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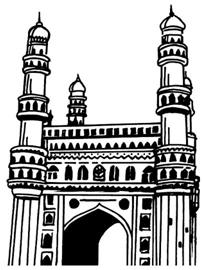

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ELECTRONICS PAPER - IV

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Operational Amplifiers: Emitter Coupled Differential amplifier. Block diagram of Op-Amp Charaeteristics of Op-Amp. Op-Amp parameters-Input resistance, Output resistance, Common mode rejection ratio (CMMR), Slew rate, Offset voltages. Input bias current. Basic Op-Amp circuits-Inverting Op-Amp. Non-inverting Op-Amp. Op Amp as: Summing amplifier, subtractor. Comparator, Voltage follower, Integrator, Differentiator and: Logarithmic amplifier.

UNIT - II

Applications of Op-Amps: Sine wave [Wien Bridge] generator and square wave [Astable] generator, Triangular wave generator, Monostable multivibrator, IC 555 Timer [Block diagram and its working], IC 555 as monostable and astable multivibrators.

UNIT - III

Modulation: Need for modulation-Types of modulation- Amplitude, Frequency and Phase modulation.

Amplitude modulation: Analysis of Amplitude modulation, side bands, modulation index, AM modulator, Balanced modulator, Demodulation – diode detector.

UNIT - IV

Frequency modulation: Analysis of FM, Working of simple frequency modulator, - detection of FM waves – FM Discriminator. Advantages of frequency modulation. AM and FM Transmitters and radio receivers [block diagram approach]. Introduction to PAM, PPM, PWM, and PCM, Delta modulation.

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1. Draw the block diagram schematic of an Op-Amp.

Ans : **(Nov.-20, June-18, Imp.)**

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2. Give the Characteristic of an ideal Op-Amp.

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3. Derive an expression for inverting Op-Amp for voltage gain.

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4. Derive an expression for inverting Op-Amp for Non-Inverting Amplifier for voltage gain.

Ans : **(Nov.-20, June-18, Imp.)**

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5. Discuss the working of op-amp as a summing amplifier and obtain its output voltage.

Ans : **(Nov.-20, June-19)**

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Ans : **(June-19, Imp.)**

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8. Derive an expression of op-amp are used differentiator circuit ?

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1. Draw and explain op-amp based wien bridge oscillator circuit.

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2. Draw the circuit diagram of triangular wave generator and explain its operation.

Ans : **(June-18, Imp.)**

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3. Draw the block diagram of IC 555 timer and describe its working.

Ans : **(June-18, Imp.)**

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4. Explain with the help of a circuit diagram how IC 555 timer is used as a monostable multivibrator.

Ans : **(Nov.-20, June-18, Imp.)**

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Ans : **(Nov.-20, June-19)**

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1. Define modulation. Explain the need for modulation.

Ans : **(Nov.-20, June-19, June-18)**

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2. State the various types of Modulation.

Ans : **(June-19, June-18)**

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3. Obtain an expression for Amplitude modulated waves.

Ans : **(June-19, June-18)**

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4. Discuss about modulation index and depth of modulation.

Ans : **(June-19)**

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Ans : **(Imp.)**

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UNIT - IV

1. What is Frequency Modulation?

Ans : **(June-19)**

Refer Unit-IV, Q.No. 1

2. Explain the analysis of FM wave.

Ans : **(June-19, June-18)**

Refer Unit-IV, Q.No. 3

3. Explain the direct method of FM generation.

Ans : **(Nov.-20)**

Refer Unit-IV, Q.No. 7

4. Give the analysis of frequency modulation. Describe the working of FM Discriminator with circuit diagram.

Ans : **(June-19, June-18)**

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5. Draw the block diagram of FM radio receiver. Explain the significance of each block.

Ans : **(Nov.-20, June-18, Imp.)**

Refer Unit-IV, Q.No. 14

6. Write about PAM and PCM.

Ans : **(June-19)**

Refer Unit-IV, Q.No. 17

7. Explain with a neat diagram explain the generation and demodulation of pulse width modulation.

Ans : **(Nov.-20)**

Refer Unit-IV, Q.No. 18

8. Explain in briefly about the generation and modulation of PPM signals.

Ans : **(Nov.-20)**

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9. Explain delta modulation with a neat block diagram.

Ans : **(Nov.-20)**

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UNIT I	**Operational Amplifiers:** Emitter Coupled Differential amplifier. Block diagram of Op-Amp Charaeteristics of Op-Amp. Op-Amp parameters-Input resistance, Output resistance, Common mode rejection ratio (CMMR), Slew rate, Offset voltages. Input bias current. Basic Op-Amp circuits-Inverting Op-Amp. Non-inverting Op-Amp. Op Amp as: Summing amplifier, subtractor. Comparator, Voltage follower, Integrator, Differentiator and: Logarithmic amplifier.

1.1 Operational Amplifiers

Q1. Define the term operational amplifiers.

Ans :

Meaning

Operational Amplifiers is a direct coupled high gain amplifier with negative feedback to control its. Overall response characteristic and acting as one or more differential amplifier. It may be used for various linear and non-linear operations. Its capable of amplifying and generating waveforms over frequency from 0Hz to several megahertz.

The operational amplifier (Op-Amp) is a versatile device that can be used to amplify DC as well as AC input signal. An op-amp is so named because it is originally designed to perform mathematical operations like summation, subtraction, multiplication, differentiation, integration etc.

Although an Op-Amp is a complete amplifier it is so designed that external component can be connected to its terminal to change its external characteristic. A modern op-amp uses integrated circuit op-amp are widely used as versatile, etc. It is a monolithic IC's namely small size, high reliability, low cost, temperature tracking and low offset voltage and current.

Definition

"An operational amplifier is essentially a high gain direct coupled amplifier with high input impedance and low output impedance to which feedback is added to regulate overall response".

1.1.1 Emitter Coupled Differential Amplifier

Q2. Explain the concept emitter coupled differential amplifier.

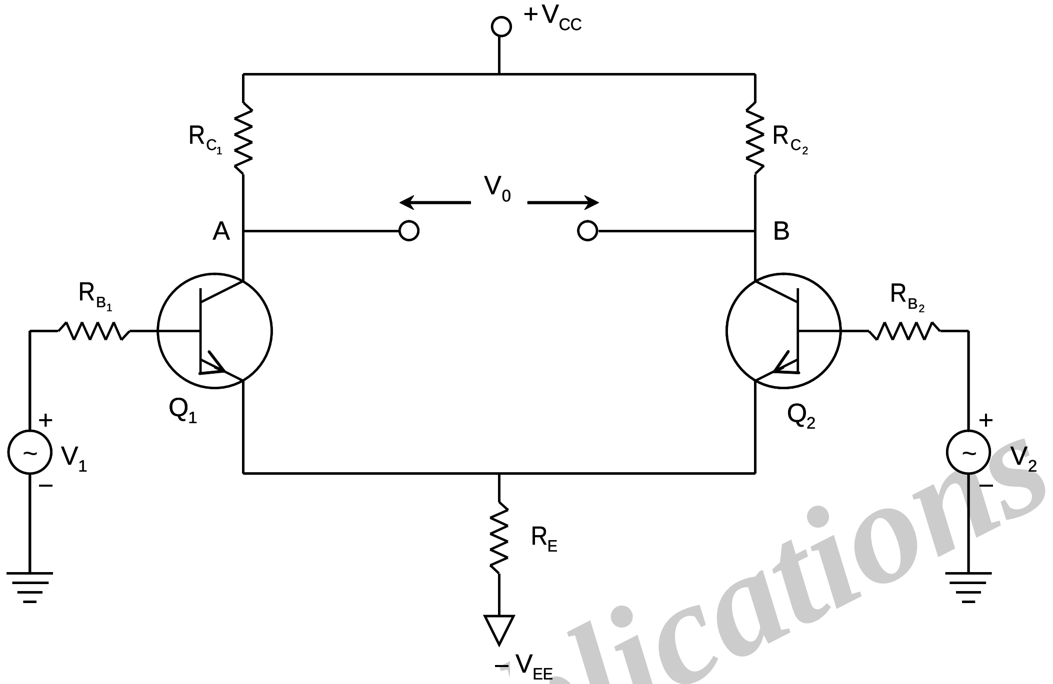
Ans :

Differential Amplifier is the basic unit of operational amplifier (Op-Amp). It amplifies the difference of two input signals. If the two input voltage signals are V_1 and V_2 then an ideal differential amplifier will give an output voltage are

$$V_0 = A_d (V_1 - V_2)$$

where A_d is the differential mode gain of the amplifier.

Circuit Diagram



The above circuit diagram shows a emitter coupled differential amplifier. It is the basic differential amplifier which consist of two identical transistor Q_1 and Q_2 which are fabricated side by side on the chip. Here both the transistors are corresponds to temperature variation, change in parameter. Thus the change will not effect the output in differential mode.

Here two input voltage signal V_1 and V_2 are connected to the basis of the transistors through registers. R_1 and R_2 respectively. Emitter resistor R_E is common to both the transistor and is connected between $-V_{EE}$ and collector resistor $R_{C_1} = R_{C_2}$. Hence the output is taken between the two collectors. (i.e., between points A and B)

∴ In differential mode, the two input signals are equal but in opposite phase i.e.,

$$V_1 = V_2$$

∴ In common mode, the two input signals are equal but in the same phase i.e.,

$$V_1 = V_2$$

∴ The input voltage in differential mode is given by

$$V_0 = A[V_1 - (-V_2)]$$

$$= A[V_1 - (-V_2)] \qquad (\because V_1 = -V_2)$$

$$\boxed{V_0 = AV_1}$$

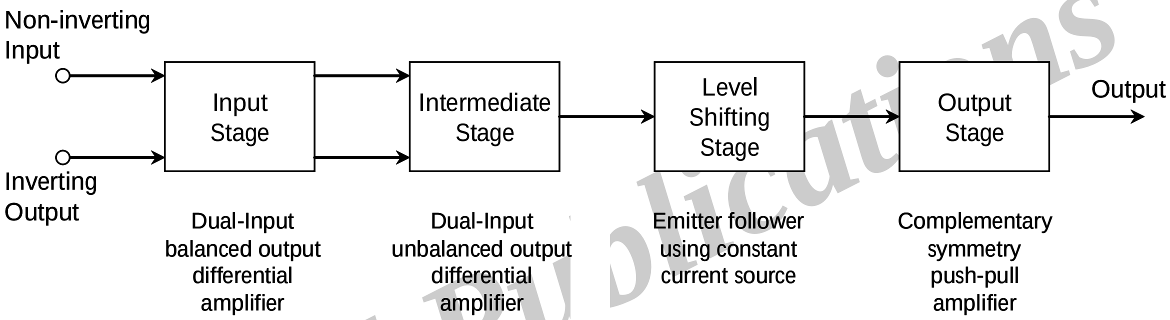
1.2 Block Diagram of Op-Amp

Q3. Draw the block diagram schematic of an Op-Amp.

Ans : **(Nov.-20, June-18, Imp.)**

The block diagram shows of op-amp IC are fabricated in various different and IC configuration. In general the system on the chip consist of four cascaded block as shown in above figure.

- At first stage, is the differential amplifier with dual-input and balanced output, at this stage amplifier determines the ultimate gain, stability, rejection of common mode signal, bias, drift, input impedance, slew rate, bandwidth and noise of the Op-Amp.
- At intermediate stage, the differential amplifier with dual-input and unbalanced output, at this stage input transistor should operate at low collector currents and it should have high gain. Because of direct coupling, the dc voltage at the output of the intermediate stage is above ground potential.



1. Input Stage

The input signals are applied to the non-inverting and inverting input terminals of the input stage of the op-amp. Generally, the input stage of an op-amp is dual input balanced output differential amplifier that has two inputs and the output is measured across two collector terminals. The input stage provides the high gain and high input resistance.

2. Intermediate Stage

This stage is a dual input unbalanced output differential amplifier or single-ended differential amplifier which has two inputs, but the output voltage is measured at any one of the collector terminals. Intermediate stage is also provides additional gain.

3. Level Shifting Stage

The output of the intermediate stage is D.C voltage, which is higher than the ground potential due to the direct coupling. So, in order to bring the D.C level to ground potential level this stage is used.

4. Output Stage

The next stage is output stage, which is complementary symmetry push-pull amplifier. The output voltage swing and op-amp current supplying capability is increased by this stage. Low output impedance is also provided by this output stage.

- At level shifter stage is usually an emitter follower whose high input resistance prevents the preceding high gain stage. It is used after the intermediate stage to shift the dc level at the output of the intermediate stage downward to zero volts w.r.t. ground.

- At output stage is usually an emitter follower of the complimentary symmetry type. It provides high current gain, wide bandwidth, high input impedance and low output impedance. So at this stage output increases the output voltage swing and raises the current.

Schematic Symbol of Op-Amp

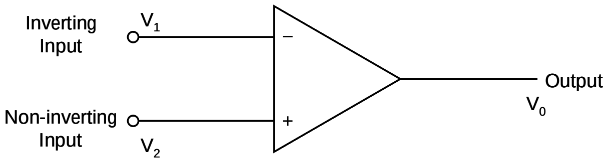


Figure shows Op-Amp schematic (or) circuit symbol which shows the most widely used of such symbols with two inputs and one output. Since the input differential amplifier stage of the op-amp is designed to be operated in differential mode, the differential inputs are designed by (+) and (–) notation where (+) for non-inverting and (–) for inverting terminals. Typically the power supply voltage is $\pm$ 15 volts. Hence the applied input produces an 180^o out-of-phase signal at the output.

1.2.1 Ideal Characteristic of Op-Amp

Q4. Give the Characteristic of an ideal Op-Amp.

Ans : **(Nov.-20, June-19)**

1. Infinite Input Impedance ($R_1 = \infty$)

   In an op-amp input resistance is measured at either non-inverting or inverting terminal with the other terminal grounded. In an ideal op-amp, the current at inverting and non-inverting terminal is zero. Therefore, any signal source can drive the op-amp without causing any loading effect on the preceding driver stage.

2. **Zero Output Impedance ($R_o = 0$)**

   In an op-amp, output resistance is measured between op-amp output terminal and ground. Since $R_0 = 0$, the output of op-amp does not depend on the current drawn from it. Therefore, the output can drive other devices.

3. **Infinite Voltage Gain ($A_{OL} = \infty$)**

   The voltage gain of an op-amp is defined as the ratio of output voltage to the difference input voltage. For an ideal op-amp, the voltage gain is infinity.

4. **Zero Offset Voltage ($V_{ios} = 0$)**

   The differential input voltage of an op-amp is zero, when both the inputs of an op-amp are at zero volts. The output of an ideal op-amp is zero, when its input is zero.

   The presence of small voltage at the output, through the voltage at both the inputs is zero is referred as offset voltage.

5. **Infinite Common Mode Rejection Ratio (CMRR = ∞)**

   CMRR is defined as the ratio of the differential mode voltage gain of an op-amp to the common mode voltage gain i.e.,

$$CMRR = \frac{A_{dm}}{A_{cm}}$$

   Where,

   A_{dm} – Differential mode voltage gain

   A_{cm} – Common mode voltage gain.

   CMRR of an ideal op-amp is infinite.

6. **Infinite Slew Rate (Slew Rate = ∞)**

   The maximum rate of change of output voltage for each unit of time is known as slew rate. It is usually specified in V/ps. It is given by, dV

$$\text{Slew rate} = \left.\frac{dV_{out}}{dt}\right|_{max} \text{V/}\mu\text{s}$$

   Slew rate of an ideal op-amp is infinite.

7. **Infinite Bandwidth (BW = ∞)**

   Bandwidth is nothing but the upper and lower range of frequencies in which the op-amp functions satisfactorily. Therefore, the operating frequency range of an op-amp varies from 0 to ∞ as BW = ∞.

8. No Effect to Temperature

The frequency response characteristics of an op- amp do not vary with temperature.

9. Power Supply Rejection Ratio (PSRR)

It is the ratio of the change in input offset voltage due to the change in supply voltage producing it, keeping other power supply voltage constant. It is expressed in mV/V or μV/V and its ideal value is zero.

1.3 Op-Amp Parameters

1.3.1 Input Resistance, Output Resistance, Common Mode Rejection Ratio (CMMR), Slew Rate, Offset Voltages, Input Bias Current

Q5 Explain various Op-Amp parameters.

Ans : **(June-18, Imp.)**

1. Input Resistance

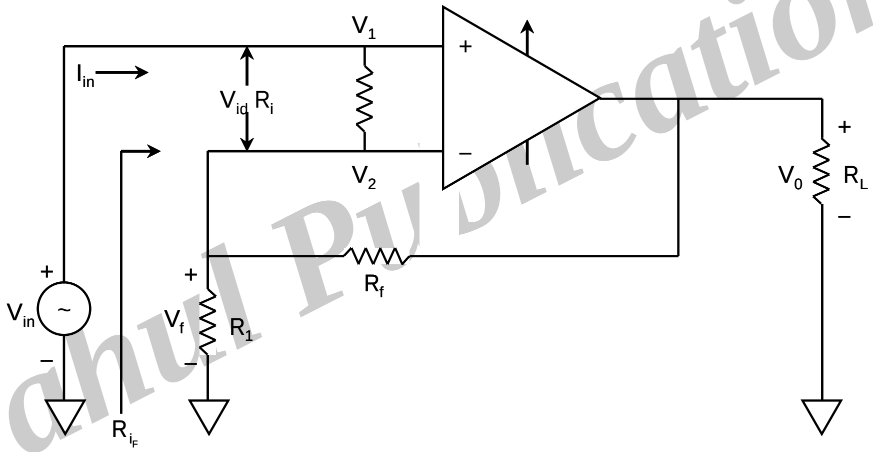


Fig shows a voltage series feedback amplifier with the op-amp equivalent circuit. In this circuit R_i is the input resistance (open loop) of the op amp and R_{i_F} is the input resistance of the amplifier with feedback.

∴ The input resistance with feedback is defined as

$$R_{i_F} = \frac{V_{in}}{I_{in}}$$

$$= \frac{\nu_{in}}{V_{id}/R_i}$$

However,

$$\nu_{id} = \frac{\nu_0}{A} \text{ and } \nu_0 = \frac{A}{1+AB}\,\nu_{in}$$

$$\therefore \quad R_{i_F} = R_i \frac{\nu_{in}}{\nu_0 / A}$$

$$= A\,R_i \frac{\nu_{in}}{A\,\nu_{in} / (1 + AB)}$$

$$\boxed{R_{i_F} = R_i(1 + AB)}$$

Hence the input resistance of the op-amp with feedback is (1 + AB) times without feedback.

2. Output Resistance

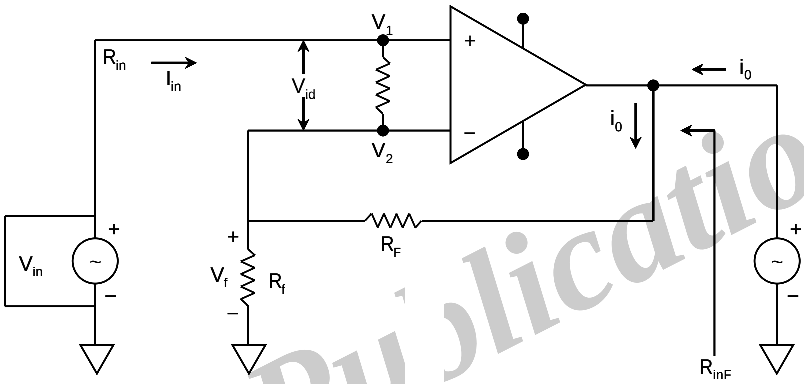


Fig shows that the resistance determined looking back into the feedback amplifier from the output terminal. This resistance can be obtained by using Thevenin's theorem for dependent sources. To find output resistance with feedback R_{of}, reduce independent source V_{in} to zero apply an external voltage V_0, and then calculate the resulting current i_0.

$$\therefore \quad R_{oF} = \frac{\nu_0}{i_0} \qquad \text{... (a)}$$

Writing Kirchhoff's current equation at output node N, we get

$$ci_0 = i_a + i_b$$

$\because$ $[(R_F + R_1)\ 1)\ R_i] >> R_0$ and $i_a >> i_b$.

$\therefore$ $i_a \cong i_b$

The current i_0 can be found by writing Kirchhoff's voltage equation for the output loop.

$$\nu_0 - R_0 i_0 - A\,\nu_i d = 0$$

$$i_0 = \frac{\nu_0 - A\nu_{id}}{R_0}$$

However,

$$\nu_{id} = \nu_1 - \nu_2$$

$$= 0 - \nu_f$$

$$= \frac{-R_1 \nu_0}{R_1 + R_F}$$

$$= -B\,\nu_0$$

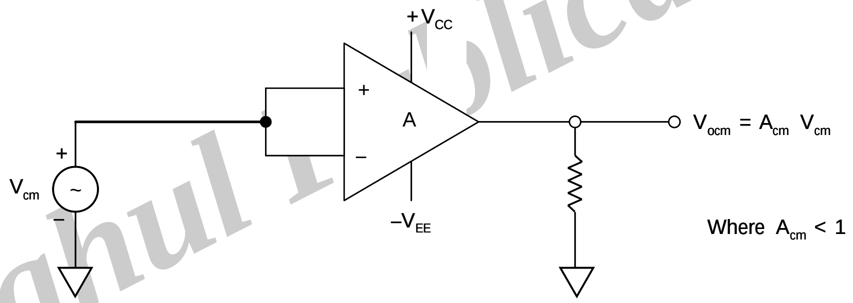
$$\therefore \quad i_0 = \frac{\nu_0 + AB\,\nu_0}{R_0}$$

$$R_{0F} = \frac{\nu_0}{(\nu_0 + AB\,\nu_0)/R_0}$$

$$\boxed{R_{0F} = \frac{R_0}{1 + AB}}$$

3. Common Mode Rejection Ratio (CMRR)

When the same input voltage is applied to both input terminal of an op-amp, it is said to be operating is an common-mode configuration. Since the input voltage applied is common to both the inputs, it is called as a common mode voltage ν_{cm} as shown in below figure.



∴ It is define as the ratio of output common mode voltage V_{0cm} to the input common-mode voltage ν_{cm}, is called the common-mode voltage gain A_{cm}, is much smaller than 1.

$$\therefore \quad A_{cm} = \frac{\nu_{ocm}}{\nu_{cm}} \qquad \text{... (1)}$$

Ideally, the common-mode voltage gain A_{cm} is zero.

Generally, CMRR can be defined as the ratio of the differential gain A_D to the common-mode gain A_{cm}.

$$\text{i.e.,} \qquad CMRR = \frac{A_D}{A_{cm}} \qquad \text{... (2)}$$

CMRR can also be expressed as the ratio of the change in input offset voltage to the total change in common-mode voltage.

$$\text{Thus,} \qquad CMRR = \frac{\nu_{io}}{\nu_{cm}} \qquad \text{... (3)}$$

From equations (2) and (3), we can establish the relationship between ν_{ocm} and CMRR.

$$CMRR = \frac{A_D}{A_{cm}} = \frac{A_D}{\nu_{ocm} / \nu_{cm}}$$

where A_D = Differentiation

A_{cm} = common mode gain

$$= \frac{A_D \ \nu_{cm}}{\nu_{ocm}} \quad \text{... (4)}$$

$$\nu_{ocm} = \frac{A_D \ \nu_{cm}}{CMRR}$$

∴ Equation (4) indicates that the higher value of CMRR, the smaller will be the amplitude of the output common-mode voltage ν_{ocm}.

Generally, the CMRR value is very large and is usually specified in decibels (d B), where

$$CMRR\ (d\ B) = 20 \log \left(\frac{A_D}{A_{cm}}\right) \quad \text{... (5)}$$

(or) from eqn. (3), we have

$$CMRR\ (d\ B) = 20 \log \left(\frac{\nu_{io}}{\nu_{cm}}\right) \quad \text{... (6)}$$

4. Slew Rate

The slew rate as the maximum possible rate of change of output voltage with respect to rated output. Thus

$$S = \max \frac{dv_s}{dt} \quad \text{... (1)}$$

Thus slew rate of an op-amp is a measure of how fast the output voltage can change. It is measured in volt / micro second.

This finite slew rate impose a limitation on the maximum amplitude and frequency to which an operational amplifier.

For a sine voltage ... (2)

$$\nu_0 = V_0 \sin wt$$

We have

$$\frac{d\nu_0}{dt} = w\, V_0 \cos wt$$

and the maximum value of dv_0/dt occurs at wt = 0, So the slew rate is

$$S = \left.\frac{dv_0}{dt}\right|_{max} \geq w V_0 \qquad ... (3)$$

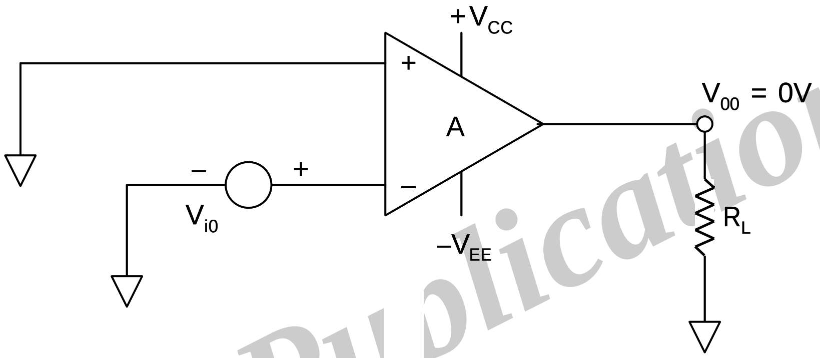
The maximum amplitude possible at a frequency f is

$$V_{max} = \frac{S}{2\pi f} \qquad ... (4)$$

Thus slew rate may be defined as the maximum rate at which output voltage can change.

5. Input Offset Voltage

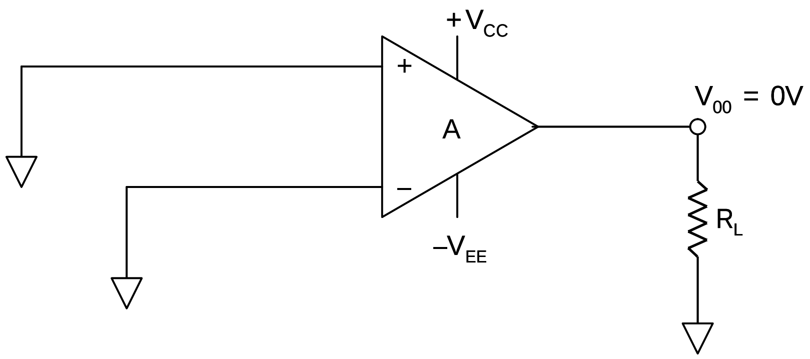
Input offset voltage e V_{i0} is the differential input voltage that exists between two input terminals of an op-amp without any external inputs applied.



Let us denote the output offset voltage due to input offset voltage V_{i0} as V_{00}. The output offset voltage V_{00} is caused by mismatching between two input terminals.

6. Output Offset Voltage

The output voltage caused by mismatching between two input terminals is the output offset V_{00}. Figure shows the output offset voltage is an op-amp without feedback.

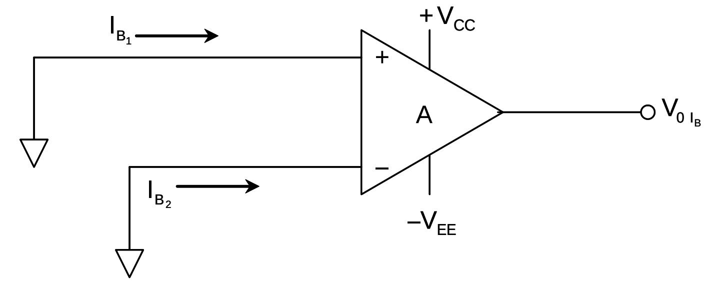


The output offset voltage V_{00} is a dc voltage, it may be positive or negative in polarity depending on whether the potential difference between two input terminals in positive or negative.

7. Input Bias Current

An input bias current I_B is defined as the average of the two input bias currents, I_{B_1} and I_{B_2} as shown in below figure.

i.e., $I_B = \dfrac{I_{B_1} + I_{B_2}}{2}$



where

I_{B_1} = dc bias current flowing into the non-inverting input.

I_{B_2} = dc bias current flowing into the inverting input.

Here both input terminals are grounded so that no input voltage is applied to the op-amp. But the plus & minus supply voltage are necessary to bias the op-amp properly.

∴ The specified input bias current I_B as being equal to either one of the two input currents I_{B_1} & I_{B_2}

i.e., $I_B = I_{B_1} = I_{B_2}$

1.4 Basic Op-Amp Circuits

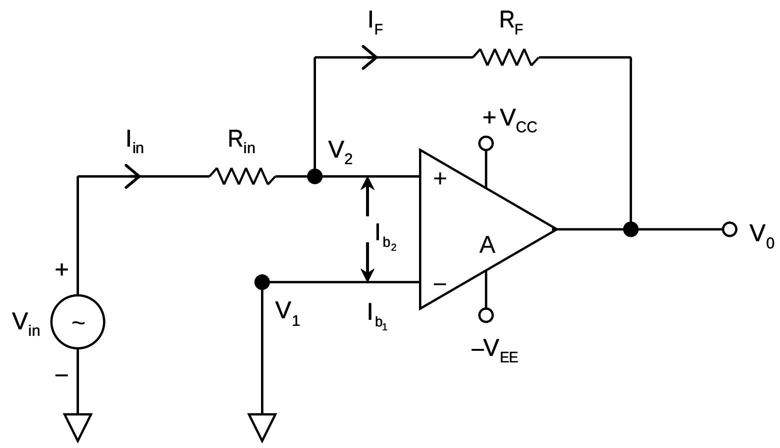
1.4.1 Inverting Op-Amp

Q6. Derive an expression for inverting Op-Amp for voltage gain.

Ans : **(Nov.-20, Jun-19)**

An inverting amplifier is a closed loop amplifier is which the input is applied to inverting terminal of the op-amp. The output of inverting amplifier is out of phase by 180° w.r.t. Input.

Circuit Diagram



The above circuit diagram represents inverting configuration of the op-amp input voltage of 'V_{in}' is applied to the inverting terminal and non-inverting terminal is grounded.

Let 'V_1' is the potential at non-inverting terminal.

Let 'V_2' is the potential at inverting terminal.

Let 'R_{in}' and 'R_f' are input and feedback resistance.

Applying Kirchhoff's current law we get

$$I_{in} = I_{b_2} + I_f$$

$\because$ I_{b_2} is negligible small

$$I_{in} \simeq I_f$$

$$\frac{V_{in} - V_2}{R_{in}} = \frac{V_2 - V_0}{R_f} \qquad \text{... (1)}$$

The output voltage is given by

$$V_0 = A(V_1 - V_2)$$

Since V_1 is at ground potential ($V_1 = 0$)

$\therefore$ $V_0 - AV_2$

$$V_2 = \frac{-V_0}{A} \qquad \text{... (2)}$$

Substituting the valve of 'V_2' in eqn. (1) we get

$$\frac{V_{in}}{R_{in}} - \left(\frac{-V_0}{AR_{in}}\right) = \frac{-V_0}{AR_f} - \frac{V_0}{R_f}$$

$$\frac{V_{in}}{R_{in}} + \frac{V_0}{AR_{in}} = \frac{-V_0}{AR_f} - \frac{V_0}{R_f}$$

$$\frac{V_{in}}{R_{in}} + \frac{V_0}{AR_f} + \frac{V_0}{R_f} + \frac{V_0}{AR_{in}} = 0$$

$$\frac{V_0}{AR_f} + \frac{V_0}{R_f} + \frac{V_0}{AR_{in}} = \frac{-V_{in}}{R_{in}}$$

$$V_0\left[\frac{1}{AR_f} + \frac{1}{R_f} + \frac{1}{AR_{in}}\right] = \frac{-V_{in}}{R_{in}}$$

$$V_0\left[\frac{R_f + R_{in} + AR_{in}}{AR_{in}R_f}\right] = \frac{-V_{in}}{R_{in}}$$

$$\frac{V_0}{V_{in}} = -\frac{AR_{in}\ R_f}{R_{in}[R_{in}+R_f+AR_{in}]}$$

$$\frac{V_0}{V_{in}} = -\frac{AR_f}{R_{in}+R_f+AR_{in}} = A_f$$

$\because$ A is taken to be very large then $AR_{in} >> R_{in} + R_f$

$$\therefore \quad \frac{V_0}{V_{in}} = \frac{-AR_f}{AR_{in}}$$

$$\therefore \quad \boxed{A_f = \frac{V_0}{V_{in}} = \frac{-R_f}{R_{in}}}$$

Hence the gain of the inverting amplifier is the ratio of feedback resistance to the input resistance.

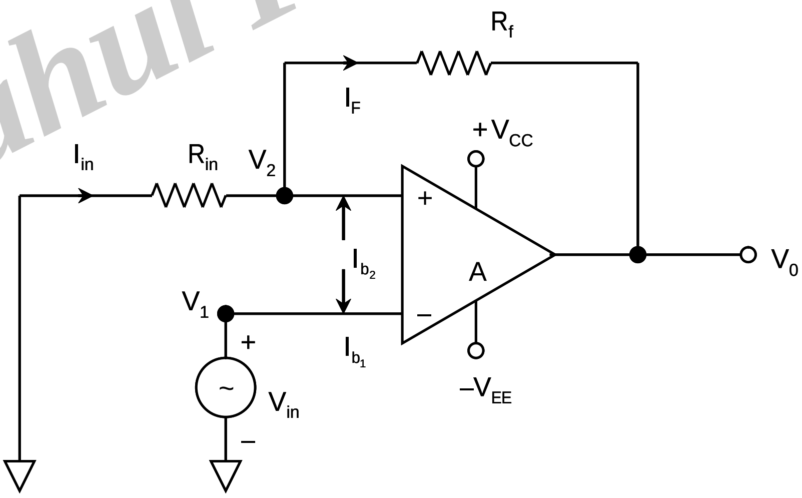
1.4.2 Non-Inverting Op-Amp

Q7. Derive an expression for inverting Op-Amp for Non-Inverting Amplifier for voltage gain.

Ans : **(Nov.-20, June-18, Imp.)**

A non-inverting amplifier is that the input signal is applied to the non-inverting terminal while its inverting terminal is grounded.

Circuit Diagram



The above circuit diagram represents an op-amp connected is non-inverting mode. Here input signal 'V_{in}' is applied to the non-inverting terminal.

Let 'V_1' is the potential at non-inverting terminal

Let 'V_2' is the potential at inverting terminal

Let 'R_{in}' and 'R_f' are the input and feedback resistor

By applying KCL, we get

$$I_{in} = I_f + I_{b_2}$$

$\because$ I_{b_2} is negligibly small

i.e., $I_{in} \approx I_f$

Then the output voltage is given by

$$V_0 = A(V_1 - V_2) \qquad \text{... (1)}$$

But $V_1 = V_{in}$ and $V_2 = \left(\dfrac{V_0}{R_{in} + R_f}\right) R_{in}$

$\therefore$ Equation (1) becomes

$$V_0 = A\left[V_{in} - \frac{V_0 R_{in}}{R_{in} + R_f}\right]$$

$$V_0 = AV_{in} - \frac{AV_0 R_{in}}{R_{in} + R_f}$$

$$V_0 = \frac{AV_0 R_{in}}{R_{in} + R_f} = AV_{in}$$

$$V_0 = \left[1 + \frac{A R_{in}}{R_{in} + R_f}\right] = AV_{in}$$

$$V_0 = \left[\frac{R_{in} + R_f + AR_{in}}{R_{in} + R_f}\right] = AV_{in}$$

$$A_f = \frac{V_0}{V_{in}} = \frac{A(R_{in} + R_f)}{R_{in} + R_f + AR_{in}}$$

$\because$ $AR_{in} >> R_{in} + R_f$

$$A_f = \frac{A(R_{in} + R_f)}{A R_{in}}$$

$$A_f = \frac{R_{in} + R_f}{R_{in}}$$

$$A_f = R_{in}\left[1 + \frac{R_f}{R_{in}}\right]$$

$\because$ $R_f >> R_{in}$ then

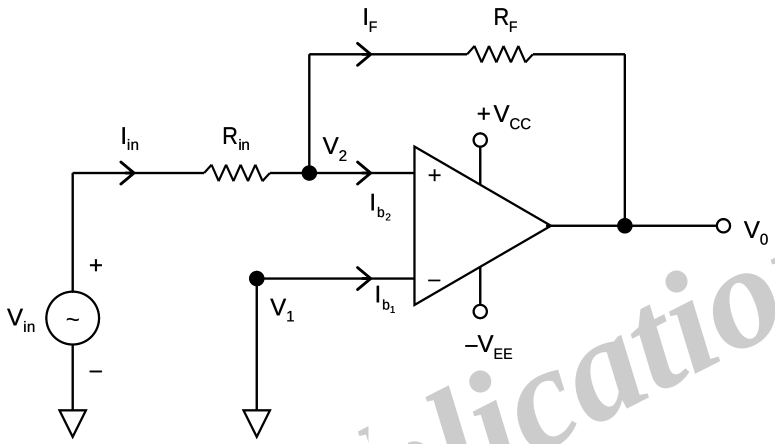
$$\boxed{A_f = 1 + \frac{R_f}{R_{in}}}$$

Hence the gain of an non-inverting amplifier is one more than the gain of inverting amplifier.

Q8. Draw the circuit diagram of op-amp in non-inverting made and derive the equation for its voltage gain.

Ans : **(June-18)**

An op-amp with low impedance results from the negative feedback voltage, which cancells the input signal at V_2 and tends to keep the branch point at ground potential. For this reason the point V_2 is called a 'VIRTUAL GROUND'. As shown in below figure.



Consider the above circuit diagram, Here V_{in} is the input voltage applied to inverting terminal of an op-amp. V_1 is the potential at non-inverting terminal & V_2 is the potential at inverting terminal. Here R_i and R_f are input and feedback resistors.

By applying KVL we get

$$I_i \approx I_f \qquad (\because\ I_{b_2} \text{ is small})$$

$$\frac{V_{in} - V_2}{R_{in}} = \frac{V_2 - V_0}{R_f}$$

The output voltage is function of differential inputs multiplied by gain i.e.,

$$V_0 = A(V_1 - V_2)$$

$\because$ V_1 is at zero potential, then

$$V_0 = -AV_2$$

$$V_2 = \frac{-V_0}{A}$$

From the ideal characteristic of an op-amp, the gain is considered to be infinite.

$\therefore$ V_2 tends to zero

i.e., $V_2 \rightarrow 0$ as gain, $A = \infty$

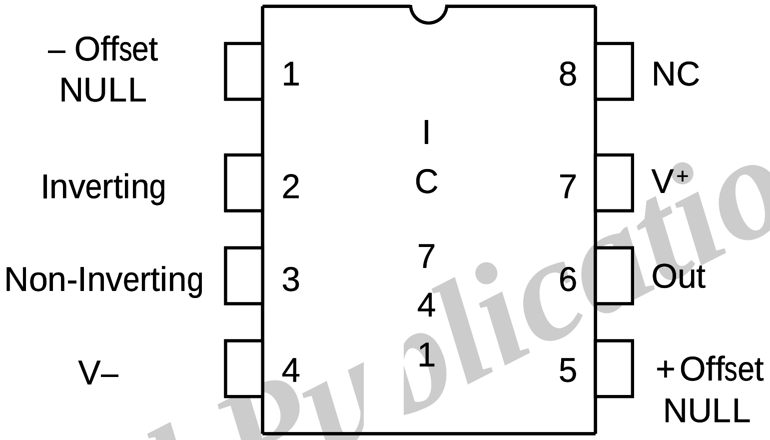
$\therefore$ If $V_1 = 0$ then V_2 tends to zero and this concept is called concept of virtual ground.

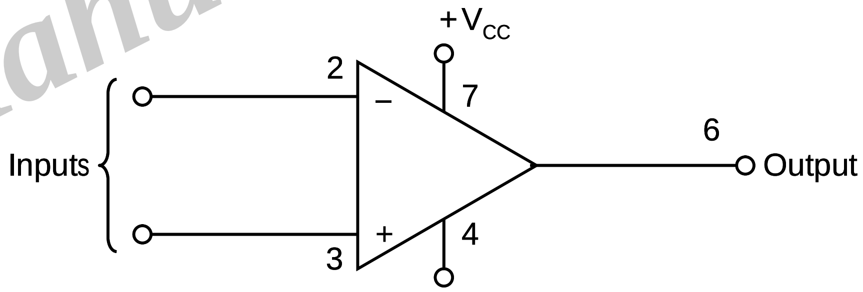
Hence feedback resistor R_f serves to keep voltage 'V_2' at zero, means no current flows into amplifier, so we use a term called "VIRTUAL".

