ANALOG ELECTRONIC CIRCUITS

(EE-325-F)

LAB MANUAL

V SEMESTER

DRONACHARYA
College of Engineering

Department Of Electronics & Communication Engg
Dronacharya College Of Engineering
Khentawas, Gurgaon – 123506

LIST OF EXPERIMENTS

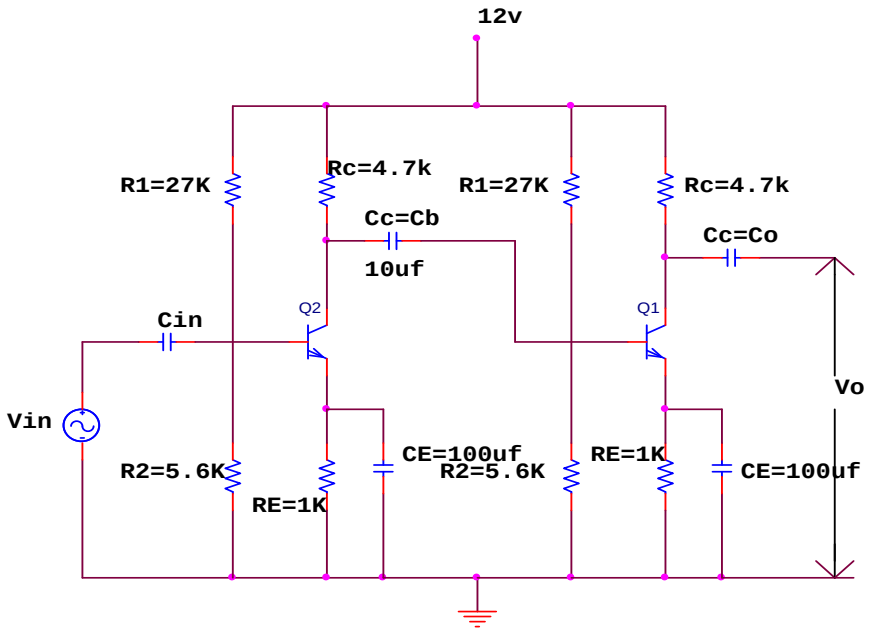
EXPERIMENT No. 1

AIM: - Design & measure the frequency response of an RC coupled amplifier using discrete components.

APPARATUS REQUIRED: - CRO, function generator, breadboard, transistor BC 104 (2 pcs), capacitor10μF (3 pcs), 100μF (2pcs), resistor 4.7K (2pcs), 5.6K (2pcs), 1K (2pcs), ± 12 V supply and connecting leads**.**

THEORY: - RC coupled amplifier is a coupling of two emitter biased transistor circuit to form a single cascade network. The output Vi of one stage is coupled to the input of the next stage. A blocking capacitor is used to keep the DC component f the output voltage at Vo1. The emitter resistor R_E and resistor R_1 and R_2 are used for biasing. The bypass capacitor is used to present loss of Amplification due to negative feedback. Output is taken across capacitor Cc.

CIRCUIT DIAGRAM: -



RC COUPLED AMPLIFIER

PROCEDURE: -

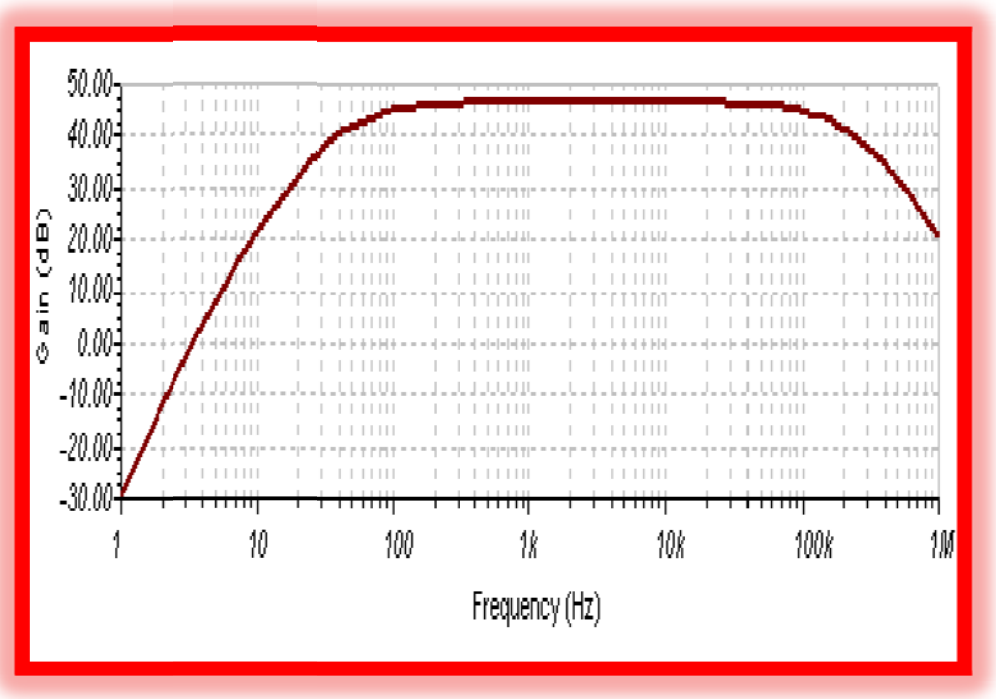
(1) Apply input signal of 10 mv amplitude and frequency 50 Hz at input terminal.
(2) Varying the frequency of the input signal from 10Hz to1MHz.
(3) Measure the output signal amplitude.
(4) Study the frequency response characteristics of RC coupled amplifier.
(5) Determine lower cut-off frequency and upper cut-off frequency from the graph.
(6) Calculate Bandwidth.

OBSERVATION TABLE:-

INPUT VOLTAGE (Vin) = Constant

S.NO.	FREQUENCY (Hz)	OUTPUT VOLTAGE (Vout)	GAIN (Vout/ Vin) IN dB

FREQUENCY RESPONSE & BANDWIDTH CALCULTION:-



PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply.
2. Before connecting the power supply plug into socket, ensure power supply should be Switched off.
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DISCUSSION: - What is the application of RC coupled amplifier?

RESULT: - The output of RC coupled amplifier is a sinusoidal wave having same phase as the input signal.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. In RC coupled amplifier which component is responsible for reduction in voltage gain in the high frequency range?
Ans. Shunt capacitance in the input circuit.

Q2. In RC coupled amplifier which component's value is responsible for low 3-dB frequency?
Ans. Increasing the value of coupling capacitor C_b.

Q3. In RC coupled amplifier which component's value is responsible for high 3-dB frequency?
Ans. By reducing the total effective shunt capacitance in the input circuit of hybrid pie model.

Q4. In a single stage RC coupled amplifier, what is the phase shift introduced in the true middle frequency?
Ans. 180˚

Q5. Which type of coupling capacitor is used in RC coupled amplifier?
Ans. 0.05 μf paper capacitor.

Q6. What is the application of RC coupled amplifier?
Ans. It is widely used as a voltage amplifier.

Q7. In single stage RC coupled amplifier, what is the phase shift at low 3-dB frequency?
Ans. 225˚

Q8. In single stage RC coupled amplifier, what is the phase shift at high 3-dB frequency?
Ans. 135˚

Q9. In RC coupled amplifier what is the effect of low 3-dB frequency by increasing the value of coupling capacitor C_b?
Ans. Decreasing.

Q10. In RC coupled amplifier what is the effect of low 3-dB frequency by increasing the value of total effective shunt capacitor?
Ans. Decreasing.

EXPERIMENT NO. 2

AIM:-Design a two stage RC coupled amplifier and determine the effect of cascading on gain and bandwidth.

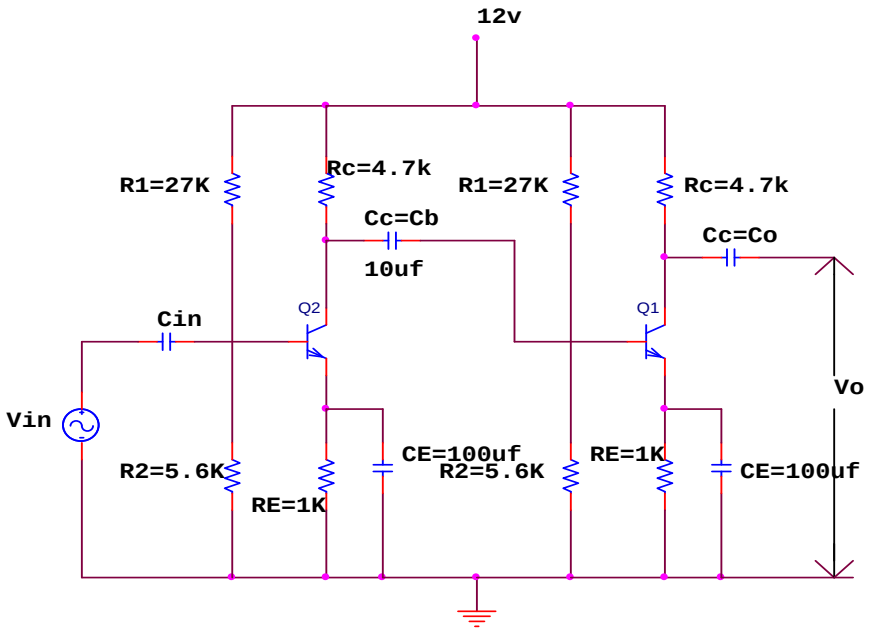
APPARATUS REQUIRED: - CRO, function generator, breadboard, transistor BC 104 (2 pcs), capacitor10µF (3 pcs), 100µF (2pcs), resistor 4.7K (2pcs), 5.6K (2pcs), 1K (2pcs), ± 12 V supply and connecting leads.

