Department of Physics
Karnatak Science College
Dharwad

Lab Manual

BSc IV semester

NEP

List of Experiments

1. **Thermal conductivity of a bad conductor by Lee's method.**
2. **Single stage RC coupled CE amplifier**
3. **Thevenin's and Norton's theorem using unbalanced Wheatstone network.**
4. **Power supply using π- section filter and study of IC regulator 78XX**
5. **Astable multivibrator using IC 555.**
6. **Op-Amp as Inverting and non-inverting amplifier**
7. **Hartley and Colpitts oscillator using BJT**
8. **Phase shift Oscillator using OP-Amp**
9. **Thermal conductivity of copper by Searle's apparatus**
10. **Op-amp as Adder and Subtractor.**

1.Thermal conductivity of a bad conductor by Lee's method.

Aim: Determine the Thermal conductivity of a given bad conductor by Lee's Method.

Given: Specific heat of the disc (S)= 0.1cal/gm/c= 370Jkg^{-1}K^{-1}.

Apparatus: Lee's apparatus, bad conductor, two thermometers, micrometer screwguage, Vernier calipers, etc.

Theory: The bad conductor B is placed between the disc DE and the base of the cylinder C. steam is passed through C. When steady state is reached i.e. the thermometers T_1 and T_2 show steady temperatures θ_1 and θ_2, all the heat transmitted across the specimen is received by the disc DE and is radiated from its exposed surface. The amount of heat conducted through the bad conductor per second is

$$\frac{Q}{t} = KA\frac{(\theta_1-\theta_2)}{d} \qquad \text{------------- (1)}$$

Where d= thickness, A= area and K= thermal conductivity of bad conductor

Heat lost per second from DE is $= MS\left(\frac{d\theta}{dt}\right)_{\theta_2}$ ....(2)

where $\left(\frac{d\theta}{dt}\right)_{\theta_2}$ Is rate of cooling at θ_2, M = mass of the disc DE, S = specific heat of its material,

The rate of cooling is obtained from the cooling curve. For this the disc DE is heated to a temperature about 10^o C above θ_2 and is then allowed to cool to about 10^o C below θ_2. However in this case heat is lost from top, bottom h is the sides of DE i.e. the area of the exposed surface = $2\pi r^2 + 2\pi rh$

Where h is the height of the disc DE. In the experiment the top face of DE is not exposed, i.e. the area exposed during experiment = $\pi r^2+2\pi rh$. We may assume that the rate of cooling is proportional to the area of the exposed surface.

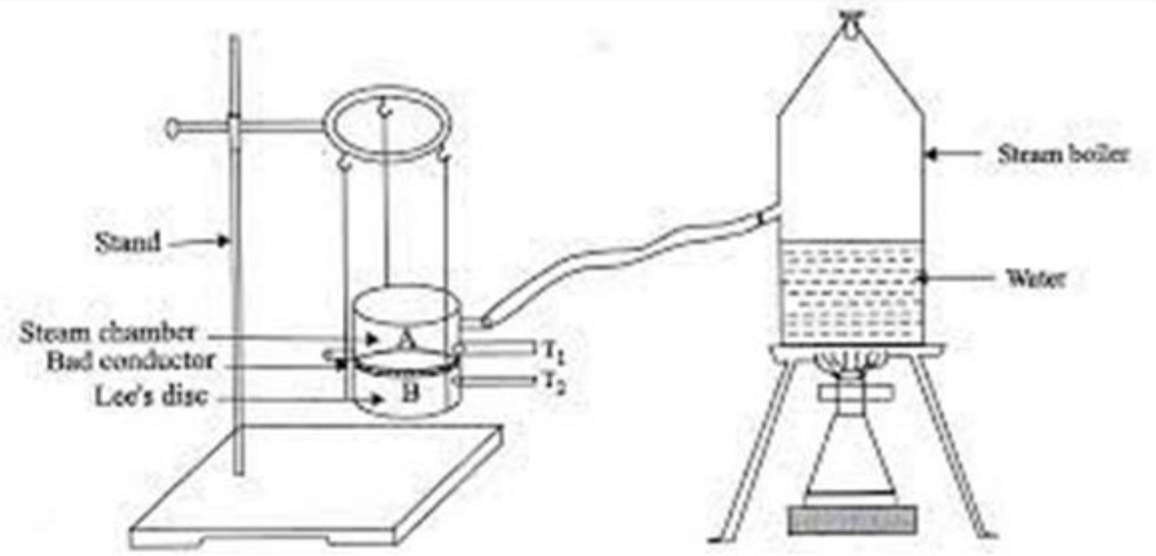
Then the rate of cooling during experiment = $\frac{\pi r^2+2\pi rh}{2\pi r^2+2\pi rh}\left(\frac{d\theta}{dt}\right)_{\theta_2} = \frac{r+2h}{2(r+h)}\left(\frac{d\theta}{dt}\right)_{\theta_2}$

Hence heat lost per sec from DE is = $MS\frac{(r+2h)}{2\,(r+h)}\left(\frac{d\theta}{dt}\right)_{\theta_2}$ .... (3)

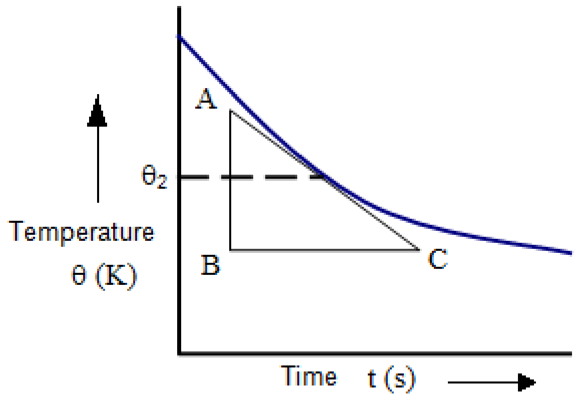
Equating the expressions on RHS of (1) and (3), and solving for κ. we have

$$\kappa = \frac{d}{2A}\frac{(r+2h)}{(r+h)}\frac{MS}{(\theta_1-\theta_2)}\left(\frac{d\theta}{dt}\right)_{\theta_2} \qquad \text{........................... (4)}$$

DIAGRAM:



GRAPH:



OBSERVATIONS:

1. Specific heat of the material of the disc= S= 370 $Jkg^{-1}K^{-1}$.

2. Room temperature = t = _____^oC = _______K

3. Thickness of the bad conductor d

i) _____________ ii) ___________ iii) ____________

Mean d = _______cm = _______m

4. Diameter of the disc 2r = i) _____________ ii) ___________ iii) ____________

Mean 2r = _______ cm = _______m

r = _______ cm = _______m

5. Mass of the lower disc M = _______ g = _______kg.

6. Height of the lower disc h = _______cm = _______m

7. Steady temperature of the cylinder Θ_1 = _______^{o}C = __________K

8. Steady temperature of the disc Θ_2 = _______^{o}C = __________K

OBSERVATIONS FOR COOLING CURVE

No of obs	Time t (min)	Temperature θ (K)
1	0	
2	2	
3	4	
	6	
	8	

RESULTS:

Thermal conductivity κ = ___________J s^{-1} $m^{-1}K^{-1}$

Procedure:

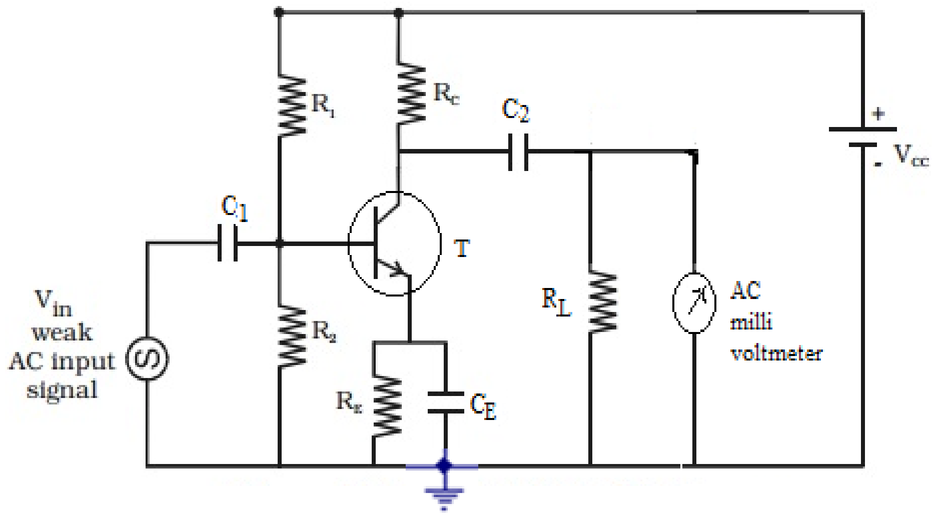
1. Place the bad conductor between steam chamber and lower disk.
2. Insert the two thermometers into the holes drilled on the steam chamber and lower disk.
3. Hang hole the apparatus by rigid support provided with three hooks.
4. Pass the steam until the thermometers show steady temperature, note down the steady temperature.
5. Now remove the bad conductor and allow the steam to pass so that rise in temperature will be 10 to 15 ^{o}C more than the steady temperature of the lower disc.
6. Remove the steam chamber and place the bad conductor on the lower disc and soon start noting the temperature and time intervals of cooling. In this process lower disc is allowed to cool and readings should be at least 10 ^{o}C over and 10 ^{o}C below the steady temperature Θ_2.
7. Plot the cooling curve and determine the slope of the curve at and hence the rating of cooling $\frac{d\theta}{dt}$.
8. Using the values from the tabular column coefficient of thermal conductivity of the rubber can be calculated.

2. RC coupled CE Amplifier

AIM: Set up R.C. coupled CE Transistor amplifier. Draw the Frequency response curve and obtain band width.

APPARATUS: working board, Transistor (BC-547), capacitors, resistors, power supply, signal generator, AC millivoltmeter etc.

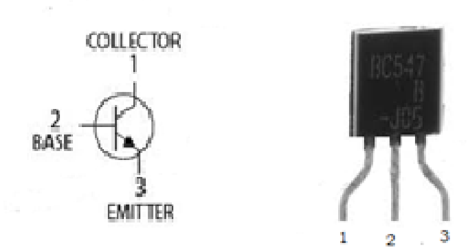
CIRCUIT DIAGRAM:



V_{in}-Signal generator	V_{cc} = 9V Power supply	R_1=47 KΩ pot
T - Transistor BC547	R_C=2.2 KΩ	R_2=5.6 KΩ
C_E = 22 μF	C_1=C_2 = 22 μF	R_L=12 KΩ
V_{out} = AC millivoltmeter	R_e=1 KΩ	

Pin Configuration

BC 547 NPN Transistor



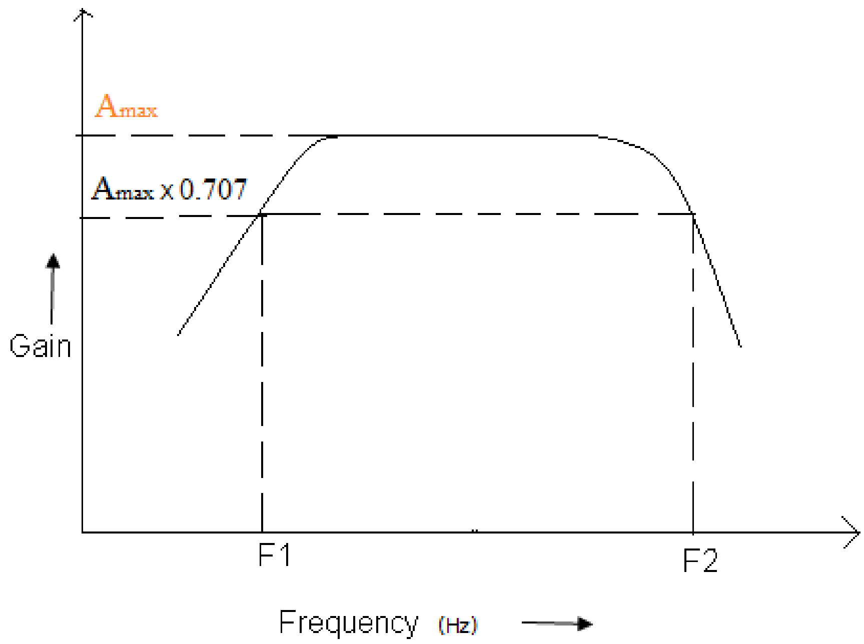
OBSERVATIONS:

1. DC condition: Adjust $V_{CE} = \frac{V_{cc}}{2}$

2. Input voltage (V) = 20 mV kept constant for all frequencies of input signal.

SI.NO	Frequency (Hz)	Output voltage V_o volts	Gain = V_o/V_{in}
1	50		
2	100		
3	200		
4			
5			
6	-		
-	-		

NATURE OF GRAPH:



RESULT:

1) Mid band gain A_{max} = _________
2) Lower half Frequency F1 = ______Hz
3) Upper half frequency F2 = ______Hz
4) Band width = F2 – F1 = _______Hz

Theory:

An amplifier is an electronic device that increases the voltage, current, or power of a signal. Amplifiers are used in wireless communications and broadcasting, and in audio equipment of all kinds. For any amplifier, the transistor is an essential part of the circuit. Transistor used can be a BJT or a FET. These are classified into various configurations based on their characteristics. Based on desired operating point transistors must be biased. Then the signal is applied as the input to the amplifier and achieved gain at the output.

A transistor in which the emitter terminal is made common for both the input and the output circuit connections is known as common emitter configuration. When this configuration is provided with the supply of the alternating current (AC) and operated in between the both positive and the negative halves of the cycle in order to generate the specific output signal is known as common emitter amplifier.

In this type of configuration the input is applied at the terminal base and the considered output is to be collected across the terminal collector. By keeping emitter terminal is common in both the cases of input as well as output. It should be noted that for using transistor as amplifier, emitter base junction should be forward biased and collector base junction should be reversed biased. These two conditions are to be achieved simultaneously using single power supply only. Hence universal voltage divider bias (VDB) method is used.

Other than this there are various electronic components are to be included in this circuit. One is the resistor R_1 that is the one to make the transistor to function in the forward biasing mode. The R_2 is responsible to make the biasing possible. There is the load resistor and the resistor that is connected at the emitter so that it controls the stability related to thermal issue. The resistors R_1 and R_2 connected across the terminal base as it is the input side. The load resistor is connected at the output side that is across the collector terminal.