Q9. Explain briefly about Op-Amp Pin configuration and symbol.

Ans :

The IC 741 is the most popularly and widely used op-amp.



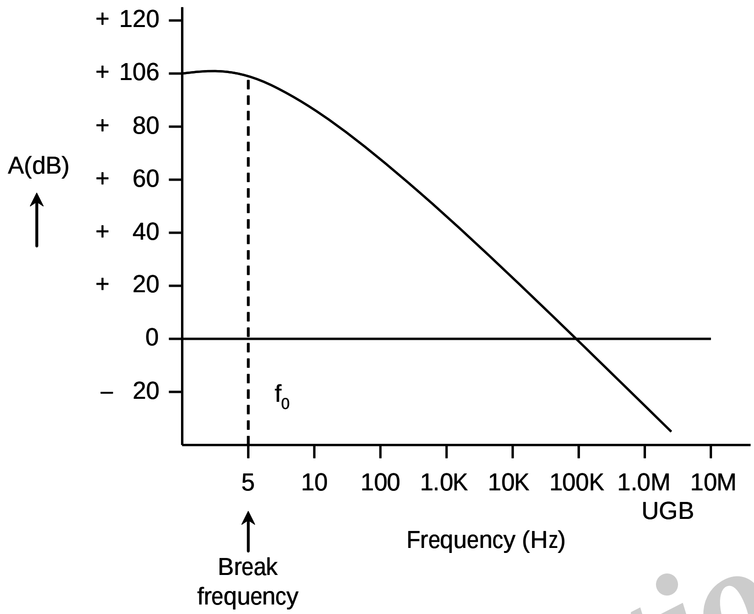


Q10. State the frequency response of Op-Amp.

Ans :

At a given frequency the gain will have a specific magnitude as well as a phase angle which means that the variation in operating frequency will cause the variation in gain magnitude and its phase angle. The manner in which the gain of the op-amp responds to different frequencies is called the frequency response. A graph of the magnitude of the gain versus frequency is called a frequency response plot.

Generally for an amplifier, as the operating frequency increases, two effect become an evident (1) the gain (magnitude) of the ampalifier decreases and (2) the phase shift between the output and input signals increases.



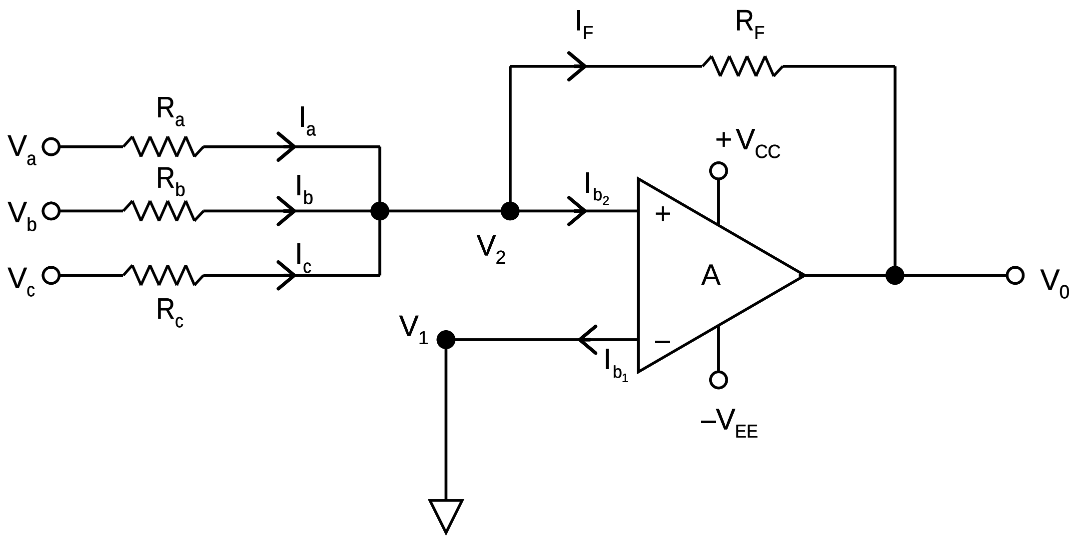
The manner is which the gain of the op-amp changes with variation is frequency and phase shift changes is known as magnitude and phase angle plot. Here phase shifts of these op-amps are less than 90^o even at cross over frequencies is also called as unity gain bandwidth (UGB), is the maximum usable frequency for a given op-amp. For the IC741 op-amp, UGB = 1 MHz.

1.4.3 Op-Amp as Summing Amplifier

Q11. Discuss the working of op-amp as a summing amplifier and obtain its output voltage.

Ans : **(Nov.-20, June-19)**

A summing amplifier is an arithmetic circuit whose output is proportional to the sum of input voltages applied. It can be constructed either in the inverting (or) non inverting mode of configuration.



The above circuit diagram represents a summing amplifier designed in inverting mode of configuration.

Let V_a, V_b, and V_c are the input voltage applied.

Let I_a, I_b, and I_c are the corresponds currents through R_a, R_b and R_c.

By applying KCL we get

$$I_a + I_b + I_c = I_{b_2} + I_f$$

$\because$ I_{b_2} is negligible small, then

$$I_a + I_b + I_c \simeq I_f$$

$$\frac{V_a - V_2}{R_a} + \frac{V_b - V_2}{R_b} + \frac{V_c - V_2}{R_c} = \frac{V_2 - V_0}{R_f}$$

By concept of virtual ground, If $V_1 = 0$ then $V_2 = 0$. Hence above equation becomes.

$$\therefore \quad \frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} = \frac{-V_0}{R_f}$$

Rearrange the terms

$$V_0 = -R_f\left[\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c}\right] \quad \ldots (1)$$

Case (i) : If $R_f = R_a - R_b = R_c$ then equation (1) becomes

$$V_0 = -[V_a + V_b + V_c]$$

Hence the output is proportional to the applied inputs.

Case (ii) : If $R_f = R$ and $R_a = R_b = R_c = 3R$ then equation (1) becomes

$$V_0 = -\left[\frac{V_a + V_b + V_c}{3}\right]$$

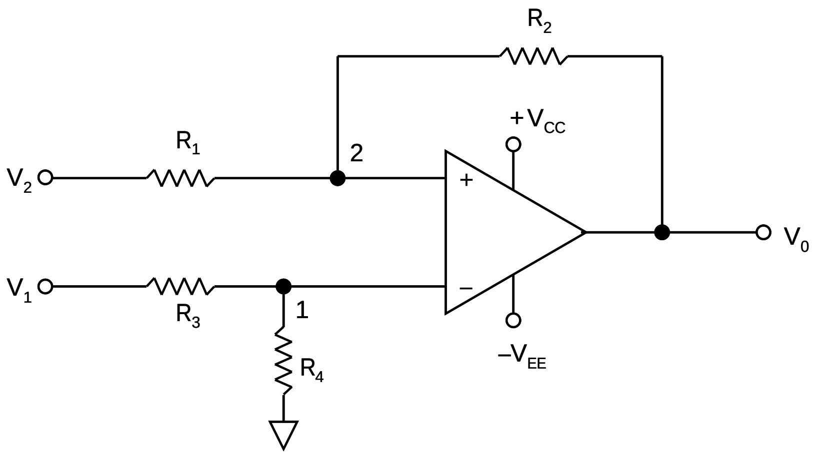
Hence the op-amp behaves like averaging (or) Scaling amplifier

1.4.4 Op-Amp as a Subtractor

Q12. Explain how op-amp can be used as a subtractor.

Ans :

A subtractor is an arithmetic circuit where output is proportional to the difference of the two inputs applied at the two terminals of op-amp.



The above circuit diagram is also called on differential amplifier.

Let V_1' and V_2' are the voltages applied to the two terminals.

By applying KCL at node '1' we get

$$\frac{V_1 - V}{R_3} = \frac{V}{R_4}$$

$$\frac{V_1}{R_3} = V\left[\frac{1}{R_3} + \frac{1}{R_4}\right]$$

$$\frac{V_1}{R_3} = V\left[\frac{R_3 + R_4}{R_3 R_4}\right]$$

$$V = \frac{V_1 . R_4}{R_3 + R_4} \qquad \text{... (1)}$$

Similarly applying KCL at node 2 we get

$$\frac{V_2 - V'}{R_1} = \frac{V - V_0}{R_2}$$

$$\frac{V_2}{R_1} = \frac{V}{R_1} + \frac{V}{R_2} - \frac{V_0}{R_2}$$

$$\frac{V_0}{R_2} = V\left[\frac{1}{R_1} + \frac{1}{R_2}\right] - \frac{V_2}{R_1}$$

$$\frac{V_0}{R_2} - V\left[\frac{R_1 + R_2}{R_1 R_2}\right] - \frac{V_2}{R_1} \qquad \text{... (2)}$$

Subtracting valve of 'V' in eqn. (2) we get

$$\frac{V_0}{R_2} = \left[\frac{V_1 R_4}{R_3 + R_4}\right]\left[\frac{R_1 + R_2}{R_1 R_2}\right] - \frac{V_2}{R_1}$$

$$V_0 = \frac{R_2}{R_1}\left\{\left[\frac{R_4}{R_3 + R_4}\right]\left[\frac{R_1 + R_2}{R_2}\right]V_1 - V_2\right\}$$

If $\frac{R_3}{R_4} = \frac{R_1}{R_2}$ then the above expansion behaves like subtractor

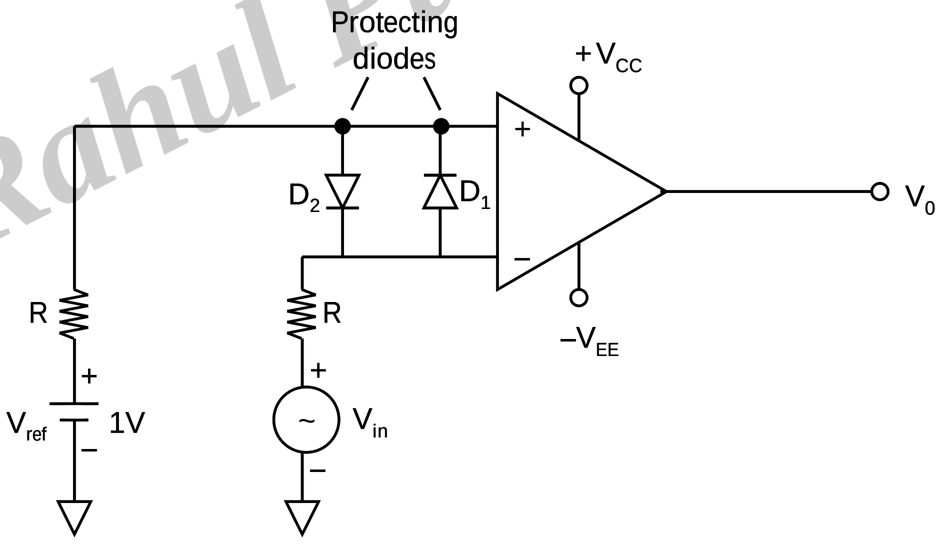
$$\boxed{V_0 = \frac{R_2}{R_1}(V_1 - V_2)}$$

1.4.5 Op-Amp as a Comparator

Q13. Explain the concept of Op-Amp as a Comparator

Ans : **(Nov.-20, June-19, Imp.)**

It is one of the important application of an op-amp where it compares two input voltages or levels.

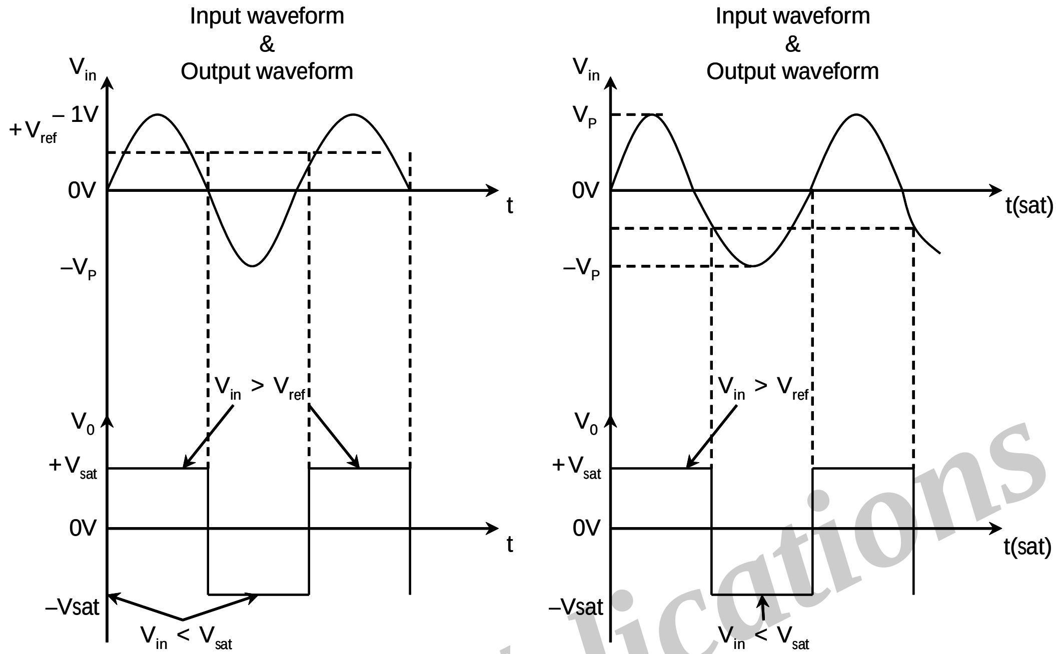


The above circuit diagrame represents a comparator. A reference voltage 'V_{ref}' is applied to the inverting terminal and input voltage V_{in} is applied at non-inverting amplifier. Hence the configuration is the non-inverting configuration. The diodes D_1 and D_2 protect the op-amp from damage due to excessive input voltage V_{in}.

Operation

- When $V_{in} < V_{ref}$, the output voltage 'V_0' is at $-V_{sat}$ (approx. equal to V_{ce}). This is because the voltage at negative terminal is higher than voltage positive terminal.

- Similarly, when $V_{in} > V_{ref}$, the output voltage 'V_0' is at $+V_{sat}$ (approx equal to $+V_{CC}$) because the voltage at positive terminal is greater than voltage at negative terminal.



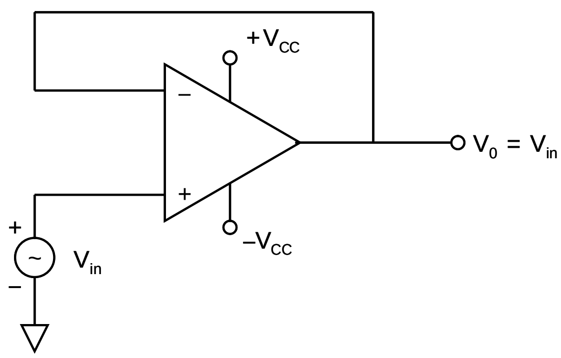
1.4.6 Op-Amp as a Voltage Follower

Q14. Explain how Op-Amp as a Voltage Follower

Ans :

When the non-inverting amplifier is configured for unity gain, it is called a voltage follower because the output voltage is equal to and in phase with the input. In other words, in the voltage follower the output follows the input. The lowest gain that can be obtained from a non-inverting amplifier with feedback is 1.

Although it is similar to the emitter follower, the voltage follower is preferred because it has much higher input resistance and the output amplitude is exactly equal to the input.



The above circuit diagram is for voltage follower can be designed by modifying the non-inverting amplifier. The input resistance is made open and the feedback resistance is shorted.

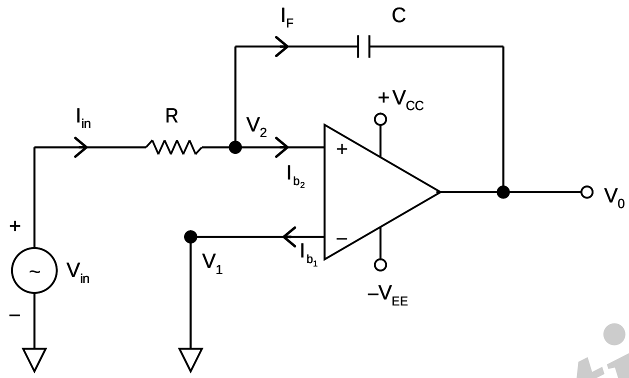
∴ All the output voltage is feedback into the input. Hence the gain become '1'. The voltage follower is also called a non-inverting butter because when it is placed between two networks, it removes the loading on the first network.

1.4.7 Op-Amp as a Integrator

Q15. Explain the working of Op-Amp as a Integrator.

Ans : **(June-19, Imp.)**

An op-amp whose output voltage is proportional to integral valve of the input voltage. Hence the integrator circuit performs the function of integration.



The above circuit represents integrator designed in inverting mode of configuration. Here feedback resistance R_f is replaced by capacitor 'C'.

By applying KCL to node V_2, we get

$$I_{in} = I_{b_2} + I_f$$

$\because$ I_{b_2} is negligibly small

$$I_{in} = I_f \quad \text{... (1)}$$

From V – I relation across the capacitor in

$$I_C = C\frac{dV_c}{dt} \quad \text{... (2)}$$

$\therefore$ Equation (1) can be written as

$$\frac{V_{in} - V_2}{R} = C\frac{d(V_2 - V_0)}{dt} \quad \text{... (3)}$$

By concept of virtual ground, i.e., $V_1 = 0$, V_2 tends to '0'.

$\therefore$ Equation (3) becomes

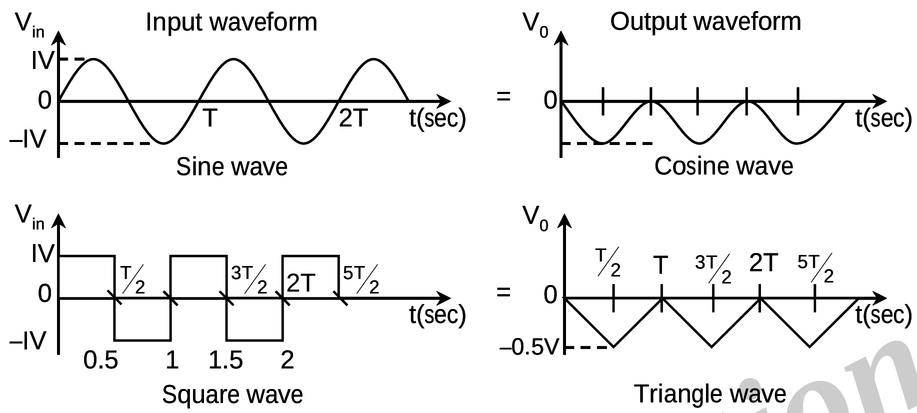
$$\frac{V_{in}}{R} = \frac{Cd(-V_0)}{dt}$$

$$\frac{dV_0}{dt} = \frac{1}{RC}.V_{in}$$

Integrating on both sides, we get

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

Where 'A' is integration constant and is proportional to output voltage at t = 0sec.

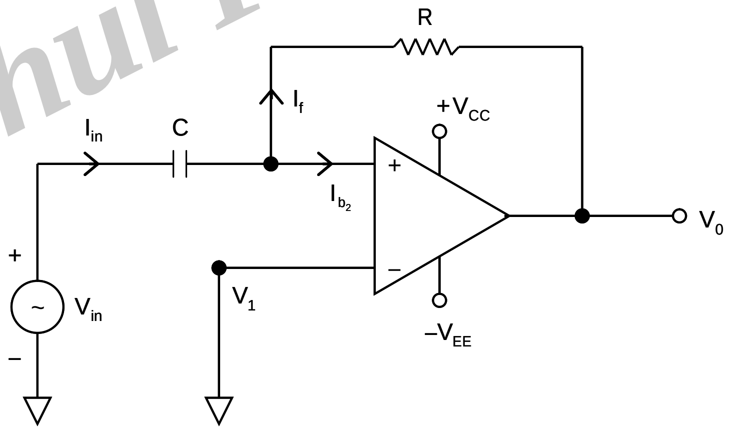


1.4.8 Op-Amp as a Differentiator

Q16. Derive an expression of op-amp are used differentiator circuit ?

Ans : **(June-19, Imp.)**

The op-amp whose output is proportional to the differential valve of the input applied is called differentiator. Hence the differentiator circuit performs differentiation.



The above circuit diagrame represents op-amp as differentiator circuit designed in inverting configuration. The input resistance is replaced by a capacitor 'C'.

By applying KCL at node 'V_2' we get

$$I_{in} = I_{b_2} + I_f$$

$\because$ I_{b_2} is negligibly small

$$I_{in} \simeq I_f$$

From V – I relation across the capacitor is given by

$$I_C = \frac{d(V_c)}{dt} \cdot C$$

$\therefore$ Equation (1) becomes

$$C\frac{d}{dt}(V_{in} - V_2) = \frac{V_2 - V_0}{R} \qquad \text{... (2)}$$

By concept of virtual ground, If $V_1 = 0$ then $V_2 \rightarrow$ '0'.

Here equation (2) becomes

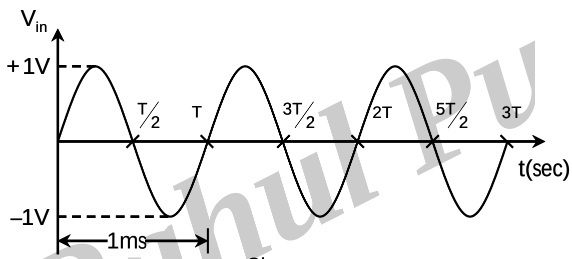
$$C\frac{d}{dt}(V_{in}) = \frac{-V_0}{R}$$

$$\boxed{V_0 = -RC\frac{d}{dt}(V_{in})}$$

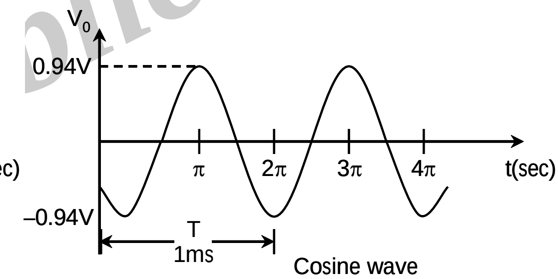
$\therefore$

Input waveform

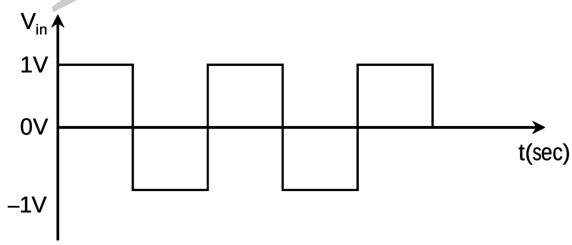
Output waveform



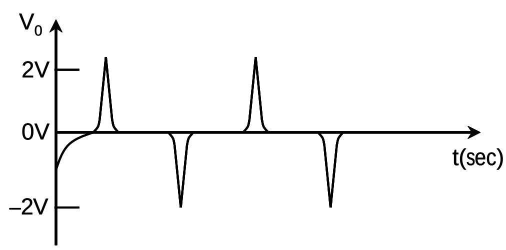
Sine wave



Cosine wave



Square wave



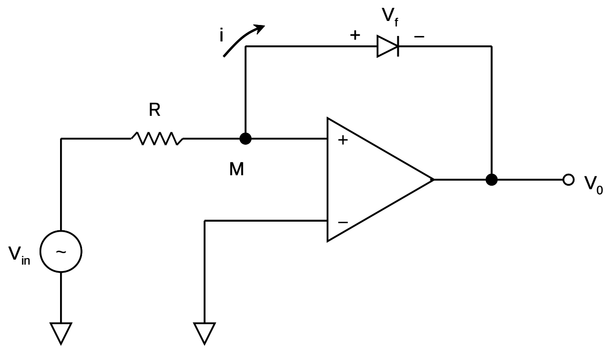
Spikes wave

1.5 Logarithmic Amplifier

Q17. Explain the concept of Logarithmic Amplifier.

Ans :

An op-amp whose output is proportional to the logarithm of the input voltage is called logarithmic amplifier.



The circuit represents an op-amp designed as logarithmic amplifier. A diode is used in the use of feedback resistance.

The V-I characteristics of the diode is given by $i = I_s\left[\exp\left(\frac{eV_f}{\eta kT}\right)-1\right]$

where

i = diode current

v_f = forward voltage

if $\frac{eV_f}{\eta kT} >> 1$

$$i = I_s \exp\left(\frac{eV_f}{\eta kT}\right)$$

$$\frac{i}{I_s} = \exp\left(\frac{eV_f}{\eta kT}\right)$$

Taking log on both sides

$$\log\left(\frac{i}{I_s}\right) = \frac{eV_f}{\eta kT}$$

$$V_f = \frac{\eta kT}{e}\log\left(\frac{i}{I_s}\right)$$

Since 'M' is virtual ground, therefore $i = \frac{V_{in}}{R}$

$$\therefore \quad V_f = \frac{\eta kT}{e}\log\left(\frac{V_{in}}{I_s R}\right)$$

Since $V_0 = -V_f$

$$V_0 = \frac{-\eta kT}{e}\left(\frac{V_{in}}{I_s R}\right)$$

Therefore output voltage is proportional to logarithm of input voltage.

Problems

1. An op-amp has a CMRR value of 60dB. Find the differential gain if the common mode gain is '3'.

Sol :

$$CMRR = \frac{A_d}{A_c}$$

Given CMRR = 60dB

AC = 3

$$60 = \frac{A_d}{3}$$

$A_d = 60 \times 3$

$A_d = 180$

2. An op-amp has a CMRR value of 60dB and differential mode gain of 1200. Find common mode gain.

Sol :

Given CMRR = 60dB

Ad = 120

$$CMRR = \frac{A_d}{A_c}$$

$$60 = \frac{1200}{A_c}$$

$$A_c = \frac{1200}{60}$$

$A_c = 20$

3. The CMR differential amplifier is 55dB and 'A_d' is 1000. Determine 'A_c' and CMRR.

Sol :

CMR = 20log A_d – 20 log A_c

55 = 20 log 1000 – 20 log A_c

20 log A_c = 20 log 1000 – 55

20 log A_c = 60 log 10 – 55

20 log A_c = 60 – 55 = 5

$$\log A_c = \frac{5}{20} = 0.25$$

A_c = Antilog (0.25)

$A_c = 1.78$

$$\text{CMRR} = \rho = \frac{A_d}{A_c}$$

$$\rho = \frac{1000}{1.78} = 561.7$$

$$\boxed{\rho = 561.7}$$

4. An inverting amplifier has R_1 = 10KΩ and R_0 = 125KΩ. Calculate the output voltage, input resistance and input current for an input voltage 4 volt.

Sol :

Given

R_1 = 10 KΩ

R_0 = 125 KΩ

R_{in} = 4V

The output voltage is given by

$$V_0 = -V_{in}\left[\frac{R_0}{R_1}\right]$$

$$V_0 = -4\left[\frac{125}{10}\right]$$

V_0 = 50V

Input resistance $R_{in} = R_1$

∴ R_{in} = 10KΩ

The input current,

$$I_{in} = \frac{V_{in}}{R_{in}}$$

$$I_{in} = \frac{4}{10 \times 10^3} = 0.4 \times 19^{-3}$$

I_{in} = 0.4 mA.

5. An operational amplifier has voltage gain of 50. Determine the values of R_{in} and R_f if.

(a) A non-inverting amplifier

(b) An inverting amplifier.

Sol :

Given

$A_f = 50$

(a) $A_f = 1 + \frac{R_f}{R_{in}}$

$50 = 1 + \frac{R_f}{R_{in}}$

$\frac{R_f}{R_{in}} = 49$

$R_f = 49\, R_{in}$

$\therefore$ If $R_{in} = 1K\Omega$ then $R_f = 49\ K\Omega$

(b) $A_f = -\frac{R_f}{R_{in}}$

$50 = -\frac{R_f}{R_{in}}$

$R_f = -50\, R_{in}$

$\therefore$ If $R_{in} = 1K\Omega$ then $R_f = 50\ K\Omega$

6. The feedback resistance is a variable of range 1KΩ to 100KΩ. If the resistance is 2KΩ then determine minimum and maximum gains for non inverting amplifier.

Sol :

Given

$R_{in} = 2K\Omega$

$R_f = 1K\Omega$ to $100K\Omega$

Case (i) :

Let $R_f = 1K\Omega$ then

$A_f = 1 + \frac{R_f}{R_{in}}$

$A_f = 1 + \frac{1}{2}$

$= 1 + 0.5$

$\boxed{A_f = 1.5}$ → Minimum gain.

Case (ii) :

Let R_f = 100KΩ then

$$A_f = 1 + \frac{R_f}{R_{in}}$$

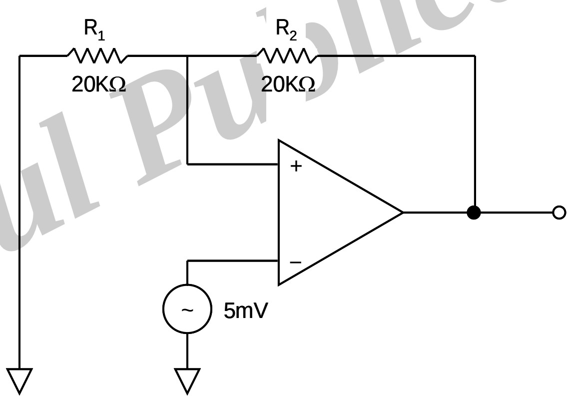
$$A_f = 1 + \frac{100}{2}$$

$= 1 + 50$

$\boxed{A_f = 51}$ → Maximum gain

∴ Minimum gain is '1.5' and maximum gain is '51'.

7. Calculate the output voltage from the given circuit. Which is having an input of Smv.



Sol :

Given

V_n = Smv

$R_{in} = R_1$ = 20 KΩ

$R_f = R_2$ = 200 KΩ

$$A_f = 1 + \frac{R_f}{R_{in}}$$

$$A_f = 1 + \frac{200}{0}$$

$\therefore \quad \boxed{A_f = 11}$

But $A_f = \dfrac{V_0}{V_{in}}$

$$\frac{V_0}{5 \times 10^{-3}} = 11$$

$V_0 = 11 \times 5 \times 10^{-3}$

$\boxed{V_0 = 55mV}$

8. For a given op-amp CMRR = 10^4 and differential mode gain A_d = 10^5. Determine common mode gain.

Sol :

Given

CMRR = 10^4

$A_d = 10^5$

$\therefore \quad CMRR = \dfrac{A_d}{A_c}$

$$10^4 = \frac{10^5}{A}$$

$$A_c = \frac{10^5}{10^4}$$

$\boxed{\therefore \; A_c = 10}$

9. An IC op-amp with differential open loop voltage gain of 40,000 has CMR of 80 dB.

(i) What is the valve CMRR.

(ii) What is common mode gain.

Sol :

Given

$A_d = 40,000$

CMR = 80 dB

CMR = 20 log A_d – 20 log A_c

80 = 20 log 40,000 – 20 log A_c

$$20 \log A_c = 20 \log 40{,}000 - 80$$

$$20 \log A_c = 20 \log (200)^2 - 80$$

$$20 \log A_c = 40 \times 2.3 - 80$$

$$20 \log A_c = 12$$

$$\log A_c = \frac{12}{20} = \frac{3}{5} = 0.6$$

$$A_c = \text{Antilog } (0.6)$$

$$A_c = 4$$

$$\therefore \quad CMRR = \frac{A_d}{A_c}$$

$$CMRR = \frac{40{,}000}{4}$$

$$\boxed{CMRR = 10{,}000}$$

---

10. Find the output voltage of an op-amp - inverting adder for the following sets of input voltages and resistors. In all cases R_f = 1 MΩ. V_1 = –3V, V_2 = +3V, V_3 = +5V, R_1 = 250 KΩ, R_2 = 500 KΩ, and R_3 = 1 MΩ.

Sol :

Given

R_1 = 250 KΩ V_1 = –3V

R_2 = 550 KΩ V_2 = +3V

R_3 = 1 KΩ V_3 = +3V

$$V_0 = -R_f \left[\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right]$$

$$V_0 = -10^6 \left[\frac{-3}{250 \times 10^3} + \frac{3}{500 \times 10^3} + \frac{5}{10^6}\right]$$

$$V_0 = -\left[\frac{-3}{25} + \frac{3}{5} + 5\right]$$

$$V_0 = -[-12 + 6 + 5]$$

$$\boxed{V_0 = 1V}$$

11. A summing amplifier has R_f = 10 KΩ, R_1 = 10 KΩ, R_2 = 5 KΩ, and R_3 = 6 KΩ. If V_1 = 6V, V_2 = –3V and V_3 = –0.8V. Calculate the value of output voltage.

Sol :

R_1 = 10 KΩ $\qquad$ V_1 = 6V

R_2 = 5 KΩ $\qquad$ V_2 = –3V

R_3 = 6 KΩ $\qquad$ V_3 = –0.8V

R_f = 10 KΩ

$$V_0 = -R_f\left[\frac{V_1}{R_1}+\frac{V_2}{R_2}+\frac{V_3}{R_3}\right]$$

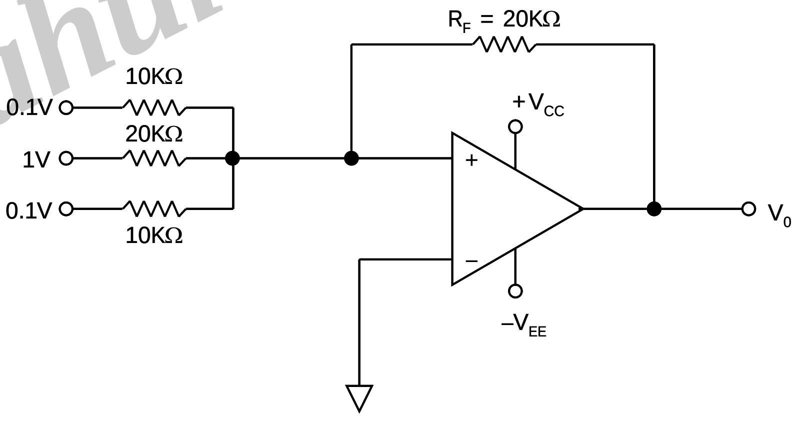
$$V_0 = -10^6 \times 10\left[\frac{6}{10\times10^3}-\frac{3}{5\times10^3}-\frac{0.8}{6\times10^3}\right]$$

$$V_0 = -10\left[\frac{6}{10}-\frac{3}{5}-\frac{0.8}{6}\right]$$

$$V_0 = -10\ [0.6 - 0.6 - 0.133]$$

$$\boxed{V_0 = 1.33\text{V}}$$

12. Find the value of the output voltage from the following circuit.



Sol :

The output voltage is given by

$$V_0 = -R_f\left[\frac{V_1}{R_1}+\frac{V_2}{R_2}+\frac{V_3}{R_3}\right]$$

Given

$V_1 = 0.1V$ $\quad R_1 = 10\ K\Omega$

$V_2 = 1V$ $\quad R_2 = 20\ K\Omega$

$V_3 = 0.1V$ $\quad R_3 = 10\ K\Omega$

$$V_0 = -20\left[\frac{0.1}{10}+\frac{1}{20}+\frac{0.1}{10}\right]$$

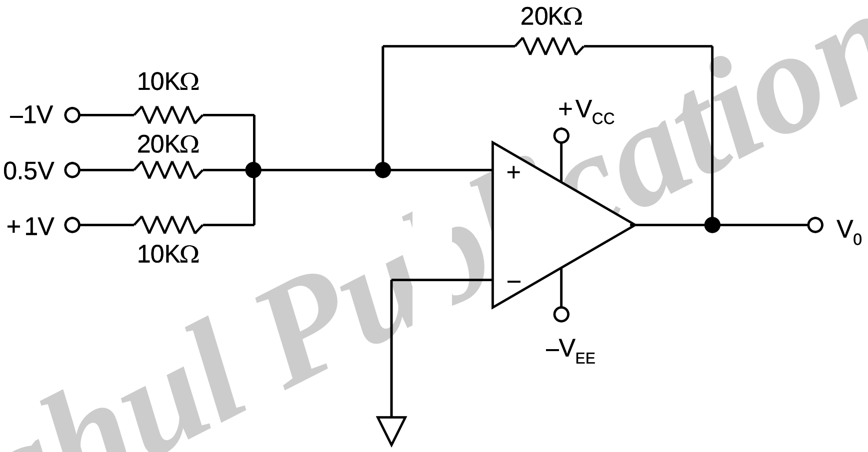
$V_0 = -20\ [0.1 + 0.5 + 0.1]$

$V_0 = -20\ (.07)$

$V_0 = -1.4$ volts.

13. Calculate the output voltage of the following circuit.

Sol :



Given

$R_f = 200\ K\Omega$

$R_1 = 10\ K\Omega$ $\quad V_1 = 1V$

$R_2 = 20\ K\Omega$ $\quad V_2 = 0.5V$

$R_3 = 30\ K\Omega$ $\quad V_3 = 1V$

Output voltage

$$V_0 = -R_f\left[\frac{V_1}{R_1}+\frac{V_2}{R_2}+\frac{V_3}{R_3}\right]$$

$$V_0 = -200\left[\frac{-1}{10}+\frac{0.5}{20}+\frac{1}{30}\right]$$

$V_0 = -200\ (-0.1 + 0.025 + 03)$

$V_0 = -200\ (-0.045)$

$V_0 = 9V$

14. A differentiator circuit has R = 2 MΩ and C = 1 μF. If an input signal V_{in} = 25_{in} 1000 πt (mV) is used as input calculate the output voltage.

Sol :

Given

R = MW

C = 1 μF

V_{in} = 2 Sin 1000 πt

The differentiator output is given by

$$V_0 = -RC\,\frac{d}{dt}\,(V_{in})$$

$$V_0 = -2 \times 10^6 \times 1 \times 10^{-6}\,\frac{d}{dt}\,(2 \sin 1000\,\pi t) \text{ mV.}$$

$$V_0 = -2 \times 2 \times 1000\,\pi \times \cos(1000\,\pi t) \times 10^{-3}\text{ V}$$

$$V_0 = (-4 \times 3.14) \cos(1000\,\pi t)$$

$$V_0 = -12.56 \cos(1000\,\pi t) \text{ volts.}$$

---

15. The input of an op-amp differentiator circuit is a sinusoidal voltage of peak value 10 μV and frequency of 2 KHz. Determine the output voltage. If R = 50 KΩ and C = 2 μF.

Sol :

Given

E_0 = 10 μV

f = 2 KHz

R = 50 KΩ

C = 2μF

The general equation for an a-c signal is given by

$$E = E_0 \sin 2\,\pi f t$$

$$E = 10 \sin(2.\pi.2 \times 10^3.t)$$

$$E = 10 \sin(4000\,\pi t)$$

The output voltage of differentiator circuit is given by

$$V_0 = -RC\,\frac{d(E)}{dt}$$

$$V_0 = -50 \times 10^3 \times 2 \times 10^{-6}\,\frac{d}{dt}\,(10 \sin 4000\,\pi t)\ \mu V$$

$$V_0 = 10^6 \times 10^{-6} \times 4000 \times \pi\,(\cos.4000\,\pi t) \times 10^{-3}\text{V}$$

$$V_0 = -12.56 \cos 4000 \text{ mV.}$$

16. A 5mV, 1 KHz Sinusoidal signal is applied to the input of an op-amp integrator, for which R = 100 KW and C = 1 μF. Find the output voltage.

Sol :

Given

$V_0 = 5$ mV

f = 1 KHz

R = 100 KW

C = 1 μF.

