the next stage. If we enable each JK flip-flop to toggle based on whether or not all preceding flip-flop outputs (Q) are *HIGH* we can obtain the same counting sequence as with the asynchronous circuit but without the ripple effect, since each flip-flop in this circuit will be clocked at exactly the same time. Then as there is no inherent propagation delay in synchronous counters, because all the counter stages are triggered in parallel at the same time, the maximum operating frequency of this type of frequency counter is much higher than that for a similar asynchronous counter circuit.

Because this 4-bit synchronous counter counts sequentially on every clock pulse the resulting outputs count upwards from **0** (**0000**) to **15** (**1111**). Therefore, this type of counter is also known as a **4-bit Synchronous Up Counter**.



4-bit Synchronous Counter Waveform Timing Diagram

A 4-bit **Synchronous Down Counter** can easily be constructed from a synchronous up counter, by connecting the AND gates to the $\bar{Q}$ output of the flip-flops as shown to produce a waveform timing diagram the **reverse of the above**, Figure 2. Here the counter starts with all of its outputs **HIGH (1111)** and it counts down on the application of each clock pulse to zero, (**0000)** before repeating again.



4-bit Synchronous Down Counter

Procedure

The connections are made as shown in figure. Logic 1 (5 V) is applied at the input of flip flop A, FFA. On each clock pulse, the outputs of each flip flop, from A to D, that is, Q_A to Q_D are noted and the number of clock pulses and outputs are tabulated, for 16 clock pulses.

Result

A synchronous 4 bit down counter using JK Flip-flop is constructed and its action is verified.

9 Serial in Parallel Out Shift Register

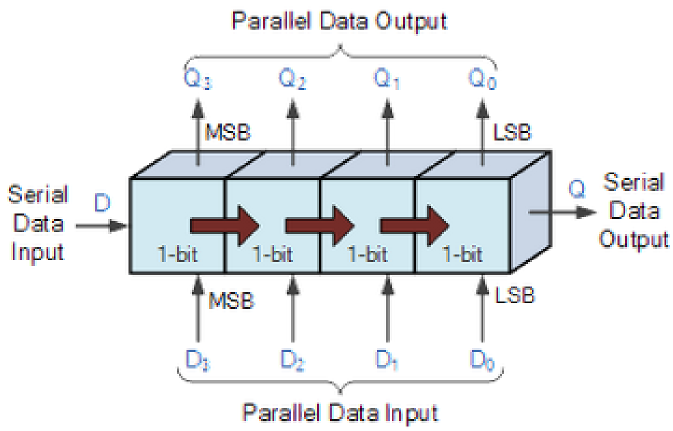
Aim

To construct a 4-bit serial-in parallel-out shift right register using JK Flip-flop and to verify its working

Theory

A register is a memory device made using flip-flops. The Shift Register is a sequential logic circuit that can be used for the storage or the transfer of binary data. This sequential device loads the data present on its inputs and then moves or *shifts* it to its output once every clock cycle, hence the name Shift Register.Data bits may be fed in or out of a shift register serially, that is one after the other from either the left or the right direction, or all together at the same time in a parallel configuration. The number of individual data latches required to make up a single Shift Register device is usually determined by the number of bits to be stored.

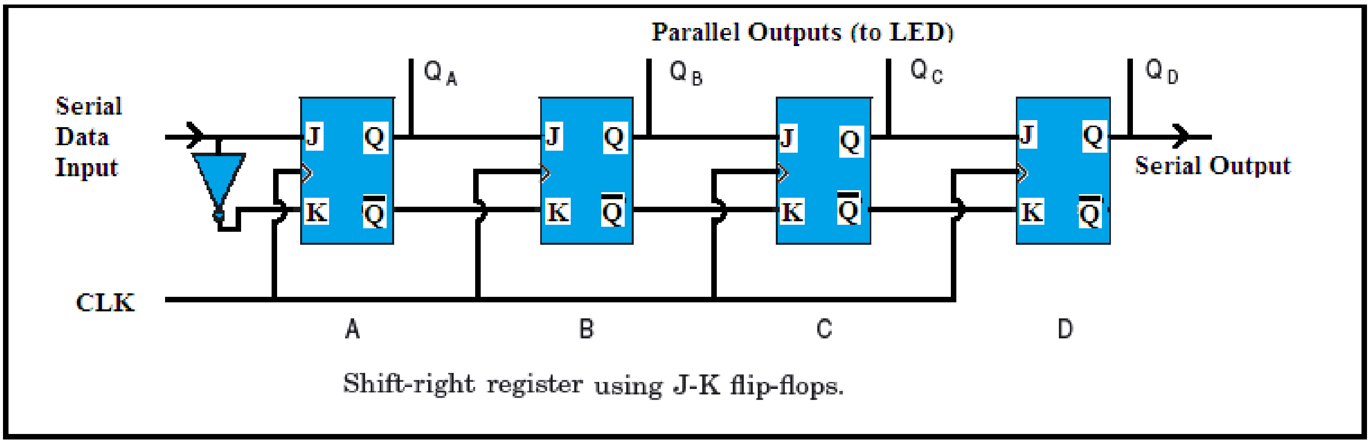
Shift Registers are used for data storage or for the movement of data and are therefore commonly used inside calculators or computers to store data such as two binary numbers before they are added together, or to convert the data from either a serial to parallel or parallel to serial format. The individual data latches that make up a single shift register are all driven by a common clock signal making them **synchronous devices**. One application of shift registers is in the conversion of data between serial and parallel, or parallel to serial.



Shift right register

J-K flip flop based shift register requires connection of both J and K inputs. Input data are connected to the J and K inputs of the left most flip flop (A) of flip flop chain. And all flip flops are connected in serially. As we know that for a JK flip flop output is followed whatever the input of J and the both the input are complimentary. Let us take an example to input a 0, one should apply a 0 at the J input, i.e., J = 0 and K = 1 and vice versa. With the application of a clock pulse the data will be shifted by one bit to the right. In this way the first data will store at Flip flop A then in next clock pulse the data of A flip flop is shifted to flip flop B in that way finally we get the serial output from flip flop D. We can also verify the data content of each flip-flop, on each clock pulse. Depending upon the data shift within the register, it may be shifted from left to right using shift-left register, or may be shifted from right to left using shift-right register.

The truth table Figure (3) and waveforms Figure (4) show the propagation of the logic **1** through the register from left to right as follows.



Shift right register using J-K flip flop

Waveforms

Procedure

The connections are made as shown in figure. A high (1) is applied as the input and on first clock pulse, the ouput of flip flop A, that is Q_A will become high. This is verified by connecting Q_A to a LED. Then the input is switched off and on the next clock pulse the output of A becomes zero and is shifted to B and Q_B becomes high. Similarly the other outputs also change. The serial output at Q_D is also verified.

Clock Pulse No	QA	QB	QC	QD
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1
5	0	0	0	0

Truth table

Result

A 4-bit serial-in parallel-out shift right register using JK Flip-flop is constructed and its working is verified

10 Common Emitter Amplifier with negative Feedback

Aim

Design and construct a single stage transistor amplifier circuit with negative feedback.

Requirements

Transistors-BC107 , Capacitors ,Resistors , Power Supply, CRO , Function generator , Variable Resistors or Potentiometers.

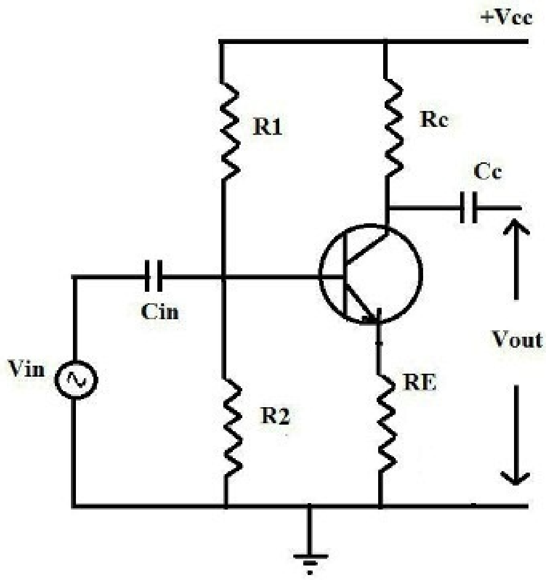
Theory

An amplifier is a circuit which can amplify current / voltage / power of the signal applied at its input.Out of the three transistor connections, the Common emitter circuit is the most efficient for making amplifiers.Common emitter configuration gives very high current gain.Due to high current gain, the common emitter circuit has the highest voltage and power gain.In a common emitter circuit, the ratio of output impedance to input impedance is small. This makes this circuit arrangement an ideal one for coupling between various transistor stages.

In order for the transistor amplifier to be a practical circuit, it is necessary to use a biasing circuit that will stabilize the Q-point. In order to make the Q-point stable, the DC collector current must be independent of beta. This can be accomplished by using voltage divider biasing. There are three variations of voltage divider biasing circuits: the unbypassed circuit with voltage gains in the range of 2 to 10 but with excellent signal parameter predictability, the fully bypassed circuit with voltage gains in the range of 50 to 500 but with unpredictable signal parameters, and the split-emitter circuit with voltage gains in the range of 5 to 50 with good signal parameter predictability.

The **split-emitter** amplifier has values of voltage gain and input impedance between those of the fully bypassed and the unbypassed circuits. The predictability of the signal parameters is also between the other two circuits. The amount of the emitter resistor left unbypassed determines the voltage gain and predictability of the circuit. Because the designer has the ability to control voltage gain and signal parameter predictability, the split-emitter voltage divider circuit has become a popular circuit in electronic systems. Figure shows the circuit arrangement of a single stage Common Emitter mode transistor amplifier. D.C. power supply, the resistances R_1, R_2 and R_E provides **potential divider biasing and stabilization network**. i.e. It establishes a proper operating point to get faithful amplification. R_E reduces the variation of collector current with temperature. The potential divider bias provides forward bias to the emitter junction and reverse bias to the collector junction. Since the emitter is grounded, it is common to both input and output signals. Therefore, the amplifier is common-emitter amplifier. Capacitor C_{in} isolates the d.c. component and the internal resistance of the signal generator and couples the a.c. signal voltage to the base of the transistor.The capacitor C_E connected across the emitter resistor R_E is of large value offers a low reactance path to the alternating component of emitter current and thus bypasses resistor R_E at audio frequencies. Consequently, the potential difference across R_E is due to the d.c. component of the current only.

During the positive half—cycle of the signal the forward bias across the emitter-base junction is increased. Therefore, more electrons flow from the emitter to the collector via the base which causes an increase in collector current. The increased collector current produces a greater voltage drop across the collector load resistance R_C. However, during the negative half-cycle of the signal the forward bias across emitter-base junction is decreased and the collector current also decreases. This results in the decreased output voltage (in the opposite direction). Hence, an amplified output is obtained between the collector and emitter terminals.



SINGLE STAGE CE AMPLIFIER WITH NEGATIVE FEEDBACK

Single stage CE amplifier without negative feedback

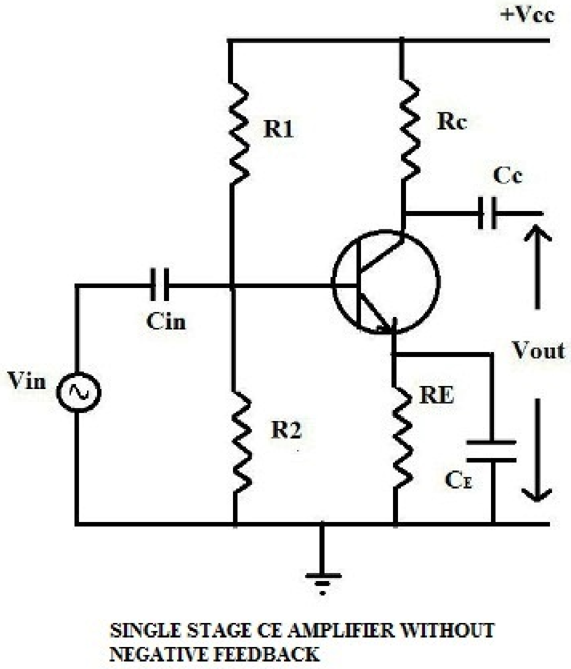
Frequency Response

The curve representing the variation of gain of an amplifier with frequency is known as frequency response curve.The voltage gain of the amplifier increases with the frequency and attains a maximum value. The maximum value of the gain remains constant over a certain frequency range and afterwards the gain starts decreasing with the increase of the frequency.

At low frequencies , the reactance of coupling capacitor is quite high and hence very small part of signal will pass to the load.This causes a falling of voltage gain at low frequencies. At mid-frequencies , the voltage gain of the amplifier is constant. The effect of coupling capacitor in this frequency range is such so as to maintain a uniform voltage gain. Thus, as the frequency increases in this range, reactance of C_C decreases which tends to increase the gain. However, at the same time, lower reactance means higher loading of the stage and hence Lower gain. These two factors almost cancel each other, resulting in a uniform gain at mid-frequency. At high frequencies , the reactance of C_C is very small and it behaves as a short circuit. This increases the loading effect of the output load and serves to reduce the voltage gain. Also at high frequency, capacitive reactance of base-emitter junction is low which increases the base current. This reduces the current amplification factor. Due to these two reasons, the voltage gain drops off at high frequency.

Feedback

The resistor in the emitter leg has been split into two parts: R_e and R_E. Resistor R_E is bypassed with a capacitor and is considered to be zero ohms when calculating signal parameters. Resistor R_e is unbypassed and must be considered when calculating signal parameters. The total value of the DC resistance is (R_e+R_E).Since there is an unbypassed emitter, the amplifier effectively has current-series negative feedback.Feedback voltage is directly proportional to the emitter current.While stabilizing the amplifier gain, the current-series feedback connection increases input and output resistance.The current through resistor R_E results in a feedback voltage that opposes the source signal applied so that the output voltage is reduced.



Single stage CE amplifier with negative feedback

Single stage CE amplifier - Potential divider biasing

Dynamic Emitter Resistance $r_e = \frac{25mV}{I_E}$

No feedback (with emitter bypass capacitor C_E)

Voltage Gain $= \frac{R_C}{r_e}$, if there is no load resistance $R_L = \infty$
Voltage Gain $= \frac{R_{AC}}{r_e}$, if there is a load resistance R_L and $R_{AC} = R_C \parallel R_L$

Negative feedback (without emitter bypass capacitor C_E)

Voltage Gain $= \frac{R_C}{r_e+R_E}$, if there is no load resistance $R_L = \infty$
Voltage Gain $= \frac{R_{AC}}{r_e+R_E}$, if there is a load resistance R_L and $R_{AC} = R_C \parallel R_L$

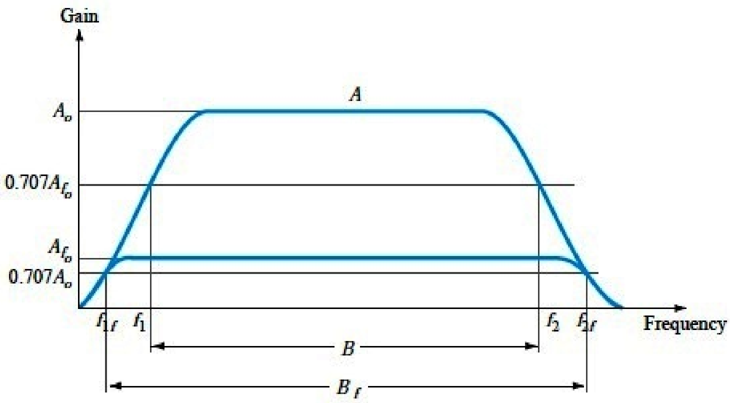
Swamped amplifier - Split-Emitter Biasing - Potential divider biasing with emitter resistance splitted in to unbypassed R_{E1} and bypassed R_{E2}

Voltage Gain $= \frac{R_C}{r_e+R_{E1}}$, if there is no load resistance $R_L = \infty$
Voltage Gain $= \frac{R_{AC}}{r_e+R_{E1}}$, if there is a load resistance R_L and $R_{AC} = R_C \parallel R_L$

Design

Design is made considering the **small signal** analysis of a common emitter amplifier of potential divider biasing with unbypassed emitter.

