BASIC ELECTRONICS

RECTIFIERS

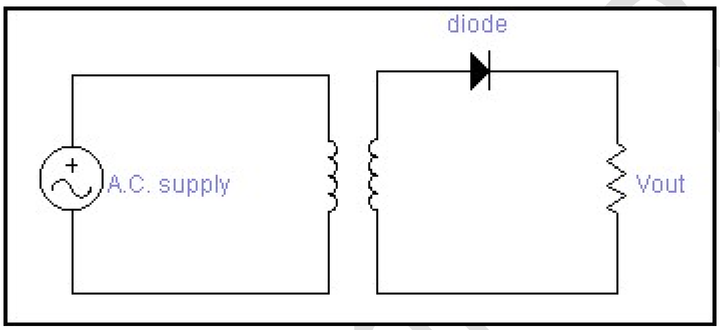
"Rectifiers are the circuit which converts ac to dc"

Rectifiers are grouped into two categories depending on the period of conductions.

1. Half-wave rectifier
2. Full- wave rectifier.

Half-wave rectifier

The circuit diagram of a half-wave rectifier is shown in fig. 2.5 below along with the I/P and O/P waveforms.



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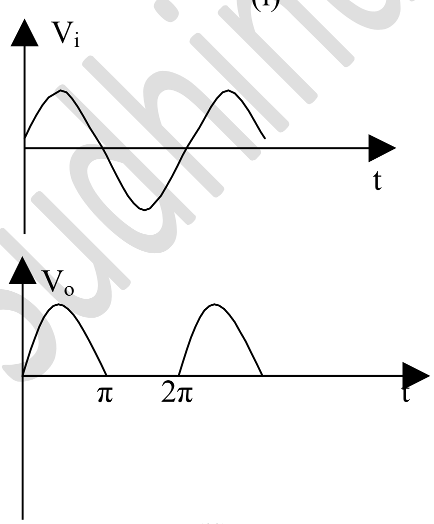


(ii)

Fig. 2.5 Half wave rectifier (i) Circuit diagram (ii) waveforms

- The transformer is employed in order to step-down the supply voltage and also to prevent from shocks.
- The diode is used to rectify the a.c. signal while , the pulsating d.c. is taken across the load resistor R_L.

- During the +ve half cycle, the end X of the secondary is +ve and end Y is -ve . Thus , forward biasing the diode. As the diode is forward biased, the current flows through the load R_L and a voltage is developed across it.

- During the –ve half-cycle the end Y is +ve and end X is –ve thus, reverse biasing the diode. As the diode is reverse biased there is no flow of current through R_L thereby the output voltage is zero.

Efficiency of a rectifier

The ratio of d.c. power to the applied imp ac power is known as rectifier efficiency.

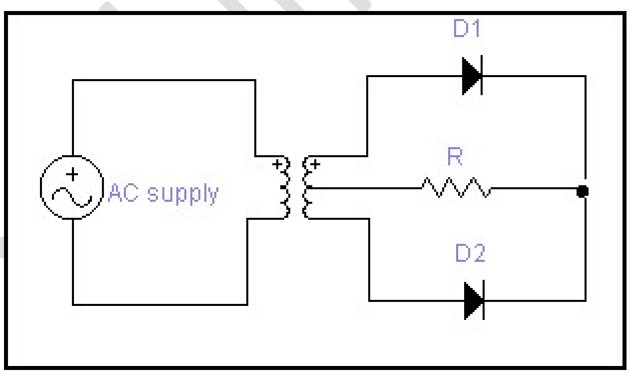
$$\textbf{Rectifier efficiency } \eta = \frac{d.c.power.output}{input.a.c.power}$$

Full-wave rectifier

Full-wave rectifier are of two types

1. Centre tapped full-wave rectifier
2. Bridge rectifier

Centre tapped full –wave rectifier



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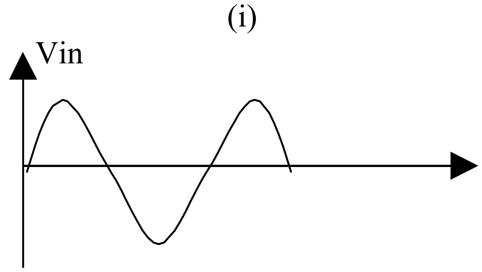
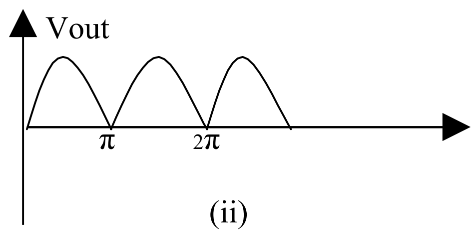




(ii)

Fig. 2.6 Centre tapped Full wave rectifier (i) Circuit diagram (ii) waveforms

- The circuit diagram of a center tapped full wave rectifier is shown in fig. 2.6 above. It employs two diodes and a center tap transformer. The a.c. signal to be rectified is applied to the primary of the transformer and the d.c. output is taken across the load $R_{L.}$

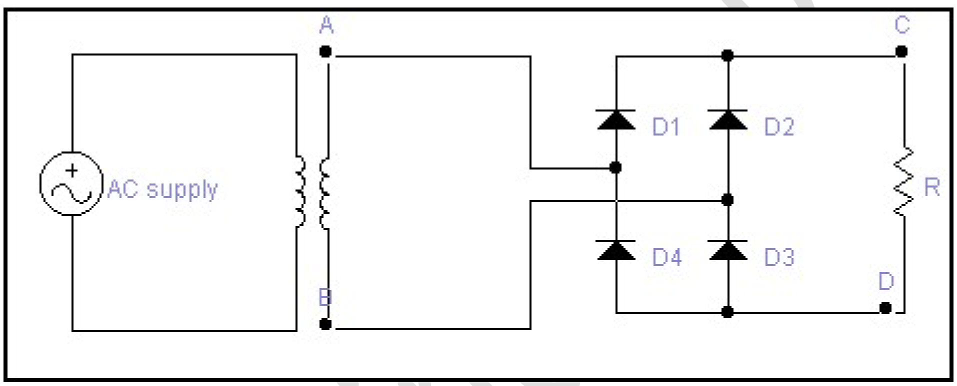
- During the +ve half-cycle end X is +ve and end Y is –ve this makes diode D_1 forward biased and thus a current i_1 flows through it and load resistor $R_{L.}$Diode D_2 is reverse biased and the current i_2 is zero.

- During the –ve half-cycle end Y is +Ve and end X is –Ve. Now diode D_2 is forward biased and thus a current i_2 flows through it and load resistor R_L. Diode D_1 is reversed and the current $i_1 = 0$.

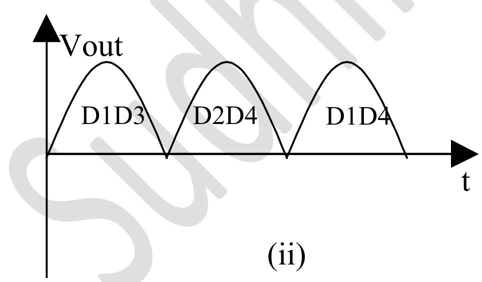
Disadvantages

- Since, each diode uses only one-half of the transformer secondary voltage the d.c. output is comparatively small.
- It is difficult to locate the center-tap on secondary winding of the transformer.
- The diodes used must have high Peak-inverse voltage.

