PROJECT

OPAMP LABORATORY ALL-IN-ONE KIT

Developed in accordance to VTU (Visvesvaraya Technological University, Belagavi), MEASUREMENTS and OP-AMP LABORATORY (Sub Code: 17EE5DLMOL)

Project Contributors:

- Dr. Balaji N (Professor EEE, DSCE, Bangalore)
- Raghunath Reddy K (Assistant Professor EEE, DSCE, Bangalore)
- Vybhav Nag M G (Student B.E EEE, DSCE, Bangalore)

Table of Contents:

Power Supply

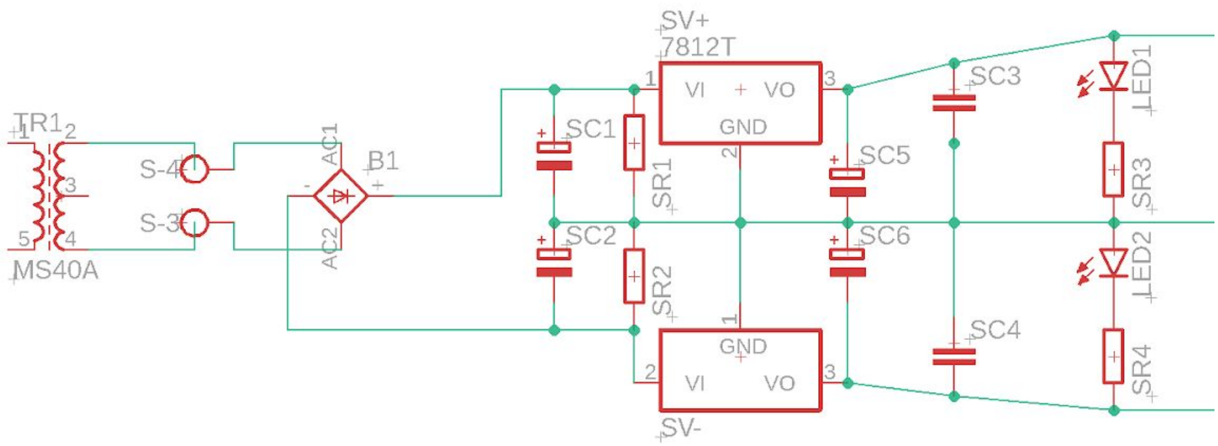


Fig. Power Supply

Rectifier :

- B1 = Diode Rectifier Module (1Amp)
- S3, S4 = Screw Connectors for transformers
- Sc1, Sc2 (T1, T2) = Supply Filter Capacitors

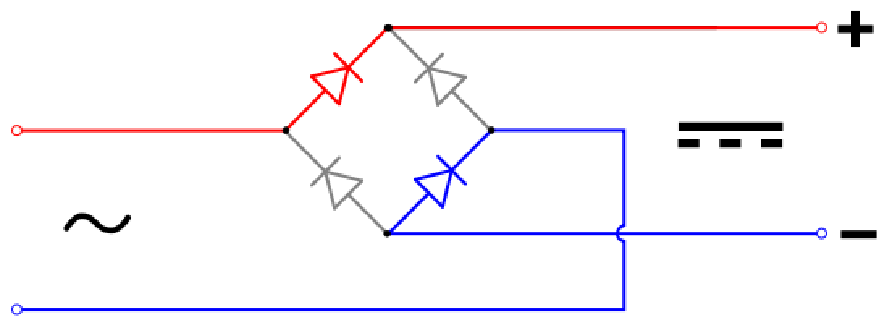


Fig. Bridge Rectifier Using Diodes

Filter :

- SRx = Supply Resistors (SR1, SR2, SR3, SR4)
- SCx = Supply Filter Capacitors (SC3, SC4, SC5, SC6)
- SV+ = LM7812 +ve voltage regulator (1amp)
- SV - = LM7912 - ve voltage regulator (1amp)
- LEDx = Indicators for +ve and -ve Supply Output (LED1, LED2)

- S2 & S1 (CRP2) = Regulated DC Output
- G = Ground

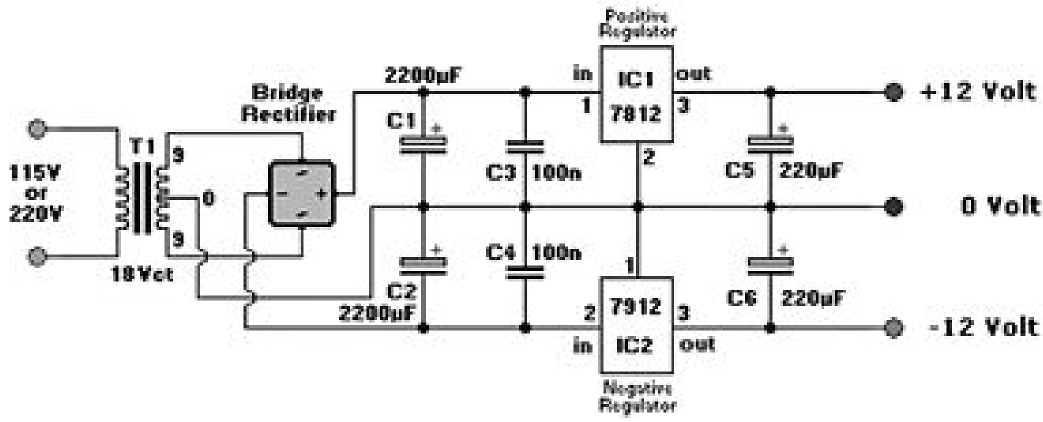
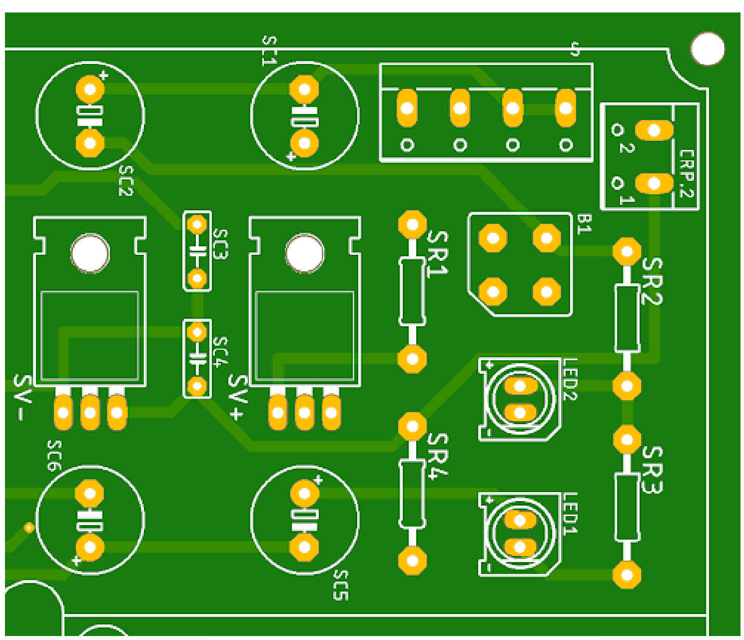


Fig. Rectifier With Voltage Regulators

Test / Probe Points: (connection = Terminal 1 & Terminal 2)

- **S3 & S4** for Stepped Down Transformer AC output (Sine Wave)
- **SC1 + & SC2 - (without capacitors installed)** for unfiltered rectified pulsating DC
- **SC1 + & SC2 - (with capacitors installed)** for filtered rectified pulsating DC
- **CRP2 + & G** for regulated +ve supply
- **CRP2 - & G** for regulated - ve supply

PCB Layout :



Section A Op-Amp

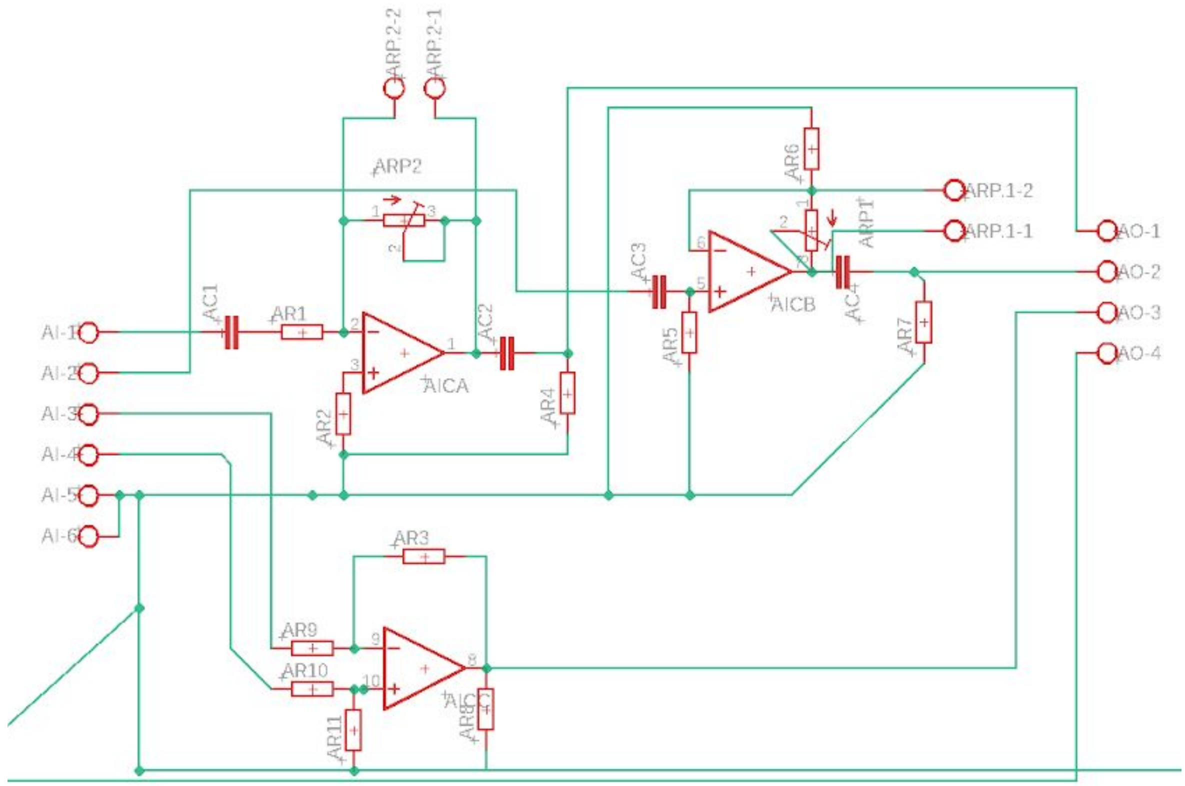


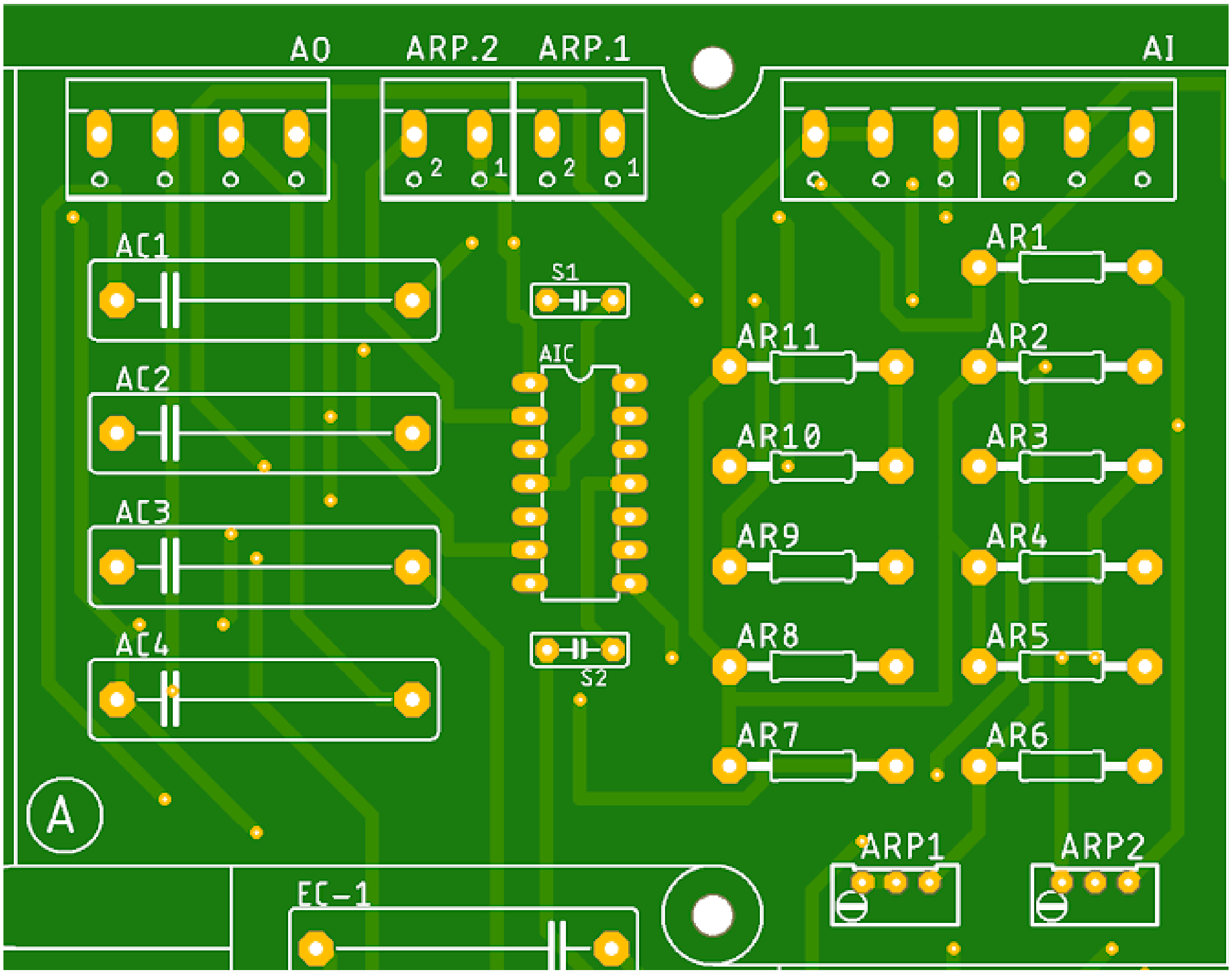
Fig. Section A Op-Amp Circuit

2.1 NON-INVERTING AC OP-AMP AMPLIFIER
2.2 INVERTING AC OP-AMP AMPLIFIER
2.3 DIFFERENCE AMPLIFIER

Components:

- LM324 Op-amp
- Resistors
- Capacitors
- POT (decade resistance Box or variable resistor)
- Decade Capacitance Box or Variable Capacitor
- Signal Generator (Section C circuit can be Used)
- CRO with Probles
- Wires

PCB layout:



AO
ARP.2
ARP.1
AI
AC1
AC2
AC3
AC4
S1
AIC
S2
AR1
AR2
AR3
AR4
AR5
AR6
AR7
AR8
AR9
AR10
AR11
ARP1
ARP2
EC-1
A

2.1 Non-inverting amplifier:

Theory:

It is a linear closed loop mode application of op-amp and employs negative feedback. The ARP1 and AR6 is the feedback network. AC3and AR5 form the input impedance network of the circuit. There will be no phase difference between the output and input. Hence it is called non-inverting amplifier. The input signal Vi is applied to the non - inverting input terminal of the op-amp through AC3 at AI2 terminal. This circuit amplifies the signal without inverting the input signal. It is also called negative feedback system since the output is feedback to the inverting input terminal. The differential voltage Vd at the inverting input terminal of the op-amp is zero ideally and the output voltage is given as, Vo = ACL Vin

$$A_v = \frac{V_0}{V_{in}} = 1 + \frac{ARP_1}{AR_6}$$

Here the +Ve sign indicates that the output will be an amplified wave in phase with the input. By varying the feedback network the gain of the amplifier can be varied to any desired value. The gain is always greater than 1. As the ideal voltage controlled voltage source, this amplifier exhibits high input impedance, low output impedance, and stable voltage gain.