THEORY: - When the voltage gain provided by a single stage is not sufficient, we use more than one stage of the amplifier. The overall gain of the two-stages is given by

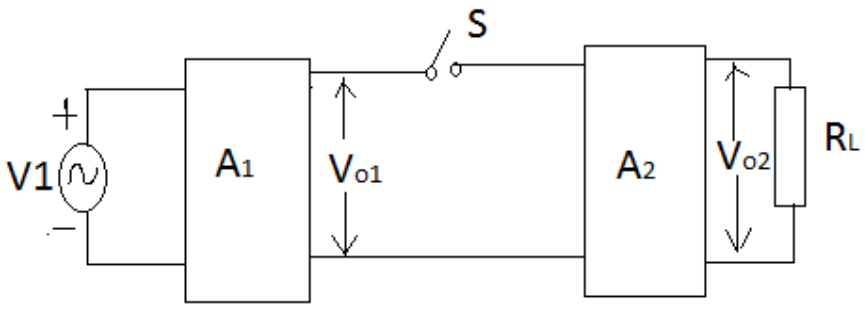
$$A=A_1 * A_2$$

Where A_1 is the voltage gain of first stage and A_2 is the voltage gain of the second stage. When the load resistance of first stage is reduced, the gain and hence output voltage also reduces.

CIRCUIT DIAGRAM:-



RC COUPLED AMPLIFIER



Two Stage amplifier (Block Diagram)

PROCEDURE: -

(1) Connect the circuit properly.
(2) Feed the ac signal at input of first stage. Adjust the frequency at 1 KHZ. See the output wave shapes on the CRO.
(3) Go on increasing the input ac voltage and measure ac voltage at (i) output of first stage (ii) output of second stage
(4) Repeat the same experiment with a single stage by opening the switch 'S'.
(5) Disconnect the second stage and then measure the output voltage of the first stage. Calculate the voltage gain of first stage under this condition and compare it with overall voltage gain of two stage amplifier.

OBSERVATIONS:-

1. Voltage Gain

S.No.	Input Voltage	Output of First stage	Output of Second stage	A_1	A_2	$A=A_1 * A_2$
1.						
2.						

2. Voltage gain with second stage disconnected

S.No.	Input Voltage	Output of First stage	Gain (A_1)
1.			
2.			

RESULT:-

1. Two stage amplifier gain= ……. db
Single stage amplifier gain= …… db
Overall voltage gain of two stage amplifier is higher than single stage amplifier. Gain of two stage amplifier is equal to the product of gains of individual stages. In practice total gain A is less than A1*A2 due to loading effect of following stages.
2. Bandwidth = upper cut-off frequency- lower cut off frequency (From Exp. 1)

QUIZ QUESTIONS WITH ANSWERS:-

Q1. In RC coupled amplifier which component is responsible for reduction in voltage gain in the high frequency range?
Ans. Shunt capacitance in the input circuit.

Q2. In RC coupled amplifier which component's value is responsible for low 3-dB frequency?
Ans. Increasing the value of coupling capacitor Cb.

Q3. In RC coupled amplifier which component's value is responsible for high 3-dB frequency?
Ans. By reducing the total effective shunt capacitance in the input circuit of hybrid pie model.

Q4. In a single stage RC coupled amplifier, what is the phase shift introduced in the true middle frequency?
Ans. 180˚

Q5. Which type of coupling capacitor is used in RC coupled amplifier?
Ans. 0.05 μf paper capacitor.

Q6. What is the application of RC coupled amplifier?
Ans. It is widely used as a voltage amplifier.

Q7. In single stage RC coupled amplifier, what is the phase shift at low 3-dB frequency?
Ans. 225˚

Q8. In single stage RC coupled amplifier, what is the phase shift at high 3-dB frequency?
Ans. 135˚

Q9. In RC coupled amplifier what is the effect of low 3-dB frequency by Increasing the value of coupling capacitor C_b?
Ans. Decreasing.

Q10. In RC coupled amplifier what is the effect of low 3-dB frequency by Increasing the value of total effective shunt capacitor?
Ans. Decreasing.

EXPERIMENT NO. 3

AIM: - Study the effect of voltage series, current series, voltage shunt and current shunt feedback on amplifier using discrete components.

THEORY:-

Voltage Series Feedback:-This is also called the shunt-derived series feedback. In this circuit, Amplifier and feedback network are connected in series-parallel. A fraction of the output voltage is applied in series opposition to the input voltage through feedback network. The feedback voltage is derived from the voltage divider circuit formed of resistors R1 and R2. The feedback voltage is given as:

$$V_f = \beta V_{out} = R1/R1+R2 V_{out}$$

$$\text{Thus } \beta = R1/R1+R2$$

And the overall gain of the amplifier is:

$$A_f = V_{out}/V_s = R1+R2/R1 = 1/\beta$$

Voltage Shunt Feedback:- This is also called the shunt-derived shunt feedback. A small portion of the output voltage is coupled back to the input voltage since the feedback network shunt both the input and output of the amplifier, both the input and output impedances are reduced by a factor 1/ (1+ β A).

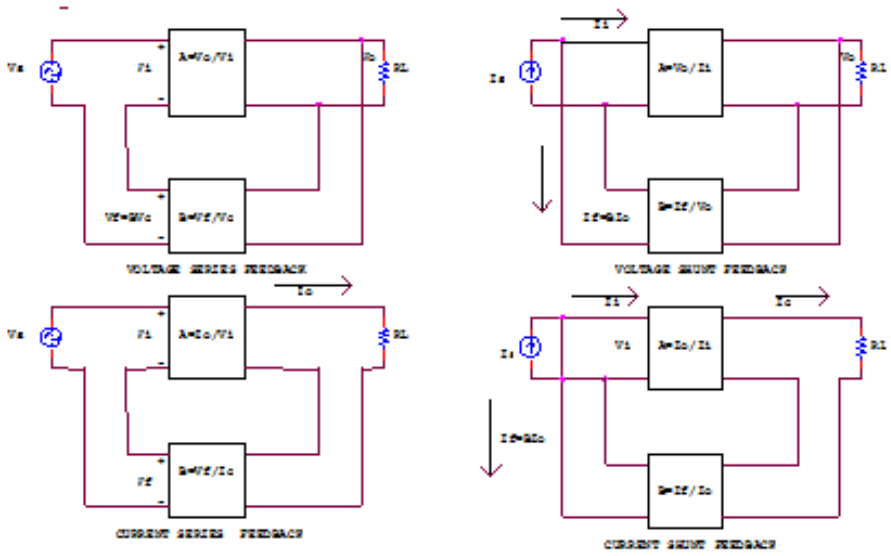
The feedback is proportional to the output voltage V_{out} and feedback current I_f. $I_f$gets added in shunt with the input. Thus this circuit from the case of voltage shunt inverse feedback amplifier.

Feedback current, $I_f = V_{in} - V_{out}/R_F = Vout/RF = \beta V_{out}$

Current Series Feedback: - This is also called the series derived series feedback. In such a feedback circuit, a part of the output current is made to develop voltage proportional to the output current and supplied back in series with the input .Since feedback network is in series with the amplifier on the output end as well as on the input end , both input and output impedances are increased with negative feedback. The current feedback can be obtained by removing the bypass capacitor across the emitter resistor R_E.

Current Shunt Feedback: - It is also known as series derived shunt feed feedback or current shunt inverse feedback. In this circuit the feedback network pick up a part of the output current and produces a feedback voltage in parallel with the input signal voltage. input impedance is reduced with feedback where as the output impedance is increased because of feedback network being in series with the output.

CIRCUIT DIAGRAM:-



DISCUSSION:-What are the applications of voltage series feedback amplifier?

RESULT:-Series and parallel voltage & current feedback circuit have been studied.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. What is the application of negative feedback amplifier?
Ans. Negative feedback amplifier makes the circuit stable.

Q2. What is voltage series feedback amplifier?
Ans. It is that amplifier in which output voltage feedback in voltage series with input Signal, resulting in an overall gain reduction.

Q3. What is the overall voltage gain with feedback in voltage series feedback amplifier?
Ans. The overall voltage gain with feedback in voltage series feedback amplifier is given by:-

$A_F=V_O/V_s=A/(1+A\beta)$

Where A= gain without feedback, β= feedback

Q4. What is the effect on input resistance due to series feedback connections?
Ans. Series feedback connections tend to increase the input resistance.

Q5. What is the effect on input resistance due to shunt feedback connections?
Ans. Shunt feedback connections tend to decrease the input resistance.

Q6. What is the effect on output impedance due to voltage feedback
Ans. Voltage feedback tends to decrease the output impedance.

Q7. What is the effect on output impedance due to current feedback
Ans. Current feedback tends to increase the output impedance.

Q8. Which factor reduces the input noise & non-linear distortions of the amplifier?
Ans. $(1+A\beta)$

Q9. What is the effect of frequency on phase shift of an amplifier?
Ans. Phase Shift of an amplifier will change with frequency.

Q10. What is the effect on output impedance of the voltage series feedback amplifier?
Ans. $Z_{of} = Z_o/(1+A\beta)$

EXPERIMENT NO:4

AIM:-Design and realize Inverting, Non-Inverting and buffer amplifier using 741 Op-amp.

APPARATUS REQUIRED: - CRO, Function Generator, Bread Board, 741 IC, ± 12V supply, resistors1KΩ, 10KΩ, and connecting leads.

THEORY: - The op-amp is a multi-terminal device used in a number of electronic circuits.

Inverting Amplifier: - In the inverting amplifier only one input is applied and that is to the inverting input (V2) terminal. The non-inverting input terminal (V1) is grounded.

Since,

$$V1= 0 \text{ V } \& \text{ } V2= V_{in}$$

$$Vo= -Av_{in}$$

The negative sign indicates the output voltage is 180° out of phase with respect to the input and amplified by gain A.

Non-Inverting Amplifier: - The input is applied to the non-inverting input terminal and the Inverting terminal is connected to the ground.

$$V1= V_{in} \text{ and } V2= 0 \text{ volts}$$

$$Vo= Av_{in}$$

The output voltage is larger than the input voltage by gain A & is in phase with the input signal.

