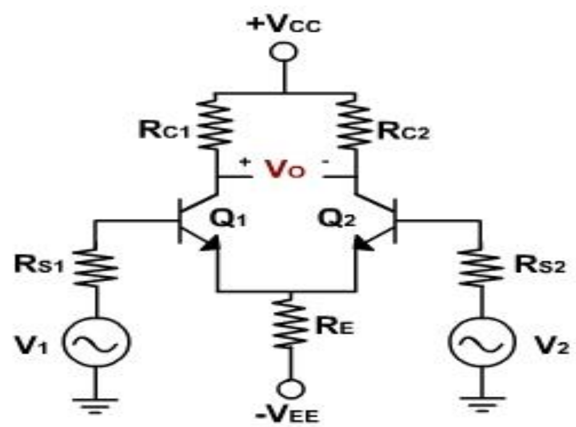
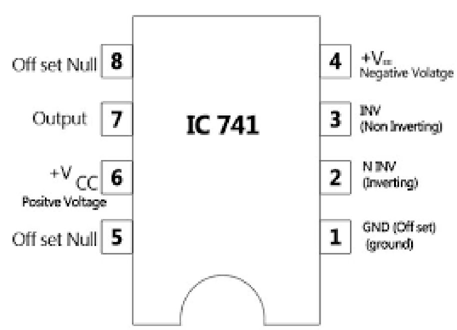
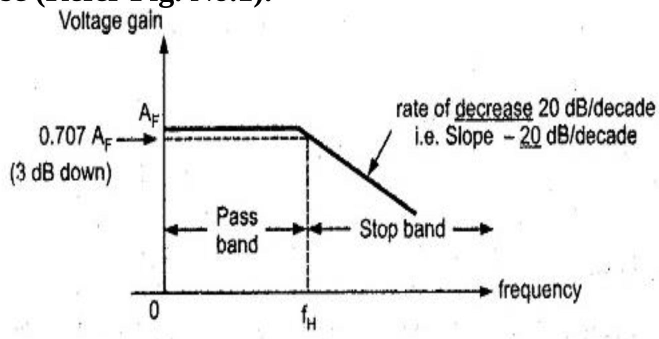
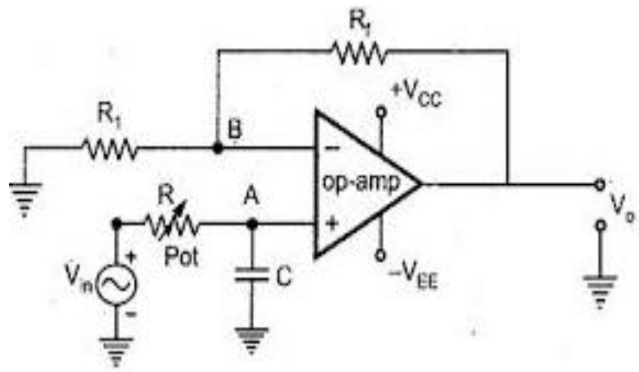
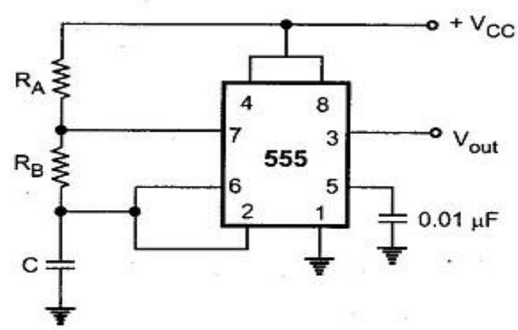
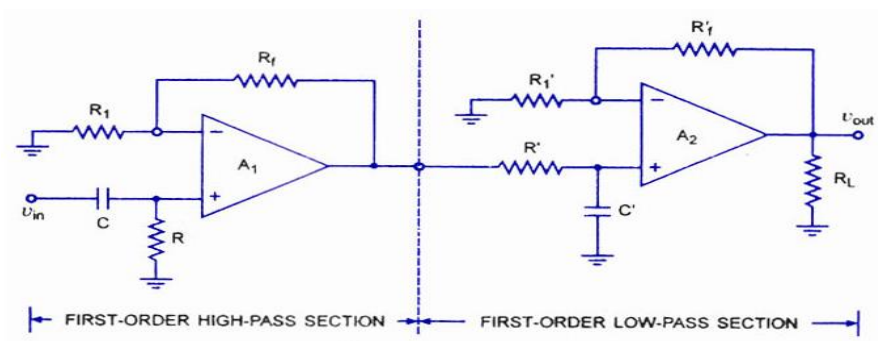
MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER– 2019 EXAMINATION

Subject Name: Analog Circuits **Model Answer** **Subject Code: 22433**

Important Instructions to examiners:
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by the candidate may vary, but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills)
4) While assessing figures, the examiner may give credit for principal components indicated in the figure. The figures drawn by the candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and the model answer.
6) In case of any questions credit may be given by judgement on the part of examiner of relevant answer based on candidate's understanding.
7) In programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1.		Attempt any FIVE of the following:	10 M
	a)	**Draw circuit diagram of dual input Balanced output differential amplifier.** **Ans:**  **Fig: Dual input Balanced output differential amplifier**	02M
	b)	**Draw pin diagram of IC 741.** **Ans:**  **Fig: Pin diagram of IC 741**	02M

	c)	**Suggest and draw op-amp based circuit using Butterworth filter to fulfill following frequency response (Refer Fig. No.1).**  **Fig. No. 1** **Ans:**  **Fig:Butterworth low pass filter**	**02M**
	d)	**Draw astable multivibrator using IC 555.** **Ans:**  **Fig: Astable multivibrator**	**02M**
	e)	**Draw circuit diagram of Butterworth band pass filter using OP-AMP** **Ans:**  **Fig: Butterworth band pass filter using OP-AMP**	**02M**

f) **Draw circuit diagram of log and antilog amplifiers using OP-AMP.** — **02M**

