Linear Integrated Circuits

Time: 3 Hrs.] Prelim Question Paper Solution [Marks : 70

Q.1 Attempt any FIVE of the following : [10]

Q.1(a) State ideal and typical values of [5]
(i) slew rate (ii) CMRR

Ans.:

Typical values of	**ideal values**
(i) Slew rate = 0.5 V/μs	Infinite
(ii) CMMR = 90 dB	Infinite

Q.1(b) State the need of signal conditioning (two points) [5]

Ans.: Need of signal conditioning

In an instrumentation system, a transducer is used for sensing various parameters. The output of transducer is an electrical signal proportional to the physical quantity sensed such as pressure, temperature etc.

However the transducer output cannot be used directly as an input to the rest of the instrumentation system.

In many applications, the signal needs to be conditioned and processed. The signal conditioning can be of different types such as rectification, clipping, clamping etc. Sometimes the input signal needs to undergo certain processing such as integration, differentiation amplification etc.

Q.1(c) List specification of IC LM 324. [5]

Ans.: Specifications of IC LM 324

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply

Q.1(d) Draw circuit diagram of basic differentiator using OP-AMP. [5]

Ans.:

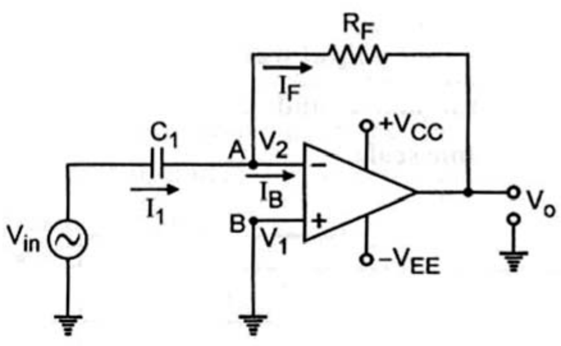
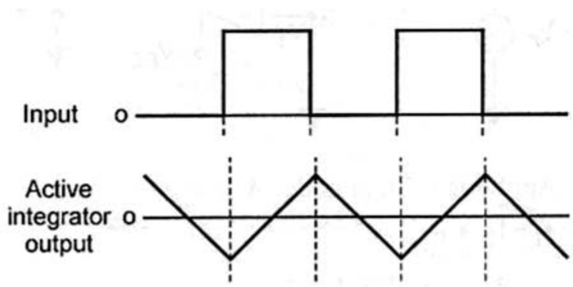


Fig. Circuit diagram of differentiator

Q.1(e) Draw input and output waveform for active integrator for square wave input. [5]
Ans.:



Q.1(f) Define the following wr. to filter: [5]
(i) Q factor (ii) roll off rate

Ans.: **(i) Q factor** : It is defined as the ratio of center frequency to the bandwidth and it is given as Q = Fc/BW

(ii) Roll off rate: The gain falls rapidly in the stop band. The rate at which it falls off is called the Roll off rate.

Q.1(g) State the applications of PLL. [5]
Ans.: **Applications of PLL**

- FM stereo decoders
- Motor speed controls
- Tracking filters
- FM modulators
- FSK decoders
- FM tuner
- Generation of local oscillator frequency

Q.2 Attempt any THREE of the following : [12]

Q.2(a) Draw closed loop inverting amplifier using op-amp and derive expression for its gain. [4]
Ans.:

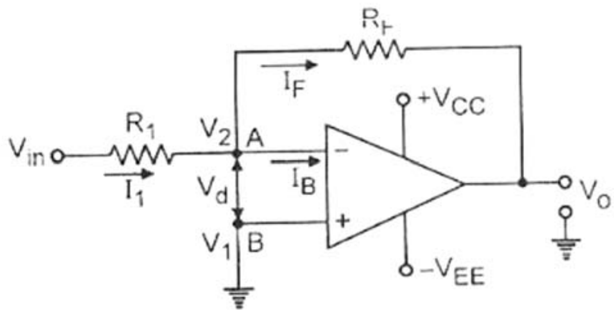


Fig.: Op-Amp as an inverting amplifier

V_0 = output voltage, V_{in} = input voltage, R_F = Feedback resistor, R_1 = Input resistor

(i) As input signal V_{in} is applied to inverting input, hence it is called as inverting amplifier and non inverting terminal is grounded.
(ii) The pase difference between input and output is 180°
(iii) A negative feedback is provided from output to inverting terminal through R_F (Feedback resistor)

Derivation:

Apply KCL at node 'A' , we get,

$I_1 = I_B + I_F$ … (i)

But, Rin = ∞

$\therefore$ $I_B = 0$

$\therefore$ $I_1 = I_F$

$\therefore$ $\frac{V_{in} - V_2}{R_1} = \frac{V_2 - V_0}{R_F}$

According to virtual ground condtion,

$V_1 = V_2 = 0$

$\therefore$ $\frac{V_{in}}{R_1} = \frac{-V_0}{R_F}$

$\therefore$ $V_0 = -\left(\frac{R_F}{R_1}\right)V_{in}$ ... (ii)

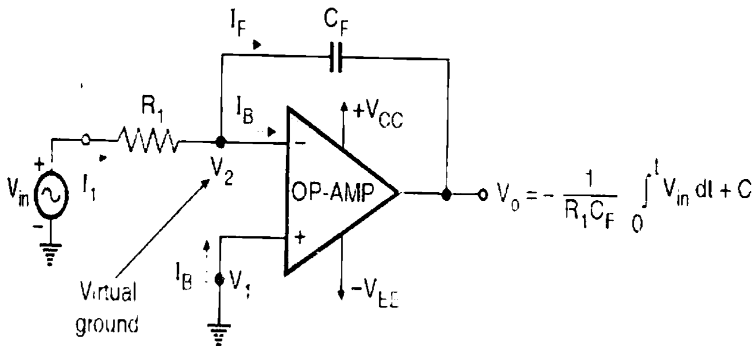
$\therefore$ $A_V = \frac{V_0}{V_{in}} = \frac{-R_F}{R_1}$ ... (iii)

