# Jawaharlal Nehru Engineering College

Department of Electronics and Telecommunications

*Laboratory Manual*

# ANALOG CIRCUITS

For

Second Year Students
(Affiliated to B.A.T.U., Lonere)

Manual Made By
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Prof S.D.Gavraskar

# FOREWORD

It is my great pleasure to present this laboratory manual for second year engineering students for the subject of Analog Circuit keeping in view the vast coverage required for visualization of concepts of basic Analog Electronics circuit.

As a student, many of you may be wondering with some of the questions in your mind regarding the subject and exactly that has been tried to answer through this manual.

Faculty members are also advised that covering these aspects in initial stage itself will greatly relieve them in future, as much of the load will be taken care by the enthusiastic energies of the students, once they are conceptually clear.

Prof S.A.Annadate
Prof S.D.Gavraskar
(ECT Department)

# LABORATORY MANUAL CONTENTS

This manual is intended for the Second year students of Electronics & telecommunication Branch in the subject of Analog Circuit. This manual typically contains Practical/Lab Sessions related to Analog Circuits covering various aspects related the subject to enhance understanding of the subject.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus, as practical aspects are the key to understanding conceptual visualization of theoretical aspects covered in the books.

Good Luck for your Enjoyable Laboratory Sessions

Prof S.A.Annadate
Prof S.D.Gavraskar
(ECT Department)

**SUBJECT INDEX**

1. Do’s and Don’ts

2. Lab exercise:

   1. Measurement of op-amp parameters viz. Input offset voltage, Bias current, Slew rate and CMRR.

   2. Op-amp applications –I: Integrator
      Design and verify the frequency response of Integrator circuit using IC741.

   3. Op-amp applications -II: Schmitt trigger.
      To study Schmitt trigger circuit using op-amp 741.

   4. Design a first order low pass Butterworth filters using op-amp.

   5. Design a square wave generator using op-amp.

   6. To study the operation of IC-565 as PLL and measure its free running

      frequency.

   7. Inverting Amplifier

   8. Non inverting Amplifier

   9. Summing Amplifier

   10. Differentiator

   11. RC phase shift oscillator using op amp

Quiz on the subject

Conduction of Viva-Voce Examination

Evaluation and Marking Systems

**Do’s and Don’ts in Laboratory:**

1. Do not handle any equipment before reading the instructions/Instruction manuals.

2. Do not apply voltage more than 15 V to IC 741.

3. Check CRO probe before connecting it.

4. Strictly observe the instructions given by the teacher/Lab Instructor.

**Instruction for Laboratory Teachers::**

1. Submission related to whatever lab work has been completed should be done during the next lab session.

2. The promptness of submission should be encouraged by way of marking and evaluation patterns that will benefit the sincere students.