Let the voltage swing of the output wave is 10V.V_{CC} is taken as 20% more than required output



Frequency response -with and without feedback

Frequency Response curve

swing.So V_{CC} = 12V and I_C=2mA(because h_{FE} is guaranteed 100 at this collector current as per data sheet, if we are using transistor BC107).

For a distorsionless output , the operating point must be kept at the middle of the load line.So $V_{CE} = 50\% V_{CC}$=12/2 = 6V.

$$V_{RE} = 10\% of V_{CC} = 1.2V$$
$$V_{RC} = V_{CC} - V_{CE} - V_{RE} = 12 - 6 - 1.2 = 4.8V$$
$$V_{RC} = I_C R_C$$
$$R_C = \frac{V_{RC}}{I_C} = 4.8V/2mA = 2.4\,k\Omega$$
$$R_E = \frac{V_{RE}}{I_E} = 1.2V/2mA = 0.6\,k\Omega$$
$$V_{BE} = 0.7V\ for\ Silicon\ transistor$$
$$V_{R2} = V_B = V_{BE} + V_{RE} = 0.7 + 1.2 = 1.9V$$

Voltage at the base V_B=potential drop across the resistor R_2.

$$V_B = V_{R_2}$$
$$V_{R_1} = V_{CC} - V_{R_2} = 12 - 1.9 = 10.1V$$
$$R_1 = V_{R_1}/10I_B = 10.1V/10 \times 0.01mA) = 101k\Omega$$
$$V_{R_2} = R_2 \times 9I_B\ R_2 = V_{R_2}/9I_B = 1.9V/(9 \times 0.01mA) = 21.1k\Omega$$

Gain of the amplifier with feedback is

$$\boxed{A_f = A/(1 + \beta A) \approx A/A\beta = 1/\beta}$$

where β is the feedback fraction.Here $\beta = \frac{I_E R_E}{I_C R_C} \approx \frac{R_E}{R_C}$.

So $A_f \approx 1/\beta = \frac{R_C}{R_E}$, with the load resistance $R_L = \infty$.

The reactance ($X_{C_{in}} = 1/(C_{in}\omega)$) of the capacitor C_{in} should be less than the input impedance of the transistor.Similarly the reactance of first coupling capacitor C_C must be less than its output impedance.(R_C).Take $C_{in} = 0.01\mu F$ and each $C_C = 10\mu F$.

The output will be inverted by the amplifier due to transistor action .So the output of the coupled stage will be in out of phase with the input signal.

% Feedback

The percentage (or fraction) of negative feedback is determined by the emitter resistance R_E. We have for a negative feedback amplifier with open-loop gain A, closed loop gain A_F, feed back fraction (or gain of the feedback circuit) β,

$$A_F = \frac{1}{1 + A\beta} \approx \frac{1}{\beta}$$

Here $\beta = \frac{R_E}{R_C}$, where R_E is the unbypassed emitter resistance.

DC Conditions

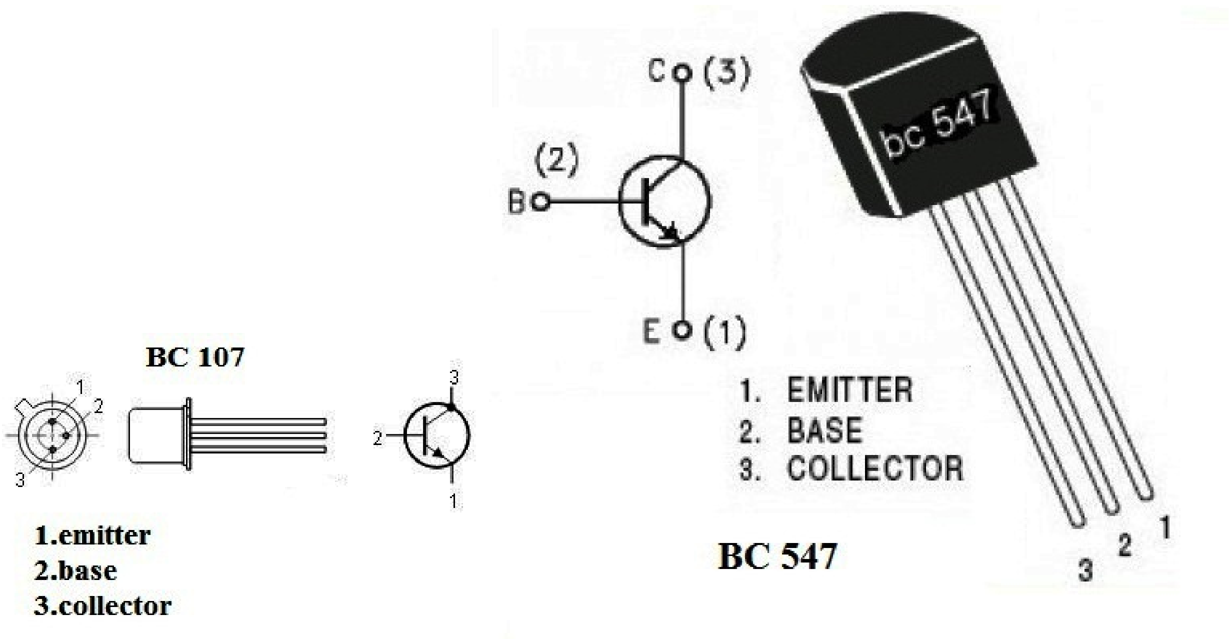
	Designed (volts)	**Measured (volts)**
V_{CC}		
V_{CE}		
V_{RE}		
V_{RC}		
V_B		
V_{BE}		
V_{R_1}		

Frequency Response-without feedback

$V_{in} = \ldots\ldots\ldots V_{PP}$

Frequency	**$\log_{10}$(frequency)**	**V_{out}(volts-peak to peak)**	**Voltage gain A=$\frac{V_{out}}{V_{in}}$**	**Gain in dB(20$\log_{10}$ A**

Procedure



1. Check the transistors.

   If we have a DVM with a “diode test” function, we can perform a functional test of a typical

NPN transistor in the same manner as if it were two common diodes connected together at their anodes. By placing the red (positive) lead of your DVM on the base and the black (negative) lead on the emitter you should see a low resistance, just like a typical , forward-biased diode would provide. Likewise, leaving the red lead connected to the base and placing the black lead on the collector, we should see another low resistance, indicative of another forward-biased semiconductor junction. By reversing the lead orientation (i.e., placing the black lead on the base and the red lead on the emitter or collector), we should read an infinite resistance in both cases. And finally connecting the DVM leads from emitter to collector in either orientation, should provide a reading of infinite resistance. The voltage between base and emitter may also be measured which equals 0.7 V when working properly.

2. Verify the dc conditions after switching ON the power supply , without applying the signal.The measured values must be in agreement with the designed values.
3. Apply a 100mV peak to peak ($0.1V_{PP}$) sine wave from the signal generator.
4. Observe the input and output waveforms simultaneously.
5. Keeping the amplitudes of the input signal constant , vary its frequency and measure the output amplitude corresponding to different frequencies.
6. Plot the frequency response curve.Find out the midband gain and the lower and upper cut-off frequencies.(frequencies corresponding to 0.707 of the midband gain (3dB down in log scale)).The bandwidth = $f_H - f_L$.Calculate the gain-bandwidth product.

Observations

Frequency Response-with negative feedback

$V_{in} = \ldots\ldots\ldots V_{PP}$

Frequency	**$\log_{10}$(frequency)**	**V_{out}(volts-peak to peak)**	**Voltage gain A=$\frac{V_{out}}{V_{in}}$**	**Gain in dB(20$\log_{10}$ A**

Results

A single stage common emitter amplifier with negative feedback is constructed. Frequency response of the amplifier is studied for the circuit with and without feedback.

Midband gain with negative feedback(theoretical) =
Midband gain with negative feedback(observed) =
Midband gain without feedback(theoretical) =
Midband gain without feedback(observed) =
Bandwidth with negative feedback =
Bandwidth without feedback =

11 Common Base Transistor Characteristics

Aim

To study the input and output characteristics of a common-base transistor

Apparatus

Transistor : 1 PNP (CK 100 or equivalent), Resistors, Multimeters, D.C. power supply, Connecting wires and Breadboard.

Principle

The bipolar junction transistor transistor is a three-layer semiconductor device consisting of either two **n** and one **p**-type layers of material or two **p** and one **n**-type layers of material. The former is called an **npn** transistor, while the latter is called a **pnp** transistor. Thus the transistor has two junctions: one between the emitter and the base, and another between the collector and the base. The emitter-base junction is called the **emitter diode** and collector-base junction is called the **collector diode**. The BJTs are usually made of Si and not of Ge.

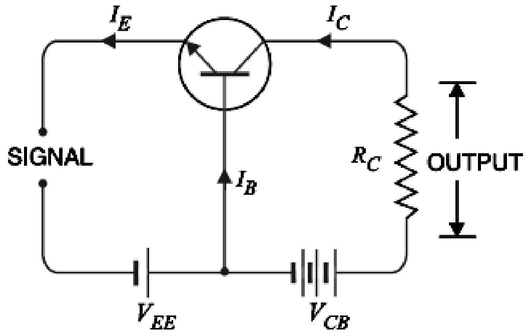
There are three leads in a transistor - emitter, base and collector terminals. When a transistor is to be connected in a circuit, we require four terminals: two for the input and two for the output. This difficulty is overcome by making one terminal of the transistor common to both input and output terminals. The input is fed between this common terminal and one of the other two terminals. The output is obtained between the common terminal and the remaining terminal. Accordingly , a transistor can be connected in a circuit in the following three ways

- Common Base configuration
- Common Emitter configuration
- Common Collector configuration

Each circuit connection has specific advantages and disadvantages. Regardless of circuit connection, the emitter is always biased in the **forward direction**, while the collector always has a **reverse bias**.

Common Base configuration

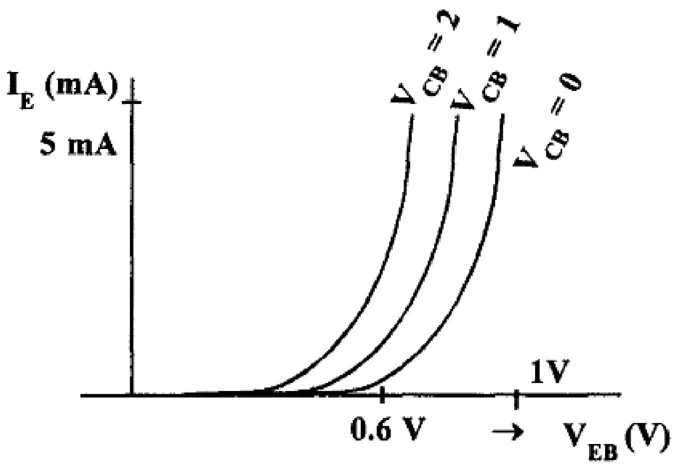
The base is made common to both the input and output sides of the configuration. Also the base is usually the terminal closest to, or at, ground potential and so it is also called a **grounded base configuration**. Emitter and Collector Voltages are measured with respect to the base. The convention is currents, entering the transistor are taken as positive and those leaving the transistor as negative. All current directions will refer to conventional (hole) flow rather than electron flow.



Common base npn transistor

All the current directions appearing in figure ?? are the actual directions (conventional flow). The applied biasing (voltage sources) are such as to establish current in the direction indicated for each branch. I_E and V_{EE} (or V_{BE}) are the input current and voltage and I_C and V_{CB} (or V_{CC}) are the output current and voltage.

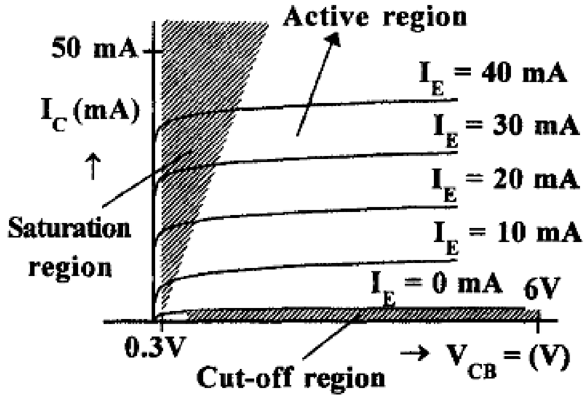
1. Input (or driving point) characteristics
   The input set for the common-base amplifier as shown in figure ?? will relate an input current (I_E) to an input voltage (V_{BE}) for various levels of output voltage (V_{CB}).



Input characteristics of common base configuration

2. Output characteristics

   The output set will relate an output current (I_C to an output voltage (V_{CB}) for various levels of input current (I_E) as shown in figure ??. The output or collector set of characteristics has three basic regions of interest, as indicated in Fig. 7: the active, cutoff, and saturation regions. The active region is the region normally employed for linear (undistorted) amplifiers. *In the active region the collector-base junction is reverse-biased, while the base-emitter junction is forward-biased.*



Output characteristics of common base configuration

Active, Cut-off and Saturation Regions

The active region is shown in the output characteristics. When the value of V_{CB} is raised above 1 or 2 V, the collector current becomes constant and now I_C is independent of V_{CB} and depends upon I_E only. The transistor is always operated in this region. At the lower end of the active region the emitter current (I_E) is zero, the collector current is simply that due to the reverse saturation current I_{CO}. The current I_{CO} (or I_{CBO}) is so small (microamperes) in magnitude compared to the vertical scale of I_C(milliamperes) that it appears on virtually the same horizontal line as $I_C = 0$.

As the emitter current increases above zero, the collector current increases to a magnitude essentially equal to that of the emitter current as determined by the basic transistor-current relations. Thus V_{CB} has a negligible effect on the collector current for the active region. and the curves clearly indicate that the relationship between I_E and I_C in the active region is given by

$$I_C \approx I_E \tag{1}$$

The cutoff region is defined as that region where the collector current is 0 A . In the cutoff region the *collector-base and base-emitter junctions of a transistor are both reverse-biased.* The saturation region is defined as that region of the characteristics to the left of $V_{CB} = 0V$. The horizontal scale in this region was expanded to clearly show the dramatic change in characteristics in this region. The collector current increase exponentially as the voltage V_{CB} increases toward 0 V. *In the saturation region the collector-base and base-emitter junctions are forward-biased.*

When transistor is being used as a *switch, it is operated between cut off and saturation regions.*

The decrease in base width with increase in collector reverse bias voltage is known as **Early Effect**. When the base width decreases, the probability of recombination of holes and electrons in the base region is less.

The input characteristics reveal that for fixed values of collector voltage (V_{CB}), as the base-to-emitter voltage increases, the emitter current increases in a manner that closely resembles the diode characteristics. Increasing levels of V_{CB} have such a small effect on the characteristics Once a transistor is in the "on" state, the base-to-emitter voltage will be assumed to be

$$V_{BE} = 0.7V \tag{2}$$

Transistor alpha α

In the dc mode the levels of I_C and I_E due to the majority carriers are related by a quantity called alpha and defined by the following equation:

$$\alpha_{dc} = \frac{I_C}{I_E} \tag{3}$$

For practical devices the level of alpha typically extends from 0.90 to 0.998, with most approaching the high end of the range. Since alpha is defined solely for the majority carriers,

$$I_C = \alpha I_E + I_{CBO} \tag{4}$$

For ac situations where the point of operation moves on the characteristic curve, an ac alpha is defined by

$$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E} \text{at constant } V_{CB} \tag{5}$$

The ac alpha is formally called the common-base, short-circuit, amplification factor.