Where, A_V = closed loop voltage gain

Q.2(b) Draw the circuit diagram and output waveform for sine and square wave input for output voltage. [4]

V_0 = $\frac{1}{RC}\int_0^t V_{in}dt + C$

Ans.:



Circuit Diagram

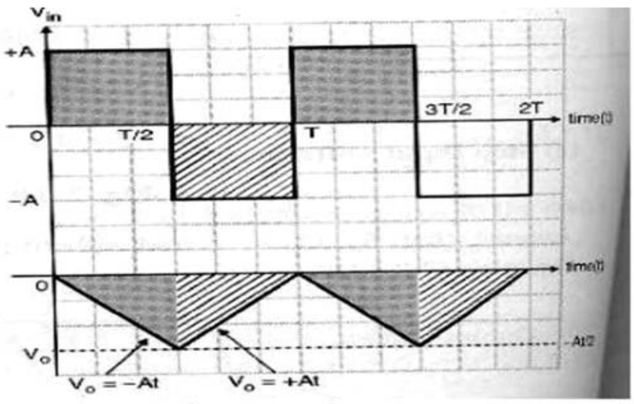


Fig: Input output voltage waveform for a square wave input

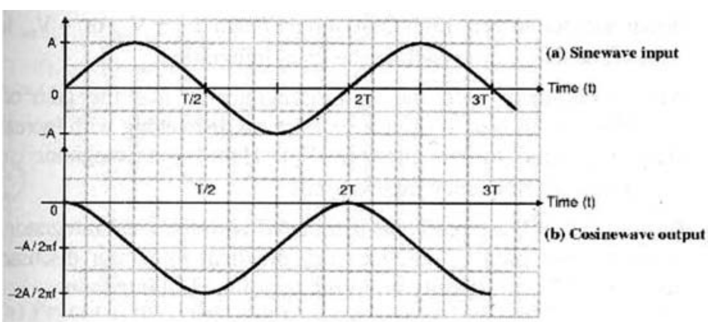


Fig: Input and output voltage waveforms for a sine wave input

Q.2(c) Using OP-AMP, draw the circuit of show the output $V_0 = 5(V_1 - 4V_2)$ where V_1 and V_2 are input voltages. **[4]**

Ans.: $V_0 = 5(V_1 - 4\,V_2)$

$= 5V_1 - 20V_2$

$= -(-5\,V_1 + 20V_2)$

$= -[5(-V_1) + 20\,V_2)]$

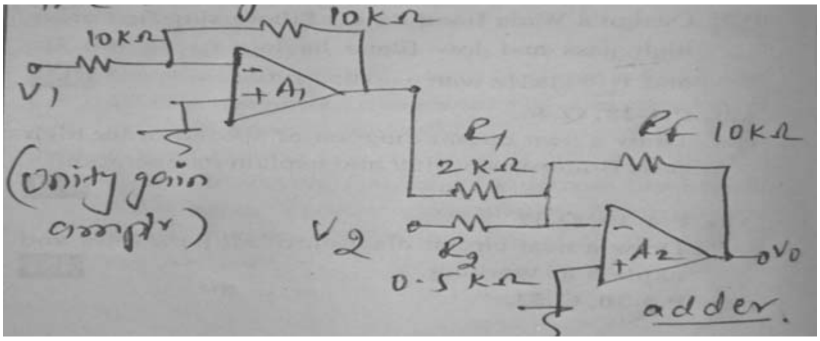
Use unity gain amplified A_1 to invert V_1 and use inverting adder A_2 to add V_2 with

$\frac{R_F}{R_1} = 5$ and $\frac{R_F}{R_2} = 20$

Let $R_F = 10\ k\Omega$, so $R_1 = 2\ k\Omega$

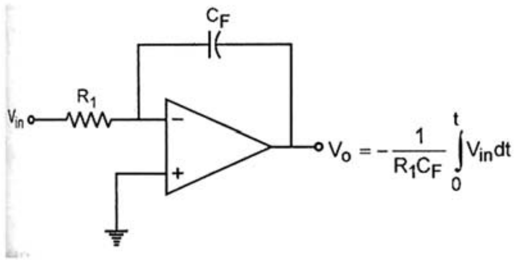
and $R_2 = 0.5\ k\Omega$

The designed circuit becomes



Q.2(d) Draw and explain Basic Integrator using op-amp. **[4]**

Ans.: Circuit diagram



Integrator is a cirucit in which output is the integral of the inut. This integrator circuit using op-amp obtained by with inverting amplifier configuration if resistor R_F s replaced by capacitor C_F.

The equation of above integrator curcuit is

$$V_0 = -\frac{1}{R1CF}\int_0^t Vin\,dt + C$$

Where C is integration constant and is proportional to the value of the output voltage V_0 at time $t = 0$ seconds.

From above equation output voltage is directly proportional to negative integral of input voltage and inversely proportional to the time constant R1CF. If input is sine wave, the output will be cosine and if input is square then output will be triangular.