Bridge rectifier



(i)



(ii)

Fig. 2.7 Full wave bridge wave rectifier (i) Circuit diagram (ii) waveforms.

- The circuit diagram of a bridge rectifer is shown above. It uses four diodes and a transformer.

- During the +ve half-cycle, end A is +ve and end B is –ve thus diodes D_1 and D_3 are forward bias while diodes D_2 and D_4 are reverse biased thus a current flows through diode $D_{1,}$ load R_L (C to D) and diode D_3.

- During the –ve half-cycle, end B is +ve and end A is –ve thus diodes D_2 and D_4 are forward biased while the diodes D_1 and D_3 are reverse biased. Now the flow of current is through diode D_4 load R_L (D to C) and diode D_2. Thus, the waveform is same as in the case of center-tapped full wave rectifier.

Advantages

- The need for center-taped transformer is eliminated.
- The output is twice when compared to center-tapped full wave rectifier. for the same secondary voltage.
- The peak inverse voltage is one-half(1/2) compared to center-tapped full wave rectifier.
- Can be used where large amount of power is required.

Disadvantages

- It requires four diodes.
- The use of two extra diodes cause an additional voltage drop thereby reducing the output voltage.

Note:

- The relation between turns ratio and voltages of primary and secondary of the transformer is given by
  - $N_1 / N_2 = V_p / V_s$
- RMS value of voltage and Max. value of voltage is related by the equation.
  - $V_{rms} = V_m / \sqrt{2}$ (for full-cycle of ac)
- If the type of diode is not specified then assume the diode to be of silicon type.
- For an ideal diode, forward resistance $r_f = 0$ and cut-in voltage , $V_\gamma = 0$.

Ripple factor

The pulsating output of a rectifier consists of d.c. component and a.c. component (also known as ripple). The a.c. component is undesirable and account for the pulsations in the rectifier output. The effectiveness of a rectifier depends upon the magnitude of a.c. component in the output : the smaller this component, the more effective is the rectifier.

" The ratio of rms value of a.c. component to the d.c. component in the rectifier output is known as ripple factor"

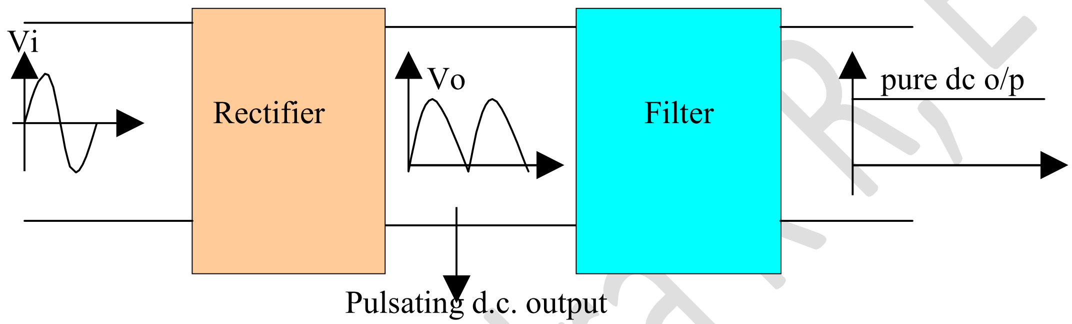
$$r = \frac{I_{ac}}{I_{dc}}$$

Comparision of Rectifiers

Particulars	Half wave rectifier	Centre-tapped Full wave rectifier	Bridge rectifier
1. No. of diodes	1	2	4
2. I_{dc}	I_m / Π	$2I_m / \Pi$	$2I_m / \Pi$
3. V_{dc}	V_m / Π	$2V_m / \Pi$	$2V_m / \Pi$
4.I_{rms}	$I_m / 2$	$I_m / \sqrt{2}$	$I_m / \sqrt{2}$
5.Efficiency	40.6	81.2 %	81.2 %
6.PIV	2	$2V_m$	V_m
7.Ripple factor	V_m 1.21	0.48	0.48

FILTERS

We know that the output of the rectifier is pulsating d.c. ie the output obtained by the rectifier is not pure d.c. but it contains some ac components along with the dc o/p. These ac components are called as Ripples, which are undesirable or unwanted. To minimize the ripples in the rectifier output filter circuits are used. These circuits are normally connected between the rectifier and load as shown below.



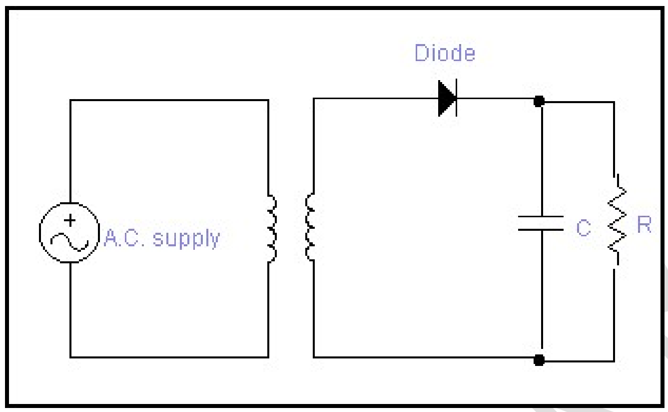
Filter is a circuit which converts pulsating dc output from a rectifier to a steady dc output. In other words, filters are used to reduce the amplitudes of the unwanted ac components inthe rectifier.

Note: A capacitor passes ac signal readily but blocks dc.

<u>Types of Filters</u>

1. Capacitor Filter (C-Filter)
2. Inductor Filter
3. Choke Input Filter (LC-filter)
4. Capacitor Input Filter (Π-filter)

Capacitor Filter(C-filter)



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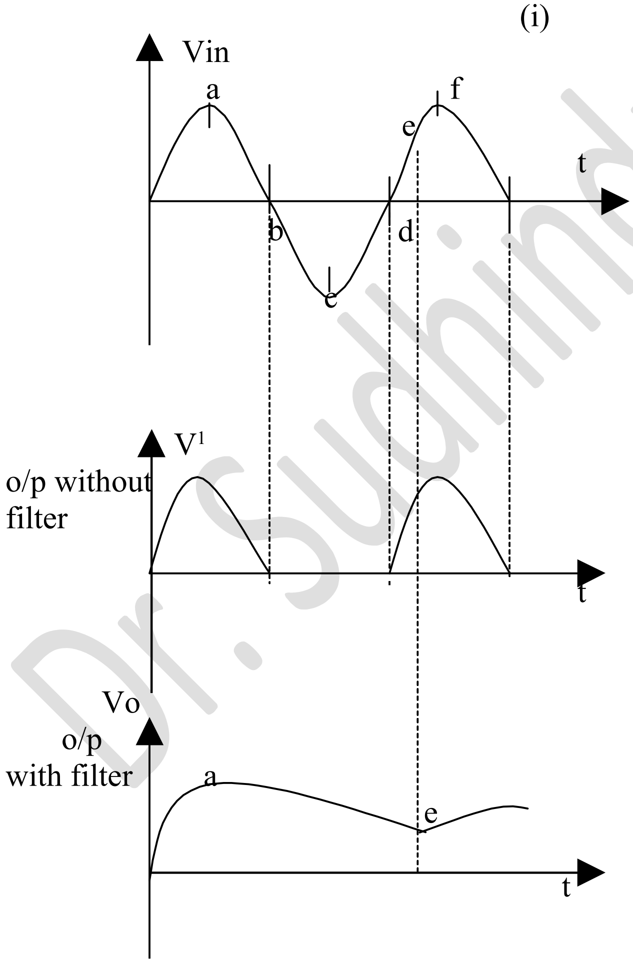