Design:

The bias current resistor AR5 and load resistor AR7 are given

AR5 = -------kΩ

AR7 = -------kΩ

Calculation of input capacitor value

The input capacitive impedance $X_{AC3} = \frac{AR_5}{10}\Big|_{At\, f_1}$ $X_{AC3} = \frac{AR_5}{10}\Big|_{At\, f_1}$ where f1 is the input cutoff frequency

Calculation of output capacitor value

The output capacitive impedance $X_{AC2} = AR_7|_{At\, f_1}$ $X_{AC2} = AR_7|_{At\, f_1}$ where f1 is the input cutoff frequency

Select appropriate gain of the circuit and conduct the experiment and draw the output voltage magnitude vs input frequency curve.

Procedure for frequency response:

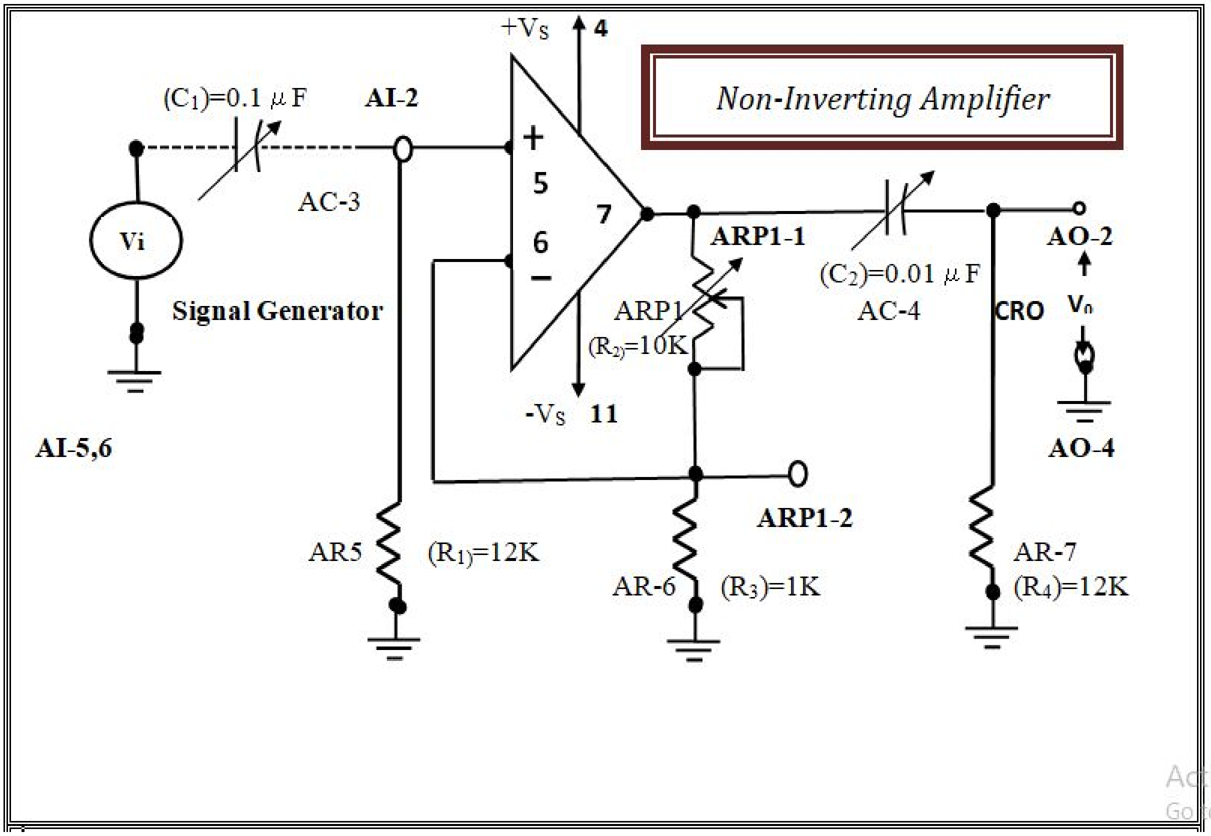
1) Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2) Insert the designed capacitor(AC3) values in to the circuit

3) Vary the input frequency from minimum to 10 times the cut-off frequency.

4) Calculate the gain in dB and plot the graph of frequency vs gain in dB

5) From the graph calculate the f_l.

Circuit diagram:



Calculations:

Gain $A_v = \frac{V_0}{V_{in}} = 1 + \frac{APR_1}{AR_6}$

$A_{VT} = 1 + \frac{APR_1}{AR_6}$

$A_{VT} = 1 + \frac{ARP_1}{AR_6}$ $A_{VT} = 1 + \frac{ARP_1}{AR_6}$

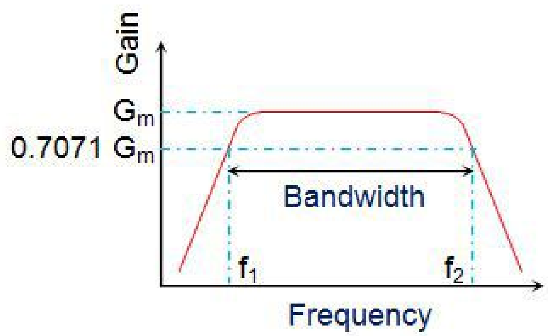
$f_l = \frac{1}{2\pi(\frac{R_1}{10})C_1}$ $\frac{1}{2\pi(\frac{R_1}{10})C_1}$

$R_L = \frac{1}{2\pi f_1 C_2}$ $\frac{1}{2\pi f_1 C_2}$

Tabular column: at gain of _______

Sl. No.	F(Hz)	V_o in volts	$A_{VP}= \frac{V_o}{V_i} \frac{V_o}{V_i}$

<u>Typical graph</u>:



<u>Procedure for Gain Characteristics</u>:

1) Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2) Insert the designed capacitor (AC3) values in to the circuit
3) Set the Input signal (Vi in mV) with a frequency (Input frequency= mid band frequency) at suitable magnitude.
4) Vary the APR1 (DRB) to obtain different gain.
5) Draw a graph between theoretical and practical gain

<u>Tabular column</u>: Gain Characteristics Verification at mid band frequency

Sl. No.	APR1(Ω)	V_o in volts	$A_{VP}= \frac{V_o}{V_i} \frac{V_o}{V_i}$	$A_{VT} = 1 + \frac{ARP_1}{AR_6}$	$A_{VP}= \frac{V_o}{V_i} \frac{V_o}{V_i}$

2.2 Inverting Amplifier:

Theory:

It is a closed loop mode application of opamp and employs negative feedback. The ARP2,AR1 and AC1are the feedback , input resistance and capacitance of the circuit respectively. AC1 blocks the DC component in the input signal. The input signal Vi is applied to the inverting input terminal through AI1 and the non-inverting input terminal of the op-amp is grounded through AR2. The input terminal of the op-amp draws no current because of the large input impedance. The potential difference across the input terminals of an opamp is zero because of the large open loop gain. Due to these two conditions, the inverting terminal is at virtual ground potential. So the current flowing through AR1 and ARP2 are the same.

$I_i = I_f$---------- (1)

The output voltage Vo is fed back to the inverting input terminal through the ARP2- AR1 network, where ARP2 is the feedback resistor. The output voltage is given as,

V_o = - ACL V_i
That is Vin/ AR1 = - Vo / ARP2 ------ due to equ(1)
Therefore $V_o/V_{in} = A_v$ = - ARP2/ AR1
Here the negative sign indicates that the output will be an amplified wave with 180° phase Shift (inverted output). By varying the ARP2 or AR1, the gain of the amplifier can be varied to any desired value. This amplifier exhibits modest input impedance, low output impedance, and stable inverting voltage gain.

Design:

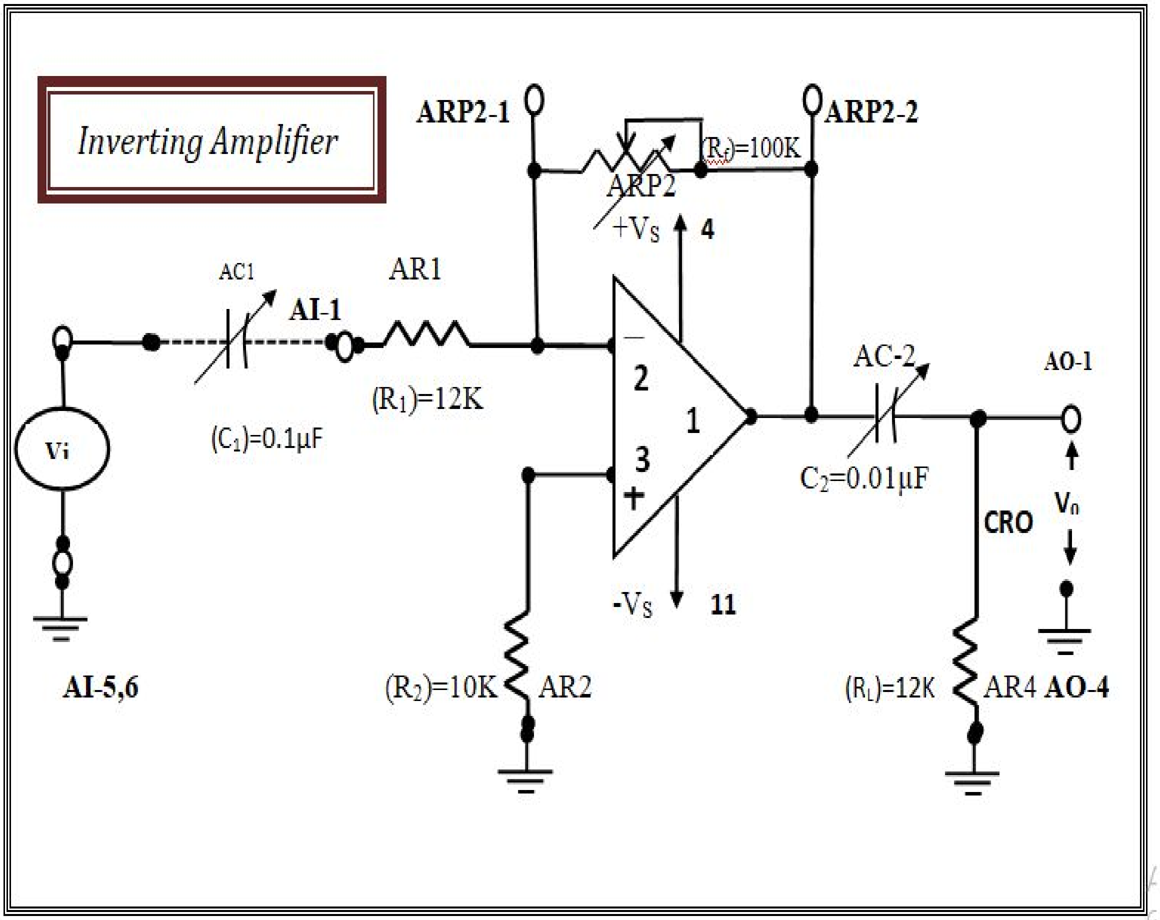
The bias current resistor AR1 and load resistor AR4 are given
AR1 = -------kΩ
AR4 = -------kΩ
Calculation of input capacitor value

The input capacitive impedance $X_{AC1} = \frac{AR_1}{10}\Big|_{At\, f_1}$ $X_{AC1} = \frac{AR_1}{10}\Big|_{At\, f_1}$ where f1 is the input cutoff frequency

Calculation of output capacitor value

The output capacitive impedance $X_{AC2} = AR_4|_{At\, f_1}$ $X_{AC2} = AR_4|_{At\, f_1}$ where f1 is the input cutoff frequency

Select appropriate gain of the circuit and conduct the experiment and draw the output voltage magnitude vs input frequency.



Circuit diagram:

Procedure for Frequency Response:

1) Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2) Insert the designed capacitor(AC1) values in to the circuit
3) Vary the input frequency from minimum to 10 times the cut-off frequency.
4) Calculate the gain in dB and plot the graph of frequency vs gain in dB.
5) From the graph calculate the f_1.

Tabular column: at gain of _______

Sl. No.	F(Hz)	V_o in volts	$A_{VP}= \frac{V_o}{V_i} \frac{V_o}{V_i}$	Gain (dB) = 20log A_{VP}

Procedure for Gain Characteristics:

1) Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2) Insert the designed capacitor (AC1) values in to the circuit.
3) Set the Input signal (Vi in mV) with a frequency (Input frequency= mid band frequency) at suitable magnitude.
4) Vary the APR2 (DRB) to obtain different gain.
5) Draw a graph between theoretical and practical gain

Tabular column: Gain Characteristics Verification at mid band frequency

Sl. No.	APR1(Ω)	V_o in volts	$A_{VP}= \frac{V_o}{V_i} \frac{V_o}{V_i}$	A_{VT} = - ARP2/ AR1

2.3 DIFFERENCE AMPLIFIER

Aim: To verify the gain characteristics of a DC Difference amplifier.