Input and Output waveforms:

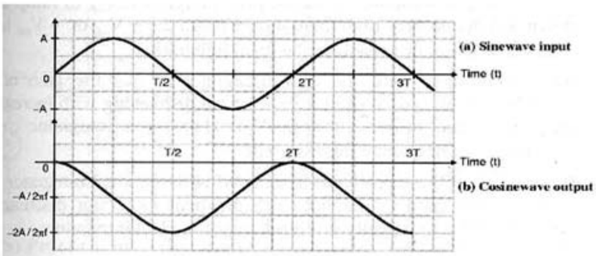


Fig.: Input and output voltage waveforms for a sine wave input

OR

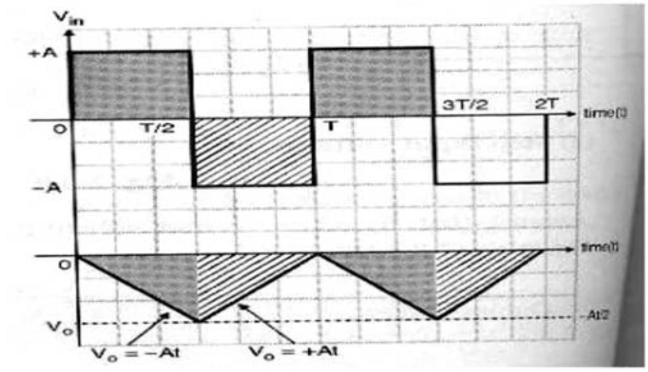


Fig.: Input output voltage waveform for a square wave input

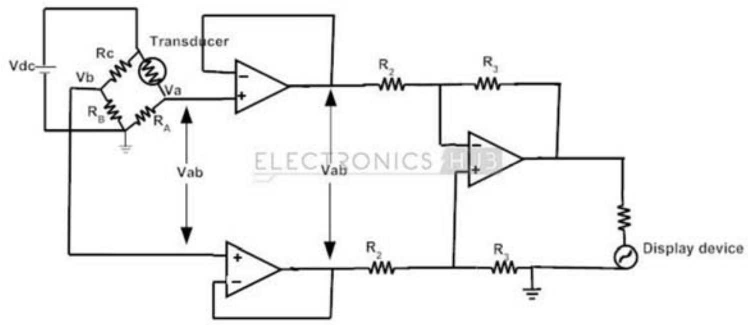
Q.3 Attempt any THREE of the following : [12]

Q.3(a) Draw the circuit diagram of instrumentation amplifier with transducer bridge and describe the operation of it to obtain output voltage. [4]

Ans.: In an instrumentation system, a transducer is used for sensing various parameters. The output of transducer is an electrical signal proportional to the physical quantity sensed such as pressure, temperature etc.

However the transducer output cannot be used directly as an input to the rest of the instrumentation system.

Such amplifiers, which are used to amplify signals to measure physical quantities are commonly known as Instrumentation Amplifiers. The input to an instrumentation amplifier is the output signal from the transducer. A transducer is a device which converts one form of energy into another.



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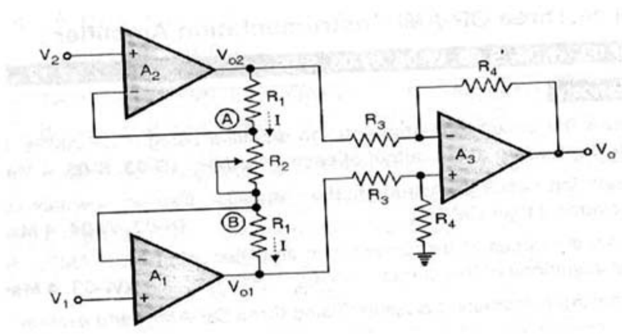


Output equation

$V_{O1} = [1 + R_1/R_2]\, V_1 - R_1/R_2\, V_2$

$V_{O2} = [1 + R_1/R_2]\, V_2 - R_1/R_2\, V_1$

$V_O = V_{O2} - V_{O1}$

$= [1 + 2R_1/R_2]\, (V_2 - V_1)$

Q.3(b) Draw and explain the circuit of V to I converter with floating load. [4]

Ans.: Figure shows the circuit of voltage to current (V to I) converter with floating load. This is also called as transconductance amplifier.

The circuit converts the voltage applied to the output current. Figure shows the V to I converter in which load resistor R_I is floating i.e. its neither side is connected to ground since A_V is large.