Transfer Characteristics: *The transfer characteristics are plotted between the input and output currents* (I_E versus I_C)

Input resistance R_i

It is the ratio of change in input voltage to the change in input current at a fixed output voltage.

$$R_i = \frac{\Delta V_{BE}}{\Delta I_E} \text{ at a constant } V_{CB} \tag{6}$$

For Common Base configuration R_i is usually low ($\approx$ 100)

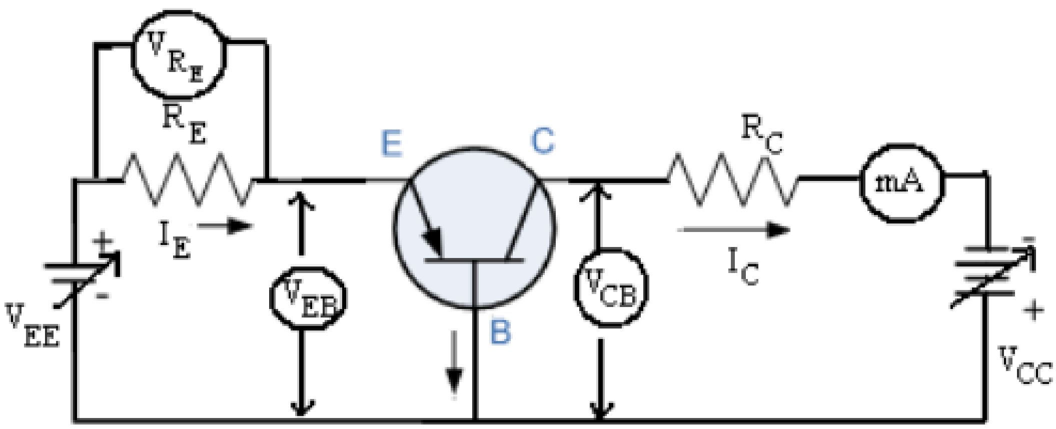
Output Resistance R_o

It is the ratio of change in output voltage to the change in output current at a fixed input current.

$$R_o = \frac{\Delta V_{CB}}{\Delta I_C} \text{ at a constant } I_E \tag{7}$$

For Common Base configuration R_o is very high($\approx 450k\Omega$)

Procedure



pnp transistor in common base configuration

1. Configure CB circuit using the PNP transistor as per the circuit diagram.

2. Use $R_E = R_C = 150\Omega$
3. For input characteristics, first fix the voltage V_{CB} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{EB} slowly (say, in steps of 0.05V) by varying V_{EE}. Measure V_{EB} using a multimeter. If V_{CB} varies during measurement bring it back to the initial set value To determine I_E, measure V_{RE} across the resistor R_E and use the relation $I_E = V_{RE}/R_E$
4. Repeat the above step for another value of V_{CB} say, 2V.
5. Take out the multimeter measuring V_{EB} and connect in series with the output circuit to measure I_C.For output characteristics, first fix $I_E = 0$, i.e. $V_{RE} = 0$. By adjusting V_{CC}, vary the collector voltage V_{CB} in steps of say 1V and measure V_{CB} and the corresponding I_C using multimeters. After acquiring sufficient readings, bring back V_{CB} to 0 and reduce it further to get negative values. Vary V_{CB} in negative direction and measure both V_{CB} and I_C, till you get 0 current.
6. Repeat the above step for at least 5 different values of I_E by adjusting V_{EE}. You may need to adjust V_{EE} continuously during measurement in order to maintain a constant I_E.
7. Plot the input and output characteristics by using the readings taken above and determine the input and output dynamic resistance.
8. To plot transfer characteristics, select a suitable voltage V_{CB} well within the active region of the output characteristics, which you have tabulated already. Plot a graph between I_C and the corresponding I_E at the chosen voltage V_{CB}. Determine α_{ac} from the slope of this graph.

Observations and Calculations

$V_{CB} = \ldots$ Volts			$V_{CB} = \ldots$ Volts		
V_{EB}	V_{RE}	I_E	V_{EB}	V_{RE}	I_E

Input characteristics

Plotting graphs

1. Input characteristics: Plot $V_{EB} - I_E$, for different V_{CB} and determine the input dynamic resistance in each case at suitable operating points.
2. Output characteristics: Plot $V_{CB} - I_C$, for different I_E and determine the output dynamic resistance in each case at suitable operating points in the active region.
3. Transfer characteristics: Plot $I_E - I_C$, for a fixed V CB and determine α_{ac}.

$I_E = \ldots$		$I_E = \ldots$		$I_E = \ldots$		$I_E = \ldots$	
V_{CB}	I_C	V_{CB}	I_C	V_{CB}	I_C	V_{CB}	I_C

Output characteristics

I_E mA	I_C mA

Transfer characteristics, $V_{CB} = \ldots$ volts

Results

The input, output and transfer characteristics of a common base transistor are studied and the curves are plotted. The current gain (current amplification factor) obtained is $\alpha_{ac} = \ldots\ldots$.

12 RS and D flip-flop

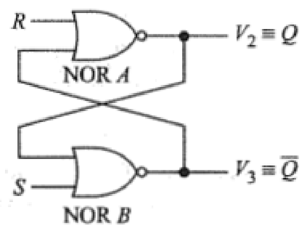
Aim

To construct R-S flip-flop and D flip-flop using NAND and NOR gates and to verify their truth-tables

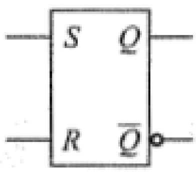
Theory

Flip-flops

Any device or circuit that has two stable states is said to be bistable. A flip-flop is a bistable electronic circuit that has two stable states-that is, its output is either binary 0 or 1. The flip-flop also has memory since its output will remain as set until something is done to change it. As such, the flip-flop can be regarded as a memory device.
Figure shows a NOR gate RS (Reset-Set) latch



The flip-flop actually has two outputs, defined in more general terms as Q and $\bar{Q}$. It should be clear that regardless of the value of Q, its complement is $\bar{Q}$. There are two inputs to the flip-flop defined as R and S. The input/output possibilities for this RS flip-flop are summarized in the truth table in Fig.



Logic symbol

R	S	Q
0	0	Last state
0	1	1
1	0	0
1	1	? (Forbidden)

(b) Truth table

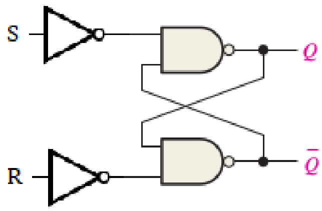
1. The first input condition in the truth table is R = 0 and S = 0. Since a 0 at the input of a NOR gate has no effect on its output, the flip-flop simply remains in its present state; that is, Q remains unchanged.

2. The second input condition R = 0 and S = 1 forces the output of NOR gate B low. Both inputs to NOR gate A are now low, and the NOR-gate output must be high. Thus a I at the S input is said to SET the flip-flop, and it switches to the stable state where Q = 1.

3. The third input condition is R = 1 and S = 0. This condition forces the output of NOR gate A low, and since both inputs to NOR gate B are now low, the output must be high. Thus a 1 at the R input is said to RESET the flip-flop, and it switches to the stable state where Q = 0 (or $\bar{Q} = 1$)

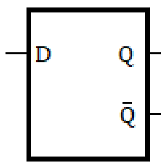
4. The last input condition in the table, R = 1 and S = 1, is forbidden, as it forces the outputs of both NOR gates to the low state. In other words, both Q = 0 and $\bar{Q}$ = 0 at the same time. But this violates the basic definition of a flip-flop that requires $\bar{Q}$ to be the complement of Q, and so it is generally agreed never to impose this input condition. Incidentally, if this condition is for some reason, imposed and the next input is R = 0, S = 0 then the resulting state Q depends on propagation delays of two NOR gates. If delay of gate A is less, i.e. it acts faster, then Q = 1 else it is 0. That's why R = 1, S = 1 is forbidden and truth table entry is ? .

The NAND gate realization of RS flip-flop is shown below.



D flip-flop

One of the main disadvantages of the basic SR flip-flop is that the indeterminate input condition of SET = 1 and RESET = 1 is forbidden. But in order to prevent this from happening an inverter can be connected between the SET and the RESET inputs to produce another type of flip flop circuit known as a **Data Latch, Delay flip flop, D-type Bistable, D-type Flip Flop** or just simply a D Flip Flop as it is more generally called.

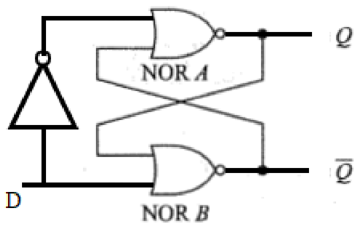


D flip-flop

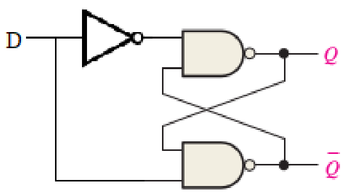
Truth-table

D	Q
0	0
1	1

The D-type flip flop are constructed from a gated SR flip-flop with an inverter added between the S and the R inputs to allow for a single D (Data) input.



D flip-flop using NOR gate



Truth-table

D	Q
0	0
1	1

D flip-flop using NAND gate

Procedure

For NOR gate, IC 7402 and for NAND gate IC 7400 are used. In both the IC's pin 14 is V_{CC} where a 5 volt is applied and pin 7 is ground. Both R-S and D flip-flops are constructed using both the universal gates. Inputs of 5 V are applied and the output voltage is measured using a voltmeter or the outputs are connected to LED's and truth-table of both the flip-flops are verified.

Results

R-S flip-flop and D flip-flop are constructed using both the universal gates and their truth-tables are verified.

13 Summing and Difference Amplifiers using Opamp

Aim

To design and construct a summing amplifier and a difference amplifiers using opamp

Apparatus

Principle

Summing Amplifier

To combine two or more analog signals into a single output, the summing amplifier as shown in figure 1 can be used. It is 2 input summing amplifier in inverting configuration. We can have as many inputs as needed for the application. The summing amplifier amplifies each input signal. The gain for each channel or input is given by the ratio of the feedback resistance to the appropriate input resistance. The output voltage of a summing amplifier is proportional to the negative of the algebraic sum of its input voltages.

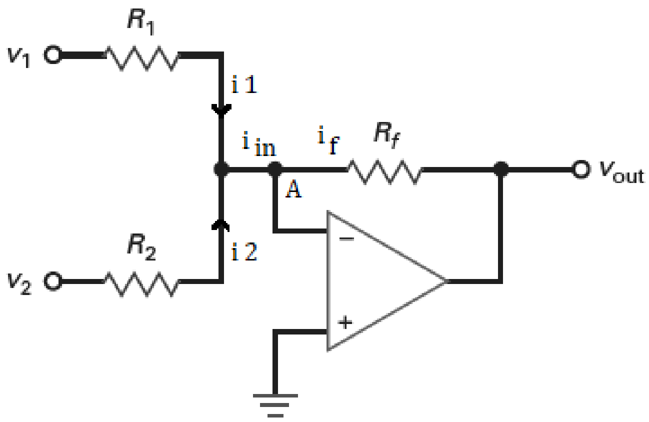


Figure 1: Inverting summing amplifier

Using the same concept of virtual ground, the voltage at A, V_A is zero. The input current i_{in} is the algebraic sum of the currents i_1 and i_2. The total input current must flow through R_f without any change in value, as the input resistance of opamp is very high. So $i_{in} = i_f$.

$$i_{in} = i_1 + i_2 = i_f$$

So, we get

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} = -\frac{v_{out}}{R_f}$$
$$v_{out} = -R_f\left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right)$$

Let $R_1 = R_2 = R$, then we get

$$v_{out} = -\frac{R_f}{R}\left(v_1 + v_2\right)$$

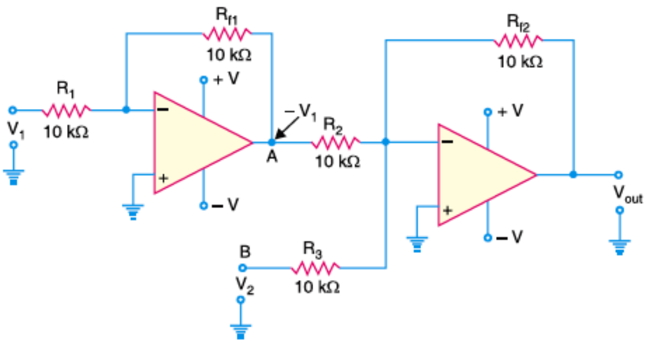
So the output voltage is the amplified (R_f/R) sum of the input voltages v_1 and v_1. We can also make $R = R_f$, so that

$$v_{out} = -(v_1 + v_2)$$

If we select $R_f/R = 1/n$, where n is the number of inputs, we get an averaging amplifier.

Difference Amplifier

By proper modifications, a summing amplifier can be made to subtraction. summing amplifier can be used to provide an output voltage that is equal to the difference of two voltages. Such a circuit is called a subtractor.



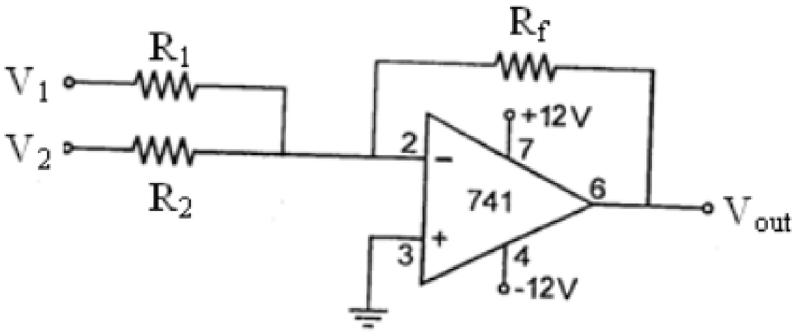
The circuit will provide an output voltage that is equal to the difference between V_1 and V_2. The voltage V_1 is applied to a standard inverting amplifier that has unity gain. Because of this, the output from the inverting amplifier will be equal to $-V_1$. This output is then applied to the summing amplifier (also having unity gain) along with V_2. Thus output from second OP-amp is given by;

$$V_{out} = -(-V_1 + V_2) = V_1 - V_2$$

It may be noted that the gain of the second stage in the subtractor can be varied to provide an output that is proportional to (rather than equal to) the difference between the input voltages. However, if the circuit is to act as a subtractor, the input inverting amplifier must have unity gain. Otherwise, the output will not be proportional to the true difference between V_1 and V_2.

Procedure

Summing Amplifier



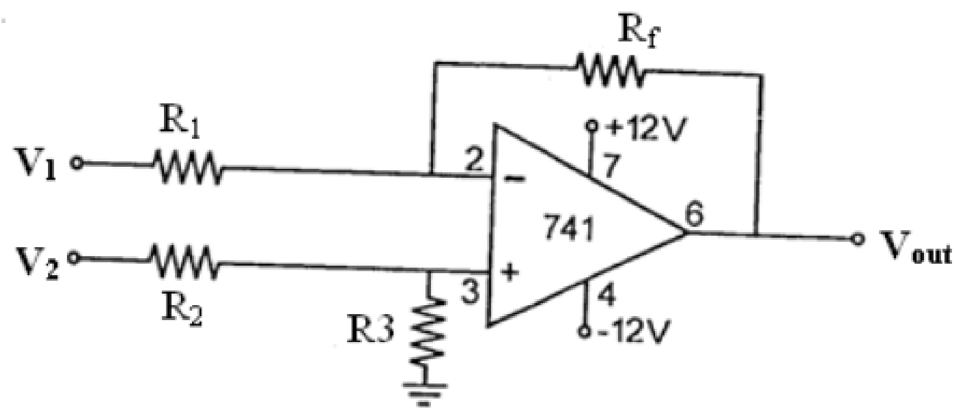
Summing Amplifier

1. Assemble the circuit as shown in circuit diagram choosing $R_1, R_2, R_f = 10K$ each. Use $0 - \pm 15V$ terminal output to provide supply to the IC.
2. Using 0-30 V and 5V terminals of the power supply, apply two inputs at the inverting terminal. Measure each input with multimeter.
3. Measure the output with multimeter for at least five input combinations.
4. Compare the output with the sum of the two inputs.