Theory:

An op amp difference amplifier can be created by combining both a non-inverting voltage amplifier and an inverting voltage amplifier in a single stage. Difference amplifier is a circuit that gives the amplified version of the difference of the two inputs. Proper gain matching between the two paths is essential to maximize the common-mode rejection ratio. Differential gain is equal to the gain of the inverting path. Vo =A(V2-V1), Where V1 and V2 are the inputs and A is the voltage gain. Here input voltage V2 is connected to non-inverting terminal through AI4 and V1 to the inverting terminal through AI3. Output of a difference amplifier can be determined using super position theorem. When V1=0, the circuit becomes an non-inverting amplifier with input V2 and the resulting output is $V_{02} = \frac{AR_3}{AR_9}(V_2)$ $V_{02} = \frac{AR_3}{AR_9}(V_2)$ .When V2=0, the circuit become a non-inverting amplifier with input V1 and the resulting output is $V_{01} = \frac{AR_3}{AR_9}(V_1)$ $V_{01} = \frac{AR_3}{AR_9}(V_1)$. Therefore the resulting output according to super position theorem is

$$V_{0T} = V_{01} + V_{02} = \frac{AR_3}{AR_9}(V_2 - V_1)$$

Design:

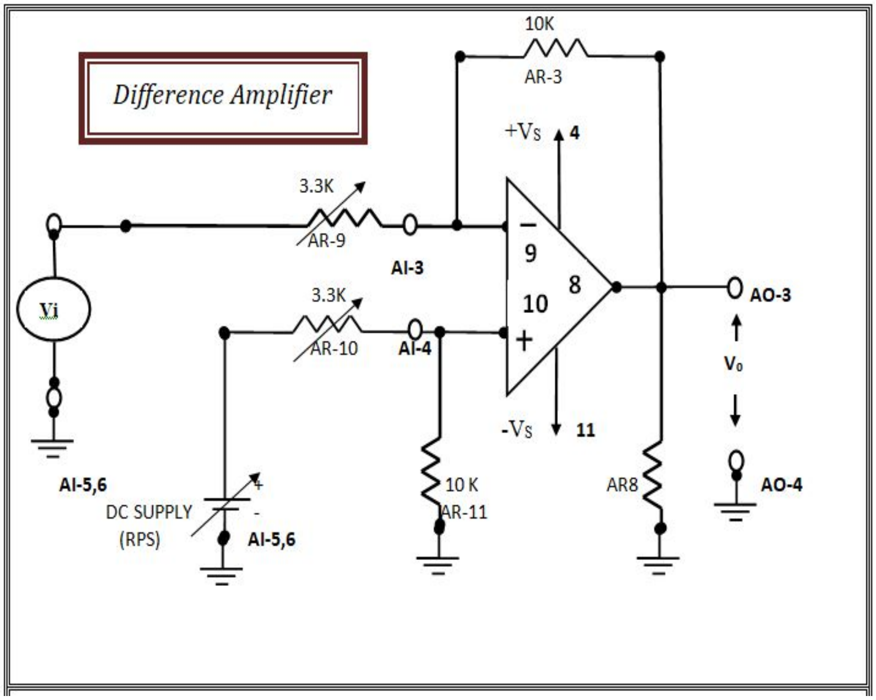
The resistor AR3 and AR11 are given
AR3 = AR11= -------kΩ

For the required gain select AR9 = AR10= --------kΩ
Vary the DC voltage and note down the output voltage

Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2. Set the Input signal (Vi in Volts) with a frequency at suitable magnitude using function generator.
3. Vary the DC voltage by using RPS and note down the output voltage.
4. Compare theoretical and practical values.

Circuit diagram:



Tabular column:

SN.O	V_{DC}(RPS)	V_{OP}	$V_{0T} = V_{01} + V_{02} = \frac{AR_3}{AR_9}(V_2 - V_1)$

Section B Op-Amp

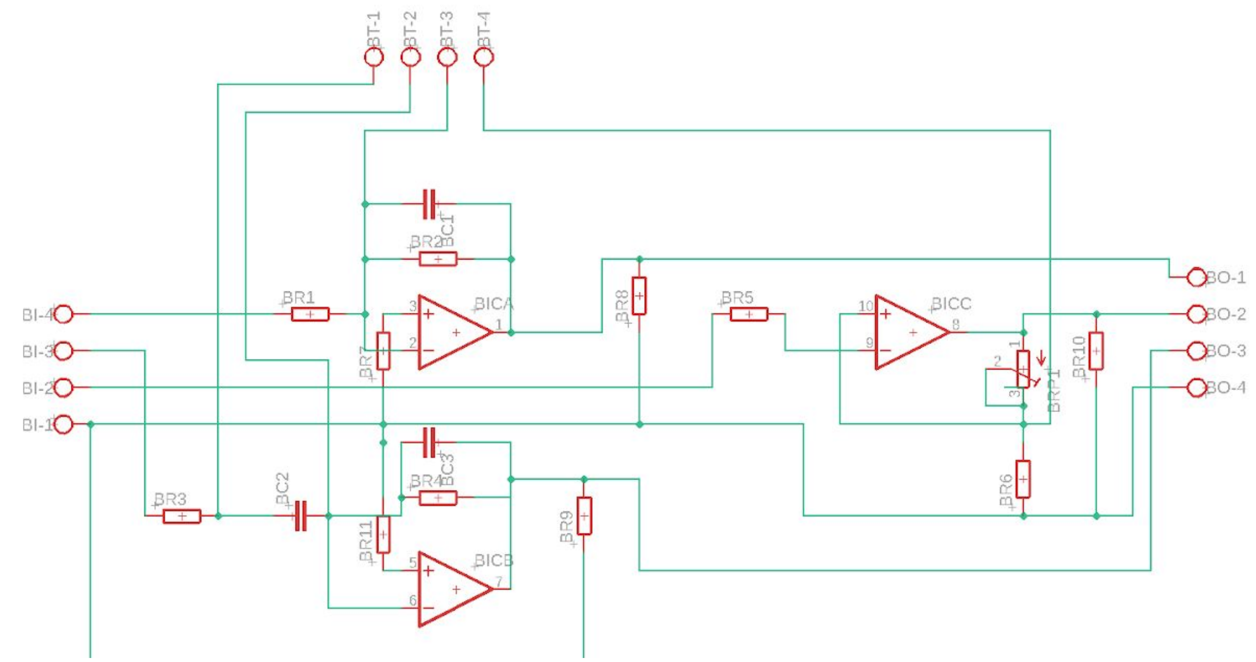


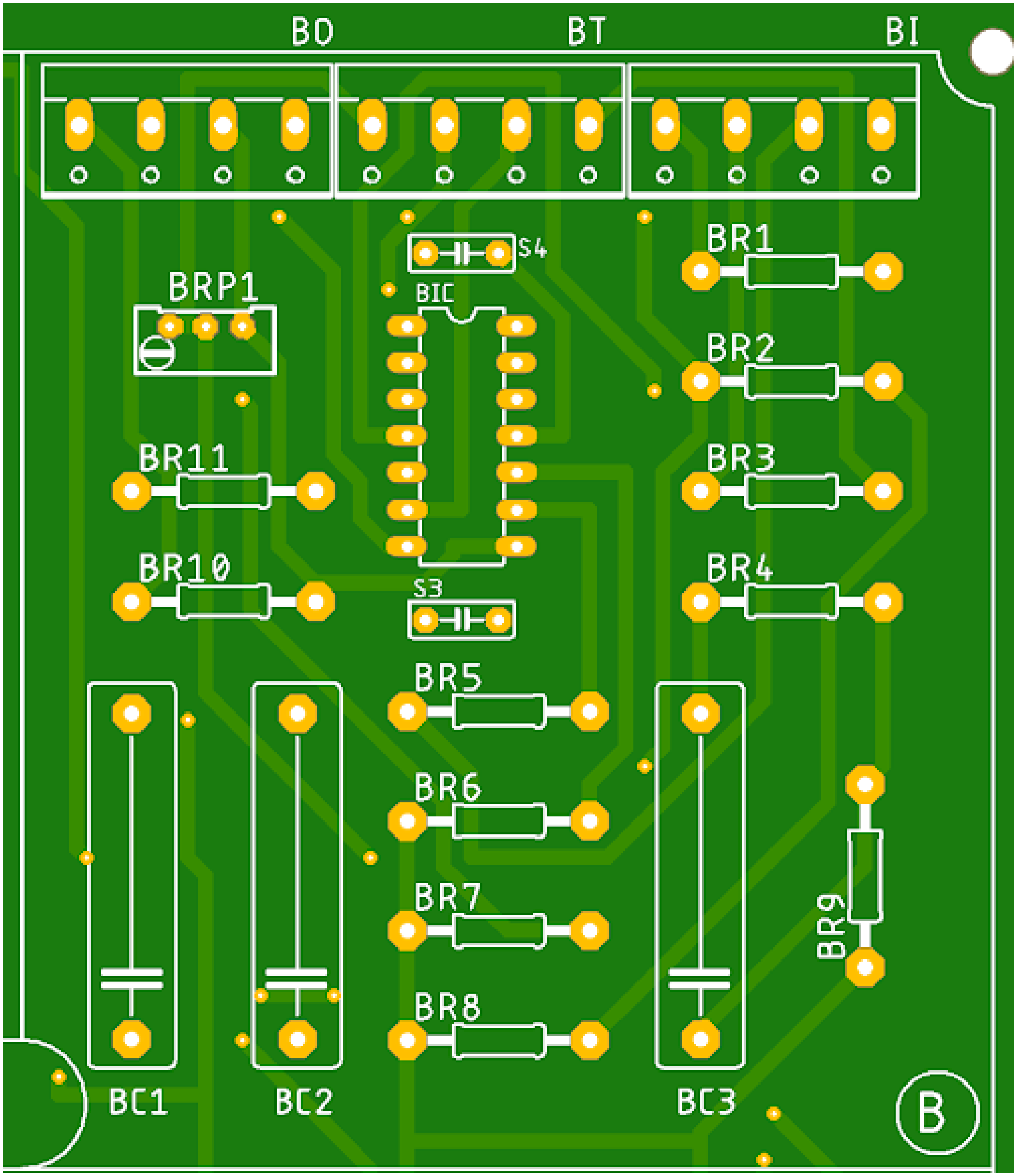
Fig. Section B Op-Amp Circuit

3.1 SCHMITT TRIGGER
3.2 DIFFERENTIATOR
3.3 INTEGRATOR

Components:

- LM324 Op-amp
- Resistors
- Capacitors
- POT (decade resistance Box or variable resistor)
- Decade Capacitance Box or Variable Capacitor
- Signal Generator (Section C circuit can be Used)
- CRO with Probles
- Wires

PCB layout:



BO
BT
BI
S4
BR1
BRP1
BIC
BR2
BR11
BR3
BR10
BR4
S3
BR5
BR6
BR9
BR7
BR8
BC1
BC2
BC3
B

3.1 SCHMITT TRIGGER

Aim: Design & realize Schmitt trigger circuit using an op – amp for desired Upper Trigger Point (UTP) and Lower Trigger Point (LTP).

Theory: It is a regenerative comparator or it is a comparator with hysteresis. This circuit uses positive feedback and the op-amp is operated in saturation. The output can take two values +Vsat and –Vsat. When output = +Vsat, the voltage appearing at the non-inverting terminal is $UTP = +V_{sat}\left(\frac{BR_6}{BR_6+BPR_1}\right)$ $UTP = +V_{sat}\left(\frac{BR_6}{BR_6+BPR_1}\right)$ called the upper threshold point. Similarly When output = - Vsat, the voltage appearing at the non-inverting terminal is $LTP = -V_{sat}\left(\frac{BR_6}{BR_6+BPR_1}\right)$ $LTP = -V_{sat}\left(\frac{BR_6}{BR_6+BPR_1}\right)$ called the lower threshold point. When V_{in} is greater than UTP, the output will switch from +Vsat to –Vsat. Similarly When Vin is less than LTP; the output will switch from -Vsat to +Vsat which is shown in the graph. The difference between UTP-LTP is called hysteresis. Hysteresis avoids false triggering of the circuit by noise. Hysteresis curve is the plot of Vo versus Vin . Schmitt trigger circuit is used to convert any irregular wave into square wave i.e. slowly varying input waveforms is converted into a square wave.

This is highly useful in triangular waveform generation, wave shape pulse generator, A/D convertor etc.

Current through feedback elements = $I_{BR6} = \frac{UTP/LTP}{BR_6}$ $I_{BR6} = \frac{UTP/LTP}{BR_6}$

$V_{BRP1} = V_{o\ sat} - V_{BR1}$

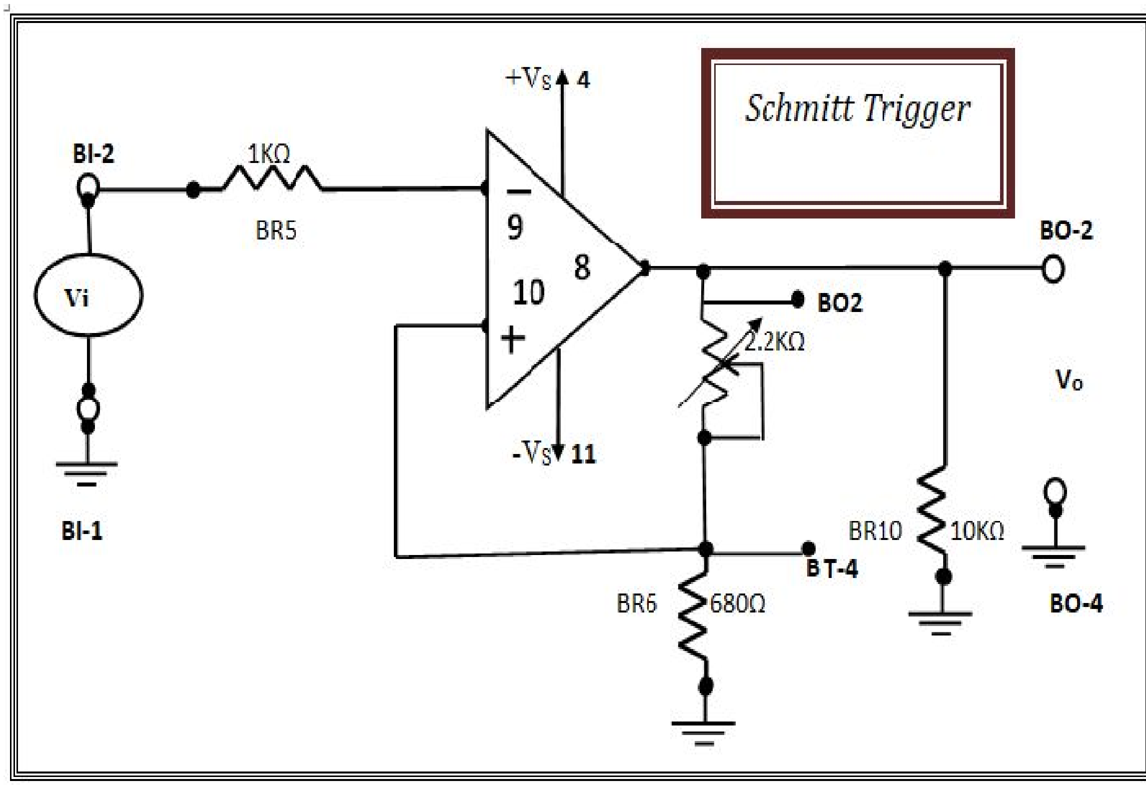
$$BRP1 = \frac{V_{BRP1}}{I_{BR6}}$$

Design: Given BR6, for a given symmetrical minimum and maximum UTP/LTP values select BRP1 range.