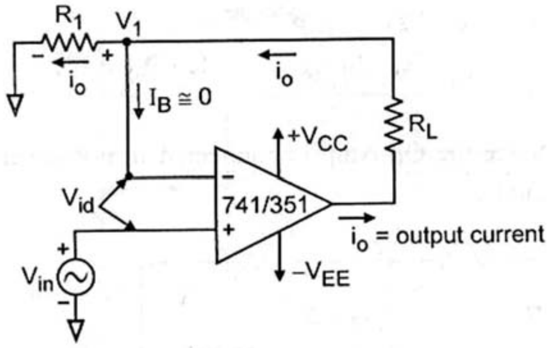


Fig.: Voltage to current converter with flating load

Derivation

V_{id} = 0 and this means

$V_{in} = V_1$

$= R_1 I_L$

Therefore,

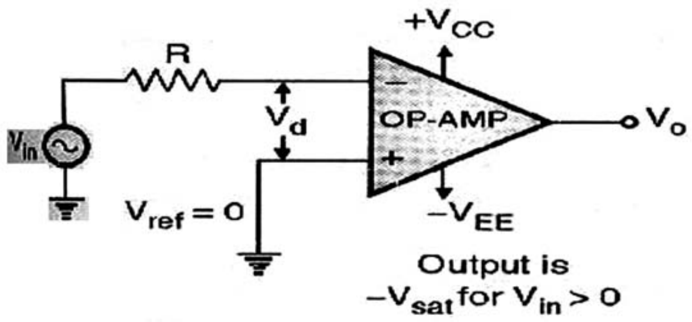
$I_L = V_{in}/R_1$

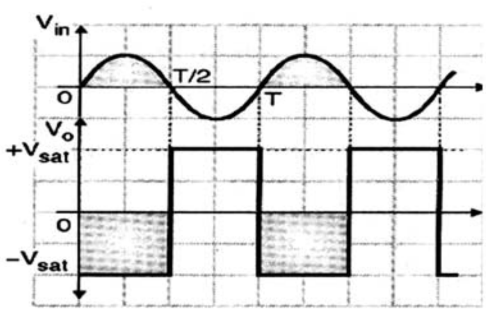
Since I_L is load current through R_L at output, the input V_{in} is converted into an output current V_{in}/R_i

Q.3(c) Describe the operation of ZCD with neat circuit diagram and waveforms. [4]

Ans.: **Description:** A zero crossing detector or ZCD is a one type of voltage comparator, used to detect a sine waveform transition from positive and negative, that coincides when the input crosses the zero voltage condition. In this article, we discuss about zero crossing detector circuit with two different circuits, working principle, theory and applications. The applications of Zero Crossing Detector are phase meter and time marker generator.

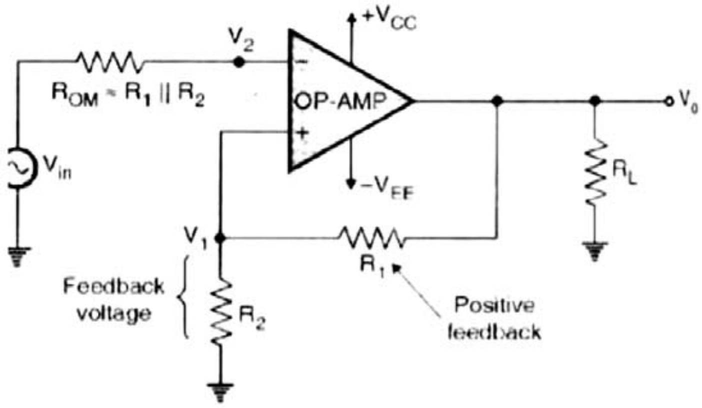
Zero crossing detector circuit is used to produce an output stage switch whenever the input crosses the reference input and it is connected to GND terminal. The output of the comparator can drive various outputs such as an LED indicator, a relay and a control gate.





Q.3(d) Draw circuit diagram and input output waveforms of op-amp based Schmitt trigger. **[4]**

Ans.:



Description:

Initially, before the application of any input, the output is assumed to be small and positive. This is the output offset voltage. The potential at point B is positive and point A = 0 V. The differential voltage V_{id} is possitive. Hence the output is driven to + V_{sat}.

At this instant, the potential at point B is

$V_B = \frac{R_2}{R_1 + R_2} \cdot (+V_{sat})$. This is called as the upper trigger point (V_{UTP}). When the input becomes more positive than VUTP, the differential input is negative. Therefore, the output is driven to – V_{sat}.

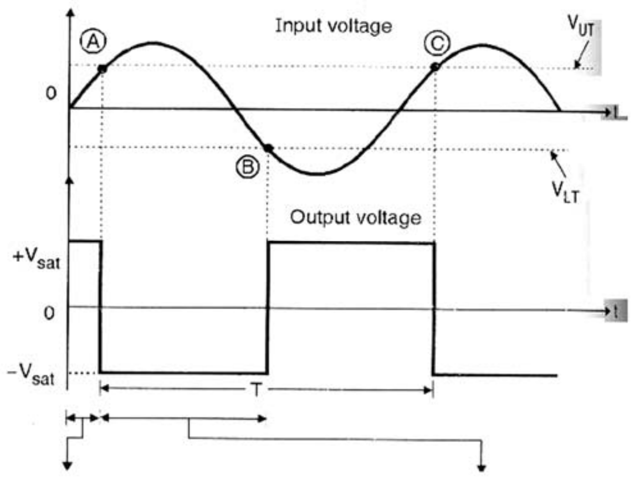
At this instant, the potential at the point B is

$V_B = \frac{R_2}{R_1 + R_2} \cdot (-V_{sat})$

This is the lower trigger point (V_{LTP}). The output remains at – V_{sat} until input voltage beocmes more negative than V_{LTP}. When the input crosses and becomes more negative than V_{LTP}, the differential input voltage is again positive and the output becomes + V_{sat}.

Thus, if the threshold votages V_{UTP} and V_{LTP} are made larger than the input noise voltages, the positive feedback will eliminate the false output transitions.

Thus, the Schmitt trigger has two, reference voltages.