C_1 and C_2 are the capacitors placed in the input and output of an amplifier they are used to couple one circuit with another hence they are called as coupling capacitors. The capacitor C_1 is at the input side and the capacitor C_2 is connected across the emitter resistor. The C_1 capacitor is responsible to separate the value of the AC signals from that of DC signals. There exists the inverse relation between the R_1 resistor and the biasing. As R_2 tends to increase the biasing tends to increase and vice-versa. Hence to the smaller or the weaker signals that are applied to the base gets amplified at the obtained output signals. Hence this is the reason it is known as CE amplifier.

The capacitor C_E is known as bypass capacitor which is used to bypass the AC signal to ground. It is very helpful because any noise signal that may be present in AC signal will be passed out from bypass capacitor.

The resistances R_1 and R_2 are placed to control base current I_B and hence provide required collector current I_C and collector to emitter voltage V_{CE} as per the Quiescent point Q (operating point) that provides the required biasing to the transistor hence they are known as biasing resistors.

The resistance R_C is a collector load placed in the collector terminal in order produce faithful amplification. The resistance R_E resistor is placed in the emitter terminal of a transistor, and it is useful to control the gain of an amplifier.

Voltage Gain

The ratio of the output voltage generated when the input voltage is applied decides the voltage gain of the common emitter amplifier. Here the load resistance is the resistor connected across the collector. The ratio in between the output current to the applied input current gives the current gain. This is denoted as beta. In this way the values of the voltage gain and the current gain are calculated for this amplifier configuration.

Characteristics

The characteristics of the common emitter configuration amplifier configuration are as follows

1. The voltage gain value obtained for the common emitter amplifier is medium.
2. It also consists of the current gain in the medium range.
3. Because of both the voltage and the current gains the power gain value of this configuration is referred to be high.
4. There is some resistance value at the inputs as well as the output but in this configuration it is maintained at the medium value.
5. Amplifier in this mode of operation introduces 80 degree shift of the phase difference between input signal and output signal.
6. In this mode there is large bandwidth.

All these characteristics of the common emitter configuration make it most widely used amplifier among all the three configurations. As the applied input signal V_i increases, base current I_B increases above the biased value thereby increasing collector current I_C by beta (β) times above the operating value which increases the voltage at the collector resulting in decreasing the output voltage. This output is mathematically represented by the equation

$$V_o = V_{cc} - I_c R_c$$

This explains the 180^o phase difference between input and output signals

Applications

The applications of this CE amplifier are as follows

1. These amplifiers are preferably used as the current amplifier than a voltage amplifier as it has more current gain than the voltage gain.
2. In the radio frequency circuitry this configuration is preferred.
3. For the lower values of noise and its amplification this configuration is preferred.
4. In order to construct the sinusoidal oscillators (such as Hartley, Colpitts, Phase shift oscillator) CE amplifier is used.

Relevant Viva Questions:

1) What is an amplifier used for?
2) What is a Common Emitter Amplifier?
3) What kind of bias is preferable in designing Common Emitter Amplifiers?
4) What is phase relation between the input and output?
5) How do you bias the BJT for amplifier application?
6) What is voltage gain, Current gain and power gain?
7) What is band width?
8) What is meant by gain band width?
9) What are applications of CE amplifier?
10) Describe the working of CE amplifier in brief.

THEVENIN'S AND NORTON'S THEOREM

AIM: To verify Thevenin's and Norton's theorems for unbalanced Wheatstone's Bridge Network. Compare and calculate value of Thevenin's impedance and Norton's impedance with respect to measured values.

APPARATUS: Power supply, resistance box, resistors, DC voltmeter, Ammeter, connecting wires, etc.

Analytical Verification:

1. **Thevenin Voltage, E_{th}:**

Open Circuit voltage between b & d:

$$E_{th} = V_{bd} = V_{bc} - V_{cd} = \left[\frac{ER_4}{R_3 + R_4} - \frac{ER_2}{R_1 + R_2}\right] = \text{......volts}$$

2. **Thevenin resistance, R_{th} is equal to Norton's resistance R_N:**

$$R_{th} = R_N = \left[\frac{R_1R_2}{R_1 + R_2} + \frac{R_3R_4}{R_3 + R_4}\right] = \_\_\_\_\_\_\_\_\_\_ \Omega$$

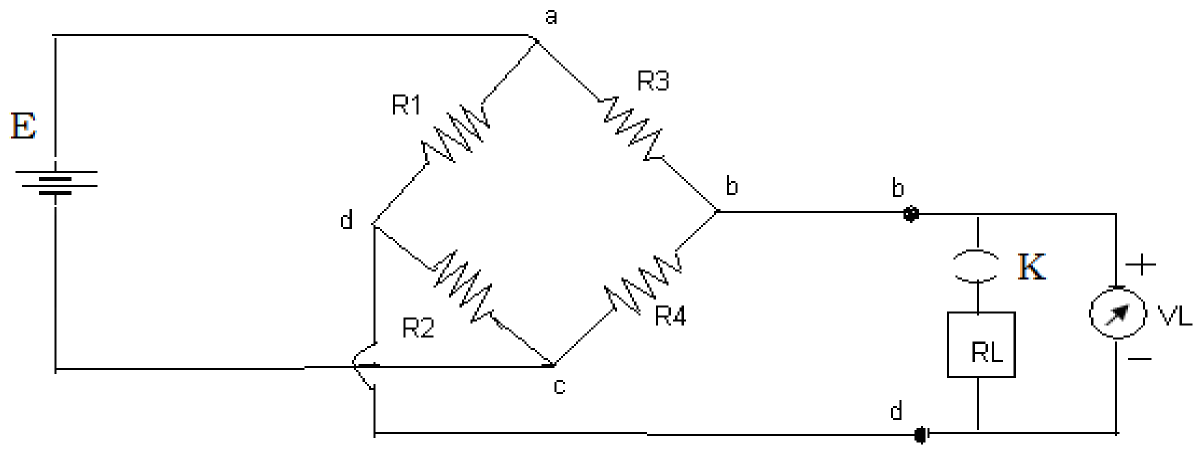
3. **Norton's current, I_N:**

$$I_N = \frac{E(R_1R_4 - R_2R_3)}{[R_1R_2(R_3 + R_4) + R_3R_4(R_1 + R_2)]} = \_\_\_\_\_\_\_\_\_\_ mA$$

Part - I: Thevenin's Theorem:

Experimental verification:

CIRCUIT DIAGRAM:



E = 5 V $\quad$ V_L = (0-20V) $\quad$ R_L - Resistance box

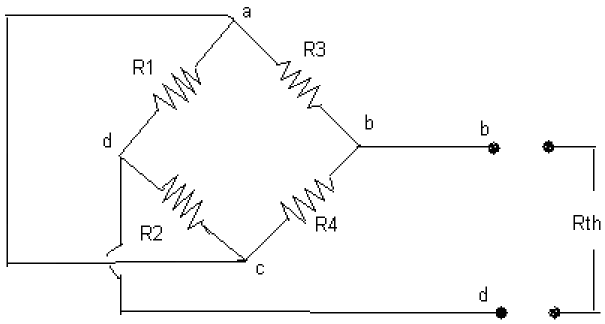
R1=100 Ω $\quad$ R2 =150 Ω $\quad$ R3 =120 Ω $\quad$ R4 = 330 Ω.

Here $\frac{R_1}{R_2} \neq \frac{R_3}{R_4}$; hence the bridge is unbalanced

THEVENIN'S AND NORTON'S THEOREM

Observations;

1. Input Voltage , E = 5 V
2. Open voltage between b & d = $V_{bd} = E_{th}$ =________V
3. Resistance Measured between b & d = R_{th} =_______Ω

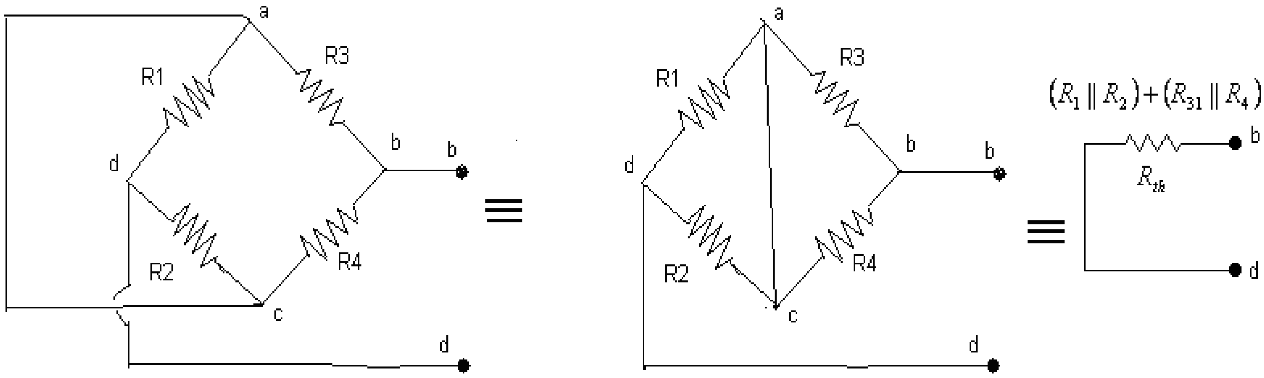


Experimentally measured values		**Experimentally determined R_{th}** By different load method			**Theoretically calculated**	
E_{th} (V) when $R_L = \infty$	R_{th} in Ω by half deflection method i.e. value of R_L when $V_L = \frac{E_{th}}{2}$	Load resistance R_L (Ω)	Voltage across Load V_L (V)	Thevenin's resistance $R_{th} = \left(\frac{E_{th} - V_L}{V_L}\right) R_L$ (Ω)	E_{th} (V)	R_{th} (Ω)
		50				
		100				
		200				
		300				
		400				
		500				
		600				
		700				
		800				
		900				
		1000				

Mean R_{th} = ____________Ω

Thevenin resistance, R_{th}:

Short circuiting E, the given bridge network reduces that can be simplified as follows:

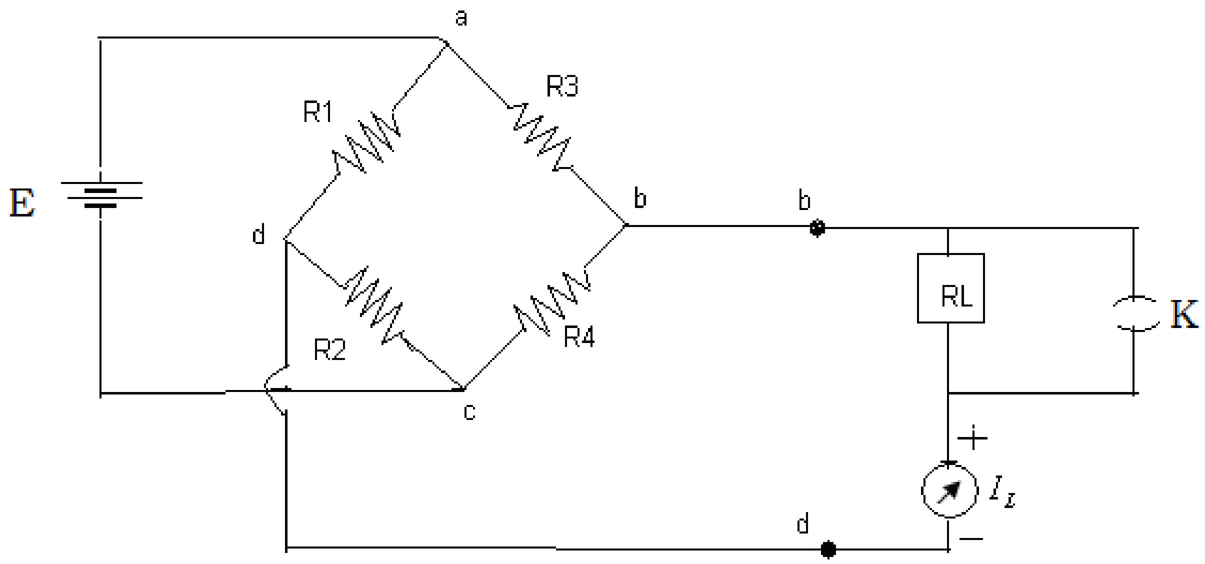


$$R_{th} = \left[\frac{R_1R_2}{R_1+R_2} + \frac{R_3R_4}{R_3+R_4}\right] = \_\_\_\_\_\_\_\_\_\_\_\_\Omega$$

PART II: NORTON'S THEOREM

Experimental verification:

CIRCUIT DIAGRAM:



E = 5 V I_L – (0-20 mA) R_L - Resistance box

R1=100 Ω R2=150Ω R3=120 Ω R4=330Ω.

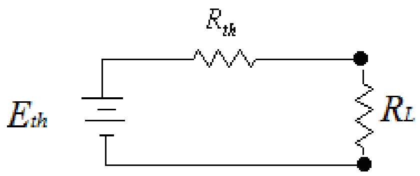
THEVENIN'S AND NORTON'S THEOREM

Experimentally measured values		**Experimentally determined R_N** By different load method			**Theoretically calculated**	
I_N (mA) when $R_L=0$	R_N in Ω by half deflection method i.e. value of R_L when $I_L = \frac{I_N}{2}$	Load resistance R_L (Ω)	Load current I_L (mA)	Norton's resistance $R_N = \frac{I_L R_L}{I_N - I_L}$ (Ω)	I_N (mA)	R_{th} (Ω)
		50				
		100				
		200				
		300				
		400				
		500				
		600				
		700				
		800				
		900				
		1000				

Mean R_N =____________Ω

Thevenin's equivalent circuit:

The Thevenin's equivalent circuit consists of the Thevenin voltage E_{th} in series with Thevenin resistance R_{th}.

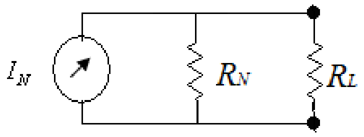


R_{th} = ____________ Ω

E_{th} = ____________ V

Norton's equivalent circuit

The Norton equivalent circuit consist of Norton current source, I_N in parallel with Norton's resistance R_N.



Where

I_N = __________ mA

Results:

	Experimentally Observed Values	**Calculated Values**
R_{th}		
E_{th}		
I_N		

AIM: Set up a Power supply using π- section filter study the variations of output voltage with load current hence determine the Percentage regulation and internal resistance. Also study the performance of IC regulator 78XX in the circuit and compare the performance of both regulated and unregulated power supply.