***Experiment No. :1***

***Aim*** : - Measurement of op-amp parameters viz. Input offset voltage, Bias current, Slew rate and CMRR.

***Apparatus*** : - IC 741, Resistors, Function generator, CRO, CRO probes, Dual power supply.

***Circuit diagram:-***

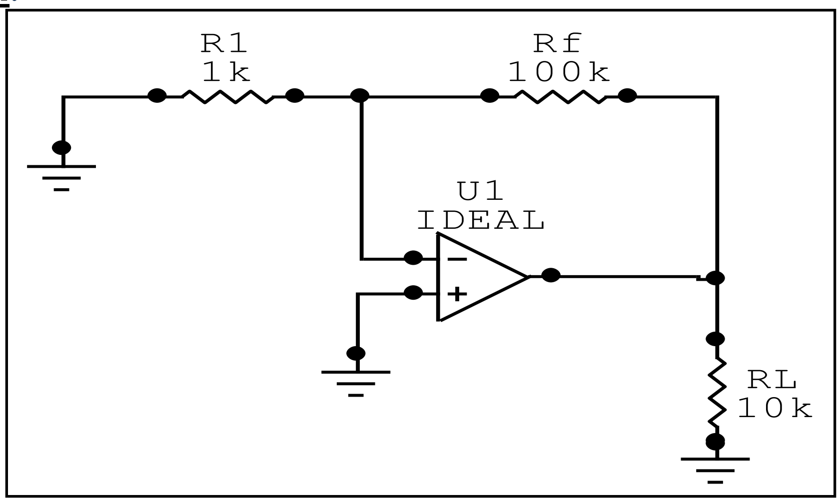



Fig 1: Input offset voltage

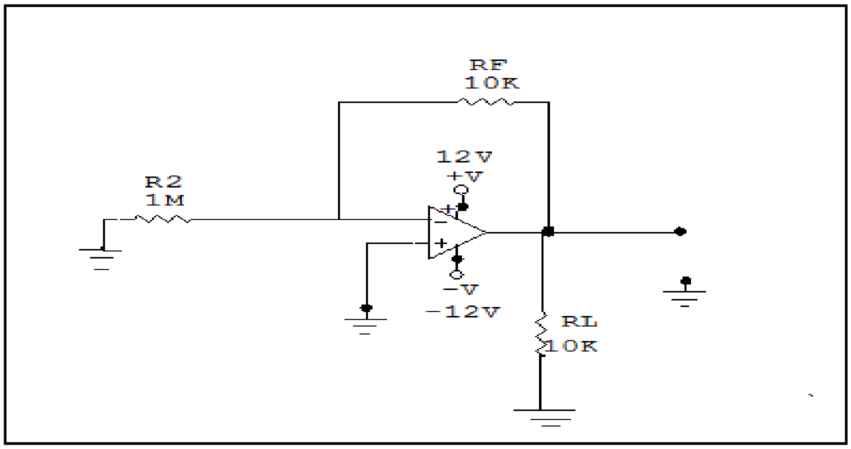



Fig 2: Bias current

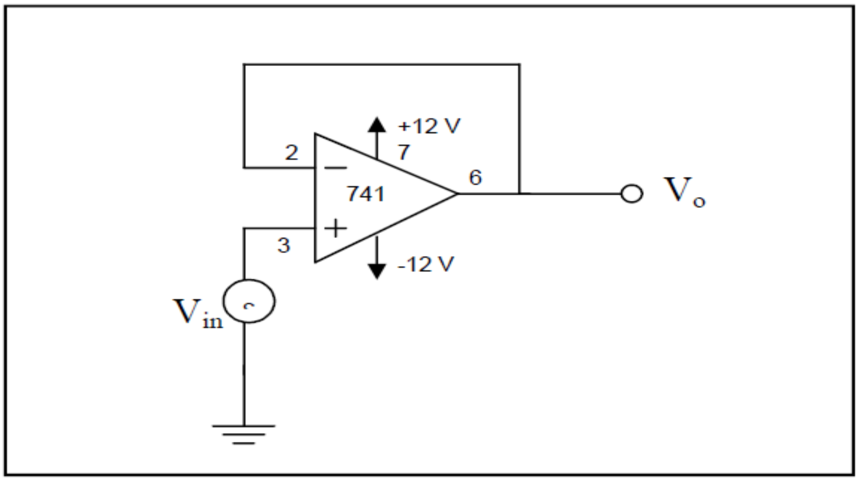



Fig.3 Measurement of Slew rate

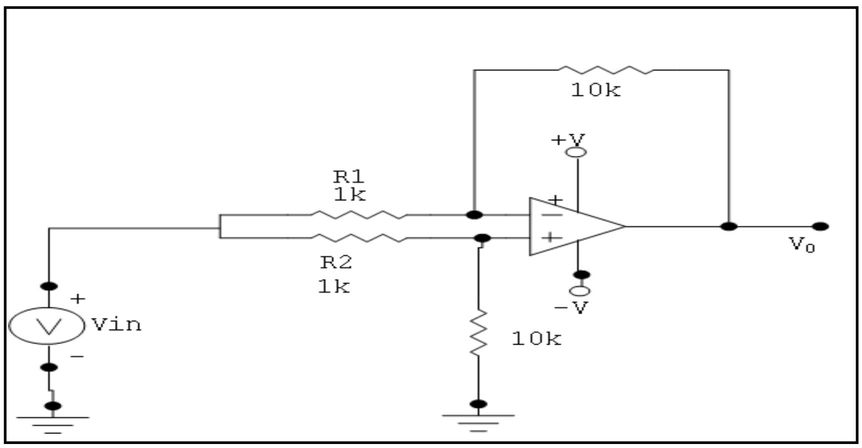



Fig 4: Common Mode for CMRR

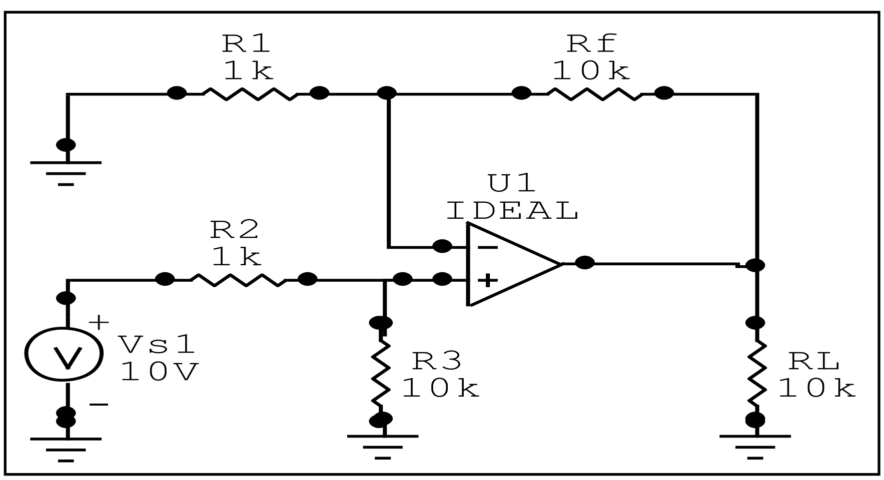



Fig 5: Differential Mode for CMRR

***Theory*** **: -**

**Input Offset Voltage**

Definition
Equation (If any)
Ideal Value and Value for IC 741

**Input Bias Current**

Definition
Equation (If any)
Ideal Value and Value for IC 741

**Slew Rate**

Definition
Equation (If any)
Ideal Value and Value for IC 741

**CMRR**

Definition
Equation (If any)
Ideal Value and Value for IC 741

***Procedure*** **: -** **For Input Offset Voltage**

1. Make connections as shown in figure.
2. Measure the output voltage.
3. Calculate the value of input offset voltage.

**For Input Bias Current**

1. Make connections as shown in figure.
2. Measure the output voltage.
3. Calculate the value of input bias current by using given formula.

**For Slew Rate**

1. Make connections as shown in figure.
2. Note down the value of $V_{peak.}$
3. Vary the frequency of input voltage & observe the output waveform.
4. Note the value of frequency at which output waveform start distorting.
5. Calculate the value of slew rate using given formula.

**For CMRR**

1. Make connections as shown in the figure.
2. Give i/p voltage of 1v peak to peak.
3. Measure the differential & common mode output.
4. Calculate Ad, Acm, & CMRR in db using formula.

***Observation*** **:-** **For Input offset voltage and Bias current**

| $V_{oo}$ (For $V_{ios}$) | $V_o$ (For $I_b$) |
|---|---|
| | |

**For Slew rate**

| Input frequency | Remark |
|---|---|
| | |
| | |
| | |
| | |

**For CMRR**

Vo1= Vo2=

***Formulae*** **: -** **For Input offset voltage**

$V_{io} = V_{oo} /(1 + R_f/R_1)$

**For bias current**

$V_o = I_B * R_F$

$I_B = V_o/R_F$

**For Slew rate**

**For CMRR**

$CMRR = 20 \log(A_d/A_c)$

$Ad = V_{o1}/V_{in}$

$Acm = V_{o2}/V_{in}$

$CMRR=20\ \log(V_{o1}/V_{o2})$

***Result*** **:-**

| Sr. No. | Op Amp Parameter | Theoretical value for IC 741 | Calculated Value |
|---|---|---|---|
| 1 | Input Offset Voltage | | |
| 2 | Input Bias Current | | |
| 3 | Slew Rate | | |
| 4 | CMRR | | |