Q.4 Attempt any THREE of the following : [12]

Q.4(a) Describe the operation of non-inverting comparator using op-amp with waveforms. [4]

Ans.:

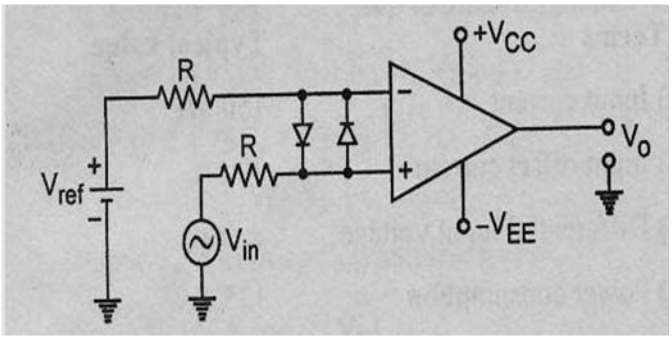


Fig.: Circuit Diagram for non-inverting comparactor using OP-AMP

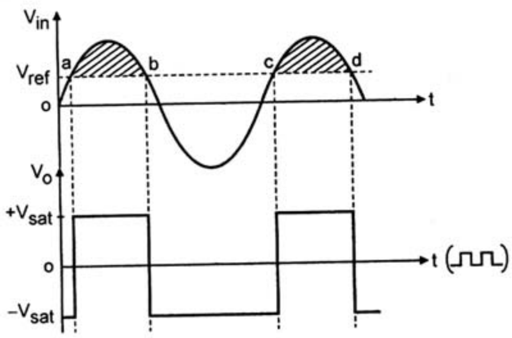


Fig.: Waveforms for non-inverting comparator using OP-AMP

Description:

When the input is given to the non-inverting terminal and the reference voltage is given to the inverting terminal, the comparator is referred to as non-inverting comparator. When $V_i < V_{ref}$, the differential input voltage is negative and hence the outuput is driven to negative saturation value.

$V_i < V_{ref}$ makes V_{id} negative and $V_O = - V_{sat}$.

When $V_i > V_{ref}$, the net differential voltage is positive and hence the output is driven to positive saturation (+ V_{sat}).

When $V_i > V_{ref}$, V_{id} positive, $V_O = + V_{sat}$.

Thus the transfer characteristics of the non-inverting comparator is shown below for positive, zero and negative, reference voltages.

Q.4(b) Design a first order low pass filter with 10 kHz cut off frequency and pass band gain 2. [4]

Ans.: **Given:** Pass band gain (A_f) = 2

Cut-off Frequency (f_c) = 10 kHz

Pass band Gain (A_f) is given by the formula

$A_f = 1 + \frac{R_F}{R_1}$

Here, $A_f = 2$

Therefore, $2 = 1+\frac{R_f}{R_1}$

So, $1 = \frac{R_f}{R_1}$

Therefore, $R_f = R_1$

Let R_f = 10kΩ
Therefore, R_1 = 10kΩ
Assume C = 0.01 uF

But $f_c = \dfrac{1}{2\pi RC}$

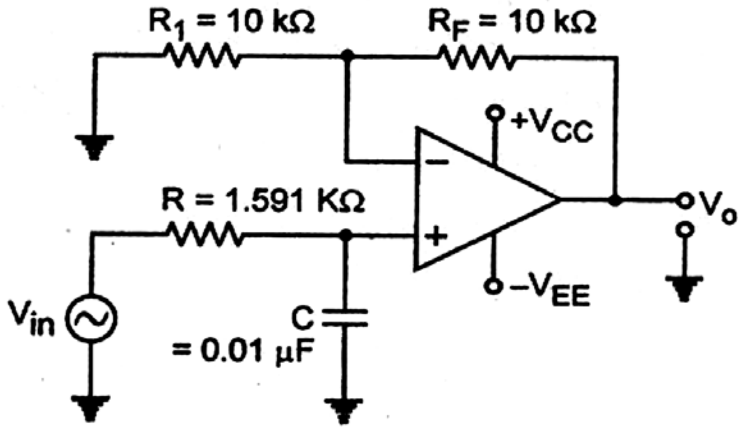
But f_c = 10 kHz

Therefore, 10 kHz = $\dfrac{1}{2\pi RC}$

So, R = $\dfrac{1}{2\pi \times 10 \times 10^3 \times 0.01 \times 10^{-6}}$

Therefore, R = 1.59kΩ

Circuit diagram



Q.4(c) Draw the second order high pass filter and describe its operation. **[4]**
Ans.:

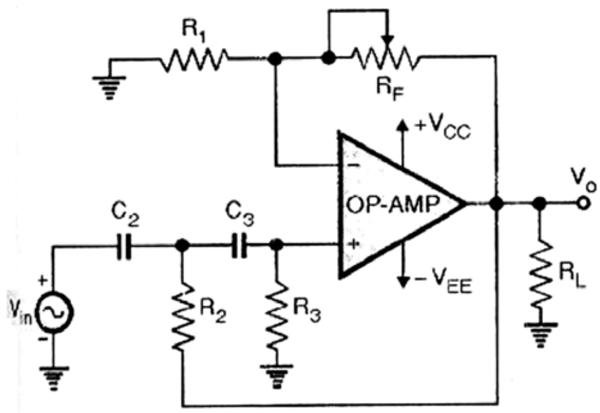


Fig.: Second order high pass filter

The resistors R_1 and R_F will decide the gain of the high pass filter. The gain can made variable by keeping R_F variable.

The cut-off frequency f_c is determined by R_2, R_3, and C_3 as follows:

$$f_c = \frac{1}{2\pi\sqrt{R_2 R_3 C_2 C_3}}$$

The voltage gain magnitude is given by,

$$\left|\frac{V_0}{V_{in}}\right| = \frac{A_{VF}}{\sqrt{1+(F_c/F)^4}}$$

$A_{VF} = \dfrac{1+R_F}{R_1}$ = Passband gain of the filter.

- The frequency response of the second order filter. It shows that the gain increases at a rate of 40 db/ decade in the attenuation band. This is doubled the rate of first order filter. This makes the frequency the frequency response shaper.
- The second order filters are important because they can be used for designing the higher order filters.