By adjusting BRP1, Set the test value of UTP and LTP and check its validity.

Through Oscilloscope observe input/output characteristics and note that the hysteresis width varies as per the design value.

Compare practical values with theoretical values.



Circuit diagram:

Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2. Apply the AC input signal of a suitable magnitude and frequency (kHz & V (p-p)).
1. By varying the BRP1, note the values of UTP and LTP.
2. Through the Oscilloscope observe input/output characteristics and note that the hysteresis width varies as per the design value (BRP1).
3. Compare practical values with theoretical values.

Tabular column:

Sl.NO	BRP1	UTP	UTP(T)	LTP	LTP(T)

3.2 Differentiator

Aim: To design and study the operation of a differentiator Op-Amp circuit for triangular input wave of given magnitude and frequency.

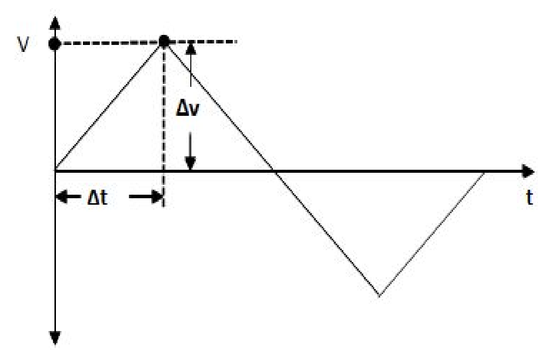
Theory: It is an op amp circuit which performs the mathematical operation of differentiation. That is the output waveform is the derivative or differential of the input voltage i.e. the output voltage is proportional to the rate of change of input. The differentiator may be constructed from a basic inverting amplifier if an input resistor is replaced by a capacitor. If the input voltage is Vin and capacitance is BC2, then the input current is given as $I_1 = BC_2\left(\frac{V_{in}}{dt}\right)$. $I_1 = BC_2\left(\frac{V_{in}}{dt}\right)$. Output voltage V0 is arrived as $V_0 = -I_1 BR_4$. $V_0 = -I_1 BR_4$. Here the negative sign indicates that the output voltage is 180°out of phase with the input signal. A resistor BR11 = BR4 is normally connected to the non-inverting input terminal of the op-amp to compensate for the input bias current. This circuit also works as high pass filter.
The concept of differentiation is usually described as "finding the slope of the curve." There are many uses for this function and differentiator is most commonly used in wave shaping circuits to detect high frequency components in an input signal and also as a rate–of–change detector in FM modulators. A differentiator can change the waveform of the input signal, for example, turning a triangle wave into a square wave. A practical differentiator cannot be used at just any frequency. There exists a useful range of differentiation, outside of which the circuit does not produce the desired effect.

Design: Select BC2 and input wave Δt and ΔV.
From these values calculate I_1.
Now Vo can be calculated by selecting appropriate BR4.
Design Equations

$$I_1 = \frac{BC_2 \Delta V}{\Delta t}$$

$$V_0 = -I_1 BR_4$$

$$V_0 = -BC_2 BR_4 \left(\frac{\Delta V}{\Delta t}\right)$$



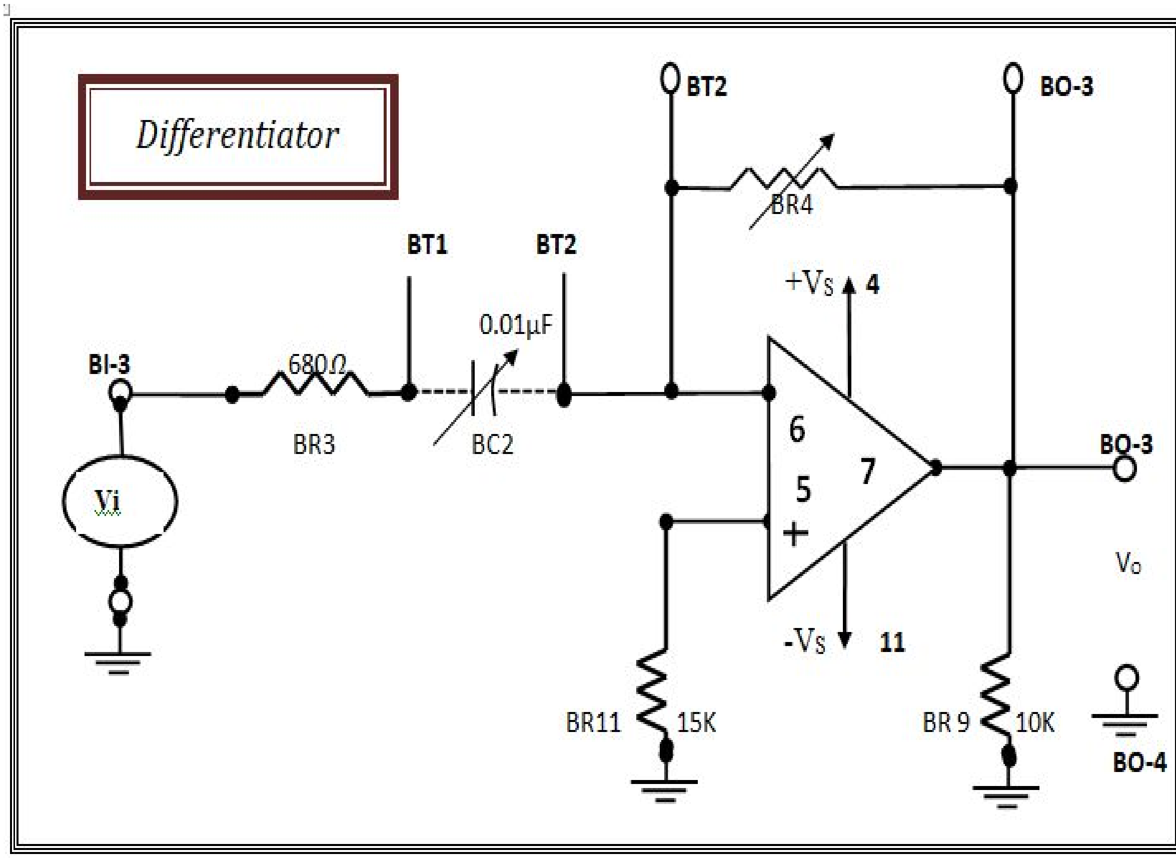
Now select BR4 to satisfy the above equation.
Recordings: Comparison of practical values and theoretical values.

Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram.
2. Insert the designed capacitance BC2 and resistance BR4 values in to the circuit.
3. Apply the triangular input wave of suitable magnitude and frequency (kHz & V (p-p)).

4. Measure and note the output voltage and time period.
5. Compare theory and practical values.

Circuit diagram:



Tabular column:

At BC2 (µF) =______

Sl. No.	BR4(Ω)	V_{OP}	Time (m.sec.)	V_{OT}
1				
2				

At BR4 (Ω) =____________

Sl. No.	BC2(µF)	V_{OP}	Time (m.sec.)	V_{OT}
1				
2				

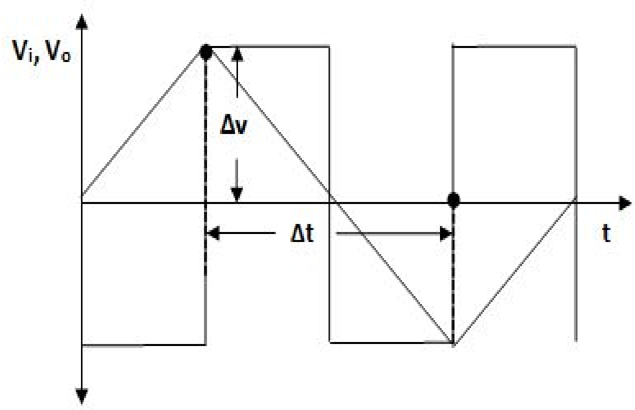
3.3 INTEGRATOR

Aim: To design and study the operation of an integrator Op-Amp circuit for square input wave of given magnitude and frequency.

Theory: A circuit in which the output voltage waveform is the integral of the input voltage waveform is the integrator. That is the output waveform is the integral of the input voltage waveform and is given by Vo = (-1/RfC) ∫Vindt. The integrator circuit is constructed from basic inverting amplifier by replacing the feedback resistance with capacitor. This circuit also works as low pass filter. The negative sign indicates that the output voltage is 180° out of phase with the input signal. A practical integrator cannot be used at just any frequency. There exists a useful range of integration, outside of which the circuit does not produce the desired effect

The concept of integration is usually described as "finding the area under the curve". The integrator is most commonly used in analog computers and ADC and signal-wave shaping circuits. An ordinary amplifier ideally changes only the amplitude of the input signal. An integrator can change the waveform of the input signal, for example, turning a square wave into a triangle wave. A practical integrator cannot be used at just any frequency.

Design: Select I_1 from the known values of input wave V_i & Δt and required ΔV, integrating capacitor BC1. From these values calculate BR1.
Then BR2 = 20BR1 is selected.
BR7 is selected such that it is the value of parallel combination of BR2 and BR1
Now Vo can be calculated by selecting appropriate BR4.
Design Equations
Let BC1= -------µF.
The input signal selected gives ΔV and Δt.
Then



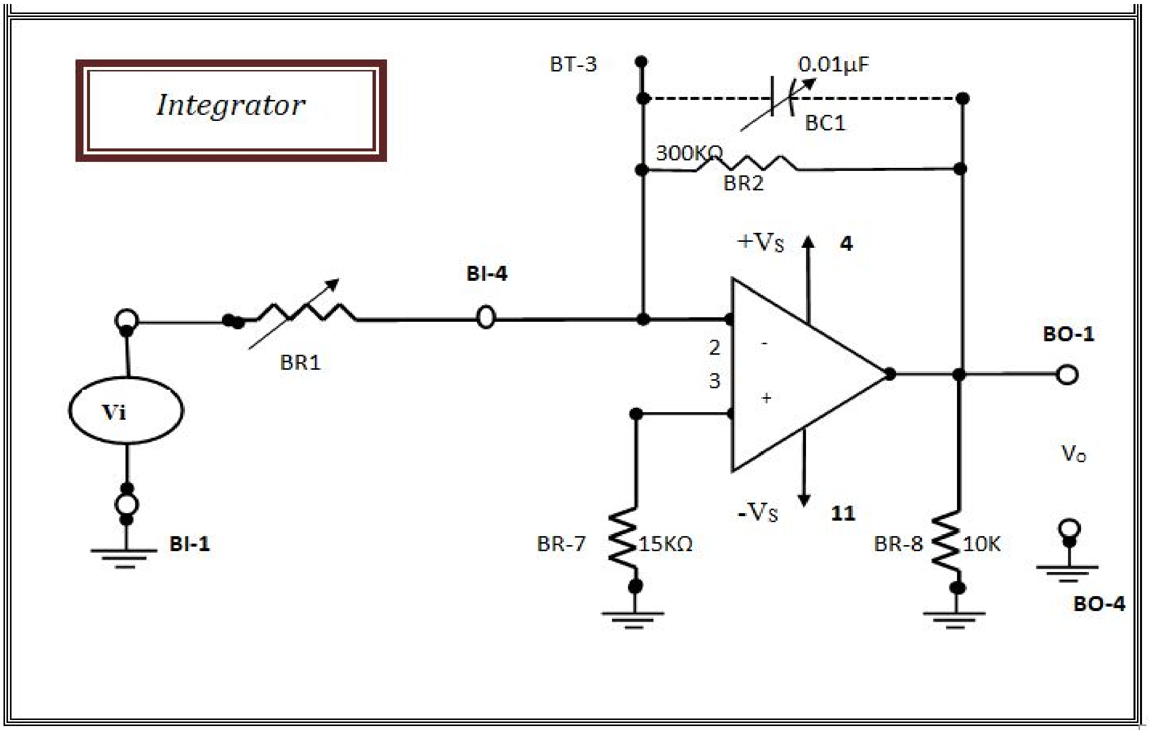
$$I_1 = \frac{BC_1 \Delta V}{\Delta t}$$

$$BR_1 = \frac{V_{in}}{I_1}$$

$$BR_2 = 20BR_1$$

Calculate BR7.
Observe the output waveform.
Recordings : Comparison of practical values and theoretical values.

Circuit diagram:



Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2. Insert the designed capacitance BC1 and resistance BR1 values in to the circuit.
3. Apply the square input wave of suitable magnitude and frequency (kHz & V (p-p)).
4. Measure and note the output voltage and time period.
5. Compare theory and practical values.