Ans:

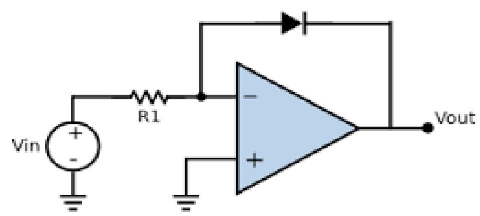


Fig: Log amplifier

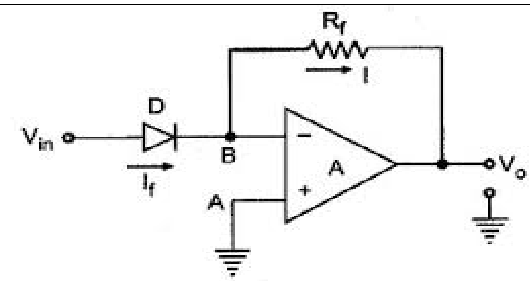


Fig: Antilog amplifier

Table: Circuit diagram of log and antilog amplifier using OP-AMP

g) **Draw circuit diagram of V to I converter using OP-AMP with grounded load.** — **02M**

Ans:

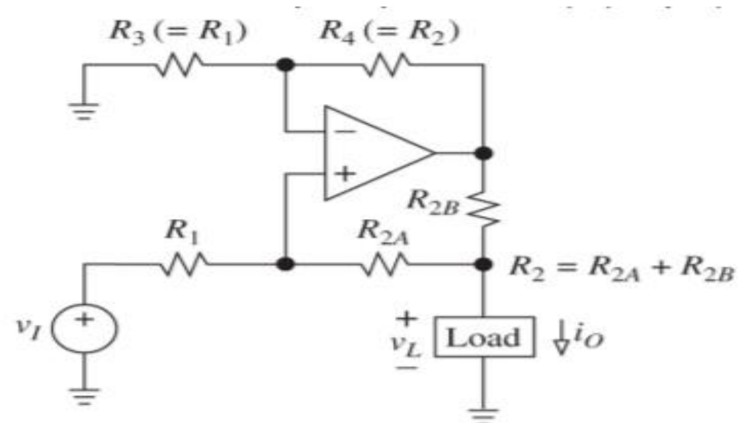


Fig: V to I converter using OP-AMP with grounded laod.

2. **Attempt any <u>THREE</u> of the following:** — **12 M**

a) **Draw circuit diagram of precision rectifier using op-amp and describe its working.**

Ans:

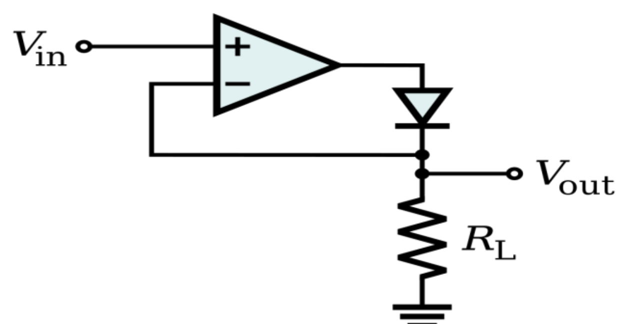


Fig: Circuit diagram of precision rectifier using op-amp — **02M**

The precision rectifier, also known as a super diode, is a configuration obtained with an operational amplifier in order to have a circuit behave like an ideal diode and rectifier.[1] It is useful for high-precision signal processing. The op-amp-based precision rectifier should not be confused with the power MOSFET-based active rectification ideal diode. The basic circuit implementing such a feature is shown on the right, where can be any load. When the input voltage is negative, there is a negative voltage on the diode, so it works like an open circuit, no current flows through the load, and the output voltage is zero.When the input is positive, it is amplified by the operational amplifier, which switches the diode on. Current flows through the load and, — **02M** because of the feedback, the output voltage is equal to the input voltage.The actual threshold of the super diode is very close to zero, but is not zero. It equals the actual threshold of the diode, divided by the gain of the operational amplifier.This basic configuration has a problem, so it is not commonly used. When the input becomes (even slightly) negative, the operational amplifier runs open-loop, as there is no feedback signal through the diode. For a typical operational amplifier with high open-loop gain, the output saturates. If the input then becomes positive again, the op-amp has to get out of the saturated state before positive amplification can take place again. This change generates some ringing and takes some time, greatly reducing the frequency response of the circuit.

b) With neat sketch derive the expression for output voltage of inverting amplifier.