Q.4(d) Draw and explain the circuit of notch (narrow band eject) filter. [4]
Ans.:

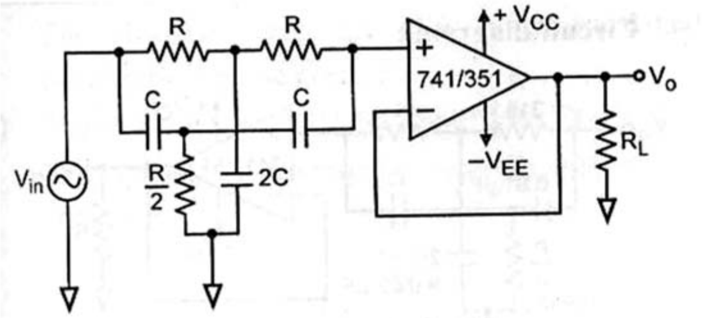


Fig. (a) Narrow band reject filter

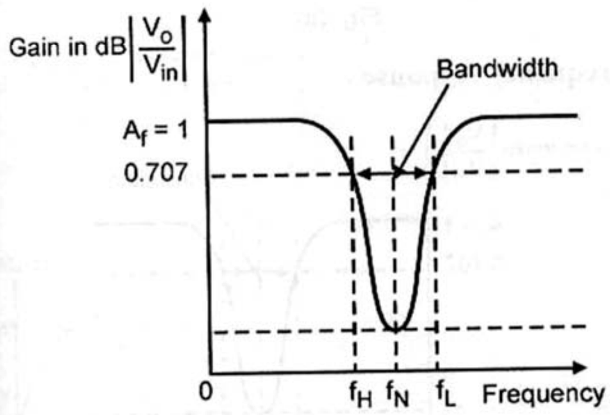


Fig. (b) Frequency response of narrow band reject filter

- Figure shows a narro band rejects active filter often called as Notch filter. It uses a twin T-network.
- The twin T-network is a passive filter composed of two T-shaped networks.
- One T- network is a made up of two resistors and capacitors while the other uses two capacitors and a resistor.
- The notch out frequency is the frequency at which maximum attenuation occurs, it is given by
  $f_N = 1/2\pi RC$ Hz … (i)
- The twin T-network has very low figure of merit Q. this is increased by using it with a voltage follower as shown in figure. The output of the voltage follower is fed back to the junction of R/2 and C.
- Q > 10 for narrow band reject filter.
- One typical application of such filter is for rejection of single frequency, such as 50 Hz power line frequency hum. This notch filter is also used in communication and Bio-medical instruments for eliminating undesired frequencies.
- Frequency in equation (1) is the frequency to be rejected. Choosing $C \leq 1\ \mu F$ and then calculate for R, from the equation.

Q.4(e) Classify filters based on **[4]**
(i) Frequency response
(ii) Components used
(iii) Frequency range
(iv) Nature of pass band and stop band.

Ans.: (i) On the basis of component used, filters can be divided as active and passive filters.
(ii) On the basis of frequency range, can be divided as AF (audio frequency) or RF (radio frequency) filters.
(iii) On the basis of frequency response filters can be divided as high pass, low pass, band pass and band reject filters.
(iv) On the basis of nature of pass band and stop band, they can be divided as narrow band pass, wide band pass, narrow band reject and wide band reject filters.

Q.5 Attempt any TWO of the following : **[12]**

Q.5(a) Draw the functional block diagram of Timer IC 555 and explain each block. **[6]**

Ans.:

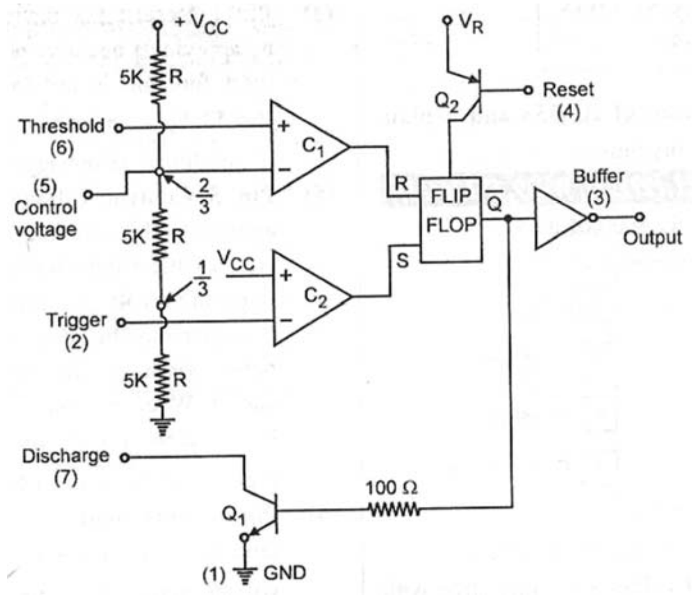
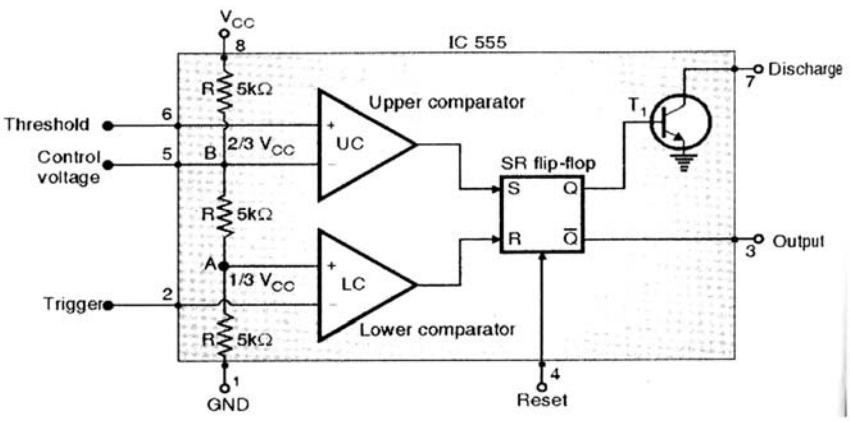


Fig.: Block diagram of IC 555

OR



Explanation

Comparator: The Comparator are the basic electronic component voltages i.e. between the inverting (-) and the non-inverting (+) input and if the non-inverting input is more than the inverting input then the output of the comparator is high. Also the input resistance of an ideal comparator is infinite.