Fig.2.8 Capacitor filter (C-filter) (i) Circuit diagram (ii) waveforms

- When the Input signal rises from o to a the diode is forward biased therefore it starts conducting since the capacitor acts as a short circuit for ac signal it gets charged up to the peak of the input signal and the dc component flows through the load $R_{L.}$

- When the input signal fall from a to b the diode gets reverse biased . This is mainly because of the voltage across the capacitor obtained during the period o to a is more when compared to V_i. Therefore there is no conduction of current through the diode.

- Now the charged capacitor acts as a battery and it starts discharging through the load R_L. Mean while the input signal passes through b,c,d section. When the signal reaches the point d the diode is still reverse biased since the capacitor voltage is more than the input voltage.

- When the signal reaches point e, the input voltage can be expected to be more than the capacitor voltage. When the input signal moves from e to f the capacitor gets charged to its peak value again. The diode gets reverse biased and the capacitor starts discharging. The final output across R_L is shown in Fig. 2.8

<u>Advantages of C-Filter</u>

- low cost, small size and good characteristics.
- It is preferred for small load currents (upto 50 mA)
- It is commonly used in transistor radio, batteries eliminator etc.

Zener Diode

The reverse voltage characteristics of a semiconductor diode including the breakdown region is shown below.

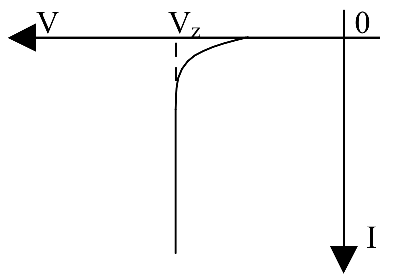

Fig. 2.9 Zener diode characteristics

Zener diodes are the diodes which are designed to operate in the breakdown region. They are also called as Breakdown diode or Avalanche diodes.

The symbol of Zener diode is shown below

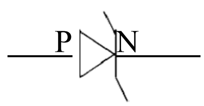

Fig. 2.10 Symbol of Zener diode

The breakdown in the Zener diode at the voltage V_z may be due to any of the following mechanisms.

Zener voltage regulator

The circuit diagram of Zener voltage regulator is shown below

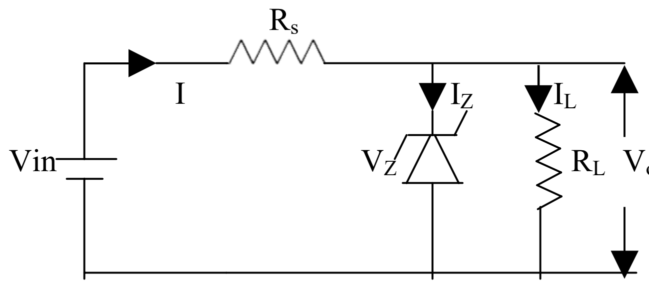

Fig. 2.13 Zener voltage regulator

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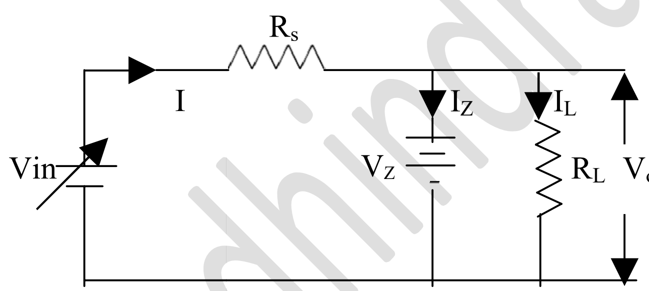
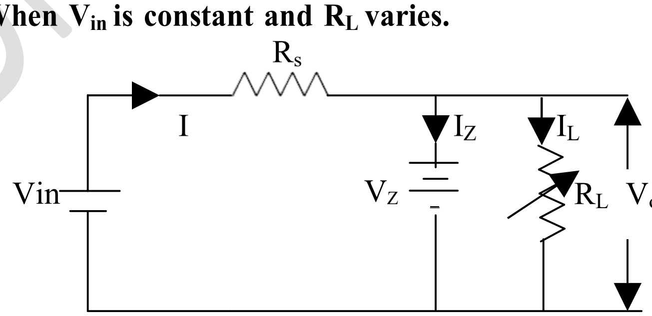
A zener diode of breakdown voltage V_Z is connected in reverse biased condition across the load R_L such that it operates in breakdown region. Any fluctuations in the current are absorbed by the series resistance R_s. The Zener will maintain a constant voltage V_Z (equal to V_o) across the load unless the input voltage does not fall below the zener breakdown voltage V_Z.

Case(i) When input voltage V_{in} varies and R_L is constant



If the input voltage increases, the Zener diode which is in the breakdown region is equivalent to a battery V_Z as shown in figure. The output voltage remains constant at V_Z (equal to Vo) and the excess voltage is dropped across the series resistance R_S. We know that for a zener diode under breakdown region large change in current produces very small change in voltage, thereby the output voltage remains constant.

Case (ii) When V_{in} is constant and R_L varies.



If there is a decrease in the load resistance R_L and the input voltage remains constant then there is a increase in load current.

Since V_{in} is constant the current cannot come from the source. This addition load current is driven from the battery V_Z and we know that even for a large decrease in current the Zener output voltage V_z remains same. Hence the output voltage across the load is also constant..

Transistor as an amplifier

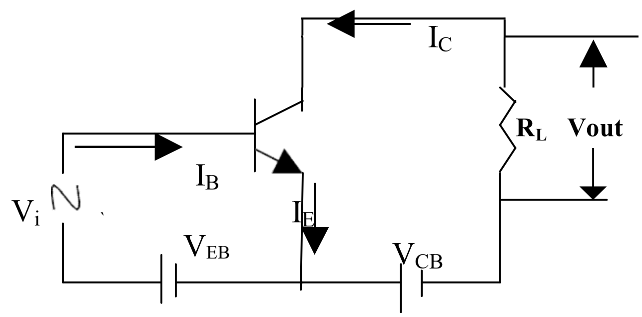


Fig 3.13: Transistor as an amplifier

Consider a npn transistor in CE configuration as shown above along with its input characteristics.

A transistor raises the strength of a weak input signal and thus acts as an amplifier. The weak signal to be amplified is applied between emitter and base and the output is taken across the load resistor R_C connected in the collector circuit.