***Conclusion*** **:-**

# ***Experiment No. :2***

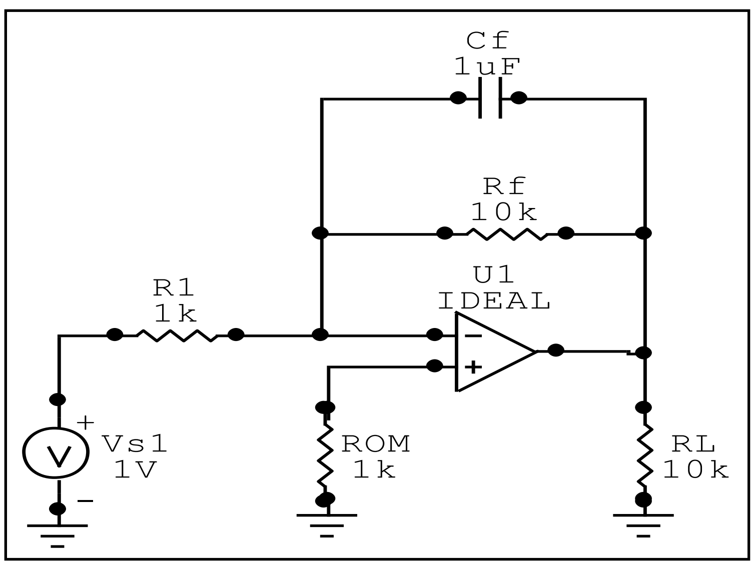
***Aim*** **: -** Design and verify the frequency response of Integrator circuit using IC741.

***Apparatus*** **: -** IC 741, Resistors, Capacitor, Function Generator, CRO, CRO probes, Dual Power Supply.

***Theory*** **: -**

Integrator definition
Derivation of output
Input and output waveforms for standard test signals
Frequency Response

***Circuit Diagram*****:-**




***Procedure*****: -**

1. Make the connections as per circuit diagram.
2. Switch on the power supply.
3. Apply input from function generator i.e. sinewave of amplitude 1V $_{(p-p)}$ (the input should be such that $T > R_F.C_F$)
4. Connect output of integrator to CRO by probe and observe the waveforms.
5. Vary input frequency and observe the change in output waveforms.
6. For different frequencies and note the corresponding output Voltage.

7. Calculate the Gain using the formula and plot the graph between frequency and Gain.

***Observations***:-

| Sr. No. | Frequency (Hz) | $V_0$ | Gain = $V_0 / V_i$ | Gain in dB = $20\log(V_0 / V_i)$ |
|---|---|---|---|---|
| 1 | 100 | | | |
| 2 | 300 | | | |
| 3 | 500 | | | |
| 4 | 800 | | | |
| 5 | 1k | | | |
| 6 | 3k | | | |
| 7 | 5k | | | |
| 8 | 8k | | | |
| 9 | 10k | | | |
| 10 | 15k | | | |
| 11 | 20k | | | |

***Cutoff Frequency*** :- $f_c = 1/ 2\pi R_f C_f$

***Result*** :- Calculated Value of cutoff frequency = ____________
Observed Value of cutoff frequency = ____________

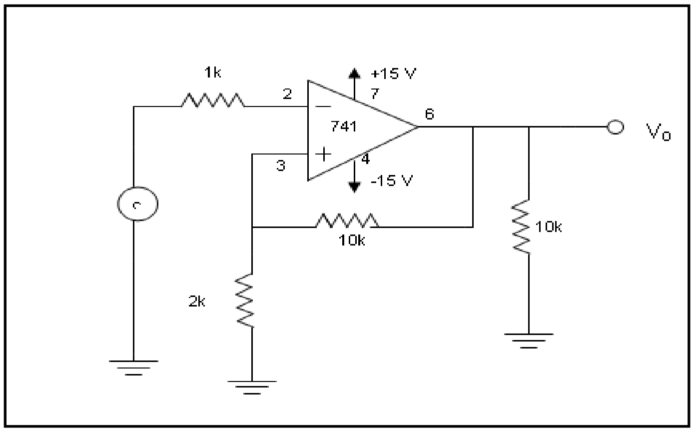
***Conclusion*** :-

## ***Experiment No. 3:***

***Aim*** : - To study Schmitt trigger circuit using op-amp 741.

***Apparatus*** : - IC 741, Resistors, Function generator, CRO, CRO probes, Dual power supply.

***Circuit diagram***:-




***Theory*** :-

Inverting Shmitt trigger
Non Inverting Shmitt trigger
Applications

***Procedure*** :-

1. Make connections as shown in figure.
2. Apply sinewave input from function generator.
3. Observe the input as well as output waveform on CRO.
4. Plot the waveforms on graph paper.
5. Draw hysteresis loop.

***Formula*** :-

$V_{UT} = +V_{sat} * (R_2 / (R_1 + R_2)\ )$ $V_{LT} = -V_{sat} * (R_2 / (R_1 + R_2))$

***Observations*** :-

$V_{LT} =$ $V_{UT} =$

***Result*** :-

| Sr. No | Calculated Value | Observed Value |
|---|---|---|
| 1 | $V_{UT}$ | |
| 2 | $V_{LT}$ | |

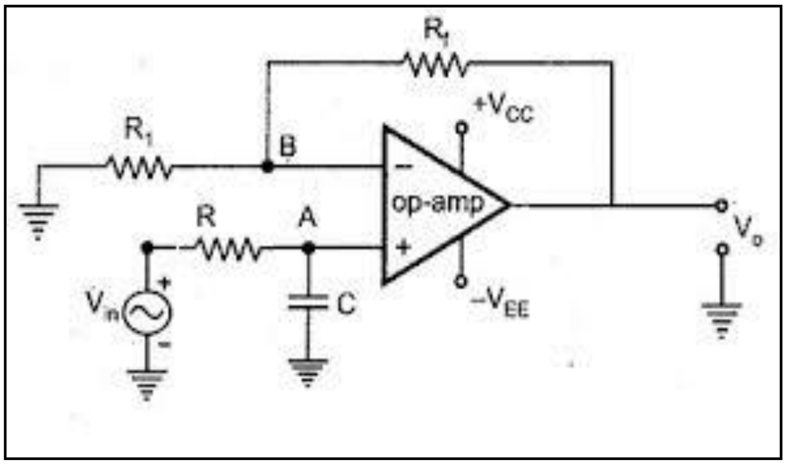
***Conclusion*** :-

**_Experiment No. :4_**

**_Aim_** **:-** Design a first order low pass Butterworth filter using op-amp..

**_Apparatus_** **:-** IC 741, Resistors, Capacitor, Function Generator, CRO, CRO probes, Dual Power Supply.

**_Circuit diagram_**:-




***$R_F$ = 10k, $R_1$ = 1k, R = 1k, C = 0.01µF***

**_Theory:-_**

Active Filter
First order Low Pass Butterworth filter
Frequency response and cut off frequency