The output voltage of integrator is given by

$$V_0(t) = -\frac{1}{RC}\int V(t).dt \ (V_0(0) = 0 \text{ at } t = 0)$$

$V(t) = V_0 \sin 2\pi ft$

$V(t) = 5 \sin (2 \times 10^3 \times \pi)\, t$ mV

$V(t) = 5 \sin (2000\, \pi t)$ mV

$$\therefore \quad V_0(t) = \frac{1}{100 \times 10^3 \times 10^{-6}} \int_0^t 5 \sin (2000\, \pi t) \text{ mV}$$

$$V_0(t) = -10 \times 5 \int_0^t \sin (2000\, \pi t) \text{ mV}$$

$$V_0(t) = -50 \times \left[\frac{-\cos\ 2000\ \pi t}{2000\ \pi}\right]_0^t \text{ mV}$$

$$V_0(t) = \frac{1}{40\pi}(\cos 200\ \pi t - 1) \text{ mV.}$$

17. An inverting amplifier has R_1 = 10 kΩ and R_f = 125 kΩ. Calculate the output voltage for an input voltage 4 V.

Sol : **(June-18)**

Given that,

For an inverting amplifier,

Input resistance, $R_1 = 10$ kΩ

Feedback resistance, $R_f = 125$ kΩ

Input voltage, $V_i = 4$ V

Output voltge, $V_0 = ?$

The expression for output voltage of an inverting amplifier is given by,

$$V = \frac{-R_f}{R_1} \times V_1$$

$$= \frac{-125 \times 10^3}{10 \times 10^3} \times 4$$

$= -12.5 \times 4$

$= -50$ V

$\therefore$ Output voltage, $V_0 = -50V$

Short Question and Answers

1. Define common mode rejection ratio, slew rate, offset voltage and bias currents?

Ans :

i) Common mode rejection ratio : CMRR can be defined as the ratio of the differential gain A_D to the common-mode gain A_{cm}.

i.e., $$CMRR = \frac{A_D}{A_{cm}}$$

ii) Slew Rate : The slew rate as the maximum possible rate of change of output voltage with respect to rated output. Thus

$$S = \max \frac{dv_s}{dt}$$

iii) Offset voltage : Input offset voltage V_{i0} is the differential input voltage that exists between two input terminals of an op-amp without any external inputs applied.

iv) Bias current : An input bias current I_B is defined as the average of the two input bias currents, I_{B_1} and I_{B_2} as shown in below figure.

i.e., $$I_B = \frac{I_{B_1} + I_{B_2}}{2}$$

2. Give the characteristics of an ideal op-amp ?

Ans :

(i) Input resistance must be infinite i.e., $R_{in} = \propto$

(ii) Output resistance should be as small as zero, i.e., $R_{out} = 0$

(iii) Bandwidth should be as wide as infinite from 0 to ∞ Hz

(iv) Infinite voltage gain A_V

(v) Infinite common-mode rejection ratio so that the output common-mode noise voltage is zero.

(vi) Infinite slew rate so that output voltage changes occur simultaneously with input voltage change.

3. Explain the concept of virtual ground ?

Ans :

An op-amp with low impedance results from the negative feedback voltage, which cancells the input signal at V_2 and tends to keep the branch point at ground potential. For this reason the point V_2 is called a 'VIRTUAL GROUND'.

From the ideal characteristic of an op-amp, the gain is considered to be infinite.

$\therefore$ V_2 tends to zero

i.e., $V_2 \to 0$ as gain, $A = \infty$

$\therefore$ If $V_1 = 0$ then V_2 tends to zero and this concept is called concept of virtual ground.

4. Define the terms

(i) Common mode voltage gain

(ii) Common mode rejection ratio

(iii) Offset voltage

Ans :

(i) Common mode voltage gain : It is define as the ratio of output common mode voltage V_{0cm} to the input common-mode voltage ν_{cm}, is called the common-mode voltage gain A_{cm}, is much smaller than 1.

$$\therefore \quad A_{cm} = \frac{\nu_{ocm}}{\nu_{cm}}$$

Ideally, the common-mode voltage gain A_{cm} is zero.

(ii) Common mode rejection ratio : CMRR can also be expressed as the ratio of the change in input offset voltage to the total change in common-mode voltage.

$$\text{Thus, CMRR} = \frac{\nu_{io}}{\nu_{cm}}$$

(iii) Offset voltage : The output offset voltage V_{00} is a dc voltage, it may be positive or negative in polarity depending on whether the potential difference between two input terminals in positive or negative.

5. Explain the concept of inverting and non-inverting amplifier ?

Ans :

An inverting amplifier is a closed loop amplifier is which the input is applied to inverting terminal of the op-amp. The output of inverting amplifier is out of phase by 180^o w.r.t. Input.

$$\therefore \quad \boxed{A_f = \frac{V_0}{V_{in}} = \frac{-R_f}{R_{in}}}$$

Hence the gain of the inverting amplifier is the ratio of feedback resistance to the input resistance.

A non-inverting amplifier is that the input signal is applied to the non-inverting terminal while its inverting terminal is grounded.

$\because \quad R_f >> R_{in}$ then

$$\boxed{A_f = 1 + \frac{R_f}{R_{in}}}$$

Hence the gain of an non-inverting amplifier is one more than the gain of inverting amplifier.

6. Define CMRR and common voltage gain ?

Ans :

When the same input voltage is applied to both input terminal of an op-amp, it is said to be operating is an common-mode configuration. Since the input voltage applied is common to both the inputs, it is called as a common mode voltage ν_{cm}

$$\text{CMRR} = \frac{A_D}{A_{cm}} = \frac{A_D}{\nu_{ocm} / \nu_{cm}}$$

where A_D = Differentiation

A_{cm} = common mode gain

$$= \frac{A_D\ \nu_{cm}}{\nu_{ocm}} \qquad \text{... (1)}$$

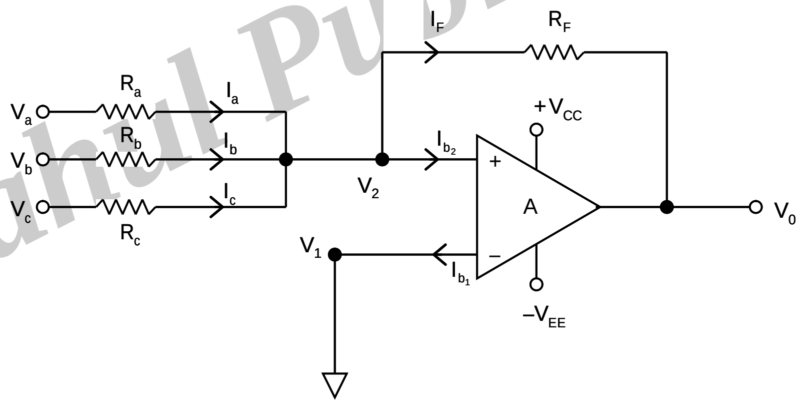
$$\nu_{ocm} = \frac{A_D\ \nu_{cm}}{\text{CMRR}}$$

∴ Equation (1) indicates that the higher value of CMRR, the smaller will be the amplitude of the output common-mode voltage ν_{ocm}.

7. Describe the working of op-amp summing amplifier ?

Ans :

A summing amplifier is an arithmetic circuit whose output is proportional to the sum of input voltages applied. It can be constructed either in the inverting (or) non inverting mode of configuration.



Case (i): If $R_f = R_a - R_b = R_c$ then equation (1) becomes

$$\boxed{V_0 = -[V_a + V_b + V_c]}$$

Hence the output is proportional to the applied inputs.

Case (ii): If $R_f = R$ and $R_a = R_b = R_c = 3R$ then equation (1) becomes

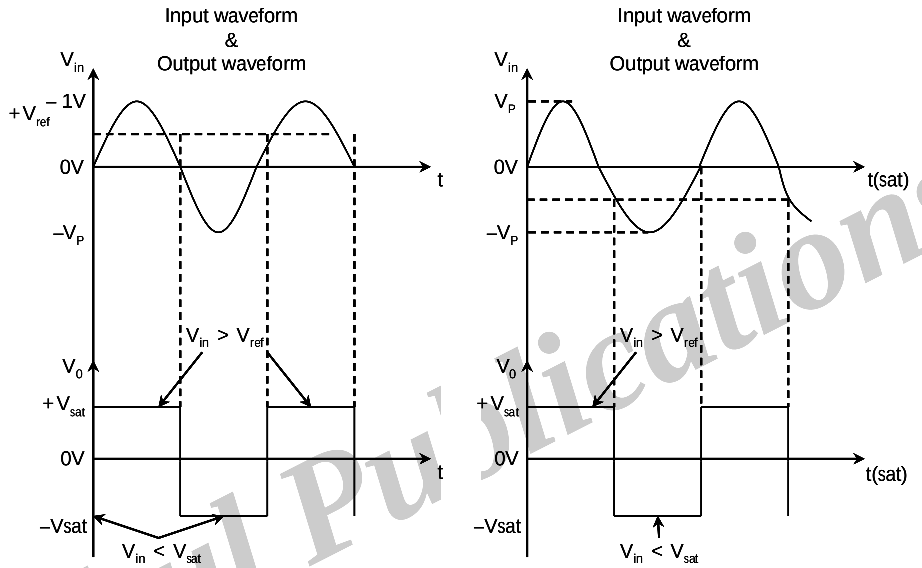
$$\boxed{V_0 = -\left[\frac{V_a + V_b + V_c}{3}\right]}$$

Hence the op-amp behaves like averaging (or) Scaling amplifier

8. Explain the comparator action of an op-amp with relevant diagrams?

Ans :

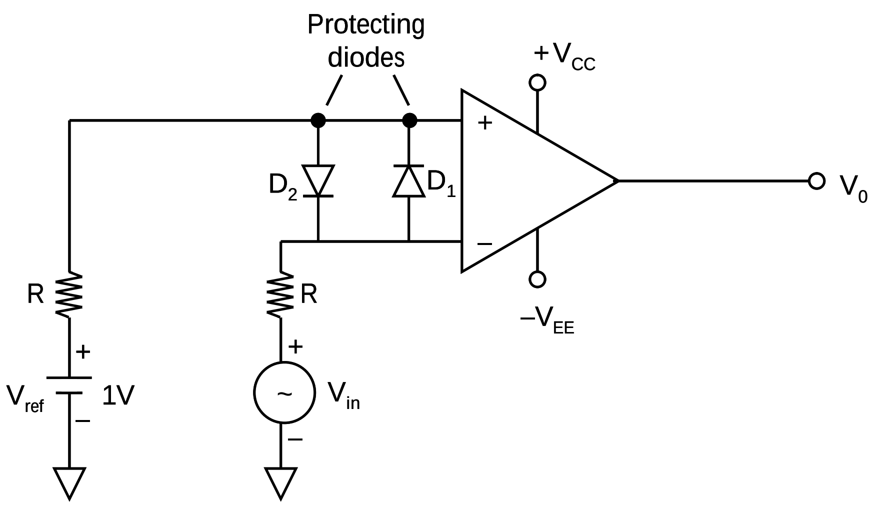
- When $V_{in} < V_{ref}$, the output voltage 'V_0' is at $-V_{sat}$ (approx. equal to V_{ce}). This is because the voltage at negative terminal is higher than voltage positive terminal.
- Similarly, when $V_{in} > V_{ref}$, the output voltage 'V_0' is at $+V_{sat}$ (approx equal to $+V_{CC}$) because the voltage at positive terminal is greater than voltage at negative terminal.



9. Explain the working of op-amp as comparator ?

Ans :

It is one of the important application of an op-amp where it compares two input voltages or levels.

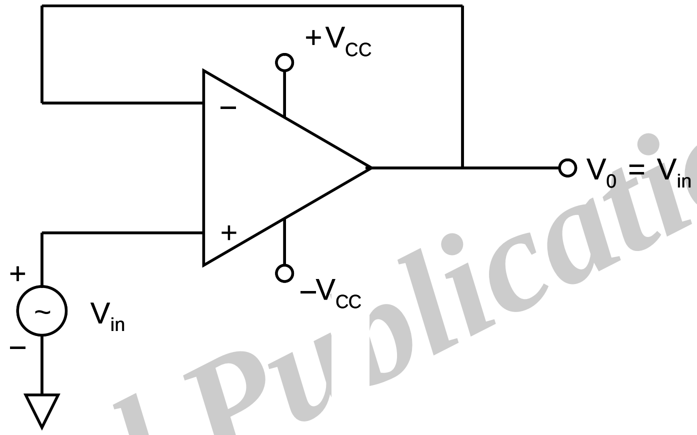


The above circuit diagrame represents a comparator. A reference voltage 'V_{ref}' is applied to the inverting terminal and input voltage V_{in} is applied at non-inverting amplifier. Hence the configuration is the non-inverting configuration. The diodes D_1 and D_2 protect the op-amp from damage due to excessive input voltage V_{in}.

10. Discuss the working of op-amp voltage follower ?

Ans :

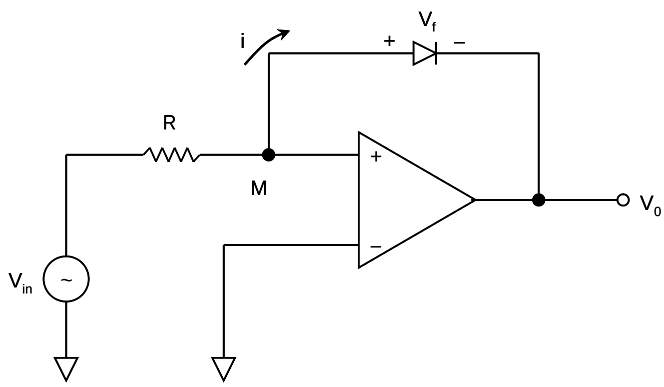
When the non-inverting amplifier is configured for unity gain, it is called a voltage follower because the output voltage is equal to and in phase with the input. In other words, in the voltage follower the output follows the input. The lowest gain that can be obtained from a non-inverting amplifier with feedback is 1.



11. Describe the working of op-amp logarithmic amplifier ?

Ans :

An op-amp whose output is proportional to the logarithm of the input voltage is called logarithmic amplifier.



The circuit represents an op-amp designed as logarithmic amplifier. A diode is used in the use of feedback resistance.

Choose the Correct Answer

1. An op-amp can be classified as : [a]

   (a) Linear IC (b) Digital IC

   (c) Positive - feedback amplifier (d) RC – Coupled amplifier

2. The gain of an actual op-amp is around [d]

   (a) 100 (b) 1,000

   (c) 10,000 (d) 1,000,000

3. CMRR, is defined as the ratio of : [c]

   (a) Differential voltage gain to the current gain

   (b) Current gain to the differential voltage gain

   (c) Differential voltage gain to the common - mode voltage gain

   (d) Common-mode voltage gain to the differential voltage gain

4. The input offset current of a differential amp is the [a]

   (a) Difference of the two base currents

   (b) Sum of the two base currents

   (c) Only signal current

   (d) Ratio of two currents

5. Since input resistance of an ideal op-amp is infinite [c]

   (a) Its output resistance is zero

   (b) Its output voltage becomes independent of load resistance

   (c) Its input current is zero

   (d) It becomes a current - controlled device

6. An ideal op-amp has : [d]

   (a) Zero output resistance (b) Infinite band width

   (c) Infinite input resistance (d) All of the above

7. In the analysis of non-inverting op-amp circuit we shall use : [b]

   (a) The potential of the two inputs equal

   (b) The current flows in either of the inputs

   (c) No current flows in either of the inputs

   (d) The potential of the two inputs are different

8. Op-Amps have become very popular in industry mainly because : [b]

   (a) they are available in different packages

   (b) their external characteristics can be changed to suit any application

   (c) they are dirt cheap

   (d) of their extremely small size

9. If the differential voltage gain of an op-amp is 4700 and the common mode gain is 0.47, then CMRR is [d]

   (a) 10,000 (b) 80dB

   (c) 60 dB (d) Both (a) and (b)

10. The op-amp can amplify [c]

   (a) dc signals only (b) ac signals only

   (c) both ac and dc signals (d) neither dc nor ac signals

Fill in the blanks

1. The ______ is the basic gain element of the integrated amplifier.
2. The difference between the two input bias currents is known as ______.
3. An IC op-amp consists of a cascade of ______ stages.
4. If the input to an op-amp comparator is ______ the output is a square wave.
5. ______ = open loop gain (dB) – closed loop gain (dB).
6. An ______ op-amp is perfectly balanced.
7. A particulary versatile ______ connection is called operational feedback.
8. The ratio of ______ to the common mode voltage gain is known as the ______.
9. In a differentiator, the output voltage wave form is the ______ of the input voltage waveform.
10. In an integrator, the output voltage – wave form is the ______ of input voltage wave form.

ANSWERS

1. Differential amplifier
2. Input offset current
3. Four
4. Sine wave
5. Loop gain (dB)
6. Ideal
7. Negative feedback
8. Differential mode gain, CMRR
9. Differential voltage
10. Integral

UNIT II	**Applications of Op-Amps**: Sine wave [Wien Bridge] generator and square wave [Astable] generator, Triangular wave generator, Monostable multivibrator, IC 555 Timer [Block diagram and its working], IC 555 as monostable and astable multivibrators.

2.1 Sine Wave [Wien Bridge] Generator

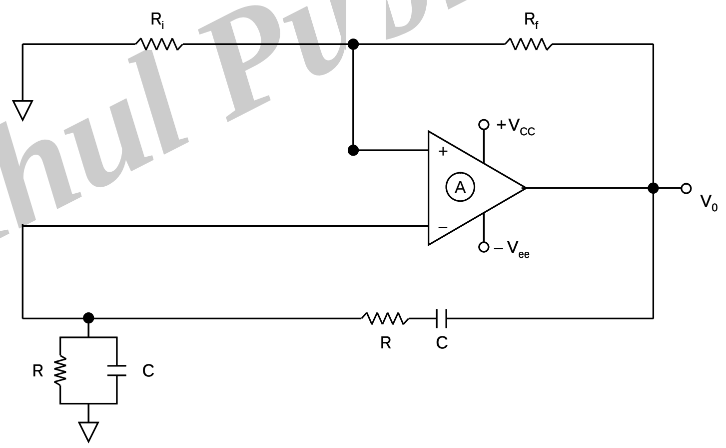
Q1. Draw the circuit diagram of Sine Wave Generator.

(OR)

Draw and explain op-amp based wien bridge oscillator circuit.

Ans : **(June-19, June-18, Imp.)**

Wien Bridge Oscillator is most commonly and widely used audio frequency oscillator. A wien bridge is called as feedback network in the oscillator. The active element is an op-amp with large gain, high input resistance and negligible output resistance.



The circuit diagram represents wien bridge oscillator. The bridge has a series RC network in one arm and a parallel RC network in the adjoining arm. The condition for oscillation is that the total phase angle around the circuit must be 0^o or 360^o. This criteria can be accomplished when the bridge is balanced i.e., at resonance. The 'R' and 'C' values in both the arms must be of same value. The frequency of oscillation is given by the formula.

$$f_0 = \frac{1}{2\Pi RC} \text{ or } \frac{0.159}{RC}$$

At this frequency the gain needed for sustained oscillation is given by

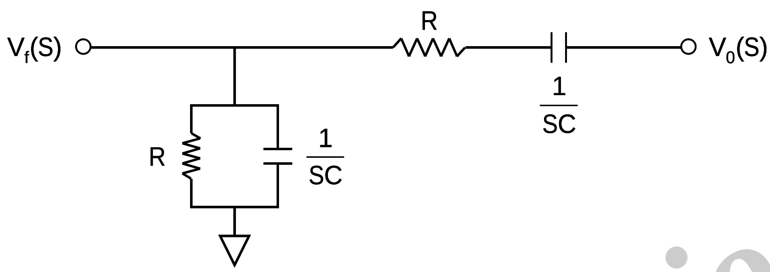
$$A_V = \frac{1}{\beta} = 3$$

i.e., $1 + \dfrac{R_f}{R_i} = 3$

$$\frac{R_f}{R_i} = 2$$

$$R_f = 2R_i$$

Consider the part of the network having arms



Converting the circuit into 'S' domain. Let us represent $j\omega = S$.

The series impedance is given by

$$Z_S(S) = R + \frac{1}{SC}$$

$$Z_S(S) = \frac{RCS+1}{SC} \qquad \ldots (1)$$

The parallel impedance is given by

$$Z_P(S) = R \parallel \frac{1}{SC}$$

$$Z_P(S) = \frac{R}{RSC+1}$$

By voltage divider rule

$$V_f(S) = \frac{Z_P(S)}{Z_P(S)+Z_S(S)} V_0(S)$$

$$V_f(S) = \frac{\left[\dfrac{R}{RSC+1}\right]}{\dfrac{R}{RSC+1}+\dfrac{RCS+1}{SC}} = V_0(S)$$

$$V_f(S) = \frac{(RSC)\,V_0(S)}{(RCS+1)^2+RCS}$$

$$B = \frac{V_f(S)}{V_0(S)} = \frac{RCS}{R^2C^2S^2 + 2RCS + 1 + RCS} = \frac{RCS}{R^2C^2S^2 + 3RCS + 1}$$

The voltage gain is given by

$$A_V = \frac{V_0(S)}{V_f(S)} = 1 + \frac{R_f}{R_i}$$

The condition for oscillation

$$A_V = B = 1$$

$$\left(1 + \frac{R_f}{R_i}\right] = \frac{RCS}{R^2C^2S^2 + 3RCS + 1} = 1$$

Substituting $S = j\omega$

$$\left(1 + \frac{R_f}{R_i}\right] jRC\omega = R^2C^2\omega^2 + j3RC\omega + 1$$

Consider the real part

$$-\omega^2C^2R^2 + 1 = 0$$

$$\omega^2C^2R^2 = 1$$

$$\omega^2 = \frac{1}{R^2C^2} \quad \text{or} \quad \omega = \frac{1}{RC}$$

$$2\pi f_0 = \frac{1}{RC}$$

$$\boxed{f_0 = \frac{1}{2\pi RC}}$$

Consider imaginary part

$$\left(1 + \frac{R_F}{R_i}\right) \omega RC = 3R\omega c$$

$$1 + \frac{R_f}{R_i} = 3$$

$$\frac{R_f}{R_i} = 2$$

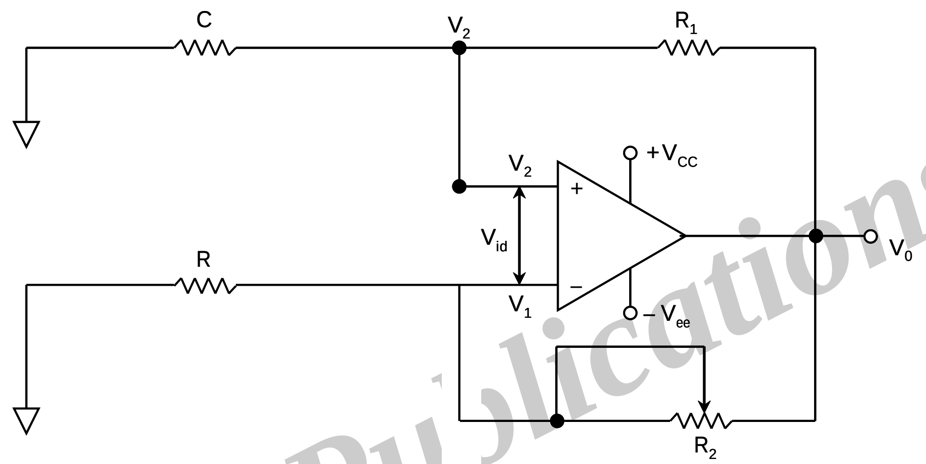
$$\boxed{R_f = 2R_i}$$

2.2 Square Wave (Astable) Generator

Q2. Draw the circuit diagram of a square wave generator and explain its operation.

Ans :

A square wave generator is non-sinusoidal generator. It is generated by forcing the op-amp to work in saturated region. That is, the op-amp is forced to swing between positive saturation ($+V_{sat}$) and negative saturation ($-V_{sat}$) the square wave generator is also called as free running multivibrator or astable multivibrator.



Operation

- Depending on differential voltage, the circuit will be in positive or negative saturation.
- When power supply is given, assume that voltage across capacitor 'C' is zero. That is $V_2 = 0$.
- However a small finite voltage exists at non-inverting terminal.
- As capacitor 'C' is shorted and gain is large, the voltage 'V_1' drives the output to positive saturation $+V_{sat}$.
- When output is at $+V_{sat}$, the capacitor 'C' charges towards $+V_{sat}$ through resistor 'R'.
- As soon as $V_2 > V_1$, the output is forced into negative saturation $-V_{sat}$.

The voltage 'V_1' is given by (during negative saturation).

$$V_1 = \left[\frac{R_1}{R_1 + R_2}\right](-V_{sat}) \qquad \text{... (1)}$$

The voltage 'V_1' during positive saturation is given by

$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)(+V_{sat}) \qquad \text{... (2)}$$

The time period 'T' is given by

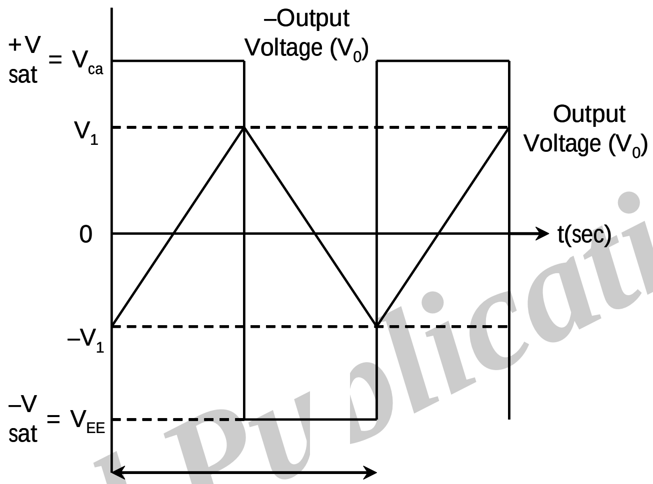
$$T = 2RC \ln\left[\frac{2R_1 + R_2}{R_2}\right]$$

$$f_0 = \frac{1}{T} = \frac{1}{2RC\ \ln\left(\frac{2R_1 + R_2}{R_2}\right)} \quad \text{... (3)}$$

If $R_2 = 1.16\ R_1$ then equation (3) becomes

$$\boxed{f_0 = \frac{1}{2RC}}$$

The output waveform with respect to capacitor voltage is given by



2.3 Triangular Wave Generator

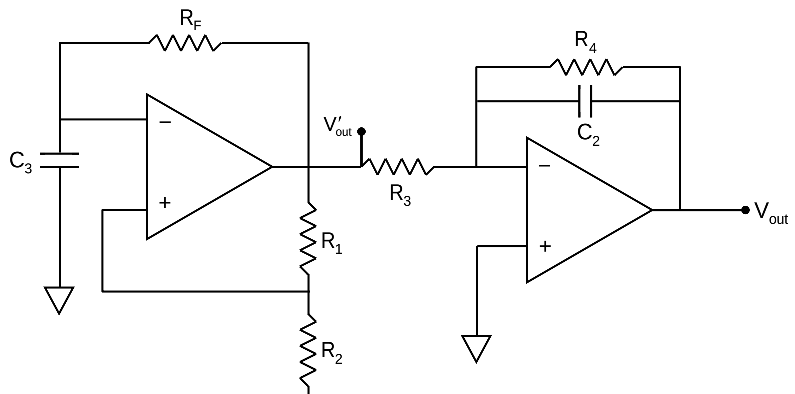
Q3. Discuss generation of triangular wave using Op-Amp and explain.

(OR)

Draw the circuit diagram of triangular wave generator and explain its operation.

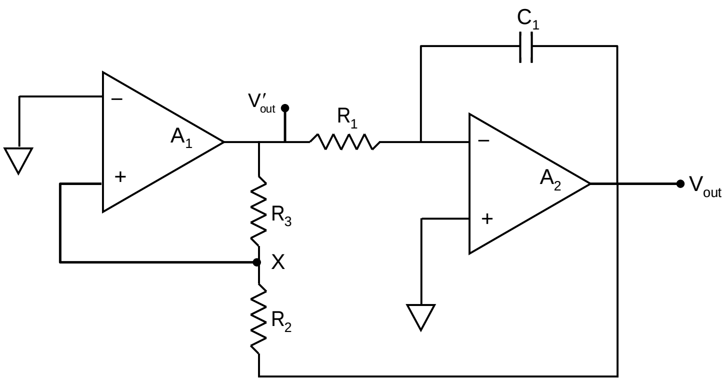
Ans : **(June-18, Imp.)**

A triangular wave is obtained by the integration of a square wave. The schematic arrangement of triangular wave generator is illustrated in figure (1).



Under high frequency signals, the capacitive reactance of feedback capacitor C_2 decreases. The resistor R_4 is placed in parallel with capacitor C_2 in order to eliminate the saturation problems rising under low frequency signals.

The modified circuit comprises of a two level comparator and an integrator as shown in figure (2).



The comparator is nothing but a square wave generator that generates a square wave whose amplitude is maintained at + V_{sat} and $-V_{sat}$. This square wave output of constant amplitude is given to the inverting input of integrator which performs integration and produces triangular wave output.

When the comparator output is at positive saturation i.e., $+V_{sat}$, a negative going ramp appears at the output of integrator.

Whenever the negative going ramp reaches $-V_r$ the voltage at node X(V_x) becomes less than 0 V and switches the comparator output from $+V_{sat}$ to $-V_{sat}$. Due to this the integrator output starts to increase in a positive direction till it reaches + V_r. Whenever the positive going ramp reaches $+V_r$, the voltage at node X becomes slightly greater than 0 V and switches the comparator output from $-V_{sat}$ to $+V_{sat}$. Thus, the cycle repeats thereby generating a triangular waveform.

Let, the output of comparator A1 is at + V_{sat} then the effective voltage at 'X' is given as,

$$-V_r + \frac{R_2}{R_2 + R_3}[V_{sat} - (-V_r)]$$

Where,

V_r – Ramp voltage

V_{sat} – Saturation voltage.

But at time t = t_1, this voltage becomes zero.

$$\Rightarrow \quad -V_r + \frac{R_2}{R_2 + R_3}[V_{sat} - (-V_r)] = 0$$

$$\Rightarrow \quad V_r = \frac{R_2}{R_2 + R_3}(V_{sat} + V_r)$$

$$\Rightarrow \quad V_r\left(1 - \frac{R_2}{R_2 + R_3}\right) = \left(\frac{R_2}{R_2 + R_3}\right)V_{sat}$$

$$\Rightarrow \quad V_r = \left(\frac{R_2}{R_3}\right)V_{sat}$$

Similarly, at time $t = t_2$, the output of A_1 is at $-V_{sat}$,

$$-V_r = \frac{R_2}{R_3}(V_{sat})$$

The triangular wave peak to peak amplitude is given by,

$$V_{out}(p-p) = +V_r - (-V_r) = 2Vr$$

$$= 2\frac{R_2}{R_3}(V_{sat}) \quad \text{... (1)}$$

The output changes from $-V_r$ to $+V_r$ in half of the time.

Then, equation (1) becomes,

$$V_{out}(p-p) = \frac{-1}{R_1C_1}\int_0^{T/2}(-V_{sat})\,dt = \frac{V_{sat}}{R_1C_1}[t]_0^{T/2}$$

$$\Rightarrow \quad V_{out}(p-p) = \frac{V_{sat}}{R_1C_1}\left(\frac{T}{2}\right)$$

$$\Rightarrow \quad T = \frac{2R_1C_1V_{out}(p-p)}{V_{sat}} \quad \text{... (2)}$$

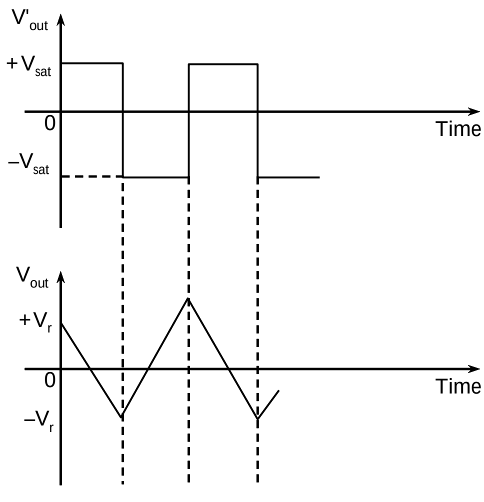
From equations (1) and (2), we get,

$$T = \frac{2R_1C_1}{V_{sat}}\left[\frac{2R_2}{R_3}V_{sat}\right] = \frac{4\,R_1C_1R_2}{R_3}$$

Hence, the triangular wave frequency of oscillation is given by,

$$f = \frac{1}{T} = \frac{R_3}{4R_1C_1R_2}$$

The input and output waveforms of triangular wave generator are shown in the figure (3).



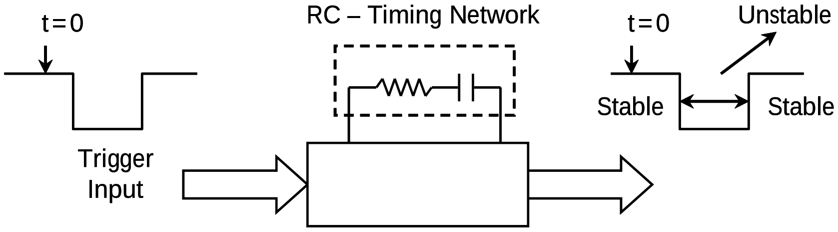
2.4 Monostable Multivibrator

Q4. Explain the concept of Monostable Multivibrator.

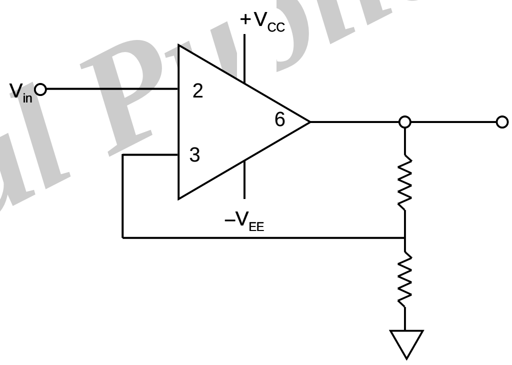
Ans :

It is a one-shot multivibrator circuits are of positive feedback switching circuits that have only one stable state producing an output pulse of a specified time duration T.

Block Diagram



The above block diagram shows that a mono stable multivibrator is constructed by adding an external resistor (R) at capacitor (C) across a switching circuit the switching circuit can be made using transistors, digital logic gates (or) general purpose op-amp the time constant, T of the resistor - capacitor combination determine the length of the pulse T.



In this basic inverting configuration the feedback fraction is a negative feedback to the inverting input. These feedback configuration between the output inverting input terminal the resistors of this negative feedback is that op-amp producers an amplified output signal which is 180° out of phase with input signal.

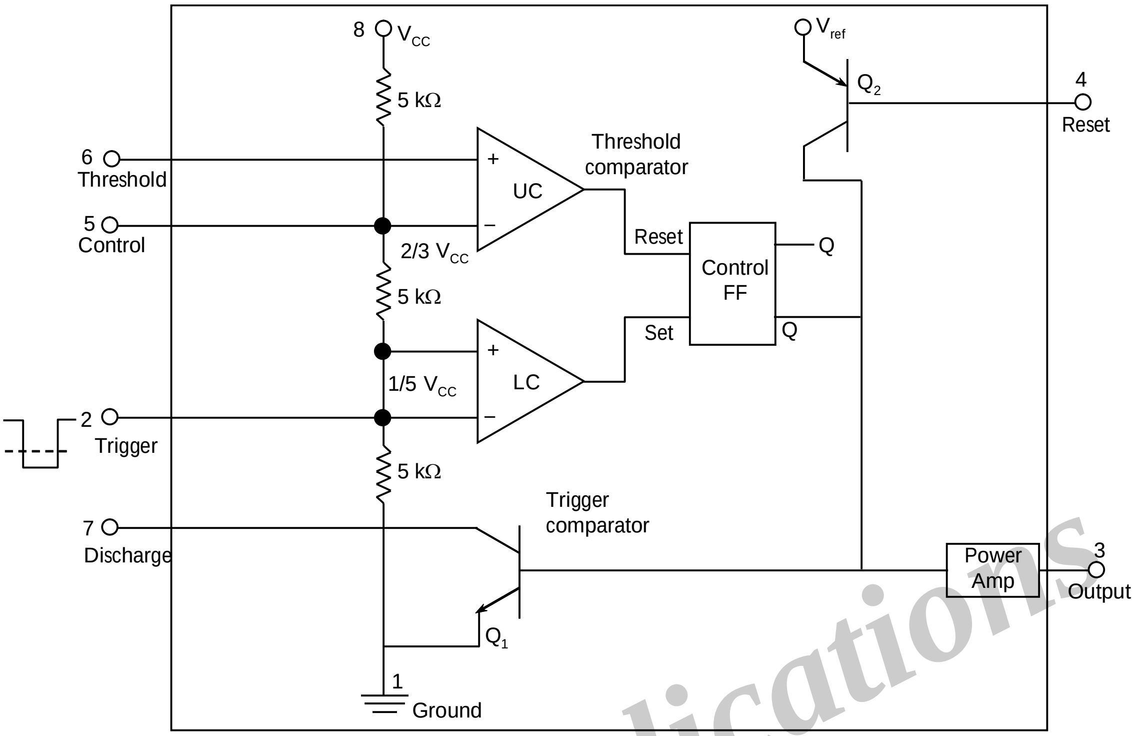
2.5 IC 555 Timer

2.5.1 Block Diagram and its working

Q5. Draw the block diagram of IC 555 timer and describe its working.

Ans : **(June-18, Imp.)**

The functional block diagram of IC 555 timer is shown in figure. It consist of three resistors, two comparators, a flip-flop, a discharge transistor and a totem pole output state.



Figure

The resistors in the circuit act as voltage divider and provides a bias voltage of $\frac{2}{3}$ VCC to upper comparator and $\frac{1}{3}$ V_{CC} to lower comparator.

Initially, the trigger input is high. As a result, the output of trigger comparator will be low causing the output of the flip-flop $\bar{Q}$ to be high.

With $\bar{Q}$ high, output $V_o = 0$ due to inverting action of the power amplifier. Here, transistor, Q_1 goes into saturation. Therefore, in stable state the timer 'output' is zero.

When a negative going trigger pulse is applied at pin (2), which has dc level greater than the 1/3 V_{CC}, then the output of the trigger comparator goes to high causing the flip-flop output $\bar{Q} = 0$.

With $\bar{Q} = 0$, the output becomes high (due to inverter action) and at the same time, transistor Q1 goes to cut-off.

When a positive trigger pulse is applied, the upper comparator reaches the threshold voltage i.e., $\frac{2}{3}$ V_{CC}, then the output of the flip-flop $\bar{Q}$ to high.

With $\bar{Q}$ high, the output is zero and transistor Q_1 is driven in saturation.

Q6. List the features of IC 555 timer.

Ans :

The features of IC 555 timer are,

i) IC 555 timer is available as a 14 pin, 8 pin DIP.

ii) It is basically a monolithic timer device.

iii) It operates in two modes i.e., Astable, Monostable.

iv) Supply voltage can vary in the range from +5 V to + 18 V.

v) It has a high current output and is capable of handling 200 mA load current.

vi) It has very good temperature stability.

vii) It is economical in use, reliable in operation.

viii) Used to produce accurate and highly stable time delays and oscillations.

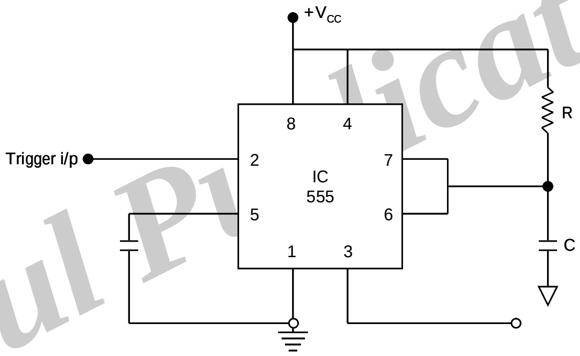
2.6 IC 555 AS MONOSTABLE AND ASTABLE MULTIVIBRATORS

Q7. Explain with the help of a circuit diagram how IC 555 timer is used as a monostable multivibrator.