Tabular column:

For two different charging currents I_1=______

SN.O	BC1(µF)	BR1(Ω)	V_{OP}	Time (m.sec.)	V_{OT}
1					
2					

For two different integrating capacitor values BC1=________

SN.O	BC1(µF)	BR1(Ω)	V_{OP}	Time (m.sec.)	V_{OT}
1					
2					

Section C Op-Amp

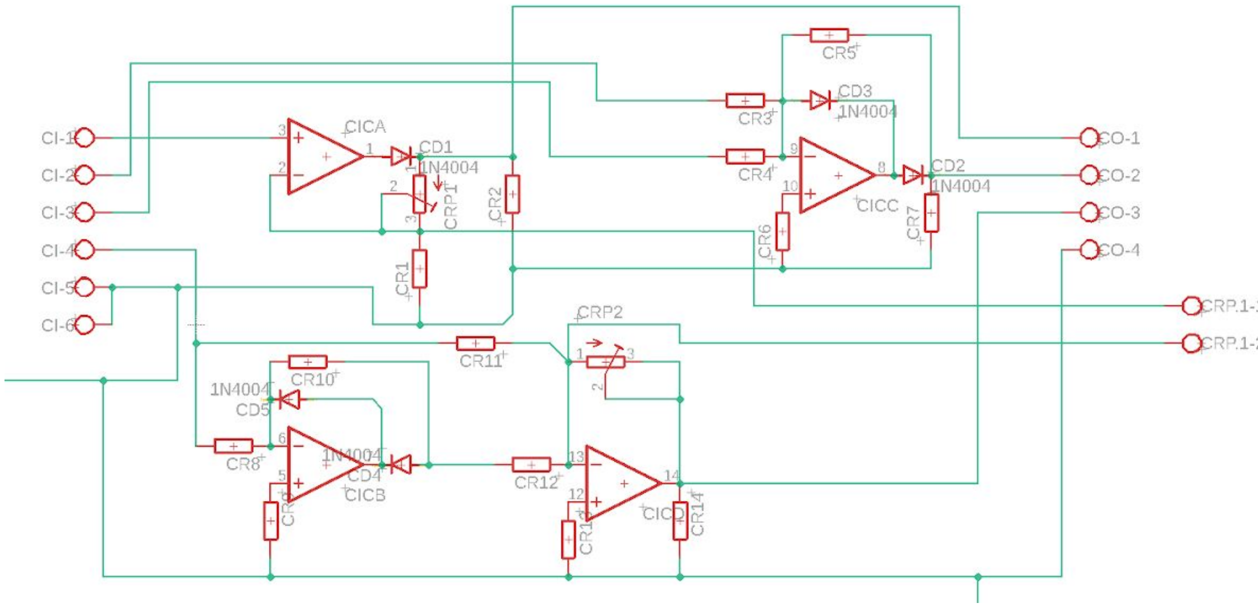


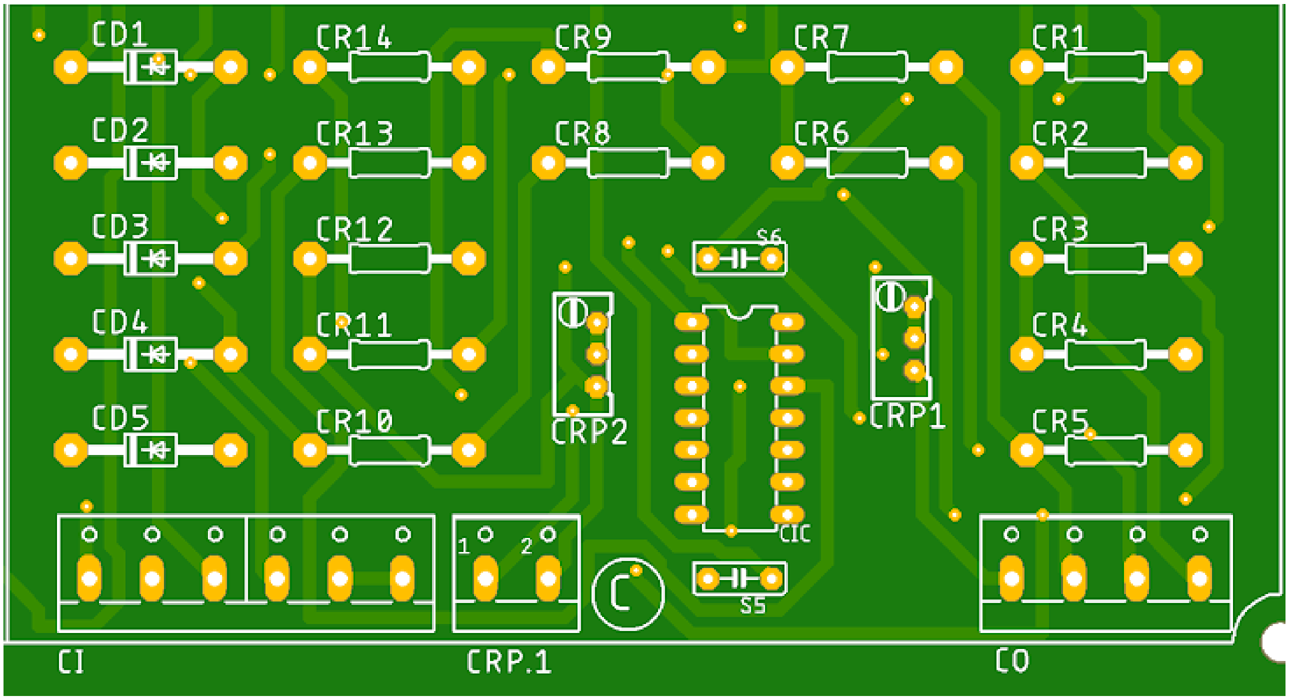
Fig. Section C Circuit Diagram

4.1 SATURATING PRECISION RECTIFIER (HALF-WAVE)
4.2 DEAD ZONE
4.3 PRECISION FULL WAVE RECTIFIER

Components:

- LM324 Op-amp
- Resistors
- Capacitors
- POT (decade resistance Box or variable resistor)
- Decade Capacitance Box or Variable Capacitor
- Signal Generator (Section C circuit can be Used)
- CRO with Probles
- RPS / FPS
- Wires

Circuit Diagream:



4.1 SATURATING PRECISION RECTIFIER (HALF-WAVE)

Aim: (1) To design a saturating type of precision half wave rectifier with non-inverting Op Amp circuit and draw the input, Op-amp output and circuit output waveforms.
(2) To note the minimum possible gain and maximum gain for the experimental setup.
(3) To observe the disadvantage of saturation type of rectification circuit.

Theory: Simple passive diode circuits cannot rectify small signals accurately. The forward bias potential of the diode acts as a constant barrier. By placing the diode inside the feedback loop of an op amp, the forward bias potential can be compensated for to a great extent. An inverting Op-Amp can be converted into a half wave rectifier by adding a diode. When Vi is positive, diode CD1 conducts causing Vo to go to positive by one diode drop. During negatine half cycle of the input diode CD1 is reverse biased. The output voltage Vo is zero because for all practical purposes no current flows through CD1 for –ve input. The circuit then acts like inverter for Rf = R1 and the output Vo becomes positive. The Op-Amp in the circuit must be of suitable high band width Op-Amp since it alternates between open loop and closed loop operations. The principal limitation of this circuit is the slew rate of the Op-Amp. Thus non-saturating type circuits are used.

Design: For a given input voltage and the range of required variation at the output for a given CR1 value calculate the CRP1 range required.
Given input voltage magnitude= Vi = -------
Given input voltage frequency= fi = -------
The output voltage gain range required = ---------
CR1= -------- ohms

From minimum gain = $1+\frac{CRP_1}{CR_1}$ $1+\frac{CRP_1}{CR_1}$ = ----- calculate CPR1 minimum

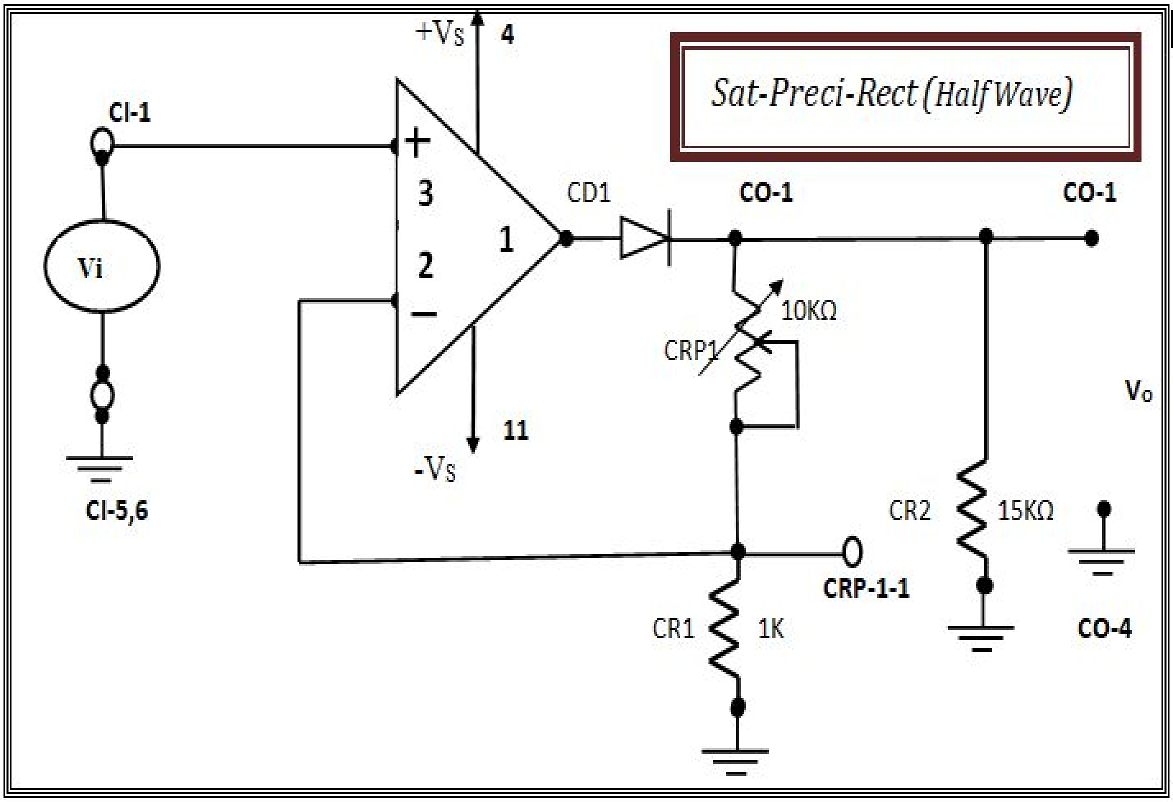
From maximum gain = $1+\frac{CRP_1}{CR_1}$ $1+\frac{CRP_1}{CR_1}$ = ----- calculate CPR1 maximum

Note down for different gains the output amplification. Compare practical values with theoretical values.

Procedure:

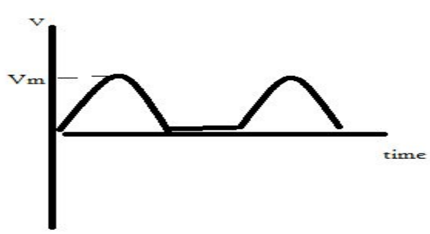
1. Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2. Apply the AC input signal of a suitable magnitude and frequency (kHz & mV (p-p)).
3. By varying the CRP1 note the output voltage.
4. Observe and verify the output.

5. Compare theoretical and practical.



Circuit diagram: **SATURATING PRECISION RECTIFIER (HALF WAVE)**

Expected Output waveform:



Tabular column:

Sl. No.	CRP1	A	Vo(Practical)	Vo(Theoretical)

4.2 DEAD ZONE

Aim: (1) To study a Op Amp circuit which can block a portion of the input voltage and remaining to appear at the output.

Theory: Without any input at terminal CI2 the circuit works as a Non-saturating type precision half wave rectifier. If the diode elements are not connected the circuit resembles an inverting summer. By providing a positive voltage level at the input terminal CI1, the circuit produces an inverted version of the negative input peak. An inverting Op-Amp can be converted into a half wave rectifier by adding two diodes. When Vi is positive, diode CD3 conducts causing Vo to go to positive by one diode drop. Hence diode CD2 is reverse biased. The output voltage Vo is zero because for all practical purposes no current flows through CD2 for –ve input, CD3 conducts and CD2 is OFF. The – ve input Vi forces the Op-Amp output Vo –ve and causes CD2 to conduct. The circuit then acts like inverter for CR4 = CR5 and the output Vo becomes positive. The Op-Amp in the circuit must be of suitable high band width Op-Amp since it alternates between open loop and closed loop operations. To overcome the limitation of slew rate of the Op-Amp non-saturating type circuits are used. The improvement in the band width is due to when the input passes through zero the Op-Amp output Vo must change from 0.6 to -0.6v or vice versa as quickly as possible in order to switch over the conduction from one diode to another.

With the circuit conditions, the circuit produces a negative peak of the input sine signal. For the circuit, since the output is the peak portion of negative input that exceeds the voltage that is provided at the terminal CI1. That is the circuit passes only this part of the input wave. All other portion of the input wave are ineffective. The ineffective portions of the input are said to occupy a dead zone. Thus the circuit is called as dead zone circuit. The circuit is used in precision clipping circuits. Now by applying proper polarity of input at CI1 and reversing the diodes result in inverted version of the positive input peak.

Design: For a given input voltage and frequency determine the input voltage level AT the terminal CI1 to make the circuit to provide specified portion of the input signal as dead zone.

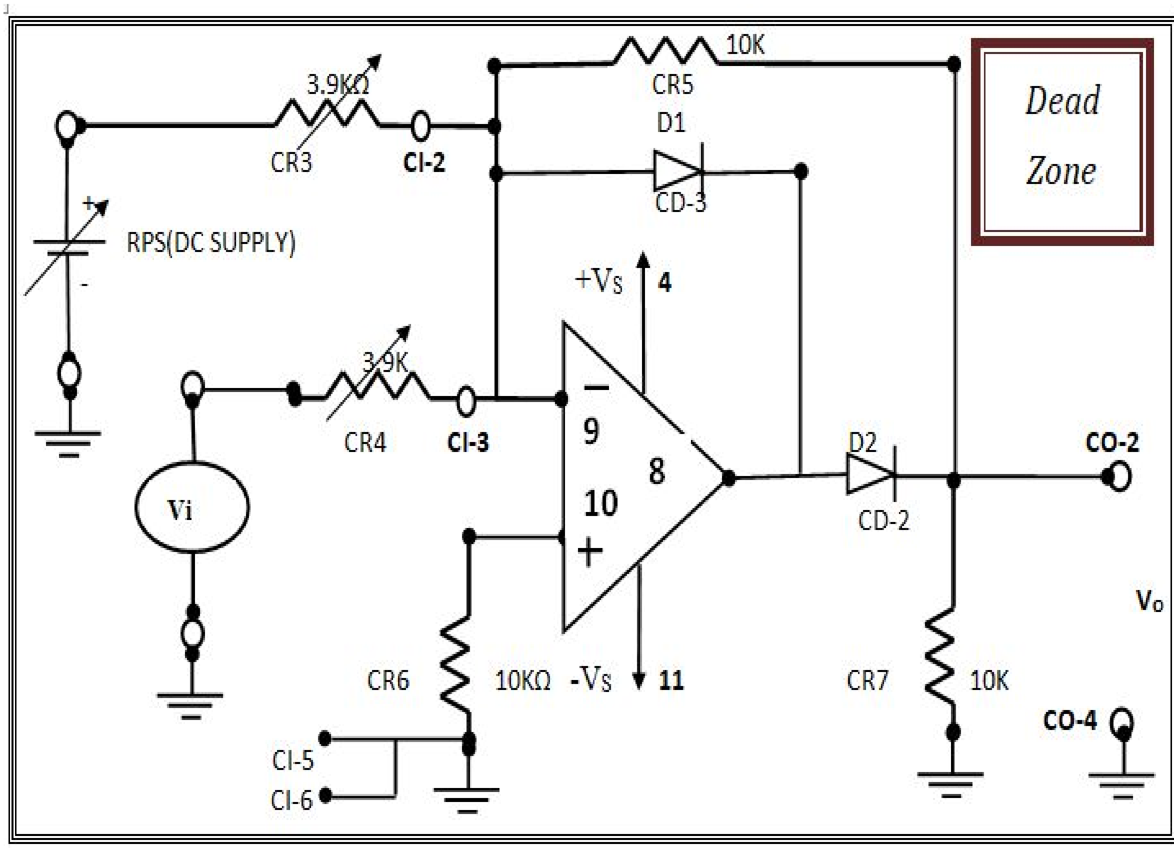
Given input voltage magnitude= Vi = -------

Given input voltage frequency= fi = -------

The input voltage dead zone required = --------- or the portion of input voltage appearing as the output ---------.