Ans:

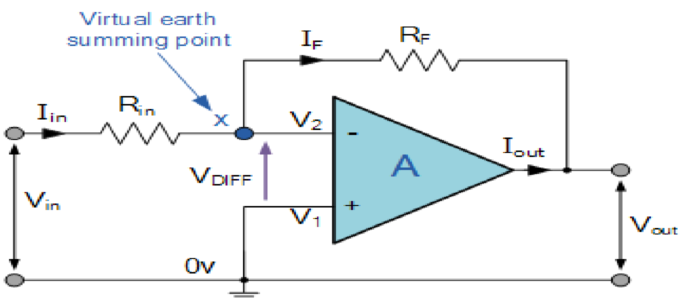


Fig: Inverting amplifier

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Expression for output voltage of inverting amplifier:

$$i = \frac{Vin - Vout}{Rin + Rf}$$

$$\text{therefore, } i = \frac{Vin - V2}{Rin} = \frac{V2 - Vout}{Rf}$$

$$i = \frac{Vin}{Rin} - \frac{V2}{Rin} = \frac{V2}{Rf} - \frac{Vout}{Rf}$$

$$\text{so, } \frac{Vin}{Rin} = V2\left[\frac{1}{Rin} + \frac{1}{Rf}\right] - \frac{Vout}{Rf}$$

$$\text{and as, } i = \frac{Vin - 0}{Rin} = \frac{0 - Vout}{Rf} \qquad \frac{Rf}{Rin} = \frac{0 - Vout}{Vin - 0}$$

$$\text{the Closed Loop Gain (Av) is given as, } \frac{Vout}{Vin} = -\frac{Rf}{Rin}$$

02M

c) Design second order butterworth high pass filter. If pass band gain is 2, R = 20 kΩ, C = 0.05 μF and draw the designed circuit diagram.

Ans:

Design steps of second order butterworth high pass filter as follows:

Let us consider the capacitor values as C1= C2 = C **= 0.05μF**

Let us consider the capacitor values as R1= R2 = R = **20kΩ**

The equation of the cut-off frequency is F = 1/ 2πRC

By re-arranging this equation we have F= 1/2πRC

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By substituting the values of capacitor as 0.05µF AND R = 20 KΩ = 2 KΩ. and calculate cut-off frequency.Therefore
cut-off frequency is **0.19 KHz**
Fc=0.159 KHz
Let the gain of the filter is 1+ R1/R2 = 2
R1 / R2 = 1
R1 = R2
Therefore we can take R1 = R2 = 20 KΩ
The gain of the filter is 1+ R1/R2 and the equation of the cut-off frequency is $f_c = 1/2\pi\sqrt{R_3R_4C_1C_2}$.

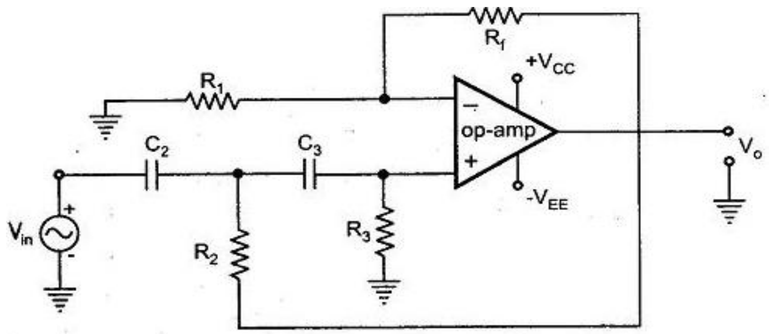

Fig: Second order butterworth high pass filter

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d) Draw I to V converter using OP-AMP. Also derive its output expression.
Ans:

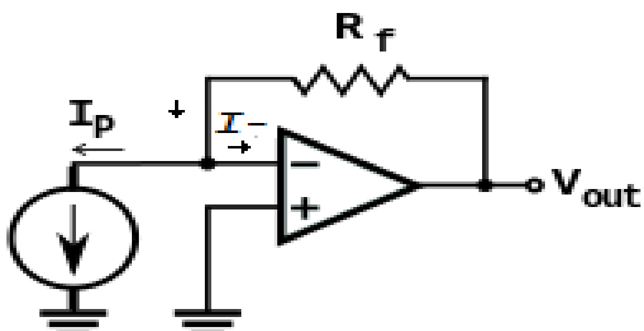

Fig: I to V converter using OP-AMP

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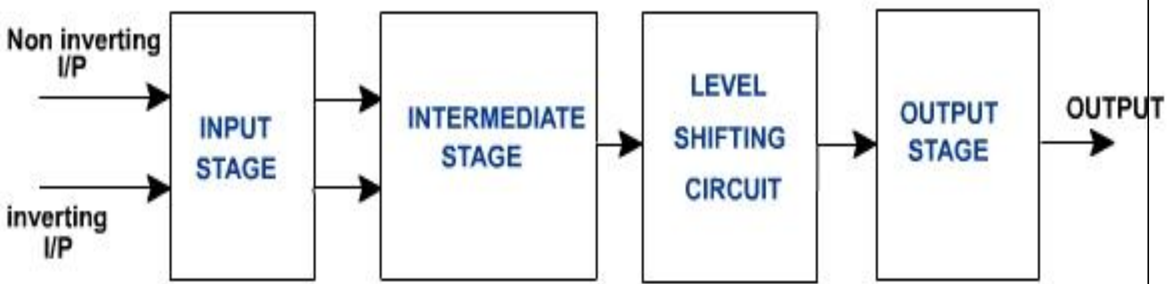
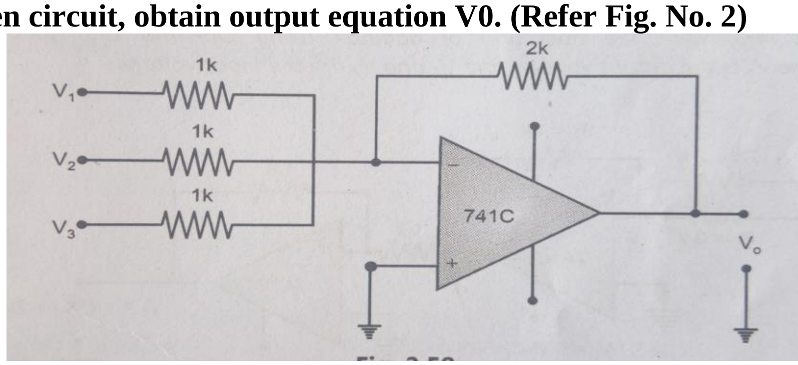
A current to voltage converter will produce a voltage proportional to the given current. This circuit is required if your measuring instrument is capable only of measuring voltages and you need to measure the current output.If your instrument or data acquisition module (DAQ) has a input impedance that is several orders larger than the converting resistor, a simple resistor circuit can be used to do the conversion. However, if the input impedance of your instrument is low compared to the converting resistor then the following opamp circuit should be used.
To analyse the current to voltage converter by inspection,