APPARATUS: Working board, Bridge rectifier, step down transformer, capacitors, inductor, resistors, rheostat (more than 1KΩ), regulator IC 78XX**,** DMM, plug key, connecting wires, etc.

FORMULAE:

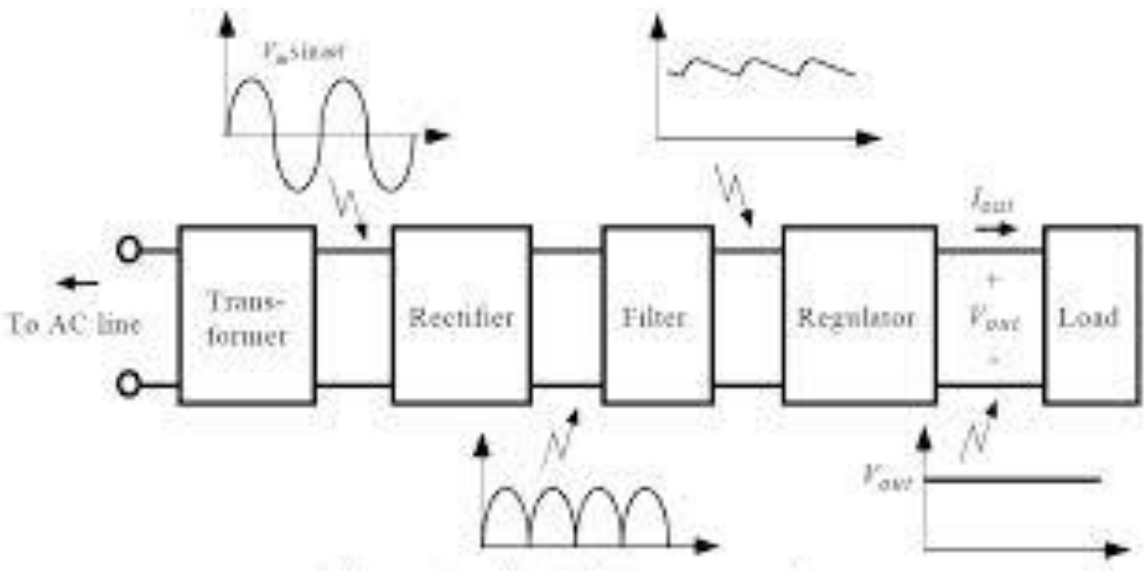
Percentage Regulation is given by

$$\frac{V_{NL} - V_{FL}}{V_{NL}} \times 100 \quad = \_\_\_\_\_ \%$$

Internal resistance is given by

$$R_i = \frac{V_{NL} - V_{FL}}{I_{L(\max)}} = \_\_\_\_\_ \ \Omega$$

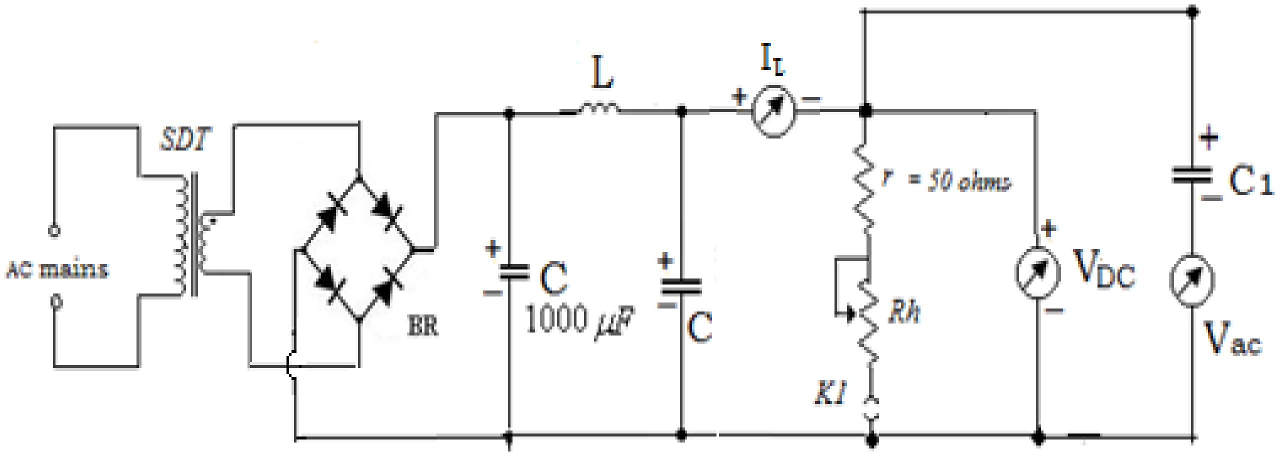
BLOCK DIAGRAM OF REGULATED POWER SPPLY



Components of a typical linear power supply

UNREGULATED POWER SUPPLY

CIRCUIT DIAGRAM:

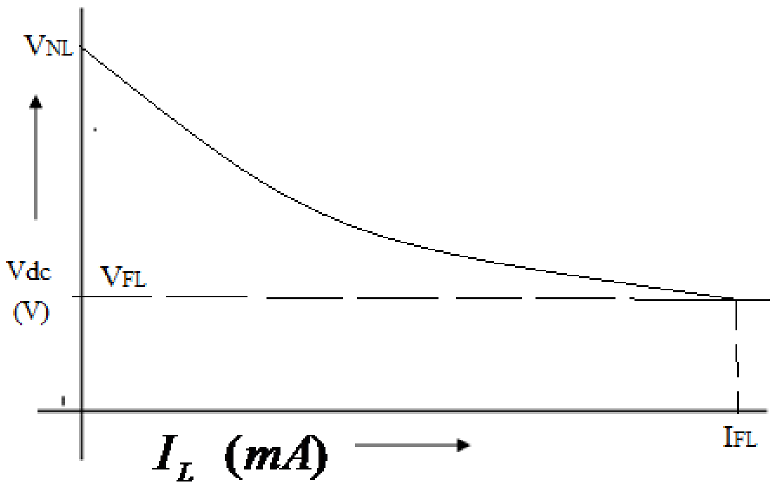


SDT-step down transformer, D1, D2, D3, D4 – diodes of Bridge rectifier

I_L = (0 - 200 mA), C – electrolyte capacitors of 1000μF, V_{DC} = (0 – 20 V)

V_{ac} = (0 - 2V), Rh – rheostat of more than 1KΩ, r = 50 Ω, C1 = 100μF

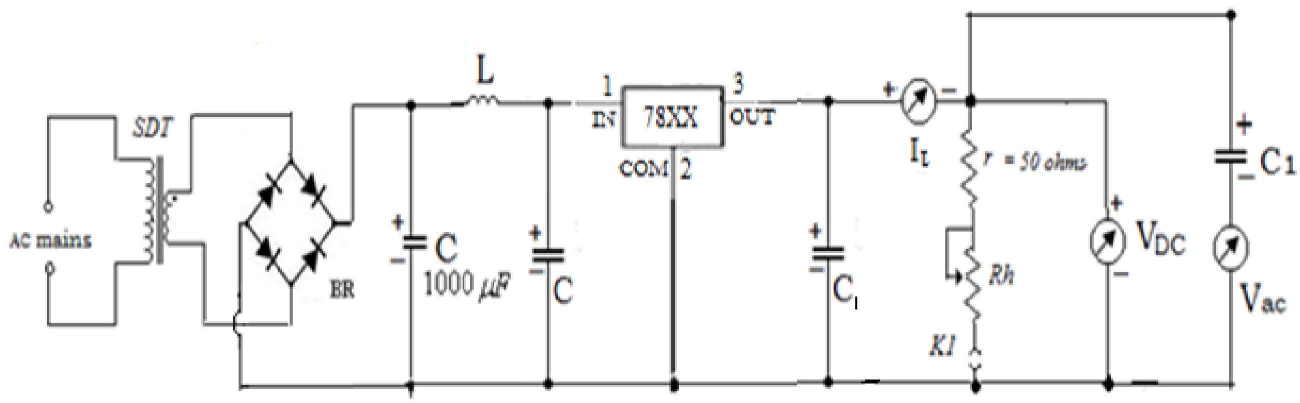
NATURE OF THE GRAPH:



OBSERVATIONS :

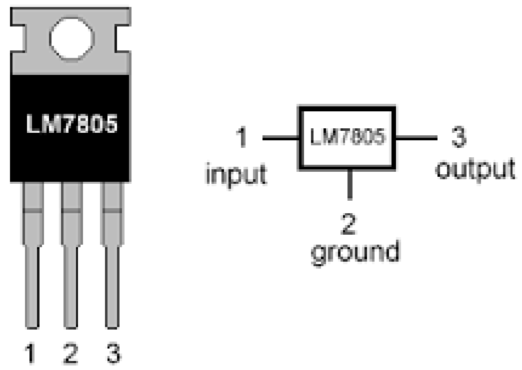
Sl. No.	Load current I_L (mA)	Load voltage V_L (volt)	V_{ac} (volts)	$\gamma = \frac{V_{ac}}{V_{DC}}$
1	I_L = 0	V_{NL} =		
2	5			
3	10			
	I_{FL}	V_{FL}		

REGULATED POWER SUPPLY
CIRCUIT DIAGRAM:

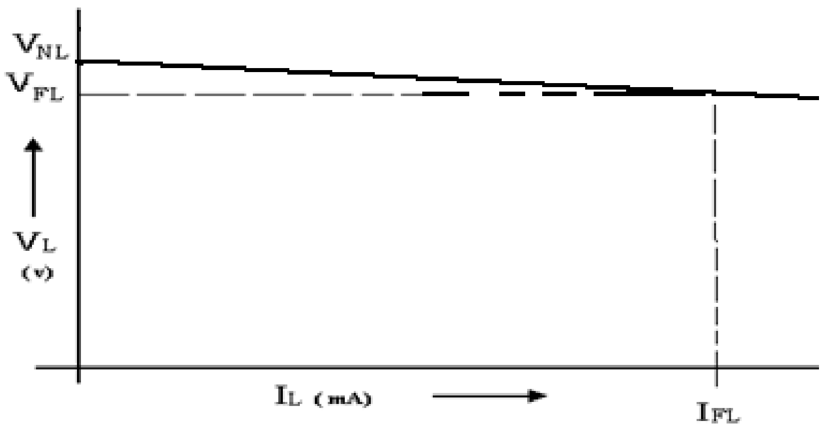


SDT- step down transformer (0-9V)
BR – Bridge rectifier (IC containing diode bridge)
C, C_1- electrolytic capacitors (C =1000μF, C_1 = 100 μF).
L - Inductor
R_h – Rheostat.
K- plug key.
I_L & V_L -- DMM.
Regulator IC-78XX

Pin configuration of IC – 78XX



NATURE OF THE GRAPH:



OBSERVATIONS :

Sl. No.	Load current I_L (mA)	Load voltage V_L (volt)	V_{ac} (volts)	$\gamma = \frac{V_{ac}}{V_{DC}}$
1	$I_L = 0$	$V_{NL} =$		
2	5			
3	10			
4	15			
5	20			
	I_{FL}	$V_{FL} =$		

Result:

	Unregulated Power Supply	Regulated Power Supply
Percentage regulation (%)		
Internal resistance R_i (Ω)		

Note:

1) In IC 78XX last two digits indicate the positive output voltage. If students are interested, you can repeat this experiment with other 78XX with different V_0, available (7805,7806,7809,7812,7815, etc).

2) IC 79XX is a negative voltage regulator the last two digits indicate negative output voltage. IC 79XXhass different pin configuration identify the pins and suitably connect. If you want to study 79XX series, same circuit, voltage and currents are negative.

Need for Power Supplies

- Power supplies provide the necessary power, voltage and current requirements for the electronic devices.
- They usually change ac to dc voltage.
- Many small sections present in the electronic devices such as Computer, Television, Cathode ray Oscilloscope etc. But all of those sections doesn't need 230V AC supply which we get.
- Some may need a 12v DC while some others may need a 30v DC.
- In order to provide the required dc voltages, the incoming 230v AC supply has to be converted into pure DC for the usage.
- The process of converting ac to dc is called rectification and is accomplished with the help of a transformer, a rectifier, a filter, a voltage regulator and a potential divider.

There are 2 types of power supplies

1. **Unregulated Power supply**
   DC terminal voltage is affected by the amount of load i.e the terminal voltage reduces as the load draws more current.
2. **Regulated Power supply**
   In this the terminal voltage remains almost constant regardless of the amount of current drawn from it.

A typical Power supply unit consists of the following.

- **Transformer** − The job of a transformer is to step up or step down the 230v AC power supply to suit the requirement of the device. It provides isolation from the supply line.
- **Rectifier** − A Rectifier circuit convert the AC components present in the signal to DC components. The output of a rectifier is called pulsating DC
- **Filter** − A filtering circuit to smoothen the variations present in the rectified output i.e. it removes the pulsations or ripples present in the output of rectifier.
- **Regulator** − A voltage regulator circuit in order to control the voltage to a desired output level. i.e. it keeps the terminal voltage constant even when
  - Ac input to the transformer varies
  - Load varies
- **Load/Voltage divider**− provides different DC voltages needed by different electronic circuits. It eliminates the necessity of providing separate dc power supplies to different devices working at different levels

Advantages of IC voltage regulators

- The IC voltage regulator is conveniently used for local regulation.
- It is easy to use.
- It is most efficient and reliable.
- It is versatile.
- It is very cheap due to mass production and easily available.
- It is compact in size, rugged and light in weight.
- A voltage regulator generates a fixed output voltage of a preset magnitude that remains constant regardless of changes to its input voltage or load conditions.

Voltage regulation is the measure of how well a power transformer can maintain constant secondary voltage given a constant primary voltage and wide variance in load current. The lower the percentage (closer to zero), the more stable the secondary voltage and the better the regulation it will provide.
The purpose of line regulation is to maintain a nearly constant output voltage when the input voltage varies.
The purpose of load regulation is to maintain a nearly constant output voltage when the load varies.

Viva Questions:

1. What is the need of regulated power supply?
2. Which diode is used to convert AC to DC?
3. How does a power supply work?
4. What is the principle of rectifier?
5. Name the basic types of rectifiers?
6. What is the difference between Half Wave and Full Wave Rectifier?
7. What is efficiency of a rectifier?
8. Why filter is used in rectifier?
9. Which filter is best for rectifier?
10. Define ripple as referred to in a rectifier circuit.
11. What is meant by voltage regulation of a dc power supply?
12. Why is it necessary to include voltage stabilizer in a power supply?