Compare practical values with theoretical values.

Circuit diagram:



Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2. Give the suitable AC signal from signal generator.
3. Verify the output in the CRO.
4. By varying the reference input voltage, Note the dead zone voltage waveform (peak).

Tabular column:

Sl.No.	Vref	Vo(Practical)

4.3 PRECISION FULL WAVE RECTIFIER

Aim: (1) To study the Non-saturating type full wave rectifier consisting a summer and a precision half wave rectifier.

(2) To observe the input and output characteristic on the Oscilloscope.

Theory: The full wave precision rectifier can be realized in many ways. The present circuit is having the advantage that the function is realized with minimum number of components. The circuit consists a non-inverting summer and a precision have rectifier. The input signal is given to a precision half wave rectifier which converts the input positive half cycle to appear at the output with a gain of two. Then the summer circuit adds this signal with the input resulting in a full wave rectifier output. The gain of the output is selected by the feedback resistor of the summer circuit.

An input voltage Vi is applied at the CI4 terminal of the circuit. During the positive half cycle of the input signal diodes CD5 is forward biased and the output of precision half wave rectifier is held at -0.7 V. This reverse biases the diode CD4. Thus this circuit works as a non-inverting amplifier with a gain of two due to CR10 resistor. Thus twice the inverted positive half of the input signal appears at one terminal of summer resistor CR12. At the second summer resistor one terminal the input signal is connected. The non-inverting summer adds these two signal to produce a precision full wave rectifier and the amplification is controlled through feedback resistor CRP-1-2 of the summer.

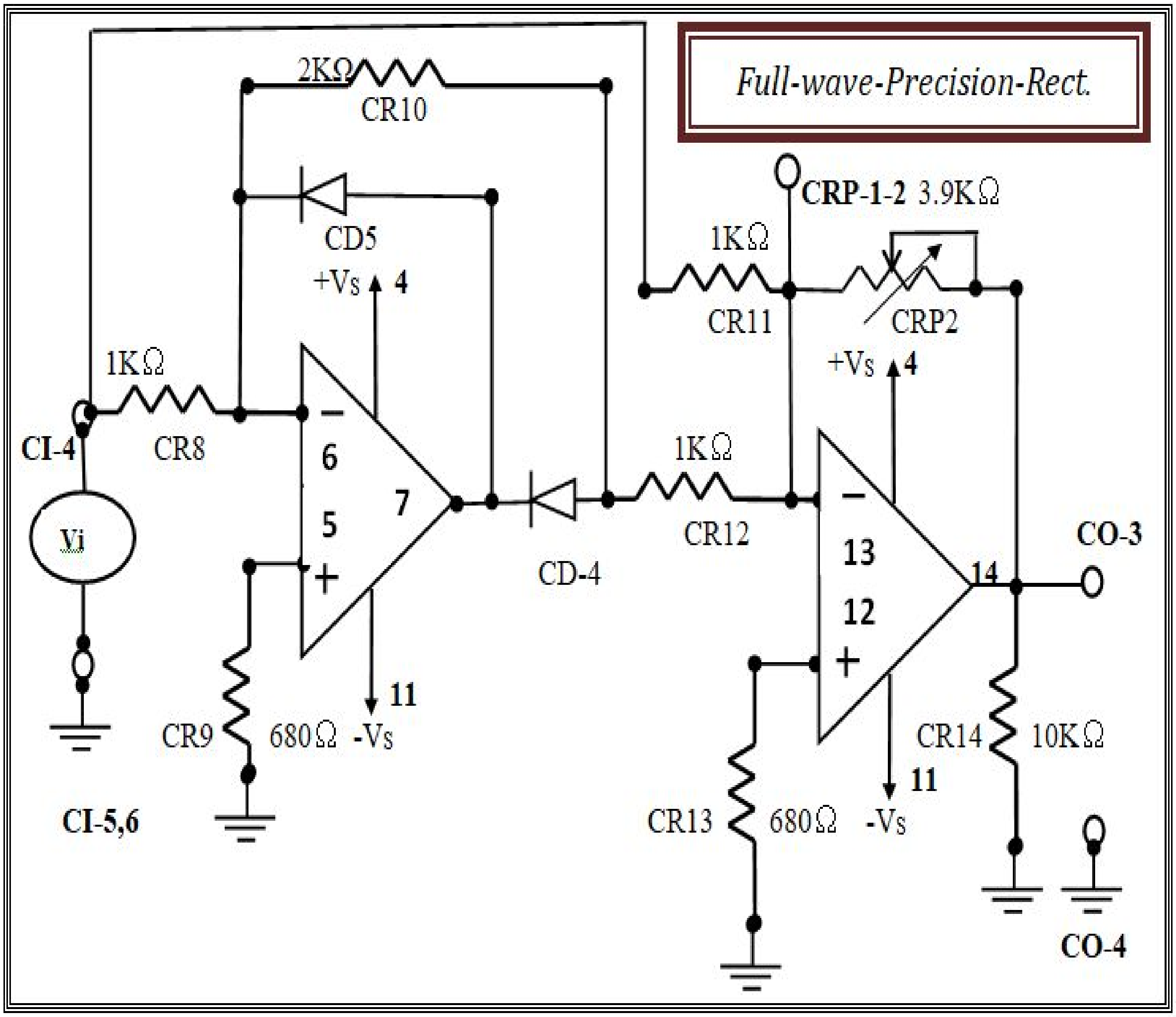
Design: For a given input voltage and frequency determine the output voltage of the circuit.
Given input voltage magnitude= Vi = -------
Given input voltage frequency= fi = -------
The output voltage gain required = --------

Note down for different gains the output amplification.
Compare practical values with theoretical values.
Observe the input and output characteristic on an Oscilloscope.

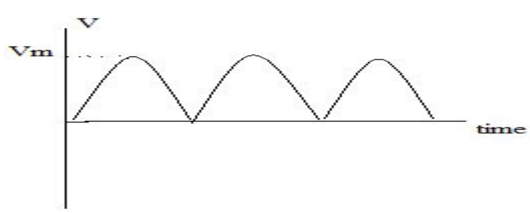
Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2. Give the AC signal from signal generator Verify the output at the load 10K in the CRO.
3. By varying the CRP2 note the output voltage

Circuit diagram:



Expected wave form:



Tabular column:

Sl.No.	CRP-2	Vo(Practical)	Vo(Theoretical)

Section D Op-Amp

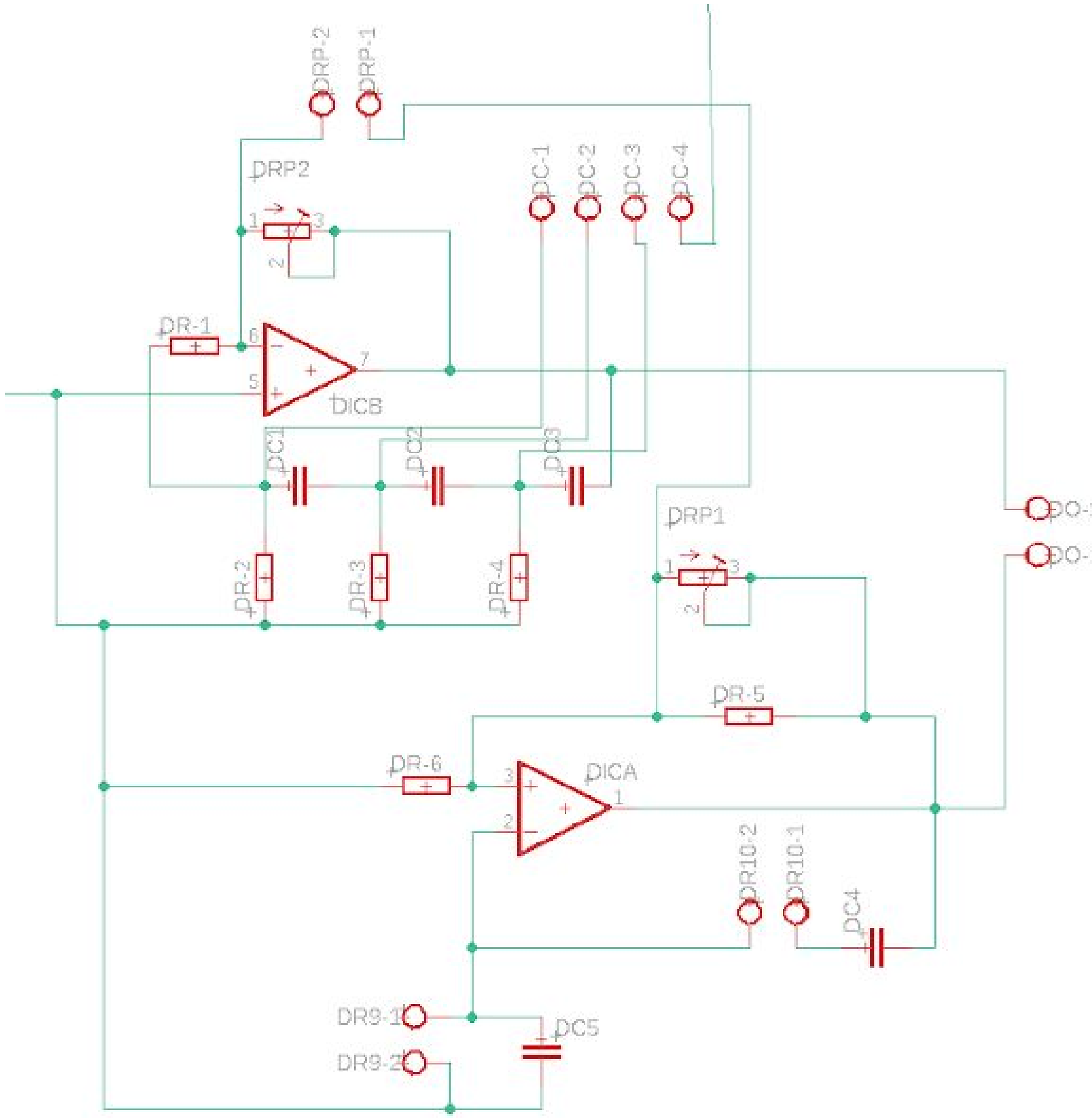


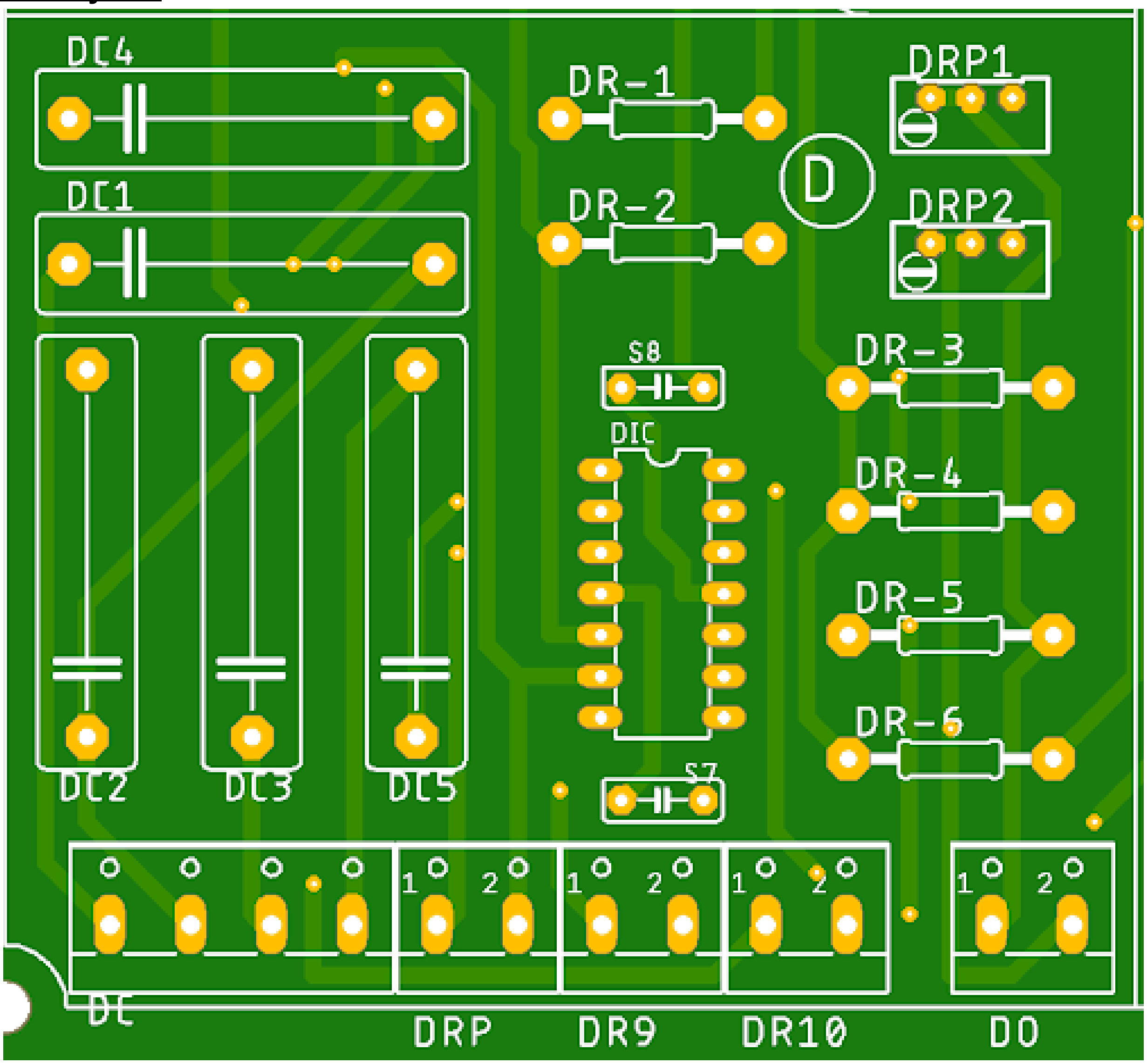
Fig. section D circuit diagram

5.1 RC PHASE SHIFT OSCILLATOR
5.2 WEIN BRIDGE OSCILLATOR

Components:

- LM324 Op-amp
- Resistors
- Capacitors
- POT (decade resistance Box or variable resistor)
- Decade Capacitance Box or Variable Capacitor
- CRO with Probles
- Wires

PCB layout:



5.1 RC PHASE SHIFT OSCILLATOR

Aim: Design and verify the output waveform of an op – amp RC phase shift oscillator for a desired Frequency.