Buffer amplifier:-The lowest gain that can be obtained from a non-inverting amplifier with Unity feedback. When the non-inverting amplifier is for unity gain it is called a voltage follower because the output voltage is equal to and in phase with the input .In the Voltage follower the output follows the input Since the voltage follower is a special case of the non inverting amplifier, all the Formulae developed for the latter are applicable to the former aspect that the gain of the feedback circuit is UNITY.

$$A_f = 1$$

$$R \text{ (if)} = A \text{ } Ri$$

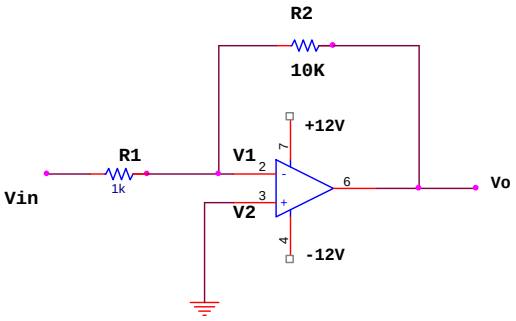
$$R \text{ (of)} = Ro/A$$

$$Vo = \pm Vsat/A$$

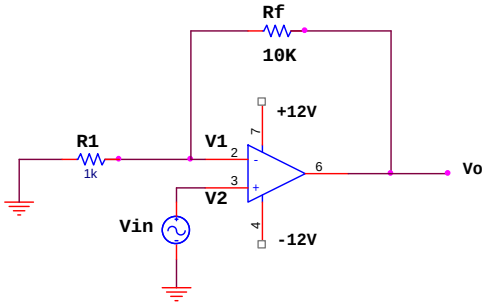
$$\text{Since } (1+A) \cong A$$

The voltage follower is also called a non inverting buffer because, when placed between two networks, it removes the loading on the first network.

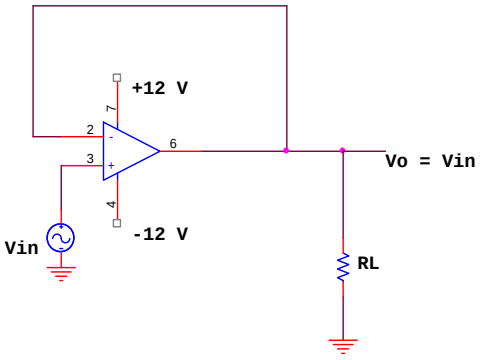
CIRCUIT DIAGRAM: -



INVERTING AMPLIFIER



NON-INVERTING AMPLIFIER



BUFFER AMPLIFIER

PROCEDURE: -

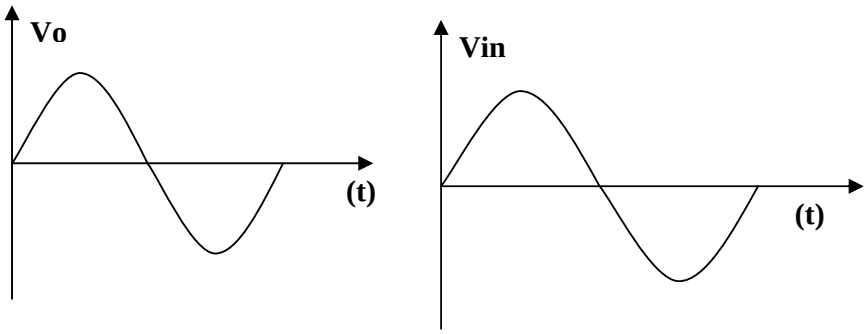
(1) Connect the circuit for inverting, non-inverting and buffer amplifier on a breadboard.
(2) Connect the input terminal of the op-amp to function generator and output terminal to CRO.
(3) Feed input from function generator and observe the output on CRO.
(4) Draw the input and output waveforms on graph paper.

OUTPUT WAVEFORM:-

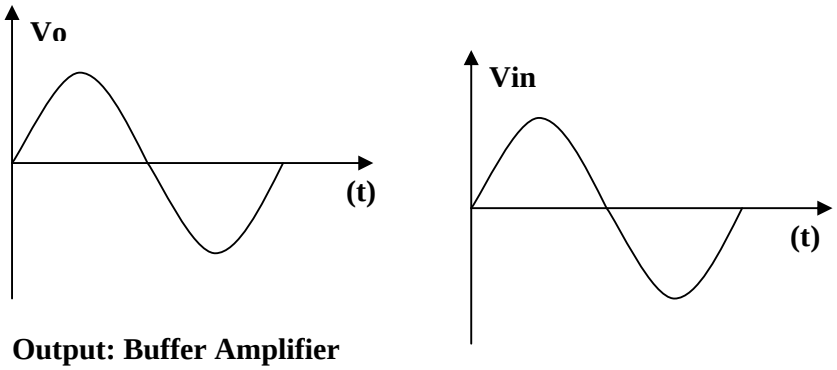
Vo **Vin**

TIME (t) **TIME (t)**

Output: Inverting Amplifier



Output: Non- Inverting Amplifier



Output: Buffer Amplifier

PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply.
2. Before connecting the power supply plug into socket, ensure power supply should be switched off
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DISCUSSIONS:-What are the application of inverting, non-inverting and buffer amplifier?

RESULT: - Amplified output waveforms are obtained.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. What is the significance of a differential amplifier?
Ans. The differential amplifier is capable of amplifying dc as well as ac input signals.

Q2. what are the applications of a differential amplifier?
Ans. In instrumentation systems

Q3. What is the meaning of CMRR?

Ans. It is the ratio of the differential voltage gain A_d to the common mode voltage gain A_{cm}.

Q4. What is the unit of CMRR?
Ans. Decibels (dB)

Q5. What is the value of CMRR for the 742 IC /
Ans. 90 dB

Q6. what is the gain of the inverting amplifier in terms of resistances?
Ans. Gain (- Rf/Ri)

Q7. what is the gain of the non- inverting amplifier in terms of resistances?
Ans. Gain = (1+Rf/Ri)

Q8. what is the condition for averaging amplifier?
Ans. Rf/Ri =1/n, where n is no. of inputs applied.

Q9. What is the effect of –ve feedback on the voltage gain of an amplifier?
Ans. Increases the stability of its voltage gain.

Q10. What is meaning of gain of an amplifier with feedback?
Ans. Closed loop voltage gain

EXPERIMENT NO.5

AIM: - Verify the operation of a differentiator circuit using op amp 741 and show that it acts as a high pass filter.

APPARATUS REQUIRED:- CRO, Function Generator, ± 12 Supply, Connecting Leads, 741 IC, capacitor 0.1μf, resistor 1KΩ, Breadboard.

THEORY: - Differentiator circuit as its name implies, performs the mathematical operation of differentiation, that is, the output waveform is the derivative of the input. The differentiator may be constructed from a basic inverting amplifier when an input resistor R_1 is replaced by a capacitor C,

$$V_o = - R_f C \, dV_{in}/dt$$

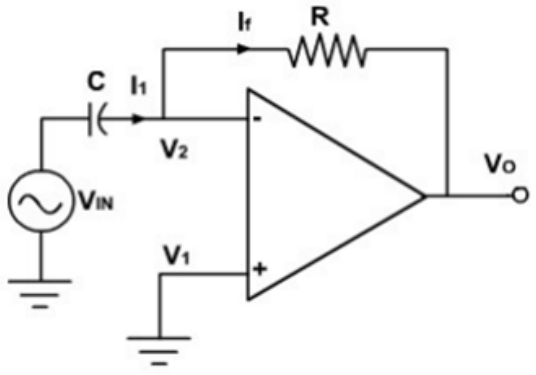
Thus, the output Vo is equal to the R_f C times the negative instantaneous rate of change of the input voltage V_{in} with time. The true differentiation is a form of high pass filtering.

$$H(j\omega) = -Z_f / Zi = -R_f / 1/j\omega C$$

$$H(j\omega) = - R_f j\omega C$$

Magnitude of H (jω) is M (ω) = $\omega R_f C$ The function is very small at low frequencies but increases linearly as the frequency increases. This explanation indicates that true differentiator is a form of high, pass filtering.

CIRCUIT DIAGRAM:-



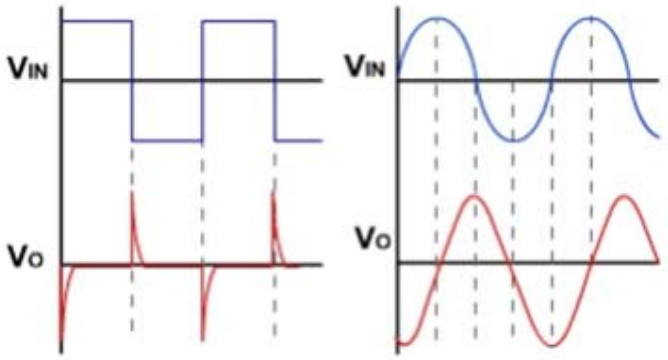
PROCEDURE: -

(1) Connect the circuit. according to the circuit diagram.
(2) Apply square wave to the input terminal of differentiator circuit.
(3) Set the input voltage at 1V peak to peak and frequency at 1 KHz.
(4) Note down the input and output waveform.

OBSERVATION TABLE:-

S.NO	I/P Voltage Vin	O/P Voltage Vo	Frequency in KHz.	Gain=20log V0/Vin

GRAPH:-



PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply.
2. Before connecting the power supply plug into socket, ensure power supply should be switched off
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DISCUSSION: - What is the application of differentiator?

RESULT: -Wave forms shows integrator is a high pass filter.

QUIZ QUESTIONS WITH ANSWERS:-

Q1.What is the differentiator?
Ans. The differentiator is that circuit in which o/p waveforms is the derivative of the input waveforms.

Q2. What is non-linear wave shaping?
Ans. Non-linear wave shaping is the process on applying any wave at input of a non-linear device, the shape of the output waves varies non-linearly with the input wave.

Q3. Give the application of a differentiator?
Ans. It is used in wave shaping circuits to detect high frequency components in an input signal and also as a rate of change of detector in F.M modulation.

Q4. What is the significance of input capacitor in a differentiator?
Ans. Input capacitor in a differentiator combines with feedback resister, selects lower cut off frequency.

Q5. When input of a differentiator is sine wave, then what is the output of the Differentiator ?
Ans. Cosine wave.

Q6. What is the condition of differentiator for proper operating?
Ans. $T > R_f C_1$.