ASTABLE MULTIVIBRATOR

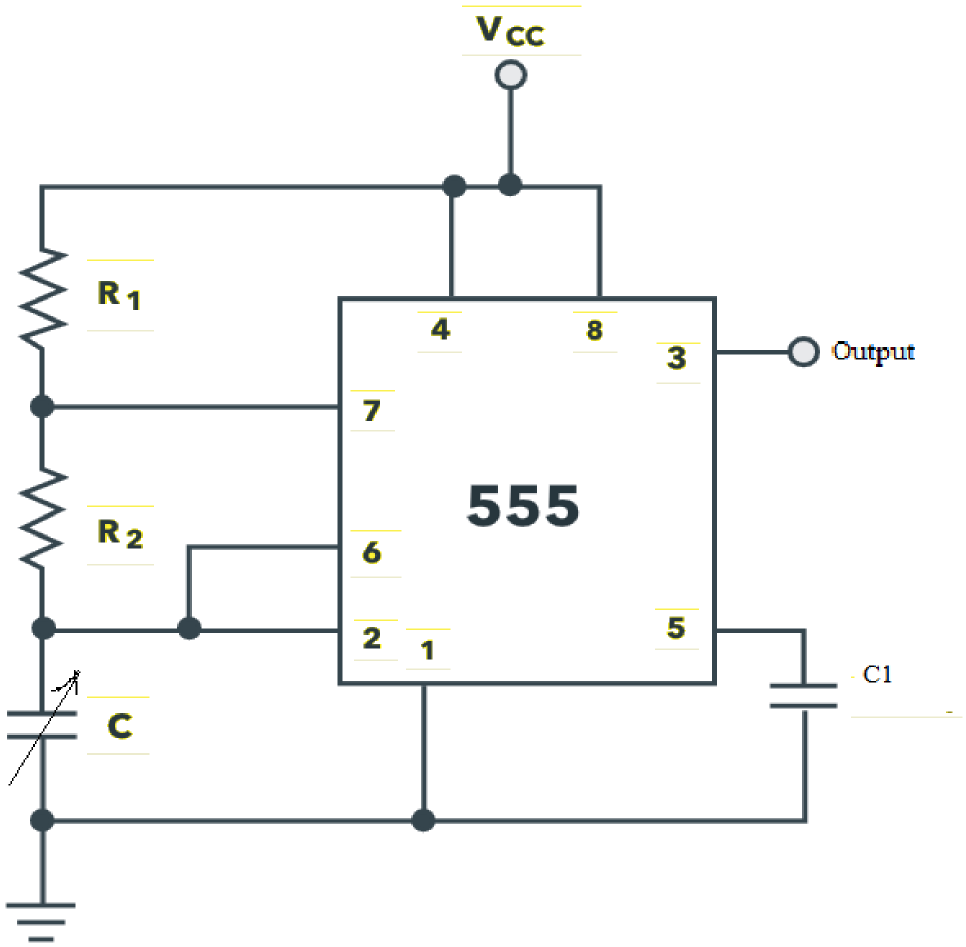
AIM: Set up astable multivibrator using IC 555 timer and measure the frequency of oscillation for different values of resistors/capacitors. Compare the results with theoretical values.

APPARATUS: CRO, Power supply, resistors, capacitors, IC 555, connecting wires etc.

FORMULA:

1. Frequency of multi vibrator calculated = $F = \dfrac{1.44}{(R_1 + 2R_2)C}$ Hz
2. Frequency of multi vibrator obtained = $F = \dfrac{1}{T}$ Hz
3. Duty Cycle calculated $D = \dfrac{R_1 + R_2}{R_1 + 2R_2} \times 100$ %
4. Duty Cycle measured $D = \dfrac{T_{ON}}{T} \times 100$ %

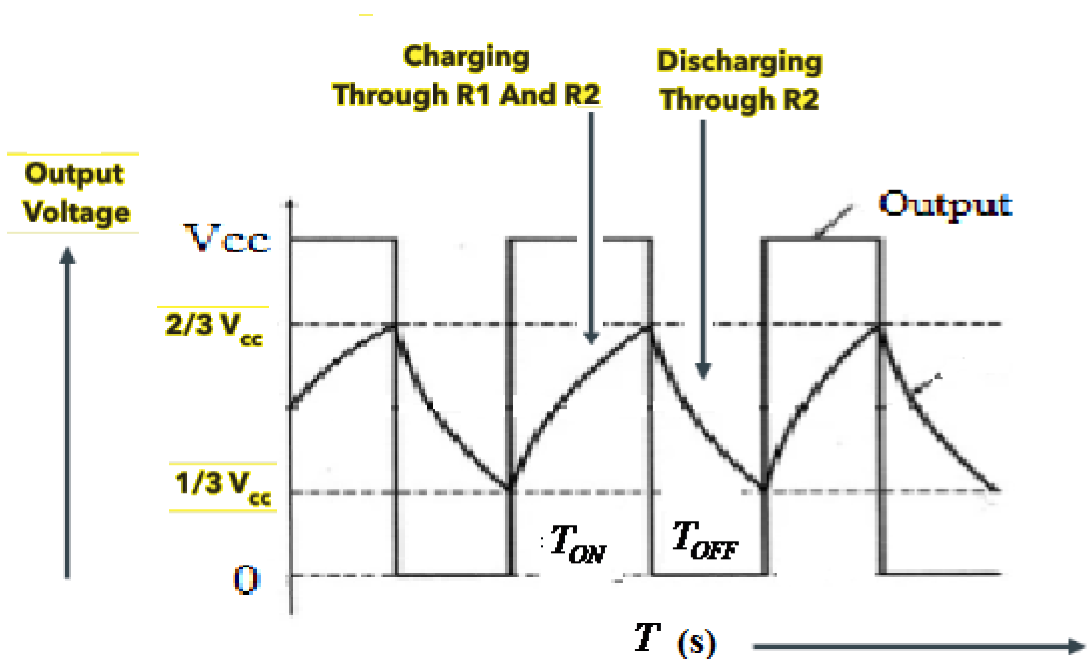
CIRCUIT DIAGRAM:



R_1 = 5.6 KΩ, R_2 = 3.3 KΩ, C_1 = 0.01μF, C = Variable Capacitor, V_{cc} = 6 V

ASTABLE MULTIVIBRATOR

NATURE OF GRAPH:



$$T = T_{ON} + T_{OFF}$$

TABULATION

Sl.No.	C (μF)	No. of div covered for two consecutive peaks λ (div)	Time base scale t (ms/div)	Time period T = λ × t (ms)	Measured Frequency $F = \frac{1}{T}$ (Hz)	Calculated Frequency $F = \frac{1.44}{(R_1 + 2R_2)C}$ (Hz)

Keep C = __________ μF constant

R_1 (KΩ)	R_2 (KΩ)	T_{ON} (ms)	T (ms)	$D = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100 \ \%$	$D = \frac{T_{ON}}{T} \times 100 \ \%$

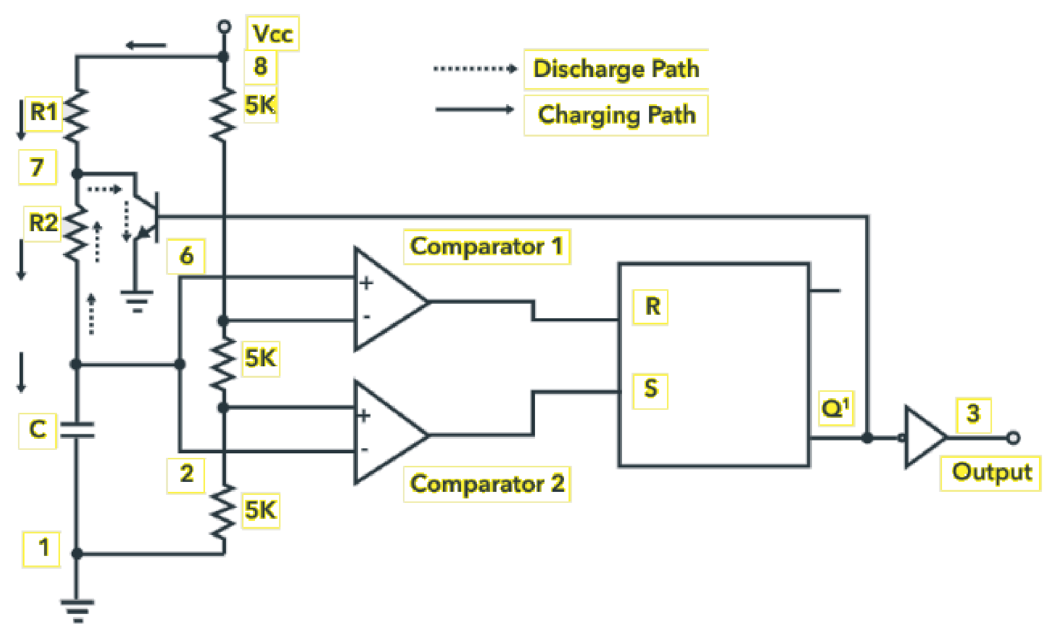
Result: The observed frequencies are in close agreement with the theoretically calculated frequencies.

ASTABLE MULTIVIBRATOR

Theory:

The versatile 555 Timer IC can be used in a variety of circuits like Time Delays, Oscillation, Pulse Generation, Pulse Width Modulation etc. In this tutorial, we will learn about the Astable Multivibrator Mode of 555 Timer IC. We will learn the circuit of Astable Multivibrator using 555 Timer IC, its operation, calculate the duty cycle and also take a look at few important applications of Astable Mode of 555 Timer IC.

Internal Circuit Of 555 Timer With Astable Mode



Astable multivibrator is also called as Free Running Multivibrator. It has no stable states and continuously switches between the two states without application of any external trigger. The IC 555 can be made to work as an astable multivibrator with the addition of three external components: two resistors (R_1 and R_2) and a capacitor (C). The schematic of the IC 555 as an astable multivibrator along with the three external components is shown below.

The pins 2 and 6 are connected and hence there is no need for an external trigger pulse. It will self trigger and act as a free running multivibrator (oscillator). The rest of the connections are as follows: pin 8 is connected to supply voltage (V_{CC}). Pin 3 is the output terminal and hence the output is available at this pin. Pin 4 is the external reset pin. A momentary low on this pin will reset the timer. Hence, when not in use, pin 4 is usually tied to V_{CC}.

The control voltage applied at pin 5 will change the threshold voltage level. But for normal use, pin 5 is connected to ground via a capacitor (usually 0.01μF), so the external noise from the terminal is filtered out. Pin 1 is ground terminal. The timing circuit that determines the width of the output pulse is made up of R_1, R_2 and C.

Operation: The following schematic depicts the internal circuit of the IC 555 operating in astable mode. The RC timing circuit incorporates R_1, R_2 and C.

Initially, on power-up, the flip-flop is RESET (and hence the output of the timer is low). As a result, the discharge transistor is driven to saturation (as it is connected to Q'). The capacitor C of the timing circuit is connected at Pin 7 of the IC 555 and will discharge through the transistor. The output of the timer at this point is low. The voltage across the capacitor is nothing but the trigger voltage. So, while discharging, if the capacitor voltage becomes less than 1/3 V_{CC}, which is the reference voltage to trigger comparator (comparator 2), the output of the comparator 2 will become high. This will SET the flip-flop and hence the output of the timer at pin 3 goes to HIGH.

This high output will turn OFF the transistor. As a result, the capacitor C starts charging through the resistors R_1 and R_2. Now, the capacitor voltage is same as the threshold voltage (as pin 6 is connected to the capacitor resistor junction). While charging, the capacitor voltage increases exponentially towards V_{CC} and the moment it crosses 2/3 V_{CC}, which is the reference voltage to threshold comparator (comparator 1), its output becomes high.

As a result, the flip-flop is RESET. The output of the timer falls to LOW. This low output will once again turn on the transistor which provides a discharge path to the capacitor. Hence the capacitor C will discharge through the resistor R_2. And hence the cycle continues.

Thus, when the capacitor is charging, the voltage across the capacitor rises exponentially and the output voltage at pin 3 is high. Similarly, when the capacitor is discharging, the voltage across the capacitor falls exponentially and the output voltage at pin 3 is low. The shape of the output waveform is a train of rectangular pulses. The waveforms of capacitor voltage and the output in the astable mode are shown below.

While charging, the capacitor charges through the resistors R_1 and R_2. Therefore the charging time constant is $(R_1 + R_2)$ C as the total resistance in the charging path is $R_1 + R_2$. While discharging, the capacitor discharges through the resistor R_2 only. Hence, the discharge time constant is R_2C.

Duty Cycle

The charging and discharging time constants depends on the values of the resistors R_1 and R_2. Generally, the charging time constant is more than the discharging time constant. Hence the HIGH output remains longer than the LOW output and therefore the output waveform is not symmetric. Duty cycle is the mathematical parameter that forms a relation between the high output and the low output. Duty Cycle is defined as the ratio of time of HIGH output i.e., the ON time to the total time of a cycle. Duty cycle is a measure of asymmetry in the output wave form (T_{ON} is not equal to T_{OFF}).

If T_{ON} is the time for high output and T is the time period of one cycle, then the duty cycle D is given by:

$$D = \frac{T_{ON}}{T} \times 100 \ \%$$

AIM: Set up Op-amp (IC – 741) as Inverting amplifier and Non-inverting amplifier and study the following. (i) Determine the gain for AC/DC input voltage (ii) Sketch the output waveforms for AC input using CRO and compare the output voltage with the theoretical one.

Components used: Op-amp (IC – 741), dual power supply, resistors, regulated power supply, signal generator, CRO, DMM, connecting wires, etc.