In order to use a transistor as an amplifier it should be operated in active region i.e. emitter junction should be always FB and collector junction should be RB. Therefore in addition to the a.c. input source V_i two d.c. voltages V_{EB} and V_{CE} are applied as shown. This d.c. voltage is called bias voltage.

As the input circuit has low resistance, a small change in te signal voltage V_i causes a large change in the base current thereby causing the same change in collector current (because $I_C = \beta I_B$).

The collector current flowing through a high load resistance R_C produces a large voltage across it. Thus a weak signal applied at the input circuit appears in the amplified form at the output. In this way transistor acts as an amplifier.

Example: Let $R_C = 5K\Omega$, $V_{in} = 1V$, $I_C = 1mA$ then output $V = I_C R_C = 5V$

Cascading transistor amplifiers

When the amplification provided by a single stage amplifier is not suffiecient for a particular purpose or when the input and output impedance is not of the correct magnituded for the required application then two or more amplifiers are connected in cascade as shown below.

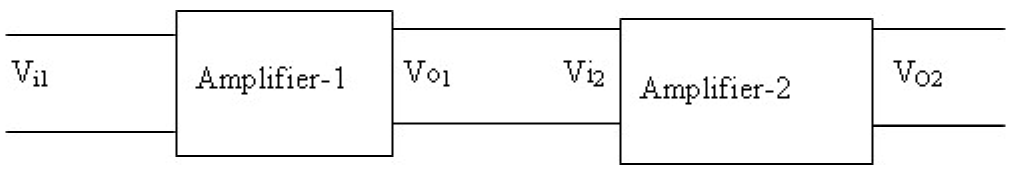


Fig: Cascading transistor amplifiers

Here the output of amplifier 1 is connected as the input of amplifier 2.

Example: The gain of a single amplifier is not sufficient to amplify a signal from a weaksource such as microphone to a level which is suitablefor the operation of another circuitas loud speaker. In such cases, amplifiers are used.

When amplifiers are cascaded, individual amplifiers provides required amplification and input and output provide impedance matching.

Decibel (dB)

Many a times it is convenient to represent the gain of an amplifier on a log scale instead of a linear scale. The unit of this log scale is called decibel.

Power gain $=\log_e($ Pout /Pin $)$ bel

Power gain in dB $=10 \log_{10}($ Pout /Pin $)$ dB

Voltage gain $=20\log_{10}($ Vout /Vin $)$ dB

Current gain $= 20\log_{10}(I_{out} / I_{in})$ dB

Note: For a multistage amplifier if A_{V1}, A_{V2}, and A_{V3} are the voltage gains of amplifier 1,2, and 3 respectively then the overall voltage gain $A_V = A_{V1} \times A_{V2} \times A_{V3}$.

If it is expressed in dB the $A_V(dB) = A_{V1}(dB) + A_{V2}(dB) + A_{V3}(dB)$

Similarly for four or more stages.

Single stage RC coupled Amplifier

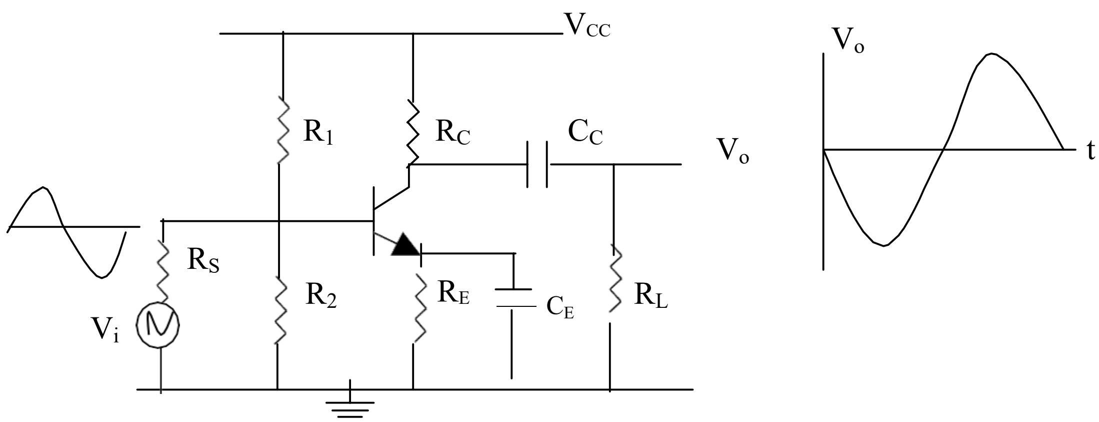


Fig 3.15:single stage RC-coupled amplifier

Figure above shows a practical circuit of a single stage RC coupled amplifier.The different circuit components and their functions are as described below.

a. **Input capacitor(C_{in})-** This capacitor is used to couple the input signal to the base of the transistor if it is not used, the signal source resistance R_S gets in parallel with R_2 thus changing the bias. The capacitor C_{in} blocks any d.c. component present in the signal and passes only a.c. signal for amplification.

b. **Biasing circuit** –The resistances R_1, R_2 and R_E forms the biasing and stabilization circuit for the CE amplifier. It sets the proper operating point for the amplifier.

c. **Emitter bypass capacitor (C_E)-**This capacitor is connected in parallel with the emitter resistance R_E to provide low reactance path to the amplified a.c. signal. If it is not used, the amplified a.c. signal passing through R_E will cause voltage drop across itthereby reducing the output voltage of the amplifier.

d. **Coupling capacitor(Cc)-** This capacitor couples the output of the amplifier to the load or to the next stage of the amplifier. If it is not used, the biasing conditions of the next stage will change due to the parallel effect of collector resistor R_C.
i.e. R_C will come in parallel with the resistance R_1 of the biasing network of the next stage thus changing the biasing conditions of the next stage amplifier.