Q7. When input of a differentiator is square wave, then what is the output of a differentiator?
Ans. Spikes waves

Q8. Give the examples of linear circuits.
Ans. Adder, Subtractor, Integrator, Differentiator

Q9. When a number of stages are connected in parallel, the overall gain is the product of the individual stage gains.
Ans. False statement

Q10. A filter that provides a constant output from dc up to a cutoff frequency and passes no signal above that frequency is called a _____ filter.
Ans. Low-pass

EXPERIMENT NO. 6

AIM: - Verify the operation of Integrator circuit using op amp 741 and show that it acts as a low pass filter.

APPARATUS REQUIRED: - CRO, Function generator, ±12V supply, 741 IC, Breadboard, Resistors10KΩ, 1KΩ, capacitor 0.1μf and connecting leads

THEORY: - A circuit in which the output waveform is the integral of the input wave is the integrator. Such a circuit is obtained by using a basic inverting amplifier configuration. If the feedback resistor R_f is replaced by a capacitor C. The output voltage can be obtained by,

$$Vo = - 1/ R C_f \int Vin\ dt + C$$

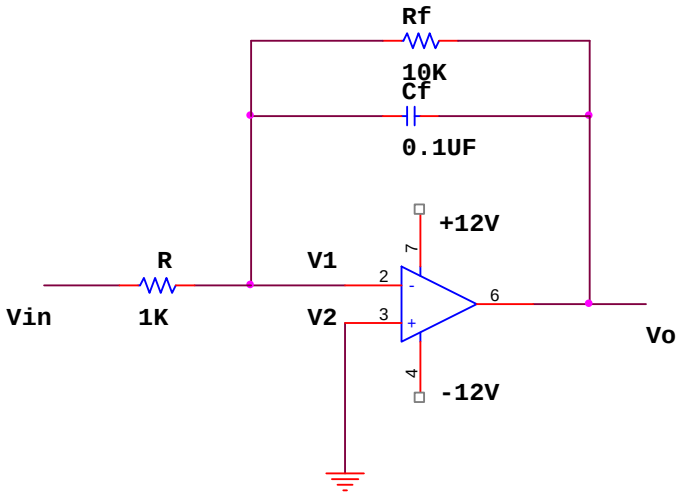
Where C is the integration constant and proportional to the value of the output Voltage Vo at time t = 0 sec. Thus, the output voltage is directly proportional to the negative integral of the input voltage and inversely proportional to the time constant R C_f. The convenient way to introduce the AC integration circuit is through frequency response and impedance consideration. The transfer function for the true integrator is given by

$$H(j\omega) = - Zf / Zi = -\frac{1/j\omega c}{R}$$

$$H(j\omega) = - 1/ j\omega cR$$

Amplitude response, $M(\omega) = 1 / \omega RC$ It is clear that integration is a form of low pass filtering i.e., the function is very large at low frequency and decreases as the frequency increases.

CIRCUIT DIAGRAM: -



INTEGRATED CIRCUIT

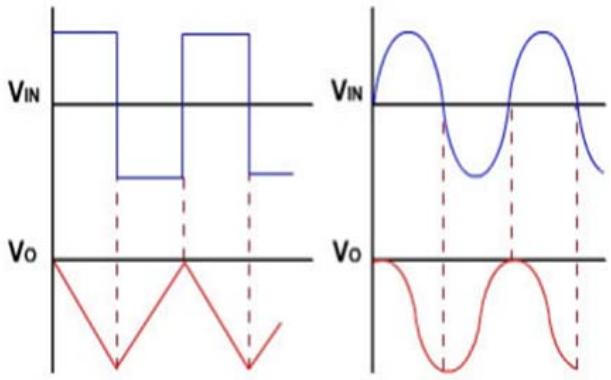
PROCEDURE: -

(1) Connect the circuit according to the circuit diagram.
(2) Apply square wave to the input terminal of integrator circuit.
(3) Set the input voltage at 1V peak to peak and frequency at 1 KHz.
(4) Note down the input and output waveform.
(5) Draw the waveform on graph paper.

OBSERVATION TABLE: -

S.NO	I/P Voltage Vin	O/P Voltage Vo	Frequency in KHz.	Gain=20log Vo/ Vin

GRAPH:-



PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply.
2. Before connecting the power supply plug into socket, ensure power supply should be switched off.
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DISCUSSION: - What is the application of integrator?

RESULT: - Waveforms shows Integrator acts as low pass filter.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. What is the integrator?
Ans. The integrator is that circuit in which output voltage is equal to the –ve of integral of input voltage.

Q2. What is the input offset voltage?
Ans. Input offset voltage is the error voltage that occurs at the i/p of op-amp, which causes to produce o/p offset voltages.

Q3. Why we use capacitor Cf in feedback loops of the integrator?
Ans. The feedback capacitor Cf combine with Rf is used to select cut off voltage.

Q4. What is the relation between input and output voltage?
Ans. Output voltage Vo is equal to the –ve of integral of input voltage.

Q5. If input of the integrator is sine wave, then which type of waveforms will obtain at the output of the integrator?
Ans. Cosine wave

Q6. What is the effect of resistor R_f that is connected across the feedback capacitor Cf in practical integrator?
Ans. The feedback resistor R_f that remove the high frequency noise signals.

Q7. If input of the integrator is d.c. voltage, then which type of waveforms will be obtained at the output of the integrator?
Ans. Ramp waveforms.

Q8. If input of the integrator is square wave , then, which type of waveforms will be obtain at the output of the integrator.
Ans. Triangular waveforms

Q9. What are the applications of an integrator?
Ans. It is used in analog computer, ADC, signal wave shaping circuits.

Q10. What is the effect of input bias current?
Ans. Input bias current produces output offset voltage at the output of an op-amp.

EXPERIMENT NO. 7

AIM: - Design & verify the operations of op amp adder and subtractor circuit.

APPARATUS REQUIRED:- CRO, function generator, ± 12V supply, breadboard, 741 IC, resistors 1KΩ (7 pieces), and Connecting leads.

THEORY: -

Adder: - If the input to the inverting amplifier is increased, the resulting circuit is known as Adder. Output is a linear summation of number of input signals. Each input signal produces a component of the output signal that is completely independent of the other input signal. When there are two inputs i.e.

$$Vo = -(V1 + V2)$$

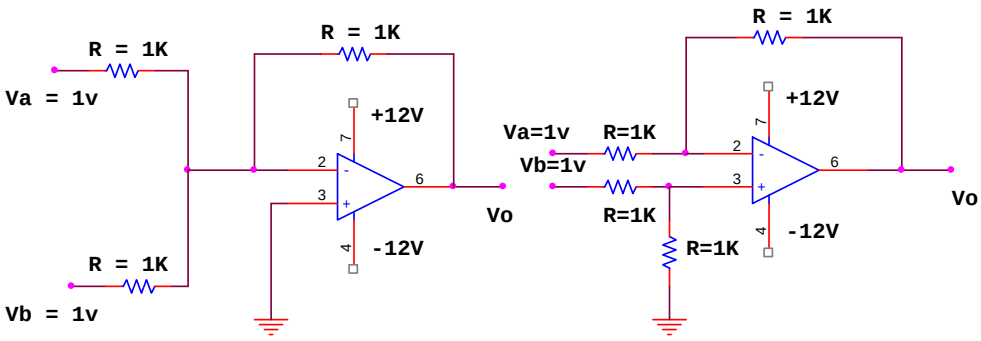
This is the inverted algebraic sum of all the inputs. If we connect the inputs to non-inverting, terminal then the adder is non-inverting adder.

Subtractor: - A circuit that finds the difference between two signals is called a subtractor. The two inputs are applied at the inverting & non-inverting terminal of op-amp. If all external resistance are equal in value, so the gain of the amplifier is equal to 1.The output voltages of the differential amplifier with a gain of unity is,

$$Vo = -R\backslash R(Va-Vb)$$

$$Vo = (Vb-Va)$$

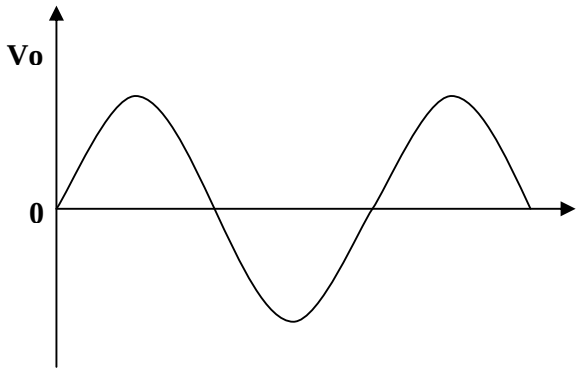
CIRCUIT DIAGRAM: -



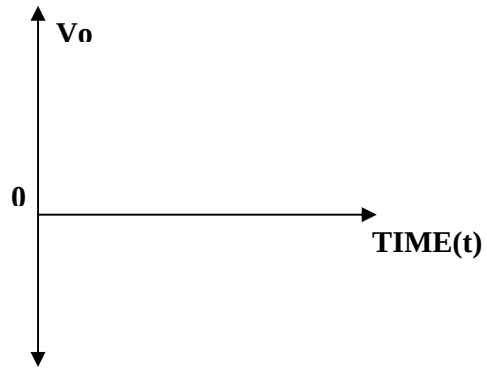
PROCEDURE: -

(1) Apply two different sine waves signal to the input of the adder and subtractor.
(2) Give the input amplitude of 5v peak to peak and frequency of 1 kHz.
(3) Verify the output on CRO.

WAVE FORM: -



ADDER



SUBTRACTOR

PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply.
2. Before connecting the power supply plug into socket, ensure power supply should be switched off
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DICUSSION:-Name the areas where adder and sub tractor circuits are used.

RESULT: - Output is a true replica of the subtraction values of the two inputs and addition of two input values.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. What is adder?
Ans. Adder is that circuit which adds the magnitude of input signals.

Q2. What is scaling amplifier?
Ans. Scaling amplifier is that circuit in which each i/p is amplified by a weighted differently at the o/p and values of resistors are different.