V_1 volts	V_2 volts	V_{out} (measured) volts	$V_1 + V_2$ (calculated) volts

Addition circuit values

Difference Amplifier



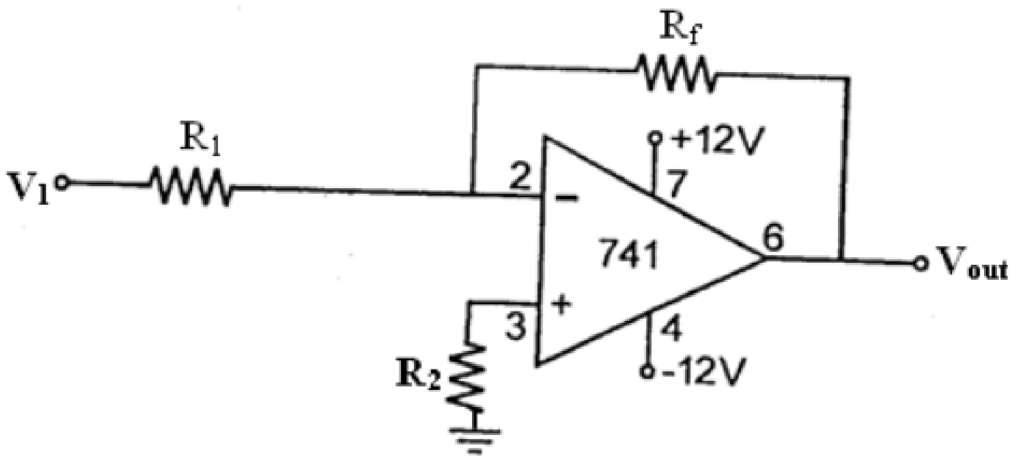
Difference Amplifier

1. Assemble the circuit as shown in circuit diagram choosing $R_1, R_2, R_3, R_f = 10K$ each. Use $0 - \pm 15V$ terminal output to provide supply to the IC.
2. Using 0 - 30V and 5V terminals of the power supply, apply two inputs, one at the inverting and the other at the non-inverting terminal. Measure each input with multimeter.
3. Measure output with multimeter for at least five input combinations.
4. Compare the output with the difference of the two inputs.

V_1 volts	V_2 volts	V_{out} (measured) volts	$V_2 - V_1$ (calculated) volts

Subtraction circuit values

Multiplying Circuit using opamp



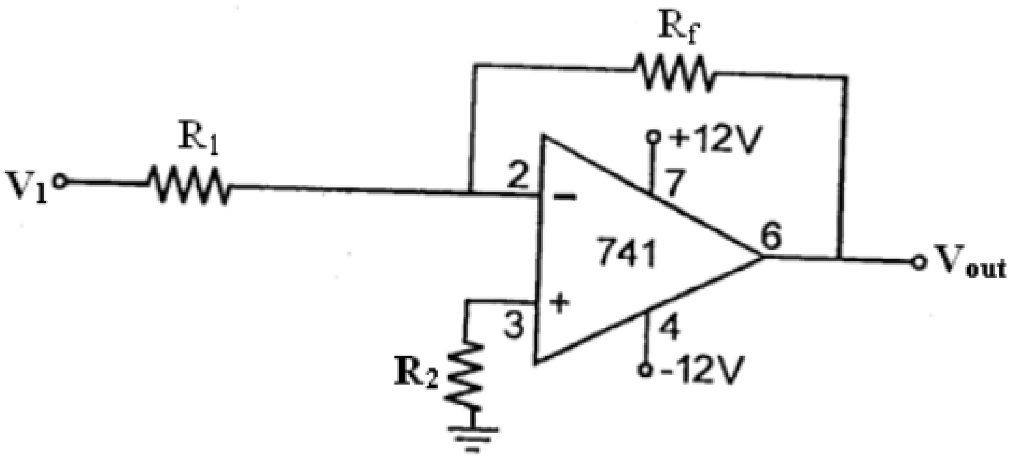
Circuit for multiplication by opamp

1. Assemble the circuit as shown in circuit diagram choosing $R_1, R_2 = 1K$ each and $R_f = 10K$. Use $0 - \pm 15V$ terminal output to provide supply to the IC.
2. Using 0 - 30V terminal of the power supply, apply different input values at the inverting terminal. Measure each input with multimeter.
3. Measure output with multimeter for at least five different input values.
4. Compare the measured output with the calculated one.

V_1 volts	V_{out} (measured) volts	V_{out} (calculated) volts

Multiplication circuit values

Division using opamp



Circuit for division by opamp

1. Assemble the circuit as shown in circuit diagram choosing $R_1 = 10K$ each and $R_2, R_f = 1K$. Use $0 - \pm 15V$ terminal output to provide supply to the IC.
2. Using 0- 30V supply, apply different input values at the inverting terminal. Measure each input with multimeter.
3. Measure output with multimeter for at least five different input values.
4. Compare the measured output with the calculated one

V_1 volts	V_{out} (measured) volts	V_{out} (calculated) volts

Division circuit values

Results

Operational amplifier circuits for addition, subtraction, multiplication and division are constructed and their operations are verified

14 Astable mutivibrater using transistor frequency measurement

Aim

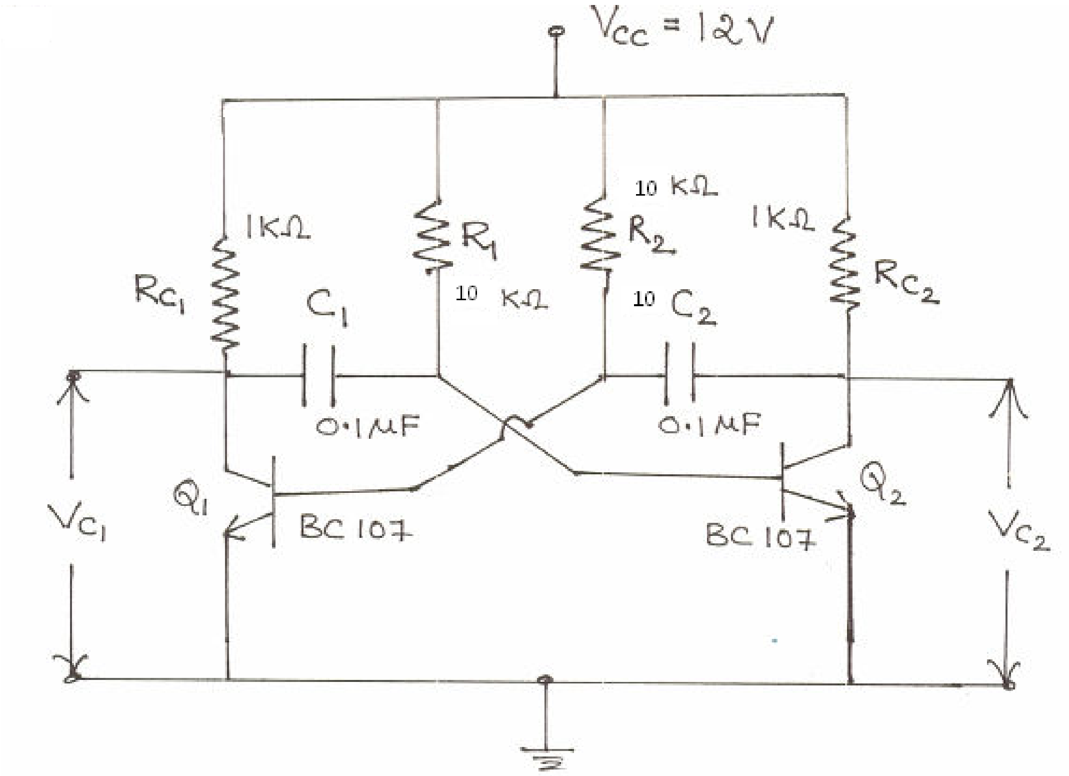
To study the operation and working principle of an Astable Multivibrator using transistors and to measure its frequencies for various capacitance-resistance values

Apparatus

CRO,Function Generator, Bread board, Resistor, Capacitors, Transistor (BC 107), Regulated D.C Power Supply, Connecting wires

Principle

The Astable circuit has two quasi-stable states. Without external triggering signal the Astable configuration will make successive transitions from one quasi-stable state to the other. The Astable circuit is an oscillator. It is also called as free running multivibrator and is used to generate *Square Wave*. Since it does not require triggering signal, fast switching is possible.



Astable multivibrator circuit using transistors

When the power is applied, due to some imbalance in the circuit, the transistor Q_2 conducts more than Q_1 i.e. current flowing through transistor Q_2 is more than the current flowing in transistor Q_1. The voltage V_{C2} drops. This drop is coupled by the capacitor C_1 to the base by Q_1 there by reducing its forward base-emitter voltage and causing Q_1 to conduct less. As the current through Q_1 decreases, V_{C1} rises. This rise is coupled by the capacitor C_2 to the base of Q_2. There by increasing its base-emitter forward bias. This Q_2 conducts more and more and Q_1 conducts less and less, each action reinforcing the other. Ultimately Q_2 gets saturated and becomes fully ON and Q_1 becomes OFF. During this time C_1 has been charging towards VCC exponentially with a time constant $T_1 = R_1C_1$.

The polarity of C_1 should be such that it should supply voltage to the base of Q_1. When C_1 gains sufficient voltage, it drives Q_1 ON. Then VC1 decreases and makes Q_2 OFF. V_{C2} increases and makes Q_1 fully saturated. During this time C_2 has been charging through V_{CC}, R_2, C_2 and Q_2 with a time constant $T_2 = R_2C_2$. The polarity of C_2 should be such that it should supply voltage to the base of Q_2. When C_2 gains sufficient voltage, it drives Q_2 On, and the process repeats.

It is seen that the multivibrator circuit alternates between a state in which Q_1 is ONand Q_2 is OFF and a state in which Q_1 is OFF and $Q2$ is ON. The time for which either transistor remains ON or OFF is given by :

$$\text{ON time for } Q_2 \text{ (or OFF time for } Q_1) \; T_1 = 0.69R_1C_1$$

$$\text{ON time for } Q_1 \text{ (or OFF time for } Q_2) \; T_2 = 0.69R_2C_2$$

Hence, total time of the square wave

$$T = T_1 + T_2 = 0.69(R_1C_1 + R_2C_2)$$

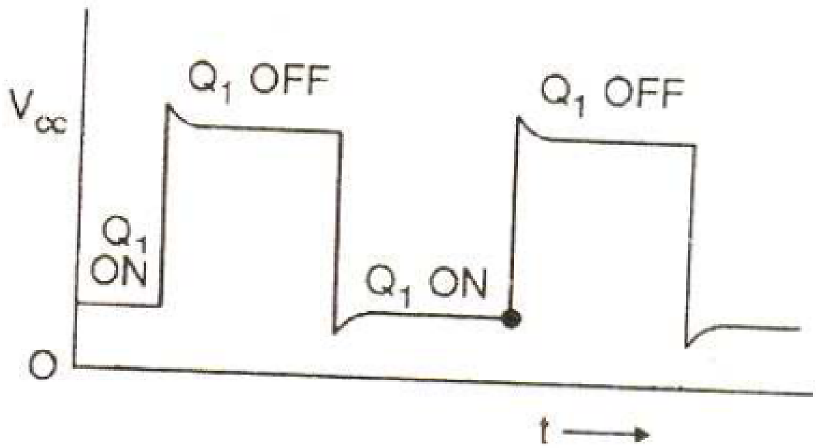
If $R_1 = R_2 = R$ and $C_1 = C_2 = C$ i.e., the two stages are symmetrical, then

$$T = 0.69(RC + RC) = 1.38RC$$

Frequency of the square wave is given by the reciprocal of the time period i.e

$$f = \frac{1}{T} = \frac{1}{1.38RC}$$

The output of the multivibrator can be taken from the collector of either transistor. The output is a square wave.



Output Waveform

Procedure

1. Make then connections as per the circuit diagram.
2. Observe the Base Voltage and Collector Voltages of Q_1&Q_2 on CRO in DC mode and measure the frequency
3. Trace the waveforms at collector and base as each transistor with the help of dual trace CRO and plot the waveforms.
4. Verify the practical output frequency with theoretical values $f = 1/T$, where $T = 1.38RC$

Observations & Calculations

Sl. No.	C_1 μF	C_2 μF	R_1 Ω	R_2 Ω	**Observed Time Period**	**Observed Frequency, Hz**	**Calculated Frequency, Hz**

Results

An astable multivibrator is constructed using transistors. Its frequencies for various capacitance-resistance values are measured.

15 JFET characteristics

Aim

Study the characteristics of a *junction field effect transistor-JFET*

Requirements

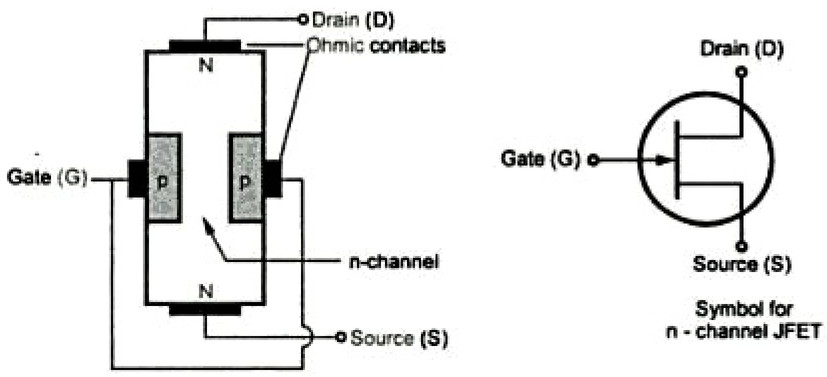
JFET , potentiometers,power supply,voltmeters,ammeters

Theory

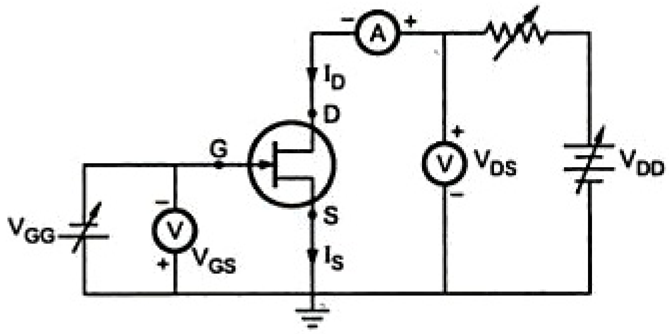
The field-effect transistor (FET) is a three-terminal, voltage controlled unipolar device having very high input impedance.The two type of FET are the junction field-effect transistor (JFET) and the metal-oxide-semiconductor field-effect transistor (MOS-FET).

Junction Field Effect Transistor-JFET

JFET is a three-terminal device with one terminal capable of controlling the current between the other two.In an *n-channel FET*, the major part is the n-type material that forms the channel between the embedded layers of p-type material. The top of the n-type channel is connected through an ohmic contact to a terminal referred to as the *drain (D)*, while the lower end of the same material is connected through an ohmic contact to a terminal referred to as the *source (S)*.The two p-type materials are connected together and to the *gate (G)* terminal.The n-channel FET requires zero or negative gate bias and a positive drain voltage.When a JFET is operated in such a manner that the source terminal is common to both input and output circuits, the mode of operation is referred to as the *common source mode.* In this mode of operation, the plot of drain current I_D against the drain to source voltage V_{DS} with with the gate to source voltage V_{GS} as a parameter is called the *static or common source* characteristics of the JFET.