**_Procedure:-_**

1. Make the connections as per circuit diagram.
2. Switch on the power supply.
3. Apply input from function generator i.e. sine wave of amplitude 1V $_{(p-p)}$
4. Connect output of LPF to CRO by probe and observe the waveforms.
5. Vary input frequency and observe the change in output waveforms.
6. For different frequencies and note the corresponding output Voltage.
7. Calculate the Gain using the formula and plot the graph between frequency and Gain.

***Observations*** :-

| Sr. No. | Frequency (Hz) | $V_0$ | Gain = $V_0 / V_i$ | Gain in dB = $20\log(V_0 / V_i)$ |
|---|---|---|---|---|
| 1 | 100 | | | |
| 2 | 300 | | | |
| 3 | 500 | | | |
| 4 | 800 | | | |
| 5 | 1k | | | |
| 6 | 3k | | | |
| 7 | 5k | | | |
| 8 | 8k | | | |
| 9 | 10k | | | |
| 10 | 15k | | | |
| 11 | 20k | | | |
| 12 | 50k | | | |
| 13 | 80k | | | |
| 14 | 100k | | | |

***Cutoff Frequency*** :- $f_c = 1/ 2\pi RC$

***Result*** :- Calculated Value of cutoff frequency = ____________

Observed Value of cutoff frequency = ____________

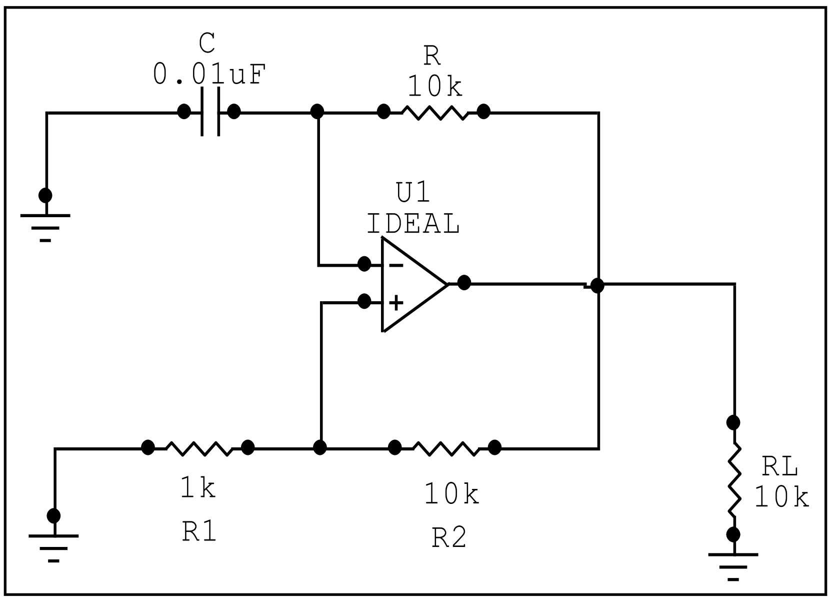
***Conclusion*** :-

## ***Experiment No. :5***

***Aim*** :- Design a square wave generator using op-amp.

***Apparatus*** :- IC 741, Resistors, Capacitor, Function Generator, CRO, CRO probes, Dual Power Supply.

***Circuit diagram***:-




***Theory*** : -

Working of square wave generator circuit
Define duty cycle
Derive the expression for output frequency of square wave

***Procedure*** : -

1. Make the connections as per circuit diagram.
2. Switch on the power supply.
3. Observe output waveform on CRO.
4. Measure the time period and calculate the practical frequency of square wave.
5. Calculate the theoretical value of frequency by given formula.
6. Plot waveform on graph paper.