Q3. What is average amplifier?
Ans. Average amplifier is that circuit in which each output is equal to the average of all the input voltage and the gain by which each input is amplified must be equal to 1 over the number of inputs.

Q4. What is the subtractor?
Ans. Subtract or is that circuit which subtracts the magnitude of input signals.

Q5. What is the use of offset minimizing resistor Rom?
Ans. To reduce the effect of i/p bias current on the o/p offset o/p.

Q6. What is gain of the inverting amplifier?
Ans. AF= - Rf / Ri

Q7. What are the applications of subtractor?
Ans. Computer, calculators, microprocessor.

Q8. what is the use of offset null compensating network in the adder?
Ans. To improves the accuracy of the adder.

Q9. What is the gain of an inverting amplifier?
Ans. Output voltage is equal to the –ve of ratio of feedback and i/p resistance.

Q10. What are the applications of adder?
Ans. Computer, calculators, microprocessor.

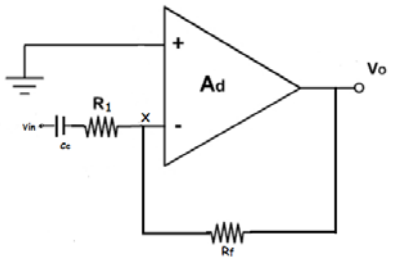
EXPERIMENT NO.8

AIM:-Plot frequency response of ac coupled amplifier using opamp 741 and study the effect of negative feedback on the bandwidth and gain of the amplifier.

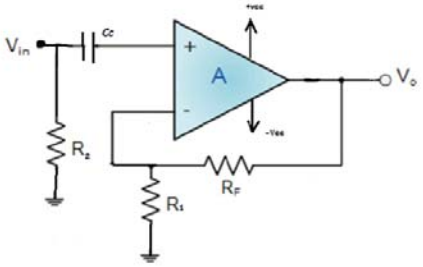
APPARATUS REQUIRED: - CRO, Function Generator, Bread Board, 741 IC, ± 12V supply, resistors1KΩ, 10KΩ, capacitors and connecting leads.

THEORY:-Inverting and non inverting amplifier respond to both ac and dc. For studying only ac frequency response, or if the ac input signal is superimposed on some dc level, it is necessary to block dc component, by using ac coupling capacitor. Two types of AC amplifier:-

1) Inverting
2) Non inverting



Inverting AC amplifier



Non-Inverting AC amplifier

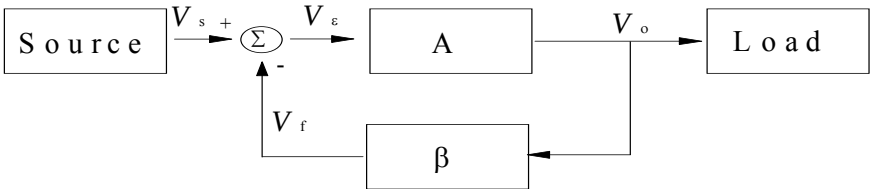
PROCEDURE: -

(1) Set the input voltage at 1V peak to peak and frequency at 1 KHz.
(2) Varying the frequency of the input signal from 10Hz to1MHz.
(3) Measure the output signal amplitude.
(4) Draw the frequency response characteristics of AC coupled amplifier.

OBSERVATION TABLE:-

S.NO.	FREQUENCY (Hz)	OUTPUT VOLTAGE (Vout)	GAIN (Vout/ Vin) IN dB

EFFECT OF NEGATIVE FEEDBACK ON GAIN AND BANDWIDTH:-



A: Open Loop Gain $A = V_o / V_\varepsilon$

β : Feedback factor $\beta = V_f / V_o$

Negative feedback takes a sample of the output signal and applies it to the input to get several desirable properties. In amplifiers, negative feedback can be applied to get the following properties

- Desensitized gain : gain less sensitive to circuit component variations
- Reduce nonlinear distortion : output proportional to input (constant gain independent of signal level)
- Reduce effect of noise
- Control input and output impedances by applying appropriate feedback topologies
- Extend bandwidth of amplifier

All of these properties can be achieved by trading off gain

NEGATIVE FEEDBACK: - If the signal fed back is of opposite polarity or out of phase by 180◦ (or odd integer multiple of 180◦) with respect to input signal, feedback is called negative feedback.

- Negative feedback is also known as **degenerative feedback** because when used it degenerates (reduces)the output voltage amplitude and in turn reduces the voltage gain.

USES:

- When used in amplifier, negative feedback stabilizes the gain, increases the bandwidth and changes the input and output resistances, reduced voltage gain, decrease in non linear distortion and reduces the effect of variations in temperature and supply voltages on the output of op-amp.

RESULT:-

(a) Frequency response curve of AC coupled amplifier has been plotted
(b) Negative feedback increases the bandwidth and stabilizes the gain.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. What is feedback in amplifiers?
Ans. The process of combining a fraction of output energy back to the input is called feedback.

Q2. What is the application of negative feedback amplifier?
Ans. Negative feedback amplifier makes the circuit stable.

Q3. What is voltage series feedback amplifier?
Ans. It is that amplifier in which output voltage feedback in voltage series with input Signal, resulting in an overall gain reduction.

Q4. By Which factor reduces the input noise & non-linear distortions of the amplifier?
Ans. $(1+A\beta)$

Q5. what is the effect of frequency on phase shift of an amplifier?
Ans. Shift of an amplifier will change with frequency.

Q6. How does negative feedback increase bandwidth of an amplifier?
Ans. The bandwidth of an amplifier without feedback is equal to separation between 3 db frequencies f1 and f2. If A is the gain, then gain bandwidth product is A* BW. With the negative feedback the amplifier gain is reduced and since gain bandwidth product has to remain constant in both cases, so the bandwidth will increase to compensate for the reduction in gain.
Q7.How do series and shunt feedback differ from each other?
Ans. Series means feedback connecting in series with input signal while shunt means feedback connecting in shunt with input signal.

Q8. Distortion in an amplifier with negative feedback increases or decreases?
Ans. Decreases

Q9. Feedback in an amplifier always helps to
Ans. Control its output

Q10.When negative feedback is applied to an amplifier, its bandwidth:
Ans. Increased.

EXPERIMENT NO.9

AIM: -Study of IC 555 as astable and monostable multivibrator.

APPARATUS REQUIRED: - IC 555

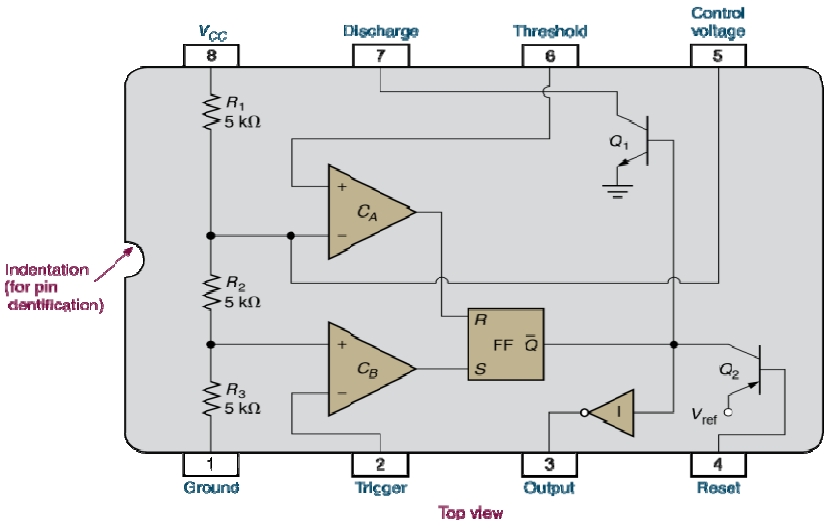
THEORY: -

555 timer – An 8-pin IC designed for use in a variety of switching applications.
Multivibrator – A circuit designed to have zero, one, or two stable output states. There are three types of multivibrators:

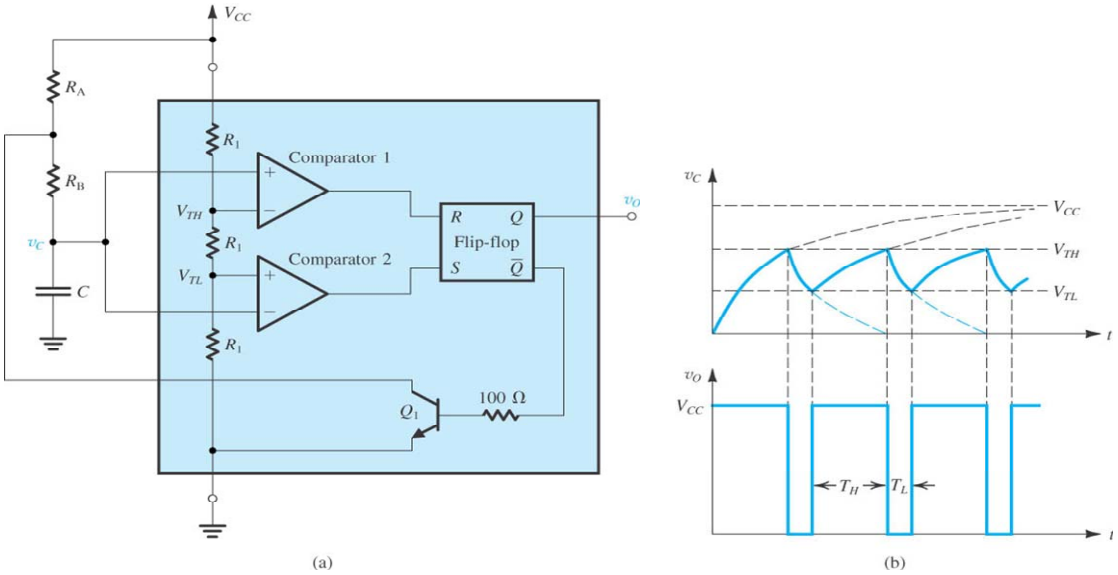
- Astable (or Free-Running Multivibrator)
- Monostable (or One-Shot)
- Bistable (or Flip-Flop)

Astable multivibrator – A switching circuit that has no stable output state. The astable multivibrator is a rectangular wave oscillator. Also referred to as a free-running multivibrator.
Monostable multivibrator – A switching circuit with one stable output state. Also referred to as a one-shot. The one-shot produces a single output pulse when it receives a valid input trigger signal.
Bistable multivibrator – A switching circuit with two stable output states. Also referred to as a flip-flop. The output changes state when it receives a valid input trigger signal, and remains in that state until another valid trigger signal is received.