Formula:

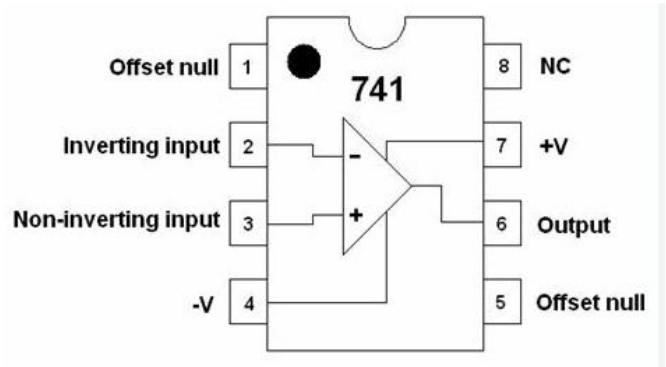
1. Design for inverting amplifier

The expression for gain is $V_o = -\frac{R_f}{R_1} V_{in}$

2. Design for non- inverting amplifier

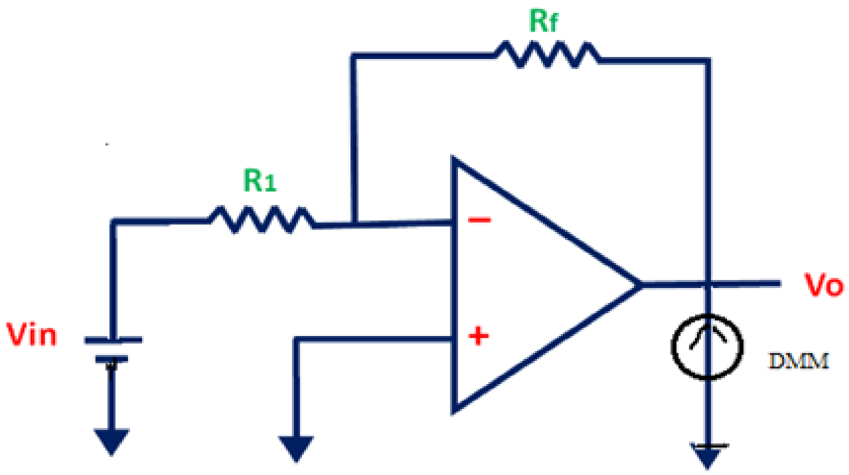
The expression for gain is $V_o = \left(1 + \frac{R_f}{R_1}\right) V_{in}$

PIN CONFIGURATION OF IC-741 OP AMP



Circuit Diagram for Inverting amplifier

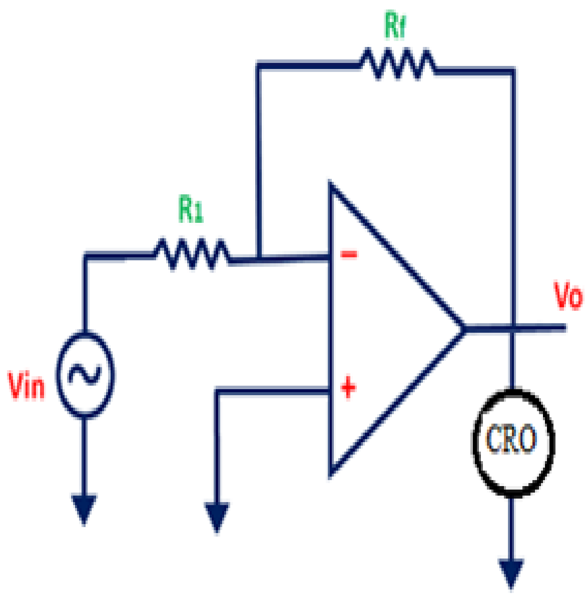
i) For DC Measurements:

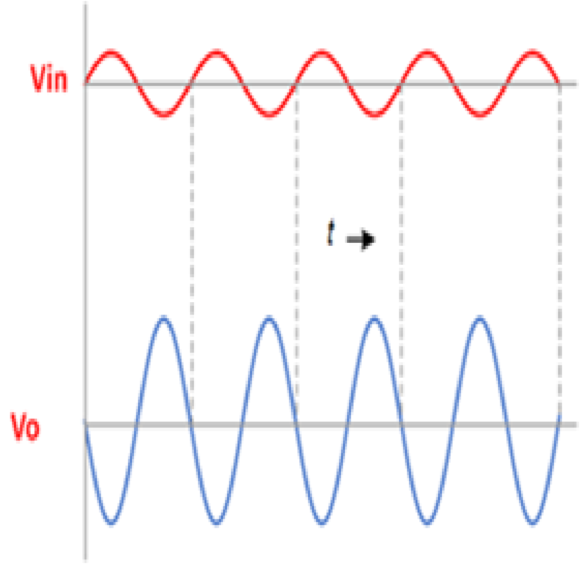


Note: Do not apply high input voltage because op amp has got saturation property and for high V_{in} output shoots to $\pm V_{sat}$

Sl.No.	Input voltage V_{in} (Volts)	Output Voltage V_o (Volts)	Measured Gain $A_v = -\frac{V_o}{V_{in}}$	Calculated Gain $A_v = -\frac{R_f}{R_1}$
1				
2				
3				
4				
5				
6				

ii) For AC Measurements:





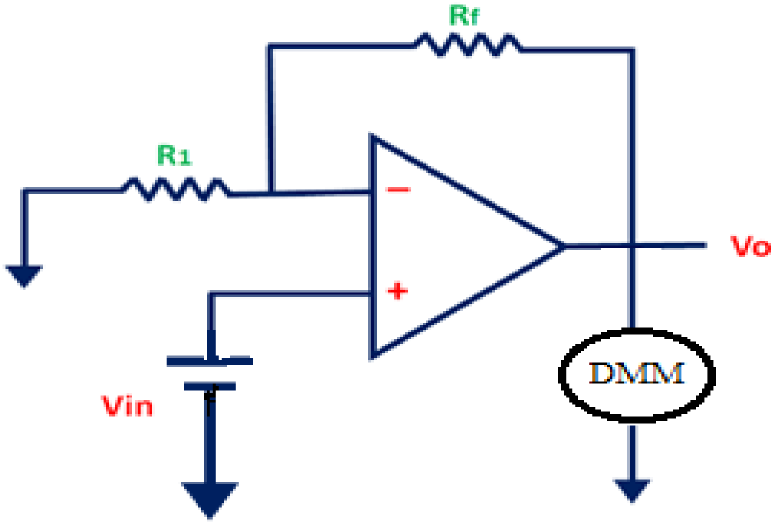
Input and output waveforms of inverting amplifier

Observations:

Sl.No.	Input voltage V_{in} (Volts)	Output Voltage V_o (Volts)	Measured Gain $A_v = -\frac{V_o}{V_{in}}$	Calculated Gain $A_v = -\frac{R_f}{R_1}$
1				
2				
3				
4				
5				
6				

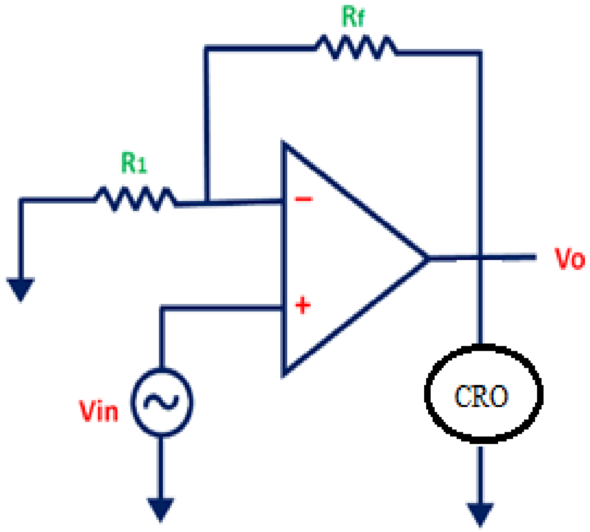
Circuit Diagram for Non -inverting amplifier

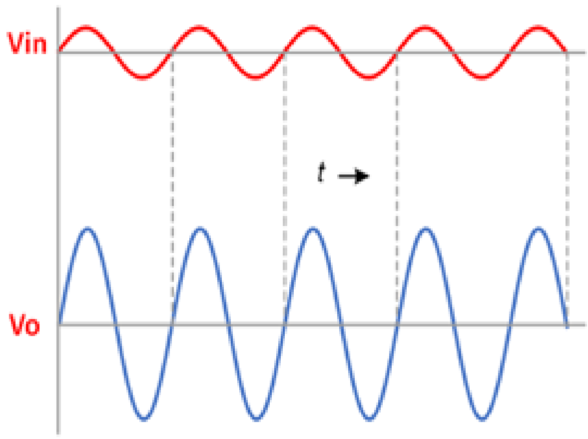
i) For DC Measurements:



Sl.No.	Input voltage V_{in} (Volts)	Output Voltage V_o (Volts)	Measured Gain $A_v = \frac{V_o}{V_{in}}$	Calculated Gain $A_v = \left(1 + \frac{R_f}{R_1}\right)$
1				
2				
3				
4				
5				
6				

i) For AC Measurements:





Input and output waveforms of non-inverting amplifier

Observations:

Sl.No.	Input voltage V_{in} (Volts)	Output Voltage V_o (Volts)	Measured Gain $A_v = \frac{V_o}{V_{in}}$	Calculated Gain $A_v = \left(1 + \frac{R_f}{R_1}\right)$
1				
2				
3				
4				
5				
6				

An op-amp or operational amplifier is basically a high gain multi-stage differential amplifier including two inputs and one output. The typical op-amp is available in two configurations like inverting op-amp and non-inverting op-amp. In an operational amplifier, the non-inverting terminal is marked with a (+) sign whereas the inverting terminal is marked with a (-) sign which is also known as positive & negative terminals.

A non-inverting amplifier produces an output signal that is in phase with the input signal, whereas an inverting amplifier's output is out of phase. Both the inverting and non-inverting op amps can be constructed from one op amp and two resistors, just in different configurations.

What is an Inverting Amplifier?

An inverting amplifier (also known as an inverting operational amplifier or an inverting op-amp) is a type of operational amplifier circuit which produces an output which is out of phase with respect to its input by 180^o. This means that if the input pulse is positive, then the output pulse will be negative and vice versa. The voltage gain of the inverting amplifier is decided by the ratio of the feedback resistor to the input resistor with the minus sign indicating the phase-reversal. Inverting amplifiers exhibit excellent linear characteristics which make them ideal as DC amplifiers.
The voltage gain of the inverting operational amplifier is, $A_v = -\frac{R_f}{R_1}$

What is Non-Inverting Op-Amp?

Non-inverting op-amp definition is, when the output of an operational amplifier is in phase with an input signal then it is known as a non-inverting op-amp. In this amplifier, the input signal is applied to the +ve terminal of an operational amplifier. A non-inverting amplifier generates an amplified output signal that is in phase with the applied input signal.
The voltage gain of the inverting operational amplifier is, $A_v = \left(1 + \frac{R_f}{R_1}\right)$

HARTLEY OSCILLATOR

AIM: Set up transistorized Hartley oscillator and study the frequency of oscillation produced for various capacitance values.

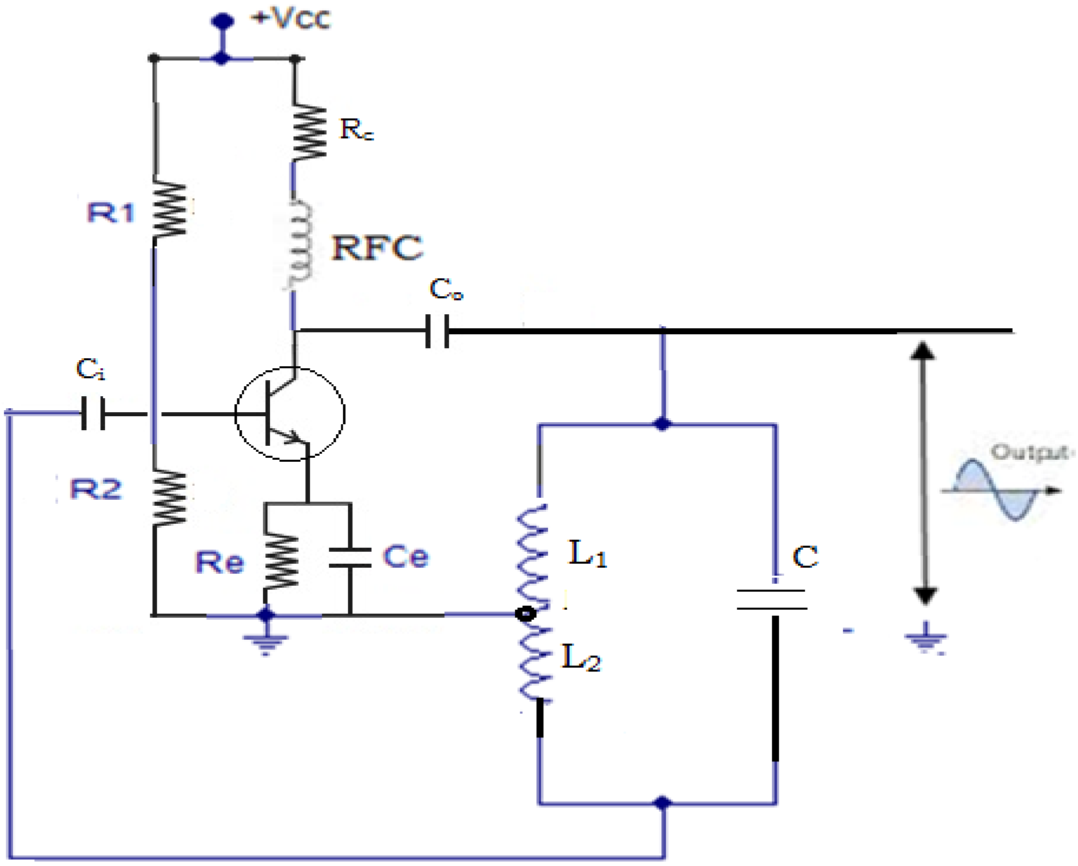
APPARATUS: Power supply, transistor BC-547, capacitors, resistors, inductance, CRO, connecting wires etc.

FORMULA :

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

$L = L_1 + L_2$

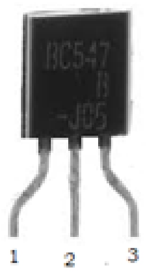
CIRCUIT DIAGRAM:



R_1 = 22 KΩ, R_2 = 2.2 KΩ, R_c = 10 KΩ, Re = 680 Ω, Vcc = 9V,
$C_i = C_o = C_e$ = 0.01μF, RFC = Radio frequency choke Q = transistor BC 547,
L_1, L_2 = different inductor, C = Capacitor.