Two stage RC coupled amplifier

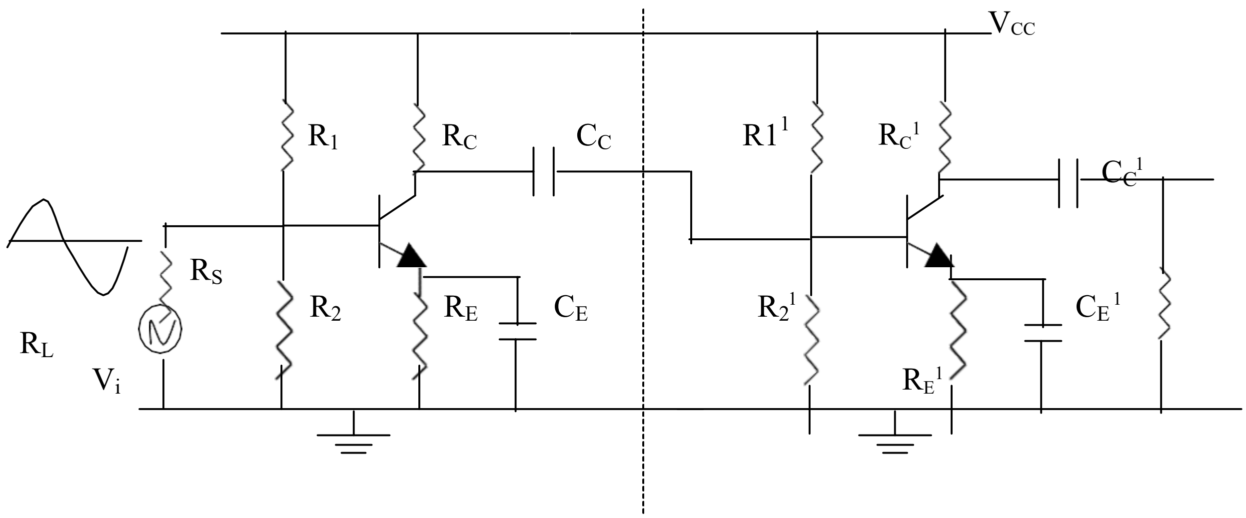


Fig 3.16: Two stage RC coupled Amplifier

Figure above shows the circuit diagram of a two stage RC coupled amplifier . The coupling capacitor C_C connects the output of the first stage to the input of the second stage. Since the coupling from one stage to the next stage is achieved by coupling capacitor along with a shunt resistor the amplifier is called RC coupled amplifier.. The input signal is first applied to the transistor T_1 and output is taken at the collector of T_1. The signal at the output will be 180^0 out of phase when compared to the input. The output is taken across R_C with the help of a coupling capacitor. This signal is fed as input to the next stage i.e transistor T_2. The signal is amplified further and the amplified output is taken across R_c^1 of T_2. The phase of the signal is reversed again. The output is amplified twice and its is amplified replica of the input signal.

Frequency response in amplifer

Frequency response is the curve between the gain of the amplifier ($A = V_o / V_i$) verses the frequency of the input signal. The frequency response of a typical RC-coupled amplifier is shown below.

Frequency response has 3 regions.

1. Low frequency range
2. Mid frequency range
3. High frequency range

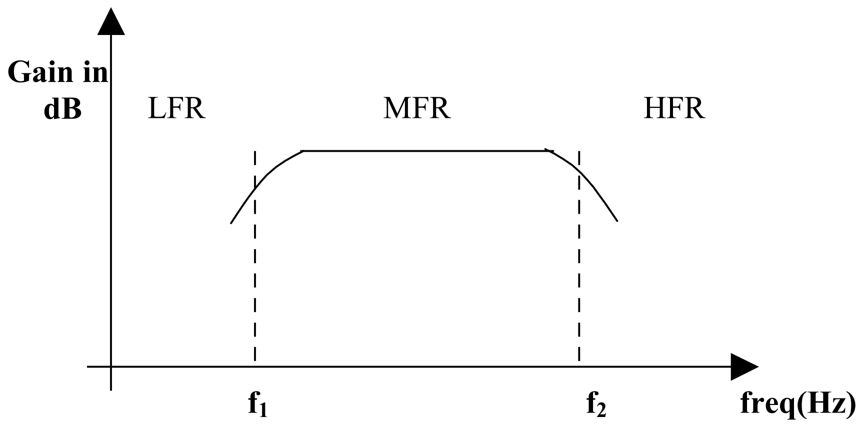


Fig 3.16: Frequency response in amplifer

Low frequency range (< 50 Hz)

We have

$X_c = \frac{1}{2\pi RC}$ where X_C ----- reactance of capacitor.;

f ---- frequency

Since frequency is inversely proportional to the reactance, the reactance of the coupling capacitor C_C will be quite high at low frequencies.

Hence very small amount of signal will pass through one stage to the next stage. Moreover C_E cannot shunt the emitter resistance R_E effectively because of its large reactance at low frequency. These two factors causes the fall of voltage gain at low frequencies.

Mid frequency range (50Hz –20KHz)

In this range of frequencies, voltage gain of the amplifier is constant. The effect of coupling capacitor in this range is as such to maintain a uniform voltage gain.

High frequency range (> 20 KHz)

In this range of frequency, the reactance of the coupling capacitor C_C is very small and it behaves as a short circuit. This increases the loading effect of next stage (R_C will comes in parallel with R_1) and reduces the voltage gain. This reduces the current amplification there by the voltage drops at high frequencies.

Advantages of RC coupled amplifer

1. **Low cost-**Because only resistors and capacitors are used for biasing and coupling which are cheap.
2. **Compact-**Because modern resistor and capacitors are small and light
3. **Good frequency response-** The gain is constant over the audio frequency range and hence suitable for audio frequency amplification.

OPERATIONAL AMPLIFIER

INTRODUCTION

Op-Amp (operational amplifier) is basically an amplifier available in the IC form. The word “operational” is used because the amplifier can be used to perform a variety of mathematical operations such as addition, subtraction, integration, differentiation etc.

Figure 1 below shows the symbol of an Op-Amp.

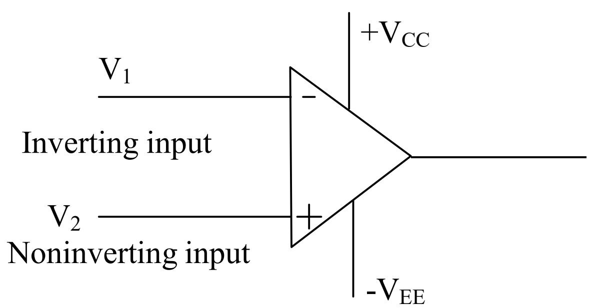


Fig.1 Symbol of Op-Amp

It has two inputs and one output. The input marked “-“ is known as Inverting input and the input marked “+” is known as Non-inverting input.

- If a voltage V_i is applied at the inverting input (keeping the non-inverting input at ground) as shown below.

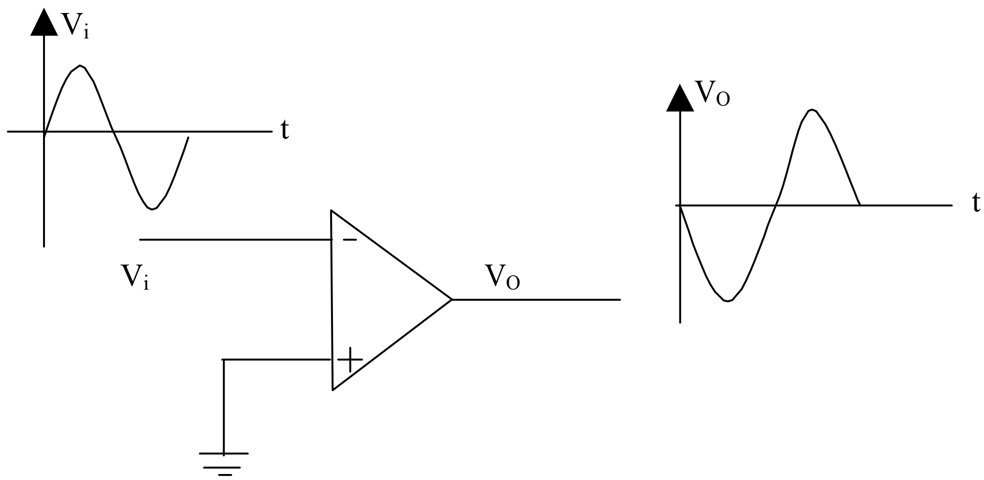


Fig.2 Op-amp in inverting mode

The output voltage V_o= $-AV_i$ is amplified but is out of phase with respect to the input signal by 180^0.