***Formulae*** : - $f_o = 1/2RC \ln((2R_1+R_2)/R_2)$

***Observations*** :-

$f_o =$

***Result*** : - Calculated Value of output frequency = ____________

Observed Value of output frequency = ____________

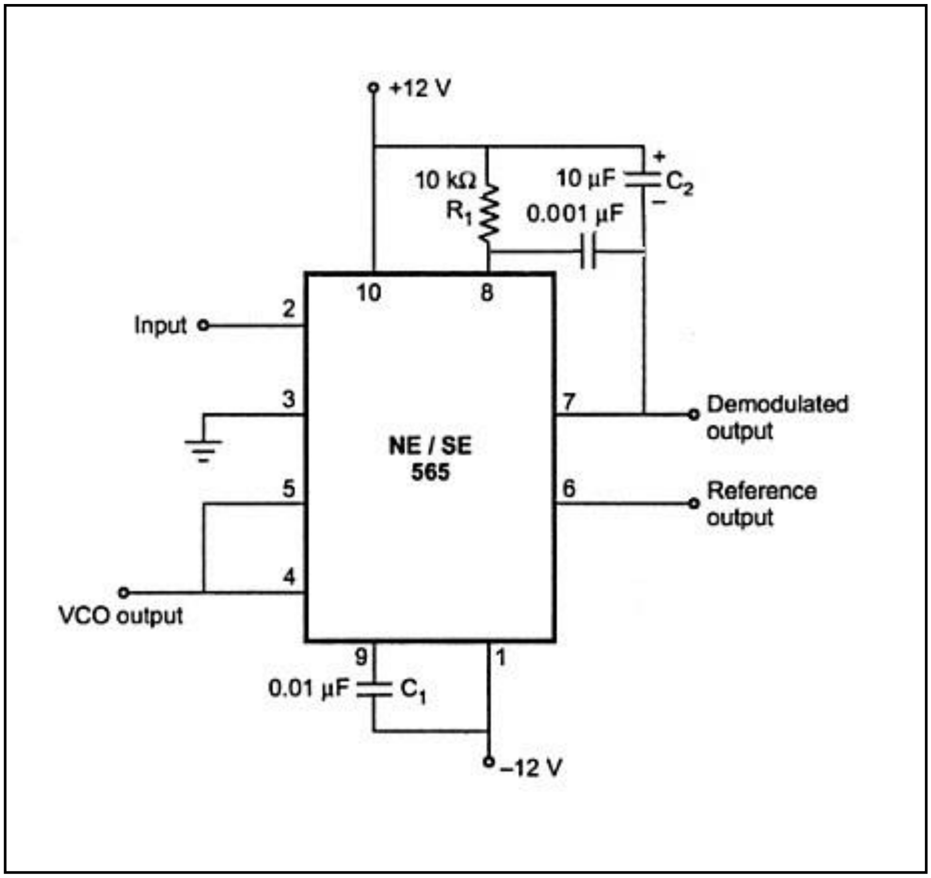
***Conclusion*** : -

## *Experiment No.- 6*

***Aim*** **: -** To study the operation of IC-565 as PLL and measure its free running frequency.

***Apparatus*** **:-** IC 565, Resistors, Capacitor, Dual Power Supply, Digital Multimeter.

***Circuit diagram***:-



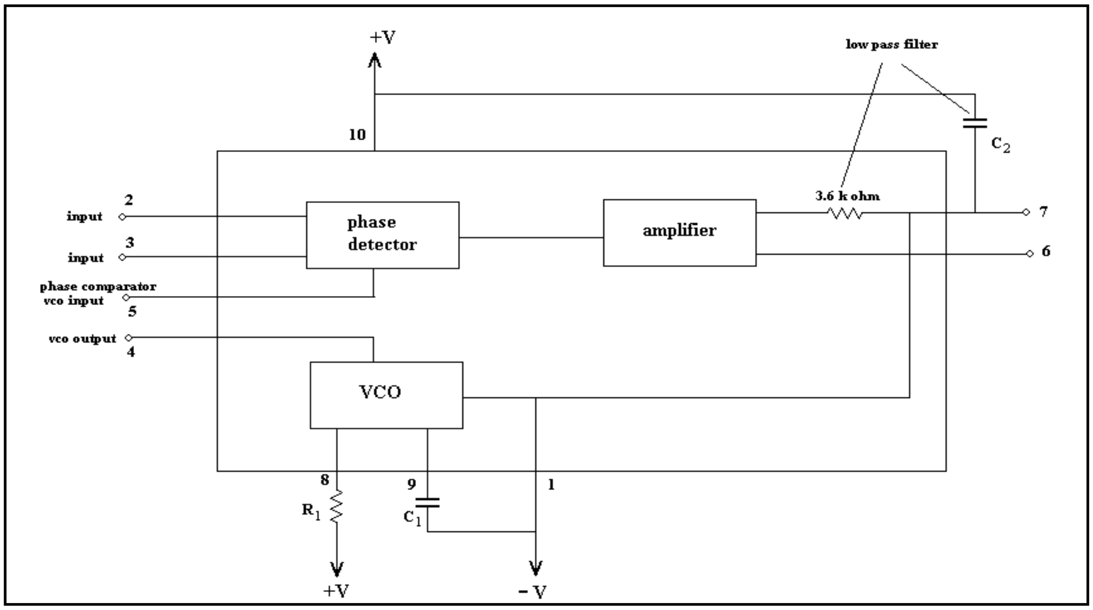

***Theory*** **: -**

**IC 565:**

**Description : -**

The Signetics SE/NE 560 series is monolithic phase locked loops. The SE/NE 560, 561, 562, 564, 565, & 567 differ mainly in operating frequency range, power supply requirements and frequency and bandwidth adjustment ranges. The device is available as 14 Pin DIP package and as 10-pin metal can package. Phase comparator or phase detector compare the frequency of input signal $f_s$ with frequency of VCO output $f_o$ and it generates a signal which is function of difference between the phase of input signal and phase of feedback signal which is basically a d.c voltage mixed with high frequency noise. LPF remove high frequency noise voltage. Output is error voltage. If control voltage of VCO is 0, then frequency is center frequency ($f_o$) and mode is free running mode. Application of control voltage shifts the output frequency of VCO from $f_o$ to f. On application of error voltage, difference between $f_s$ & f tends to decrease and VCO is said to be locked. While in locked condition, the PLL tracks the changes of frequency of input signal.

**Block Diagram of IC 565**

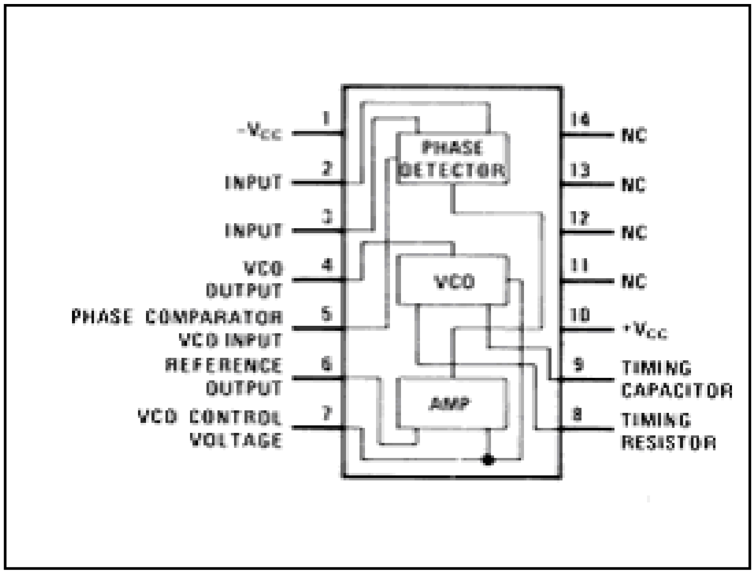



**Specifications:**

| | | | |
|---|---|---|---|
| 1. | Operating frequency range | : | 0.001 Hz to 500 KHz |
| 2. | Operating voltage range | : | ±6 to ±12V |
| 3. | Inputs level required for tracking | : | 10mV rms minimum to 3v (p-p) max. |
| 4. | Input impedance | : | 10 KΩ typically |
| 5. | Output sink current | : | 1mA typically |
| 6. | Drift in VCO center frequency ($_{fout}$) with temperature | : | 300 PPM/$^o$C typically |
| 7. | Drif in VCO centre frequency with supply voltage | : | 1.5%/V maximum |
| 8. | Triangle wave amplitude | : | typically 2.4 $V_{PP}$ at ± 6V |