Voltage Divider: As we know that the input resistance of the comparators is infinite hence the input voltage is divided equally between the three resistors. The value being $V_{in}/3$ across each resistor.

Flip/Flop: Flip/Flop is a memory element of Digital-electronics. The output (Q) of the flip/flop is 'high' if the input at 'S' terminal is 'high' and 'R' is at 'Low' and the output (Q) is 'low' when the input at 'S' is 'low' and at 'R' is high.

Q.5(b) Describe the operation of phase detector and role of VCO in PLL. **[6]**

Ans.: **Voltage controlled oscillator (VCO):**

- The control voltage Vc is applied at the input of a VCO.
- The output frequency of VCO is directly proportional to the dc control voltage V_C. The VCO frequency fr is compared with the input frequency fs by the phase detector and it (VCO frequency) is adjusted continuously until it is equal to the input frequency f_s i.e. $f_0 = f_s$
- The voltage controlled oscillator (VCO) is a free running multivibrator and operates at a frequency (which is determined by external timing capacitor and external resistor.
- The operating frequency can be shifted on either side by applying a dc control voltage V_C externally.

Phase detector or phase comparator

- The two points to a phase detector or comparator are the input voltage V_s at frequency f_S and the feedback voltage from a voltage controlled oscillator (VCO) at the frequency f_0
- The phase detector compares these two signals and produces a dc voltage V_e which is proportional to the phase difference between f_S and f_0. The output voltage V_e of the phase detector is called as error voltage.
- This error voltage is then applied to a low pass filter.

Q.5(c) Design an Astable multivibrator using IC 555 timer for a frequency of 2 KHz. **[6]**

Ans.: F_0 = 2kHz

T = 0.5m sec

$T_{ON} = 0.693\ (R_{AT}\ T_B)C$

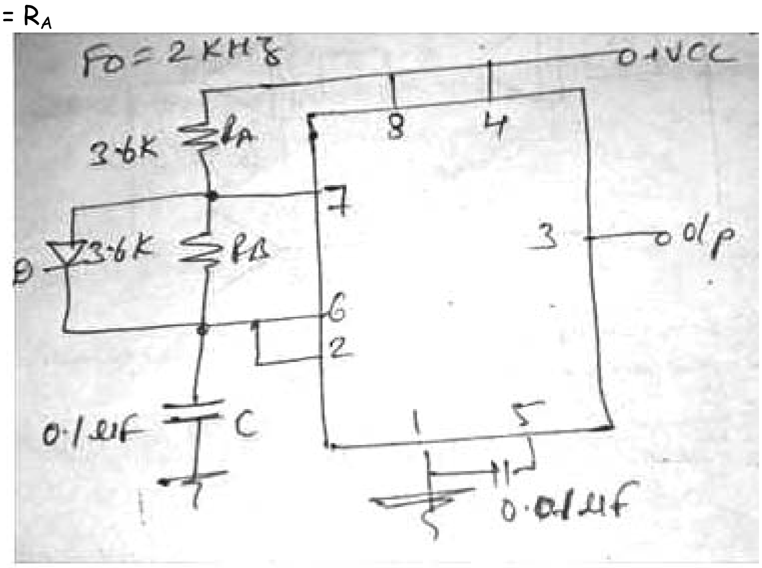
$T_{off} = 0.693\ R_{B.C}$

Let $T_{ON} = T_{off}$ = 0.25msec

$T_{off} = 0.25 \times 10^{-3} = 0.693\ R_{B.\ C}$ (let c = 0.14F)

$$\frac{0.25\times10^{-3}}{\left(0.1\times10^{-6}\times0.693\right)} = R_B$$

$R_B = 3.6\ k\Omega = R_A$

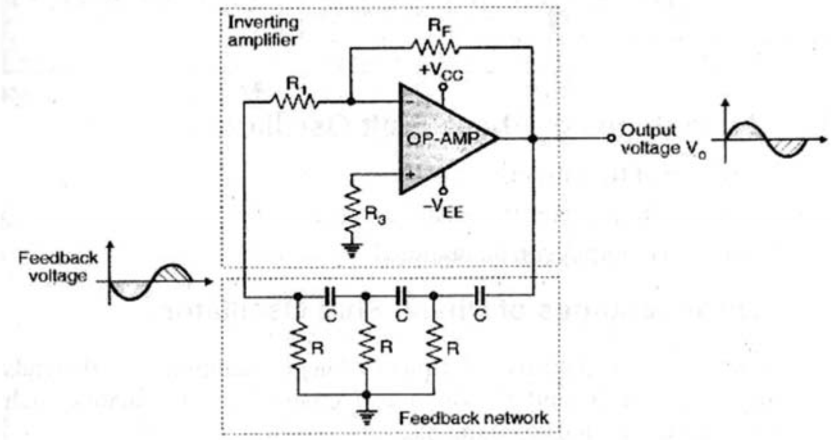


RA = RB = 3.6 KΩ for square wave

Q.6 Attempt any TWO of the following : [12]