- If a voltage V_i is fed at the non-inverting input (Keeping the inverting input at ground) as shown below.

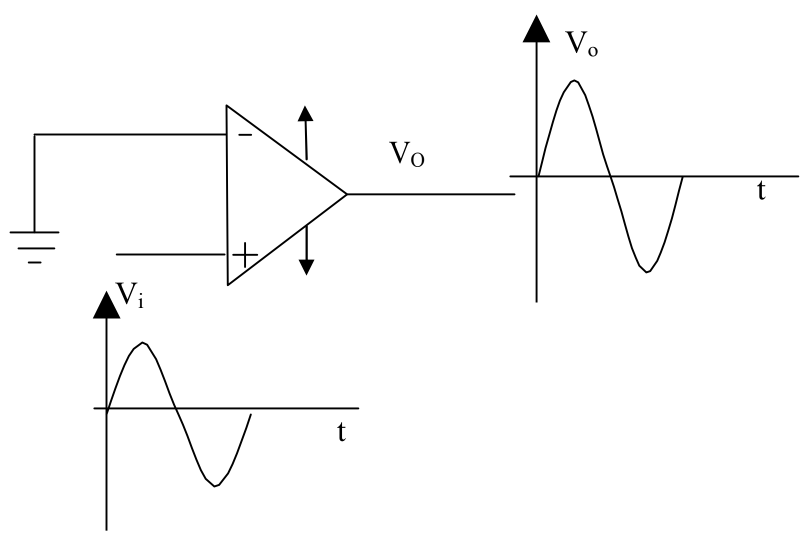


Fig.3 Op-Amp in Non-inverting mode

The output voltage $V_o = AV_i$ is amplified and in-phase with the input signal.

- If two different voltages V_1 and V_2 are applied to an ideal Op-Amp as shown below.

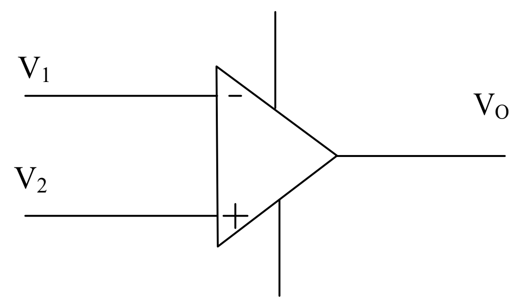


Fig.4 Ideal Op-Amp

The output voltage will be $V_o = A(V_1 - V_2)$

i.e the difference of the tow volatages is amplified. Hence an Op-Amp is also called as a High gain differential amplifier.

Note: Op-Amp is 8 pin IC (named as μA 741) with pin details as shown.

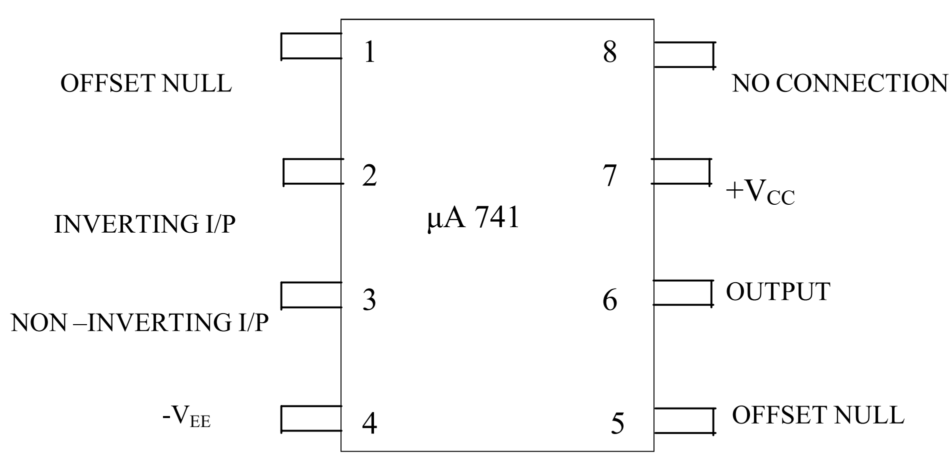


Fig. 5 Pin details of Op-Amp

Block Diagram of an Op-AMP

An Op-Amp consists of four blocks cascaded as shown above

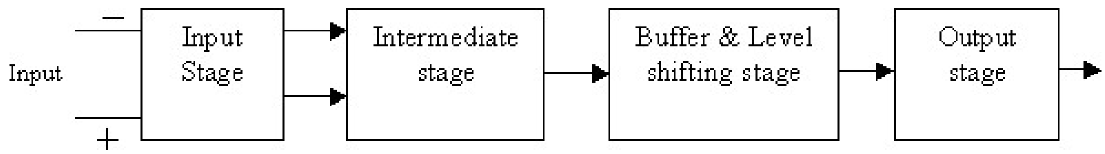


Fig. Block diagram of an Op-Amp

Input stage: It consists of a dual input, balanced output differential amplifier. Its function is to amplify the difference between the two input signals. It provides high differential gain, high input impedance and low output impedance.

Intermediate stage: The overall gain requirement of an Op-Amp is very high. Since the input stage alone cannot provide such a high gain. Intermediate stage is used to provide the required additional voltage gain.

It consists of another differential amplifier with dual input, and unbalanced (single ended) output

Buffer and Level shifting stage

As the Op-Amp amplifies D.C signals also, the small D.C. quiescent voltage level of previous stages may get amplified and get applied as the input to the next stage causing distortion the final output.
Hence the level shifting stage is used to bring down the D.C. level to ground potential, when no signal is applied at the input terminals. Buffer is usually an emitter follower used for impedance matching.

Output stage- It consists of a push-pull complementary amplifier which provides large A.C. output voltage swing and high current sourcing and sinking along with low output impedance.

Concept of Virtual ground

We know that , an ideal Op-Amp has perfect balance (ie output will be zero when input voltages are equal).

Hence when output voltage $V_o = 0$, we can say that both the input voltages are equal ie $V_1 = V_2$.

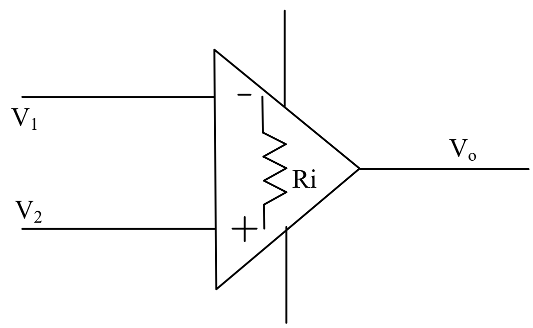


Fig. Concept of Virtual ground

Since the input impedances of an ideal Op-Amp is infinite (R_i =). There is no current flow between the two terminals.

Hence when one terminal (say V_2) is connected to ground (ie $V_2 = 0$) as shown.