Structure and symbol for n-channel JFET



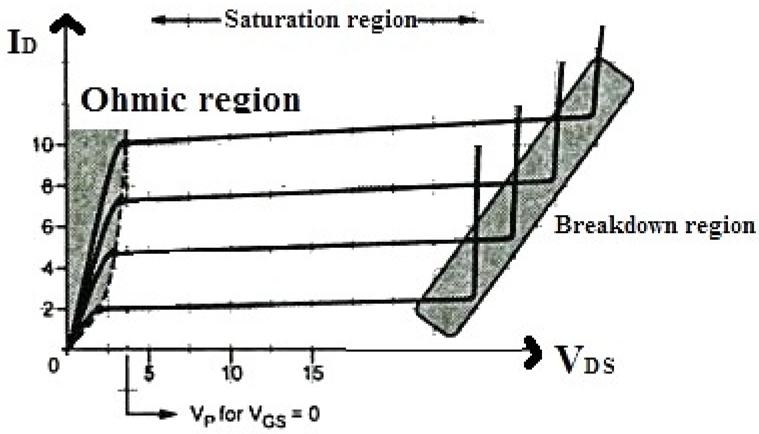
Experimental setup to plot JFET characteristics

n-channel JFET drain-source characteristics

- $V_{GS} = 0$ & V_{DS} is positive

  Let the gate-source voltage V_{GS} is zero.When the drain-source voltage V_{DS} is increased from zero to small values , the n-type bar acts a semiconductor resistor and the drain current I_D increases linearly with V_{DS}.When V_{DS} is increased I_D also increases,the ohmic voltage drop between the source and the channel region reverse biases the junction and the width of the channel region starts to decrease.At a particular high V_{DS} ,the channel is *pinched off* at which I_D begins to level off and becomes a constant.This value of V_{DS} is called *pinch-off voltage* V_P.The maximum drain current when source is grounded is called the shorted-gate drain current I_{DSS}.

  There is a maximum drain-source voltage-V_{DSmax} that can be applied to a JFET, after which the JFET would breakdown.The region between pinch-off and breakdown is the constant-current region or active region.The maximum voltage that can be applied between any two terminals of the FET is the lowest voltage that will cause avalanche breakdown across the gate junction.



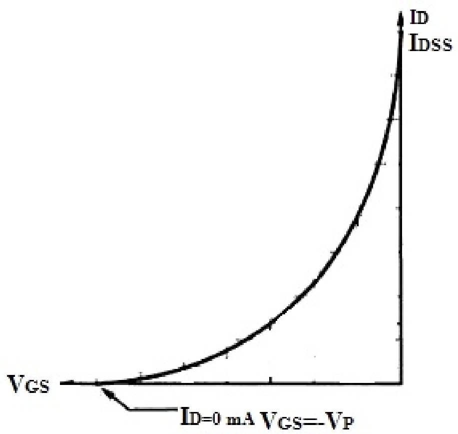
Drain V-I characteristics of n-channel JFET

Drain-source characteristics

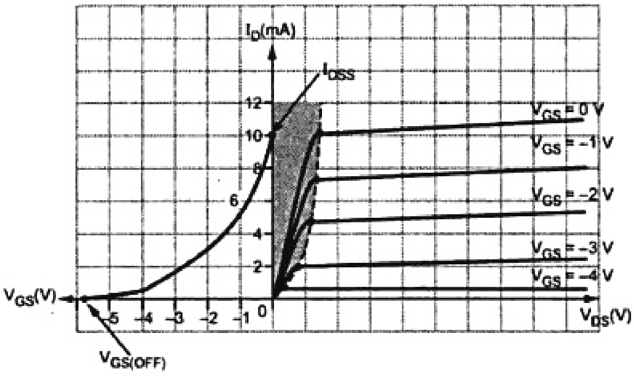
$V_{GS} = 0$ volt		$V_{GS} = -2$ volts		$V_{GS} = -4$ volts		$V_{GS} = -6$ volts	
V_{DS} **volts**	I_D **mA**	V_{DS} **volts**	I_D **mA**	V_{DS} **volts**	I_D **mA**	V_{DS} **volts**	I_D **mA**
0							
2							
4							
6							
8							
10							
12							
14							

Transfer characteristics

$V_{DS} = 2$ volts		$V_{DS} = 4$ volts		$V_{DS} = 6$ volts		$V_{DS} = 8$ volts	
V_{GS} **volts**	I_D **mA**	V_{GS} **volts**	I_D **mA**	V_{GS} **volts**	I_D **mA**	V_{GS} **volts**	I_D **mA**
0							
-2							
-4							
-6							



Transfer characteristics of n-channel JFET



Obtaining the transfer characteristics from drain characteristics

- V_{GS} is negative & V_{DS} is positive
  If a gate-source voltage V_{GS} is applied in a direction to provide additional reverse bias, pinch-off will occur for smaller values of $|V_{DS}|$.Avalanche occurs at a lower value of $|V_{DS}|$ when the gate is reverse-biased than for $V_{GS} = 0$.This is because the reverse-bias gate voltage adds to the drain voltage and hence increases the effective voltage across the gate junction.

n-channel JFET transfer characteristics

The transfer characteristics is a variation curve of drain current I_D corresponding to gate-source voltage V_{GS} while the drain-source voltage V_{DS} is constant. Two points, $)_{DSS}$ and V_P are the most important points in this transfer characteristic curve. When these two points are fixed in the coordinate axes, the remaining points can be looked up from this transfer characteristic curve or can be solved from the formula

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$$

Transfer curve can be obtained from drain characteristics.

The *amplification factor* μ of a JFET can be defined as

$$\mu = -\frac{\partial V_{DS}}{\partial V_{GS}} \quad at \ \ a \ \ constant \ I_D$$

The *mutual conductance* or *transconductance* g_m is

$$g_m = \frac{\partial I_D}{\partial V_{GS}} \quad at \ \ a \ \ constant \ V_{DS}$$

The *drain* or *output resistance* r_d is defined as

$$r_d = \frac{\partial V_{DS}}{\partial I_D} \quad at \ \ a \ \ constant \ V_{GS}$$

The three constants μ, g_m and r_d are connected as

$$\mu = r_d g_m$$

Procedure

Complete the connections as shown. For drain-source characteristics, vary V_{DS} slowly and measure corresponding I_D making V_{GS} constant. Repeat the same for different V_{GS} values. Transfer curve can be obtained from drain characteristics by noting the values from drain-source characteristics in to the table for Transfer characteristics.

To check the FET-Resistance from source to drain (or from drain to source) can be checked for checking the FET. This resistance should be relatively low (a few hundred ohms) when the gate-source PN junction voltage is zero. By applying a reverse-bias voltage between gate and source, pinch-off of the channel should be apparent by an increased resistance reading on the meter.

Results

The characteristics of a n-channel JFET is studied and the curves are plotted.The constants for the FET are calculated from the plots.

Transconductance =

Drain resistance =

Amplification factor =

16 Colpitt's Oscillator

Aim

To construct a Colpitt's oscillator and to measure its frequency for various capacitance values

Apparatus

BJT Transistor, Capacitors, Resistors, Inductor, CRO, Power Supply etc

Theory

High-frequency oscillations (between 1 and 500 MHz) can be produced with LC oscillators. Figure 2 shows a Colpitt's oscillator with the voltage-divider bias which sets up a quiescent operating point. The very high inductive reactance of R_F choke , so it appears open to the ac signal. Because the RF choke appears open to the ac signal, the ac collector resistance is primarily the ac resistance of the resonant tank circuit and this ac resistance has a maximum value at resonance.

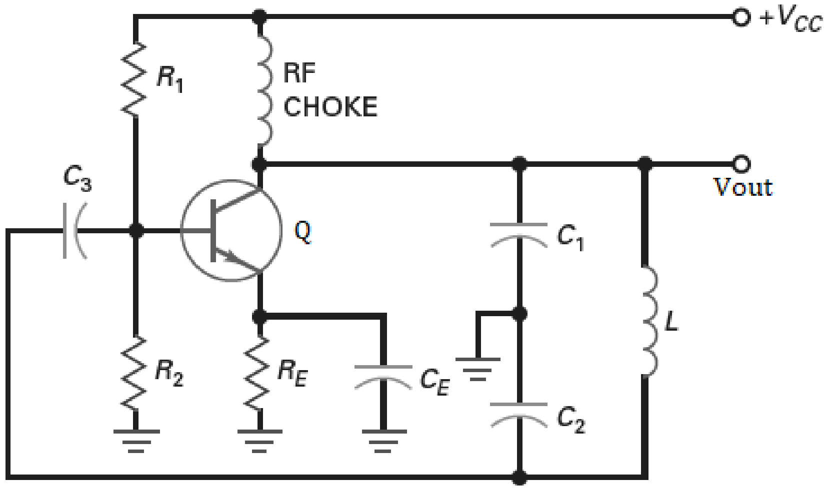


Figure 2: Colpitt's oscillator

The frequency of oscillations is determined by the capacitance values C_1 and C_2 and inductance L.

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

where

$$C_T = \frac{C_1C_2}{C_1 + C_2}$$

When the circuit is turned on, the capacitors C_1 and C_2 are charged and they discharge through L, setting up oscillations. The output voltage of the amplifier appears across C_1 and feedback voltage is developed across C_2 which is 180^0 out of phase with the voltage developed across C_1. The voltage across C_2 to the transistor provides positive feedback.

A 180^0 phase shift is produced by the transistor action and a further phase shift of the same amount is produced by $C_1 - C_2$ voltage divider arrangement. The current in the L$-C_2$ branch lags the tank voltage by 90^0 at resonance. Since the voltage across C_2 must lag its current by 90^0, the feedback voltage must lag the tank voltage (ac collector voltage) by 180^0. Thus, feedback is properly phased to produce continuous undamped oscillation.

The feedback fraction in this oscillator is

$$m_V = \frac{V_f}{V_{out}} = \frac{X_{C_2}}{X_{C_1}} = \frac{C_1}{C_2}$$

Procedure

1. The connections are made as shown in figure
2. Suitable capacitance and inductance values are taken
3. Power supply is switched on
4. Sinusoidal output is viewed on CRO
5. Time period is measured and hence frequency of oscillations is calculated
6. The experiment is repeated for various capacitance values
7. $R_1 = 33k\Omega, R_2 = 4.7k\Omega, R_C = 2.2k\Omega, R_E = 330\Omega, C_3 = C_4 = 0.22\mu F, C_E = 100\mu F$

Observations & Calculations

C_1 μF	C_2 μF	L mH	Time period	Measured Frequency	Calculated Frequency
0.027	0.1	200			

Results

A Colpitt's oscillator is constructed and its frequency of oscillations is determined for various capacitance values.

17 Spectrometer - i - i' curve for given angle of deviation II method

18 Spectrometer - small angled prism

Hartley Oscillator

8085 μP ALP to subtract two numbers

The following pages are downloaded from Google

Exp.No.2.2

Spectrometer-i_1-i_2 curve

Aim: To study the relationship between the two angles of incidence (one is the angle of incidence i_1 and the other is the angle of emergence i_2) for a given angle of deviation. We also aim to study the variation of angle of emergence with angle of incidence and to draw the i_1-i_2 curve.

Apparatus: Spectrometer, sodium vapor lamp, prism, reading lens etc.

Theory:

Let i_1 and i_2, respectively, be the angle of incidence and the angle of emergence of a prism of angle A corresponding to the angle of deviation d. Then,

$$i_1 + i_2 = A + d \qquad (1)$$

$$r_1 + r_2 = A \qquad (2)$$

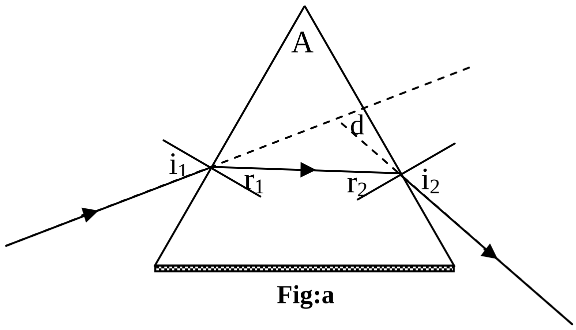


Fig:a

Fig.b gives the variation of angle of emergence i_2 with angle of incidence i_1. When the angle of deviation is minimum, $i_1 = i_2 = i$, $r_1 = r_2 = r$ and d = D. Then, from fig.b,

$$i = \frac{OB + OC}{2} \qquad (3)$$

By eqn.1,

$$2i = A + D \qquad (4)$$

$$D = 2i - A \qquad (5)$$

By eqn.4,

$$i = \frac{A + D}{2} \qquad (6)$$

From eqn.2,

$$r = \frac{A}{2} \qquad (7)$$

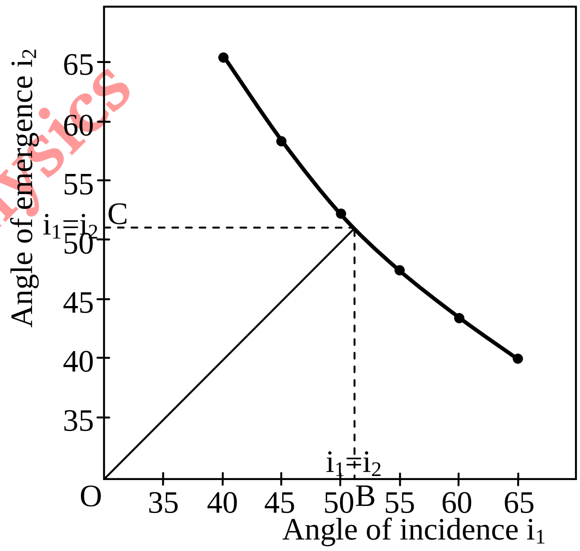


Fig.b: i_1-i_2 curve for an equilateral prism of μ = 1.56
See that the scales are same for X and Y axes

Refractive index of the material of the prism,

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + D}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad (8)$$

Procedure: Preliminary adjustments of the spectrometer are made (refer Exp. No. 1.11 of practical-I) and the prism is mounted on the prism table with its base is parallel and close to the clamp. The prism table is leveled either by observing the reflected images from both the sides of the prism or by using a spirit level.

The angle of the prism is found out either by the supplementary angle method (refer Exp. No. 2.6 of practical-II) or by observing the reflected rays from both sides of the prism.

Now the prism is set for a particular angle of incidence, say $i_1 = 40°$ as in the i-d curve experiment. The telescope is then released and is brought in a line with the refracted ray. (The dashed curves indicate the motion of the telescope). The telescope is clamped there. By using the tangential screw of the telescope, the refracted image of the slit is made to coincide with the vertical wire.

Now looking through the telescope the vernier table is rotated in such a direction that the refracted image moves towards the minimum deviation position (the refracted image moves towards the direction of direct ray). Continue the rotation of the vernier table in the same direction till the refracted image is returned at the vertical wire of the telescope. The vernier table is then clamped and the tangential screw of it is adjusted to get the refracted image on the vertical cross wire.

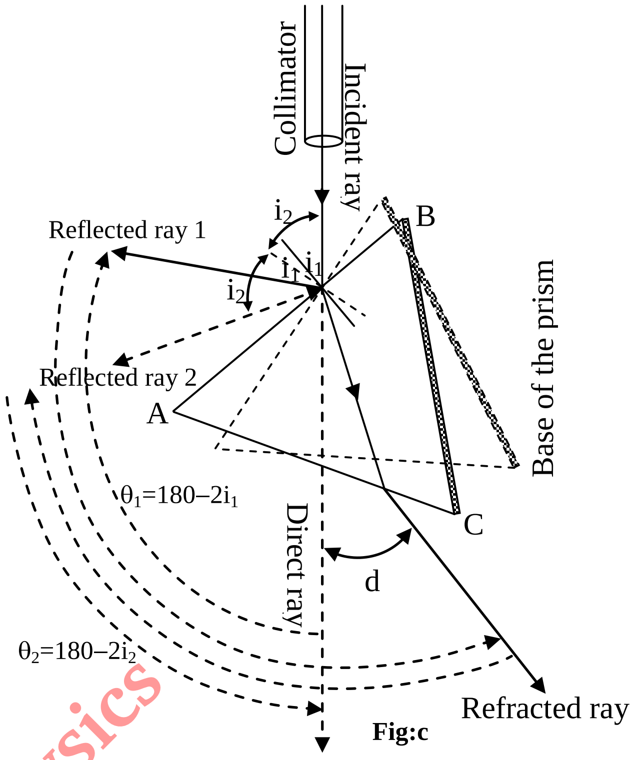


Fig:c

The telescope is released and is rotated towards the reflected ray. (Reflected ray 2 in the fig.c). By adjusting the tangential screw of the telescope, the reflected image of the slit is obtained exactly on the cross wire. The readings on both the verniers are noted. (Use the reading lens). Let it be ‘a’.