- if we apply KCL to the node at V- (the inverting input) and let the input current to the inverting input be I-, then
  Vout−V−Rf=Ip+I−(1)(1)Vout−V−Rf=Ip+I−
- since the output is connected to V- through R_f, the opamp is in a negative feedback configuration. Thus
  V−=V+=0(2)(2)V−=V+=0
- and assuming that I- is 0 and simplifying,
  Vout=IpRf(3)

02M

3.		**Attempt any <u>THREE</u> of the following:**	**12 M**
	a)	**Draw block diagram of OP-AMP. State function of level shifter and output stage.** **Ans:**  **Fig: The block diagram of OP-AMP** Level shifting stage is used to bring the dc level to zero volts w.r.t. ground. Op-amp is a direct coupled amplifier, So when input is zero or at ground potential ,the output of op-amp will be at some positive DC level which is an error voltage called as offset voltage . So in order to pull this o/p DC offset voltage to zero, the DC level shifter is used. The output stage increases the output voltage swing and raises the current supplying capability of the OPAMP. It also provides low output resistance.	**02M** **02M**
	b)	**For the given circuit, obtain output equation V0. (Refer Fig. No. 2)**  **Fig. No. 2** **Ans:** In the circuit, the input signals Va,Vb,Vc are applied to the inverting input of the opamp through input resistors Ra, Rb, Rc. Any number of input signals can be applied to the inverting input in the above manner. Rf is the feedback resistor. Ra=1kΩ, Rb=1kΩ, Rc=1k Ω and Rf=1kΩ Ra = Rb = Rc = R **Solution: For inverting adder:** $V_o = -\left(\frac{R_F}{R_1}V_1 + \frac{R_F}{R_2}V_2 + \frac{R_F}{R_3}V_3\right)$ $R_1 = R_2 = R_3 = R$ $V_o = \frac{R_F}{R}(V_1 + V_2 + V_3) = \frac{2k}{1k}(V_1 + V_2 + V_3) = -2(V_1 + V_2 + V_3)$	**02M** **02M**
	c)	**Draw and explain the working principle of wein bridge oscillator using IC 741.** **Ans:** When bridge oscillator is an audio frequency sine wave oscillator of high stability and simplicity. Before that let us see what is oscillator? An oscillator is a circuit that produces periodic electric signals such as sine wave or square wave. The	

application of oscillator includes sine wave generator, local oscillator for synchronous receivers etc. Here we are discussing wein bridge oscillator using 741 op amp IC. It is a low frequency oscillator. The op-amp used in this oscillator circuit is working as non-inverting amplifier mode. Here the feedback network need not provide any phase shift. The circuit can be viewed as a wien bridge with a series RC network in one arm and parallel RC network in the adjoining arm. Resistors Ri and Rf are connected in the remaining two arm. **02M**

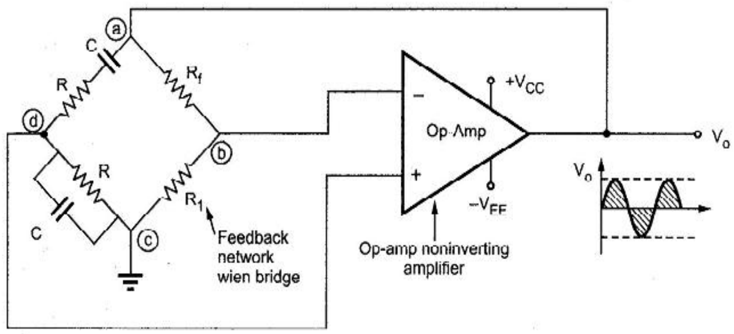


Fig: Wein bridge oscillator using IC 741 **02M**

d) **Draw the labeled circuit diagram of Band reject filter. Also sketch its frequency response for ± 20 dB/decade roll off rate.**

Ans:

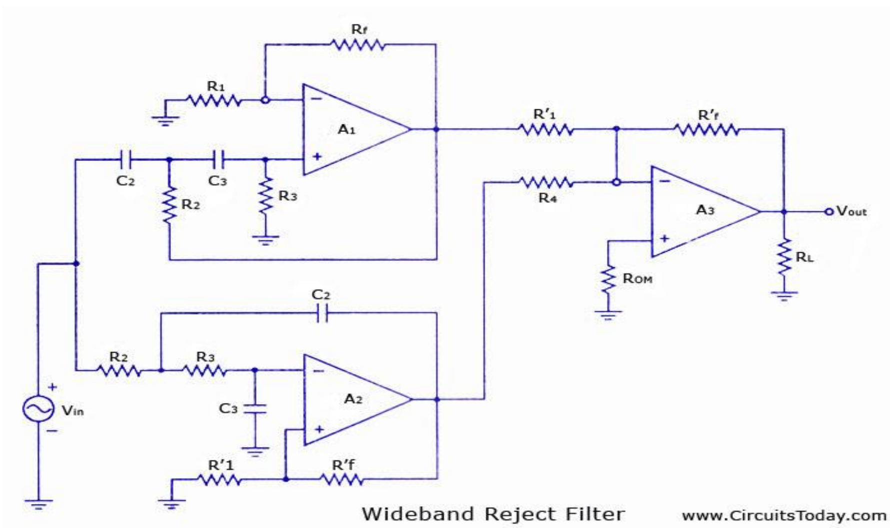


Fig: Circuit diagram of band reject filter **02M**

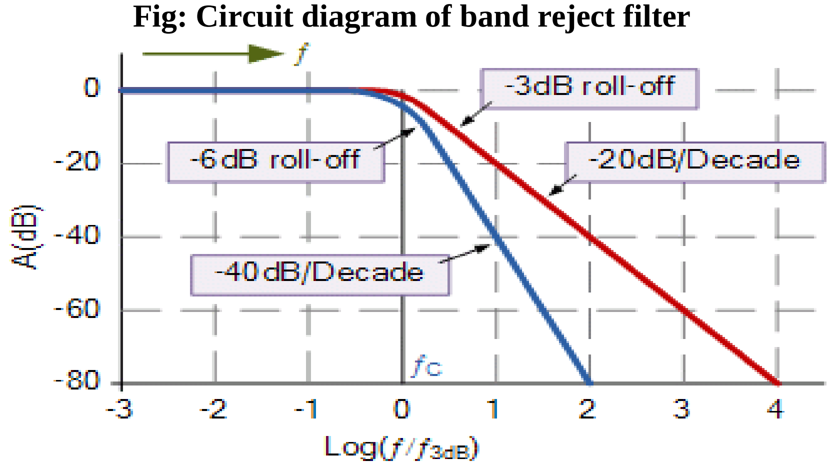
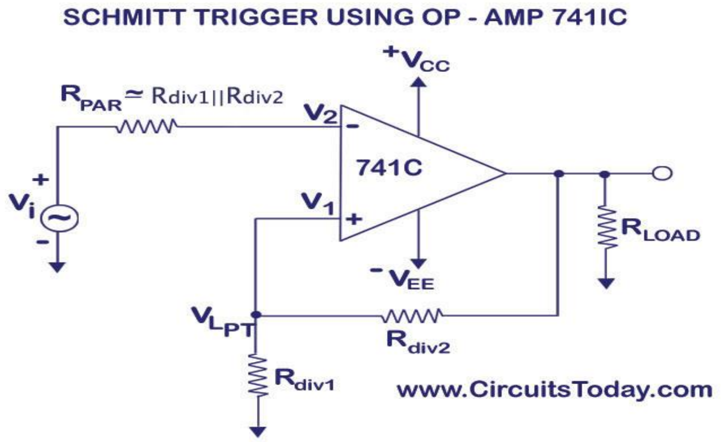
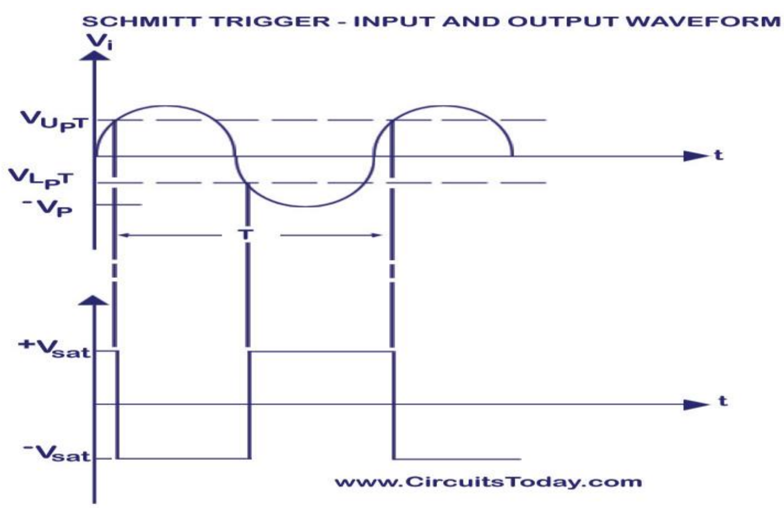
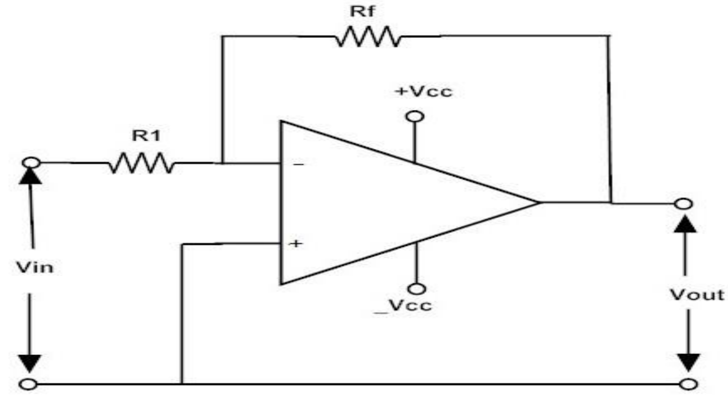
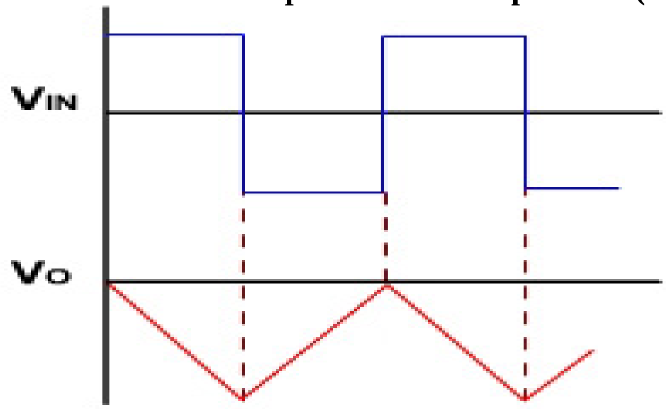
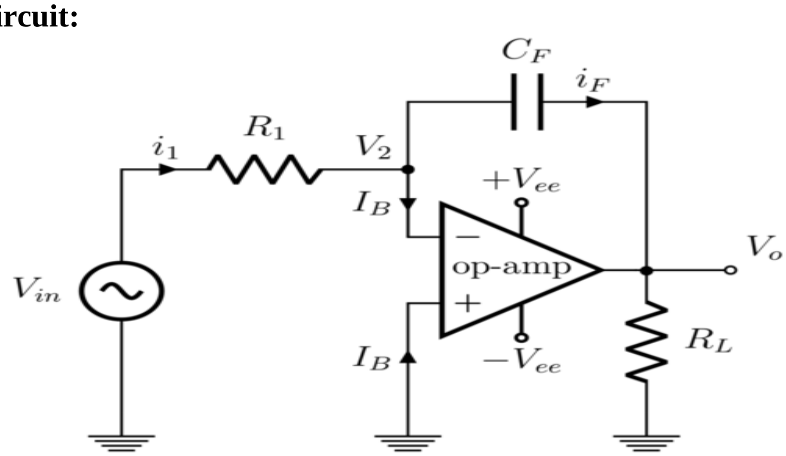
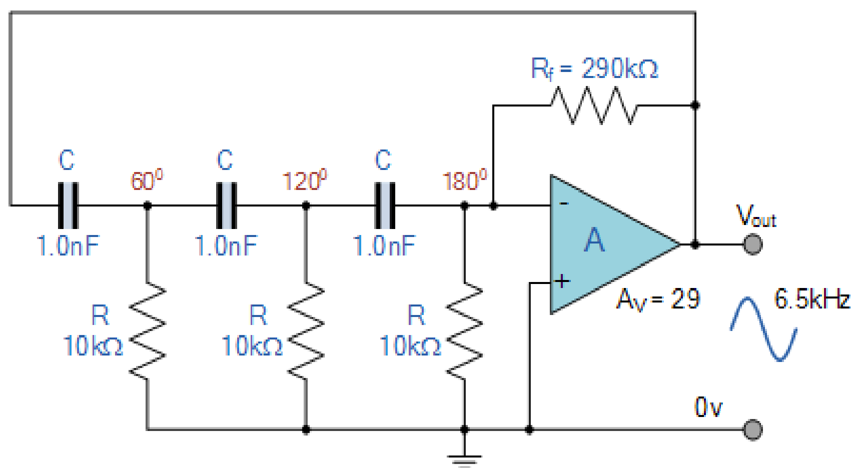