Q.6(a) Draw and explain the working of phase shift oscillator using IC 741. [6]

Ans.:



- **The OP- AMP is used as an inverting amplifier. Therefore it introduces a phase shift of 180 between its input and output.**
- The output of the inverting amplifier is applies at the input of the RC phase shift network. As discussed earlier, this network will introduce a phase shift of 180°. This feedback network attenuates the signal at its input and feeds it to the amplifier input. The level of attenuation is decided by the feedback factor β.
- The gain of the inverting amplifier is decided by the values of RF and Rj. This gain is adjusted in such a way that the product $A\beta$ is slightly greater than 1.
- It can be proved that the value of feedback factor β at the frequency of oscillations is P= 1/29. For sustained oscillations, the loop gain $A\beta > 1$. Therefore, in order to make the loop gain $A\beta$ >, the gain of the inverting amplifier A should be greater than or equal to 29,
- Gain of the inverting amplifier is given by,

  $A = R_F / R_1$

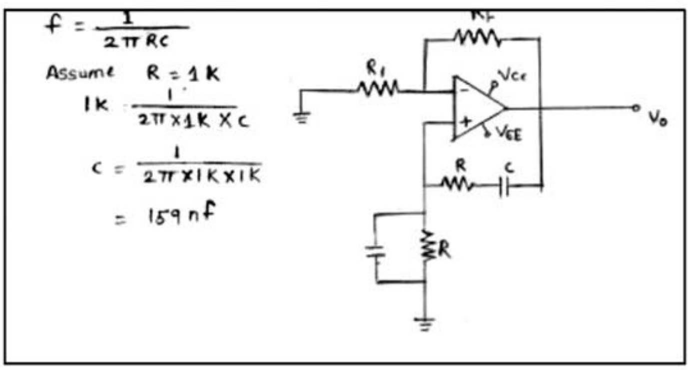
  Therefore: $R_F / R_1 \geq 29$ or $R_f \geq 29R_1$
- These values of RF and Ri will insure sustained oscillations.
- The expression for frequency of oscillations of an RC phase shift oscillation using OP_ AMP is given by,

  $f_0 = 1 / 2\pi\sqrt{6}RC$

Q.6(b) Design op-amp based Wein Bridge Oscillator for frequency of 1 KHz. [6]

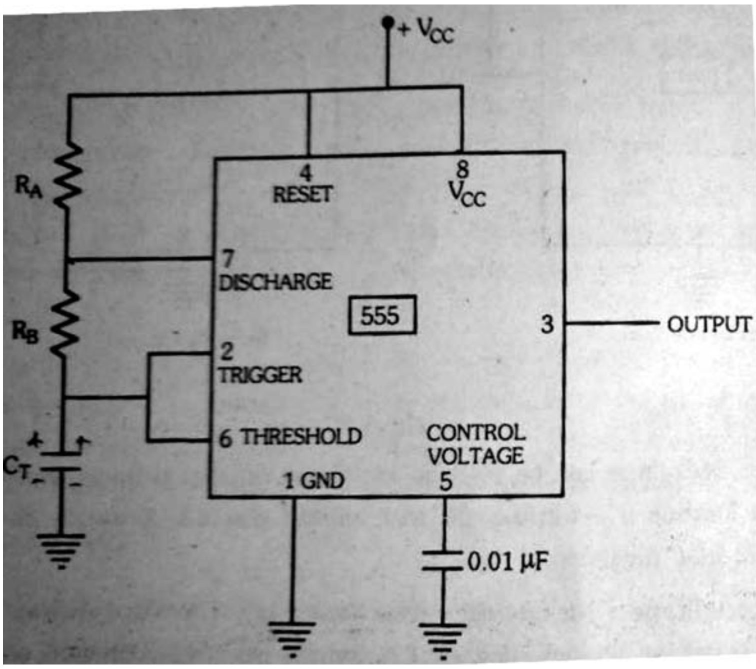
Ans.:

NOTE: students can assume any value of R so accordingly answer for C will change.



Q.6(c) Draw the circuit of astable multivibrator using IC 555 and describe its working. [6]

Ans.: Astable multivibrator is a circuit which will trigger itself and go from one state to another state after a predetermined interval of time. It has two quasi stable state generating rectangular waveforms.



Working: Initially the capacitor is kept uncharged. When V_{CC} is applied, the internal transistor is held OFF and the output goes high. The external capacitor CT charges through R_A and R_B with a time constant (R_A+ R_B) Of. When the voltage across the capacitor reaches $\frac{2}{3}V_{CC}$, [Connected to pin 6] it makes a positive transistor near the reference voltage of comparator C_1. whose output resets the flip flop. The output of the IC goes low. The internal transistor Q_1 is ON and the capacitor discharges through the resistor R_B and the internal transistor Q_1 to ground. When the capacitor discharges to $\frac{1}{3}$ V_{CC} (connected to pin 2), it makes a negative transition near the reference voltage of comparator C_2, making the output of the comparator set the flip flop. The output goes high. The internal transistor Q_1 becomes OFF and the capacitor again starts charging. The discharging time constant is R_B Cp. Subsequently the capacitor charges from $\frac{1}{3}$ V_{CC} to $\frac{2}{3}$ VC_C and discharges from $\frac{2}{3}$ V_{cc} to $\frac{1}{3}$ Vcc. The cycle repeats and generates rectangular pulses at the output.

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