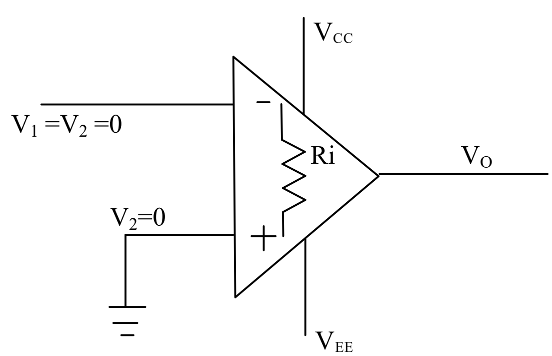


Fig. **Concept of Virtual ground**

Then because of virtual ground V_1 will also be zero.

Applications of Op-Amp

An Op-Amp can be used as

1. Inverting Amplifer
2. Non-Iverting Amplifer
3. Voltage follower
4. Adder (Summer)
5. Integrator
6. Differentiator

Definitions

1. **Slewrate(S):** It is defined as " The rate of change of output voltage per unit time"

$$s = \frac{dV_O}{dt} \quad volts/\mu \sec$$

Ideally slew rate should be as high as possible.But its typical value is s=0.5 V/µ-sec.

2. **Common Mode Rejection Ratio(CMRR):** It is defined as " The ratio of differential voltage gain to common-mode voltage gain".

$$CMRR = \frac{A_d}{A_{CM}}$$

Ideally CMRR is infinite, but its typical value is CMRR = 90 dB

3. **Open Loop Voltage Gain (A_V):** It is the ration of output voltage to input voltage in the absence of feed back.

   Its typical value is $A_V = 2x10^5$

4. **Input Impedance (R_i):** It is defined as " The impedance seen by the input(source) applied to one input terminal when the other input terminal is connected to ground.

   Ri ≈ 2MΩ

5. **Output Impedance (R_O):** It is defined as " The impedance given by the output (load) for a particular applied input".

   Ro ≈ 75Ω

Note: Typical values given above are for Op-Amp IC=µA741

Characteristics of an Ideal Op-Amp

An ideal Op-Amp has the following characteristics.

1. Infinite voltage gain (ie $A_V = \infty$)
2. Infinite input impedance ($R_i = \infty$)
3. Zero output impedance($R_o = 0$)
4. Infinite Bandwidth (B.W. = C
5. Infinite Common mode rejection ratio (ie CMRR $=\infty$)
6. Infinite slew rate (ie $S=\infty$)
7. Zero power supply rejection ratio (PSRR =0)ie output voltage is zero when power supply $V_{CC} = 0$
8. Zero offset voltage(ie when the input voltages are zero, the output voltage will also be zero)
9. Perfect balance (ie the output voltage is zero when the input voltages at the two input terminals are equal)
10. The characteristics are temperature independent.

Inverting Amplifier

An inverting amplifier is one whose output is amplified and is out of phase by 180^0 with respect to the input

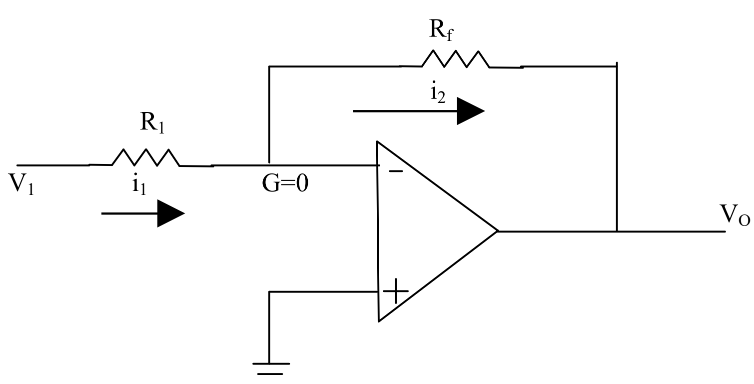


Fig. Inverting Amplifier

The point "G" is called virtual ground and is equal to zero.

The output and input voltages are related by the following equation

$$V_o = -\frac{R_f}{R_1} V_1$$

Where the ration Rf / Ri refers to the gain of the amplifier and negative sign indicates that the output is inverted with respect to the input

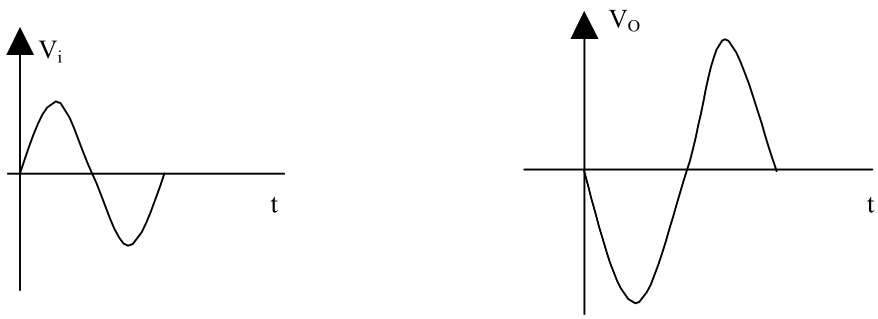


Fig. Waveforms of Inverting Amplifiers

2. Non- Inverting Amplifier

A non-inverting amplifier is one whose output is amplified and is in-phase with the input.

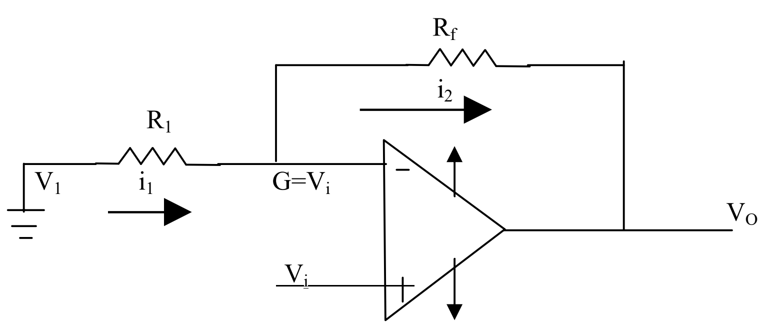


Fig.10 Non Inverting Amplifiers

The output and input voltages are related by the following equation

$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_1$$

Where the ration $\left(1 + \frac{R_f}{R_1}\right)$ refers to the gain of the amplifier and negative sign indicates that the output is inverted with respect to the input

3. Voltage follower

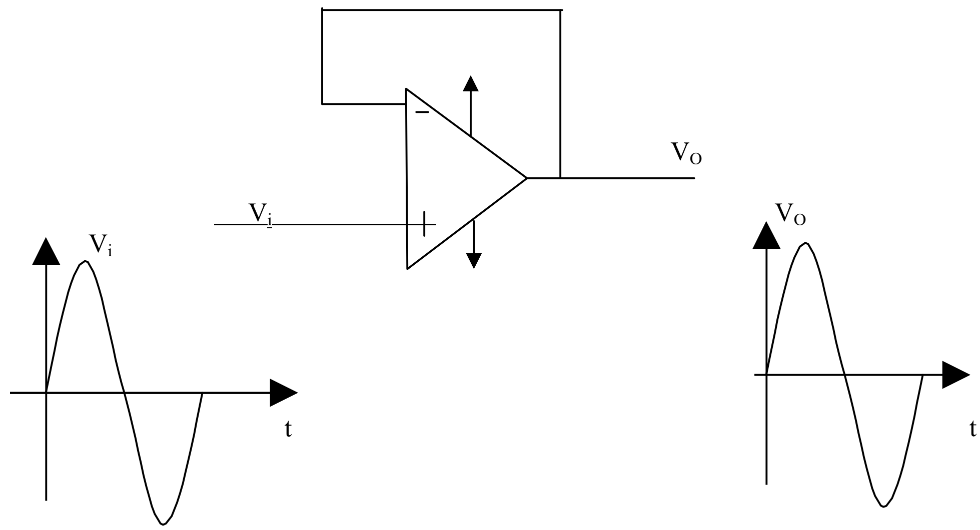


Fig. 11 Voltage follower

Voltage follower is one whose output is equal to the input.