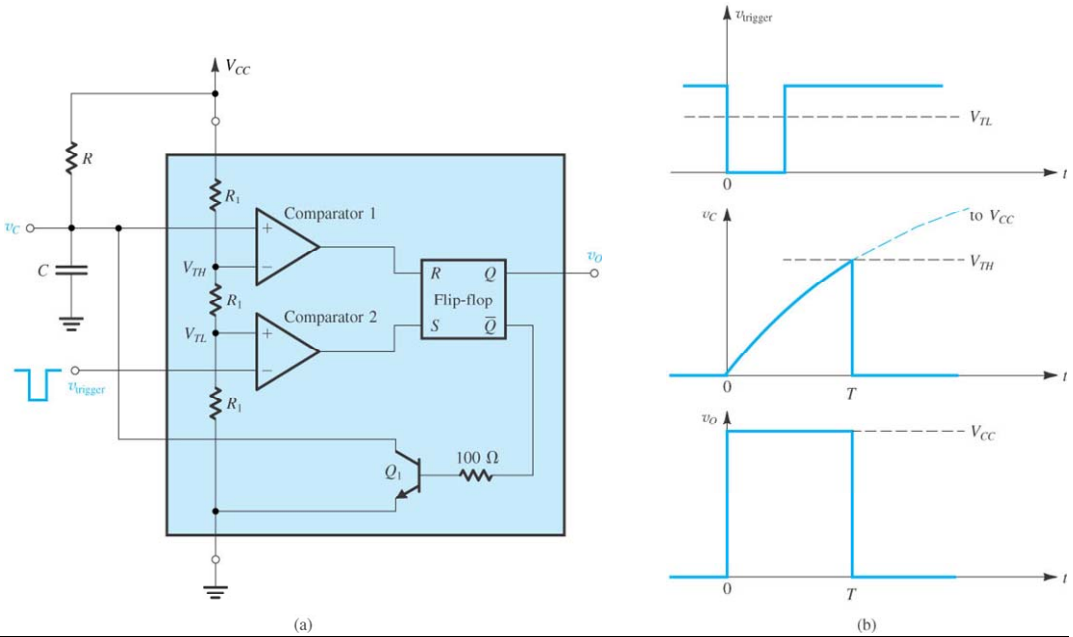
PIN CONFIGURATION OF IC 555:-



CIRCUIT DIAGRAM & WAVEFORM OF ASTABLE MULTIVIBRATOR: -



CIRCUIT DIAGRAM & WAVEFORM OF MONOSTABLE MULTIVIBRATOR: -



RESULT: - Astable and monostable multivibrator has been studied.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. Why astable multivibrator is known as free running multivibrator?
Ans. A multivibrator that generates square wave of its own is known as astable multivibrator. This has no stable state. There are two quasi stable states. The circuit changes automatically from one quasi state to another without any external triggering pulse. Thus it is just an oscillator since it does not require any external pulse for its operation so it is known as free running multivibrator.

Q2.In an astable multivibrator, the frequency of output mainly depends on:
Ans. Values of R and C in circuit.

Q3. A monostable multivibrator has:
Ans. only one stable stage

Q4. A bistable multivibrator has:
Ans. two stable stages

Q5. A circuit that generates square wave is called:
Ans. Astable multivibrator

Q6. What is the use of reset pin in IC 555?
Ans. Reset pin controls flip flop directly.

Q7. What is the use of discharge pin in IC 555?
Ans. discharge pin used for discharging the capacitor.

Q8. What are the applications of multivibrators?
Ans: (i) used to generate square wave and pulse generator
(ii) used as frequency dividers
(iii) used in radar and TV circuits

Q9.Which type of feedback is used in multivibrator?
Ans: A multivibrator circuit is essentially an amplifier with 100% positive feedback.

Q10. How many states in switch?
Ans: Two

EXPERIMENT NO.10

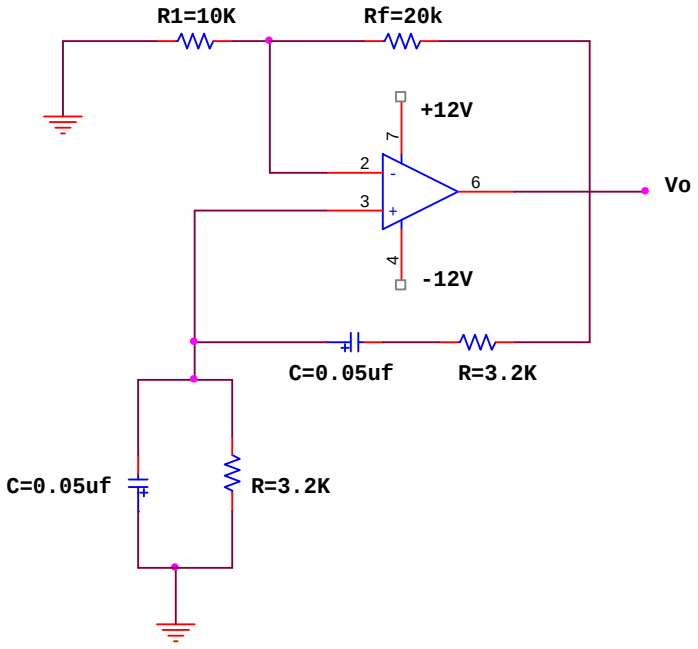
AIM: - Design and realize using op amp741, wein bridge oscillator.

APPARATUS REQUIRED:- Bread board, CRO, ± 12V power supply, Resistors 10KΩ, 20KΩ, 3.2KΩ, 0.05μf, and connecting leads.

THEORY: - In Wein bridge oscillator, Wein bridge circuit are connected between amplifier input and output terminal. The bridge have a series RC network in one arm and a Parallel RC network in adjoining arm, on the remaining two arms of bridge, resistor R_1 and R_f are connected. The phase angle criterion for oscillator is that the total phase shift around the circuit must be 0°.This condition occurs only when the bridge is balanced, i.e. at resonance. The frequency of oscillation f_0 is exactly the resonant frequency of the balanced wein bridge and is given by

$$f_0 = 1/2\pi RC = 0.159/RC$$

CIRCUIT DIAGRAM:-

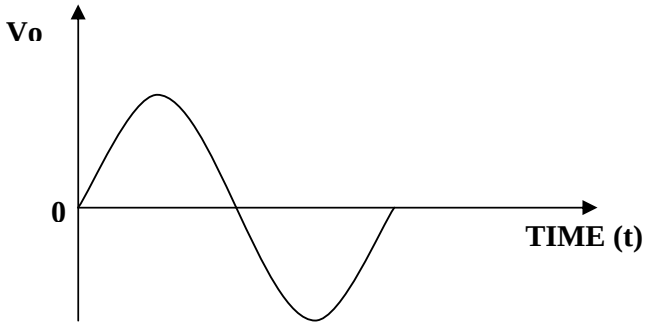


WEIN BRIDGE OSCILLATOR

PROCEDURE: -

(1) Connect the circuit as per the circuit diagram.
(2) Switch 'on' the power supply.
(3) Output of the circuit is shown on CRO.

WAVE FORM: -



PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply?
2. Before connecting the power supply plug into socket, ensure power supply should be switched off
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DICUSSION: - Wein bridge oscillator generates sine wave forms.

RESULT: - Sine wave is generated on CRO.

QUIZ QUESTIONS WITH ANSWERS:

Q1. What is the oscillator?
Ans. The oscillator is a circuit that generates repetitive waveforms of fixed amplitudes and frequency without any external i/p signal.

Q2. What is the application of the oscillator?
Ans. A radio, T.V., Computers and communications.

Q.3 what is the principle of the oscillator?
Ans. If the signal feedback is of proper magnitude and phase, the circuit produces alternating currents or voltage.

Q4. what are the two requirements for oscillation?
Ans. 1. Magnitude of the loop gain must be at least 1
2. Total phase shift of the loop gain must be equal to 0 or 360 degree.

Q5. What is frequency stability?
Ans. The ability of the oscillator circuit to oscillate at one exact frequency is frequency stability.

Q6. What is the total phase for oscillation?
Ans. 360 or 0 degree.

Q7. What is the condition for wein bridge oscillator to balance?
Ans. Total phase shift around the circuit must be 0 degree.

Q8. What is wein bridge oscillator?
Ans. Wein bridge oscillators that circuit in which the wein bridge circuit is connected between the amplifiers i/p terminals and the o/p terminals.

Q9. Which type of feedback used in oscillator?
Ans. +ve feedback

Q10. What is the frequency response for a wein bridge oscillator?
Ans. F= 0.159/RC

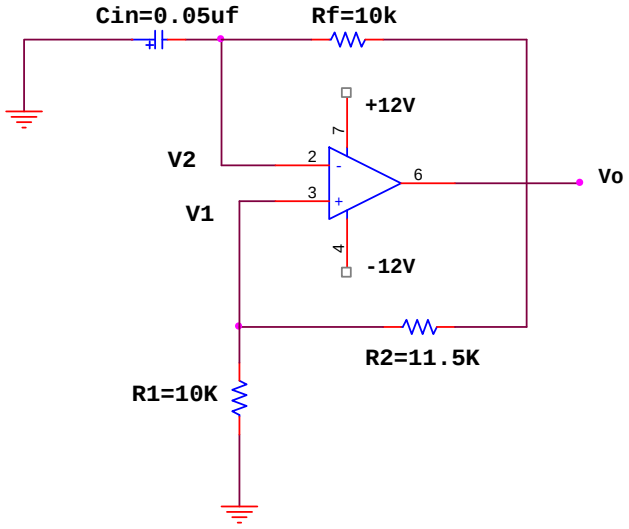
EXPERIMENT NO.11

AIM: - To design and realize using op amp741, square wave generator.