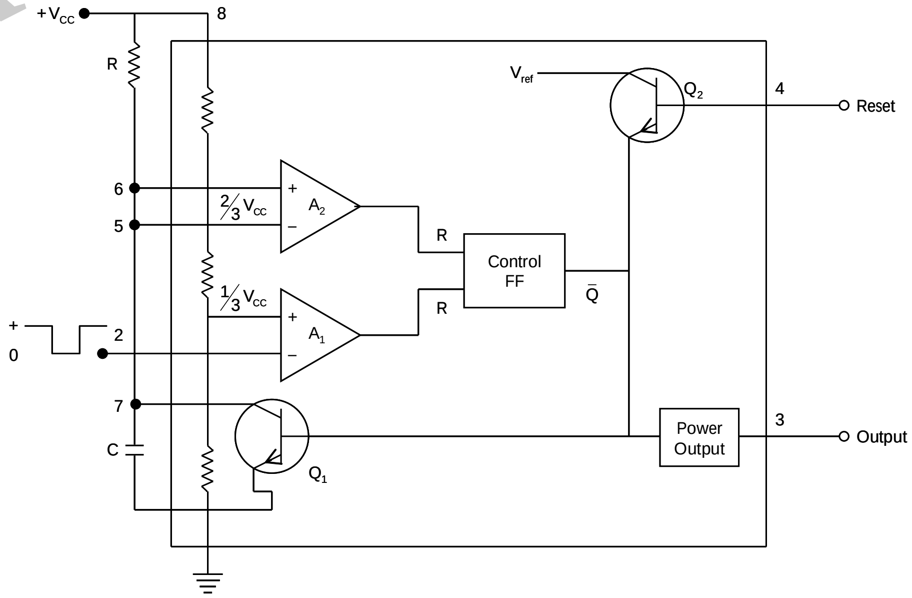
Ans : **(Nov.-20, June-18, Imp.)**

A multivibrator is circuit which produces or generates non-sinusoidal waveform like square waveform.

A monostable multivibrator is also called a one shot multivibrator. It has two states where one is stable or permanent state and the other is called quasistable state or temporary state. The pin connection of IC 555 as a monostable multivibrator.



The functional diagram is shown below.



Operation

- In stand by mode the control flip flops maintains 'Q_1' in ON state. This derives external timing capacitor 'C' to ground.
- Hence, the output is at ground potential.
- The three internal resistance each of 5KW provides the necessary biasing voltage of $\frac{1}{3}$ V_{CC}.
- The lower comparator 'A_1' is in standby state as long as the trigger input at pin no. '2' is held above $\frac{1}{3}$ of V_{CC}.
- When pin no '2' is triggered by negative gain pulse, the flip flop is set which releases the short circuit across timing capacitor and thus drives 'Q_1' to OFF state.
- Hence, the output goes HIGH.
- At this point, the capacitor charges exponentially to V_{CC} through 'R'.
- After certain time interval, the capacitor voltage becomes equal to $\frac{2}{3}$ V_{CC} and the upper comparator resets the flip - flops.
- **This in tur**n discharges the capacitor and the transistor 'Q_1' will be in ON state thereby making output to be at ground potential.

Mathematical Analysis

The voltage across capacitor is given by

$$V = V_{CC}\left[1 - e^{-t/RC}\right] \quad \text{... (1)}$$

Since the capacitor voltage becomes $\frac{2}{3}$ V_{CC} at $t = T$ at negative triggering.

$$\frac{2}{3} V_{CC} = V_{CC}\left[1 - e^{-T/RC}\right]$$

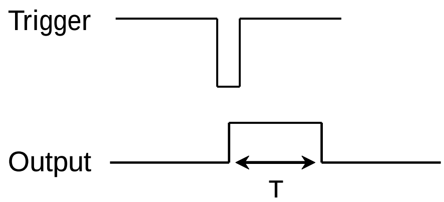
$$e^{-T/RC} = \frac{1}{3}$$

Taking log on both sides

$$-\frac{T}{RC} = \log_e\left(\frac{1}{3}\right)$$

$$T = -RC \log_e\left(\frac{1}{3}\right)$$

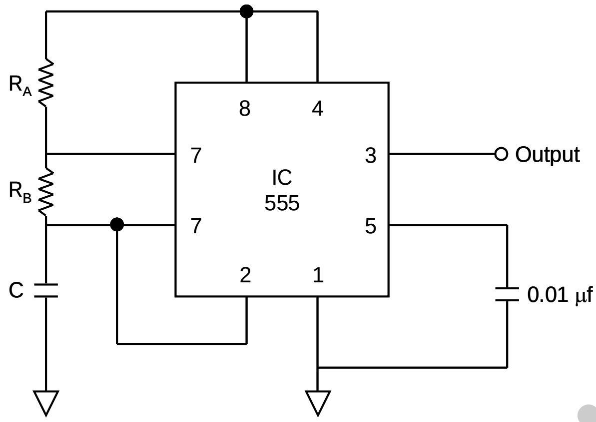
$$T = 1.1\ RC \text{ (seconds)}$$



Q8. Explain the working of astable multivibrator using IC 555.

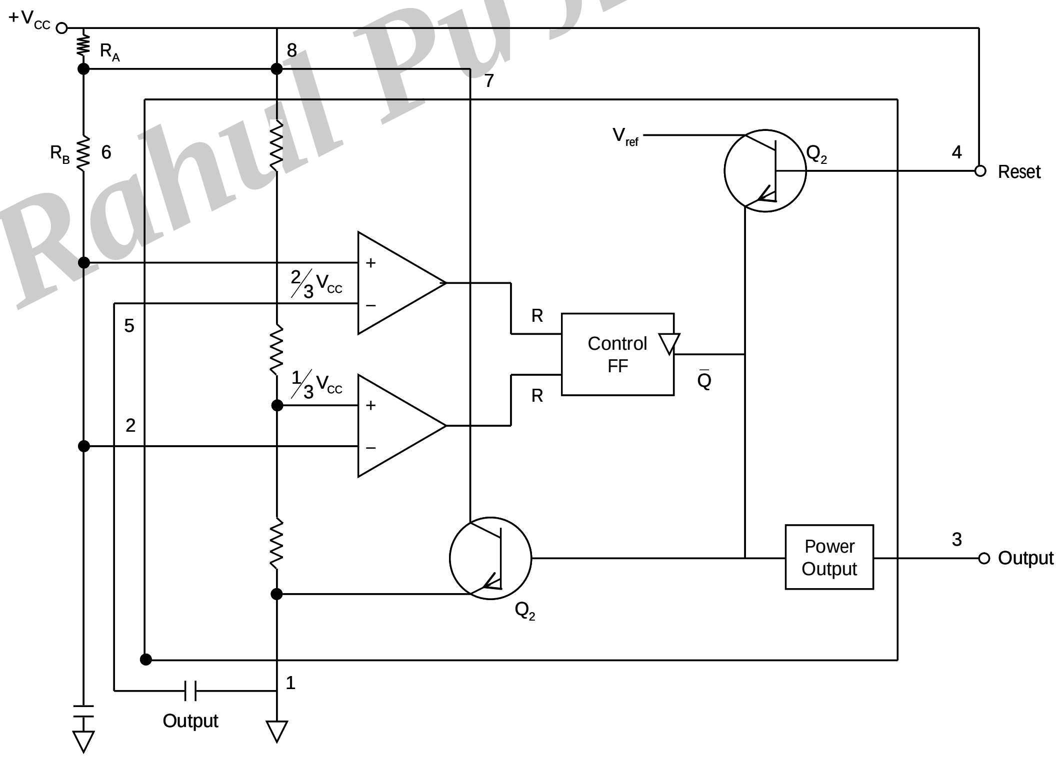
Ans : **(Nov.-20, June-19)**

Astable multivibrator is also called as free running multivibrator. This is because it does not require any external triggering. It has two Quasi state states. The pin connection diagram is given below.



Here there is no triggering required and hence pin no. 2 is connected to pin no.6 for internal generation of the triggering signal. Unlike in monostable, the two states automatically changes after certain interval of time. And thus produces square wave output.

The functional block diagram of astable multivibrator.



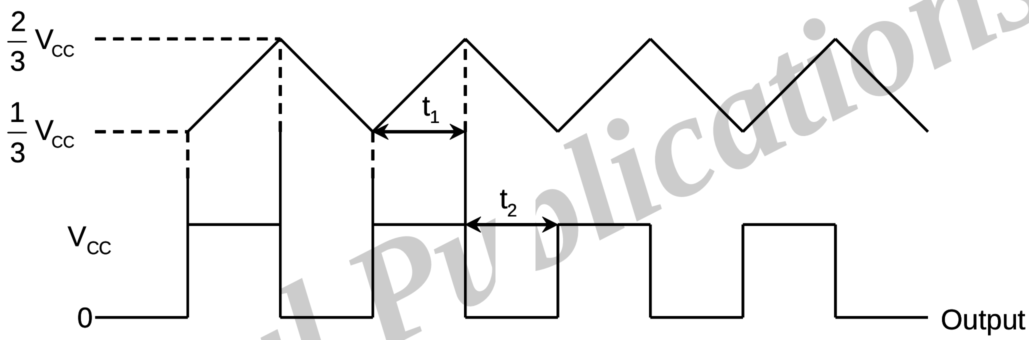
- The timing resistor is split into 2 sections 'R_A' and 'R_B'.
- The discharging transistor is connected to junction of R_A and R_B.

- The timing capacitor charges towards $\frac{2}{3}$ V_{CC} through R_A and R_B.

- When capacitor voltage reachers to $\frac{2}{3}$ V_{CC}, the upper comparator triggers flip flop and capacitor starts to discharge towards ground through R_B.

- When the discharge reaches $\frac{1}{3}$ V_{CC}, the lower comparator is triggered and a new cycle is started.

The periodic charging and discharging of capacitor between $\frac{2}{3}$ V_{CC} and $\frac{1}{3}$ V_{CC} is given below



$$t_1 = (R_A + R_B)\, C \log_e \left[\frac{V_{CC} - \frac{2}{3}V_{CC}}{V_{CC} - \frac{1}{3}V_{CC}} \right]$$

$$t_1 = 0.693\,(R_A + R_B)\,C.$$

The output state is low during discharge cycle time period t_2.

$$t_2 = 0.693\, R_B\, C$$

Hence total period is $t = t_1 + t_2$.

$$t = 0.693\,(R_A + R_B)\,C + 0.693\, R_B\, C$$

$$t = 0.693\,(R_A + R_B)\,C$$

∴ The frequency is given by

$$f = \frac{1}{T} = \frac{1.4}{(R_A + R_B)C}$$

Q9. Explain the concept of Voltage Regulator.

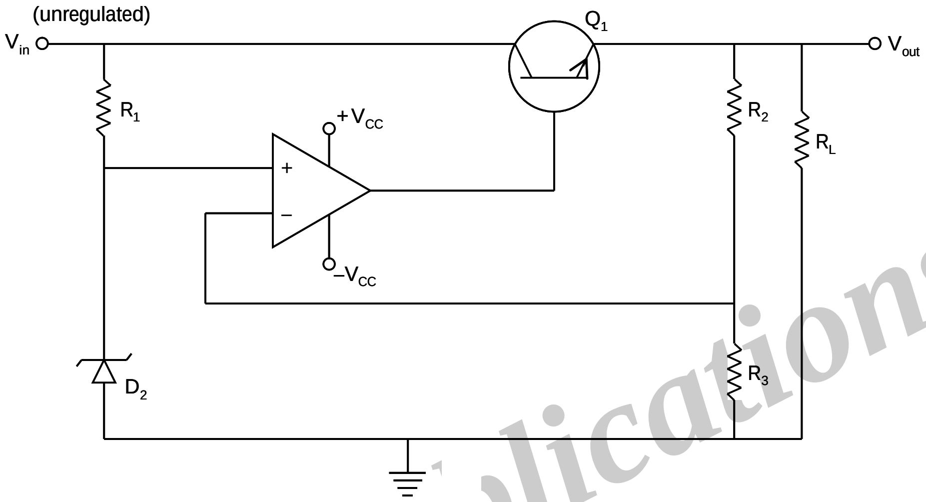
Ans :

A voltage regulator is required to maintain a constant dc voltage supply. This are 2 basic configurations.

(i) Series Regulator : Regulating dc voltage by controlling the series current supplied to load.

(ii) Shunt Regulator : Regulating dc voltage by shunting away some the current from the load.

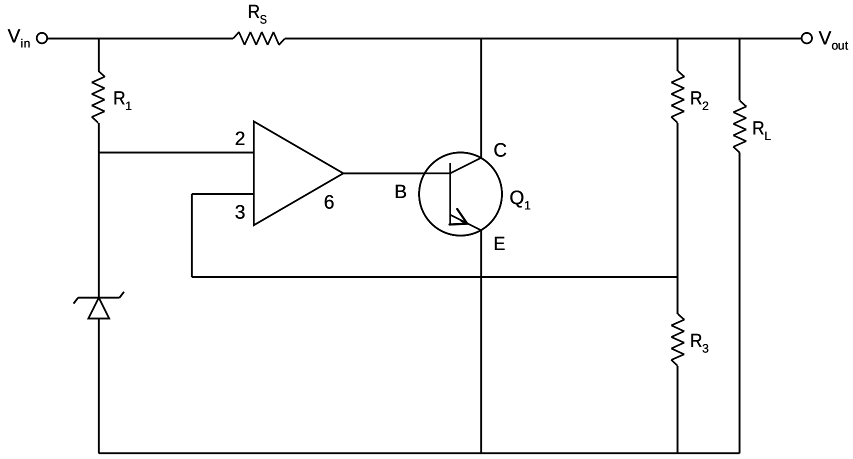
1. Op-Amp as Series Voltage



The above circuit diagram shows a an op-amp series voltage regulator. Here, if the output voltage, V_{out} decreases, the transistor will conduct further to provide more current of the output voltage, V_{out} decreases the voltage across the sensing resistor for the op-amp would increase. Due to the feedback configuration of the resistor and the op-amp the increases in the voltage causes the op-amp to less drive the transistor at its outputs this in turn reduces the current going int V_{out}.

$$V_0 = \left(1 + \frac{R_f}{R_i}\right) V_{ref}$$

2. Op-Amp Shunt Voltage Regulator



The above circuit diagram shows that shunt regulator circuit. It provide regulation by shunting current away from the load to regulate the output voltage. Here zener diode is compared to the feedback voltage obtained from voltage divider R_1 and R_2 to provide the control drive current to the shunt element of Q_1 the current through resistor R_S is controlled so that the output voltage is maintained.

$$V_0 = \left(1 + \frac{R_f}{R_i}\right) V_z$$

Short Question and Answers

1. Describe the working of op-amp voltage regulator ?

Ans :

A voltage regulator is required to maintain a constant dc voltage supply. This are 2 basic configurations.

(i) Series Regulator : Regulating dc voltage by controlling the series current supplied to load.

(ii) Shunt Regulator : Regulating dc voltage by shunting away some the current from the load.

2. List the features of IC 555 timer.

Ans :

The features of IC 555 timer are,

i) IC 555 timer is available as a 14 pin, 8 pin DIP.

ii) It is basically a monolithic timer device.

iii) It operates in two modes i.e., Astable, Monostable.

iv) Supply voltage can vary in the range from +5 V to + 18 V.

v) It has a high current output and is capable of handling 200 mA load current.

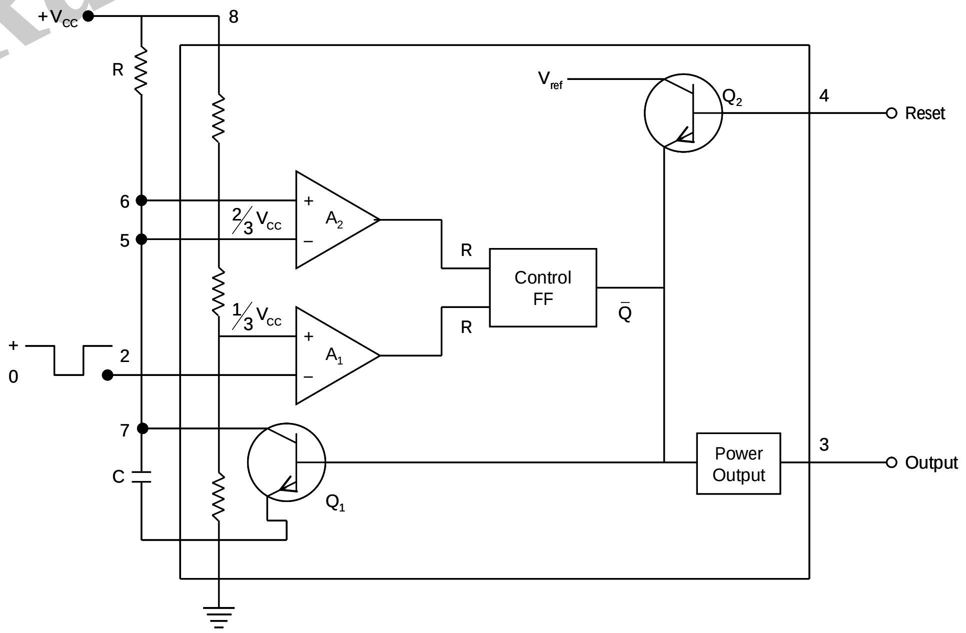
vi) It has very good temperature stability.

vii) It is economical in use, reliable in operation.

viii) Used to produce accurate and highly stable time delays and oscillations.

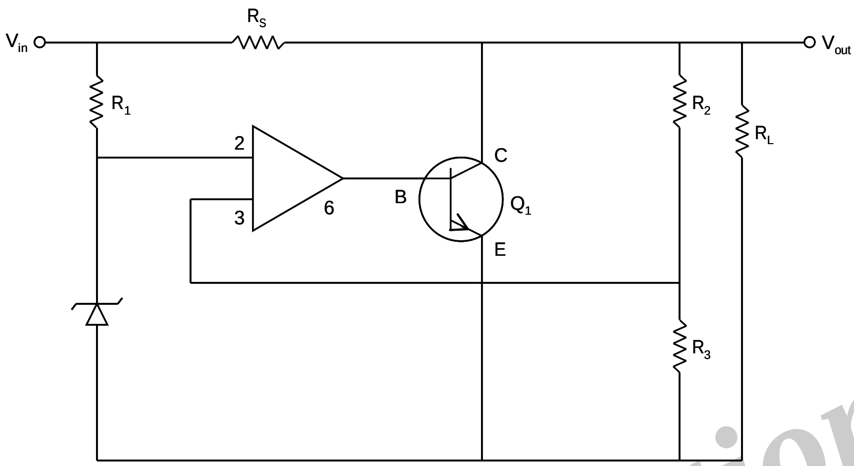
3. Draw the block diagram of IC 555 - timer ?

Ans :



4. Draw the op-amp voltage regulator circuit and describe its operation ?

Ans :



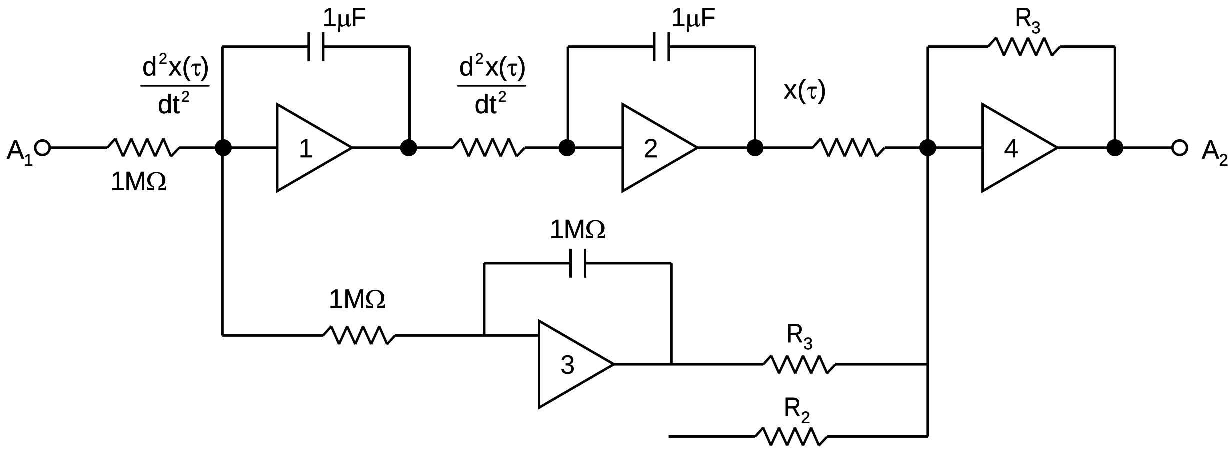
$$V_0 = \left(1 + \frac{R_f}{R_i}\right) V_z$$

5. Draw the circuit diagram of an op-amp to solve a second order differential equation?

Ans :

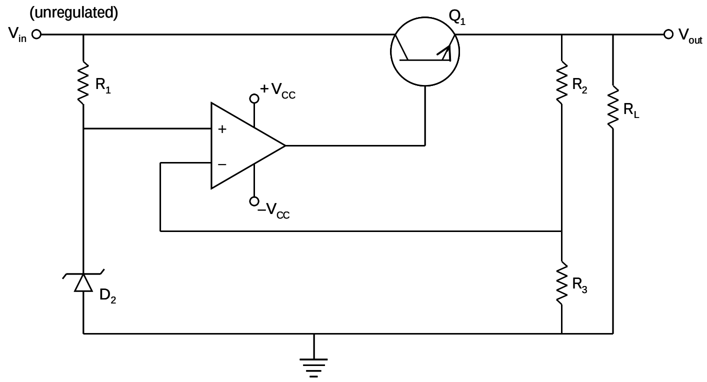
Consider the following differential equation

$$\frac{d^2X\ t}{dt^2} + 2\ \frac{dX(t)}{dt} + 3X\ (t) = 4 \text{ with initial conditions as } X(0) = 0,\ \frac{dX(0)}{dt} = 0$$



6. Using op-amp, explain how voltage regulation can be achieved ?

Ans :



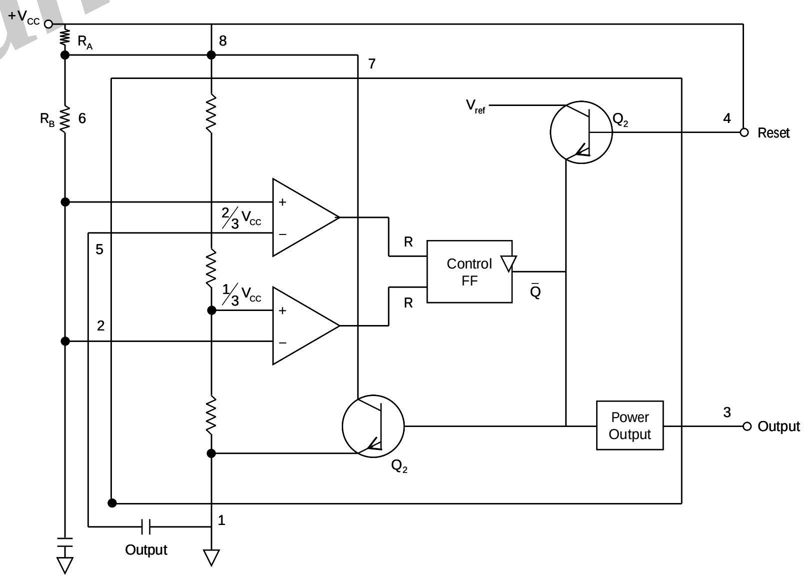
The above circuit diagram shows a an op-amp series voltage regulator. Here, if the output voltage, V_{out} decreases, the transistor will conduct further to provide more current of the output voltage, V_{out} decreases the voltage across the sensing resistor for the op-amp would increase. Due to the feedback configuration of the resistor and the op-amp the increases in the voltage causes the op-amp to less drive the transistor at its outputs this in turn reduces the current going int V_{out}.

$$V_0 = \left(1 + \frac{R_f}{R_i}\right) V_{ref}$$

7. Draw the circuit diagram of a free running multivibrator (using op-amp) and explain its action ?

Ans :

The functional block diagram of astable multivibrator.



- ➢ The timing resistor is split into 2 sections 'R_A' and 'R_B'.
- ➢ The discharging transistor is connected to junction of R_A and R_B.

➢ The timting capacitor charges towards $\frac{2}{3}$ V_{CC} through R_A and R_B.

➢ When capacitor voltage reachers to $\frac{2}{3}$ V_{CC}, the upper comparator triggers flip flop and capacitor starts to discharge towards ground through R_B.

➢ When the discharge reaches $\frac{1}{3}$ V_{CC}, the lower comparator is triggered and a new cycle is started.

∴ The frequency is given by

$$f = \frac{1}{T} = \frac{1.4}{(R_A + R_B)C}$$

8. Define multivibrators ?

Ans :

A multivibrator is circuit which produces or generates non-sinusoidal waveform like square waveform.

A monostable multivibrator is also called a one shot multivibrator. It has two states where one is stable or permanent state and the other is called quasistable state or temporary state.

9. Distinguish between monostable and astable multivibrators ?

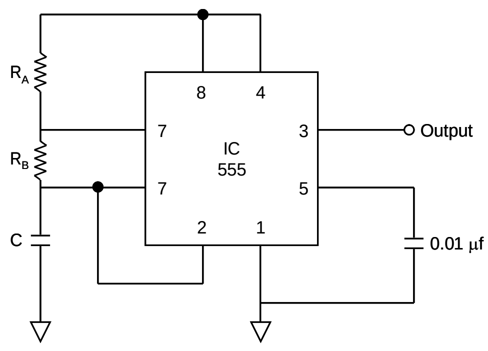
Ans :

Monostable	Astable
1. It is one shot multivibrator.	1. It is free running multivibrator
2. It require triggering pulse.	2. It does not require external triggering pulse.
3. It has two permanent state of stability	3. It has two temporary state of stability.
4. Its times period T = –RC $\log_e$ (f)	4. Its time period, T = 0.693 (R_A + R_B) C

10. Draw the circuit of Astable multivibrator using IC-555.

Ans :

Astable multivibrator is also called as free running multivibrator. This is because it does not require any external triggering. It has two Quasi state states. The pin connection diagram is given below.

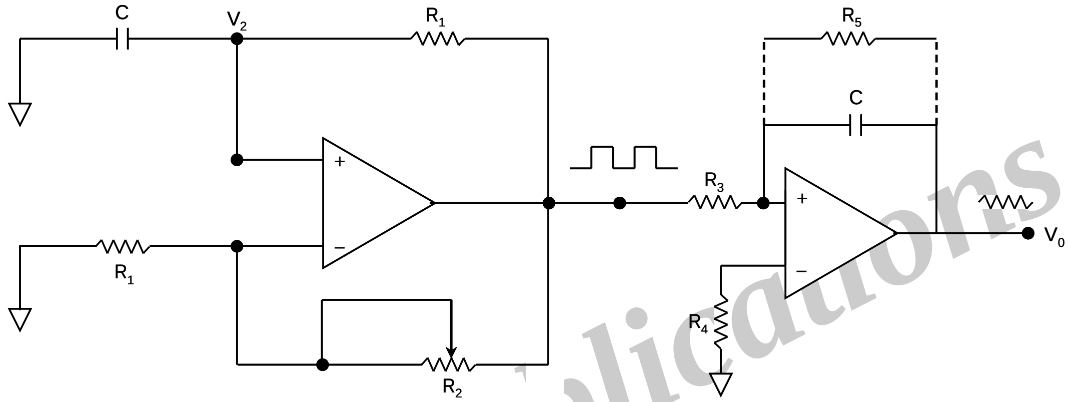


Here there is no triggering required and hence pin no. 2 is connected to pin no.6 for internal generation of the triggering signal. Unlike in monostable, the two states automatically changes after certain interval of time. And thus produces square wave output.

11. Draw the circuit diagram of a triangle wave generator.

Ans :

A triangular wave generator can be designed by considering an integrator circuit where the output of an integrator is triangular waveform when the input is square. The triangular wave generator can be designed by connecting the output of a square wave generator to an integrator circuit.



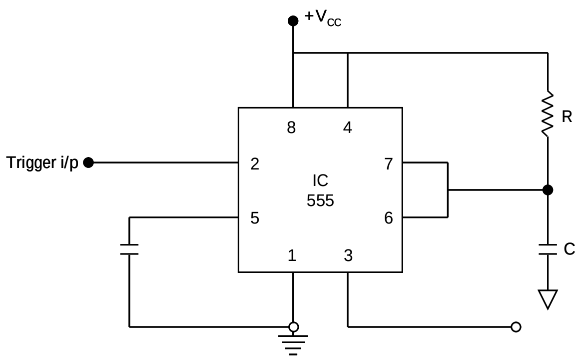
- The circuit diagram consists of two capacitors and atleast 5 resistors.
- For fixed values of R_1, R_2 and C, the frequency depends on the value of R.
- As 'R' is increased or decreased the frequency of triangular wave also changes.
- Even though the amplitude of square wave is at $\pm V_{sat}$, the triangular waves amplitude decreases with increase in frequency and vice versa.

A multivibrator is circuit which produces or generates non-sinusoidal waveform like square waveform.

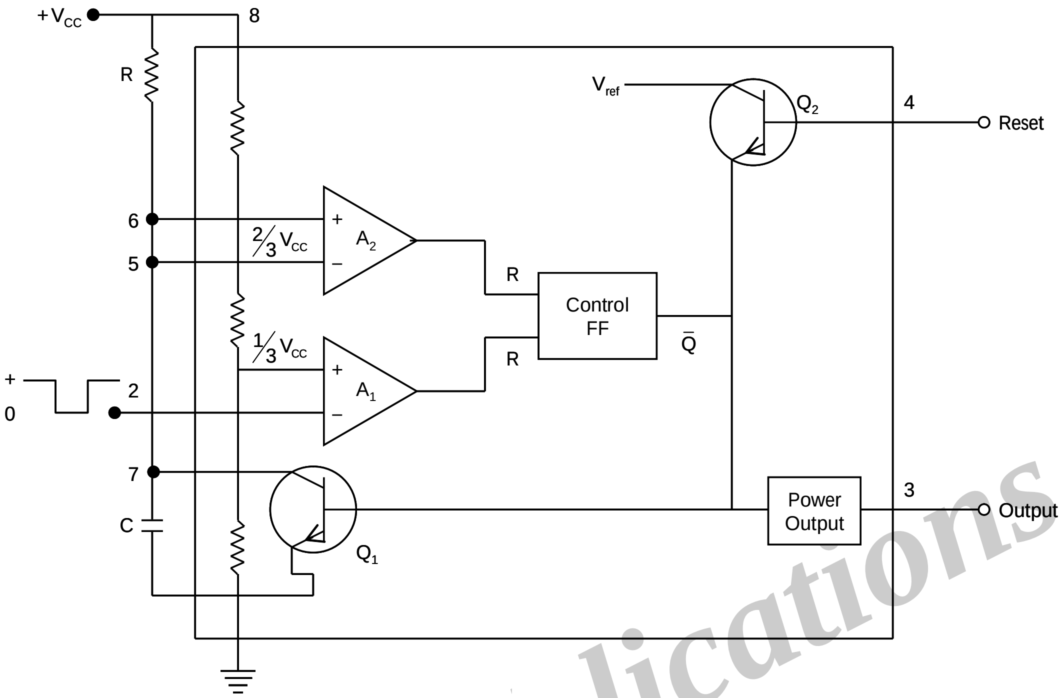
A monostable multivibrator is also called a one shot multivibrator. It has two states where one is stable or permanent state and the other is called quasistable state or temporary state. The pin connection of IC 555 as a monostable multivibrator.

12. Explain monostable multivibrator using IC 555.

Ans :



The functional diagram is shown below.



Choose the Correct Answer

1. A voltage follower [d]

   (a) is non-inverting (b) has a voltage gain of 1

   (c) has no feedback resistor (d) has all of the above

2. A triangular wave generator [d]

   (a) generates triangular waveform a square wave

   (b) uses two op-amps

   (c) uses both comparator and integrator circuits

   (d) all of the above

3. In op-amp logarithm amplifier [d]

   (a) Granded base transistor is placed in the feedback path

   (b) Collector is held at virtual ground

   (c) Output voltage is proportional to the logarith of input voltage

   (d) all the above are true

4. A voltage follower has [b]

   (a) very low input resistance (b) very low output resistance

   (c) very high input current (d) All of the above

5. In analog computer, solution of second order equation is used [b]

   (a) Addition (b) Differentiation

   (c) Subtraction (d) Multiplication

6. A reduced peak-to-peak output voltage swing can be obtained is [b]

   (a) Triangular wave generator (b) Square wave generator

   (c) Sinewave generator (d) All

7. Timer 555 device is used to which multivibrator [d]

   (a) Bi-stable (b) Monostable

   (c) Free-stable (d) b and c

8. The voltage across monostable multivibrator is [c]

   (a) $V = -V_{CC}\left(1 - e^{-t/RC}\right)$ (b) $V = \pm V_{CC}\left(1 - e^{-t/RC}\right)$

   (c) $V = V_{CC}\left(1 - e^{-t/RC}\right)$ (d) None

9. The output frequency f_0 of square wave generator is [a]

(a) $f_0 = \frac{1}{2RC}$

(b) $f_0 = \frac{1}{2LC}$

(c) $f_0 = \frac{1}{2LR}$

(d) $f_0 = \frac{1}{2RLC}$

10. ________ amplifier is that in which o/p voltage is proportional to input voltage. [c]

(a) Integral

(b) Antilog

(c) Logarithmic

(d) Differential

Fill in the blanks

1. The voltage gain of voltage follower is _______.
2. The generate a triangular ware, we use _______ op-amp.
3. A sine wave generator, in which a _______ bridge is used as the feedback network.
4. The operational amplifier which has a very large positive _______ negligible _______ and very _______ input resistance.
5. The output of the op-amp is forced to suring repetitively between _______ + V_{sat} and _______.
6. The square wave generator is also called a _______ or _______.
7. The frequency of the output f_0 is not only a function of the RC time constant but if R_2 = _______.
8. The square wave generator is useful in frequency range _______.
9. The circuit is called an astable multivibrator (AMV) because it has _______ stages.
10. The triangle wave generator consists of _______ and _______ circuit.

Answers

1. 1
2. Feedback
3. Balanced
4. Voltage gain, output resistance, high (infinite)
5. positive saturation, negative saturation
6. Free running, Astable multivibrator
7. 1.16 R_1
8. 10 Hz to 10 KHz
9. Quasi - stable
10. Square wave generator, integrator

UNIT III	**Modulation:** Need for modulation-Types of modulation- Amplitude, Frequency and Phase modulation. **Amplitude modulation**: Analysis of Amplitude modulation, side bands, modulation index, AM modulator, Balanced modulator, Demodulation – diode detector.

3.1 Modulation

3.1.1 Need for Modulation

Q1. Define modulation. Explain the need for modulation.

Ans : **(Nov.-20, June-19, June-18)**

Meaning

The frequencies in the audio range (20 Hz to 20KHz) is usually a speech or music signal. Since the energy is proportional to frequency the energy is very low to be transmitted over long distances. The power is very low to be radiated even if speech signal is converted into electrical signals.

The transmission can be accomplished by superimposing a high frequency wave called as carrier wave on the audio - frequency wave.

The method of raising the frequency of an audio frequency wave by super imposing it with a high frequency carrier wave is called Modulation. The net wave after modulation is called modulated wave.

Need

The necessity of modulation is very important in communications due to the following reasons.

(i) Short Range

Audio frequency signals being low frequency signal has low energy and cannot be radiated over longer distance. Hence it has very short range of operation.

(ii) Mutual Interference

The audio signals interfere with each other in the atmosphere if they are directly transmitted. Hence they are indistinguishable

(iii) Poor Efficiency

Radiation of audio to frequency signal directly into the spade is not possible. This is because efficiency is quite poor in low frequency range.

(iv) Practical Antenna Height

According to the principle of transmission, the height 0 the transmitting antenna must be approximately proportional to wavelength of the wave. For example an audio signal of frequency 20 KHz to be transmitted requires antenna of height equal to

$$\eta = \frac{V}{n}$$

where

'V' = velocity of radio waves

'n' = frequency of signal

$$\eta = \frac{3 \times 10^8 \, m/s}{20 \times 10^3 \, Hz}$$

$$\boxed{\eta = 15Km}$$

Therefore it is particularly impossible to construct an antenna with such height to keep it safe against winds, storms and rain.

Hence, because of the above said four factors. The frequency of the audio signal is raised by the technique called modulation. The enables low frequency signal to be transmitted over long distances.

3.2 Types of Modulation

3.2.1 Amplitude, Frequency and Phase modulation.

Q2. State the various types of Modulation.

Ans : **(June-19, June-18)**

Based on the changes in contain characteristics of the carrier waves, modulation is classified into different types.

The general equation of a carrier wave is represented by

$$E = E_C \sin (W_C t + \phi)$$

or

$$E = E_C \sin (2\pi f_c t + \phi)$$ where

$E_C \rightarrow$ Amplitude of carrier wave

$f_c \rightarrow$ Frequency of carrier wave

$\phi \rightarrow$ Phase of carrier wave

(i) Amplitude Modulation (AM)

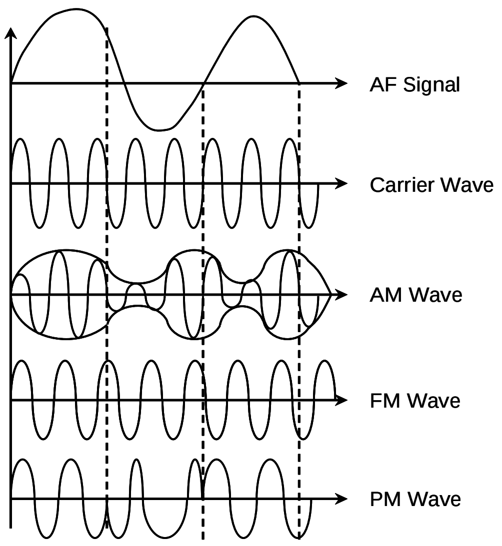
If the amplitude of the carrier wave is change in accordance to the audio frequency signal while its frequency and phase is constant is called amplitude modulation.

(ii) Frequency Modulation (FM)

The process by which if the frequency of the carrier wave is changed in accordance with AF signal while its amplitude and phase is constant is called frequency modulation.

(iii) Phase Modulation (PM)

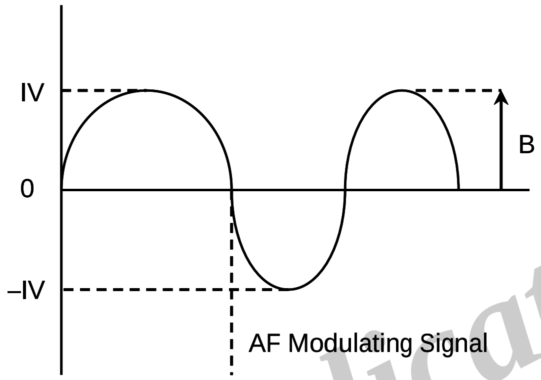
The modulation in which if the phase of the carrier wave is changed in accordance with AF signal while in frequency and amplitude is constant is called phase modulation.



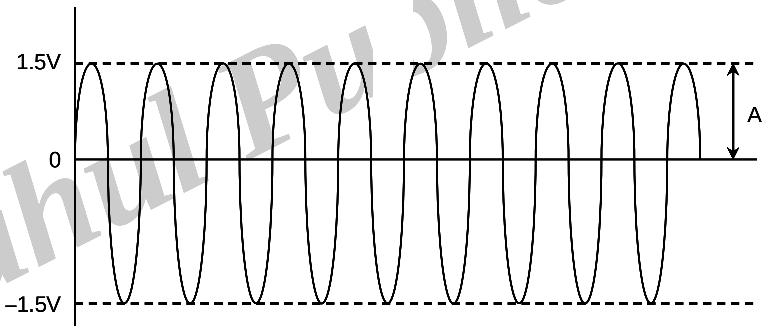
Q3. Explain the concept of Amplitude Modulation.

Ans :

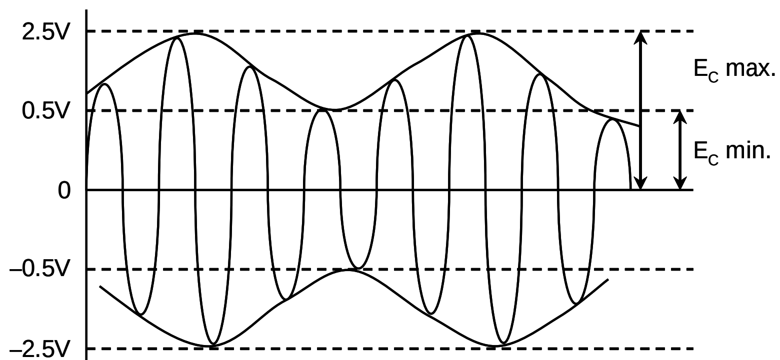
- Amplitude modulation is a process in which the maximum amplitude of carrier wave is changed in accordance with the instantaneous amplitude of audio frequency signal.
- The frequency and phase of the carrier wave is constant.
- Higher the amplitude of modulating signal, greater will be the swing in the modulated wave.
- The first wave represents modulating signal with an amplitude of ‘B’.