Fig: Frequency response for ± 20 db/decade roll off rate. **02M**

4.		**Attempt any <u>THREE</u> of the following:**	**12 M**
	a)	**Draw the circuit diagram of Schmitt trigger using OP-AMP. Describe its working with input and output waveforms.** **Ans:**  **Fig: Circuit diagram of Schmitt trigger using OP-AMP**	**02M**
		As shown in the circuit diagram, a voltage divider with resistors Rdiv1 and Rdiv2 is set in the positive feedback of the 741 IC op-amp. The same values of Rdiv1 and Rdiv2 are used to get the resistance value Rpar = Rdiv1||Rdiv2 which is connected in series with the input voltage. Rpar is used to minimize the offset problems. The voltage across R1 is fedback to the non-inverting input. The input voltage Vi triggers or changes the state of output Vout every time it exceeds its voltage levels above a certain threshold value called Upper Threshold Voltage (Vupt) and Lower Threshold Voltage (Vlpt).	**01M**
		 **Fig: Input and output waveform.**	**01M**
	b)	**Draw the OP-AMP based circuit diagram to provide output V0 = 5V, if Vin = -1V applied.** **Ans:** The OP-AMP based circuit diagram to provide output V0 = 5V,if Vin = -1V applied is known **as Inverting circuit.**	**02M**

		 **Fig: OP-AMP based circuit diagram**	**02M**
	c)	**Suggest the OP-AMP based circuit to perform below operation (Refer Fig. No. 3)**  **Fig. No. 3** **Ans:** **Integrator circuit:**  **Fig: Integrator circuit**	**01M**
		The integrator circuit outputs the integral of the input signal over a frequency range based on the circuit time constant and the bandwidth of the amplifier. The input signal is applied to the inverting input so the output is inverted relative to the polarity of the input signal. The ideal integrator circuit will saturate to the supply rails depending on the polarity of the input offset voltage and requires the addition of a feedback resistor, R2 , to provide a stable DC operating point. The feedback resistor limits the lower frequency range over which the integration function is performed. This circuit is most commonly used as part of a larger feedback/servo loop which provides the DC feedback path, thus removing the requirement for a feedback resistor The formula for determining voltage output for the integrator is as follows:	**02M**