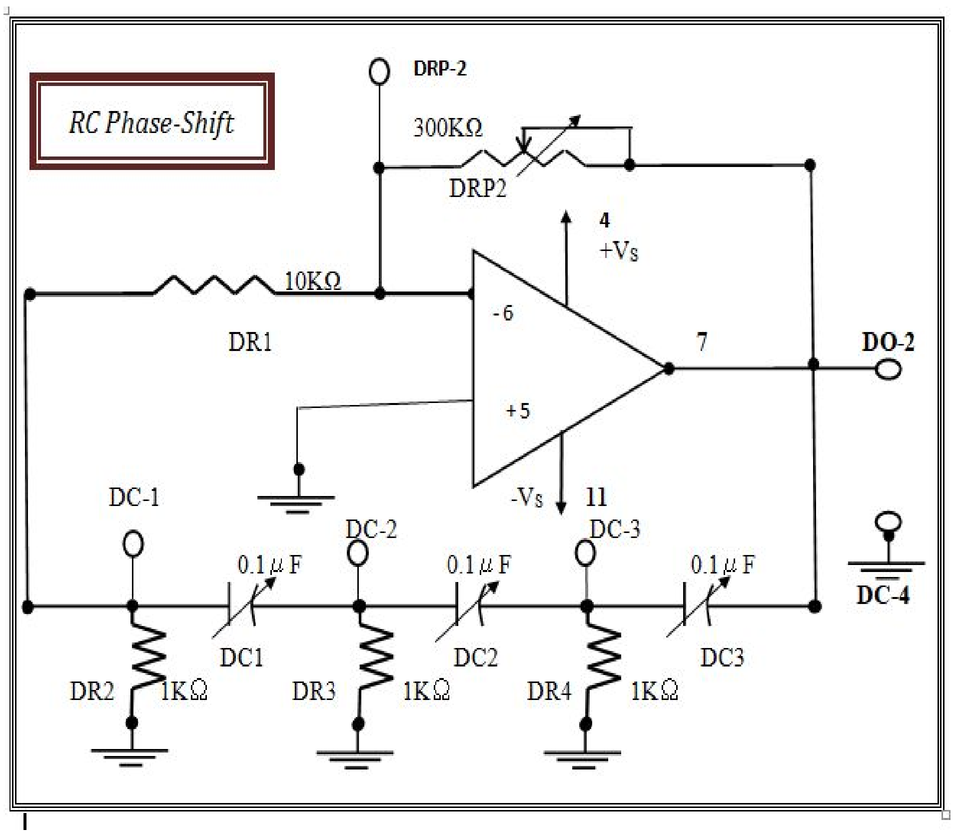
Theory: RC phase shift oscillator uses op-amp, in inverting amplifier mode and the circuit generates its own output signal. It consists of an op-amp as an amplifier and 3 RC cascaded network as the feedback circuit. A positive feedback of a fraction of output voltage of amplifier fed to the
input in the same phase, generate sine wave. Since the op-amp is used in the inverting mode, any signal that appears at the inverting terminal is shifted by 180° at the output. An additional 180° phase shift required for oscillation is provided by the cascaded RC network. Thus the total phase shift around the circuit is 360° or 0°. At some specific frequency, the phase shift of the cascaded RC network is exactly 180° and feedback factor is 1/29. If the gain of the amplifier is 29, the total loop gain of the circuit becomes 1. The circuit will oscillate at this specific frequency and is given by fo = 1 / √ 6 (2 π R C)

Design: DR1 and DRP2 are gain control resistors of the circuit.
DR3=DR4=DR5 resistors and DC1=DC2=DC3 capacitors contribute for the phase shift.

(1) For a given values of resistors DR3=DR4=DR5, calculate the values of capacitors DC1=DC2=DC3 for a specified frequency.

Compare practical values with theoretical values.

Circuit diagram:



Procedure:

1) Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2) Insert the designed capacitance values DC1, DC2 and DC3 and DRP2 values in to the circuit.
3) Observe & Note the output wave forms in CRO.

Tabular column:

SN.O.	DC1(μF) =DC2 (μF)= DC3(μF)	DRP2	V_o

5.2 WEIN BRIDGE OSCILLATOR

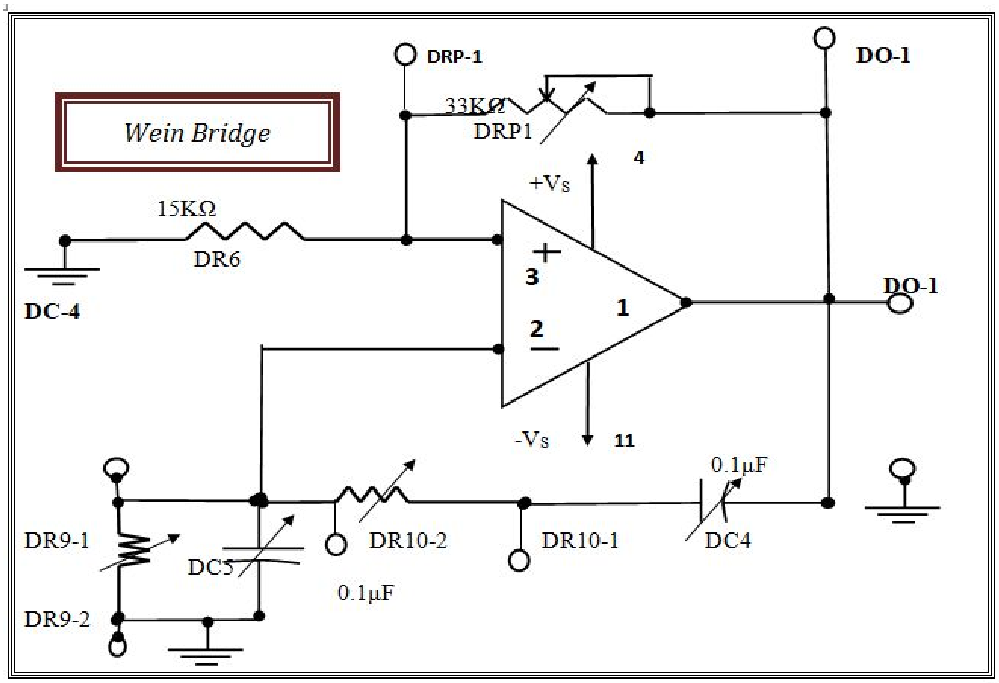
Theory: It is the commonly used audio frequency oscillator which employs both positive and negative feedback. The Wien bridge is a four element resistor-capacitor network that can be thought of as a combination of lead and lag networks. As such, it attenuates very high and very low frequencies. At its critical frequency, where the magnitude of DC4 and DC5 is equal to DR9 and DR10 (Xc equals R), the bridge voltage produces no phase shift and exhibits a modest signal loss of 1/3. The feedback signal is connected in the non-inverting input terminal so that the amplifier is working in non-inverting mode. The Wien bridge circuit is connected between amplifier input terminal and output terminal. The bridge has a series RC network DR10 and DC4 in one arm and a parallel RC network DR9 and DC5 in the adjoining arm. In the remaining two arms of the bridge, resistor DR6 and DPR1 are connected. The phase angle criterion for oscillation is that the total phase shift around the circuit must be zero. This condition occurs when bridge is balanced. At resonance, the frequency of oscillation is exactly the resonance frequency of balanced Wien bridge and is given by f0 = 1/ (2πRC). At this frequency, the gain required for sustained oscillation is 3.It is provided by the non-inverting amplifier with Gain = 1+ (DPR1/DR6) = 3.

Design: DR6 and DPR1 are gain control resistors of the circuit.
DR9=DR10 resistors and DC4=DC5 capacitors contribute for the phase shift.

(1) For a given values of capacitors DC4=DC5, calculate the values of resistors DR9=DR10 for a specified frequency.

Compare practical values with theoretical values.

Circuit diagram:



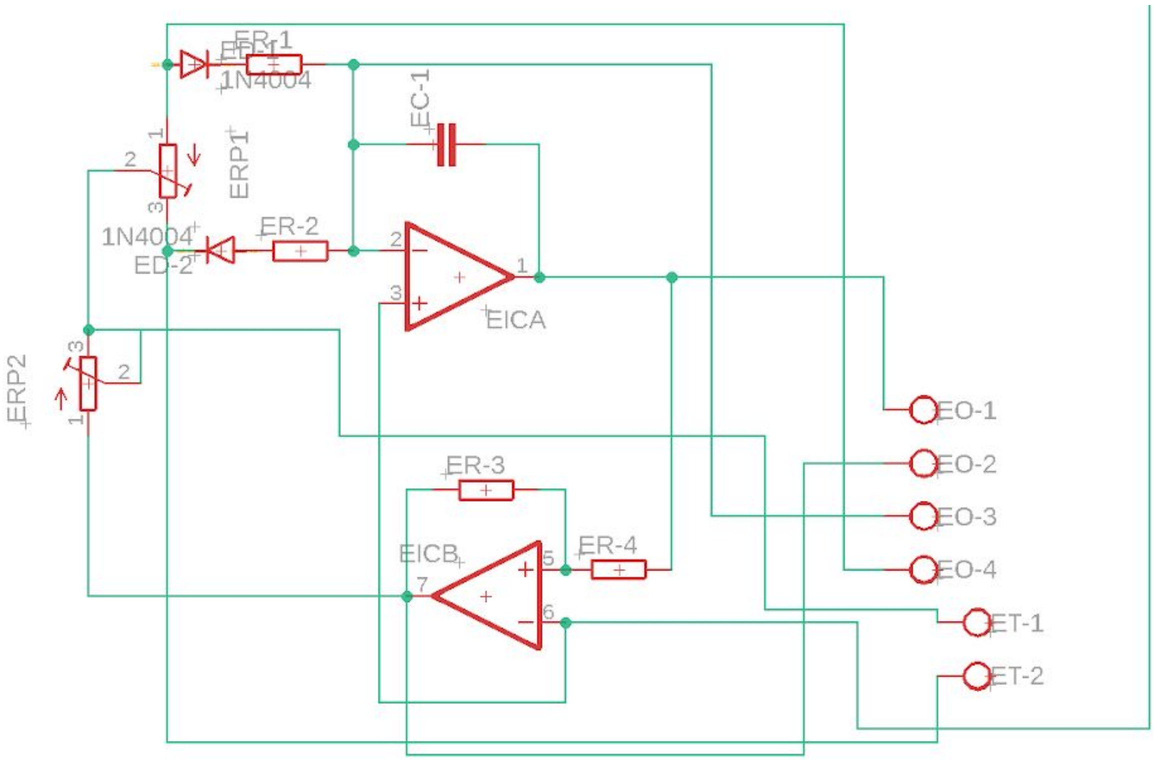
Procedure:

1) Connect the Op-Amp module as per the Terminal Connection Diagram Switch ON the Op-Amp module.
2) Insert the designed resistance values DRP1, DR9 and DR10 values in to the circuit.
3) Observe & Note the output wave forms in CRO.

Tabular column:

SN.O.	DRP1	DR9	DR10	V_o

Section E Op-Amp



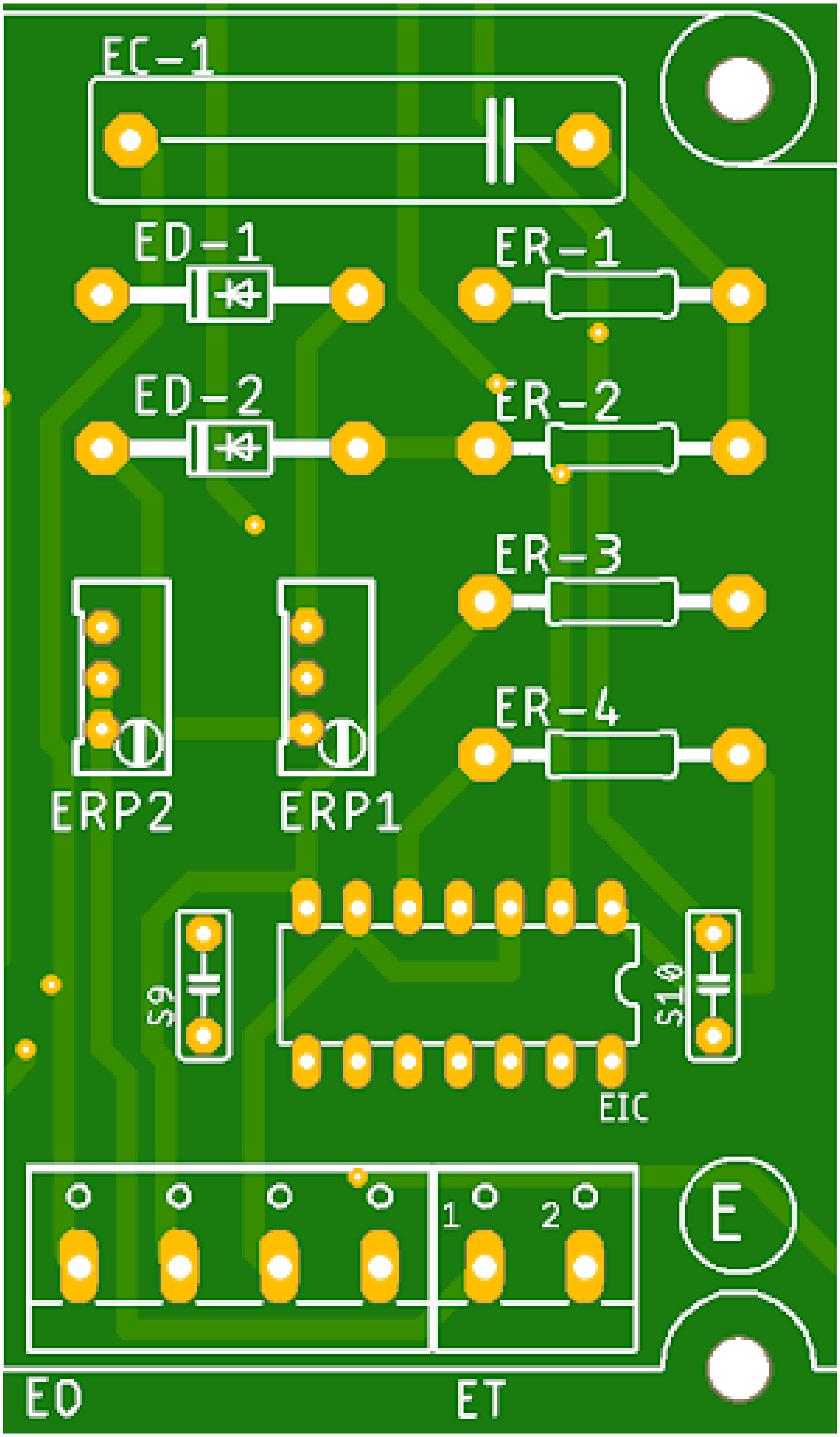
Ftig. Section E Circuit

6.1 SQUARE / TRIANGULAR WAVE FORM GENERATOR

Components:

- LM324 Op-amp
- Resistors
- Capacitors
- POT (decade resistance Box or variable resistor)
- Decade Capacitance Box or Variable Capacitor
- CRO with Probles
- Wires

PCB layout:



6.1 SQUARE / TRIANGULAR WAVE FORM GENERATOR

Aim: To generate triangular & square waveforms at the desired magnitude and frequency of oscillations respectively.