9. Square wave amplitude : typically 5.4 $V_{PP}$ at ± 6V
10. Output source current : 10mA typically
11. Bandwidth adjustment range : < ±1 to > ± 60%

**Pin Configuration:**




**How to calculate the Free running frequency, Lock range and capture range for IC 565?**

If $R_1$, $C_1$ and $C_2$ are the externally connected components to the PLL IC 565 as shown in figure above then the Free running frequency, Lock range and capture range can be calculated as

Free running frequency $f_{out} = 1.2/4R_1C_1$ Hz

Lock range, $F_L$ and Capture range, $f_c$ can be calculated as

$$f_L = \pm \frac{8 f_o}{V} \text{ Hz}$$

$f_o$ = free running frequency of VCO in Hz

$V = (+V) - (-V)$ volts

$$f_c = \pm \left[ \frac{f_L}{2\pi (3.6)(10^3)(C_2)} \right]^{1/2}$$

**Applications:**

1. Frequency multiplier
2. Frequency shift keying (FSK) demodulator

3. FM detector

***Procedure*: -**

1. Make the connections as per circuit diagram.
2. Switch on the power supply.
3. Measure the frequency of output waveform which is free running frequency of PLL.

***Observation*: -**

Free running frequency of PLL = _______ Hz.

***Formula*: -**

Free running frequency $f_{out}$ $= 1.2/4R_1C_1$ Hz

***Result*** :- Calculated Value of Free running frequency = ___________
Observed Value of Free running frequency = ___________

***Conclusion:-***

**Experiment No 7**

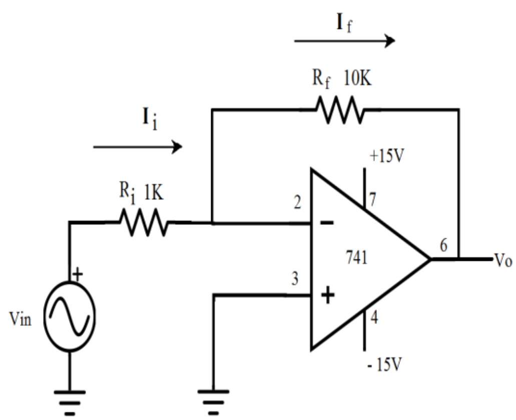
## INVERTING AMPLIFIER

***Aim***: To design an Inverting Amplifier for the given specifications using Op-Amp IC 741.

***Apparatus*** : Function Generator, CRO , Dual Power supply , Bread Board , Resistors , IC 741

***Theory :*** **1.** Working of an Inverting amplifier
**2**. Justify $V_o = - A_{CL} V_i$
3. Output waveform for sine wave as input

***Circuit Diagram :***




***Procedure:***

1.. Check the components.
2. Setup the circuit on the breadboard and check the connections
3. Switch on the power supply.
4. Give 1 Vpp / 1 KHz sine wave as input.
5. Observe input and output on the two channels of the oscilloscope simultaneously.
6. Note down and draw the input and output waveforms on the graph.
7. Verify the input and output waveforms are out of phase.
8. Verify the obtained gain is same as designed value of gain.

***Design:***

Gain of an inverting amplifier $Av = V_o/V_{in} = - R_f / R_i$
The required gain = 10,
That is $Av = - R_f/ R_i = 10$
Let $R_i = 1K\Omega$, Then $R_f = 10K\Omega$

***<u>Observations</u>:***

Vin = 1 Vpp

Vo=?

Gain, Av = Vo/Vin =?

Observed phase difference between

***<u>Result</u> :***

***<u>Graph</u>:***

## Experiment No. 8

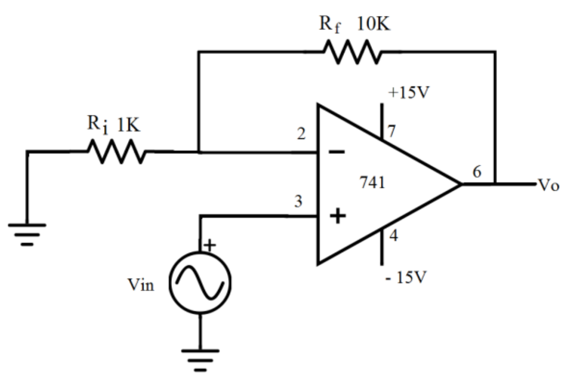
# NON- INVERTING AMPLIFIER

***Aim*:** To design and setup a non-inverting amplifier circuit with OPAMP IC 741C

***Apparatus***: Function Generator, CRO , Dual RPS , Bread Board , Resistors , IC 741

***Theory*:** **1.** Working of an Inverting amplifier
**2**. Justify $V_O = 1+ [RF/R1]$
3. Output waveform for sine wave as input.

***Circuit Diagram* :**




***Procedure*:**
1. Check the components.
2. Setup the circuit on the breadboard and check the connections.
3. Switch on the power supply.
4. Give 1 Vpp / 1 KHz sine wave as input.
5. Observe input and output on the two channels of the CRO simultaneously.
6. Note down and draw the input and output waveforms on the graph.
7. Verify the input and output waveforms are in phase.
8. Verify the obtained gain is same as designed value.

***Design*:**
Gain of an inverting amplifier $Av=V_o/V_{in} = (1+R_f)/ R_i$,
Let the required gain be 11,
Therefore $Av= (1+R_f)/ R_i= 11$
$R_f/ R_i = 10$
Take $R_i= 1K\Omega$, Then $R_f = 10K\Omega$

***Observations:***
Vin = 1Vpp
Vo = ?
Gain Av = Vo/Vin =?
Observed phase difference between the input and the output on the CRO =?