APPARATUS REQUIRED: - Power supply, CRO, Function Generator, Connecting Leads, Breadboard, 741 IC, Resistance (10KΩ, 11.5KΩ), 0.05μf capacitor.

THEORY: - Square Waves are generated when the Op-Amp is forced to operate in the saturation region. That is, the output of the op-amp is forced to swing respectively between $+V_{sat.}$ and $-V_{sat.}$ resulting in the generation of square wave. The square wave generator is also called a free- running or astable multivibrator. Assuming the voltage across capacitor C is zero at the instant the d.c Supply voltage at +Vcc and $-V_{EE}$ are applied. Initially the capacitance C acts, as a short circuit. The gain of the Op-Amp is very large hence V_1 drives the output of the Op-Amp to its saturation.

CIRCUIT DIAGRAM: -

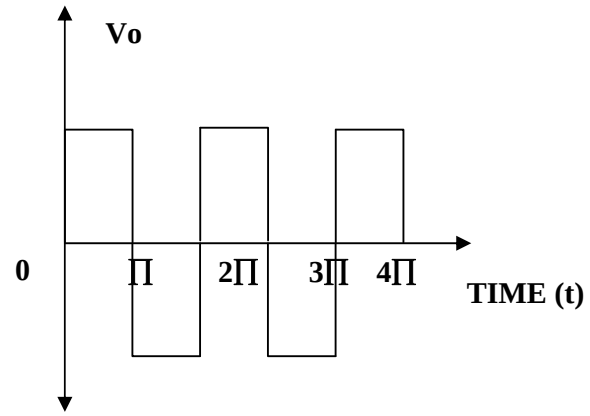


SQUARE WAVE GENERATOR

PROCEDURE: -

(1) Connect the circuit as shown in figure Switch 'ON' the supply.
(2) No. Input signal is feed from the generator. It is self-generating.
(3) Frequency can be varied by changing RC combination.
(4) Output is obtained at Pin 6 of op-Amp.

WAVE FORM:



PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply.
2. Before connecting the power supply plug into socket, ensure power supply should be switched off.
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DICUSSION:-What is the application of squire wave generator.

RESULT: - Squire Wave is obtained on CRO.

QUIZ QUESTIONS WITH ANSWERS:-

Q1.What is square wave generator?
Ans. In this circuit, square wave output is generated when the op-amp is forced to Operates in the saturated region.

Q2.What is other name of square wave generator?
Ans. Free running or a stable multivibrator.

Q3**.** Give the application of a square wave generator
Ans. To generate square wave form at the output of a square wave generator.

Q4. What is the use of zener diode?
Ans. To set amplitude of square wave at the input of a square wave generator.

Q5. What is the effect of slew rate of the op-amp in the square wave generator?
Ans. The highest frequency generated by square wave generator is set by slew rate of the op-amp.

Q6. Which type of wave forms obtained at the output of a square wave generator?
Ans. Square wave waveforms

Q7**.** When input of a square wave generator is a D.C signal, then what is the output of a square wave generator?
Ans. Ramp signal.

Q8. What is the comparator?
Ans. Comparator compares two input signal i.e. know voltage with a reference voltage.

Q9. What are the applications of a comparator?
Ans. Analog to digital converter (ADC), Schmitt Trigger.

Q10. Which component is required to convert a square wave into a triangular wave?
Ans**.** Integrator.

EXEPERIMENT NO.12

AIM: - To design and realize using op amp 741, logarithmic amplifier & VCCS.

APPARATUS REQUIRED: - CRO, function generator, breadboard, resistor 10KΩ, 1 KΩ and 12V supply, diode IN 4007 and connecting leads.

THEORY OF LOGARITHMIC AMPLIFIER: - In fig., there is an op-amp with the feedback resister R replaced by the diode D. Logarithmic amplifier is used when it is desired to have the output voltage proportional to the logarithm of the input voltage. We know from the volt-ampere diode characteristic

$$\text{If} \quad I = I_o (e^{Vf/nVt} - 1)$$

$$I = I_o e^{Vf/nVt}$$

Provided that $V_f/nV_t >> 1$ or $If >> Io$. Hence

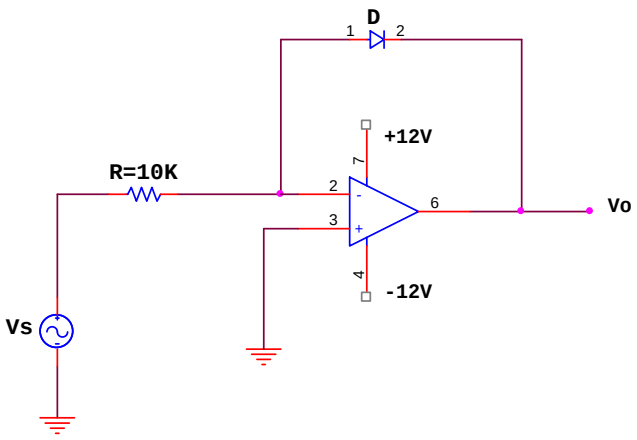
$$V_f = nVt (I_n I_f - I_n I_o) \quad \text{---------} \quad (1)$$

Since $I_f = I_s = V_s/R$ due to the virtual ground at the amplifier input, then

$$V_o = - V_f = - nVt (I_n V_s/R - I_n I_o) \quad \text{----------} \quad (2)$$

From Eq^n. (2) the output voltage V_o is temperature dependent due to the scale factor nV_t and to the saturation current Io.

CIRCUIT DIAGRAM:-



LOGARITHMIC AMPLIFIER

PROCEDURE: -

(1) Connect the circuit on the breadboard as per circuit diagram.
(2) Switch on the power supply and observe the output waveform on the CRO.

WAVE FORM: -

Vi V0

0 π 2π 3π TIME (t) 0

THEORY OF VCCS (VOLTAGE CONTROLLED CURRENT SOURCE):-

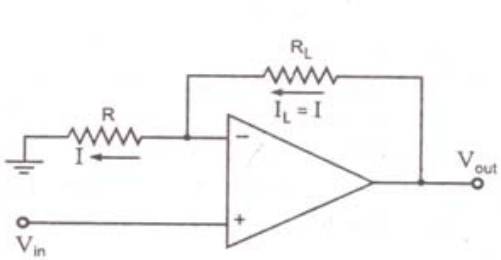
In many applications, one may have to convert a voltage signal to a proportional output current. A circuit which can perform this job is called a voltage –to- current converter. For this, there are two types of circuits possible:

V-I Converter with floating load
V-I Converter with grounded load

$I_L = I = V_{in} / R$

From above Eq. it is obvious that the output current I_L is independent of load resistance R_L and is proportional to the input voltage V_{in}. This is because of the virtual ground at the inverting input terminal of the op-amp. Such a circuit is employed in analog-to- digital converter (ADC).One good thing about the Op-amp. Voltage –to-current converter is that it can be driven by a voltage source which is itself not capable of supplying the load current called I_L. This is because the voltage source only has a drive a Non- inverting Op-amplifier, whose input impedance is very high. The load current itself is supplied by the Op-amplifier.

CIRCUIT DIAGRAM: -



Voltage-To-Current Converter

PROCEDURE: -

1. Connect the circuit as shown in figure Switch 'ON' the supply.
2. A voltage is given to the input pin.
3. Output is obtained at Pin 6 of op-Amp.

PRECAUTIONS:-

1. Do not use open ended wires for connecting to 230 V power supply
2. Before connecting the power supply plug into socket, ensure power supply should be switched off
3. Ensure all connections should be tight before switching on the power supply.
4. Take the reading carefully.
5. Power supply should be switched off after completion of experiment.

DICUSSION: - How can we use logarithmic amplifier as a clipper circuit?
How VCCS is ideal circuit for low voltage dc and ac voltmeters?

RESULT: -Output is the negative of the log of an input.
In VCCS, load current depends upon the input voltage Vin and resistor R.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. what is sample and hold circuit?
Ans. A sample and hold circuit samples an input signal and holds on to its last sampled value until the input sampled again.

Q2. what is the application of sample and hold circuit?
Ans. Digital interfacing, ADC, pulse code modulation system.

Q3. what is the application of logarithmic amplifier?
Ans. Calculator, computer.

Q4. what is the function of a diode in a feedback loop in a logarithmic amplifier?
Ans. In logarithmic amplifier circuit, diode acts as clipper.

Q5. what is the other name of clamper?
Ans. DC inserter or restorer.

Q6. what is the use of resistor R in clamper?
Ans. The resistor R is used to protect the OP-AMP. Against excessive discharge current from capacitor especially when the DC supply voltages are switched off.

Q7. What is positive clipper?
Ans. Positive calipers are one which removes the positive half cycles of the input voltage.

Q8. what is negative clipper?
Ans. Negative calipers are one which removes negative half cycles of the input voltage.

Q9. what is clamping?
Ans. A circuit that places either the positive or negative half cycles of the input voltage.

Q10. How many types of clampers are there?
Ans. There are two types of clampers
(1) Positive clamper
(2) Negative clamper

Q11. What is current to voltage converter?
Ans: A device that produces a voltage proportional to input signal current is called I to V converter.

Q12. What are the applications of VCCS?
Ans; It is an ideal circuit for low voltage dc and ac voltmeter, LED and zener diode tester.

Q13. What are the applications of I to V converter?
Ans: used in sensing current from photodetectors and in digital to analog converter.

Q14. what is Voltage to Current converter.
Ans. A circuit that produces output current proportional to input voltage.

Q15. How many types of voltage to current converter are there?
Ans. There are two types of voltage to current converter: With floating load and with grounded load.

Q16. What is good thing about op-amp.
Ans. It I can be driven by a voltage source which itself is not capable of supplying the load current.

Q17. In V-C converter output current is proportional to,
Ans. The light flux.