Theory: Wave form Generator is a non-sinusoidal periodic waveform that can be denoted as an infinite summary of sinusoidal waves. It has an alternate of amplitude at a fixed frequency between stable min and max value with the equal duration. It looks like a comparator with hysteresis. The circuit has a time dependent elements such as resistance and capacitor to set the frequency of oscillation. The Wave Generator Using Op amp means the astable multivibrator circuit using opamp. Resistor and capacitor determines the frequency of wave. Another Resistors forms a voltage divider setup which feedbacks a fixed fraction of the output to the non-inverting input of the IC.

Initially, when power is not applied the voltage across the capacitor is 0. When the power supply is switched ON, the Capacitor starts charging through the resistor and the output of the opamp will be high (+Vcc). A fraction of this high voltage is fed back to the non- inverting pin by the resistor network .When the voltage across the charging capacitor is increased to a point the voltage at the inverting pin is higher than the non-inverting pin, the output of the opamp swings to negative saturation (-Vcc). The capacitor quickly discharges through Resistor and starts charging in the negative direction. Now a fraction of the negative high output (-Vcc) is fed back to the non-inverting pin by the feedback network . When the voltage across the capacitor has become so negative that the voltage at the inverting pin is less than the voltage at the non-inverting pin, the output of the opamp swings back to the positive saturation. Now the capacitor discharges through Resistor and starts charging in positive direction. This cycle is repeated over time and the result is a square wave swinging between +Vcc and -Vcc at the output of the op-amp.

When the input to the integrator (square wave) falls to the negative peak the capacitor quickly discharges through the input resistor and starts charging in the opposite polarity. Now the conditions are reversed and the output of the opamp will be a ramp that is going to the negative side at a rate proportional to the time constant. This cycle is repeated and the result will be a triangular waveform at the output of the opamp integrator.

The triangle-square wave generator consists of two main parts: a Schmitt trigger circuit and a ramp generator or integrator. The circuit is self-sustaining by nature. The ramp generator requires a square wave input. It gets this signal from the Schmitt trigger circuit. The Schmitt trigger circuit in turn generates the square wave from the triangle wave appearing at the output of the ramp generator. The output frequency is determined primarily by the RC timing values of the ramp generator, and secondarily by the switching thresholds of the comparator. The practical output frequency limit is set by the bandwidth and slew rate of the op amps. At higher frequencies, slew rate limiting will noticeably slow the edges of the square wave. This will impact the output of the ramp generator and will affect both the linearity of the wave shapes and the output frequency.

Design:

Schmitt trigger circuit design

Let the current through resistor ER3 be I_3 and is =----------

Let the triangle peak to peak value be =---------

$$ER_3 = \frac{V_{0\ sat}}{I_{3\ min}}$$

$$ER_4 = \frac{UTP}{I_3}$$

Integrator design

Let the charging current for capacitor EC1 be I_1 and is =----------

Minimum pulse width = ---------

Maximum pulse width = ---------

Minimum Frequency =f1= ---------

Maximum Frequency =f2= ---------

Let the charge resistor=the discharge resistor =ER1=ER2+ -----------

At the lowest frequency f1, calculate PW max = ---------

Then EC1 is selected as

$$EC_1 = \frac{I_1 \Delta t}{\Delta V}$$

Calculation of ERP1+ERP2+ER1 = $\frac{+V_{0\ sat} - V_F}{I_{1\ min}}$ $\frac{+V_{0\ sat} - V_F}{I_{1\ min}}$

If2 is calculated as $I_{f2} = \frac{I_{1\ min} \times f_2}{f_1}$ $I_{f2} = \frac{I_{1\ min} \times f_2}{f_1}$

Then ERP1+ER1 is arrived as

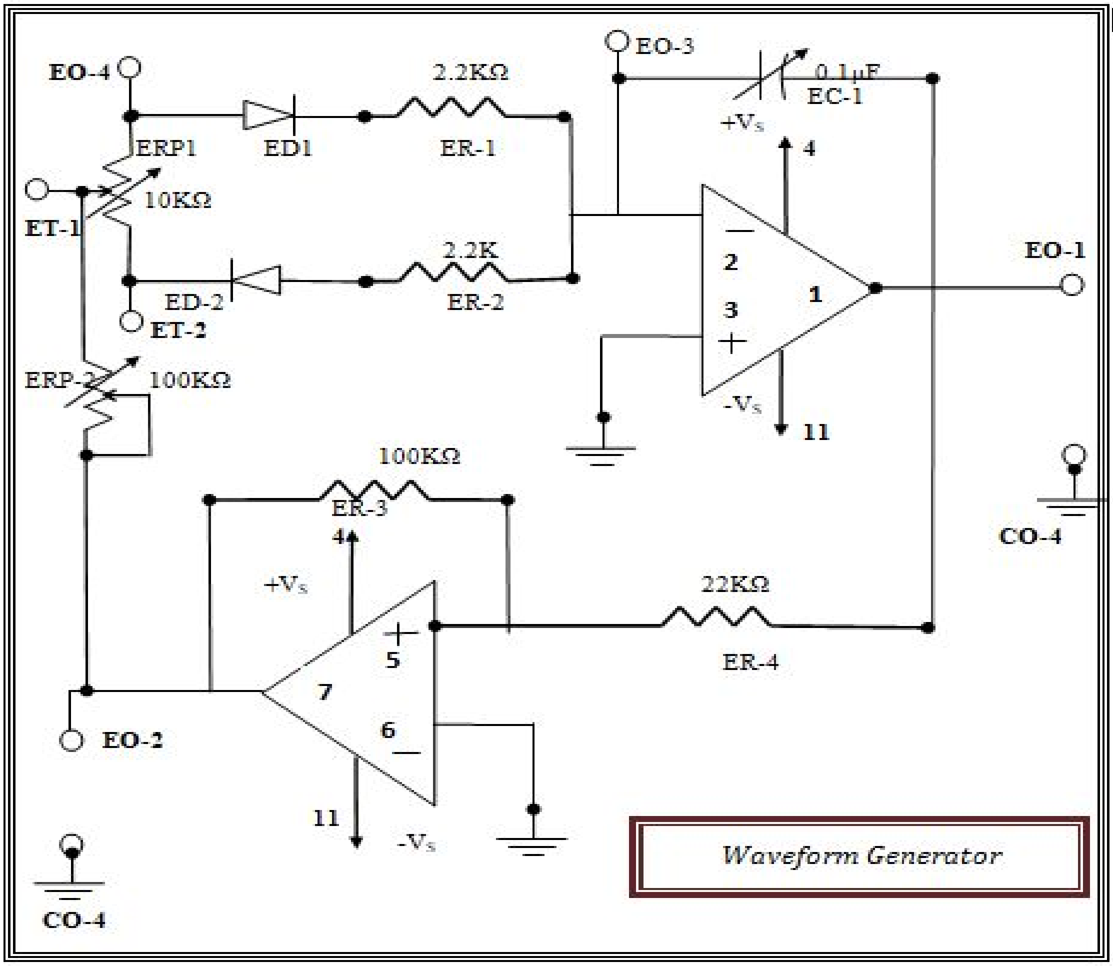
$$EPR_1 + ER_1 = \frac{+V_{0\ sat} - V_F}{I_{f2}}$$

Since ER1 is given EPR1 is calculated.

Now calculate the minimum possible practical pulse width.

Compare practical values with theoretical values.

Circuit diagram:



Procedure:

1. Connect the Op-Amp module as per the Terminal Connection Diagram and Switch ON the Op-Amp module.
2. By keeping ERP1 constant and by varying the ERP2 note down the minimum and maximum frequency of oscillations and duty cycle.
3. By keeping ERP2 constant and by varying the ERP1 note down the minimum and maximum duty cycle and frequency of oscillations.

Tabular column:

ERP1=constant

S.NO.	ERP2	F(Hz)	Duty Cycle(δ)	

ERP2=constant

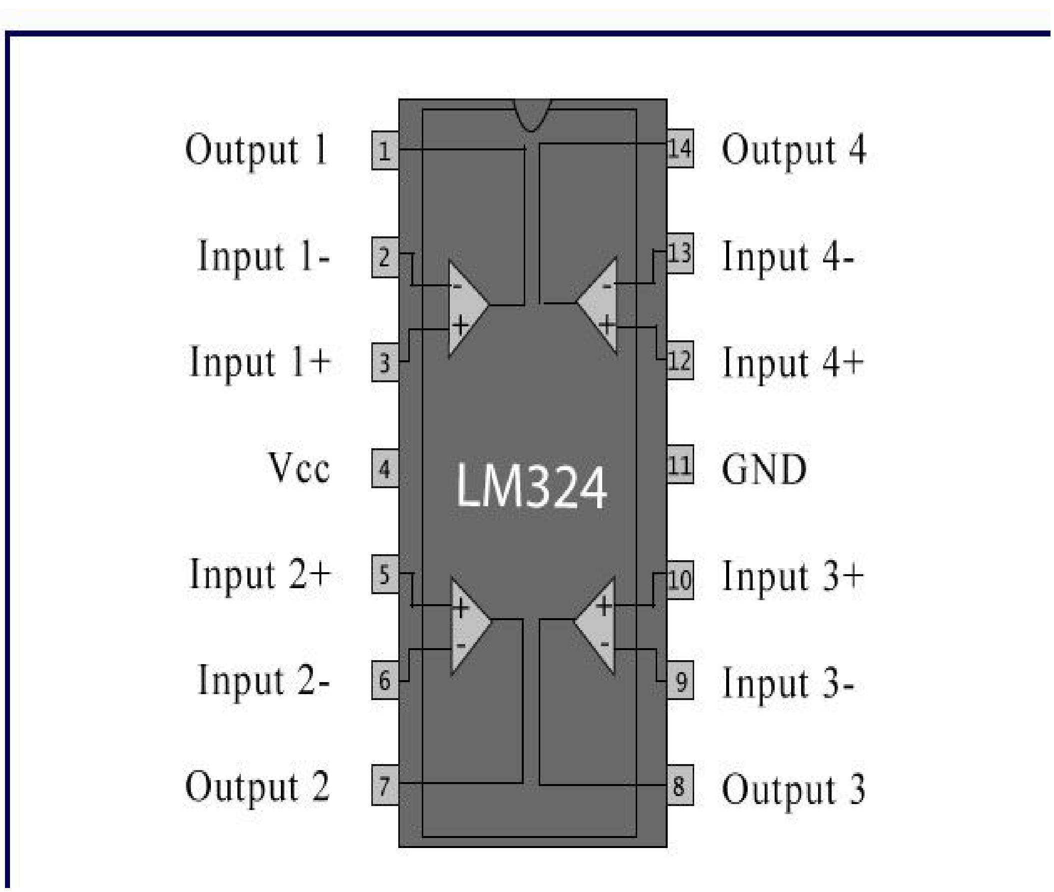
S.NO.	ERP1	Duty Cycle(δ)	F(Hz)	

Applications: The applications of waveform generator include sampling circuits, thyristor firing circuits, frequency generator circuits, tone generator circuits etc.

Appendix

LM324 is a 14pin IC consisting of four independent operational amplifiers (op-amps) compensated in a single package. Op-amps are high gain electronic voltage amplifier with differential input and, usually, a single-ended output. The output voltage is many times higher than the voltage difference between input terminals of an op-amp.

These op-amps are operated by a single power supply **LM324** and need for a dual supply is eliminated. They can be used as amplifiers, comparators, oscillators, rectifiers etc. The conventional op-amp applications can be more easily implemented with LM324.



PIN DESCRIPTION:

Pin No	Function	Name
1	Output of 1st comparator	Output 1
2	Inverting input of 1st comparator	Input 1-
3	Non-inverting input of 1st comparator	Input 1+
4	Supply voltage; 5V (up to 32V)	Vcc
5	Non-inverting input of 2nd comparator	Input 2+
6	Inverting input of 2nd comparator	Input 2-
7	Output of 2nd comparator	Output 2
8	Output of 3rd comparator	Output 3
9	Inverting input of 3rd comparator	Input 3-
10	Non-inverting input of 3rd comparator	Input 3+
11	Ground (0V)	Ground
12	Non-inverting input of 4th comparator	Input 4+
13	Inverting input of 4th comparator	Input 4-
14	Output of 4th comparator	Output 4

LM324 Quad Op-Amp IC features and specifications

1. Integrated with four Op-Amps in a single package
2. Wide power supply Range
3. Singe supply – 3V to 32V
4. Dual supply – ±1.5V to ±16V
5. Low Supply current – 700uA
6. Single supply for four op-amp operation enables reliable operation
7. Operating ambient temperature – 0˚C to 70˚C
8. Soldering pin temperature – 260 ˚C (for 10 seconds – prescribed)

Applications:

- Transducer Amplifiers
- Filter circuits, Voltage followers
- Integrator, Differentiator, Summer, adder, Voltage follower, etc.,
- DC gain blocks
- Comparators (Loop control & regulation)