		$$\frac{dv_{out}}{dt} = -\frac{V_{in}}{RC}$$ *or* $$V_{out} = \int_0^t -\frac{V_{in}}{RC}\,dt + c$$ *Where,* c = Output voltage at start time (t=0)	**01M**
	d)	**Define i) Roll off rate of filter ii) Cut off frequency of filter iii) Q factor of filter iv)Bandwidth of filter.** **Ans:** i) **Roll-off rate of filter:** The gain falls off rapidly in the stop band. The rate at which it falls off is called as the roll-off rate.The roll-off rate is decided by order of filter. ii) **Order of filter**: The high pass & low pass filters the term pole and order will have the same meaning. That means the no. Of poles will equal to the filter order. iii) ***Q* factor of filter** : It is a dimensionless parameter that describes how underdamped an oscillator or resonator is,[1] and characterizes a resonator's bandwidth relative to its centre frequency iv) **Bandwidth of filter** : Bandwidth is the difference between the upper and lower frequencies in a continuous band of baseband bandwidth applies to a low-pass filter or baseband signal.	**01M Each**
	e)	**Draw and describe the circuit diagram of RC phase shift oscillator using IC 741.** **Ans:**  **Fig: Circuit diagram of RC phase shift oscillatorusing IC 741**	**02M**
		In the amplifier tutorials we saw that a single stage transistor amplifier can produce 180°of phase shift between its output and input signals when connected in a class-A type configuration.For an oscillator to sustain oscillations indefinitely, sufficient feedback of the correct phase, that is "Positive Feedback" must be provided along with the transistor amplifier being used acting as an inverting stage to achieve this.In an **RC Oscillator** circuit the input is shifted 180° through the amplifier stage and 180°again through a second inverting stage giving us "180° + 180° = 360°" of phase shift which is effectively the same as 0° thereby giving us the required positive feedback. In other words, the phase shift of the feedback loop should be "0".In a **Resistance-Capacitance Oscillator** or simply an **RC Oscillator**, we make use of the fact that a phase shift occurs between the input to a RC network and the output from the same network by using RC elements in the feedback branch.	**02M**

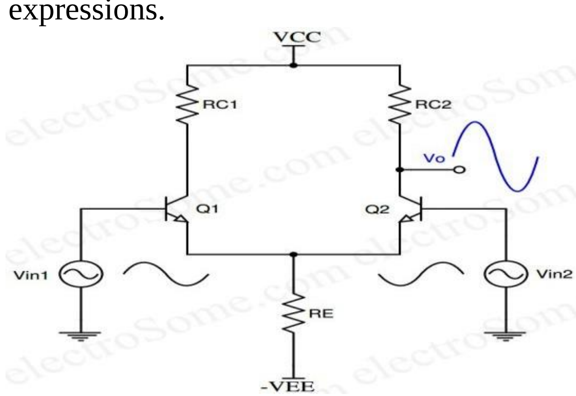
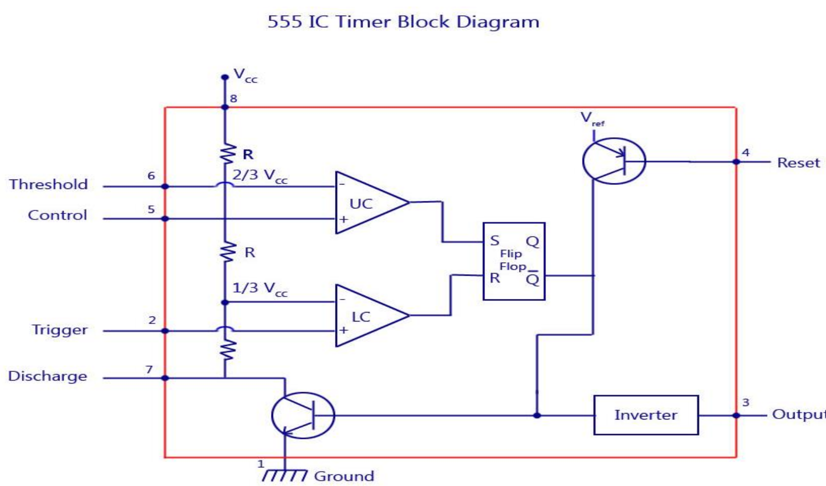
5.		**Attempt any <u>TWO</u> of the following:**	**12 M**
	a)	**State the need of differential amplifier in OP-AMP. Draw dual input unbalanced output differential amplifier.** **Ans:** It is basically used as a building block of an operational amplifier which is called as operational amplifier (op-amp). The main function of the differential amplifier is, it amplifies the changes between two i/p voltages. But, conquers any voltage common to the two i/ps. This article gives an overview of differential amplifier along with its mathematical expressions.  **Fig: Differential amplifier in OP-AMP**	**03M** **03M**
	b)	**Draw and explain block diagram of IC 555. Draw pin configuration of IC 555.** **Ans:**  **Fig: Block diagram of IC 555** The block diagram of a 555 timer is shown in the above figure. A 555 timer has two comparators, which are basically 2 op-amps), an R-S flip-flop, two transistors and a resistive network.Resistive network consists of three equal resistors and acts as a voltage divider.Comparator 1 compares threshold voltage with a reference voltage + 2/3 V_{CC} volts.Comparator 2 compares the trigger voltage with a reference voltage + 1/3 V_{CC} volts.Output of both the comparators is supplied to the flip-flop. Flip-flop assumes its state according to the output of the two compaÂrators. One of the two transistors is a discharge transistor of which collector is connected to pin 7. This tranÂsistor saturates or cuts-off according to the output state of the flip-flop. The saturated transisÂtor provides a discharge path to a capacitor conÂnected externally. Base of another transistor is connected to a reset terminal. A pulse applied to this terminal resets the whole timer irrespective of any input.	**02M** **02M**