AF Modulating Signal



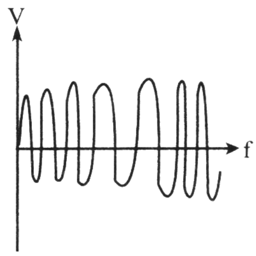
Carrier Wave



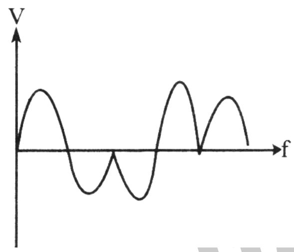
Amplitude Modulated Wave

- The second wave represents high frequency carrier wave of amplitude ‘A’.
- The resultant amplitude modulated wave is shown in third figure.
- When the signal increases at positive side, the AM wave also increases.

- During negative sense, the amplitude of Am wave decreases.
- Thus the amplitude of carrier wave changes accordingly with modulating signals.



Frequency Modulation



Phase Modulation

3.3 Analysis of Amplitude Modulation

Q4. State the Analysis of Amplitude Modulation.

OR

Obtain an expression for Amplitude modulated waves.

Ans : **(June-19, June-18)**

Let the instantaneous voltage of carrier wave is given by

$e_c = E_c \sin \omega_c t$

where

E_c – maximum amplitude of carrier

ω_c – Angular frequency of the carrier wave and is given by

$\omega_c = 2\pi f_c$

Let the modulating wave voltage is given by

$e_m = E_m \sin \omega_m t$ ... (2)

where

E_M – Maximum amplitude of modulating signal

ω_c – Angular frequency of the carrier wave and is given by

$\omega_c - 2\pi f_c$

Let the modulating wave voltage is given by

$e_m = E_m \sin \omega_m t$ ... (3)

where

E_M – Maximum amplitude of modulating signal

ω_m – Angular frequency of the modulating signal and is given by

$\omega_m - 2\pi f_m$

In amplitude modulation, the amplitude of carrier 'E_e' is changed in accordance with the amplitude of modulating signal.

Therefore

$E = E_c + K_a K_m \sin \omega_m t$ ... (4)

where

K_a = proportionally constant that determines depth of modulation

The instantaneous voltage of modulated wave is give by

$e = E \sin \omega_m t$

$$e = E_c \left[1 + \frac{K_a E_m}{E_c} \sin \omega_c t\right] \sin \omega_c t$$

$e = E_c [1 + M \sin \omega_c t] \sin \omega_c t$

where

$M = K_a \dfrac{E_m}{E_c}$ is modulation index

$e = E_c \sin \omega_c t + m E_c \sin \omega_c t + \sin \omega_c t$

$$e = E_c \sin \omega_c t + \frac{m E_c}{2} \sin \omega_c t + \sin \omega_c t$$

$$e = E_c \sin \omega_c t + \frac{m E_c}{2} \cos (\omega_c - \omega_m)t - \frac{m E_c}{2} \cos (\omega_c - \omega_m)t$$

($\because$ 2 sin A cosB = Cos (A – B) – cos (A + B))

Therefore from the above equation it is clear that

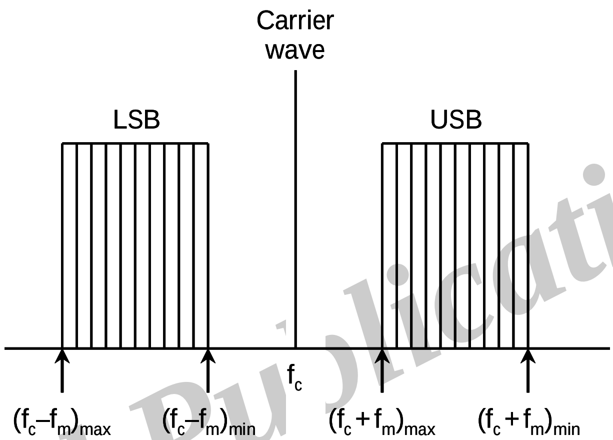
- The first term has amplitude 'E_c' and frequency 'f_c'
- Second and third term has amplitude $\dfrac{m E_c}{2}$ and frequency ($f_c \pm f_m$)
- The modulation does not change carrier wave but produces two additional frequencies called side band frequencies

3.4 Side Bands

Q5. Explain concept of Side Bands.

Ans : **(June-18)**

The signal after modulation is not perfectly sinusoidal in nature, instead it consists of closely spaced frequency components on either side of the carrier wave. They are known as side bands. The band on the higher frequency region is called upper side band (USB) and the frequency on lower side is called lower side band (LSB).



- The USB contains sum of frequency of signal components and carrier components.
- The LSB contains difference of frequency of signal and carrier components.
- The bandwidth is given by difference between extreme frequencies i.e., the maximum frequency of USB and minimum frequency of LSB.

i.e., $(f_c + f_m)_{max} - (f_c + f_m)_{max}$

$B.W = fc_{max} + fm_{max} + fc_{max} + fm_{max}$

$B.W = 2fm_{max}$

BW = 2 × maximum frequency of modulating signal.

The bandwidth is also called as channel width

3.5 Modulation Index

Q6. Discuss about modulation index and depth of modulation.

Ans : **(June-19)**

The modulation index denoted as ‘m’ specifies the extent to which the carrier wave changes. It also specifies the quality of the signal to be transmitted. The modulation index has many definition and are as follows :

It is defined as the ratio of change in the amplitude of carrier wave to the amplitude of normal carrier wave.

$$m = \frac{\text{Change in amplitude of carrier wave}}{\text{Amplitude of normal carrier wave}}$$

(or)

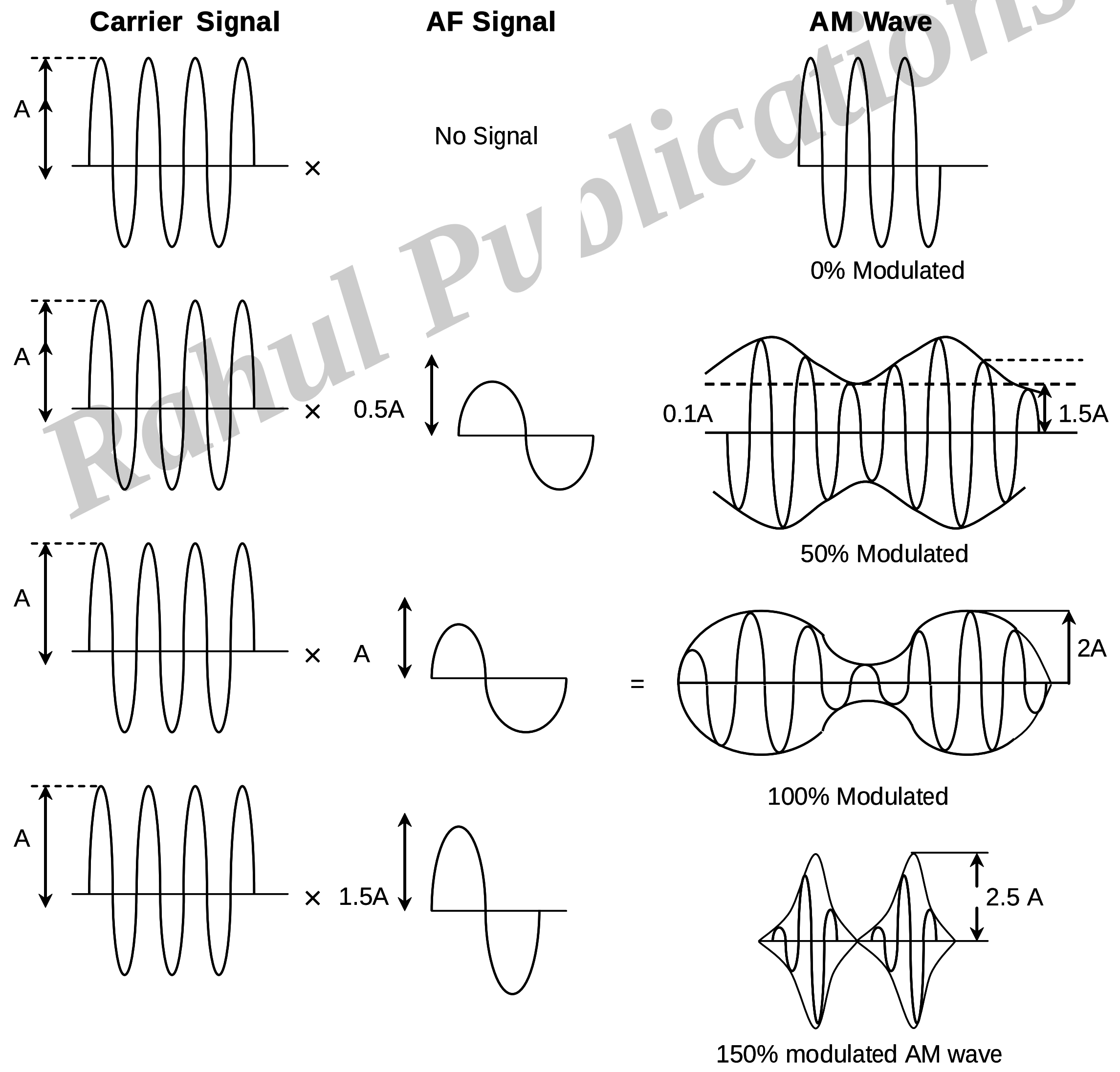
It is defined as peak value of modulating signal to peak value of carrier wave.

$$m = \frac{\text{Maximum value of modulating signal}}{\text{Maximum value of carrier signal}}$$

Percentage modulation is given by the formula

$$m\% = \frac{E_{c(max)} - E_{c(min)}}{E_{c(max)} + E_{c(min)}} \times 100$$

Various degrees of modulation



Q7. Obtain the expression for bandwidth of an A.M signal.

Ans :

Expression for Bandwidth of an AM Signal

The expression for AM wave is,

$$v = v_c \sin\omega_c t + \frac{mv_c}{2}[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t]$$

$$= v_c \sin 2\pi f_c t + \frac{mv_c}{2}[\cos 2\pi(f_c - f_m)t - \cos 2\pi(f_c + f_m)t] \quad (\because \omega = 2\pi f)$$

In above equation, f_c – Carrier frequency

v_c - Carrier amplitude

1. $f_c - f_m$ is the LSB (Lower Side Band) with amplitude $\frac{mv_c}{2}$

2. $f_c + f_m$ is the USB (Upper Side Band) with amplitude $\frac{mv_c}{2}$

The bandwidth of a signal is the difference between Upper Side Band (USB) frequency and Lower Side Band (LSB) frequency.

i.e., BW = USB – LSB .... (1)

USB Frequency

The USB frequency is the sum of carrier frequency (f_c) and modulating frequency (f_m)

i.e., USB = $f_c + f_m$ ..... (2)

LSB Frequency

It is the difference between carrier frequency (f_c) and modulating frequency (f_m)

i.e., LSB = $f_c + f_m$

On substituting equations (2) and (3) in equation (1), we get,

$$BW = (f_c + f_m) - (f_c - f_m)$$

$$= f_c + f_m - f_c + f_m = 2f_m$$

$$\boxed{\therefore BW = 2f_m}$$

Therefore, bandwidth of amplitude modulated signal is twice the frequency of modulating signal.

3.6 AM Modulator

Q8. Describe the methods of AM signal generation.

Ans :

The methods used for the generation of AM signals are,

(a) Square law modulator and

(b) Switching modulator.

(a) Square Law Modulator

The AM signals can be generated by using square law modulator. The circuit diagram of a square law modulator is as shown in figure (1),

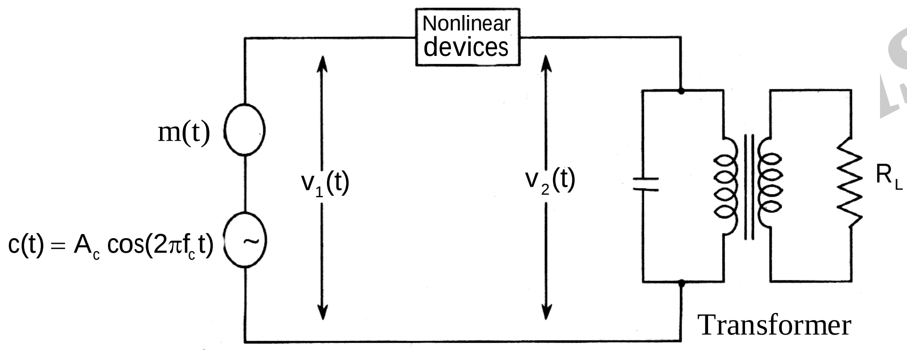


Fig :. Square Law Modulator

Figure (1) consists of carrier signal c(t), message signal m(t), non-linear device, band pass filter and transformer.

Non-linear Device

Semiconductor diodes and transistors are commonly used non-linear devices for implementation of square law modulator.

Bandpass Filter

It is used to tune to desired carrier frequency.

Working

Initially, the carrier and message signals are applied to the non-linear device. The corresponding signal is then sent to the tuned circuit where it is tuned to carrier frequency 'f_c'.

Mathematical Analysis

The input voltage v_1 (t) of the circuit is a combination of carrier and message signal, which is given as,

$$v_1(t) = m(t) + c(t)$$

$$= m(t) + A_c \cos(2\pi f_c t) \quad \ldots \quad (1)$$

For non linear device, the input output relation is given as,

$$v_2(t) = a_1 v_1(t) + a_2 v_1^2(t) \qquad \ldots \qquad (2)$$

On substituting equation (1) into equation (2), we get,

$$v_2(t) = a_1[m(t) + A_c\cos(2\pi f_c t)] + a_2[m(t) + A_c\cos(2\pi f_c t)]^2$$

$$= a_1 m(t) + a_1 A_c\cos(2\pi f_c t) + a_2[(m(t))^2 + (A_c\cos(2\pi f_c t))^2 + 2m(t)A_c\cos(2\pi f_c t)]$$

$$[\because (a+b)^2 = a^2 + b^2 + 2ab]$$

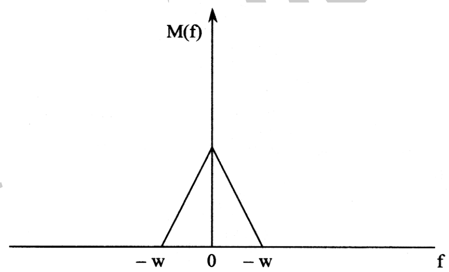
$$= a_1 m(t) + a_1 A_c\cos(2\pi f_c t) + a_2[m^2(t) + A_c^2\cos^2(2\pi f_c t) + 2m(t)A_c\cos(2\pi f_c t)]$$

$$= a_1 m(t) + a_1 A_c\cos(2\pi f_c t) + a_2 m^2(t) + a_2 A_c^2\cos^2(2\pi f_c t) + 2a_2 A_c m(t)\cos(2\pi f_c t)$$

$$\therefore v_2(t) = a_1 A_c\left[\frac{1+2a_2}{a_1} m(t)\right]\cos(2\pi f_c t) + a_1 m(t) + a_2 m^2(t) + a_2 A_c^2\cos^2(2\pi f_c t) \qquad \ldots(3)$$

The term $a_1 A_c\left[1 + \frac{2a_2}{a_1} m(t)\right]\cos(2\pi f_c t)$ in equation (3) represents the desired AM wave.

The waveforms of a square law modulator is as shown in figure (2),



(a) Spectrum of a message signal

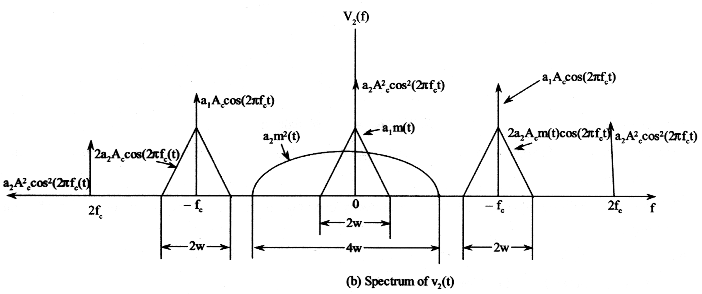


Fig:. Waveforms of a Square Law Modulator

Figure 2(a) represents the spectrum of a message signal which is band limited in the interval $-W \le f \le W$, and figure 2(b) represents the output spectrum which contains three unwanted terms and AM wave. The unwanted components $a_1 m(t)$, $a_2 m^2(t)$ and $a_2 A_c^2\cos^2(2\pi f_c t)$ can be removed from $v_2(t)$ by using tuned filter at the output of modulator.

(b) Switching Modulator

Switching modulator is used for the generation of AM wave. This technique operates on the principle of switching diode wherein a carrier wave of high voltage is applied.

Figure (1) shows the circuit of switching modulator.

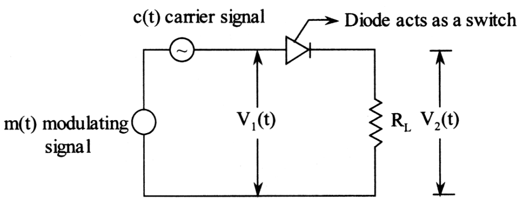


Fig: (1) Switching Modulator

Q9. Explain about a switching modulator. Draw the necessary circuit and waveform.

Ans :

Switching modulator is used for the generation of AM wave. This technique operates on the principle of switching diode wherein a carrier wave of high voltage is applied.

Figure (1) shows the circuit of switching modulator.

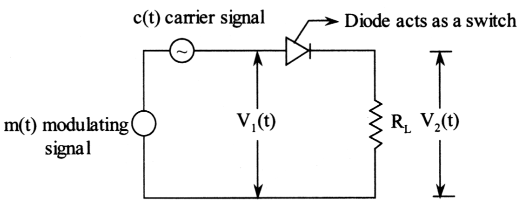


Fig: (1) Switching Modulator

Operation

Consider diode as an ideal switch and well performed by applying a large amplitude carrier signal such that the diode is forward biased when carrier c(t) is greater than zero which results in zero impedance. Similarly, the diode is reverse biased when the carrier signal of less than zero which results in infinite impedance.

Mathematical Analysis

The input voltage signal V_1 (t) is given by,

$$V_1(t) = A_c \cos(2\pi f_c t) + m(t) \quad ...(1)$$

Here,

$$|m(t)| << A_c$$

And the resultant output voltage is given as,

$$V_2(t) = \begin{cases} V_1(t), & c(t) > 0 \\ 0 \ , & c(t) < 0 \end{cases} \quad ...(2)$$

From the above equation it is observed that $V_2(t)$ varies periodically between $V_1(t)$ and zero by applying the carrier signal.

$$\therefore V_2(t) \simeq [A_c \cos(2\pi f_c t) + m(t)]\, g_p(t) \qquad ...(3)$$

Where,

$$g_p(t) = \frac{1}{2} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos[2\pi f_c t(2n-1)] \qquad ... (4)$$

$g_p(t)$ represents a periodic train pulse of a duty cycle whose period $\tau_0 = \frac{1}{f_c}$, as shown in figure (2).

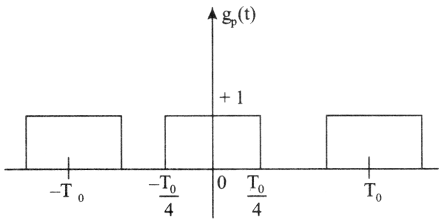


Fig: (2) Periodic Pulse Train of g_p (t)

On substituting equation (4) in equation (3), we gets sum of two components, i.e.,

$$V_2(t) = \underbrace{\frac{A_c}{2}[1 + \frac{4}{\pi A_c} m(t)]\cos(2\pi f_c t)}_{(1)} + \underbrace{\text{Unwanted components}}_{(2)}$$

The first term represents the AM wave with amplitude sensitivity, $K_a = \frac{4}{\pi A_c}$. The second term represents the unwanted components in AM wave which can be eliminated by passing it through band-pass filter.

Related Waveforms

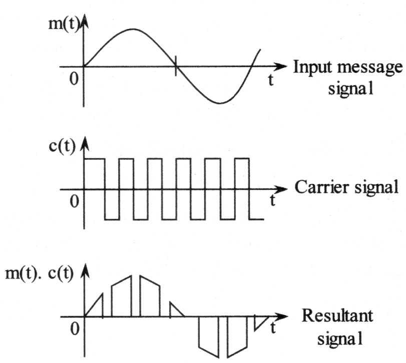


Fig: (3)

3.7 Balanced Modulator

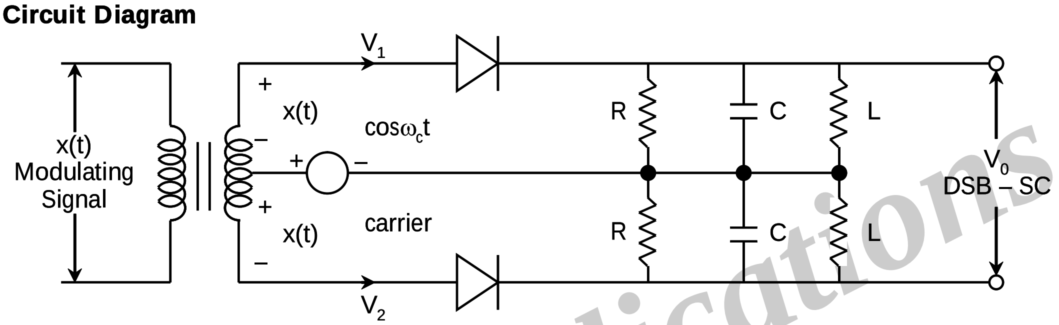
Q10. Draw a circuit diagram of Balanced Modulator.

Ans :

It is a modulator that mixes the audio signal and ratio frequency carrier signal, but suppresses the carrier tearing only the side bands.

The output from the balanced modulator is a double sideband suppressed carrier signal and it contains all the information that the AM signal has

Circuit Diagram



The above circuit diagrame shows the balanced modulator using diodes as non-linear device. where a modulating signal x(τ) is applied equally with 180° phase shift at the input of both the diodes through the input center tapped transformer.

The carrier signal is applied to the center tap of the secondary. Hence input voltage to D_1 is given by

$$\nu_1 = \cos\omega_c t + x(\tau) \quad \ldots (1)$$

and the input voltage to D_2 is given by

$$\nu_2 = \cos\omega_c t - x(\tau) \quad \ldots (2)$$

Let two diodes having currents i_1 and i_2 are given by

$$i_1 = a\nu_1 + b\nu_1^2$$

$$i_1 = a[x(\tau) + \cos\omega_c t] + b\,[x(\tau) + \cos\omega_c t]^2$$

$$i_1 = a[x(\tau) + \cos\omega_c t] + b\,[x(\tau) + \cos\omega_c t]^2$$

$$i_1 = ax(\tau) + a\cos\omega_c t + b[x^2(\tau) + 2bu(\tau)\cos\omega_c t + b\cos^2\omega_c t] \quad \ldots (3)$$

Similarly

$$i_2 = a\nu_2 + a\nu_2^2$$

$$i_2 = a[x(\tau) - \cos\omega_c t] + b[x(\tau) - \cos\omega_c t]^2$$

$$i_2 = a[x(\tau) - \cos\omega_c t] + b[x^2(\tau) - 2\,x(\tau)\cos\omega_c t + \cos^2\omega_c t]$$

$$i_2 = ax(\tau) - a\cos\omega_c t + bx^2(\tau) - 2bx\,(\tau)\cos\omega_c t + \cos^2\omega_c t \quad \ldots (4)$$

∴ The output voltage is given by

$V_0 = i_1R - i_2R$ ... (5)

Substituting the value of equation (3) and (4) in equation (5), we get

$$\boxed{V_0 = R[2ax(\tau) + 4bx(\tau)\cos\omega_c t]}$$

(or)

$$V_0 = \underbrace{2a\ Rx(t)}_{\text{Modulating signal}} + \underbrace{4b\ Rx(t)\cos\omega_c t}_{\text{DSB-SC signal}}$$

Hence the output voltage contains a modulating signal term and DSB – SC signal.

Hence, the modulating signal term is eliminated and second term is allowed to pass through to the output by LC band pass filter section.

$\therefore$ The o/p voltage, $V_0 = 4bRx(\tau)\cos\omega_c t$

i.e., $\boxed{V_0 = Kx(\tau)\cos\omega_c t}$

Thus the diode balanced modulator produces the DSB – SC signal at its outputs.

3.8 Demodulation - Diode Detector

Q11. What is dc modulation?

Ans : **(June-19)**

Digital Modulation

Digital modulation is the process of transmitting digitally modulated analog signals among two or more communicating systems. In some cases, it is also referred as digital radio. The propagation of the modulated signals via, earth's atmosphere is applied in wireless communication system. In a digital modulation, the carrier signal is a sinusoidal signal or any other analog signal and the message signal is a digital signal.

Q12. Explain the salient features of amplitude modulation with the help of appropriate wave forms. Give the theory and working of diode detector to detect the AM signals.

OR

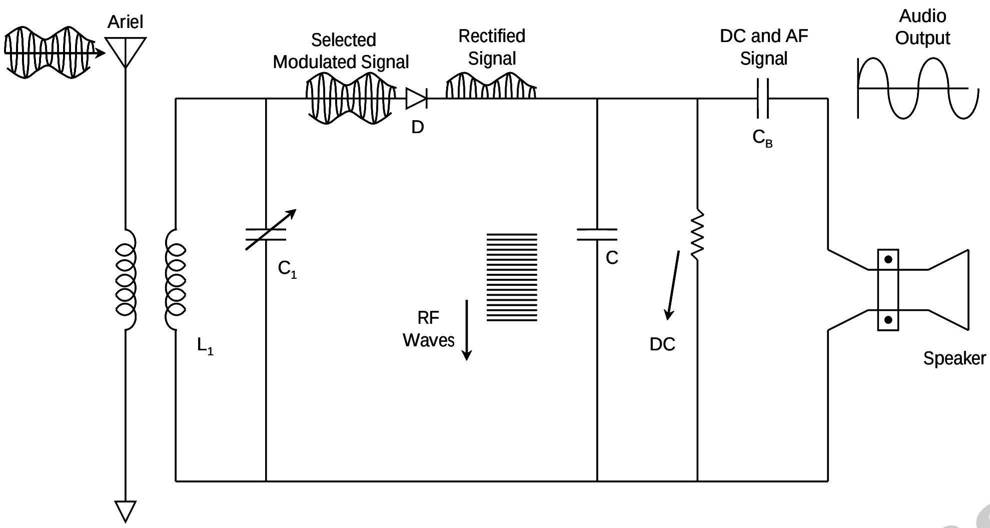
Draw the circuit diagram of an AM detector and explain how the original signal is received from AM signal is recovered from AM signal.

OR

Explain the process of demodulation in AM receivers.

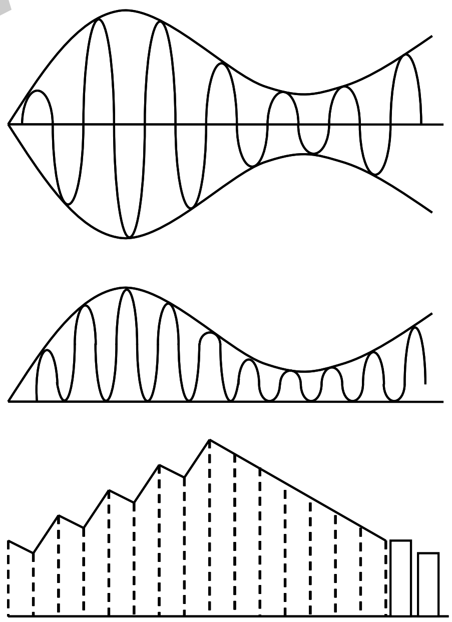
Ans : **(June-19)**

- A diode detector is similar to half wave rectifier with capacitor filter.
- The tuned circuits L_1 C_1 selects the modulated signal.
- The other elements are 'C', 'R' and 'C_B'



Operation

- By changing the value of 'C_1' the desired, AM wave is selected is passed to the diode 'D'.
- The diode performs the rectification process and eliminates the negative half of the modulated wave.
- The capacitor 'C' provides low reactance path to RF carrier and thus carrier is bypassed.
- The DC component of the signal cannot pass through 'C_B' and hence it is bypassed through 'R'.
- Now the low frequency signal is passed to loud speaker and sound can be heard.



Q13. What are the Limitation of Amplitude Modulation

Ans : **(Imp.)**

1. Low Efficiency

The signal is present in side band frequencies. The useful power that is present in side bands are very small i.e., for 100% modulation only $\frac{1}{3^{rd}}$ of total power is used. Hence efficiency is very less.

2. Small Range

Since efficiency is very small, the intelligence or messages cannot be transmitted over longer distances.

3. Noisy Reception

A noise is nothing but it is an electrical amplitude. Hence the noise also gets modulated and the receiver cannot distinguish the noise and signal. Hence the output is very noisy.

4. Lack of Audio Quality

To reproduce all signal upto 15 KHz, a band width of 30 KHz is needed. But the AM broadcasting station is assigned only 10 KHz bandwidth to minimize interference. Hence a modulating frequency of only 5 KHz is allotted which is insufficient to produce the music quality.

Problems

1. An antenna current of AM transmitting antenna is 8A. When a carrier is superimposed it increases to 8.93 A. Find percentage modulation ?

Sol :

The total power is given by

$$P_T = P_C\left[1+\frac{m^2}{2}\right]$$

$$\frac{P_T}{P_C} = 1 + \frac{m^2}{2}$$

$$1 + \frac{m^2}{2} = \frac{I_M^2 R}{I_C^2 R}$$

where

I_M = Current when carrier is modulated

I_C = Current of unmodulated carrier

$$1 + \frac{m^2}{2} = \frac{I_M^2}{I_C^2}$$

$$\frac{m^2}{2} = \frac{I_M^2}{I_C^2} - 1$$

$$m^2 = 2\left[\frac{I_M^2}{I_C^2} - 1\right]$$

$$m^2 = 2\left[\left(\frac{8.93}{8}\right) - 1\right] = 2\left[\frac{79.74}{64} - 1\right]$$

$$m^2 = 2\left[\frac{79.74 - 64}{64}\right] = \frac{15.74}{32}$$

$$m^2 = 0.49$$

$$\boxed{m = 0.7}$$

2. An audio signal is given by e_m = 15 sin 2π (2000t) modulates the carrier by e_c = 60 sin 2π (100,000)t. Calculate :

(a) Percentage modulation

(b) Frequency spectrum

Sol :

Given

(a) $e_m = 15 \sin 2\pi (2000)t$ ... (1)

$e_c = 60 \sin 2\pi (100{,}000)t$ ... (2)

Signal amplitude 'B' = E_M = 15 volts

Carrier amplitude 'A' = E_C = 60 volts

Modulation index $M = \frac{B}{A} = \frac{15}{60} = 0.25$

M% = 25%

(b) Comparing equation (1) and (2) with $e_M = E_M \sin 2\pi f_M t$ and $e_C = E_c \sin 2\pi f_C t$.

$f_M = 2000$ and $f_C = 100{,}000$

The frequencies are

$f_C - f_M$ = 100 KHz – 2 KHz

$f_C - f_M$ = 98 KHz

$f_C - f_M$ = 100 KHz + 2 KHz ...

$f_C - f_M$ = 102 KHz

Therefore the frequency spectrum is 98 KHz to 102 KHz.

3. A modulated carrier wave has maximum and minimum amplitudes of 1500 mV and 500 mV. Calcualte the value of percentage modulation ?

Sol :

Given

E_C max = 1500 mV

E_C min = 500 mV

$$\text{Percentage modulation \%} = \frac{E_C \max - E_C \min}{E_{C\max} + E_{C\min}} \times 100$$

$$P.M\ \% = \frac{1500-500}{1500+500} \times 100$$

$$= \frac{1000}{2000} \times 100$$

$$\boxed{P.M\% = 50\%}$$

---

4. An AM wave is represented by the expression.

$(e_C)_{AM} = 7.5\,(1 + 0.6 \cos 6280t) \cos (10^2\,\pi t)V.$

Calculate the maximum and minimum amplitude of AM wave ?

Sol :

The given AM wave may also be written as

$(e_C)_{AM} = 7.5\,(1 + 0.6 \cos (6280t)) \sin (10^6\,\pi t)\ V$

Comparing it with the instantaneous value of amplitude wave

$e = E_C\,(1 + M \sin \omega_S t) \sin \omega_C t$

we get

$E_C = 7.5$ volt, $\quad M = 0.6$

$\omega_S = 6280, \quad \omega_C = 10^6\pi$

(i) Peak output results when positive half cycle of modulating signal occurs. The maximum output voltage is given by sum E_C and E_S. Thus maximum amplitude of AM wave

$= E_C + E_S$

$= E_C + mE_C \qquad \left(\because\ m = \frac{E_S}{E_C}\right)$

$= 7.5 + 0.6 \times 7.5$

$= 12$ volt

Similarly, minimum amplitude of AM wave

$= E_C - E_S = E_C - mE_C$

$= 7.5 - 0.6 \times 7.5 = 3$ volt.

---

5. The antenna current of an AM transmitter is 8A when only the carrier is sent but it increases to 8.93 A when the carrier is modulated. Find percent modulation.

Sol :

The modulated or total power carried by AM wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right)$$

If R is load resistance, I_M is the current when carrier is modulated and I_C the current when unmodulated, then

$$\frac{P_T}{P_C} = \frac{I_M^2 R}{I_C^2 R}$$

$$1 + \frac{m^2}{2} = \frac{I_M^2 R}{I_C^2 R}$$

$$m^2 = 2\left(\frac{I_M^2}{I_C^2}-1\right)$$

(or)

Given $I_m = 8.93$ A, $I_C = 8$A

$$m^2 = 2\left[\left(\frac{8.93}{8.0}\right)^2-1\right]$$

$$m = 0.7$$

Therefore, modulation index = 70%.

6. The load current in the transmitting antenna of an unmodulated AM transmitter is 6 Amp. What will be the antenna current when modulation is 60% ?

Sol :

The power carried by AM wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right) \quad \text{... (1)}$$

where P_C is the power of carrier component and m is the modulation factor.

If R is the resistance I_m the antenna load current when modulation is 60% and I_C is the antenna load current when unmodulated, then

$$\frac{P_T}{P_C} = \frac{I_M^2 R}{I_C^2 R}$$

$$1 + \frac{m^2}{2} = \frac{I_M^2}{I_C^2} \qquad \text{(using (1))}$$

or $$I_m = I_C \sqrt{\left(1+\frac{m^2}{2}\right)}$$

Given

I_C = 6 Amp, m = 0.6

$$I_m = 6\left[1+\frac{(0.6)^2}{2}\right]^{1/2}$$

$$= 6\ [1.086] = 6.52\ \text{Amp}$$

---

7. A carrier wave of 1000 W is subjected to 100% modulation. Calcualte:

(i) Power of modulated wave

(ii) Power in USB

(iii) Power in LSB

Sol :

(i) Total power of modulated wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right)$$

$$= 1000 = \left(1+\frac{1^2}{2}\right)$$

$$= 1000 \times 1.5$$

= 1500 walt

(ii) Power in USB

$$= \frac{1}{2} P_{SB}$$

where power carried by side bands is given by

$$P_{SB} = P_C\left(\frac{m^2}{2}\right)$$

$$= 1000\left(\frac{1^2}{2}\right) = 500 \text{ walt.}$$

$$\therefore \quad P_{USB} = \frac{1}{2} P_{SB} = \frac{1}{2} \times 500 = 250 \text{ walt.}$$

(iii) Since power in LSB = Power in USB

$$\therefore \quad P_{LSB} = P_{USB} = 250 \text{ walt.}$$

---

8. The antenna current of an AM transmitter is 8A when only the carrier is sent but it increase to 8.93 A when the carrier is modulated. Find percent modulation.

Sol : **(Nov.-20)**

$$I_t = I_c\sqrt{1+\frac{m^2}{2}}$$

$$8.93 = 8\sqrt{1+\frac{m^2}{2}}$$

$$\sqrt{1+\frac{m^2}{2}} = 1.116$$

Therefore m = 0.601 = 60.1%

Short Question and Answers

1. Explain the need for modulation ?

Ans :

(i) Short Range

Audio frequency signals being low frequency signal has low energy and cannot be radiated over longer distance. Hence it has very short range of operation.

(ii) Mutual Interference

The audio signals interfere with each other in the atmosphere if they are directly transmitted. Hence they are indistinguishable.

(iii) Poor Efficiency

Radiation of audio to frequency signal directly into the spade is not possible. This is because efficiency is quite poor in low frequency range.

(iv) Practical Antenna Height

According to the principle of transmission, the height 0 the transmitting antenna must be approximately proportional to wavelength of the wave. For example an audio signal of frequency 20 KHz to be transmitted requires antenna of height equal to

---

2. Write a short note an power relations in AM wave ?

Ans :

The useful power of AM wave is present in the side bands. Hence, the area of interest is how much the power is used or it is useful.

The total power in AM wave is proportional to sum of the square of the 3 amplitudes.

$$P_T \alpha \left[\left(\frac{E_C}{\sqrt{2}}\right)^2 + \left(\frac{mE_C}{2\sqrt{2}}\right)^2 + \left(\frac{mE_C}{2\sqrt{2}}\right)^2\right]$$

$$P_T \alpha \left[\frac{E_C^2}{2} + \frac{m^2E_C^2}{8} + \frac{m^2E_C^2}{8}\right]$$

$$P_T \alpha \left[\frac{E_C^2}{2} + \frac{m^2E_C^2}{4}\right]$$

$$P_T \alpha \frac{E_C^2}{2}\left[1 + \frac{m^2}{2}\right]$$

The power in carrier wave is given by

$$P_T \alpha \frac{E_C^2}{2}$$

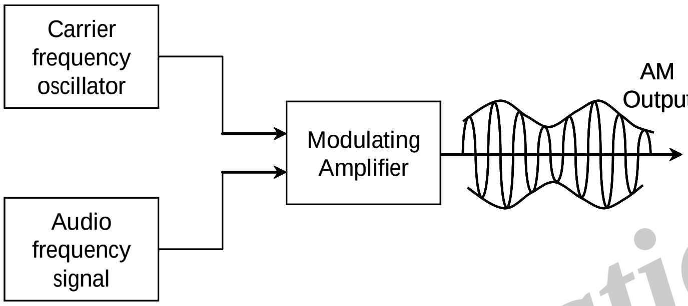
∴ Equation (1) becomes

$$P_T \,\alpha\, P_C \left[1+\frac{m^2}{2}\right]$$

3. Explain amplitude modulation ?

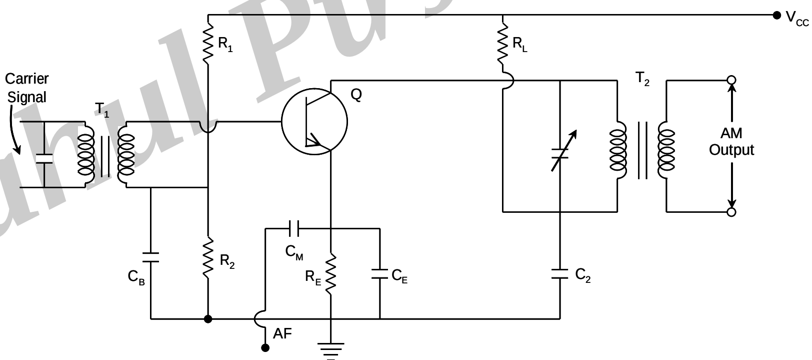
Ans :

An amplitude modulated wave can be generated if the carrier wave is passed through an amplifier whose gain is controlled by the frequency of modulating signal.



4. How amplitude modulation is achieved ?

Ans :



The amplitude modulator is designed in common emitter configuration. The modulating signal is applied to emitter terminal of the transistor. 'Q' the carrier signal is applied to the base of the transistor. The resistor R_1 and R_2 provides proper biasing voltage. The bypass capacitors for carrier wave are C_B, C_c and C_E.

5. What are the limitations of AM ?

Ans :

1. Low Efficiency

The signal is present in side band frequencies. The useful power that is present in side bands are very small i.e., for 100% modulation only $\frac{1}{3^{rd}}$ of total power is used. Hence efficiency is very less.

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4. Lack of Audio Quality

To reproduce all signal upto 15 KHz, a band width of 30 KHz is needed. But the AM broadcasting station is assigned only 10 KHz bandwidth to minimize interference. Hence a modulating frequency of only 5 KHz is allotted which is insufficient to produce the music quality.