The telescope is again released. It is brought in the line of the collimator and the direct image of the slit is obtained on the cross wire. Again readings (b) on both the verniers are taken. The difference between the reading of the reflected image and the direct image gives $\theta_2=180-2i_2$. From that i_2 can be calculated.

The experiment is repeated for different values of i_1 = 45°, 50°, 55° etc. In each case i_2 is calculated. A graph is drawn between i_1 and i_2. From the graph, the angle of incidence ‘i’ corresponding to angle of minimum deviation D can be found by using eqn.3. Hence D can be calculated using the equation $D = 2i - A$.

Finally, the refractive index of the material of the prism is calculated using the eqn.8.

Precautions:

- See all the precautions given in the i-d curve experiment.
- Draw the i_1-i_2 curve with same scale in both the axes. Then it is easy to find out the $i = i_1 = i_2$ for minimum deviation from graph by simply drawing the bisector of the angle between X and Y axes (diagonal of squares on the graph).

Observation and tabulation

Value of one main scale division (1 m s d) = ...

Number of divisions on the vernier n = ...

Least count (L C) = $\frac{\text{Value of 1 m s d}}{n}$ = ...

[One degree = 60 minute, $(1^\circ = 60')$]

Angle of the prism A

	Ver I			Ver II			Mean 2A	A
	M S R	V S R	Total	M S R	V S R	Total		
Reflected image from first face 'a'								
Reflected image from second face 'b'								
Difference between the above readings 2A = a~b				2A = a~b				

Determination of i_2

Angle of incidence 'i_1'	Direct reading on any vernier	$\theta_1 = 180-2i_1$	Reading corresponding to reflected ray for second angle of incidence 'a'						Reading corresponding to direct ray after the second reflection 'b'						θ_2 = a~b			$i_2 = \frac{180-\theta_2}{2}$
			Ver 1			Ver II			Ver 1			Ver II						
			M S R	V S R	Total	M S R	V S R	Total	M S R	V S R	Total	M S R	V S R	Total	Ver I	Ver II	Mean	
35																		
40																		
45																		
50																		
55																		
60																		
65																		
70																		

Result

Angle of the prism A = ...

Angle of incidence corresponding to minimum deviation, i = ...

Angle of minimum deviation D = ...

Refractive index of the material of the prism μ = ...

Standard data*: Same as in the experiment for i-d curve.

Exp.No.2.3

Spectrometer-Cauchy's constants

Aim: To determine the constants in the Cauchy's dispersion formula for the material of the prism.

Apparatus: Spectrometer, mercury vapor lamp, prism, reading lens etc.

Theory: Considering the microscopic properties of the bound charged particles of a transparent medium Cauchy developed a relation connecting the refractive index of the material and the wavelength of light passing through it. *Cauchy's relation* between the refractive index μ of the material and the wavelength λ of the light is given by,

$$\text{Refractive index,} \quad \mu = A + \frac{B}{\lambda^2} \tag{1}$$

where, A and B are constants for a transparent material and are called the Cauchy's constants. (Do not confuse with constant A and the angle of the prism A). These constants can be determined by a method as follows. Let μ_1 and μ_2 be the refractive indices corresponding to the wavelengths λ_1 and λ_2 respectively. Then, (if $\mu_1 > \mu_2$)

$$\mu_1 = A + \frac{B}{\lambda_1^2} \tag{2}$$

$$\mu_2 = A + \frac{B}{\lambda_2^2} \tag{3}$$

$$\mu_1 - \mu_2 = B\left(\frac{1}{\lambda_1^2} - \frac{1}{\lambda_2^2}\right) = B\left(\frac{\lambda_2^2 - \lambda_1^2}{\lambda_1^2\lambda_2^2}\right)$$

$$B = \frac{(\mu_1 - \mu_2)\lambda_1^2\lambda_2^2}{\lambda_2^2 - \lambda_1^2} \tag{4}$$

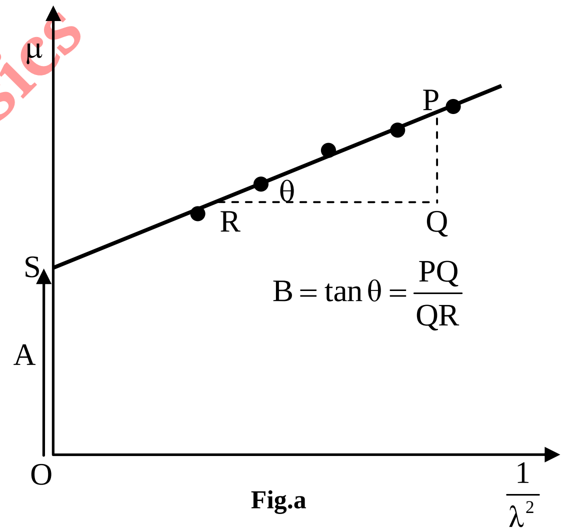


Fig.a

From eqn.2 and 3,

$$A = \mu_1 - \frac{B}{\lambda_1^2} \tag{5a}$$

Or, $$A = \mu_2 - \frac{B}{\lambda_2^2} \tag{5b}$$

If D is the angle of minimum deviation for a wavelength λ when it passes through a prism of angle A', the refractive index μ is given by,

$$\mu = \frac{\sin\left(\frac{A' + D}{2}\right)}{\sin\left(\frac{A'}{2}\right)} \tag{6}$$

Cauchy's constants can also be determined graphically. A graph is drawn with $\frac{1}{\lambda^2}$ along the X axis and μ along the Y axis (fig.a). The graph will be a straight line. Its slope gives the constant B and the Y intercept gives the constant A.

Procedure: As usual, the preliminary adjustments, including the leveling of the prism table, of the spectrometer are made. The angle of the prism A' is determined as described in Exp.No.1. 11 of practical-I or Exp. No. 2.6 of practical-II.

The prism is then adjusted to obtain the refracted spectrum. It consists of different spectral lines with violet being deviated most and red the least. The prism is then adjusted to be in the minimum deviation position for the violet line as described in experiment number 11 and 12 of Part 1. Readings on both the verniers are taken. The prism is removed carefully and the readings on both the verniers for direct ray are noted. The difference between these readings gives the angle of minimum deviation for violet light. Similarly the angles of minimum deviation for the other colours are found out. Refractive indices of the material of the prism for various colours are calculated using eqn.6. The Cauchy's constants are determined by the calculation and graphical methods.

Precaution:

- See all the precautions given in the i-d curve experiment.
- The prism is set to the minimum deviation position for each spectral line and in each case the direct reading is to be taken.

Observation and tabulation

Value of one main scale division (1 m s d) = ...

Number of divisions on the vernier n = ...

$$\text{Least count (L C)} = \frac{\text{Value of 1 m s d}}{n} = \text{..............}$$

[One degree = 60 minute, $(1° = 60')$]

Angle of the prism A'

	Ver I			Ver II			Mean $2A'$	A'
	M S R	V S R	Total	M S R	V S R	Total		
Reflected image from the first face 'a'								
Reflected image from the second face 'b'								
Difference between the above readings $2A' = a\sim b$				$2A' = a\sim b$				

Determination of refractive indices for various colours

Colours of spectral lines	Wavelength λ	Reading corresponding to the minimum deviation position of the refracted ray 'a'						Reading corresponding to the direct ray 'b'						Angle of minimum deviation D = a~b			μ	$\frac{10^{-12}}{\lambda^2}$
		Ver 1			Ver II			Ver 1			Ver II							
		M S R	V S R	Total	M S R	V S R	Total	M S R	V S R	Total	M S R	V S R	Total	Ver I	Ver II	Mean		

Calculation of Cauchy's constants

μ_1	μ_2	λ_1	λ_2	B	A
			Mean		

Cauchy's constants from graph A = ……….. B = ………..

Result

Angle of the prism A′ = ………

Cauchy's constants A = ………

B = ………..

Standard data*

Mercury spectral lines

Colour	Wavelength in nm
Yellow I	579.06
Yellow II	576.96
Green	546.07
Greenish blue	491.60
Blue	435.83
Violet I	407.78
Violet II	404.65

Exp.No.2.6

Small angled prism- normal incidence & normal emergence

Aim: To find the refractive index of the material of the given small angled prism by setting the prism for (1) normal incidence and (2) normal emergence.

Apparatus: Spectrometer, sodium vapor lamp, small angled prism, reading lens etc.

Theory: For a given prism, corresponding to a given angle of deviation there are two possible angles of incidence i_1 and i_2. These two angles are such that if one of the angles is the angle of incidence, the other angle will be the angle of emergence. So these two angles are interchangeable. In the following experiment we make use of this property.

Let i_1 and i_2 be the two angles of incidence and r_1 and r_2 be the corresponding angles of refraction for the given angle of deviation d. Then,

$$i_1 + i_2 = A + d \qquad (1)$$

$$r_1 + r_2 = A \qquad (2)$$

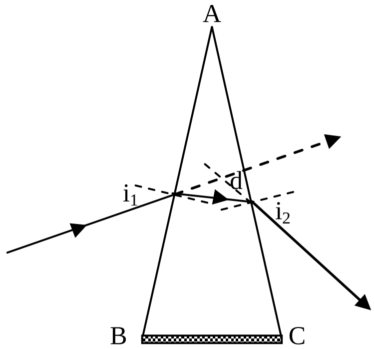


Fig.a

Normal incidence: In this case the incident ray is normal to one of the refracting faces (AB) of the prism. Then, $i_1 = 0$ and $r_1 = 0$. Thus, by eqn.1,

$$i_2 = A + d \qquad (3)$$

And by eqn.2, $$r_2 = A \qquad (4)$$

Refractive index, $$\mu = \frac{\sin i_2}{\sin r_2} = \frac{\sin(A+d)}{\sin A} \qquad (5)$$

Normal emergence: In this case the emergent ray is normal to the face (AC) of the prism. Then, $i_2 = r_2 = 0$. Hence, $i_1 = A + d$ and $r_1 = A$. Thus,

Refractive index, $$\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin(A+d)}{\sin A} = \frac{\sin i_1}{\sin(i_1 - d)} \qquad (6)$$

Procedure: All the preliminary adjustments of the spectrometer are made. The small angled prism is then mounted on the prism table with its base parallel and close to the clamp.

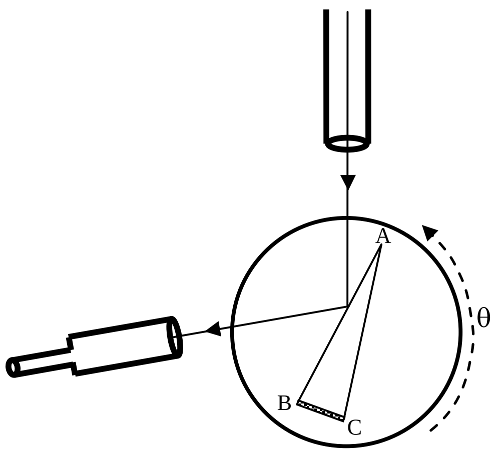


Fig.b

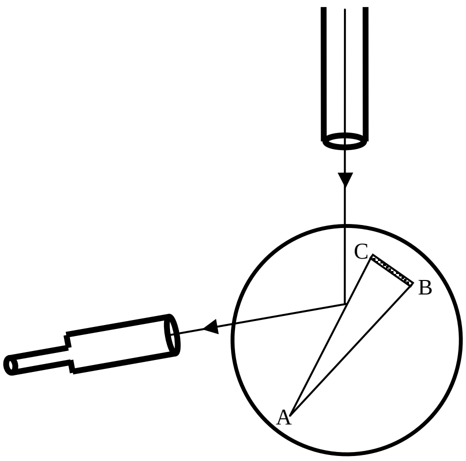


Fig.c

To find the angle of the prism by supplementary angle method: The telescope is clamped nearly normal to the collimator. The vernier table is slowly rotated until the reflected image of the slit from one of faces, say AB, is obtained on the cross wire of the telescope (fig.b). The vernier table is then clamped and using its tangential screw the image is made to coincide exactly with the vertical wire. The readings on both the verniers are noted. Then the vernier table is released and is rotated through an angle θ as shown in fig.b such that the reflected image from the other face (AC) is obtained on the cross wire of the telescope (fig.c). After making the fine adjustments of the vernier table, the readings on both the verniers are taken. The difference between the two readings gives θ and (180−θ) gives the angle of the prism.

To set the prism for normal incidence: (We follow the same method as in the case of grating normal incidence). The prism is removed from the prism table. The telescope is brought in a line with the collimator and the direct image is made to coincide with the vertical cross wire. This position of the telescope is noted by taking reading on one of the verniers. The telescope is now turned 90° and is clamped.

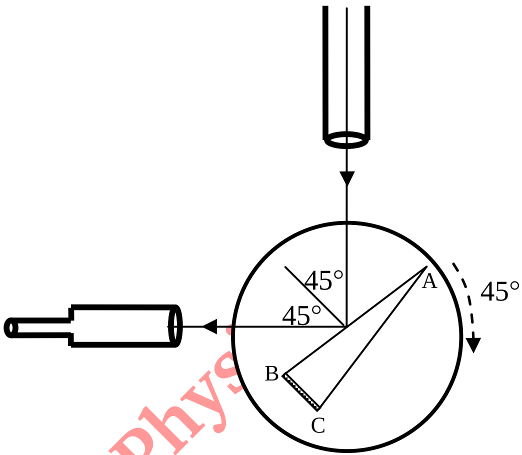


Fig.d

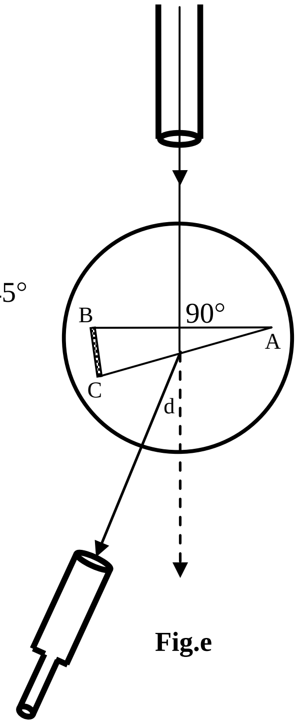


Fig.e

Next the prism is mounted on the prism table with one of its refracting surface facing the collimator and the prism table (vernier table) is rotated till the reflected image from that face of the prism coincides with the vertical wire (fig.d). If necessary the leveling screws of the prism table are adjusted such that the reflected image is divided by the horizontal wire and again the vernier readings are noted. Then the vernier table is rotated exactly through 45° in the proper direction so that the surface facing the collimator now becomes normal to the incident light (fig.e). The vernier table is clamped in this position.

Determination of the angle of deviation in normal incidence: The telescope is released and is brought in the line of refracted ray (fig.e). By making the fine adjustments with the tangential screw of the telescope the refracted image is obtained exactly on the vertical cross wire. The readings on both the verniers are noted. The prism is then removed carefully without changing the vernier table. The telescope is released and is made to coincide with the direct image. The readings on both the verniers are again noted. The difference between these two readings gives the angle of deviation. The refractive index is calculated by the eqn.5.

Normal emergence: To find the angle of deviation and the angle of incidence at the first face when the ray undergoes normal emergence, we make use of the property of the prism that the incident and the emergent rays are interchangeable.

The prism is again set for normal incidence and the refracted image is made to coincide with the vertical cross wire. After clamping the telescope the vernier table is released and is rotated such a direction that the refracted image moves towards the minimum deviation position. The rotation of the vernier is continued in the same direction until the refracted image returns to the cross wire. The vernier table is then clamped at this position and the fine adjustment of the vernier is done if necessary. Now the prism is set for normal emergence at the second face (fig.f). The readings on both the verniers are taken. Let it be ‘a’.

The telescope is then released and is brought in the line of the reflected image from the first face. By making fine adjustments the reflected image is made to coincide with the vertical cross wire and readings on both the verniers are noted. Let it be ‘b’.

The prism is then removed carefully. The telescope is brought in the line of the direct ray and the readings on both verniers are noted (c). The difference between the refracted image readings and the direct image readings (a~c) gives the angle of deviation corresponding to the normal emergence. The difference in the readings between reflected image and the direct image (b~c) gives $\theta = 180 - 2i_1$, from which i_1 can be calculated. Finally the refractive index of the material of the prism is calculated using eqn.6.