HARTLEY OSCILLATOR

BC 547 NPN Transistor



OBSERVATIONS

C (μF)	L (μH)	**Theoretical frequency** $f = \frac{1}{2\pi\sqrt{LC}}$ (Hz)	**Observed Frequency**			
			No. of divisions a	Time base setting b (sec)	T = a x b (sec)	$f = \frac{1}{T}$ (Hz)

RESULT: Hartley oscillator was rigged up from its components and output waveform was observed on CRO. The calculated and observed values of the frequency are compared for different values of L and C.

HARTLEY OSCILLATOR

A very popular local oscillator circuit that is mostly used in radio receivers is the Hartley Oscillator circuit. The constructional details and operation of a Hartley oscillator are as discussed below.

Construction

In the circuit diagram of a Hartley oscillator shown below, the resistors R_1, R_2 and R_e provide necessary bias condition for the circuit. The capacitor C_e provides a.c. ground thereby providing any signal degeneration. This also provides temperature stabilization.

The capacitors C_c and C_b are employed to block d.c. and to provide an a.c. path. The radio frequency choke (R.F.C) offers very high impedance to high frequency currents which means it shorts for d.c. and opens for a.c. Hence it provides d.c. load for collector and keeps a.c. currents out of d.c. supply source

Tank Circuit

The frequency determining network is a parallel resonant circuit which consists of the inductors L_1 and L_2 along with a variable capacitor C. The junction of L_1 and L_2 are earthed. The coil L_1 has its one end connected to base via C_c and the other to emitter via C_e. So, L_2 is in the output circuit. Both the coils L_1 and L_2 are inductively coupled and together form an Auto-transformer. The tank circuit is shunt fed in this circuit. It can also be a series-fed.

Operation

When the collector supply is given, a transient current is produced in the oscillatory or tank circuit. The oscillatory current in the tank circuit produces a.c. voltage across L_1.

The auto-transformer made by the inductive coupling of L_1 and L_2 helps in determining the frequency and establishes the feedback. As the CE configured transistor provides 180^o phase shift, another 180^o phase shift is provided by the transformer, which makes 360^o phase shift between the input and output voltages.

This makes the feedback positive which is essential for the condition of oscillations. When the loop gain $|\beta A|$ of the amplifier is greater than one, oscillations are sustained in the circuit.

HARTLEY OSCILLATOR

Frequency

The equation for frequency of Hartley oscillator is given as

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

$L = L_1 + L_2$

Here, L is the total cumulatively coupled inductance; L_1 and L_2 represent inductances of 1^{st} and 2^{nd} coils.

Advantages

The advantages of Hartley oscillator are

- Instead of using a large transformer, a single coil can be used as an auto-transformer.
- Frequency can be varied by employing either a variable capacitor or a variable inductor.
- Less number of components are sufficient.
- The amplitude of the output remains constant over a fixed frequency range.

Disadvantages

The disadvantages of Hartley oscillator are

- It cannot be a low frequency oscillator.
- Harmonic distortions are present.

Applications

The applications of Hartley oscillator are

- It is used to produce a sinewave of desired frequency.
- Mostly used as a local oscillator in radio receivers.
- It is also used as R.F. Oscillator.

COLPITT'S OSCILLATOR

AIM : Set up transistorized Colpitt's oscillator and study the frequency of oscillations produced for different capacitance of the capacitor.

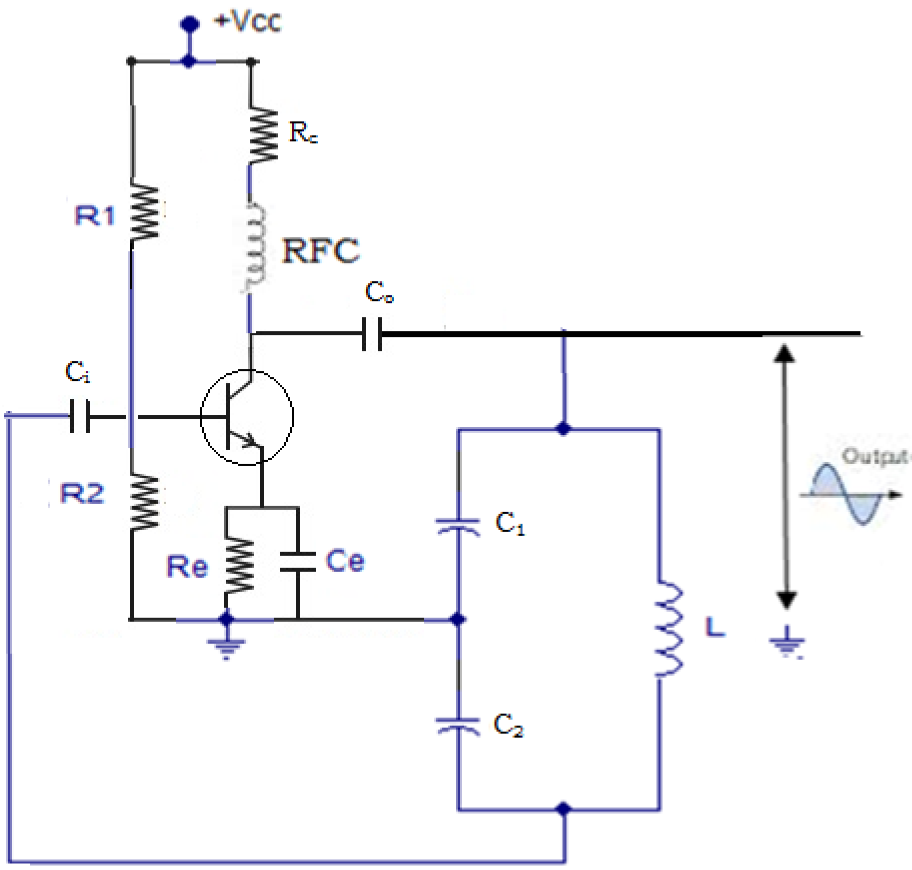
APPARATUS : Transistor BC547, RFC, resistors, inductor, capacitors, power supply, CRO, cables, bread board, connecting wires etc.

FORMULA :

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

$$C = \frac{C_1 C_2}{C_1 + C_2} = \_\_\_\_\_\_\_\_ \mu\text{F}$$

CIRCUIT DIAGRAM :



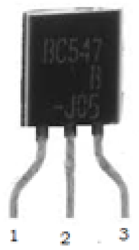
R_1 = 22 KΩ, R_2 = 2.2 KΩ, R_c = 10 KΩ, R_e = 680 Ω, Vcc = 9V,

C_{in} = C_{out} = C_e = 0.01μF, RFC = Radio frequency choke

Q = transistor BC547, C1, C_2 = different capacitors, L – inductor.

COLPITT'S OSCILLATOR

BC 547 NPN Transistor



OBSERVATIONS

C (μF)	L (μH)	**Theoretical frequency** $f = \frac{1}{2\pi\sqrt{LC}}$ (Hz)	**Observed Frequency**			
			No. of divisions a	Time base setting b (sec)	T = a x b (sec)	$f = \frac{1}{T}$ (Hz)

RESULT: Colpitt's oscillator was rigged up from its components and output waveform was observed on CRO. The calculated and observed values of the frequency are compared for different values of L and C.

COLPITT'S OSCILLATOR

Colpitts Oscillator

Oscillator is an amplifier with the positive feedback and it converts DC input signal into AC output waveform with certain variable frequency drive and certain shape of output waveform (like sine wave or square wave, etc) by using the positive feedback instead of input signal. Oscillators which utilizes the inductor L and capacitor C in their circuit are called as LC oscillator which is a type of linear oscillator.

It consists of a tank circuit which is an LC resonance sub circuit made of two series capacitors connected in parallel to an inductor and frequency of oscillations can be determined by using the values of these capacitors and inductor of the tank circuit.

It can be realized by using gain device such as Bipolar Junction Transistor(BJT), operational amplifier and field effect transistor(FET) as similar in other LC oscillators also. The capacitors C1 & C2 forms potential divider and this tapped capacitance in the tank circuit can be used as the source for feedback and this setup can be used to provide better frequency stability compared to the Hartley oscillator in which tapped inductance is used for feedback setup.

R_e resistor in the above circuit provides stabilization for circuit against variations in temperature. The capacitor C_e connected in the circuit which is parallel to the R_e, provides low reactive path to the amplified AC signal acting as Bypass capacitor. The Resistors R_1 and R_2 form voltage divider for circuit and provides bias to the transistor. The circuit consists of a RC coupled amplifier with common emitter configuration transistor. The coupling capacitor C_o blocks DC by providing an AC path from the collector to the tank circuit.

Whenever power supply is switched on, the capacitors C_1 and C_2 shown in the above circuit start charging and after the capacitors get fully charged, the capacitors starts discharging through the inductor L1 in the circuit causing damped harmonic oscillations in the tank circuit. Thus, an AC voltage is produced across C_1 & C_2 by the oscillatory current in the tank circuit. While these capacitors get fully discharged, the electrostatic energy stored in the capacitors get transferred in the form of magnetic flux to the inductor and thus inductor gets charged.

Similarly, when the inductor starts discharging, the capacitors start charging again and this process of energy charging and discharging capacitors and inductor continues causing the generation of oscillations and the frequency of these oscillations can be determined by using the resonant frequency of the tank circuit consisting of inductor and capacitors. This tank circuit is considered as the energy reservoir or energy storage. This is because of frequent energy charging and discharging of the inductor, capacitors that part of LC network forming the tank circuit.

The continuous undamped oscillations can be obtained from the Barkhausen criterion. For sustained oscillations, the total phase shift must be 3600 or 00. In the above circuit as two capacitors C1 & C2 are center tapped and grounded, the voltage across capacitor C2 (feedback voltage) is 1800 with the voltage across capacitor C1 (output voltage). The common emitter transistor produces 1800 phase shift between the input and output voltage. Thus, from the Barkhausen criterion we can get undamped continuous oscillations.
The resonant frequency is given by $f = \frac{1}{2\pi\sqrt{LC}}$

Where f is the resonant frequency

C is the equivalent capacitance of series combination of C_1 and C_2 of the tank circuit

It is given as $C = \frac{C_1 C_2}{C_1 + C_2}$

L represents the self inductance of the coil.

Applications of Colpitts Oscillator

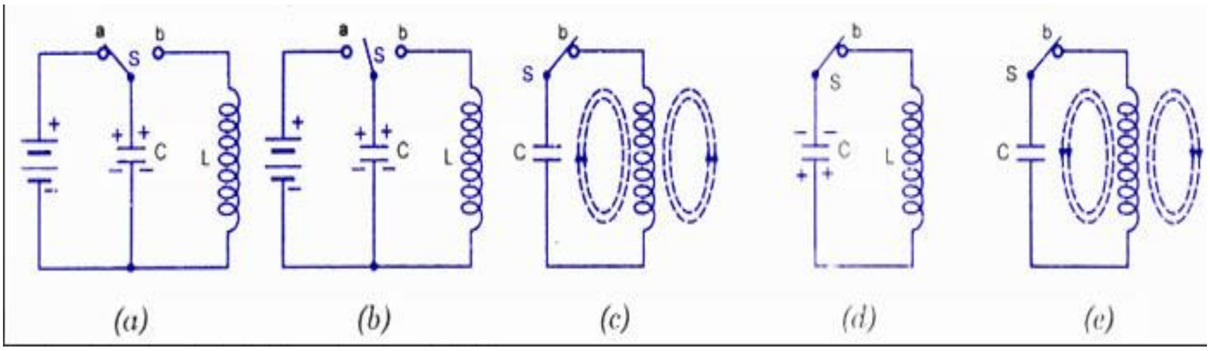
- It is used for generation of sinusoidal output signals with very high frequencies.
- The Colpitt's oscillator using SAW device can be used as the different type of sensors such as temperature sensor. As the device used in this circuit is highly sensitive to perturbations, it senses directly from its surface.
- It is frequently used for the applications in which very wide range of frequencies are involved.
- Used for applications in which undamped and continuous oscillations are desired for functioning.
- This oscillator is preferred in situations where it is intended to withstand high and low temperatures frequently.
- The combination of this oscillator with some devices (instead of tank circuit) can be used to achieve great temperature stability and high frequency.
- It is used for the development of mobile and radio communications.
- It has many applications used for the commercial purposes.

COLPITT'S OSCILLATOR

Working of LC tank circuit

Both the capacitor and inductor are capable of storing energy

- The capacitor stores energy in its dielectric field whenever a pd exists across its plates
- while the inductor stores energy in its magnetic field whenever current flows through it.



- Let the capacitor be charged from a dc source with the polarity as shown in figure (a).
- when the capacitor is fully charged and the switch S is opened, as shown in figure (b), the capacitor cannot discharge through L
- The switch S when kept in position 'b' the current starts flowing in the circuit.
- Due to flow of current, magnetic field is set up which stores the energy given by the electric field, as shown in figure (c).
- Thus, at the instant the capacitor gets completely discharged, the electrostatic energy stored in the capacitor gets converted into the magnetic field energy associated with the inductor L.
- The capacitor now starts getting charged but with opposite polarity, as shown in fig.(d). In this case, the energy associated with the magnetic field is again converted into electrostatic energy.
- This charging and discharging of the capacitor results in alternating motion of electrons and produces oscillations
- The interchange of energy between L and C would continue indefinitely if there were no losses in the tank circuit.

PHASE SHIFT OSCILLATOR

AIM: Set up a phase shift oscillator using Op-Amp (IC-741) and determine the frequency of oscillation using CRO also determine the phase shift introduced at different stages of phase shift network.

APPARATUS USED: IC 741 (Op-Amp), Dual power supply, CRO, capacitors (disc capacitor)Resistors, potentiometer, bread board, connecting wires, etc.