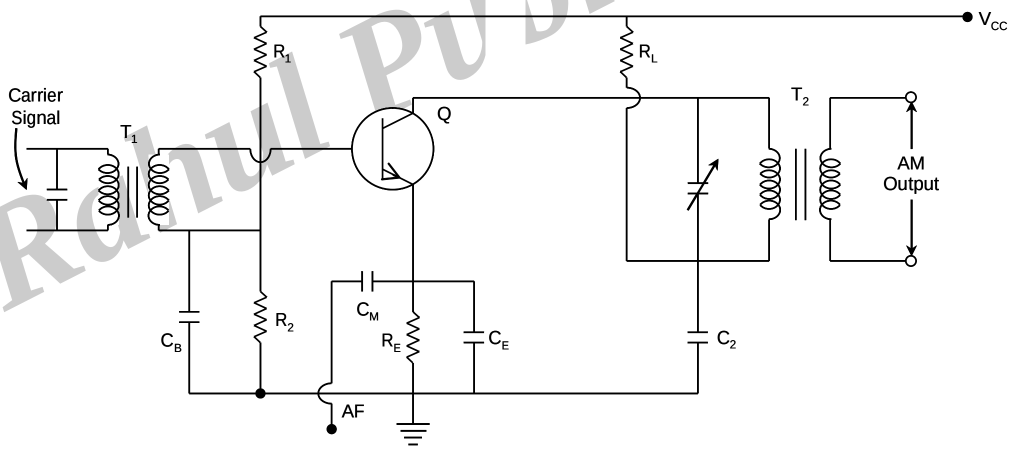
6. Why are the waves modulated in communication ?

Ans :

The waves are modulated in communication due to modulate a amplitude of any signal. Where frequency modulated wave is given its frequency at a particular channel. For transmitting and receiving on signals at various broadcasting & radio communication levels.

7. Draw the labelled circuit diagram of a simple amplitude modulator?

Ans :



The amplitude modulator is designed in common emitter configuration. The modulating signal is applied to emitter terminal of the transistor. 'Q' the carrier signal is applied to the base of the transistor. The resistor R_1 and R_2 provides proper biasing voltage. The by-pass capacitors for carrier wave are C_B, C_c and C_E.

8. What is demodulation ? Why after all it is essential ?

Ans :

The process of recovering a original signal from a modulated wave is known an demodulation. It is essential because to get back a low signal from a modulator circuit and its more efficient than modulated wave at where its signal is carried in different modulation signals i.e., AM, FM and PM.

9. Define modulation

Ans :

The frequencies in the audio range (20 Hz to 20KHz) is usually a speech or music signal. Since the energy is proportional to frequency the energy is very low to be transmitted over long distances. The power is very low to be radiated even if speech signal is converted into electrical signals.

The transmission can be accomplished by superimposing a high frequency wave called as carrier wave on the audio - frequency wave.

The method of raising the frequency of an audio frequency wave by super imposing it with a high frequency carrier wave is called Modulation. The net wave after modulation is called modulated wave.

10. State the various types of Modulation.

Ans :

(i) Amplitude Modulation (AM) : If the amplitude of the carrier wave is change in accordance to the audio frequency signal while its frequency and phase is constant is called amplitude modulation.

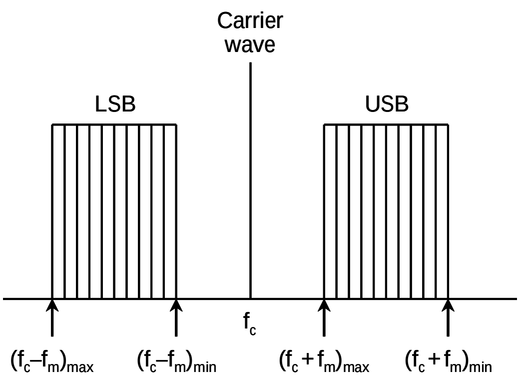
(ii) Frequency Modulation (FM) : The process by which if the frequency of the carrier wave is changed in accordance with AF signal while its amplitude and phase is constant is called frequency modulation.

(iii) Phase Modulation (PM) : The modulation in which if the phase of the carrier wave is changed in accordance with AF signal while in frequency and amplitude is constant is called phase modulation.

11. Explain concept of Side Bands.

Ans :

The signal after modulation is not perfectly sinusoidal in nature, instead it consists of closely spaced frequency components on either side of the carrier wave. They are known as side bands. The band on the higher frequency region is called upper side band (USB) and the frequency on lower side is called lower side band (LSB).



- The USB contains sum of frequency of signal components and carrier components.
- The LSB contains difference of frequency of signal and carrier components.

- The bandwidth is given by difference between extreme frequencies i.e., the maximum frequency of USB and minimum frequency of LSB.

  i.e., $(f_c + f_m)_{max} - (f_c + f_m)_{max}$

  $B.W = fc_{max} + fm_{max} + fc_{max} + fm_{max}$

  $B.W = 2fm_{max}$

  BW = 2 × maximum frequency of modulating signal.

  The bandwidth is also called as channel width

12. Define Band width.

Ans :

The expression for bandwidth of AM signal is,

$B.W = 2f_m$. .....(1)

Where,

f_m – modulating frequency.

The general expression for modulating signal $V_m(t)$ is,

$V_m(t) = V_m \sin \omega_m t$ ......(2)

$\omega_m = 628$

$\Rightarrow 2\pi f_m = 628 \quad (\because \omega = 2\pi f)$

$\Rightarrow f_m = \frac{628}{2\pi}$

$\therefore f_m = 100$ Hzz

13. Modulation index .

Ans :

The modulation index denoted as 'm' specifies the extent to which the carrier wave changes. It also specifies the quality of the signal to be transmitted. The modulation index has many definition and are as follows :

It is defined as the ratio of change in the amplitude of carrier wave to the amplitude of normal carrier wave.

$$m = \frac{\text{Change in amplitude of carrier wave}}{\text{Amplitude of normal carrier wave}}$$

(or)

It is defined as peak value of modulating signal to peak value of carrier wave.

$$m = \frac{\text{Maximum value of modulating signal}}{\text{Maximum value of carrier signal}}$$

Percentage modulation is given by the formula

$$m\% = \frac{E_{c(max)} - E_{c(min)}}{E_{c(max)} + E_{c(min)}} \times 100$$

Choose the Correct Answer

1. In amplitude modulation amplitude of modulated wave varies as [a]

   (a) Amplitude of modulating wave (b) Frequency of modulating wave

   (c) Amplitude of carrier wave (d) Frequency of carrier wave

2. In amplitude modulation, band width is ______ [b]

   (a) Equal to the audio signal frequency

   (b) Twice of the audio signal frequency

   (c) Thrice of the audio signal frequency

   (d) Four times the audio signal frequency

3. In modulation, ratio - frequency waves are used as carrier waves because they [d]

   (a) Are undamped (b) can contain more power

   (c) travel faster (d) Require small transmitting antenna

4. Modulation factor of an AM wave depends upon [a & c]

   (a) signal amplitude (b) signal frequency

   (c) carrier amplitude (d) carrier frequency

5. For a given carrier wave maximum undistorted power is transmitted when modulation is ______ [c]

   (a) 0% (b) 50%

   (c) 100% (d) 150%

6. For modulation factor m, the power of amplitude modulated wave is proportional to ______ [b]

   (a) $\frac{E_C^2}{2}(1 + m^2)$ (b) $\frac{E_C^2}{2}\left(1+\frac{m^2}{2}\right)$

   (c) $E_C^2\left(1+\frac{m^2}{2}\right)$ (d) $E_C^2(1 + m^2)$

7. In an AM wave, the useful power is carried by ______ [b]

   (a) carrier (b) side bands

   (c) both carrier and side bands (d) upper side band only

8. If M is the depth of modulation is amplitude modulation, the magnitude of side bands is ______ [c]

(a) M times the carrier amplitude
(b) $M/4$ times the carrier amplitude
(c) $M/2$ times the carrier amplitude
(d) 2M times the carrier amplitude

9. A sinusoidal carrier voltage of frequency 1000 KHz is amplitude modulated by a band of frequencies from 0 – 5 KHz. The USB and LSB will have frequencies [c]

(a) 1005 KHz and 1000 KHz
(b) 1010 KHz and 995 KHz
(c) 1005 KHz and 990 KHz
(d) 1000 KHz and 995 KHz

10. An amplitude detector detects ______ [d]

(a) Average value of carrier signal
(b) Peak value of carrier signal
(c) Peak value of the modulating signal
(d) Envelope of the modulating signal

Fill in the blanks

1. Modulation is done to transmit _______ signal to long distances.
2. For direct transmission of intelligence, the required transmitting antenna would be _______.
3. In an amplitude modulated wave, there are altogether _______ frequencies, known as _______ frequency, the _______ frequency and the _______ frequency.
4. Distortion takes place if modulation is _______ 100%.
5. The required bandwidth for transmission of a AM signal is _______ the highest modulating frequency.
6. In amplitude modulation, carrier _______ is changed but not its _______.
7. The _______ degree of modulation, the stronger and clearer will be the audio signal.
8. When m = 0, power carried by side bands is equal to _______.
9. For 100% modulation side bands carry _______ percent of AM power.
10. All transmitted intelligence is in _______ in amplitude modulation.

ANSWERS

1. Audio
2. Extremely large
3. Three, original carrier, lower side, upper side
4. More than
5. Twice
6. Amplitude, Frequency
7. Greater
8. Zero
9. 33.3
10. Side bands

UNIT IV

Frequency modulation: Analysis of FM**,** Working of simple frequency modulator, - detection of FM waves – FM Discriminator. Advantages of frequency modulation. AM and FM Transmitters and radio receivers [block diagram approach]. Introduction to PAM, PPM, PWM, and PCM, Delta modulation.

4.1 Frequency Modulation

4.1.1 Analysis of FM

Q1. What is Frequency Modulation?

Ans : **(June-19)**

A frequency modulation is a process in which the frequency of carrier wave is changed in accordance with the instantaneous amplitude of the modulating signal while the amplitude and phase of the carrier remains constant.

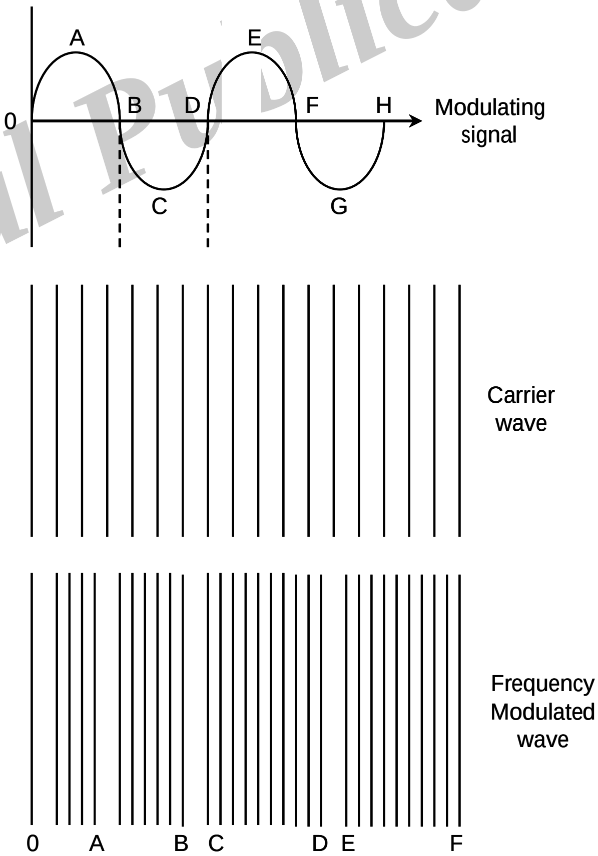


Fig. (a) Fig. (b) Fig. (c)

- When the modulating signal voltage is zero at '0', B, D, F and H the carrier frequency will be unchanged.

- The carrier frequency is maximum when modulating signal approaches the peaks A and F.
- The carrier frequency decreases to minimum at C and G.
- Hence the frequency of modulated carrier increases with increase in signal amplitude but decreases as signal amplitude decreases.
- The carrier frequency does not vary when modulating amplitude is zero. This frequency is called resting frequency.
- Louder the sound, greater is the frequency deviation.

Q2. Briefly explain frequency deviation of FM signal.

Ans :

A FM Radio broadcasting center broadcasts the signal at a fixed carrier frequency called resting frequency. This is the frequency when amplitude of modulating signal is zero when the modulating and carrier - signals are super imposed, the following phenomena is observed.

- There is a positive change in the carrier frequency when the modulating signal goes positive.
- The carrier frequency changes negatively when the modulating signal changes negatively.
- Hence the carrier frequency swings above or below the center frequency.

The swing either above or below the center frequency is called frequency deviation. It is denoted by Δf.

The carrier swing is the total change in frequency from lowest to highest frequency. Hence Carrier Swing (CS) = 2 × frequency – deviation

$$\boxed{CS = 2.\Delta f}$$

Note :

The FM broadcasting has maximum permissible value of frequency deviation of Δf = 75 KHz.

$$\therefore \left.\begin{array}{c}\text{FM Carrier Swing} \\ \text{(or)} \\ \text{FM Channel Width}\end{array}\right\} = 2 \times 75 = 150 \text{ KHz}$$

Modulation Index

The modulation index (m_f) for frequency modulation is defined as ratio of frequency deviation to the frequency of modulating signal.

$$m_f = \frac{\text{Frequency Deviation}}{\text{Modulating Frequency}}$$

$$\boxed{m_f = \frac{\Delta f}{f_m}}$$

Note :

- 'm_f' can have value less than or greater than unity.
- The value of 'm_f' specifies the significant bands and bandwidth

Deviation Ratio

It is defined as the ratio of maximum allowed frequency deviation (Δ_1 mx) to the maximum modulating frequency. It is the worst case of modulation index.

Hence $$\delta = \frac{\Delta_{f\ max}}{(f_m)_{max}}$$

Percentage Modulation

It is defined as the ratio of actual frequency deviation to the maximum frequency deviation

$$\text{Percentage Modulation} = \frac{(\Delta_f)\ \text{a actual}}{(\Delta_f)\ \text{max}}$$

Q3. Explain the analysis of FM wave.

Ans : **(June-19, June-18)**

The general expression for the instantaneous frequency 'f' of frequency modulated (FM) wave is,

$$f = f_c + k_f V_m \sin\omega_m t \quad \text{... (1)}$$

Where,

f_c – Unmodulated carrier frequency

k_f – Proportionality constant

$v_m \sin\omega_m t$ – Intantaneous modulating voltage.

For maximum deviation $\sin\omega_m t = \pm 1$, equation (1) becomes,

$$f = f_c + k_f V_m (\pm 1)$$

$$\Rightarrow \quad f = f_y \pm k_j V_m$$

Where,

$k_f v_m$ – Maximum deviation (δ_f).

The expression for the instantaneous amplitude of FM Signal is,

$$v_{FX} = Vc \sin [f(\omega_c, \omega_m)] \quad \text{... (2)}$$

Where,

$f(\omega_c, \omega_m)$ – Function of carrier and modulating frequencies.

Let, $f(\omega_c, \omega_m) = \theta$

Equation (2) can be written as,

$$V_{FM} = V_c \sin\theta \quad \text{... (3)}$$

Where θ is the angle traced by a vector v_c in time (t) as shown in figure.

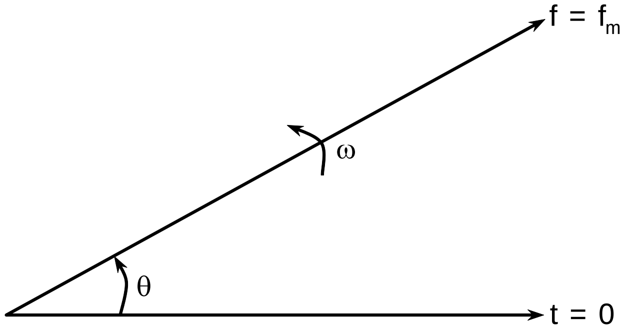


Figure: Frequency Modulated Vectors

Let the carrier voltage (v_c) rotates with constant angular velocity (ω).

On multiplying and dividing equation (1) by 2π, we get,

$$f = \frac{2\pi}{2\pi}\,[f_c + k_f v_m \sin \omega_m t]$$

$$\Rightarrow \quad 2\pi f = 2\pi f_c + 2\pi k_f v_m \sin \omega_m t$$

$$\Rightarrow \quad \omega = \omega_c + 2\pi k_f v_m \sin \omega_m t \qquad \ldots (4)$$

$$\text{But,} \quad 0 = \int \omega.dt \qquad \ldots (5)$$

On substituting equation (4) in equation (5), we get,

$$\theta = \int [\omega_c + 2\pi k_f v_m \sin \omega_m t]\, dt$$

$$= \int \omega.dt + \int 2\pi k_f v_m \sin \omega_m t.dt$$

$$= \omega_c \int 1.dt + 2\pi k_f v_m \int \sin \omega_m t.dt$$

$$= \omega_c t + \frac{2\pi k_f v_m - \cos \omega_m t}{\omega_m} \qquad \left[\begin{array}{l} \therefore \int 1.dt = 1 \\ \int \sin(nt)dt = \dfrac{-\cos nt}{n} \end{array}\right]$$

$$= \omega_c t + \frac{2\pi k_f v_m - \cos \omega_m t}{\omega_m}$$

[$\because$ θ is traced in the opposite direction of t]

$$= \omega_c t + \frac{2\pi \delta_f \cos \omega_m t}{2\pi f_m} \qquad \left[\begin{array}{c} \because \delta_f = k_f v_m \\ \text{and} \\ \omega_m = 2\pi f_m \end{array}\right]$$

$$\Rightarrow \qquad \theta = \omega_c t + \frac{\delta_f}{f_m} \cos\omega_m t \qquad \text{... (6)}$$

On substituting equation (6) in equation (3), we get,

$$V_{FM} = v_c \sin\left[w_c t + \frac{\delta_f}{f_m}\cos\omega_m t\right]$$

Where,

$\frac{\delta_f}{f_m}$ – Modulation index (m_f).

$$\boxed{\therefore v_{FM} = v_c \sin[\omega_c t + m_f \cos\omega_m t]} \qquad \text{... (7)}$$

Equation (7) represents the time domain equation for FM signal.

Q4. Explain Narrow Band Frequency Modulation (NBFM).

Ans :

The frequency modulation in which the value of modulation index 'β' is less than unity (i.e., $\beta << 1$) is referred as Narrow Band Frequency Modulation (NBFM).

The general form of frequency modulated (FM) wave is given by,

$$s(t) = A_c\cos[\omega_c t + (\beta \sin \omega_m t] \qquad \text{... (1)}$$

Where, β – Modulation index.

From equation (1),

$$s(t) = A_c \{\cos(\omega_c t)\cos(\beta(\sin\omega_m t)) - \sin(\omega_c t)\sin(\beta\sin(\omega_m t))\} \qquad \text{... (2)}$$

$$[\therefore \cos(A + B) = \cos A \cos B - \sin 4 \sin S]$$

Since in NBFM $\beta << 1$, hence the following approximations are made,

$$\cos(\beta(\sin\omega_c t)) \simeq 1 \text{ and}$$

$$\sin(\beta\sin(\omega_m t)) \simeq \beta\sin(\omega_m t) \qquad \text{... (3)}$$

On substituting equation (3) into equation (2), we get,

$$s(t) = A_c[\cos(w_c t) - b\sin(w_c t)\sin(w_c t)]$$

$$= A_c\{\cos\omega_c t + [\cos(\omega_c + \omega_m)f - \cos(\omega_c - \omega_m)t]\} \qquad \text{... (4)}$$

$$[\therefore 2\sin A \times \sin B = \cos(A - B) - \cos(A + B)]$$

Taking Fourier transform of equation (4), we get,

$$S(f) = \frac{A_c}{2}[\delta(\omega - \omega_c) + \delta(\omega + \omega_c)] + \frac{A_c\beta}{4}[\delta(\omega - (\omega_c + \omega_m)) + \delta(\omega_c + (\omega_c + \omega_m)] - \frac{A_c\beta}{4}$$

$$[\delta(\omega - (\omega_c - \omega_m) + \delta(\omega + (\omega_c - \omega_m))] \quad [\therefore F.T(\cos\omega_c t) = \frac{1}{2}\delta(\omega - \omega_c) + \delta(\omega + \omega_c)]$$

The spectra of NBFM is as shown in figure.

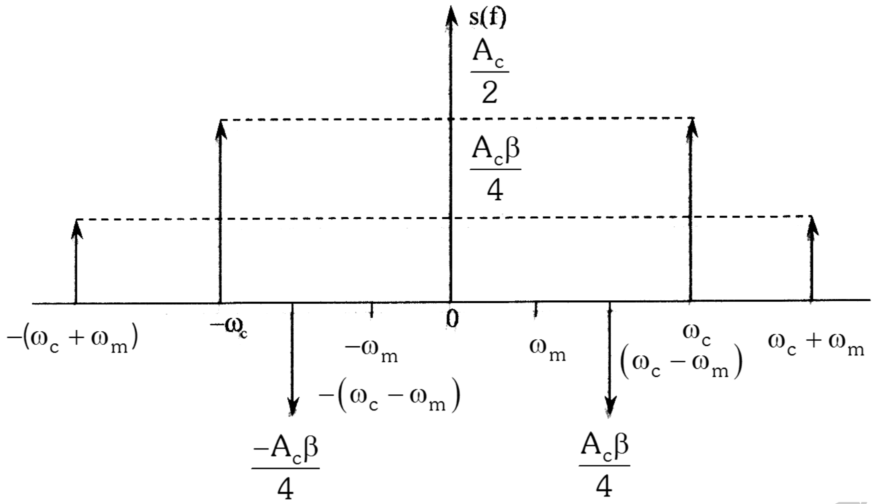


Fig.: Spectra of NBFM

The equation (4) of NBFM is similar to the equation of an AM wave except the second component which is positive in cas7 of AM and is negative in case of NBFM.

Q5. Explain Wide Band Frequency Modulation (WBFM).

Ans :

The frequency modulation in which the value of modulation index 'β' is greater than unity (i.e., $\beta >> I$ is referred as wide band frequency modulation. The spectra of a WBFM can be obtained from the spectral analysis of sinusoidal signal.

Consider, the FM wave generated by a sinusoidal modulating wave,

i.e., 5(0 = $A_c \cos[2\pi f_c t + \beta \sin(2\pi t f_m t)]$ ...(1)

Equation (1) can be rewritten as,

$$s(t) = \text{Re}\left[A_c e^{(f 2\pi f_c t + f\beta \sin(2\pi f_m t))}\right]$$

$$= \text{Re}\left[\tilde{S}(t) e^{f 2\pi f_c t}\right] \quad ...(2)$$

Where, $\tilde{S}(t)$ – Complex envelope of the FM wave s(t).

i.e., $\tilde{S}(f) = A_c e^{f\beta \sin(2\pi f_m f)}$ ... (3)

Equation (3) represents that, it is a periodic function of time with fundamental frequency f_m.

Equation (3) can be expanded in the form of a complex Fourier series,

i.e., $\tilde{S}(t) =$ 5(0 $= \sum_{n=-\infty}^{\infty} C_n e^{f 2\pi n f_m t}$ ...(4)

Where, C_n – Complex Fourier coefficient.

$$C_n = f_m \int_{-1/2f_m}^{1/2f_m} \tilde{S}(t)e^{(-f2\pi n f_m t)dt}$$

$$= f_m A_c \int_{-1/2f_m}^{1/2f_m} e^{f\beta \sin(2\pi f_m)} e^{-f2\pi n f_m)dt} \quad [\therefore \text{ From equation (3)}]$$

$$= f_m A_c \int_{-1/2f_m}^{-1/2f_m} e^{f\beta \sin(2\pi f_m t) - f2\pi n f_m tdt}$$

On substituting 0 = 2nfj in equation (5), we get,

$$C_n = \frac{A_c}{2\pi} \int_{-\pi}^{\pi} e^{f(\beta \sin\theta - n\theta)} d\theta \qquad ...(6)$$

The integral of equation (6) represents the «th order Bessel function of the first and argument 'P' is usually indicated by the symbol J_n (β) i.e.,

$$J_n(\beta) = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{f(\beta \sin\theta - n\theta)} d\theta \qquad ...(7)$$

On substituting equation (7) into equation (6), we get, ...(8)

$$C_n = A_c J_n(\beta)$$

On substituting equation (8) into equation (4), we get,

$$\tilde{S}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) e^{f2\pi n f_m t} \qquad ...(9)$$

On substituting equation (9) into equation (2), we get,

$$S(t) = A_c \text{Re}\left[\sum_{n=-\infty}^{\infty} J_n(\beta) e^{[f2\pi(f_c + nf_m)t]}\right]$$

$$\tilde{S}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos[2\pi(fc + nf_m)t]$$

Equation (10) indicates the Fourier series representation of the single-tone FM wave s(t).

By applying the Fourier transform on both sides of equation (10), we get,

$$S(f) = \frac{A_c}{2} \sum_{n=-\infty}^{\infty} J_n(\beta)[\delta(f - f_c - nf_m) + \delta(f + f_c + nf_m)]$$

For $\beta = 4$, the resultant spectrum is shown in figure.

Equation (10) can be expanded as,

$$\tilde{S}(t) = A_c J_\upsilon(\beta) \cos(2\pi f_c t) + A_c[J_1(\beta) \cos\{(2\pi f_c t + 2\nu f_m)t\} + J_{-1}(\pi) \cos\{(2\pi f_c - 2\pi f_m t\}]$$

$$+ A_c [J_2 (\pi) \cos\{(2\pi f_c + 2(2\pi f_m\} + J_{-2}(\beta) \cos\{(2\pi f_c - 2(2\pi f_m t\}] + ... \qquad ...(11)$$

From the second property of Bessel function, we get,

When n is even, $J_{-n}(\beta) = J_n(\beta)$

When n is odd, 7_n (P) = - J (P) ...(12)

By substituting equation (12) in equation (11), we get,

$$\tilde{S}(f) = A_c J_0(\beta) \cos(\omega_c t) + A_c J_1(\beta) [\cos\{(\omega_c + \omega_m)t\} - \cos\{(\omega_c - \omega_m)t\}] + A_c J_2(\beta) [\cos\{(\omega_c + 2\omega_m t\} + \cos\{(\omega_c t - 2\omega_m)t\}] + A_c J_3(\beta) [\cos\{(\omega_c + 3\omega_{c)} t - \cos\{(\omega_c - 3\omega_c t\}] + ...$$

$$[\therefore \omega_c = 2\pi f_c, \omega_c = 2\pi f_m]$$

The spectrum of a single-tone FM signal in terms of the Bessel function is as shown in figure.

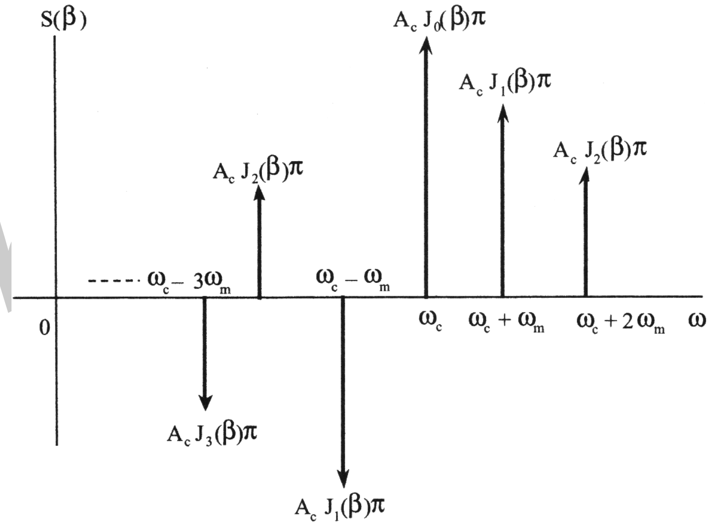


Fig.: Figure: Spectrum of a Single-tone FM Signal in Terms of the Bessel Function $J_n(\beta)$

Q6. Distinguish between Narrow band FM and wideband FM. Mention their specific applications.

Ans :

Sl.No.	Wide Band Frequency Modulation (WBFM)	Sl.No.	Narrow Band Frequency Modulation (NBFM)
1.	The frequency modulation in which the modulation index is greater than unity (i.e., b > > 1) is referred as wide-band frequency modulation.	1.	The frequency modulation in which the modulation index is less than unity (i.e., b < 1) is referred as narrow-band frequency modulation.

2.	The wide band FM signal is given as, $S(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos[2\pi(f_c + nf_m)t]$.	2.	The narrow band FM signal is given as, $S(t) = Ac \cos[(2\pi f_c(t) - \beta A_c \sin(2\pi f_c t) \sin(2\pi f_m t)]$.
3.	The spectrum of WBFM signal consists of infinite two number of sidebands and carrier.	3.	The spectrum of NBFM signal consists of sidebands and carrier.
4.	The modulation index of WBFM at maximum frequency is 5.	4.	The modulation idex of NBFM at maximum frequency is 1.67.
5.	The bandwidth of a WBFM is given by $BW = 2(\delta + f_m(max))$.	5.	The bandwisth of a NBFM is given by, $BW = 2f_m$
6.	Maximum frequency deviation in WBFM is 75 kHz.	6.	Maximum frequency deviation in NBFM is 5 kHz.

4.2 WORKING OF SIMPLE FREQUENCY MODULATOR

Q7. Draw the block diagram of FM transmitter using reactance method and explain its working.

(OR)

Explain the direct method of FM generation.

Ans : **(Nov.-20)**

FM Transmitter using reactance employs a reactance tube modulator for generation of FM waves. It is also known as direct method of FM generation.

The block diagram of FM transmitter using reactance method is as shown in figure.

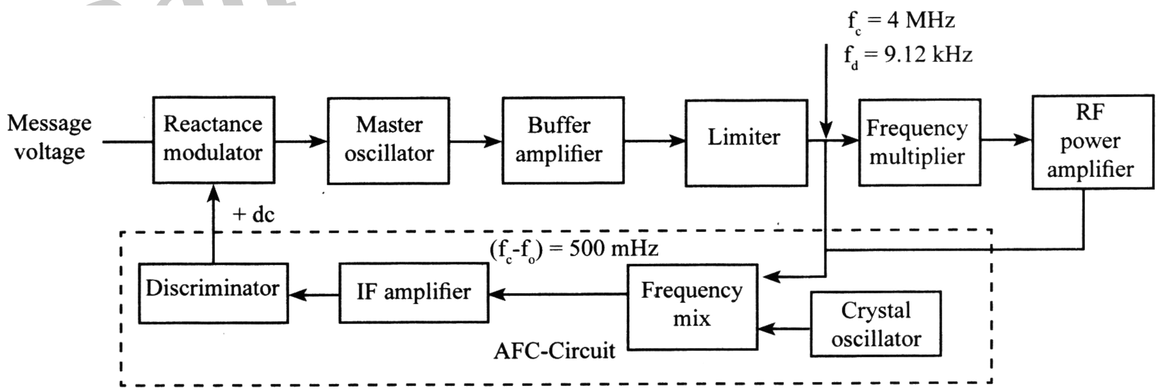


Figure: FM Transmitter Using Reactance Modulation

(i) Reactance Modulator

A reactance modulator circuit is used for generating frequency modulated waves. The input to this circuit is an audio signal which is to be frequency modulated. A reactance modulator can either be a varactor diode or a field effect transistor (FET). This circuit supplies a voltage variable reactance to the LC oscillator which deviates the oscillator frequency with respect to the amplitude of modulating signal.

(ii) LC Oscillator

The LC (inductive - capacitive) oscillator is used for producing centre carrier frequencies. The output of this circuit is fed to a series of frequency multipliers for multiplying frequency deviations.

(iii) Frequency Multipliers

Frequency multipliers in FM transmitters are essentially a chain of class C amplifiers, which multiplies the deviations of FM signal. Along with multiplication of frequency deviations, the multiplier also performs amplification of the centre carrier frequency obtained from the LC oscillator.

(iv) Automatic Frequency Control (AFC) Circuit

In direct FM transmitters, frequency of oscillator is directly varied, due to which stable frequencies cannot be produced. To overcome this instability issue, an automatic frequency control (AFC) circuit is employed. The main function of this circuit is to maintain stable carrier frequency.

The various blocks involved in AFC circuit are,

(a) Crystal Oscillator

A crystal oscillator is employed generally to produce stable carrier frequency.

(b) Mixer

A mixer circuit is used for combining the high carrier frequency obtained from the frequency multiplier with the stable carrier frequency obtained from the crystal oscillator. The output of this circuit is the sum and difference of the two frequencies applied.

(c) Amplifier

The amplifier performs amplification of the frequencies obtained from the mixer and passes it to the discriminator circuit.

(d) Discriminator

A discriminator is generally tuned to a correct frequency difference that lies between the LC oscillator and crystal oscillator. The higher frequency applied to the discriminator is corrected by the circuit and is obtained in the form of a positive d.c. voltage. The d.c voltage obtained is fed to the reactance modulator for decreasing the oscillator frequency. This helps in achieving a stable carrier frequency at the output.

(v) Power Amplifier

The power amplifier used at the end of transmitting circuit is used for amplifying the power of the FM signal and is finally fed to the transmitting antenna.

4.3 Detection of FM Waves

Q8. Discuss in detail about FM demodulation.

Ans :

Detection (or demodulation) is the process of recovering original modulating signals from the modulated waves.

Since an FM carrier signal contains information in the form of frequency variations above and below the centre frequency of the carrier, it is essential that these frequency variations be converted first into voltage variations. For it, use is made of the fact that the reactance of a coil or capacitor varies with frequency. When an FM signal is applied to an inductor, the current through the inductor, varies in amplitude according to the changes in frequency of the applied signal which in turn depends upon the amplitude of the modulating AF signal. Thus frequency changes in FM signal are convert into amplitude changes in current which when passed through a resistor produce corresponding changes in voltages.

In this way, the frequency variations in FM signal are converted into voltage changes and there exists a linear relationship between the two.

4.3.1 FM Discriminator

Q9. Discuss the operation of FM discriminator.

(OR)

Give the analysis of frequency modulation. Describe the working of FM Discriminator with circuit diagram.

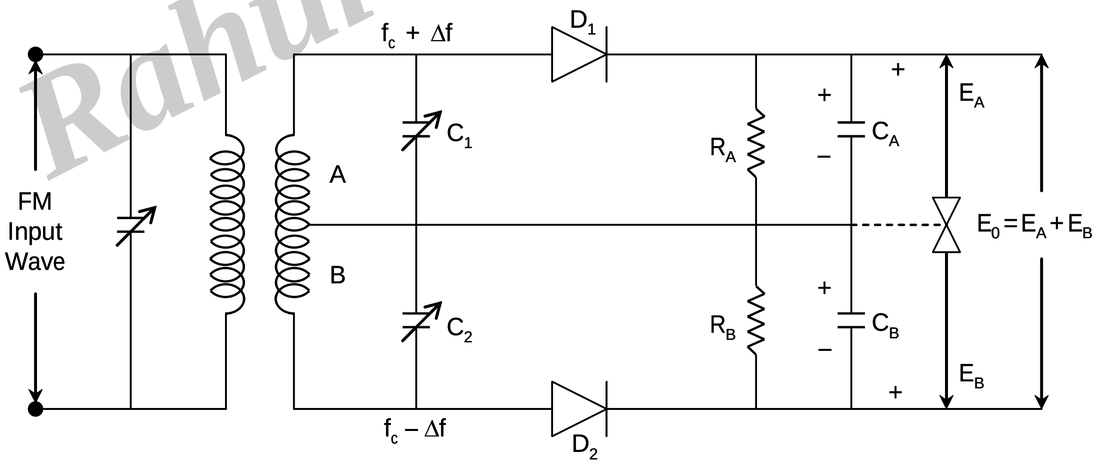
Ans : **(June-19, June-18)**

An FM detector performs the function of recovering original information signal from frequency modulated wave. The demodulation process involves two steps.

1. The FM wave is changed to corresponding AM wave. The frequency deviation is converted into amplitude variation. This amplitude variation is identical to one it has caused the frequency deviation.
2. The AM wave contained after conversion is given in linear detector to extract the original signal.

The obtain the FM demodulation a circuit called as discriminator is used.

Double Tuned Discriminator



The circuit consists of two slope detectors. It eliminates the distortions present in signel tuned discriminator. It consists of primary coil which is tuned to centre frequency 'f_c'. The tuned circuit 'AC_1' is tuned to $f_c + \Delta f$ and the 'AC_2' is tuned to $f_c - \Delta f$.

Operation :

1. When the incoming signal frequency 'f_c'. Both the resonant circuits will be at 'Δf'. Hence the variation in the output will be equal and opposite ($E_A - E_B$) and as a result $E_0 = 0$.

2. When incoming signal frequency is greater than 'f_c' the signal frequency deviates towards (f_c + Δf). As a result E_A becomes greater than E_B and the output goes positive.

3. Similarly when incoming signal frequency is lesser than 'f_c', the signal frequency deviates toward $f_c - \Delta f$. Hence E_B becomes greater than E_A and the output goes negative.

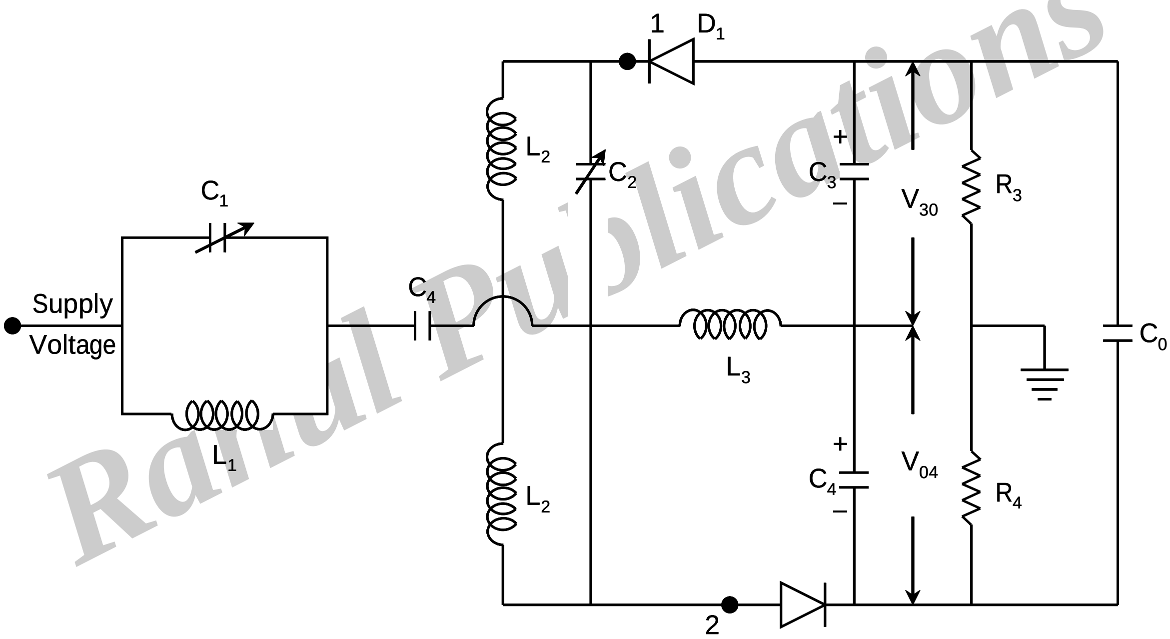
Advantages :

- Good linearity is provided.

Disadvantages :

- No amplitude limiter is provided.
- Adjustment of transformer to various tuned frequencies is difficult.

Ratio Detector



The circuit diagram represents a ratio detector. Two important changes are made in the discriminator circuit.

- One diode is reversed.
- An electrolytic capacitor 'C' has been introduced across the resistors R_3 and R_4.

Operation :

1. All the center frequency 'f_c' let the voltage across capacitor 'C_3' is given by V_{30} = –V and the voltage across 'C_4' is given by V_{04} = –V. Thus the output potential at centre frequency is given by V_0 = –V –V = –2V.

2. If the input frequency varies slightly from centre frequency 'f_c' then V_{30} and V_{04} changes by equal amounts i.e., V_{03} changes to –V + ΔV and V_{04} to –V + ΔV. and V_{04} to –V – ΔV. The new output potential is

$V_0' = (-V + \Delta V) + (-V - \Delta V) = -2V$

$V_0' = -2V.$

Hence output remains unchanged.

3. Since the sum of voltage across C_3 and C_4 remains constant, their ratio depends on signal frequency. Hence it is called as ratio detector.

Advantages :

1. Noise free output.
2. Requires fewer components.
3. It requires no limiter due to which small signal air rejection is improved.