***Result:***

***Graph:***

**Experiment No. 9**

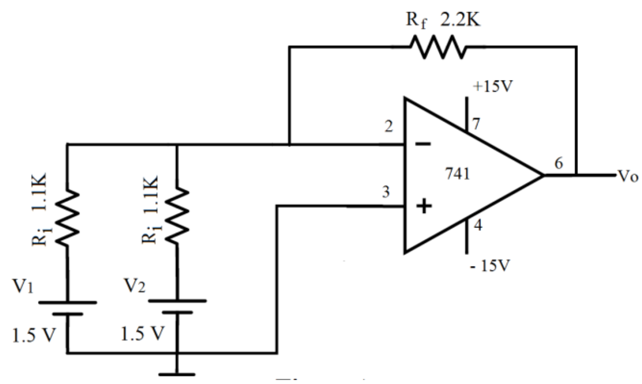
# SUMMING AMPLIFIER

***Aim*:** To design and setup a summing amplifier circuit with OP AMP 741C for a gain of 2 and verify the output.

***Apparatus***: Function Generator, CRO , Dual RPS , Bread Board , Resistors , IC 741

***Theory:*** 1. Working of summing amplier
2. Prove $V_o = -(R_f / R_i)(V_1+V_2)$
3.Application of summing amplifier

***Circuit diagram***




***Procedure :***
1. Check the components.
2. Setup the circuit on the breadboard and check the connections.
3. Switch on the power supply.
4. Give $V_1 = V_2 = +1.5V$ DC with polarity as shown in fig.1.
5. Make sure that the CRO selector is in the D.C. coupling position**.**
6. Observe input and output on two channels of the oscilloscope simultaneously.
7. Note down and draw the input and output waveforms on the graph.
8. Verify that the output voltage is -6VDC

***Design:***
The output voltage of an inverting summing amplifier is given by

$$V_o = -(R_f / R_i)(V_1+V_2)$$

Let $R_i = 1.1K\Omega$

Then $R_f = 2.2K\Omega$ ,

$$V_o = -2(V_1+V_2)$$

***Observation*:**

$V_1$= 1.5 DC

$V_2$= 1.5 DC

Then VO=?

***Result:***

## Experiment No. 10

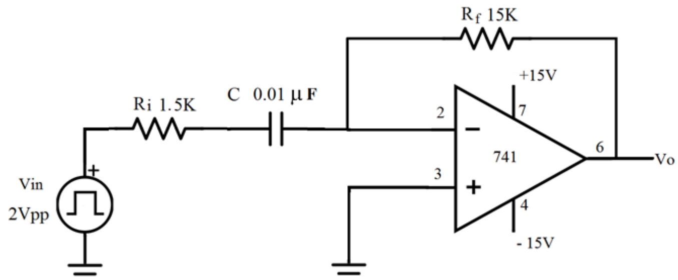
## DIFFERENTIATOR

***Aim*:** To design and setup a Differentiator circuit using OP AMP 741C and plot their pulse response.

***Apparatus*:** Function Generator, CRO , Dual RPS , Bread Board , Resistors , IC 741

***Theory* : 1.** Working of Differentiator
2. Prove $V_o = -R_f C d(V_{in})/dt$.

***Circuit diagram:***




***Procedure:***

1. Check the components.
2. Setup the circuit on the breadboard and check the connections.
3. Switch on the power supply.
4. Keep the oscilloscope in AC coupling mode.
5. Give $V_i$= 2Vpp, 1KHz square wave.
6. Observe input and output on two channels of the oscilloscope simultaneously.
7. Note down and draw the input and output waveforms on the graph

***Design :***

Given f = 1 KHz
T = 1/f = 1ms
Design equation is $T = 2\pi R_f C$
Let C = 0.01µF
$R_f$ = 15KΩ
Let Ri = Rf/10 = 1.5KΩ

***Result :***

***Graph:***

## Experiment No. 11

## RC PHASE SHIFT OSCILLATOR USING OP AMP

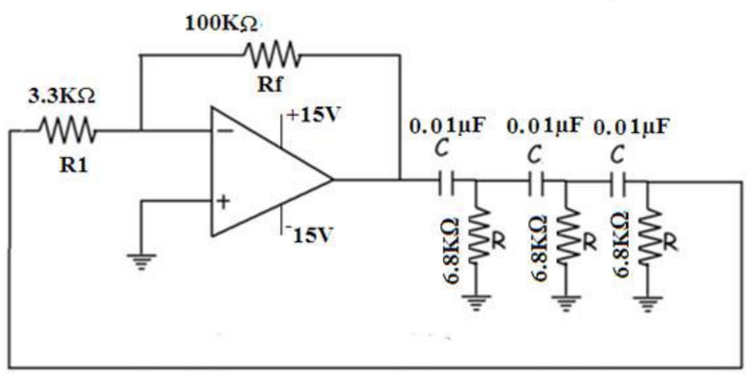
***Aim*:** To Design and setup a RC phase shift oscillator using Op-Amp 741 and (i) Plot the output waveform (ii) Measure the frequency of oscillation.

***Apparatus*:** **:** Function Generator, CRO , Dual RPS , Bread Board , Resistors , Capacitors ,IC 741.

***Theory***: 1. Working of RC phase shift oscillator

2. Prove F osci $= \frac{1}{2\pi RC\sqrt{6}}$

***Circuit diagram*:**




***Procedure* :**

1. Check the components.
2. Setup the RC phase shift oscillator circuit on the breadboard and check the connections.
3. Switch on the power supply.
4. Observe output voltage on oscilloscope.
5. Draw the waveforms on the graph.
6. Measure the frequency of oscillation

***Design* :**

F osci $= \frac{1}{2\pi RC\sqrt{6}}$

Let f = 1 KHz, and C= 0.01μF

R = 6.8KΩ

Gain = 29

$R_f/R_1 = 29$

If R1 = 3.3KΩ ; Rf = 95.7KΩ Use 100KΩ pot

***Observations*:**

Measured frequency of oscillation is =?