FORMULA: Observed frequency is given by $F = \frac{1}{T} =$ _____ Hz

Theoretical frequency of the phase shift oscillator is given by

$$F = \frac{1}{2\pi\sqrt{6}RC} = \frac{1}{15.39RC} = \_\_\_\_\_\_\_\_ \text{Hz}$$

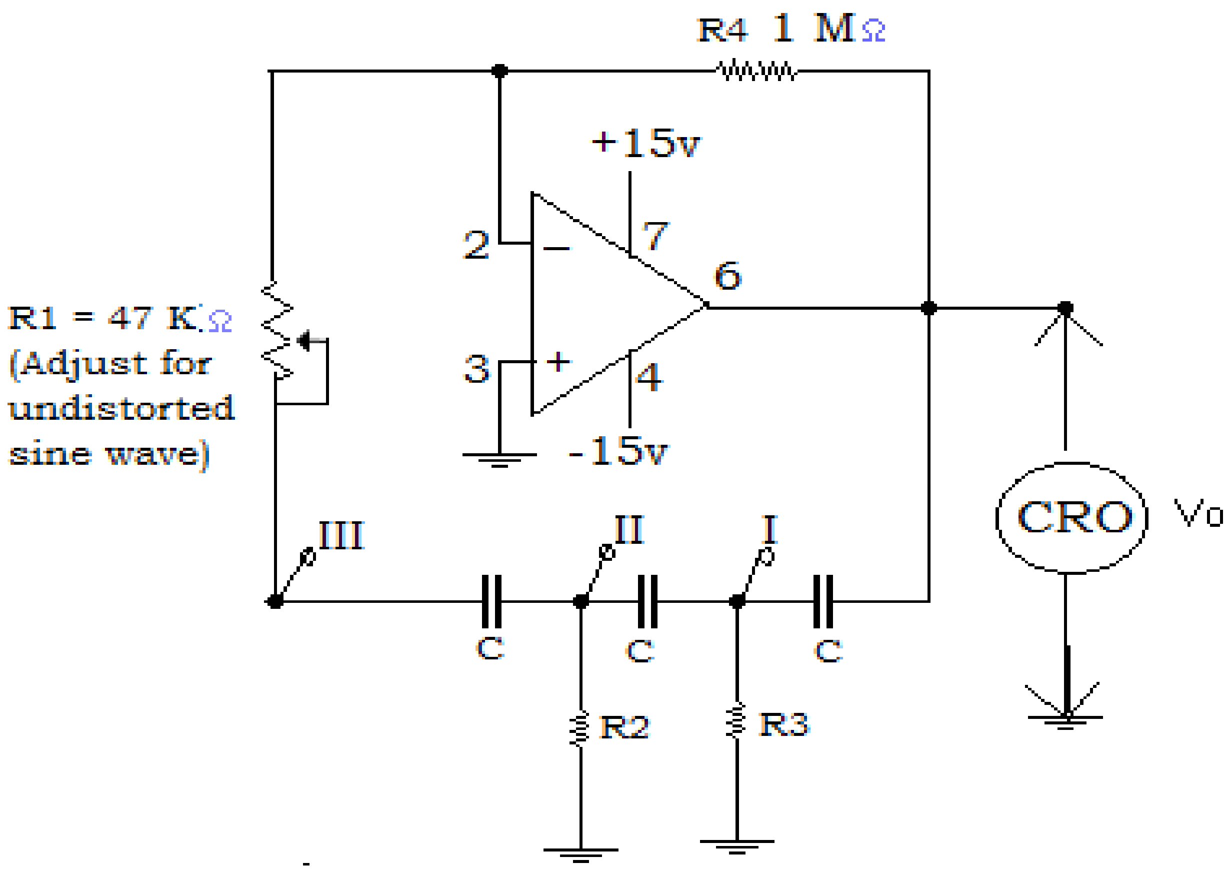
where R = Resistance (Ω)

C= Capacitance (F)

$R_1=R_2=R_3=R$

$R_4 \geq 29R$

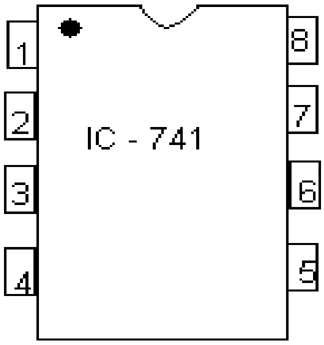
CIRCUIT DIAGRAM:



Resistors: R1=47 KΩ potentiometer, R4=1MΩ $R_1=R_2=R_3=R=10$ KΩ
Capacitors: C=0.01 μF (disc capacitor)

PHASE SHIFT OSCILLATOR

PIN CONFIGURATION OF IC-741 OP AMP



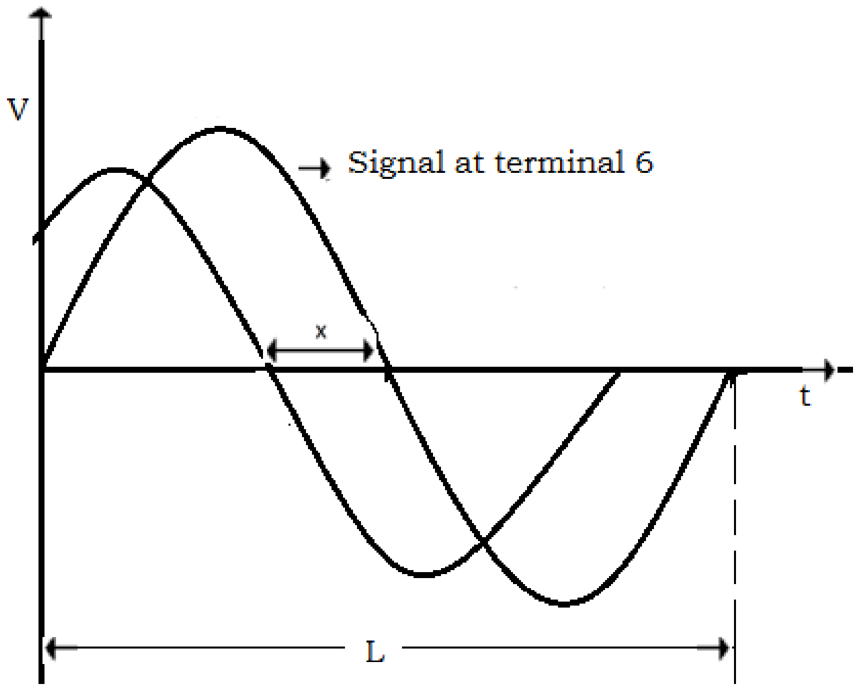
1 & 5: offset
2: Inverting
3: Noninverting
4: -V_{cc}
6: Output
7: + V_{cc}

I. TO FIND THE FREQUENCY OF OSCILLATION

R(Ω)	C (μF)	Theoretical Value	Measured Value			
		$f = \frac{1}{2\pi(\sqrt{6})RC}$ in Hz	No. of div between two consecutive peaks λ	Time base setting t (mS)	Time Period T=λ*t (mS)	Observed frequency $F = \frac{1}{T}$ (Hz)

II. TO DETERMINE THE PHASE SHIFT

NATURE OF THE GRAPH:



Set L = 50 sub divisions
L (in Sub divisions) = Phase diff of 360^0
1 sub div = $\frac{360^o}{L}$
x Sub div = $\left(\frac{360^o}{L}\right)x$
Therefore Phase difference δ = $\left(\frac{360^o}{L}\right)x$

Observations: No. of subdivision corresponding to 360^0 = L=__________

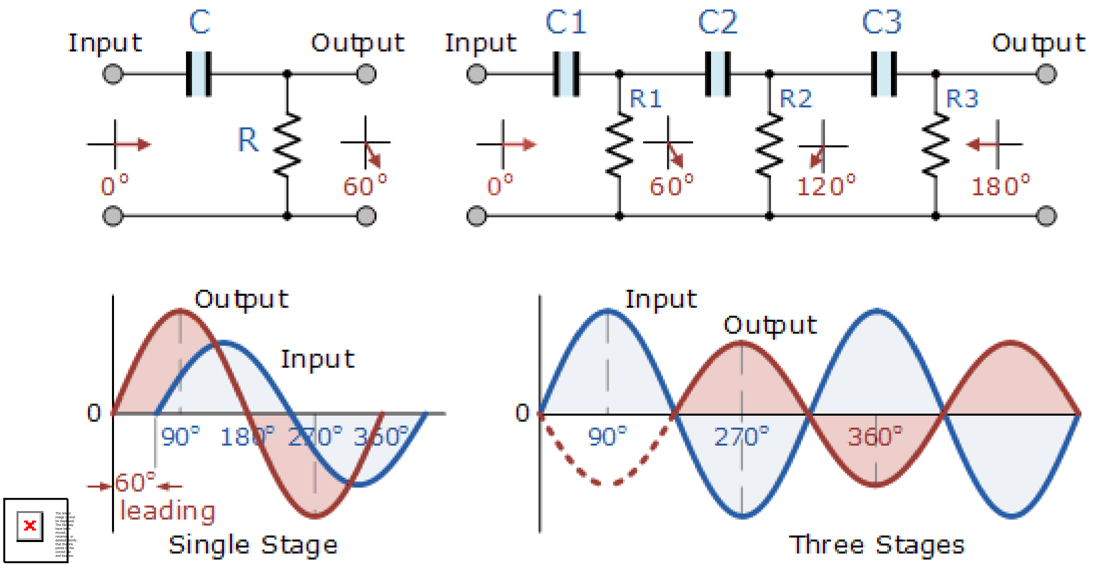
Stage	x (distance between two points which are in phase in sub divisions)	Phase shift δ = $\left(\frac{360^o}{L}\right)x$ deg
I		
II		
III		

RESULT: A Phase shift oscillator was rigged up from its components and output waveform was observed on CRO. The calculated and observed values of the frequency of oscillations are compared for different values of R and C. Also the phase shift at different stages is observed.

PHASE SHIFT OSCILLATOR

Theory: An **oscillator** is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

RC phase-shift oscillators use resistor-capacitor (RC) network (Figure 1) to provide the phase-shift required by the feedback signal. They have excellent frequency stability and can yield a pure sine wave for a wide range of loads.



Ideally a simple RC network is expected to have an output which leads the input by 90°. However, in reality, the phase-difference will be less than this as the capacitor used in the circuit cannot be ideal. Mathematically the phase angle of the RC network is expressed as

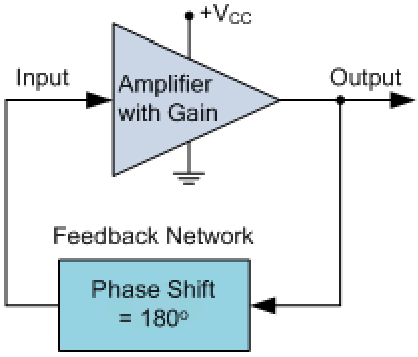
$$\varphi = tan^{-1}\frac{X_C}{R}$$

Where, X_C = 1/(2πfC) is the reactance of the capacitor C and R is the resistor. In oscillators, these kind of RC phase-shift networks, each offering a definite phase-shift can be cascaded so as to satisfy the phase-shift condition led by the Barkhausen Criterion.

One such example is the case in which RC phase-shift oscillator is formed by cascading three RC phase-shift networks, each offering a phase-shift of 60° . For an RC oscillator to sustain its oscillations indefinitely, sufficient feedback of the correct phase, that is positive (in-phase)

PHASE SHIFT OSCILLATOR

Feedback must be provided along with the voltage gain of the single transistor amplifier being used to inject adequate loop gain into the closed-loop circuit in order to maintain oscillations allowing it to oscillates continuously at the selected frequency.



In an RC Oscillator circuit the input is shifted 180° through the feedback circuit returning the signal out-of-phase and 180° again through an inverting amplifier stage to produces the required positive feedback. This then gives us "180° + 180° = 360°" of phase shift which is effectively the same as 0°, thereby giving us the required positive feedback. In other words, the total phase shift of the feedback loop should be "0" or any multiple of 360° to obtain the same effect.

The circuit consists of an op amp in its amplifying stage and a series of RC networks in its feed back network. As the feedback is connected to the inverting input, the operational amplifier is therefore connected in its "inverting amplifier" configuration which produces the required 180° phase shift while the RC network produces the other 180° phase shift at the required frequency (180° + 180°). This type of feedback connection with the capacitors in series and the resistors connected to ground (0V) potential is known as a *phase-lead* configuration. In other words, the output voltage leads the input voltage producing a positive phase angle.

Advantages of RC Phase Shift Oscillator

The advantages of this phase shift oscillator include the following.

- The oscillator circuit designing is easy with basic components like resistors as well as capacitors.
- This circuit is not expensive and gives excellent frequency stability.
- These are mainly suitable for low-frequencies

- This circuit is simpler compared with a Wein bridge oscillator because it doesn't require the stabilization planning & negative feedback.
- The circuit output is sinusoidal that is somewhat distortion free.
- The frequency range of this circuit will range from a few Hz to hundreds of kHz

Disadvantages of RC-Phase Shift Oscillator

The disadvantages of this phase shift oscillator include the following.

- The output of this circuit is small because of the smaller feedback
- It requires 12 volts battery for developing a suitably huge feedback voltage.
- It is hard for this circuit to create oscillations because of the small feedback
- The frequency stability of this circuit is not good to compare with Wien bridge oscillator.

RC Phase Shift Oscillator Applications

The applications of this type of phase shift oscillator include the following

- This phase shift oscillator is used to generate the signals over an extensive range of frequency. They used in musical instruments, GPS units, & voice synthesis.
- The applications of this phase shift oscillator include voice synthesis, musical instruments, and GPS units.

Thermal Conductivity of Copper by Searl's Method

Aim : To determine the thermal Conductivity of copper by Searl's method

Formula : $\kappa = \frac{C_w m(\theta_4 - \theta_3)d}{A(\theta_2 - \theta_1)}$ ($Ws^{-1}K^{-1}$)

Where κ is thermal conductivity of copper

C_w: Specific heat of water

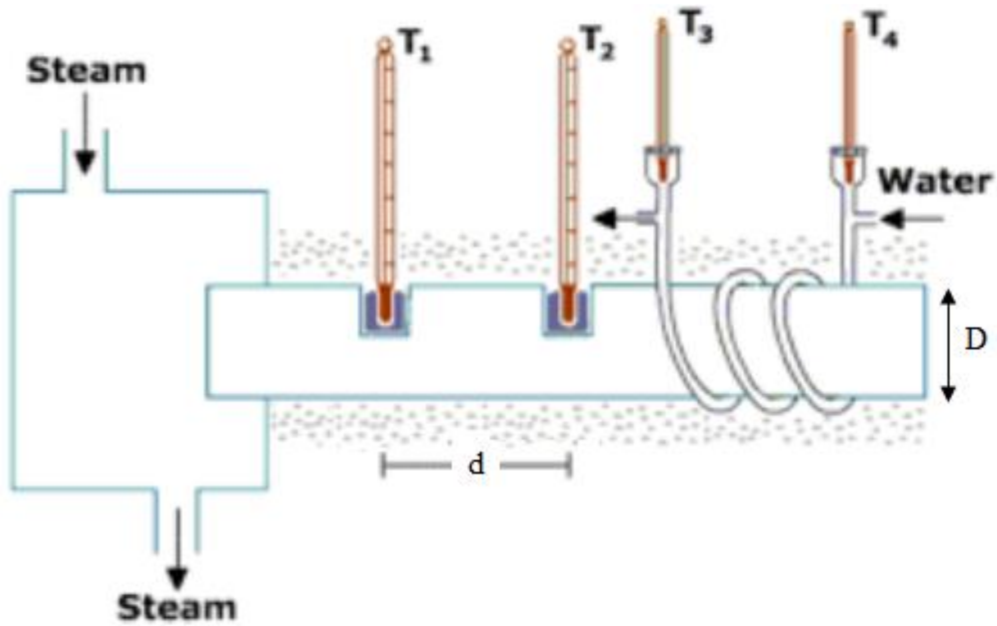
m: mass of flow of water per second

d: distance between two thermometer (T_1 and T_2) position

A: Cross sectional area of copper rod

$\theta_1, \theta_2, \theta_3, \theta_4$: Steady temperatures of the thermometers T_1, T_2, T_3, and T_4 respectively.