4.4 AM AND FM TRANSMITTERS

4.4.1 Advantage of frequency modulation

Q10. State the advantages of frequency modulation.

Ans : **(June-18)**

- As most of noise is amplitude based this can be removed by running the signal through a limiter, so that only frequency variation appear.
- It does not suffer audio amplitude variation as the signal level varies and it makes, FM ideal for use in mobile application where signal level constant.
- In FM, recovered voice depends on frequency and not amplitude. Hence the efficiency of noise are minimum.
- It covers all the frequency range which human can hear. Hence FM ratio has better quality of sound in comparison with AM ratio.
- It gives noisless reception, noise is a form of amplitude Variation and a FM receiver will reject such noise signal.
- Operating range is quite large.
- The efficiency of transmission is very high.

Q11. State the disadvantages frequency modulation.

Ans :

1. The bandwidth of FM is much larger than that of AM.
2. The bandwidth of FM can be reduced by decreasing the modulation index, which intum decreases the noise immunity.
3. In FM, the range of communication is limited only at UFLF, VHF and microwave frequencies.
4. Transmitters and receivers employing FM are more complex and expensive than that of AM.

Q12. Draw the block diagram of low level modulation transmitter and explain its operation.

(OR)

Draw the block diagram of low level AM transmitter and write the function of each block.

Ans :

A low level amplitude modulation (AM) transmitter performs modulation at lower levels of power. The block diagram of a low level AM transmitter is as shown in figure.

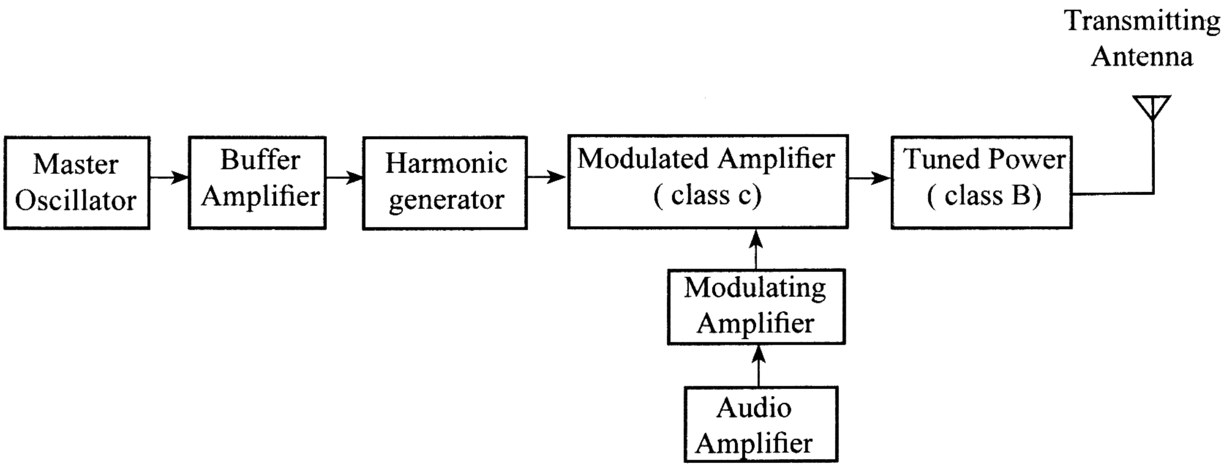


Fig.: Block Diagram of Low- level AM Transmitter

(i) Master Oscillator: A crystal controlled oscillator is used as master oscillator. It generates a carrier signal of desired frequency. If the master oscillator is connected directly to the harmonic generator, certain amount of power is drawn from the master oscillator. This in turn results in loading which causes frequency variations in the tank circuit of master oscillator. To avoid this, a buffer amplifier is employed, which does not draw any power from the oscillating circuit.

(ii) Buffer Amplifier: A buffer amplifier matches the output impedance of the master oscillator with the input impedance of harmonic generator. It avoid the loading effect. Further, it isolates the carrier oscillator from harmonic generator.

(iii) Harmonic Generator: Harmonic generator is a multiplier circuit which comprises of a class C amplifier and a tuned circuit. It is generally employed to generate harmonic frequency involves. The generation of harmonic frequency involves,

(a) The distortion of output R.F (radio frequency) voltage, using class C amplifier,

(b) Timing of output amplifier circuit, using a tuned circuit, in order to select the desired harmonic frequency.

(iv) Audio Amplifier: Audio amplifier is a small signal amplifying circuit, used to increase the strength of modulation signal applied at its input terminal.

(v) Modulating Amplifier: It is a class B push amplifier used for increasing the power level of modulating signal. The amplified output is then fed to the modulated amplifier.

(vi) Modulated Amplifier: A class C amplifier of push pull type is used as a modulated amplifier. The inputs to this circuit are: A carrier signal fed from the harmonic generator and a modulation signal obtained from the modulating amplifier. The amplifier performs modulation and produces an amplitude modulated signal at its output.

(vii) Tuned Power Amplifier: A tuned power amplifier is basically a class B power amplifier, used for increasing the power level of AM signal. The output from tuned power amplifier is finally fed to the transmitting antenna for effective radiation.

Q13. Draw block diagram for heterodyne AM transmitter and briefly explain its operation.

(OR)

Draw the block diagram of high level AM transmitter and explain the function of each block.

Ans :

A high level amplitude modulated (AM) transmitter, performs modulation at higher levels of power i.e., after the amplification process.

The block diagram of a high level AM transmitter is as shown in figure.

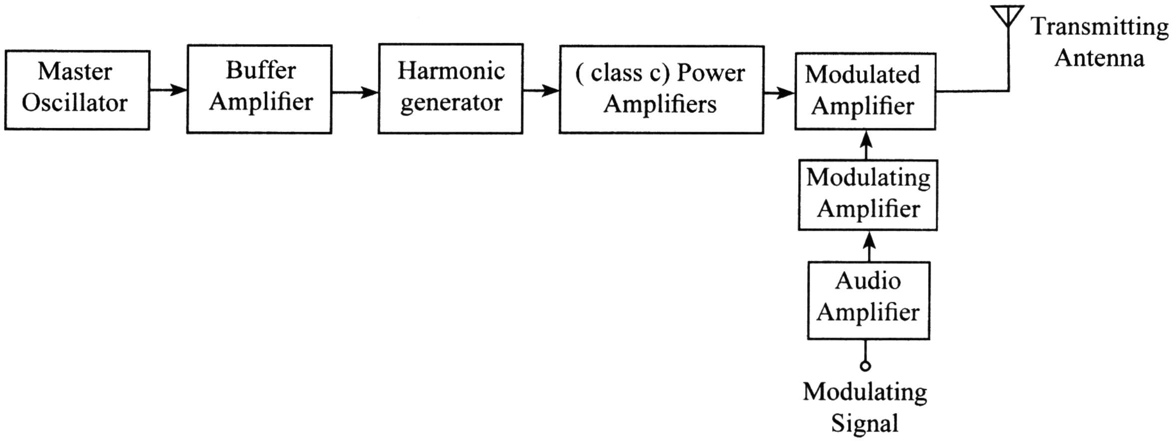


Fig.: Block Diagram of High Level AM Transmitter

(i) Master Oscillator: A crystal controlled oscillator is used as master oscillator. It generates a carrier signal of desired frequency. If the master oscillator is connected directly to the harmonic generator, certain amount of power is drawn from the master oscillator. This in turn results in loading which causes frequency variations in the tank circuit of master oscillator. To avoid this, a buffer amplifier is employed, which does not draw any power from the oscillating circuit.

(ii) Buffer Amplifier: It matches the output impedance of the master oscillator with the input impedance of harmonic generator. It avoid the loading effect. Further, it isolates the carrier oscillator from harmonic generator.

(iii) Harmonic Generator: It is a multiplier circuit which used to generate harmonic frequencies. It is the combination of a class C amplifier and a tuned circuit. It generates the desired harmonic frequency by distorting the RF voltage first, followed by the tuning of amplifier output circuit.

(iv) Class C Power Amplifier: The output carrier signal obtained from the master oscillator is of very low power. Therefore, to enhance the power level of carrier signal, a class-C power amplifier is employed. These amplifiers provide high efficiency of about 70%.

(v) Audio Amplifier: The signal to be modulated is fed as input to an audio amplifier. This audio amplifier circuit increases the strength of modulating signal.

(vi) Modulating Amplifier: A modulated amplifier is basically a class B push pull amplifier. It receives input from the audio amplifier and increase the power of modulating signal to a desired level.

(vii) Modulated Amplifiers: A modulated amplifier is a class C tuned amplifier of push- pull type. It is the highest power audio amplifier, which receives two inputs i.e., an amplifier carrier signal and an amplified modulating signal. These signals are modulated over the antenna.

Q14. Draw the block diagram of FM receiver. How does it differ from AM receiver.

(OR)

Draw the block diagram of FM radio receiver. Explain the significance of each block.

Ans : **(Nov.-20, June-18, Imp.)**

FM Receiver

The block diagram of an FM receiver is as shown in figure.

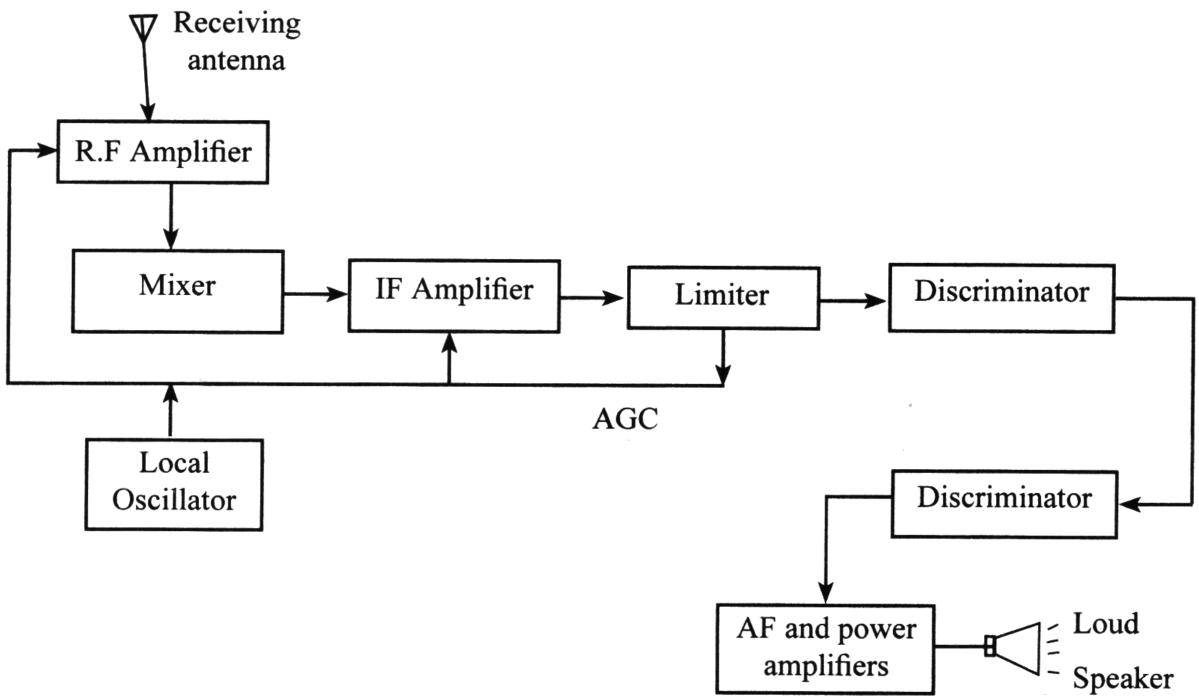


Fig.: Block Diagram of FM Receiver

1. RF Amplifiers

RF amplifiers select the desired signal and amplify them to the required level as the signal'coming to the antertna is in the order of microvolts. These are used in FM receivers to minimize the noise figure and to match the input impedance of the receiver with the impedance of antenna. These amplifiers increase the strength and feeds the amplified output to the mixer.

2. Local Oscillator

The local oscillator is used in FM receiver to generate carrier waves of frequency.

3. Mixer

A mixer is used to combine the RF amplified output with the output of local oscillator to produce a high intermediate frequency(IF). This high IF helps in attaining effective image rejection capability of a receiver.

4. IF Amplifier

IF amplifiers are used for amplifying intermediate frequencies. These amplifiers provide high gain and larger bandwidths of the order of 150 kHz.

5. Limiter

Limiter is a form of clipping device, in which the output remains constant irrespective of the variations in the input signal. FM receiver uses an amplitude limiter to clip off the amplitude variations present in the signal. As a result noise gets reduced without affecting the information content of the signal. The constant frequency modulated carrier is then applied to a discriminator circuit.

6. Discriminator

A discriminator or an FM detector, applied next to the limiter circuit, extracts the original audio frequency from the frequency modulated (FM) carrier.

7. De-Emphasis Network

A de-emphasis circuit is employed to reduce the high audio frequencies which are directly proportional to the frequencies of transmitter. These circuits also help in reducing the frequency - modulated noise which enters the front - end of the receiver.

8. AF and Power Amplifier

The audio frequency power amplifier accepts input from the de-emphasis network, amplifies the audio signal to a desired level. This amplified output is then fed to the loud speaker at the receiving end.

Q15. Explain the concept of radio broadcasting and reception.

Ans :

A radio broadcasting and reception is a process by which information or intelligent messages are sent, processed and received by means of radio waves. The 3 main function performed in radio communication are :

1. Broadcasting
2. Propagation
3. Reception

1. Broadcasting

The speech or music which is low frequency signals usually in the audio frequency range is converted into electrical amplitudes using microphone. These low frequency current in audio range is superimposed with high frequency carrier by process of modulation and is transmitted into space.

2. Propagation

The electromagnetic waves transmitted into space travels in all directions and is intercepted by receiving antenna.

3. Reception

The part of radio waves intercepted by the receiving antenna, the information signal is separated and passed to loud speaker. The loud speaker converts the electrical signal into the sound signals.

Q16. What are the differences between AM and FM ?

Ans :

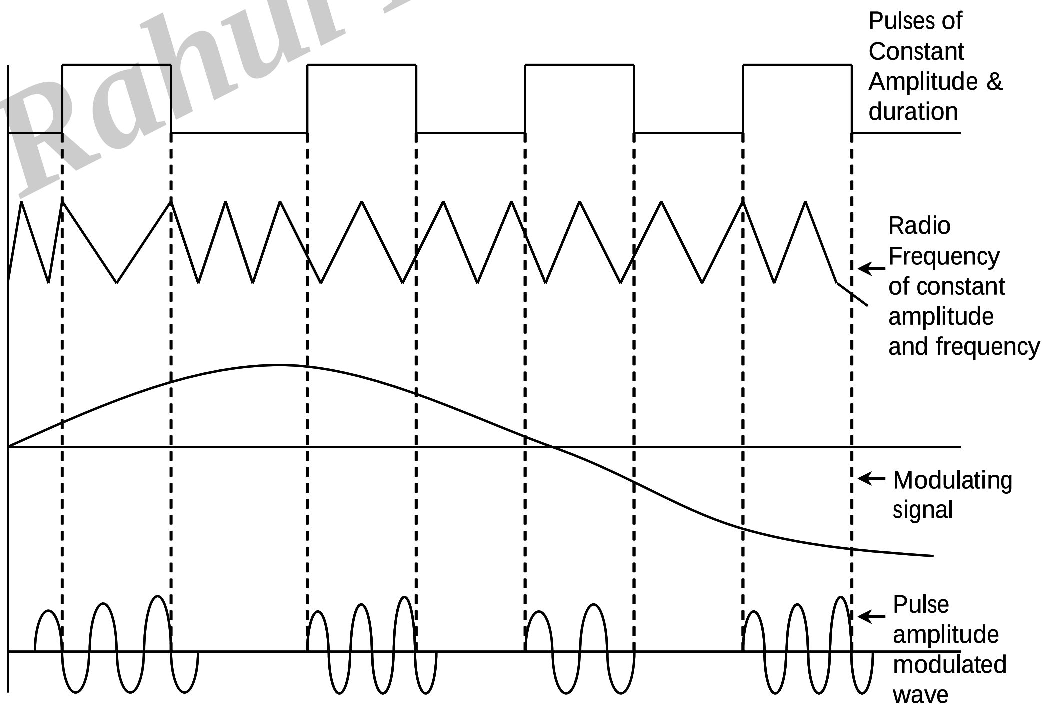
AM		FM	
1.	In AM, there is change in amplitude modulation w.r.t input signal.	1.	In FM, there is change in frequency modulation w.r.t to input signal.
2.	Here modulation index, $m_f = \frac{(\Delta m)_{max}}{(\Delta s)_{max}}$	2.	Here modulation index, $m_f = \frac{\Delta_f}{f_m}$
3.	Bandwidth of side band is BW = $2fm_{max}$	3.	Carrier swing of a signal is, CS = $2.\Delta f$
4.	Percentage of modulation is $m\% = \frac{\epsilon_{max} - \epsilon_{min}}{\epsilon_{max} + \epsilon_{min}} \times 100$	4.	Percentage of modulation is $m\% = \frac{(\Delta f)_{actual}}{(\Delta t)_{max}}$

4.5 Introduction to PAM, PPM, PWM, and PCM, Delta modulation

Q17. Write about PAM and PCM.

Ans : **(June-19)**

A PAM is a process in which the relative amplitudes of successive pulses serves as a measure of signal amplitudes at the sampling instants where width and position remains constant.



Classification

Pulse modulation can be broadly classified into two major types. They are,

(i) Analog pulse modulation

(ii) Digital pulse modulation.

(i) Analog Pulse Modulation

In analog pulse modulation technique amplitude or time of a carrier (consisting of pulse train) is varied in accordance with the instantaneous value of analog modulating signal.

Analog pulse modulation technique is further classified into two types namely.

(ii) Digital Pulse Modulation

In digital pulse modulation technique, analog modulation signal is converted into discrete signal by changing the amplitude of carrier pulse train. These discrete levels are then represented by digital codes for transmission. Digital pulse modulation technique is further classified into three types. They are,

(a) Pulse Code Modulation (PCM)

(b) Delta Modulation (DM)

(c) Continuous Variable Slope DM (CVSDM).

(a) Pulse Code Modulation (PCM): Pulse code modulation can be defined as a signal-encoding technique, where in an analog information signal is sampled and amplitude of these samples is approximated to the nearest value among the finite set of discrete levels. This approximation is carried out such that both amplitude and times is indicated in discrete format. PCM is further classified into Differential Pulse Code Modulation (DPCM). In this type of modulation, difference in the amplitude levels of two successive samples is transmitted instead of the absolute value of the actual sample.

(b) Delta Modulation (DM): Delta modulation is the simplest form of DPCM wherein difference between successive samples are encoded into data streams of «-bits. It employs single-bit DPCM code to digitally transmit analog signals.

It is further classified into Adaptive Delta Modulation (ADM) technique. ADM can be defined as a delta- modulation technique which varies step size of the signal, based on the amplitude characteristics of the applied analog signal.

(c) Continuous Variable Slope DM (CVSDM): Continuous Variable Slope Delta Modulation (CVSDM) can be defined as a type of delta modulation technique which employs continuously varying step size in transmission.

Figure (ii) illustrates the complete classification of pulse modulation technique.

➢ The modulating signal is sampled at a basic rate of $\frac{1}{2}$ f_m where 'f_m' is maximum value of frequency present in the modulating signal.

- The amplitude modulated pulses modulate the radio frequency carrier.
- The AM radio frequency output is transmitted in the form of short bursts.
- The duration of each burst is equal to duration of pulse.
- Instantaneous amplitude of each radio frequency burst is proportional to the auto frequency signal.

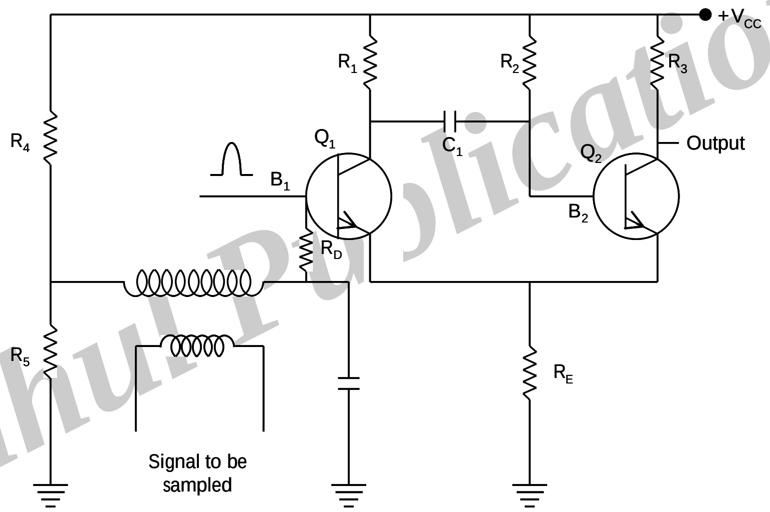
Advantages :

- Greater peak power
- Signal-to-noise ratio is improved.

Q18. Explain with a neat diagram explain the generation and demodulation of pulse width modulation.

Ans : **(Nov.-20)**

The process is which the width of the pulse is varied in accordance with the modulating signal where as amplitude and positions are fixed.

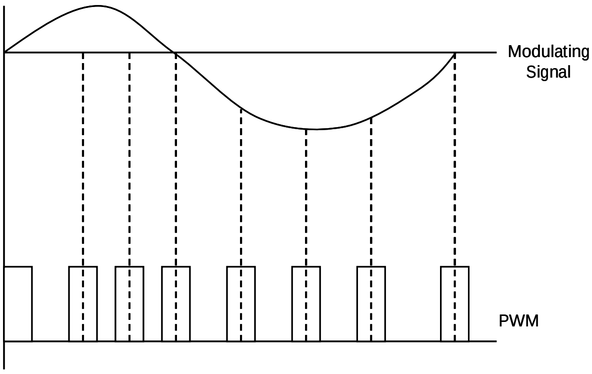


An emitter coupled multivibrator generating pulse width modulation is shown. A triggering pulse controls the start time of the output pulses and the duration of it is controlled signal that is required to be sampled is applied to base of 'Q_1' through resistance 'R_b.

Operation

- Initially consider the stable state of Q_1 – OFF and Q_2 – ON
- A triggering pulse applied at the base of transistor Q_1 starts conducting.
- The voltage of 'A' drops since 'Q_1' draws collector current.
- This fall of voltage of 'A' is applied to base of 'Q_2'. This makes emitter less positive with respect to ground.
- Therefore 'Q_1' conducts more making 'B_2' more negative.
- Hence 'Q_2' gets cutoff and 'Q_1' remains in condition.
- When 'Q_2' is cutoff, capacitor 'C_1' begins to change towards $+V_{CC}$ through 'R_2'.
- The voltage across 'C_1' increased making 'B_2' sufficiently positive.

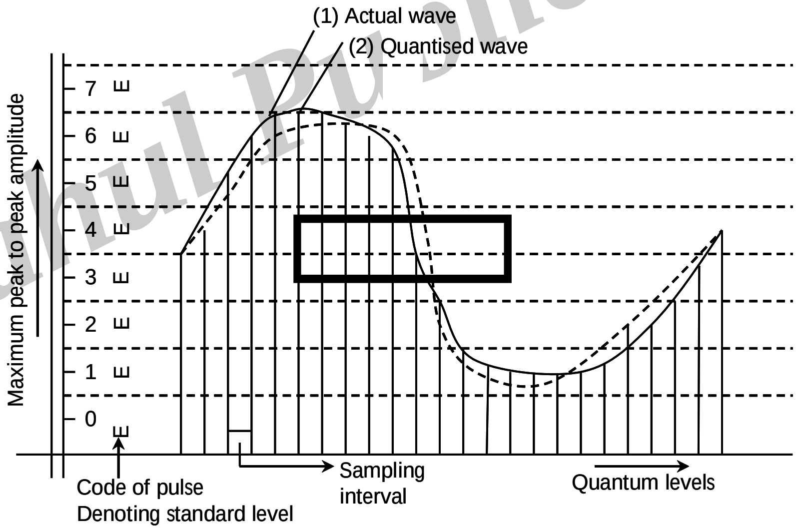
- There Q_2 starts conducting and 'Q_1' is cutoff.
- Thus the output varies in accordance width modulating signal.



Q19. Explain the process of coding and decoding in PCM.

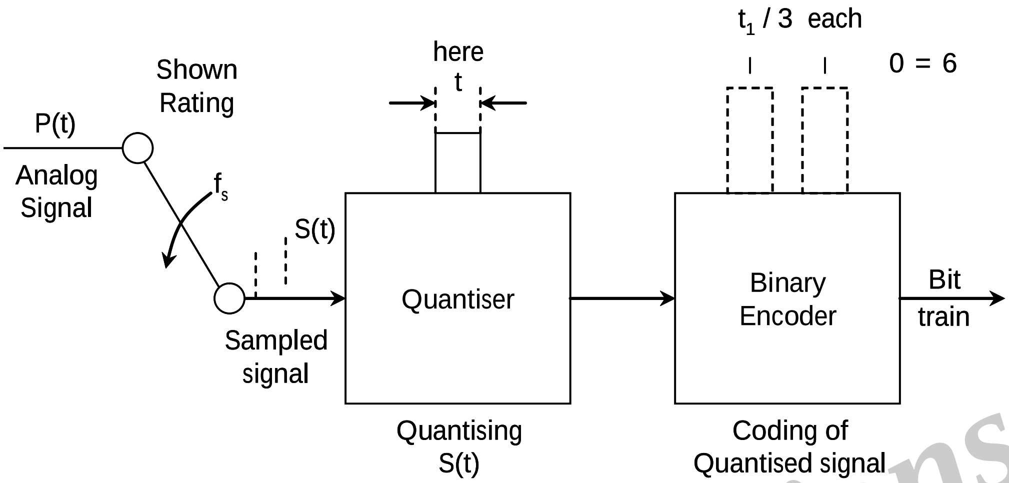
Ans :

A PCM is a process is which the signal is first sampled and the sampled amplitude is selected in the nearest standard amplitude called quantisation. The standard amplitude is represented interms of code of pulses and is then transmitted.



- The signal is sampled at an interval 't' and is usually small to get more number of samples.
- The actual amplitude of sampled signal is quantised to nearest standard amplitude.
- For example 'b' in the figure is the nearest standard amplitudes of 'a'.
- The distortions in the quantization process is minimized by increasing number of standard amplitudes.
- The selected amplitude is indicated by a code of pulses (0 to 7) as shown in the figure represented by 3 pulse code (000 to 111).
- Therefore a group of pulses represented in binary from is corresponding to analog modulating signal is transmitted.

The PCM transmission system is



- The analog signal p(t) is sampled periodically at a rate of 'f_s' samples per second.
- The sampled signal is then quantised at a sampling interval of 't_1' seconds each.
- The quantised signal is then transmitted after it is encoded to suitable binary pulses.

Disadvantages :

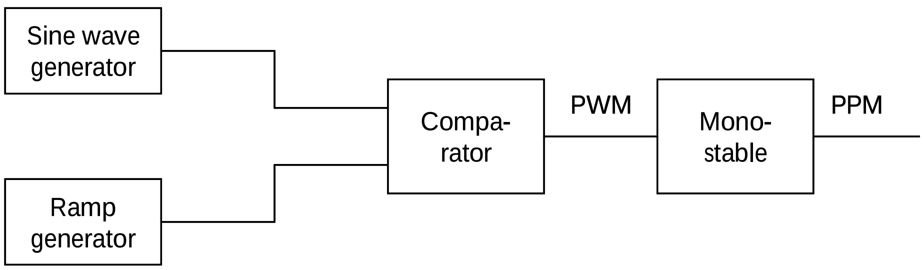
- It requires large bandwidth i.e., for a speech signal of 3.2 KHz to be transmitted using a sampling frequency of 8 KHz and if the system have 128 quantising levels. The number of bits required are 2^n = 128 and hence n = 7 bits. Hence the total bit rate is 7 × 8 = 56 Kbps.

Q20. Explain in briefly about the generation and modulation of PPM signals.

Ans : **(Nov.-20)**

It is a form of signal modulation is which 'M' messages bits are enclosed by transmitting a single pulse in one of possible required time shifts.

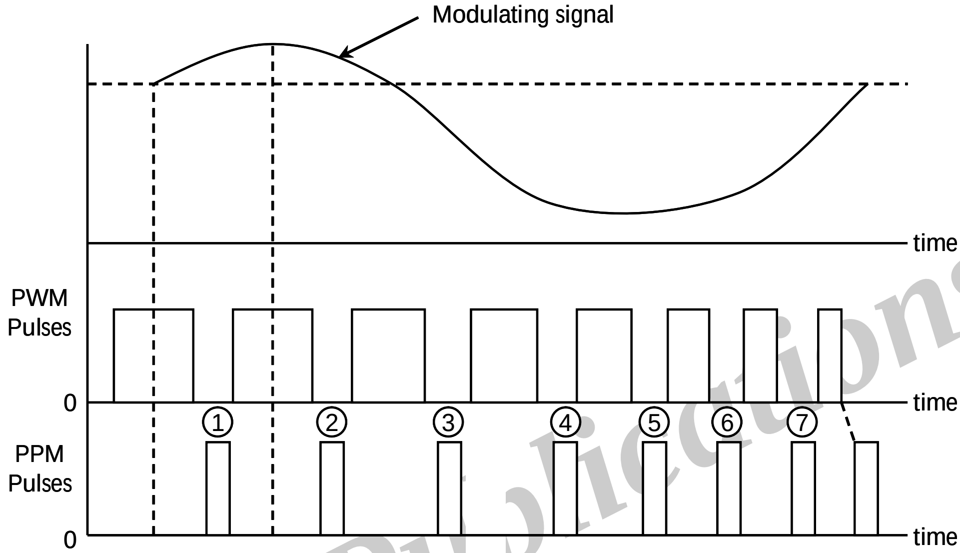
This is repeated for every T seconds, such that the transmitted bit rate is bits/seconds.



The above block diagram shows the PPM modulation system. It consist of sine wave generator, ramp generator, comparator and monostable multivibrator.

In PPM, the emplitude and width of the pulses in kept constant but the position of each pulse is varied in accordance with the amplitude of the sampled value of the modulating signal.

The position of the pulses is changed with respect to the position of reference pulses. PPM pulses can be derived from the PWM pulses with increase in the modulating voltage.



The vertical dotted lines drawn in above figure are treated as reference lines to measure the shifts in position of PPM pulses the PPM pulses marked 1, 2 and 3.

If the increase in modulating signal amplitude then as the modulating voltage decrease the PPM pulses 4, 5, 6, 7 closer to reference line.

Q21. Distinguish between PAM, PWM and PPM.

Ans :

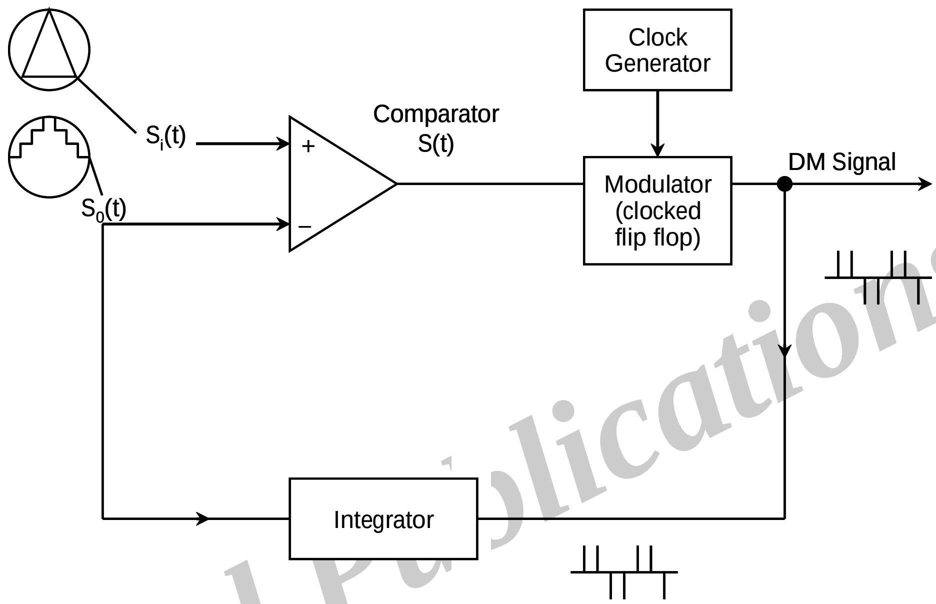
Difference between PAM, PPM and PWM is mentioned in table,

S.No.	Characteristics	Pulse Amplitude Modulation (PAM)	Pulse width Modulation (PWM)	Pulse Position Modulation (PPM)
1	**Relation with modulating signal**	The amplitude of the pulse signal is directly varied with the amplitude of the modulating signal.	The width of the pulse is directly varied with the amplitude of the modulating signal.	The position of the pulse is directly varied with the amplitude of the modu-1 lating signal.
2.	**Transmission channel band width**	It depends on the pulse width.	It depends on the pulse rise time.	It also depends on the pulse rise time.
3.	**Instantaneous power**	Instantaneous power of PAM does not remain constant	Instantaneous power of PWM does not remain constant.	Instantaneous power of PPM remains constant.
4.	**Noise interference**	Maximum	Minimum	Minimum
5.	**System complexity**	High	Low	Low.

Q22. Explain delta modulation with a neat block diagram.

Ans : **(Nov.-20)**

In delta modulation, instead of actual amplitude in PCM the slope of the signal is transmitted. This can be achieved by integrating the output of modulator and comparing it with the input signal through high gain differential comparator.

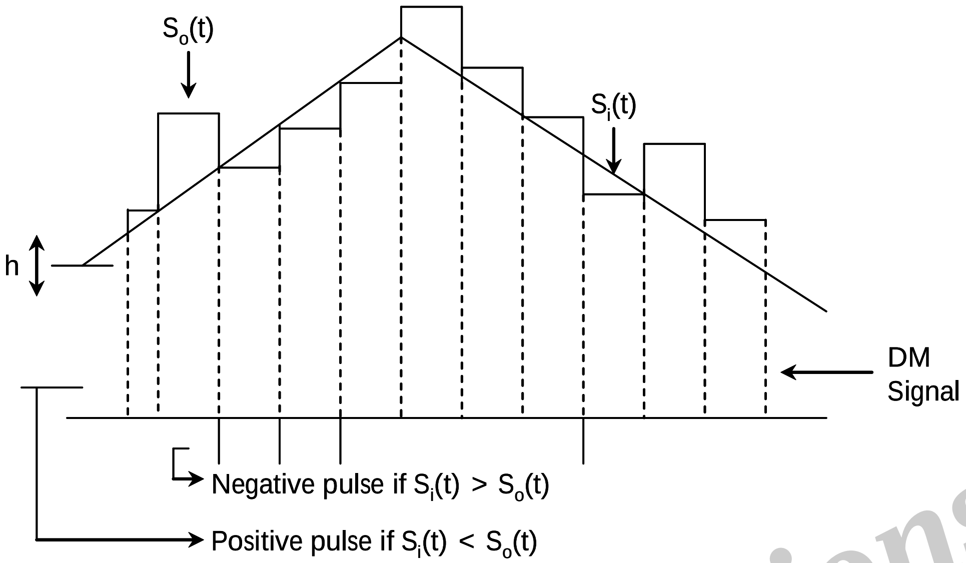


Operation

- $S_i(t)$ is original analog signal to be modulated and $S_0(t)$ is signal obtained from output of integrator.
- The comparator output is proportional to difference of the two inputs.

  S(t) a $S_i(t) - S_0(t)$
- The output of comparator is given to modulator.
- If $S_i(t) > S_0(t)$, modulator produces a positive pulse.
- Similarly if $S_i(t) < S_0(t)$, the modulator produces a negative pulse.
- If output of comparator is zero then the modulator produces positive and negative pulses altenratively and these signals are called DM signals.
- The DM signal is also passed through integrator which causes rise or fall by fixed step height 'h'. If 'h' is magnitude of voltage steps and 'T_s' is competition time, then the condition of proper transmission is given by

$$T_s = \frac{ds_i(t)}{d(t)} \leq h.$$



Advantages

- It is very simple and less costly hardware.

Disadvantages

- It cannot readily handle rapid amlitude fluctuations.

Solved Problems

1. The total power of an AM wave is 2.64 KW at a modulation factor of 80%. Calculate.

(a) Power in carrier wave

(b) Power in USB

(c) Power in LSB

Sol :

Given

$P_T = 2.64$ KW

$m = \frac{80}{100} = 0.8$

(a) Power in carrier wave

$$P_T = P_C\left[1+\frac{m^2}{2}\right] \text{ or } P_C\left[\frac{2+m^2}{2}\right]$$

$$P_C = \frac{2P_T}{m^2+2}$$

$$\therefore \quad P_C = \frac{2\times 2.64}{(0.8)^2+2}$$

$$P_C = \frac{5.28}{64+2}$$

(b) Power in USB

(c) Power in LSB

The side band power is given by

$$P_{SB} = \frac{P_C\ m^2}{2}$$

$$P_{SB} = \frac{2\times(.8)^2}{2} \Rightarrow P_{SB} = 640 \text{ watts}$$

$$\therefore \quad P_{USB} = P_{LSB} = \frac{P_{SB}}{2}$$

$$= \frac{640}{2} = 320 \text{ walts}$$

$\therefore \quad P_{USB} = 320$ wants

$P_{LSB} = 320$ wants

2. An audio signal of 2 KHz is used to modulate a carrier of 1000 KHz as AM wave. Determine.

(a) Side band frequencies

(b) Bandwidth

Sol :

Given

$f_m = 2$ KHz

$f_c = 1000$ KHz

(a) The side band frequencies are

$f_c + f_m$ and $f_c - f_m$

$\therefore \quad f_c + f_m = 1000 + 2 = 1002$ KHz

$f_c - f_m = 1000 - 2 = 998$ KHz

(b) Band width

$$BW = (f_c + f_m)\ (f_c - f_m)$$

$$= 1002 - 998$$

$$= \boxed{B.W = 4 \text{ KHz}}$$

3. The power of an AM signal is 100 W. If modulation index is 1. Find the carrier power.

Sol :

Given

$P_T = 100$ W

$m = 1$

$$\therefore \quad P_T = PC\left(\frac{m^2+2}{2}\right)$$

$$P_C = \frac{2P_7}{m^2+2} = \frac{2\times 100}{1+2}$$

$$\boxed{P_C = 66.6 \text{ Walts}}$$

4. Calculate the modulation index of an FM wave which has carrier swing of 160 KHz and is modulated by a signal of 10 KHz.

Sol :

Given

C.S = 160 KHz

$f_m = 10$ KHz

C.S = $2\,\Delta_f$

$$\Delta_f = \frac{C.S}{2} = \frac{160}{2}$$

$\therefore \quad \Delta_f = 80$ KHz

The modulation index is given by

$$m_f = \frac{\Delta_f}{f_m}$$

$$m_f = \frac{80}{10}$$

$$\boxed{m_f = 8}$$

---

5. An FM wave has centre frequency of 100 MH. When modulated by AF signal of 5 KHz, it has lowest frequency of 99.95 MHz. Calcualte.

(a) Highest frequency

(b) Frequency deviation

(c) Carrier swing

(d) Modulating index

(e) Percentage modulation

Sol :

Given

$f_c = 100$ MHz

$f_m = 5$ KHz $= 0.05$ MHz

Lowest frequency $f_{min} = 99.95$ MHz

(a) $f_{max} \rightarrow$ highest frequency

$f_{min} = f_c - nf_m$

$$n = \frac{f_c - f_{min}}{f_m}$$

$$n = \frac{100 - 99.95}{.05} = \frac{.05}{.05}$$

Hence $f_{max} = f_c + nf_m$

$f_{max} = 100 + 1 \times 0.5$

$f_{max} = 100.05$ MHz

(b) Frequency deviation Δ_f

$\Delta_f = f_{max} = f_c - f_c - f_{min}$

$\therefore \quad \Delta_f = 100.055 - 100$

$\Delta_f = 0.05$ MHz or 50 KHz

(c) Carrier swing

$$C.S = 2 \times \Delta_f$$

$$C.S = 2 \times 50 \text{ KHz}$$

$$\boxed{C.S = 100 \text{ KHz}}$$

(d) Modulation index (m_f)

$$m_f = \frac{\Delta_f}{f_m}$$

$$m_f = \frac{50 \text{ KHz}}{5 \text{ KHz}}$$

$$\boxed{m_f = 10}$$

(e) Percentage Modulation

$$m\% = \frac{\Delta_{f\ (actual)}}{\Delta_{f\ (max)}}$$

Where $\Delta_{f\ (max)}$ is the maximum allowed frequency deviation and is typically 75 KHz for an FM broadcasting station.

$$\therefore \quad m\% = \frac{50 \text{ KHz}}{75 \text{ KHz}}$$

$$\boxed{m\% = 66.6}$$

---

6. A 100 MHz carrier is FM by a 5 KHz sinusoidal modulating signal. If maximum frequency deviation is 50 KHz. Determine modulation index.