***Graph:***

***3. Quiz on the subject:***

1. What are the values of high input impedance , low output impedance & high voltage gain obtained in operational amplifier
   a)2MΩ, 50Ω, 1MΩ    b) 2KΩ, 5kΩ, 1MΩ    c) 2MΩ, 75Ω, 1MΩ    d)2MΩ, 75Ω, 1KΩ

2. The CMRR of good quality op-amp is of the order of
   a) 12 dB    b) 25 dB    c)100 dB    d) 120 dB

3. The frequency at which differential gain in op-amp is zero dB is known as
   a) unity gain crossover frequency    b) resonant frequency
   c) 3 dB frequency    d) zero frequency

4. Compared to non-inverting amplifier, the gain of inverting amplifier using identical op-amp is
   a) equal    b) slightly smaller    c) slightly greater    d) very large

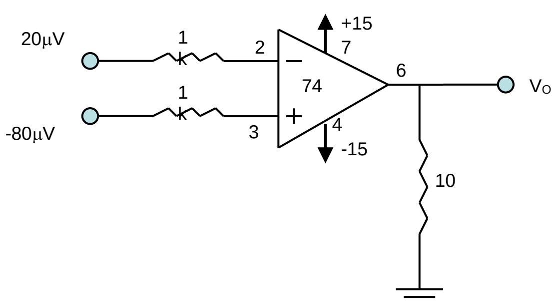
5. Op-amp operating in its non-inverting saturation region can convert a sine wave into
   a) sine wave    b) triangular wave    c) square wave    d) saw tooth wave

6. Gain of an op-amp inverting amplifier with an input of 0.25 V & output of 17.5 V is
   a) 50    b) 40    c) 80    d) 70

7. Closed loop voltage gain of ideal non-inverting op-amp is given by
   a) $\frac{R_f}{R_1}$    b) $-\frac{R_f}{R_1}$    c) $1+\frac{R_f}{R_1}$    d) $\frac{R_1}{R_f}$

8. Closed loop voltage gain of ideal inverting op-amp is given by
   a) $\frac{R_f}{R_1}$    b) $-\frac{R_f}{R_1}$    c) $1+\frac{R_f}{R_1}$    d) $\frac{R_1}{R_f}$

9. The op-amp shown below has $A_V$=20,000 & $Z_O$=20Ω. The approximate $V_O$ is




a) 2V    b) 3V    c) 60 µV    d) 2mV

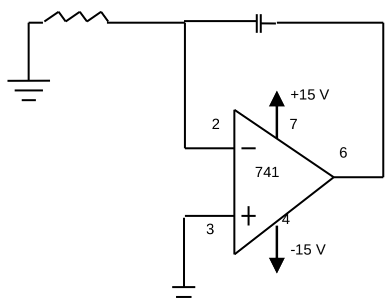
10. An op-amp has gain of 50 & bandwidth of 100 KHz. Its unity gain frequency is
    a) 5 MHz    b) 50 MHz    c) 100KHz    d) 50 Hz

11. Which of the following op-amp system is a linear system.
    a) Integrator b)Clipper c) Sample& Hold d) square wave

12. Which of the following op-amp system is a linear system.
    a) current to voltage converter b) Logarithmic c)comparator
    d)Square wave generator

13. Which of the following op-amp system is a nonlinear system.
    a) Voltage to current converter b) voltage follower c) Active filter d) sample & hold

14. The op-amp circuit below behaves as a
    a) Integrator b) Differentiator c)voltage follower d) Comparator

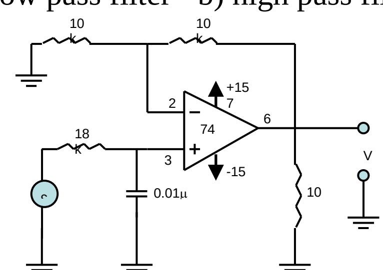



15. An op-amp Schmitt trigger is basically an comparator with
    a) negative feedback b) positive feedback
    c) open loop configuration d) none of these

16. An op-amp zero crossing detector is basically
    a) cosine to sine wave converter b) sine to cosine wave converter
    c) sine to square wave converter d) sine to triangular wave converter

17. Compared to open loop bandwidth of close loop is
    a) equal b) less c) greater d) none of these

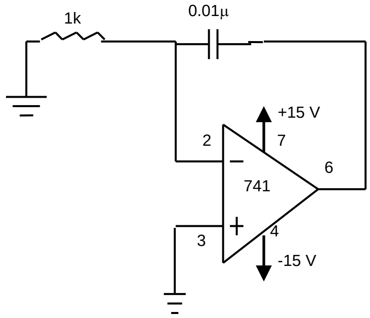
18. The op-amp circuit below behaves as a
    a) low pass filter b) high pass filter c) buffer amplifier d) adder




19. Input impedance of Ideal op-amp should be
    a) 100Ω b) zero c) 1 MΩ d) Infinite

20. CMRR of Ideal op-amp should be
    a) 100Ω b) zero c) 1 MΩ d) Infinite

21. The op-amp circuit given below behaves as
    a) Integrator b) Differentiator c) high pass filter d) low pass filter




22. Frequency range of audio amplifier is
    a) 10Hz to 100 KHz b) 20Hz to 20 KHz c) 20MHz to 100 GHz d) 10KHz to 100 MHz

23. The range of frequencies over which the PLL can maintain lock with incoming signal is called
    a) capture range b) lock range c) input frequency range d) bandwidth

24. The range of frequencies over which the PLL can acquire lock with incoming signal is called
    a) capture range b) lock range c) input frequency range d) bandwidth

25. Slew rate of Ideal op-amp should be
    a) 100Ω b) zero c) 1 MΩ d) Infinite

***4. Conduction of Viva-Voce Examinations:***

Teacher should conduct oral exams of the students with full preparation. Normally, the objective questions with guess are to be avoided. To make it meaningful, the questions should be such that depth of the students in the subject is tested. Oral examinations are to be conducted in cordial environment amongst the teachers taking the examination. Teachers taking such examinations should not have ill thoughts about each other and courtesies should be offered to each other in case of difference of opinion, which should be critically suppressed in front of the students.

***5. Evaluation and marking system:***

Basic honesty in the evaluation and marking system is absolutely essential and in the process impartial nature of the evaluator is required in the examination system to become. It is a wrong approach or concept to award the students by way of easy marking to get cheap popularity among the students, which they do not deserve. It is a primary responsibility of the teacher to see that right students who are really putting up lot of hard work with right kind of intelligence are correctly awarded.

The marking patterns should be justifiable to the students without any ambiguity and teacher should see that students are faced with just circumstances.