Diagram



Observations:

1. Distance between two thermometers (T_1 and T_2)
   d = ______cm = ________m
2. Diameter of the copper rod D =________cm = _______m
3. Radius of the copper rod r = ________cm = ________m
4. Cross sectional area of copper rod $A = \pi r^2$ =______cm^2 = ______m^2
5. Density of water ρ = 1 gm/cm^3 = 1000 Kg/m^3
6. Specific heat of water C_w= 1 cal/g/℃ = 4200 J/Kg/K

Tabular Column:

Note: Volume of the water is measured in cc using measuring jar but expressed in m^3 using (1cc = 10^{-6} m^3)

	Steady Temperature θ_1 (K)	Steady Temperature θ_2 (K)	Steady Temperature θ_3 (K)	Steady Temperature θ_4 (K)	Volume of water collected for 300 s V (m^3)	Volume of water collected per sec M =V/300 (m^3)	Mass of the water collected per sec m= M ρ (kg/s)	Thermal conductivity of copper **K ($Ws^{-1}K^{-1}$)**
1								
2								
3								
4								

Mean Thermal conductivity of copper κ = ____________ ($Ws^{-1}K^{-1}$)

Result: Thermal conductivity of copper κ = ___________ ($Ws^{-1}K^{-1}$)

PROCEDURE:

- Set the experiment as shown in the figure.
- Ensure that all thermometers T1, T2, T3 and T4 read the same temperature before passing the steam through the steam chamber.
- Now pass the steam to the copper rod using steam chamber at one end. Maintain the inlet and outlet flow of water through water jacket surrounding the copper rod at the other end. Monitor the temperature of all the thermometers.
- **When steady temperature is reached in all thermometers**, collect the water from outlet for known amount of time (say 300 s) and record the steady temperature of all the thermometers as shown in tabular column and also record the amount of water collected using measuring jar .
- Now calculate the thermal conductivity of copper rod using the formula.
- Repeat the same procedure for another trial.

AIM: To study the working of Op- amp IC-741 as an adder and subtractor. Use AC/DC inputs and verify the output with the theoretical values.

COMPONENTS USED: Op-amp IC (741), dual power supply resistors, regulated power supply, Signal generator, DMM, CRO, connecting wires, etc.

FORMULA:

A) Output Voltage V_o of Adder/Summing Amplifier is given by:

$$V_o = -\frac{R_f}{R_1}V_1 - \frac{R_f}{R_2}V_2 - \frac{R_f}{R_3}V_3$$

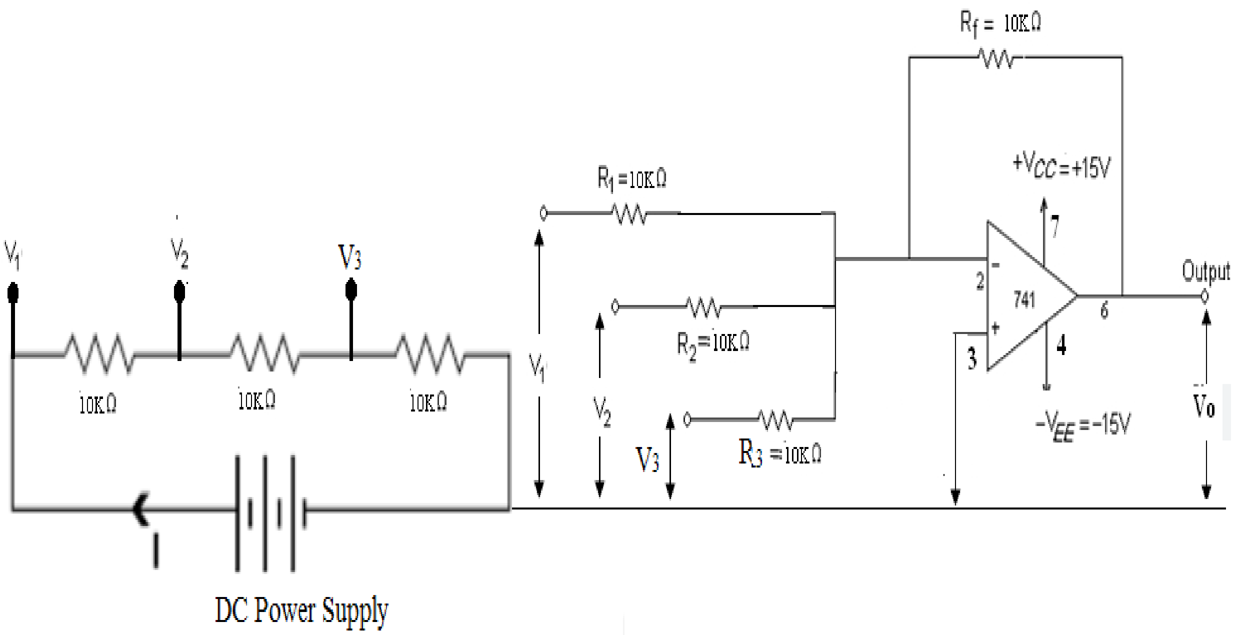
B) If $R_1 = R_2 = R_3 = R$ then

$$V_o = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

C) If $R_f = R$ then

$$V_o = -(V_1 + V_2 + V_3)$$

CIRCUIT DIAGRAM FOR SUMMING AMPLIFIER/ADDER:



Note: For AC measurements replace DC power supply by Signal generator.

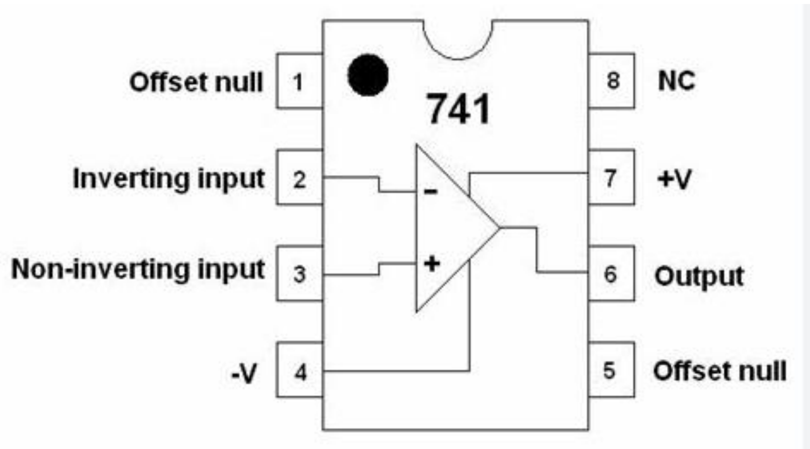
1) For DC Measurements

Sl.No.	Measured Input Voltages (Volts)			Calculated Output Voltage V_o (Volts)	Measured Output Voltages V_o (Volts)
	V_1	V_2	V_3	$V_o = -(V_1 + V_2 + V_3)$	
1					
2					
3					
4					
5					
6					

2) For AC Measurements:

Sl.No.	Measured Input Voltages (Volts)			Calculated Output Voltage V_o (Volts)	Measured Output Voltages V_o (Volts)
	V_1	V_2	V_3	$V_o = -(V_1 + V_2 + V_3)$	
1					
2					
3					
4					
5					
6					

PIN CONFIGURATION OF IC-741 OP AMP



Adder/ Summing Amplifier:

Op-Amp may be used to design a circuit whose output is the sum of several input signals such as circuit is called a summing amplifier or summer. We can obtain either inverting or non-inverting summer. The circuit diagrams shows a two input inverting summing amplifier. It has three input voltages V_1, V_2 and V_3, three input resistors R_1, R_2 and R_3 and a feedback resistor R_f. Assuming that op-amp is in ideal conditions and input bias current is assumed to be zero, there is no voltage drop across the resistor R_{comp} and hence the non inverting input terminal is at ground potential.

By taking nodal equations.

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \frac{V_o}{R_f} = 0$$

$$V_o = -\frac{R_f}{R_1}V_1 - \frac{R_f}{R_2}V_2 - \frac{R_f}{R_3}V_3$$

If $R_1 = R_2 = R_3 = R$ then

$$V_o = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

If $R_f = R$ then

$$V_o = -(V_1 + V_2 + V_3)$$

Thus output is inverted and sum of input.

Procedure:

1. Connect the circuit as per the diagram.
2. Apply the supply voltages of +15V to pin7 and -15V to pin4 of IC741 respectively.
3. Apply the inputs V_1, V_2 and V_3 as shown.
4. Apply two different signals (DC/AC) to the inputs.
5. Vary the input voltages and note down the corresponding output at pin 6 of the IC 741 adder circuit.
6. Notice that the output is equal to the sum of the three inputs.

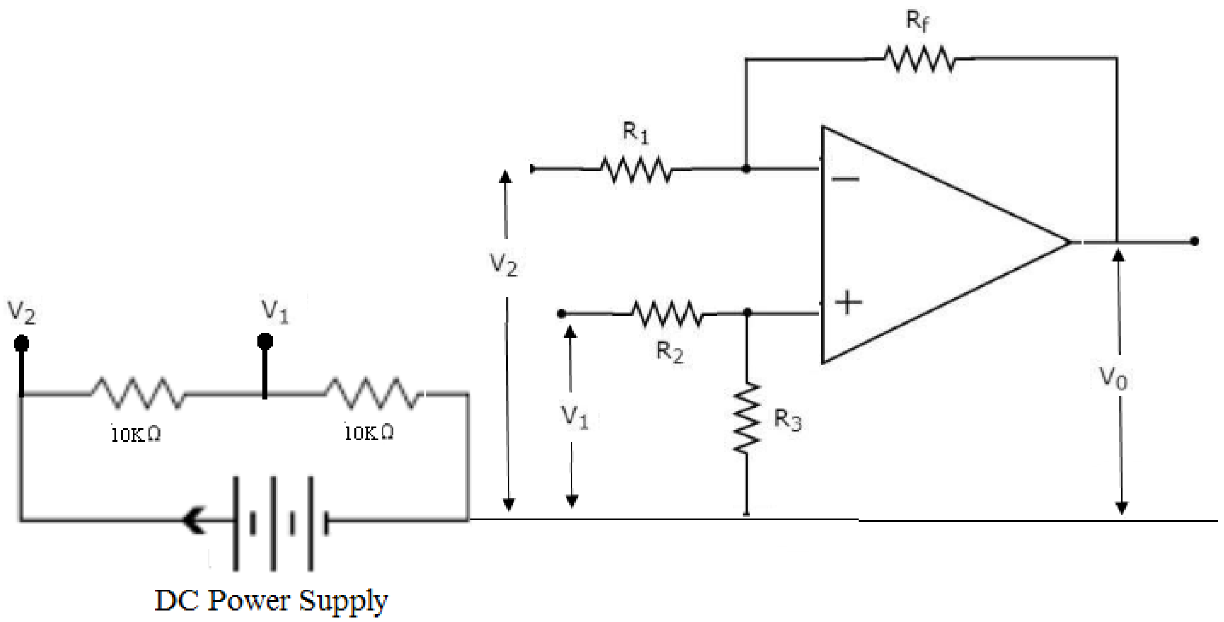
SUBTRACTOR/DIFFERENCE AMPLIFIER

FORMULA:

Output Voltage V_o of Difference Amplifier is given by:

If $R_1 = R_2 = R_3 = R_4 = R$ then $V_o = (V_1 - V_2)$

CIRCUIT DIAGRAM FOR SUBTRACTOR/DIFFERENCE AMPLIFIER:



$R_1 = R_2 = R_3 = R_4 = R = 10K\Omega$

Note: For AC measurements replace DC power supply by Signal generator.

1) For DC Measurements

Sl.No.	Measured input voltage (Volts)		Calculated Output Voltage V_o (Volts)	Measured Output Voltages V_o (Volts)
	V_1	V_2	$V_o = (V_1 - V_2)$	
1				
2				
3				
4				
5				
6				

2) For AC Measurements:

Sl.No.	Measured input voltage (Volts)		Calculated Output Voltage V_o (Volts)	Measured Output Voltages V_o (Volts)
	V_1	V_2	$V_o = (V_1 - V_2)$	
1				
2				
3				
4				
5				
6				

Subtractor/ Difference Amplifier:

The subtractor circuit, input signals can be scaled to the desired values by selecting appropriate values for the resistors. When this is done, the circuit is referred to as scaling amplifier. However in this circuit all external resistors are equal in value. So the gain of amplifier is equal to one. The output voltage V_o is equal to the voltage applied to the non-inverting terminal minus the voltage applied to the inverting terminal; hence the circuit is called a subtractor.

Procedure:

1. Connect the circuit as per the diagram.
2. Apply the supply voltages of +15V to pin7 and pin4 of IC-741 respectively.
3 Apply the inputs V_1 and V_2.
4. Apply two different signals (DC/AC) to the inputs.
5. Vary the input voltages and note down the corresponding output at pin 6 of the IC 741 subtractor circuit.
6. Notice that the output is equal to the difference of the two inputs.

Viva Questions:

1. Mention some of the linear applications of op–amps?
2. Mention some of the non – linear applications of op-amps?
3. What happens when the common terminal of V+ and V- sources is not grounded?
4. What are the ideal characteristics of an op-amp?
5. What is CMRR?
6. What is Amplifier?
7. Why OPAMP is called direct coupled high gain differential circuit?
8. Why open-loop op-amp configurations are not used in linear applications?