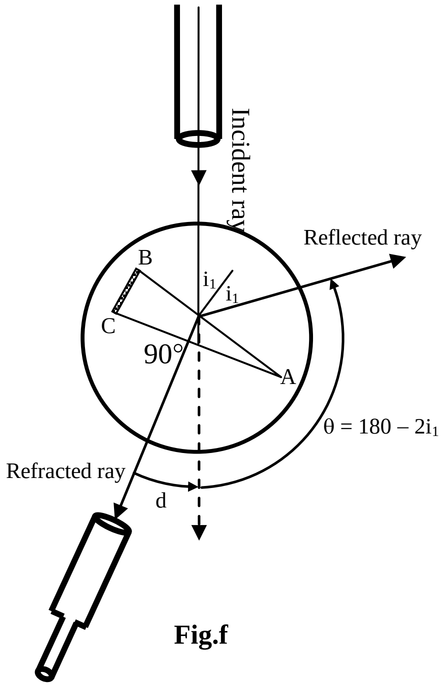


Fig.f

- If the image is not in field of view of the telescope make sure that the prism table is leveled. Looking through the prism with naked eye (without telescope) you can see the image and judge its direction which helps to know whether it passes through the field of view of the telescope and the leveling of vernier is needed.

Observation and tabulation

Value of one main scale division (1 m s d) = ...

Number of divisions on the vernier n = ...

$$\text{Least count (L C)} = \frac{\text{Value of 1 m s d}}{n} = \text{..............}$$

[One degree = 60 minute, $(1^\circ = 60')$]

Angle of the prism A (Supplementary angle method)

	Ver I			Ver II			Mean	
	M S R	V S R	Total	M S R	V S R	Total	θ	A=180–θ
Reflected image from first face ‘a’								
Reflected image from second face ‘b’								
Difference between the above readings θ = a~b				θ = a~b				

To set prism for normal incidence

	Ver I	Ver II
Direct reading		
Reading at which telescope is to be set = Direct reading + 90° =		
Reading corresponding to the reflected image		
Reading at which vernier is to be set = Reflected reading ± 45° =		

To find angle of deviation 'd' for normal incidence

Reading corresponding to	Ver I			Ver II			Mean d
	M S R	V S R	Total	M S R	V S R	Total	
Refracted image 'a'							
Direct image 'b'							
Difference between the above readings d = a~b				d = a~b			

Refractive index of the material of the prism, $\mu = \dfrac{\sin(A+d)}{\sin A} = \ldots\ldots\ldots\ldots$

To set prism again for normal incidence (for normal emergence method)

	Ver I	Ver II
Direct reading		
Reading at which telescope is to be set = Direct reading + 90° =		
Reading corresponding to the reflected image		
Reading at which vernier is to be set = Reflected reading ± 45° =		

To find angle of deviation 'd' and angle of incidence i_1 for normal incidence

Reading corresponding to	Ver I			Ver II			Mean d	Mean θ
	M S R	V S R	Total	M S R	V S R	Total		
Refracted image 'a'								
Reflected image 'b'								
Direct image 'c'								
Difference between the readings	a~c = d			a~c = d				
Difference between the readings	b~c = θ			b~c = θ				

Angle of incidence at the first face for normal emergence, $i_1 = \dfrac{180-\theta}{2} = \ldots\ldots\ldots$

Refractive index of the material of the prism $\mu = \dfrac{\sin i_1}{\sin(i_1 - d)} = \ldots\ldots\ldots$

Result

Mean refractive of the material of the prism, $\mu = \ldots\ldots\ldots$

Standard data*: Same as given for normal incidence method.

Exp.No.2.7

Air Wedge-Diameter of a thin wire

Aim: To find the diameter of a thin wire by measuring the width of the interference band formed by an air wedge arrangement with this thin wire and two plane glass plates.

Apparatus: An air wedge, sodium vapour lamp, travelling microscope, reading lens etc.

Theory: An air wedge is produced by two optically plane rectangular glass plates in contact with one pair of the edges and a thin wire, whose diameter is to be determined, is kept in between the plates near the other end parallel to the line of contact of the two plates.

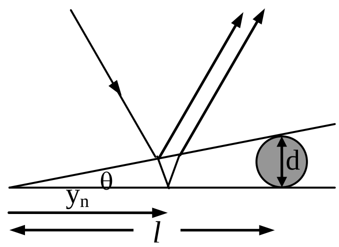


Fig.a

If the angle between the two glass plates is small and the ray incident normally, the approximate path difference between the two reflected rays from the upper and lower surfaces of the air film is given by,

$$\Delta = 2t_{\text{in medium}} - \frac{\lambda}{2} = 2\mu t_{\text{in air}} - \frac{\lambda}{2}$$

Since when the reflection takes place at the boundary of an optically denser medium (lower surface of the air film) the reflected ray undergoes a phase change π or an equivalent path difference λ/2. (μ is the refractive index of the thin wedge shaped film in between the glass plates. For air wedge μ = 1). For constructive interference path difference 'Δ' is an even multiple of λ/2. Thus,

$$2\mu t - \frac{\lambda}{2} = 2n\frac{\lambda}{2} \quad \text{where, } n = 0, 1, 2, 3\ldots$$

i.e., $$2\mu t = (2n+1)\frac{\lambda}{2}, \text{ where, } n = 0, 1, 2, 3\ldots \qquad (1)$$

For destructive interference path difference 'Δ' is an odd multiple of λ/2 . Thus,

$$2\mu t - \frac{\lambda}{2} = (2n-1)\frac{\lambda}{2}$$

Or, $$2\mu t = 2n\frac{\lambda}{2} = n\lambda, \text{ where, } n = 0, 1, 2, 3\ldots \qquad (2)$$

If y_n is the distance of the n^{th} dark fringe from the line of contact of the two glass plates, $t = y_n\theta$. Then, eqn.2 becomes,

$$2\mu\, y_n\theta = n\lambda \qquad (3)$$

For $(n+1)^{th}$ dark fringe, $$2\mu\, y_{n+1}\theta = (n+1)\lambda \qquad (4)$$

Subtracting eqn.3 from eqn.4, we get,

$$2\mu(y_{n+1} - y_n)\theta = \lambda$$

Therefore, fringe width, $$\beta = y_{n+1} - y_n = \frac{\lambda}{2\mu\theta} \qquad (5)$$

From eqn.1 we can also show that the distance between two consecutive bright fringes $x_{n+1} - x_n = \frac{\lambda}{2\mu\theta}$. If an *air wedge* is formed by placing a thin wire of diameter 'd' in between the glass plates at a distance '*l*' from the line of contact of the two glass plates, the fringe width is given by,

$$\beta = \frac{\lambda}{2\theta} = \frac{\lambda l}{2d} \qquad (6)$$

Since $\theta = \frac{d}{l}$ and for air $\mu = 1$.

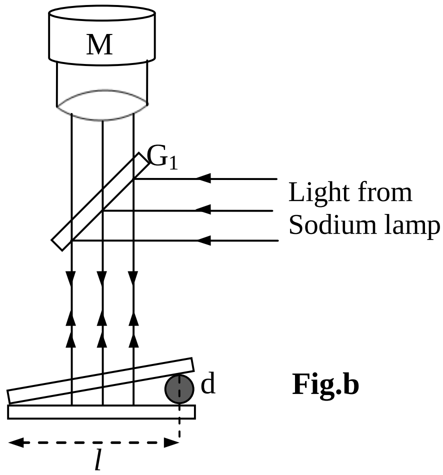


Fig.b

Procedure: Light from the sodium lamp is allowed to fall on the glass plate G_1 kept at 45° with the horizontal. The air wedge is placed such that the reflected light from the glass plate G_1 falls normally on it. The interference pattern is viewed from above by the travelling microscope as shown in fig.b. The pattern consists of large number of equally spaced alternate dark and bright bands as shown in fig.c. The microscope is moved towards one of the sides, say left, and one of the cross wires is made to coincide with any of the dark line, say n_0. The microscope is then moved in the opposite direction. (Remember now onwards the tangential screw is rotated only in one direction to avoid the backlash error). It is then made to coincide with the n^{th} dark line and the microscope reading on the horizontal scale corresponding to it is noted. Then the microscope is moved and the cross wire is made to coincide with the dark lines (n+3), (n+6), (n+9), ……….upto (n+27) and the corresponding readings are noted. From these observations find out mean band width β.

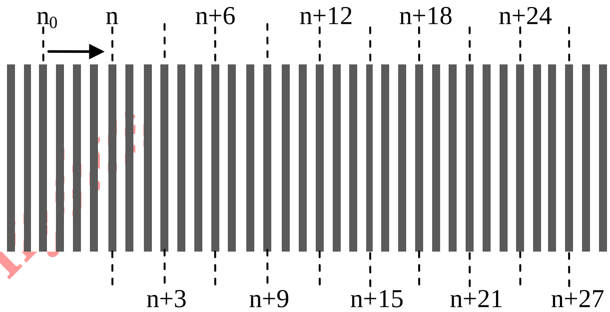


Fig.c

To find the distance *l* between wire and the line of contact of the glass plates take microscope readings corresponding to the line of contact and the wire. The difference between these readings gives '*l*'. (Microscope measurement is not essential).

Knowing the values of β and *l* and assuming the wavelength of sodium light (589.3 nm) the diameter of the wire can be calculated using the equation $d = \frac{\lambda l}{2\beta}$.

Precautions

- The glass plate G_1 should be 45° with the light from the sodium lamp.
- The glass plate G_1 should be oriented such that the light from the sodium lamp incident at the inner side of it. This helps the incident light to reflect towards the air wedge.
- To see the interference bands clearly focus the microscope. The objective lens of the microscope must be at a certain distance from the air wedge. This can be achieved by adjusting the main clamping screw and the rack and pinion arrangement of the microscope.

- In order to avoid the backlash error of the travelling microscope, initially the tangential screw of the microscope is rotated in a direction and the cross wire is moved from back of the n^{th} line and is then made to coincide with the n^{th} line. The tangential screw should not be rotated in the opposite direction (or to and fro) while coinciding with the first line and throughout the experiment. By mistake, if you have moved the microscope in the opposite direction while taking the reading give up all the readings taken and do the experiment from the beginning itself.
- Before starting to take readings ensure that we can move the microscope from the n_0^{th} line to more than n+30 lines. If it is not so loose the main screw of the vernier and loosen or tighten sufficiently the tangential screw and then tighten the main screw.

Observation and tabulation

Value of one main scale division (1 m s d) = ………. cm

Number of divisions on the vernier n = ……….

Least count $= \dfrac{1 \text{ m s d}}{n}$ = ……… cm

Determination of band width

Number of bands	Microscope readings			Width of 15 bands cm	Mean width of 15 bands w cm	Band width β = w/15 m
	M S R cm	V S R	Total cm			
n						
n+3						
n+6						
n+9						
n+12						
n+15						
n+18						
n+21						
n+24						
n+27						

Distance between the wire and the line of contact of the plates l = ………. m

Diameter of the wire, $d = \dfrac{\lambda l}{2\beta} =$ = …….. m

Angle of the wedge, $\theta = \dfrac{d}{l} = \dfrac{\lambda}{2\beta} =$ = ……… radian

Result

Diameter of the wire, d = ………. M

Angle of the wedge, θ = ………. radian

Standard data*

Wavelength of sodium light, λ = 589.3 nm.

Exp.No.3.15

Hartley Oscillator using Transistor

Aim: To construct a Hartley oscillator and measure its frequency using a C R O.

Components and accessories required: Transistor, resistors, capacitors, inductors, power supply, C R O, etc.

Circuit, theory and procedure

An electronic oscillator is an electronic circuit that converts d c energy into a c energy. It is essentially an amplifier in which a part of the output is fed back in phase to the input. To maintain steady oscillations the feedback circuit must satisfy the Barkhausen criterion for oscillation, which is,

(a) The feedback factor or loop gain $\beta A = 1$, where A is the gain without feedback.

(b) The feedback should be positive.

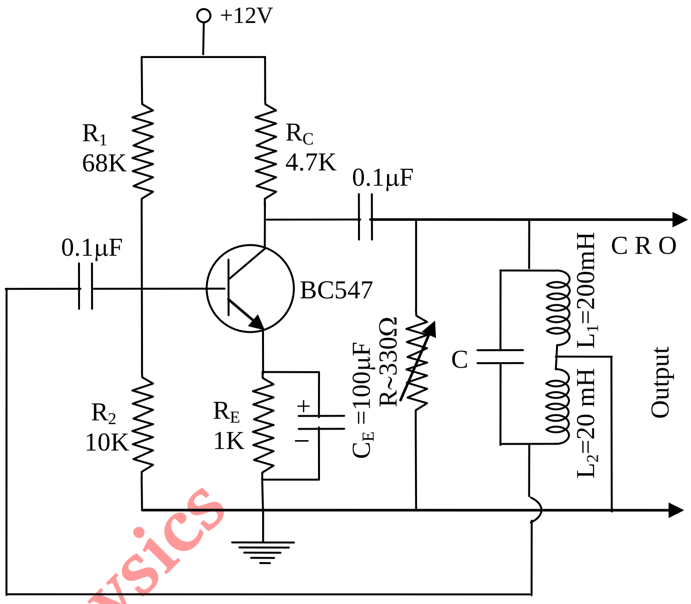


Fig.a: Hartley oscillator

Fig.a shows the circuit of a Hartley oscillator. In this oscillator, the feedback is supplied inductively. The frequency of oscillation is frequency of the tank circuit and is given by,

$$f = \frac{1}{2\pi\sqrt{LC}}, \text{ where, } L \approx L_1 + L_2$$

The circuit is soldered out in a board as shown in the fig.a. The output is measured by a C R O. If T is the time period of the oscillation, then frequency of oscillation is given by,

$$f = \frac{1}{T}$$

The time period can be determined as follows. The time base of C R O is adjusted such that the wave is seen clearly. Measure the number of divisions of the horizontal scale in the C R O screen in between two adjacent points with same phase-length of a wave- (distance between two adjacent negative peaks or positive peaks). Let it be ‘x’. Then the time period T is obtained by multiplying ‘x’ with time per division of the time base.

$$T = \text{‘x’ division} \times \text{time per division}$$

L_1, L_2 and C are measured by an L-C-R meter. The experiment may be repeated for different values of C, L_1 and L_2.

- Try with L_1 ~ 200 mH and L_2 ~ 20 mH.
- C = 0.01μF, 0.02 μF, 0.001μF, etc. preferred.
- In order to achieve the Barkhausaen criterion use a variable resistance R (~330Ω) (potentiometer of resistance 2K or 1K) to reduce the gain of the amplifier.

Observation and tabulation

Length of a wave 'x' cm	Time per division 't' sec/cm	T= xt sec	$f = \frac{1}{T}$	Mean f	L_1 henry	L_2 henry	$L \approx L_1 + L_2$ henry	C μF	$f = \frac{1}{2\pi\sqrt{LC}}$

Result

The Hartley oscillator is constructed. The frequency is measured and compared with the calculated frequency.

Exp.No.3.16

Colpitt's Oscillator using Transistor

Aim: To construct a Colpitts oscillator and measure its frequency using a C R O.

Components and accessories required: Transistor, resistors, capacitors, inductors, power supply, C R O, etc.

Circuit, theory and procedure

Colpitts Oscillator is also an electronic circuit that converts d c energy into a c energy. It is essentially an amplifier in which a part of the output is fed back in phase to the input.