Fig: Pin configuration of IC 555 — **02M**

c) **Draw and explain differentiator using IC 741. State its output expression.**

Ans:

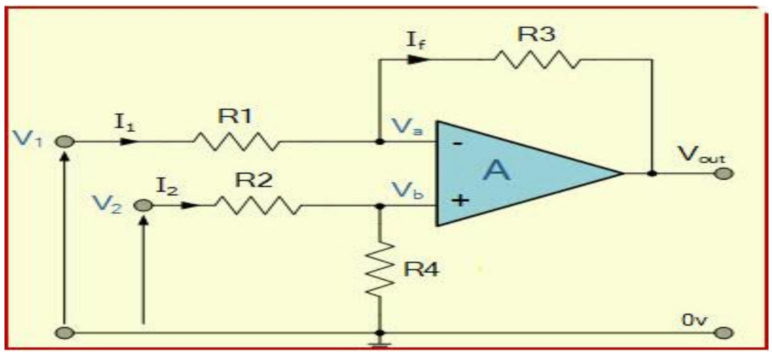


Fig: Differential amplifier using IC 741 — **03M**

All operational amplifiers (op-amps) are differential amplifiers because of their input configuration. When the first voltage signal is connected to the input terminal and another voltage signal is connected onto the opposite input terminal then the resultant output voltage are proportional to the difference between the two input voltage signals of V1 and V2. The output voltage can be solved by connecting each i/p intern to 0v ground using super position theorem. — **03M**

6. **Attempt any <u>TWO</u> of the following:** — **12 M**

a) **Draw circuit diagram of instrumentation amplifier using 3 op-amps and state its output voltage expression.**

Ans:

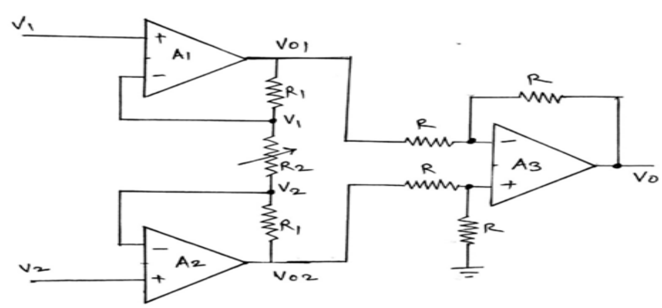


Figure 1 : Circuit diagram of Instrumentation Amplifier

Fig: Instrumentation amplifier using 3 OP-AMP — **03M**

A circuit providing an output based on the difference between two inputs (times a scale factor) is given in the above figure. In the circuit diagram, opamps labelled A1 and A2 are the input buffers. Anyway the gain of these buffer stages are not unity because of the presence of R1 and Rg. Op amp labelled A3 is wired as a standard differential amplifier. R3 connected from the output of A3 to its non inverting input is the feedback resistor. R2 is the input resistor. The voltage gain of the instrumentation amplifier can be expressed by using the equation below.

Voltage gain (Av) = Vo/(V2-V1) = (1 + 2R1/Rg) x R3/R2

If need a setup for varying the gain, replace Rg with a suitable potentiometer. Instrumentation amplifiers are generally used in situations where high sensitivity, accuracy and stability are required. Instrumentation amplifiers can be also made using two opamps, but they are rarely used and the common practice is to make it using three opamps like what is shown here. The only advantages of making an instrumentation amplifier using 2 opamps are low cost and improved CMRR.

A high gain accuracy can be achieved by using precision metal film resistors for all the resistances. Because of large negative feedback employed, the amplifier has good linearity, typically about 0.01% for a gain less than 10. The output impedance is also low, being in the range of milli-ohms. The input bias current of the instrumentation amplifier is determined by the op-amps A1 and A2.

A simplified instrumentation amplifier design is shown below. Here the resistances labelled R1 are shorted and Rg is removed. This results in a full series negative feedback path and the gain of A1 and A2 will be unity. The removal of R1 and Rg simplifies the equation to Av = R3/R2.

03M

b) Compare open loop and closed loop configuration of OP-AMP (6 points)

Ans:

parametres	Open loop	Closed loop
1. feedback	No feedback is used.	Positive or negative feedback is used.
2. Input resistance	Very high	Depends on the circuit
3. Output resistance	Low	Very low
4. Bandwidth	Bandwidth is low	Bandwidth is high
5. Gain	Voltage gain is very high	Voltage gain is low as compared to open
6. Stability	Not Stable	More stable
7. Effect of noise	More	Less
8. Application	Comparator ,zero crossing detector	It is used in linear amplifier, oscillator

Table: Compare open loop and closed loop configuration of OP-AMP

01M Each point

c) Advantages of active filter over passive filter (any six).

Ans:

Active filters have three main advantages over passive filters:

- Inductors can be avoided. Passive filters without inductors cannot obtain a high Q (low damping), but with them are often large and expensive (at low frequencies), may have significant internal resistance, and may pick up surrounding electromagnetic signals.
- The shape of the response, the Q (Quality factor), and the tuned frequency can often be set easily by varying resistors, in some filters one parameter can be adjusted without affecting the others. Variable inductances for low frequency filters are not practical.
- The amplifier powering the filter can be used to buffer the filter from the electronic components it drives or is fed from, variations in which could otherwise significantly affect the shape of the frequency response.

02M Each point