Q18. what is the equation of output current,
Ans. I=Vin/R

EXPERIMENT NO: 13

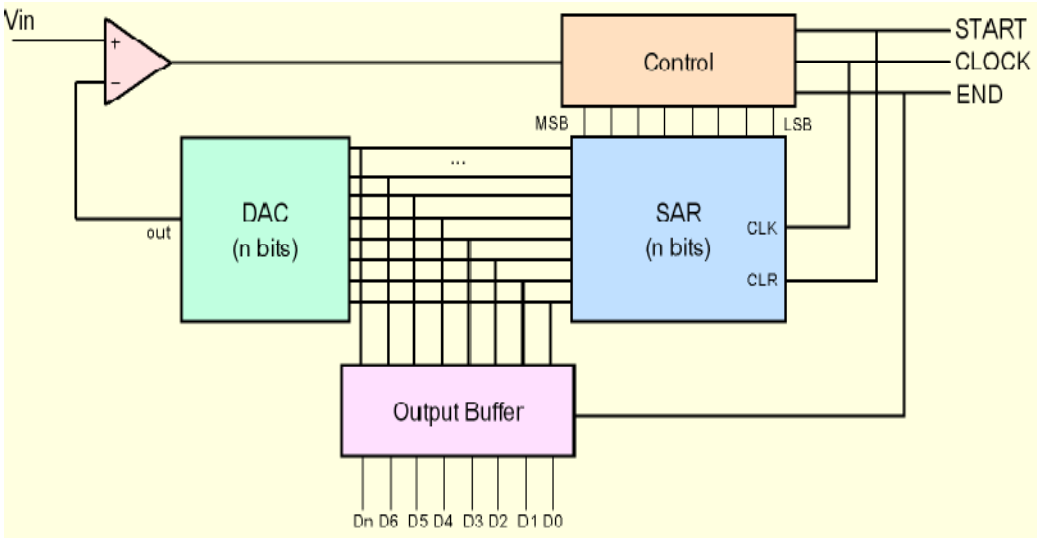
AIM: -Study of 8-bit monolithic Analog to digital converter.

APPARATUS REQUIRED: - ST2601 with power supply cord, Connecting Cords

THEORY: - Successive approximation ADC uses one or a few comparators, operated iteratively, to yield high accuracy conversion with far fewer components than flash conversion.

A/D converter using successive approximation technique effectively performs a binary search in a digital analog look up table and using a digital to analog converter (DAC) and comparator circuit. Successive approximation converters also allow higher resolutions but tend to be slower since they usually require N cycles to produce the answer. Successive approximation ADC operates at much slower conversion rates than flash ADC. Sub ranging analog to digital converters provide an intermediate compromise between flash ADCs and successive approximation ADCs. Sub ranging analog to digital converters typically use a low resolution flash quantizer during a first or coarse pass to convert the analog input signal into the most significant bits (MSB) of its digital value. A digital to analog converter (DAC) then generates an analog version of the MSB word. The residue signal is sent through one or more fine passes to produce the lower significant bits of the input signal. The lower significant bits and the MSB word are then combined by digital error correcting circuitry to produce the desired digital output word. A switched capacitor analog to digital converter (ADC) operated according to successive approximation register technique comprises a plurality of weighted capacitors with associated switches and a local DAC. The capacitors are charged by a voltage sample of an analog signal to be converted. The voltage sample is compared with an analog signal generated by the local DAC.

CIRCUIT DIAGRAM:-



PROCEDURE:-

1. Connect supply to the trainer.
2. Make the connections as shown in figure.
   a. Connect the USB/ BOB to GND.
   b. Connect the DC output to V_i of Monolithic converter.
   c. Keep the DC potentiometer in counterclockwise direction.
   d. Keep the Auto /Manual switch in Auto position.
3. Switch ON the power supply.
4. Vary the DC potentiometer and observe the corresponding digital output on LEDs.
5. Now keep the Auto /Manual switch in Manual position.
6. Keep the Blank / Convert switch in Blank position
7. Vary the DC potentiometer
8. Set the switch to convert position, The LEDs will light forming a digital word which corresponds to the digital conversion of the analog voltage applied to the input.
9. Perform the same procedure with different DC voltages.
10. Now, connect the USB / BOB terminal to +5V and bipolar o/p to Vi. This gives Output voltage from +2.5V to -2.5V.
11. Keep the switch in Auto position.
12. Vary the Bipolar potentiometer from -2.5V to +2.5V, and note the corresponding digitized outputs.
13. Set the Auto / Manual switch to manuals position.
14. Keep the Blank / Convert switch to blank position.
15. Now to observe the conversion you have to throw the switch to convert position.
16. Perform the experiment with various DC inputs.

RESULTS:-According to applied input signal in form of DC level it provides the digital signals in 1 and 0 forms.

QUIZ QUESTIONS WITH ANSWERS:-

Q1. What is Analog to digital converter?
Ans: Analog to Digital Converters (ADC) is device that converts continuous signals to discrete digital numbers.

Q2. How many types of analog to digital converters are there?
Ans: Analog to Digital Converters is commonly of two types.

- Linear Analog to Digital Converter is designed to produce an output which is a linear function or proportional to the output.
- The other common type of Analog to Digital Converter is the Logarithmic Analog to Digital Converter, which functions by using voiced communications systems to increase the entropy of the digitized signal.

Q3. Why to use analog to digital converter?
Ans: A digital signal is superior to an analog signal because it is more robust to noise and can easily be recovered, corrected and amplified. For this reason, the tendency today is to change an analog signal to digital data.

Q4. What are the steps to execute the process of analog to digital converter?
Ans: Analog to digital converter process is executed in three steps:
1. Sampling
2. Quantizing
3. Coding

Q5. What do you mean by sampling?
Ans: To convert continuous time signal to discrete time signal, a process is used called as sampling.

Q6. What is sampling theorem?
Ans: The Sampling Theorem states that a signal can be exactly reproduced if it is sampled at a frequency Fs , where Fs is greater than twice the maximum frequency Fmax in the signal.

$$Fs > 2 \cdot Fmax$$

Q7. Which of the following is a type of error associated with digital-to-analog converters (DACs)?
Ans. nonmonotonic and offset error

Q8. A 4-bit R/2R digital-to-analog (DAC) converter has a reference of 5 volts. What is the analog output for the input code 0101.
Ans. 3.125V

Q9. What is the resolution of a digital-to-analog converter (DAC)?
Ans. It is the smallest analog output change that can occur as a result of an increment in the digital input.

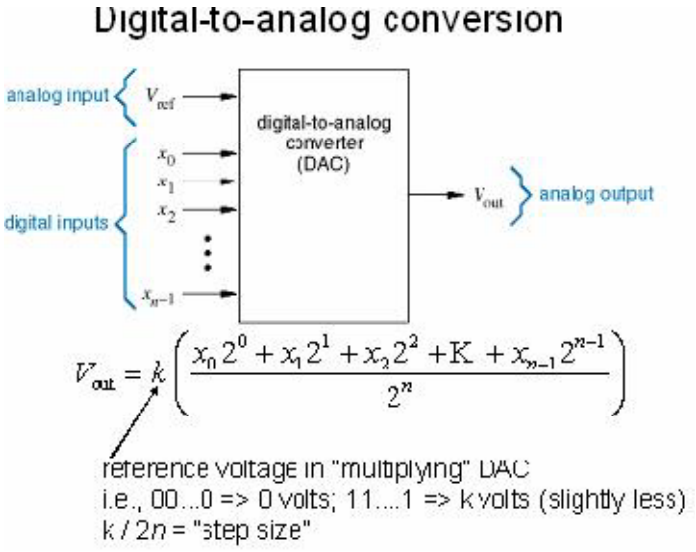
Q10. The practical use of binary-weighted digital-to-analog converters is limited to:
Ans: 4-bit D/A converters

EXPERIMENT NO: 14

AIM: -Study of R-2R ladder network and 8-bit monolithic digital to analog converter.

APPARATUS REQUIRED: - ST2602 with power supply cord, Connecting Cords.

THEORY: -The digital to analog converters compose the devices transforming a digital word, binary encoded and generated for example by a computer, into a discrete analog signal, in the sense that to every input digital word a single output analog value corresponds.



PROCEDURE:-

1. Connect the power supply to the board.
2. Connect the D_0- D_3 of the logic switches to the corresponding jacks B_0-B_3 of the converter.
3. Set the switches S_0-S_3 to logic level 0.
4. Connect the V_{REF} socket to +5V.
5. Connect a Multi meter as voltmeter for DC, to the output V_0 of the converter.
6. Switch the logic switches in binary progression & measure & record the output voltage in correspondence of every combination of the input code.
7. With input code S_3 S_2 S_1 S_0 = 0000 the output voltage V_O has to be null: eventual little deviations against zero are due to the operational amplifier offset.
8. Switch off the power supply.

OBSERVATION TABLE: -

S0	S1	S2	S3	Vo(V)
0	0	0	0	
0	0	0	1	
0	0	1	1	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

RESULT:-As per the applied inputs through the switches then according to the reference voltage the output voltage is generated in analog form.

QUIZ QUESTIONS:-

Q1.The difference between analog voltage represented by two adjacent digital codes, or the analog step size, is the:
Ans: Resolution

Q2. The primary disadvantage of the flash analog-to digital converter (ADC) is that:
Ans: a large number of comparators is required to represent a reasonable sized binary number

Q3.What is the major advantage of the R/2R ladder digital-to-analog (DAC), as compared to a binary-weighted digital-to-analog DAC converter?
Ans. It only uses two different resistor values.

Q4. The resolution of a 0–5 V 6-bit digital-to-analog converter (DAC) is:
Ans. 1.56 %

Q5. In a flash analog-to-digital converter, the output of each comparator is connected to an input of a:
Ans. Priority Encoder

Q6. Which is not an analog-to-digital (ADC) conversion error?
Ans. differential nonlinearity

Q7. Sample-and-hold circuits in analog-to digital converters (ADCs) are designed to:
Ans. stabilize the input analog signal during the conversion process

Q8. A 4-bit R/2R digital-to-analog (DAC) converter has a reference of 5 volts. What is the analog output for the input code 0101.
Ans. 3.125V

Q9. What is the resolution of a digital-to-analog converter (DAC)?
Ans. It is the smallest analog output change that can occur as a result of an increment in the digital input.

Q10. The practical use of binary-weighted digital-to-analog converters is limited to:
Ans: 4-bit D/A converters