Sol :

Given

f_c = 100 MHz

f_m = 5 KHz

Δ_f = 50 KHz

Modulation Index $m_f = \frac{\Delta_f}{f_m}$

$$m_f = \frac{50}{5}$$

$$\boxed{m_f = 10}$$

7. An FM carrier is having a carrier swing of 100 KHz is frequency modulated by a signal of 10 KHz. Calculate modulation index.

Sol :

Given

$C.S = 100$ Hz

$f_m = 10$ KHz

$C.S = 2\Delta_f$

$$\Delta_f = \frac{C.S}{2} = \frac{100}{2}$$

$\Delta_f = 50$ KHz

Modulation index $m_f = \frac{\Delta_f}{f_m}$

$$m_f = \frac{50}{10}$$

$$\boxed{m_f = 5}$$

8. Calculate the percent modulation of a signal in the FM broadcast at 92 MHz with 20 KHz frequency deviation.

Sol :

Given

$\Delta_f = 20$ KHz

The maximum allowed frequency deviation of FM broadcasting is 75 KHz

$$\therefore \quad m_f\% = \frac{\Delta_f}{(\Delta_f)_{max}} \times 100$$

$$m_f\% = \frac{20}{75} \times 100$$

$$\boxed{m_f\% = 26.6\%}$$

9. In a FM circuit, the highest modulation frequency of 20 KHz provides modulation index m_f = 10. Calculate the approximate bandwidth of modula-ted FM wave.

Sol :

$f_m = 20$ KHz

$m_f = 10$

Since $m_f > 6$, the approximation is tabulated by $BW = 2(\Delta_f + f_m)$

$$mf = \frac{\Delta_f}{f_m}$$

$\Delta_f = (m_f)(f_m)$

$\Delta_f = (10)(20)$

$\Delta_f = 200$ KHz

$\therefore \quad B.W = 2(\Delta_f + f_m)$

$B.W = 2(200 + 20)$

$B.W = 440$ KHz.

10. An FM signal has a centre frequency 105 MHz. When modulated AF signal of 5 KHz. It has highest frequency of 105.03 MHz. It has highest frequency of 105.03 MHz. Calculate :

(a) Lowest frequency of FM wave

(b) Frequency deviation

(c) Carrier swing

(d) Modulation index

(e) Percentage modulation

Sol :

Given

$f_c = 105$ MHz

$f_m = 5$ KHz $= 0.05$ MHz

$f_{max} = 105.03$ MHz

(a) Lowest frequency $= f_c - \Delta_f$

$= 105 - 0.03 = 104.97$ MHz

(b) Frequency deviation

$f_{max} = \Delta_f + f_c$

$\Delta_f = 105.03 - 105$

$\Delta_f = 0.03$ MHz or 30 KHz

(c) Carrier swing

$$C.S = 2.\Delta_f$$

$$C.S = 2 \times 30$$

$$C.S = 60 \text{ KHz}$$

(d) Modulation Index (m_f)

$$m_f = \frac{\Delta_f}{f_m}$$

$$m_f = \frac{30}{5} = 6$$

(e) Percentage modulation

$$\frac{\Delta_f}{\Delta_{f\,max}} = \frac{30}{70} \times 100\%$$

$$\boxed{P.M = 40\%}$$

11. Calculate the modulation index of an FM wave which has carrier swing of 160 KHz and has been modulated by a signal of 10 KHz.

Sol : **(June-18)**

Given that,

For an AM wave,

Carrier swing = 160 kHz

Modulating frequency, f_m = 10 kHz

Modulation index, m_f = ?

The expression for modulation index of FM signal is given by,

$$m_f = \frac{\delta_f}{f_m} \quad \text{... (1)}$$

Where,

δ_f – Frequency deviation

f_m – Modulating frequency.

Carrier Swing = $2\delta_f$ ... (2)

$$\Rightarrow \quad \delta_f = \frac{\text{Carrier swing}}{2} = \frac{160}{2} \text{ kHz}$$

$$\delta_f = 80 \text{ kHz}$$

On substituting the corresponding values in equation (1), modulation index is obtained as,

$$m_f = \frac{80 \text{ kHz}}{10 \text{ kHz}} = 8.$$

$$\boxed{\therefore \text{Modulation index, } m_f = 8}$$

Short Question and Answers

1. What are the advantages of FM over AM ?

Ans :

- As most of noise is amplitude based this can be removed by running the signal through a limiter, so that only frequency variation appear.
- It does not suffer audio amplitude variation as the signal level varies and it makes, FM ideal for use in mobile application where signal level constant.
- In FM, recovered voice depends on frequency and not amplitude. Hence the efficiency of noise are minimum.
- It covers all the frequency range which human can hear. Hence FM ratio has better quality of sound in comparison with AM ratio.
- It gives noisless reception, noise is a form of amplitude Variation and a FM receiver will reject such noise signal.

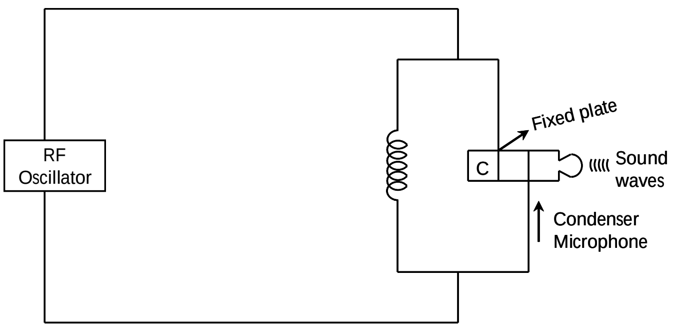
2. What are the differences between AM and FM ?

Ans :

AM		FM	
1.	In AM, there is change in amplitude modulation w.r.t input signal.	1.	In FM, there is change in frequency modulation w.r.t to input signal.
2.	Here modulation index, $m_f = \dfrac{(\Delta m)_{max}}{(\Delta s)_{max}}$	2.	Here modulation index, $m_f = \dfrac{\Delta_f}{f_m}$
3.	Bandwidth of side band is BW = $2f m_{max}$	3.	Carrier swing of a signal is, CS = $2.\Delta f$
4.	Percentage of modulation is $m\% = \dfrac{\epsilon_{max} - \epsilon_{min}}{\epsilon_{max} + \epsilon_{min}} \times 100$	4.	Percentage of modulation is $m\% = \dfrac{(\Delta f)_{actual}}{(\Delta t)_{max}}$

3. Explain with circuit diagram the working of frequency modulator ?

Ans :



- It consists of basically an RF oscillator along with a tuned circuit formed by 'L' and 'C'.
- The capacitor one plate is fixed and other plate is the diaphragm
- The sound waves passed to the microphone starts vibrating the diaphragm to and few.
- This movement of diaphragm changes the value of capacitance which turn changes the frequency of the resonant circuit.

4. Explain the principle of detection of FM waves ?

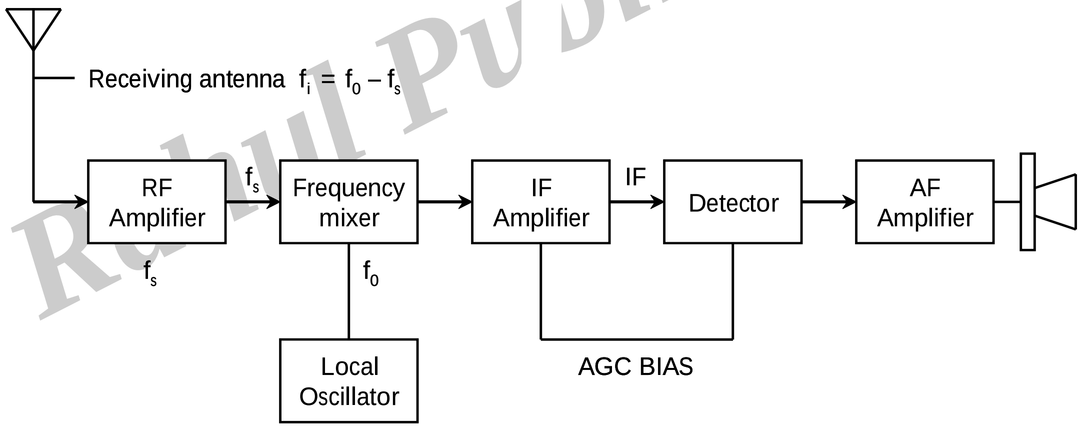
Ans :

Detection (or demodulation) is the process of recovering original modulating signals from the modulated waves.

Since an FM carrier signal contains information in the form of frequency variations above and below the centre frequency of the carrier, it is essential that these frequency variations be converted first into voltage variations. For it, use is made of the fact that the reactance of a coil or capacitor varies with frequency. When an FM signal is applied to an inductor, the current through the inductor, varies in amplitude according to the changes in frequency of the applied signal which in turn depends upon the amplitude of the modulating AF signal.

5. Explain the block diagram of superheterodyne receiver ?

Ans :



(i) Antenna : It intercepts e.m waves, selects the desired frequency and converts them to RF voltages or currents. This voltage is passed to RF amplifier.

(ii) RF Amplifier : The voltage developed should be amplified to detect weak signals. It raises the level of the voltage before it is fed to the mixer.

(iii) Mixer or frequency converter : This stage converts the incoming frequency into intermediate frequency. The IF is obtained by mixing incoming RF signal with frequency produced by local oscillator. The IF is typically 455 KHz in most of the cases.

(iv) IF Amplifier : The IF amplifier has one or more stages to amplify narrow band of frequencies around central fixed frequency.

(v) Detector and AGC : It separates information from the carrier signal and also provides. AGC (Automatic Gain Control) bias to preceding stages.

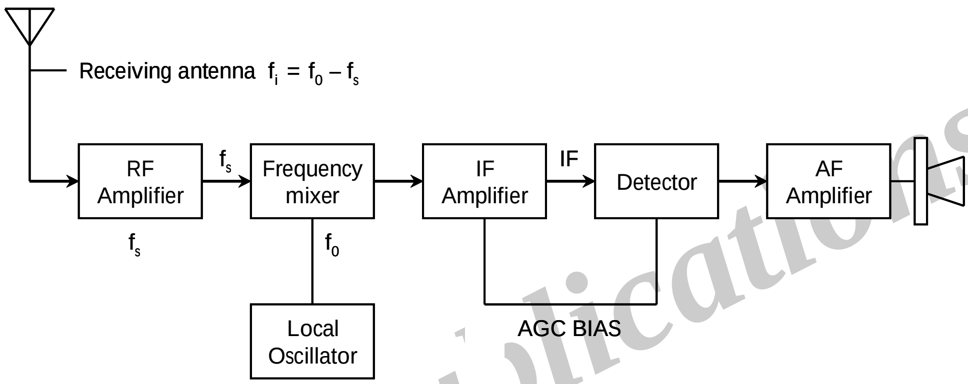
(vi) AF Amplifier : The AF signal obtained after demodulated is very weak and hence it is amplified by AF amplifier.

(vii) Loud Speaker : The loud speaker converts the electrical signals into sound signals.

6. Explain the working of a super heterodyne receiver ?

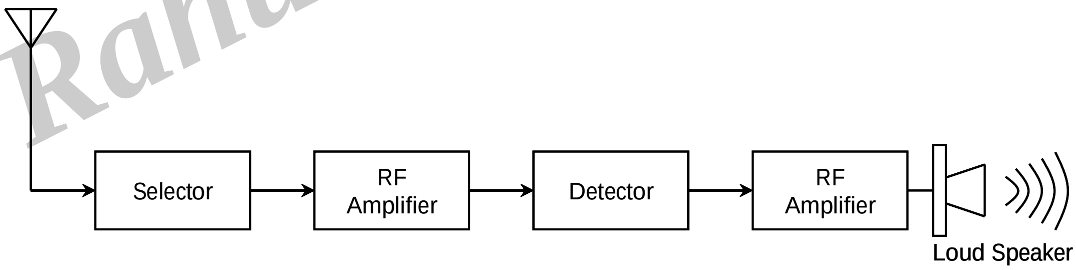
Ans :

Super heterodyne means mixing of two different frequency to produce the beat frequencies above the audible range. Here all the incoming signal frequencies are converted into lower fixed value called as intermediate frequency (IF). The change in the carrier frequency is achieved by mixing the incoming R.F signal with the oscillations developed by local oscillator. The new frequency produced is the difference of the frequencies that are mixed.



7. Draw the block diagram of a radio receiver. Explain its working ?

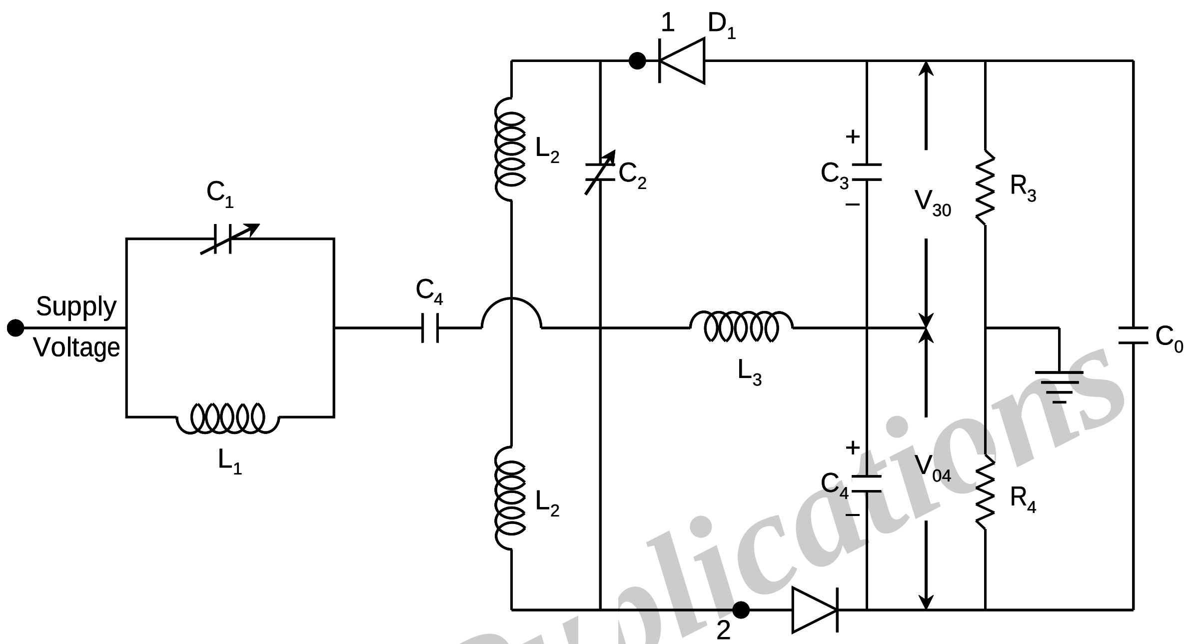
Ans :



- The straight forward receiver is also called as tuned radio receiver and consists of the blocks selector, RF amplifier, detector or, AF amplifies and followed by loud speaker.
- The selector is a parallel resonant circuit which tuned to select a desired carrier frequency.
- The modulated signal is passed through the detector which separates the information from the carrier.
- The A.F. signal is amplified to the desired level.
- The amplified A.F. signal is fed to the loud speaker which converts the electrical signals into sound or speech signals.
- The circuit is simple and highly sensitive.

8. Explain diode detector circuit ?

Ans :



The circuit diagram represents a ratio detector. Two important changes are made in the discriminator circuit.

- One diode is reversed.
- An electrolytic capacitor 'C' has been introduced across the resistors R_3 and R_4.

1. All the center frequency 'f_c' let the voltage across capacitor 'C_3' is given by V_{30} = –V and the voltage across 'C_4' is given by V_{04} = –V. Thus the output potential at centre frequency is given by V_0 = –V –V = –2V.
2. If the input frequency varies slightly from centre frequency 'f_c' then V_{30} and V_{04} changes by equal amounts i.e., V_{03} changes to –V + ΔV and V_{04} to –V + ΔV. and V_{04} to –V – ΔV. The new output potential is

$$V_0' = (-V + \Delta V) + (-V - \Delta V) = -2V$$

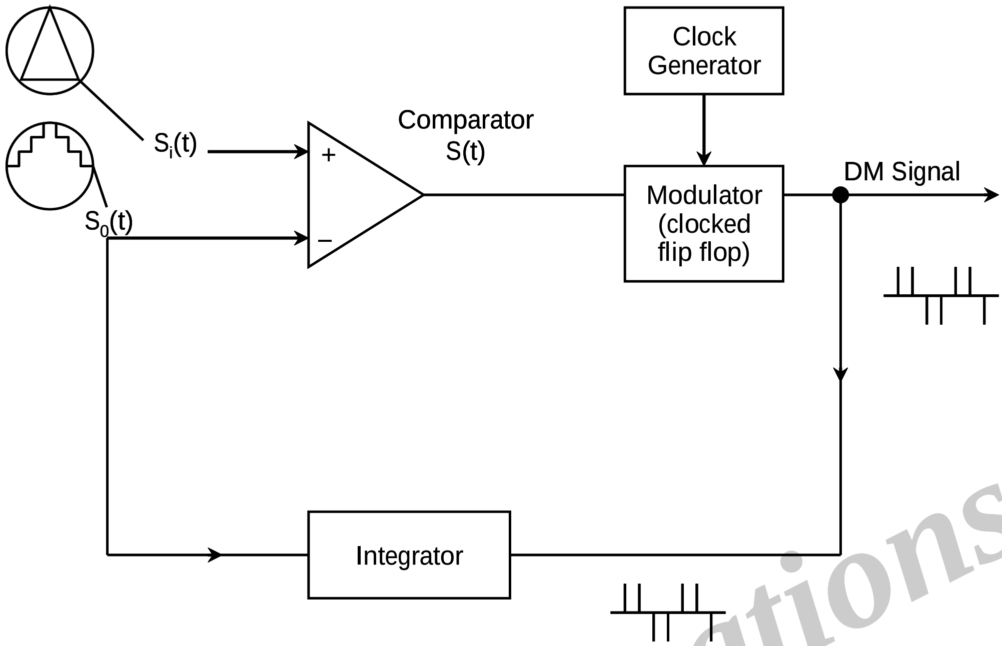
$$V_0' = -2V.$$

Hence output remains unchanged.

9. Write about delta modulation ?

Ans :

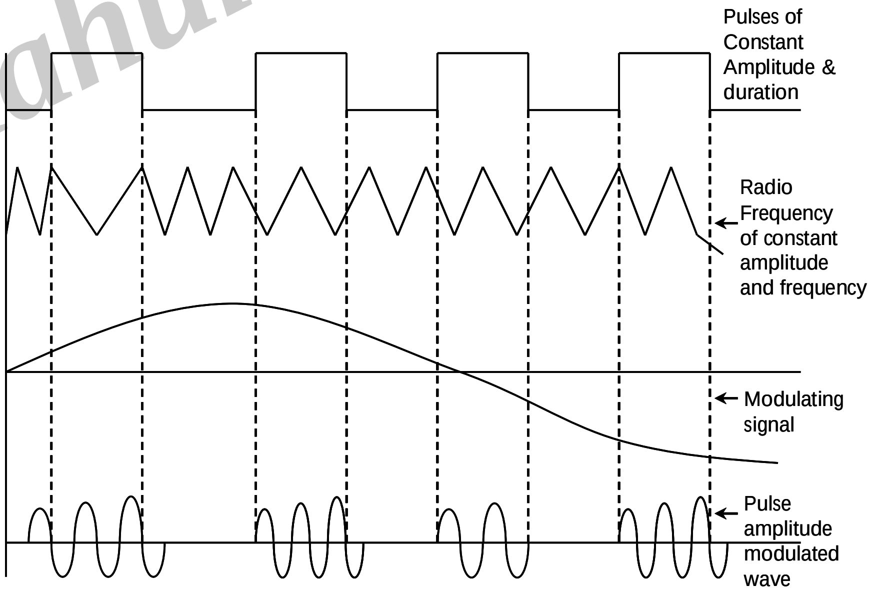
In delta modulation, instead of actual amplitude in PCM the slope of the signal is transmitted. This can be achieved by integrating the output of modulator and comparing it with the input signal through high gain differential comparator.



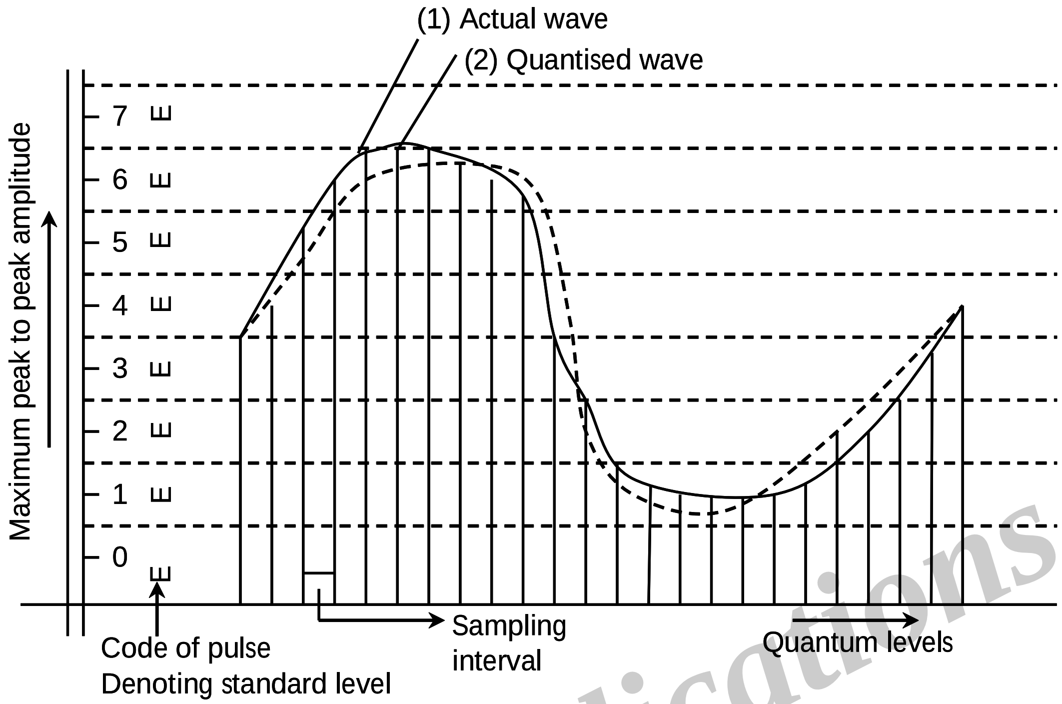
10. Write about PAM, PCM ?

Ans :

A PAM is a process in which the relative amplitudes of successive pulses serves as a measure of signal amplitudes at the sampling instants where width and position remains constant.



A PCM is a process is which the signal is first sampled and the sampled amplitude is selected in the nearest standard amplitude called quantisation. The standard amplitude is represented interms of code of pulses and is then transmitted.



11. FM discriminator.

Ans :

An FM detector performs the function of recovering original information signal from frequency modulated wave. The demodulation process involves two steps.

1. The FM wave is changed to corresponding AM wave. The frequency deviation is converted into amplitude variation. This amplitude variation is identical to one it has caused the frequency deviation.
2. The AM wave contained after conversion is given in linear detector to extract the original signal.

   The obtain the FM demodulation a circuit called as discriminator is used.

Choose the Correct Answer

1. In FM, when frequency deviation is doubled [a]
   (a) Modulation is doubled (b) Modulation is halved
   (c) Carrier swing is halved (d) Modulation index is decreased

2. The most serious disadvantages of FM transmission is its ______ [d]
   (a) Adjacent channel interference (b) Expensive equipment
   (c) High static noise (d) Limited line of sight range

3. The deviation ratio for sound portion of TV transmission is ______ [a]
   (a) 1.67 (b) 2
   (c) 5 (d) 6.67

4. In FM, number of side bands [a, b, c]
   (a) Depends directly on amplitude of modulating signal.
   (b) Depends inversely on the frequency of modulating signal.
   (c) Increase as frequency deviation increases.
   (d) Depends upon carrier frequency

5. In frequency domodulation, double tuned discriminator [a, b]
   (a) Comprises of two identical tuned circuits.
   (b) The two outputs are arranged to oppose each other.
   (c) The two outputs are in the same phase.
   (d) A single tuned circuit is used.

6. The basic element of radio communication system which generates radio waves is ______ [b]
   (a) Microphone (b) Transmitter
   (c) Transmitting (d) Loud speaker

7. U.H.F band covers the range of ______ [d]
   (a) 0 – 300 KHz (b) 3 – 30 MHz
   (c) 300 – 3000 KHz (d) 300 MHz – 3 GHz

8. The bandwidth in FM receivers is ______ [a & d]

   (a) More than that of AM receivers
   (b) Less than that in AM receivers
   (c) Equal to that in AM receivers
   (d) 150 KHz or more

9. The output of comarator is given to modulator as ______ [b]

   (a) $S(\tau) \propto S_i(\tau) + S_0(\tau)$
   (b) $S(\tau) \propto S_i(\tau) - S_0(\tau)$
   (c) $S(\tau) \propto S_i(\tau) . S_0(\tau)$
   (d) All

10. In Dm signal, the condition of proper transmition is given by ______ [b]

   (a) $T_S . \frac{d_{S_0}(1)}{d(1)} < h$
   (b) $T_S \frac{d_{S_i}(t)}{d(1)} \leq h$
   (c) $T_S \, d_{S(\tau)} / d(t) > h$
   (d) None

Fill in the blanks

1. In frequency modulation, the ________ of the carrier is changed and not its ________.
2. In FM, information is carried as variations in the ________ of the carrier.
3. Frequency modulation gives ________ noise.
4. A frequency modulated wave, consists of ________ of side frequency components.
5. In FM, number of significant side bands depends on ________.
6. A transmitter ________ the radio waves.
7. The value of IF frequency used in FM receiver is ________.
8. A ________ is a processes which relative amplitude of successive pulses serves on a measure of signal.
9. An ________ multivibrator generate pulse width modulation.
10. The sampled amplitude is selected in the nearest amplitude called ________.

Answers

1. Frequency, amplitude
2. Frequency
3. Less
4. An infinite number
5. Modulation inded
6. Generates
7. 10.7 MHz
8. PAM
9. Emitter caupled
10. Quantization

FACULTIES OF SCIENCE

B.Sc. IV - Semester(CBCS) Examination

November - 2020

ELECTRONICS

Linear Integrated Circuits and Basics of Communication

Time : 2 Hours] **[Max. Marks : 80**

PART - A (4 × 5 = 20 Marks)

Note: Answer any four questions.

Answer

1. Give the characteristics of an ideal Op-amp. **(Unit I, SQA-2)**
2. Describe how an op-amp can be used as inverting amplifier. **(Unit I, SQA-5)**
3. Draw the circuit diagram of an op-amp to solve a second order differential equation? **(Unit II, SQA-5)**
4. Explain mono stable multi vibrator using IC 555. **(Unit II, SQA-12)**
5. Briefly explain about Phase modulation. **(Unit III, SQA-2)**
6. The antenna current of an AM transmitter is 8A when only the carrier is sent but it increase to 8.93 A when the carrier is modulated. Find percent modulation. **(Unit III, Prob. 8)**
7. Write about PAM and PCM. **(Unit IV, SQA-10)**
8. Compare AM and FM. **(Unit IV, SQA-2)**

PART - B (3 × 20 = 60 Marks)

Note: Answer any three questions.

9. Draw the block diagram of Operational amplifier and briefly explain each part. **(Unit I, Q.No.3)**
10. Explain the concept of (i) Op - Amp as a summing amplifier (ii) Op - Amp as a comparator. (iii) A non - inverting Op - Amp. **(Unit I, Q.No.11,13,7)**
11. Draw the circuit of a stable multivibrator using timer IC-555 and describe its operation. **(Unit II, Q.No.2)**
12. Describe an analog computation circuit using Op - Amp to solve simple second order differential equation. Explain its working with suitable example. **(Out of Syllabus)**
13. Explain the action of linear diode detector in the reception of an amplitude modulated wave. Draw the circuit of diode detector. **(Unit III, Q.No. 11,12)**

14. What is modulation? Explain the need for modulation. Draw the circuit details of Amplitude modulator and discuss its mathematical analysis. **(Unit III, Q.No.1,3)**

15. What are the advantages of frequency modulation over amplitude modulation? Derive the expression for the spectrum of frequency modulated wave. **(Unit IV, Q.No.10)**

16. Draw the block diagram of FM radio receiver. Discuss briefly about PPM, PWM and Delta modulation. **(Unit IV, Q.No.14, 10, 18, 22, 20)**

FACULTIES OF SCIENCE

B.Sc. IV - Semester(CBCS) Examination

May / June - 2019

ELECTRONICS

Linear Integrated Circuits and Basics of Communication

Time : 3 Hours] **[Max. Marks : 80**

PART - A (5 × 4 = 20 Marks)

(Short Answer Type)

Note: Answer any FIVE of the following Questions

ANSWER

1. Give ideal characteristics and OP-Amplifier. **(Unit - I, SQA-2)**
2. Explain how voltage regulation can be achieved using OP-Amp? **(Out of Syllabus)**
3. Explain different types of modulation methods. **(Unit - III, SQA-10)**
4. Write about PAM & PCM. **(Unit - IV, SQA-10)**
5. Describe how an OP-Amp can be used as inverting Amplifier? **(Unit - I, SQA- 5)**
6. Draw the circuit of Astable multi vibrator using IC-555. **(Unit - II, SQA-10)**
7. Discuss the need for modulation and define modulation index. **(Unit - III, SQA-1,13)**
8. Discuss the operation of FM discriminator. **(Unit - IV, SQA-11)**

PART - B (4 × 15 = 60 Marks)

(Essay Answer Type)

Note: Answer ALL the Questions

9. (a) Explain the working of OP - Amp as,

    (i) Comparator **(Unit - I, Q.No.12)**

    (ii) Differentiator and **(Unit - I, Q.No.15)**

    (iii) Integrator. **(Unit - I, Q.No.14)**

    OR

    (b) Draw the circuit diagram of Summing amplifier using OP-Amp and explain its working, drive an expression for its output voltage. **(Unit - I, Q.No.10)**

10. (a) Explain the working of Wien Bridge Oscillator with circuit diagram and obtain an expression for its frequency. **(Unit - II, Q.No.1)**

    OR

    (b) Describe analog computation circuit using OP-Amp to Solve Simple Second order differential equation with an example. **(Out of syllabus)**

11. (a) Define amplitude Modulation and obtain an expression for Amplitude modulated wave. **(Unit - III, Q.No.3,4)**

OR

(b) What is de modulation ? Explain the working of Diode detector for AM waves. **(Unit - III, Q.No.11,12)**

12. (a) Draw the block diagram of FM receiver. How does it differ from AM receiver. **(Unit - IV, Q.No.14,16)**

(b) Explain frequency modulation (FM) and give the analysis of FM modulated wave. **(Unit - IV, Q.No. 1,3)**

FACULTIES OF SCIENCE

B.Sc. IV - Semester(CBCS) Examination

May / June - 2018

ELECTRONICS

Linear Integrated Circuits and Basics of Communication

Time : 3 Hours] **[Max. Marks : 80**

PART - A (5 × 4 = 20 Marks)

(Short Answer Type)

Note: Answer any FIVE of the following Questions

ANSWER

1. Define CMRR and Slew rate of an OP - amp. **(Unit - I, SQA-4)**
2. An inverting amplifier has $R_1 = 10\ k\Omega$ and $R_f = 125\ k\Omega$. Calculate the output voltage for an input voltage 4 V. **(Unit - I, Prob. 12)**
3. Discuss generation of triangular wave using OP - AMP and explain. **(Unit - II, SQA-11)**
4. Explain mono stable multi vibrator vibrator using IC 555. **(Unit - II, SQA-12)**
5. Define modulation index in AM. Explain types of modulation. **(Unit - III, Q.No. 13,10)**
6. Mention advantages of FM over AM. **(Unit - IV, SQA-1)**
7. Write a short note on side bands and bandwidth of AM. **(Unit - III, SQA-11, 12)**
8. Calculate the modulation index of an FM wave which has carrier swing of 160 KHz and has been modulated by a signal of 10 KHz. **(Unit - IV, Prob. 11)**

PART - B (4 × 15 = 60 Marks)

(Essay Answer Type)

Note: Answer ALL the Questions

9. (a) Draw the block diagram of Op-Amp and explain in detail. Describe the parameters of op-amp. **(Unit - I, Q.No.3)**

OR

(b) Draw the circuit diagram op-amp in non inverting mode and derive the equation for its voltage gain. **(Unit - I, Q.No.7)**

10. (a) Explain the working of Wein Bridge oscillator using op-amp with neat circuit diagram and obtain its frequency of oscillations. **(Unit - II, Q.No.1)**

OR

(b) Draw the block diagram of IC 555 Timer and describe its working. **(Unit - II, Q.No.5)**

11. (a) What is amplitude modulation? Show that an AM wave contains a carrier and two side bands for every modulating frequency. **(Unit - III, Q.No.3,4)**

OR

(b) Explain the salient features of amplitude modulation with the help of appropriate wave forms. Give the theory and working of diode detector to detect the AM signals. **(Unit - III, Q.No.12)**

12. (a) Give the analysis of frequency modulation. Describe the working of FM Discriminator with circuit diagram. **(Unit - IV, Q.No.3,9)**

OR

(b) Draw the block diagram of FM radio receiver. Explain the significance of each block. **(Unit - IV, Q.No.14)**

FACULTY OF SCIENCE

B.Sc. II Year IV Semester (CBCS) Examination

Model Paper - I

LINEAR INTEGRATED CIRCUITS AND BASICS OF COMMUNICATION

Time : 3 Hours] **[Max. Marks : 80**

SECTION - A (5 × 4 = 20 M)

Answer any 5 Questions

ANSWERS

1. Explain the concept of inverting and non-inverting amplifier ? **(Unit-I, SQA-5)**
2. Give the characteristics of an ideal op-amp ? **(Unit-I, SQA-2)**
3. Draw the block diagram of IC 555 - timer ? **(Unit-II, SQA-3)**
4. Describe the working of op-amp voltage regulator ? **(Unit-II, SQA-1)**
5. Explain the need for modulation ? **(Unit-III, SQA-1)**
6. An audio signal is given by $e_m = 15 \sin 2\pi (2000t)$ modulates the carrier by $e_c = 60 \sin 2\pi (100{,}000)t$. Calculate : **(Unit-III, Prob. 2)**
   (a) Percentage modulation
   (b) Frequency spectrum
7. Write about PAM, PCM ? **(Unit-IV, SQA-10)**
8. Calculate the percent modulation of a signal in the FM broadcast at 92 MHz with 20 KHz frequency deviation. **(Unit-IV, Prob. 8)**

SECTION - B (4 × 15 = 60 M)

Answer all the Questions

9. a) Draw the block diagram schematic of an Op-Amp. **(Unit-I, Q.No. 3)**

   (OR)

   b) Discuss the working of op-amp as a summing amplifier and obtain its output voltage. **(Unit-I, Q.No. 11)**

10. a) Draw the circuit diagram of Sine Wave Generator. **(Unit-II, Q.No. 1)**

    (OR)

    b) Explain the working of astable multivibrator using IC 555. **(Unit-II, Q.No. 8)**

11. a) Define modulation. Explain the need for modulation. **(Unit-III, Q.No. 1)**

    (OR)

    b) Draw the circuit diagram of an AM detector and explain how the original signal is received from AM signal is recovered from AM signal. **(Unit-III, Q.No. 12)**

12. a) Explain the analysis of FM wave. **(Unit-IV, Q.No. 3)**

    (OR)

    b) Draw the block diagram of FM receiver. How does it differ from AM receiver. **(Unit-IV, Q.No. 14)**

FACULTY OF SCIENCE

B.Sc. II Year IV Semester (CBCS) Examination

Model Paper - II

LINEAR INTEGRATED CIRCUITS AND BASICS OF COMMUNICATION

Time : 3 Hours] **[Max. Marks : 80**

SECTION - A (5 × 4 = 20 M)

Answer any 5 Questions

		Answers
1.	Discuss the working of op-amp voltage follower ?	(Unit-I, SQA-10)
2.	Define common mode rejection ratio, slew rate, offset voltage and bias currents?	(Unit-I, SQA-1)
3.	Draw the circuit diagram of an op-amp to solve a second order differential equation?	(Unit-II, SQA-5)
4.	Distinguish between monostable and astable multivibrators ?	(Unit-II, SQA-9)
5.	What is demodulation ? Why after all it is essential ?	(Unit-III, SQA-8)
6.	The load current in the transmitting antenna of an unmodulated AM transmitter is 6 Amp. What will be the antenna current when modulation is 60% ?	(Unit-III, Prob. 6)
7.	What are the advantages of FM over AM ?	(Unit-IV, SQA-1)
8.	Explain the principle of detection of FM waves ?	(Unit-IV, SQA-4)

SECTION - B (4 × 15 = 60 M)

Answer all the Questions

9.	a)	Derive an expression for inverting Op-Amp for voltage gain.	(Unit-I, Q.No. 6)
		(OR)	
	b)	Explain the concept of Op-Amp as a Comparator	(Unit-I, Q.No. 13)
10.	a)	Discuss generation of triangular wave using Op-Amp and explain.	(Unit-II, Q.No. 3)
		(OR)	
	b)	Explain with the help of a circuit diagram how IC 555 timer is used as a monostable multivibrator.	(Unit-II, Q.No. 7)
11.	a)	State the Analysis of Amplitude Modulation.	(Unit-III, Q.No. 4)
		(OR)	
	b)	Explain about a switching modulator. Draw the necessary circuit and waveform.	(Unit-III, Q.No. 9)
12.	a)	Discuss the operation of FM discriminator.	(Unit-IV, Q.No. 9)
		(OR)	
	b)	Explain with a neat diagram explain the generation and demodulation of pulse width modulation.	(Unit-IV, Q.No. 18)

FACULTY OF SCIENCE

B.Sc. II Year IV Semester (CBCS) Examination

Model Paper - III

LINEAR INTEGRATED CIRCUITS AND BASICS OF COMMUNICATION

Time : 3 Hours] **[Max. Marks : 80**

SECTION - A (5 × 4 = 20 M)

Answer any 5 Questions

ANSWERS

1. Explain the concept of virtual ground ? **(Unit-I, SQA-3)**
2. An operational amplifier has voltage gain of 50. Determine the values of R_{in} and R_f if. **(Unit-I, Prob.-5)**
   (a) A non-inverting amplifier
   (b) An inverting amplifier.
3. Draw the circuit of Astable multivibrator using IC-555. **(Unit-II, SQA-10)**
4. List the features of IC 555 timer. **(Unit-II, SQA-2)**
5. Why are the waves modulated in communication ? **(Unit-III, SQA-6)**
6. Explain concept of Side Bands. **(Unit-III, SQA-11)**
7. What are the differences between AM and FM ? **(Unit-IV, SQA-2)**
8. Write about delta modulation ? **(Unit-IV, SQA-9)**

SECTION - B (4 × 15 = 60 M)

Answer all the Questions

9. a) Derive an expression for inverting Op-Amp for Non-Inverting Amplifier for voltage gain. **(Unit-I, Q.No. 7)**

(OR)

   b) Derive an expression of Op-Amp are used differentiator circuit ? **(Unit-I, Q.No. 16)**

10. a) Distinguish between monostable and astable multivibrators ? **(Unit-II, Q.No. 9)**

(OR)

   b) Draw the op-amp voltage regulator circuit and describe its operation ? **(Unit-II, Q.No. 5)**

11. a) Discuss about modulation index and depth of modulation. **(Unit-III, Q.No. 6)**

(OR)

   b) Draw a circuit diagram of Balanced Modulator. **(Unit-III, Q.No. 10)**

12. a) Explain in briefly about the generation and modulation of PPM signals. **(Unit-IV, Q.No. 20)**

(OR)

   b) Explain the direct method of FM generation. **(Unit-IV, Q.No. 7)**