Fig.a shows the circuit of a Colpitts oscillator. In this oscillator, the feedback is supplied capacitatively. The frequency of oscillation is frequency of the tank circuit and is given by,

$$f = \frac{1}{2\pi\sqrt{LC}},$$

where, $$C = \frac{C_1C_2}{C_1+C_2}$$

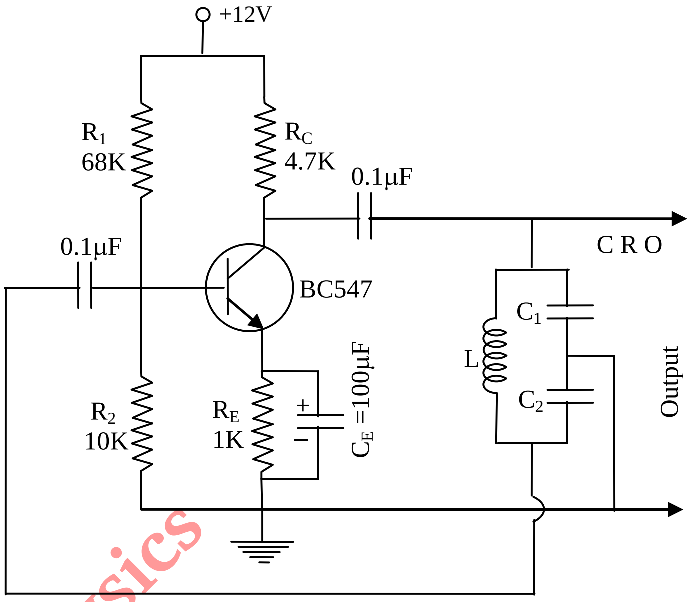


Fig.a: Colpitts oscillator

The circuit is soldered out in a board as shown in the figure. The output is measured by a C R O. If T is the time period of the oscillation, then frequency of oscillation is given by,

$$f = \frac{1}{T}$$

The time period can be determined as follows. The time base of C R O is adjusted such that the wave is seen clearly. Measure the number of divisions of the horizontal scale in the C R O screen in between two adjacent points with same phase-length of a wave- (distance between two adjacent negative peaks or positive peaks). Let it be 'x'. Then the time period T is obtained by multiplying 'x' with time per division of the time base.

$$T = \text{'x' division} \times \text{time per division}$$

L and C are measured by a L-C-R meter. The experiment may be repeated for different values of L, C_1 and C_2.

- L in the range of less than ~2 mH preferred.
- C_1 = 0.01μF, 0.02 μF, etc. and C_2 = 0.01μF, 0.02 μF, etc. preferred.
- In order to achieve the Barkhausaen criterion use a variable large resistance (potentiometer of large resistance) in series with the feedback circuit to reduce the gain of the amplifier.

Observation and tabulation

Length of a wave ‘x’ cm	Time per division ‘t’ sec/cm	T= xt sec	$f=\frac{1}{T}$ Hz	Mean f	C_1 µF	C_2 µF	$C=\frac{C_1C_2}{C_1+C_2}$ µF	L mH	$f=\frac{1}{2\pi\sqrt{LC}}$ Hz

Result

The Colpitts oscillator is constructed. The frequency is measured and compared with the calculated frequency.

Exp. No.3.18

Multivibrator- using Transistors

Aim: To construct an astable multivibrator using a bipolar junction transistor and measure its frequency.

Components and accessories required: Transistors, resistors, capacitors, power supply, C R O, etc.

Circuit, theory and procedure

Multivibrators are basically two stage amplifiers with positive feedback from the output of one of the amplifiers to the other. These devices are very useful as pulse generating, storing and counting circuits. There are three basic types of multivibrators, (1) *astable multivibrators (free running)*, (2) *monostable multivibrators* and (3) *bistable multivibrators*.

Fig.a shows the circuit of an astable multivibrator. It has no stable state, but has only two quasi-stable states. Fig.b shows the output of such an astable multivibrator.

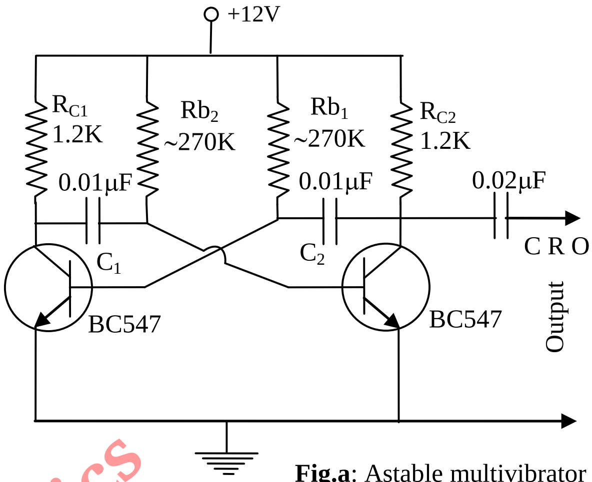


Fig.a: Astable multivibrator

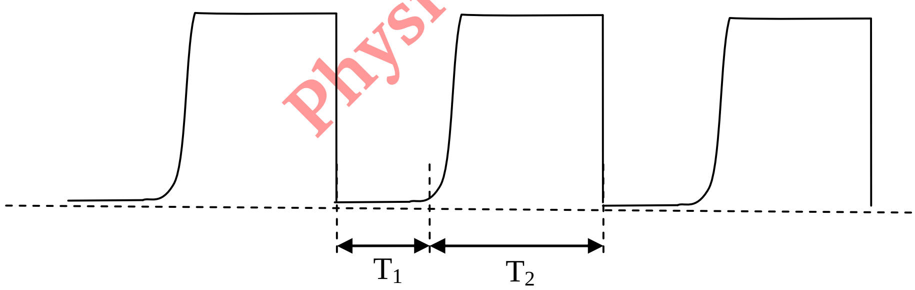


Fig.b: Output of an astable multivibrator

The switching times of the two transistors can be calculated as,

$$T_1 = 0.69R_{b1}C_2$$

$$T_2 = 0.69R_{b2}C_1$$

Hence the time period of the wave is,

$$T = T_1 + T_2 = 0.69\left(R_{b1}C_2 + R_{b2}C_1\right)$$

$$\text{Frequency, } f = \frac{1}{0.69\left(R_{b1}C_2 + R_{b2}C_1\right)}$$

If $R_{b1} = R_{b2} = R$ and $C_1 = C_2 = C$

$$T = 1.38RC$$

$$\text{Frequency, } f = \frac{1}{T} = \frac{0.725}{RC}$$

The circuit is soldered out in a board and the time period is measured using a C R O. Calculate the frequency of the wave. Repeat the experiment for different values of C.

- To ensure oscillations, the β value of the transistors must satisfy the conditions that,

$$\beta_1 \geq \frac{R_{b1}}{R_{c1}} \quad \text{and} \quad \beta_2 \geq \frac{R_{b2}}{R_{c2}}$$

  If $\beta_1 = \beta_2 = \beta$, $R_{b1} = R_{b2} = R_b$ and $R_{c1} = R_{c2} = R_c$, then the condition becomes

$$\beta \geq \frac{R_b}{R_c}$$

  So select R_b and R_c such that the above condition must be satisfied.
- For BC547 transistors R_b = 270 K and R_c = 1.2 K preferred
- Use capacitors C_1 and C_2 in the range of values from 0.02 nF to about 50 nF.

Observation and tabulation

Length of a wave 'x' cm	Time per division 't' sec/cm	T= xt sec	$f = \frac{1}{T}$ Hz	Mean f	R Ω	C F	$f = \frac{0.725}{RC}$ Hz

Result

The multivibrator is constructed. The frequency is measured and compared with the theoretical frequency.

Exp.No.3.24
Characteristics of JFET

Aim: To draw the common source drain characteristics and transfer characteristics of a junction field effect transistor and hence to determine the JFET parameters a c drain resistance r_d, transconductance g_m and the amplification factor μ.

Components and accessories: The JFET (BFW10 or 11), power supplies, voltmeters, milli-ammeter etc.

Circuit, theory and procedure

Field effect transistor is a three terminal unipolar solid state device in which the current is controlled by the field. They are constructed as either n-channel FET or P-channel FET. In n-channel FET two p-type junctions are diffused on opposite sides of a narrow bar of n-type semiconductor. A p-channel FET is constructed by diffusing n-type material on opposite sides of a bar of p-type material.

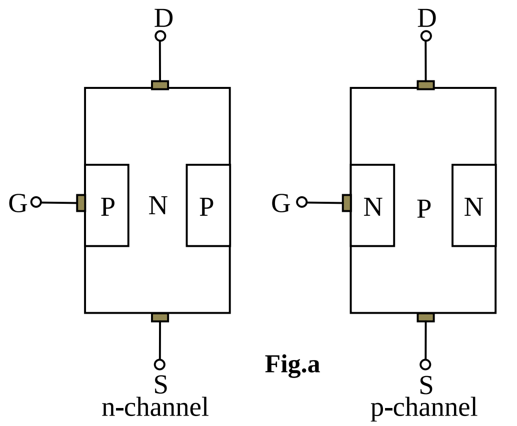


Fig.a

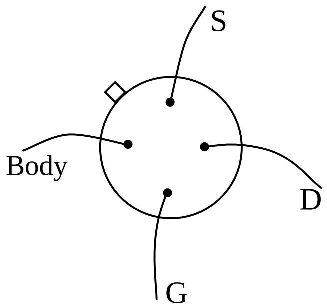


Fig.b: FET with pins upward

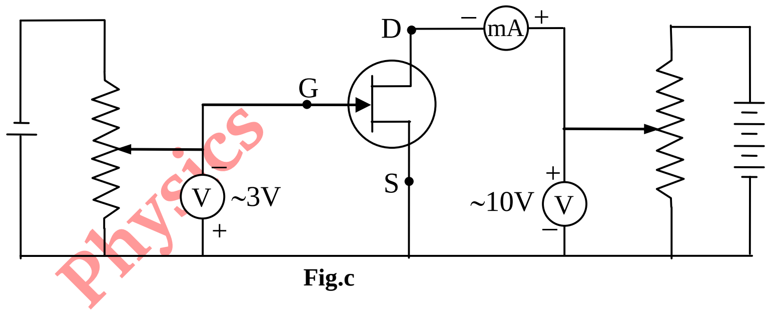


Fig.c

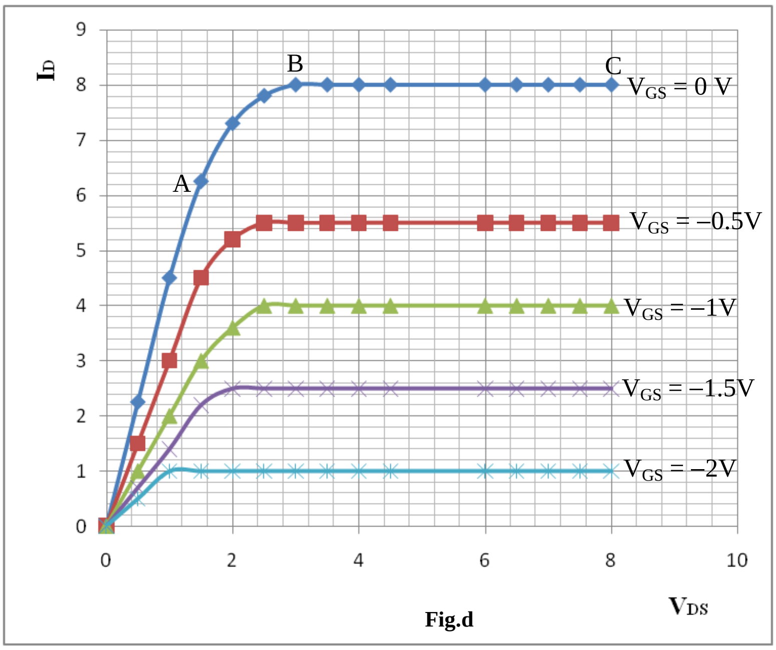


Fig.d

There three terminals connected to FET are *source*, *drain* and *gate*. Source is the terminal through which the majority carriers enter the bar. Drain is the terminal through which the majority carriers leave the bar. Gate is two internally connected heavily doped regions which form two P-N junctions. Gates are always reverse biased. They control the current through the FET. (There is a fourth terminal on a BFW10 or 11 FET. This terminal is connected to the body of the FET.

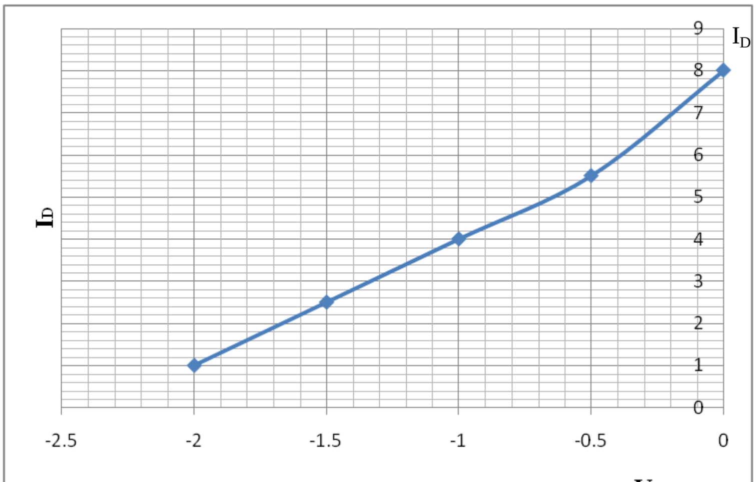


Fig.e

We now draw two characteristics of a JFET. They are *static characteristics* or *common source characteristics* or *drain characteristics* and *transfer characteristics*. The common source characteristics is the graph between drain current I_D and drain-source voltage V_{DS} for constant gate-source voltage V_{GS}. We can draw a family of curves for different gate-source voltages as shown in fig.d.

The region OA of the graph is called the ohmic region in which the current is proportional to the voltage V_{DS}. In the curve region AB the current changes at inverse square law rate. The point B is called the *pinch-off point*. The voltage corresponding to it is called the pinch-off voltage and is denoted as V_{PO}. The region BC is called the *pinch-off region* (C is the point at which the current again increases sharply nearly 20 V, which is not shown in the graph) or *saturation region* or *amplifier region*.

Transfer characteristics is the graph between the drain current I_D and the gate-source voltage V_{GS} as shown in fig.e. The transfer characteristic is obtained from the drain characteristics. For a constant V_{DS} we get different values of I_D corresponding to different values of V_{GS}.

To do the experiment, connections are made as shown in the fig.c. Keep V_{GS} constant, say zero and measure the drain current I_D for different V_{DS}. A graph is drawn between I_D and V_{DS}. Repeat the experiment for different negative voltages for gate and the family of curves is drawn on the same graph paper.

From the drain characteristics (or from the same observations for drain characteristics) we get I_D for different V_{GS}. Draw the graph between I_D and V_{GS}.

To find the FET parameters r_d, g_m and μ: The FET parameters are *a c drain resistance* r_d, *Transconductance* g_m, and the *Amplification factor* μ. They are defined as follows.

When JFET is operating in the pinch off region,

$$a\,c\text{ drain resistance } r_d = \left(\frac{\Delta V_{DS}}{\Delta I_D}\right)_{V_{GS}}$$

It is the slope of the drain characteristics in the pinch-off region.

$$\text{Transconductance } g_m, = \left(\frac{\Delta I_D}{\Delta V_{GS}}\right)_{V_{DS}}$$

It is the slope of the transfer characteristic. Its unit is siemen.

Amplification factor $\mu = \left(\frac{\Delta V_{DS}}{\Delta V_{GS}}\right)_{I_D}$

It can be proved that, $\mu = r_d \times g_m$

- Pins near the projection are either source or body. Using multi-meter check the continuity of pin connected to the body and identifies it. Then the other one is source. In the clockwise direction drain and gate.
- Practically we can find out the FET parameters near the pinch-off region (curved region AB).

Observation and tabulation

To draw drain characteristics

V_{DS} volt	Drain current I_D in mA for V_{GS} =				
	0 V	0.5 V	1 V	1.5 V	2 V
0					
0.5					
1					
1.5					
2					
2.5					
3					
3.5					
4					
4.5					
5					
5.5					
6					
6.5					
7					
7.5					
8					

To draw transfer characteristic

Constant V_{DS} volt	Drain current I_D in mA for V_{GS} =				
	0 V	0.5 V	1 V	1.5 V	2 V

Result

The characteristics of FET are drawn and the FET parameters are determined.

Drain resistance r_d = ……… ohm

Transconductance, g_m = ……… mho

Amplification factor, μ = ………

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