The voltage follower configuration shown above is obtained by short circuiting “R_f” and open circuiting “R_1” connected in the usual non-inverting amplifier.

Thus all the output is fed back to the inverting input of the op-Amp.

Consider the equation for the output of non-inverting amplifier

$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_1$$

When $R_f = 0$ short circuiting
$R_1 = \infty$ open circuiting

$\therefore \; V_O = V_i$

Therefore the output voltage will be equal and in-phase with the input voltage. Thus voltage follower is nothing but a non-inverting amplifier with a voltage gain of unity.

4. Inverting Adder
Inverting adder is one whose output is the inverted sum of the constituent inputs

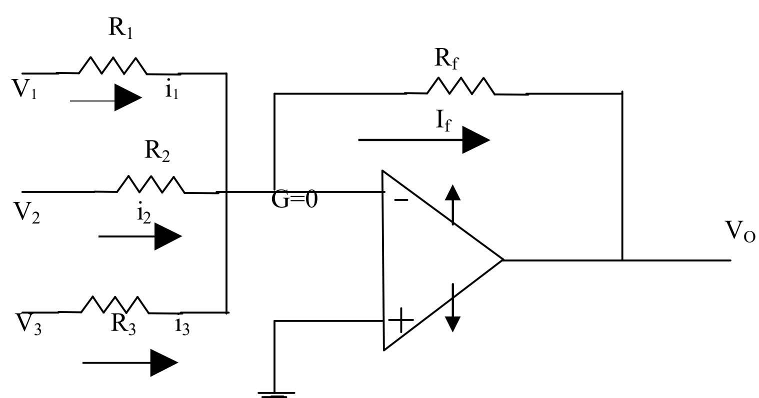


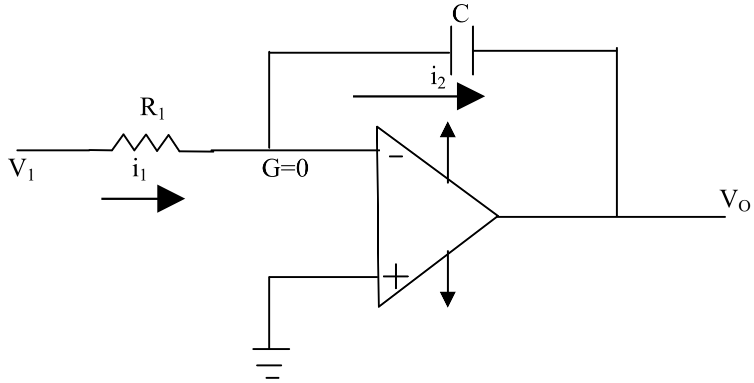
Fig. Inverting Adder

If $R_1 = R_2 = R_3 = R_f = R$ then

$$V_O = -[\, V_1 + V_2 + V_3 \,]$$

Hence it can be observed that the output is equal to the inverted sum of the inputs.

5. Integrator



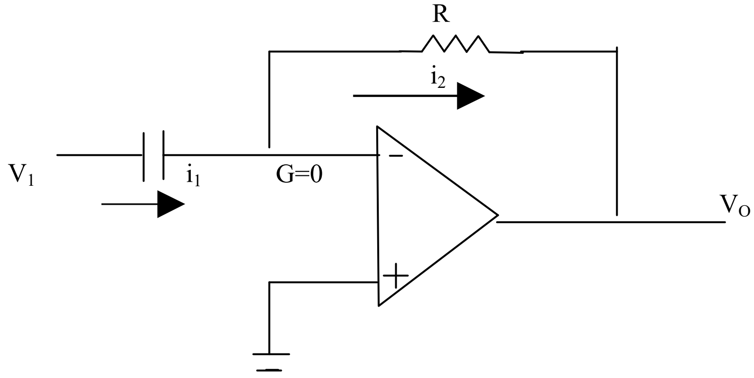
Fig, Integrator

An integrator is one whose output is the integration of the input.

$$V_o = -\frac{1}{RC}\int V_i dt$$

Differentiator

A differentiator is one whose output is the differentiation of the input



$$V_o = -RC\frac{dV_i}{dt}$$

Problems

1. For an inverting amplifer R_i=100KΩ and R_f=600KΩ. What is the output voltage for an input of -3V?

Soln:

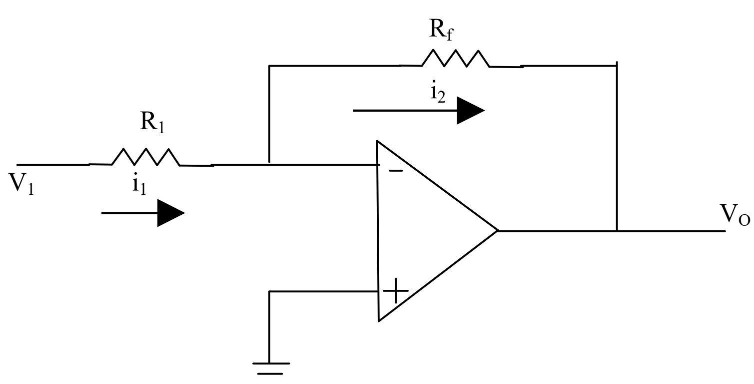
Given: R_1=100KΩ
R_f=600KΩ
V_i=-3V
V_O=?

$$V_O = 18\ V$$

2. Design an inverting amplifer for output voltage of -10V and an input voltage of 1V.

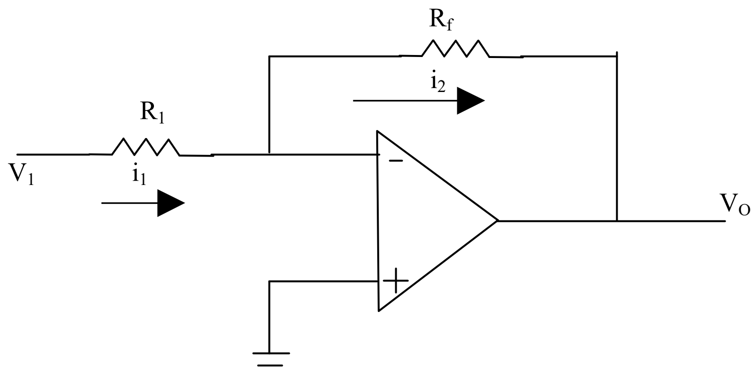
Soln:

Given: Vi =1 V
V_O= -10V



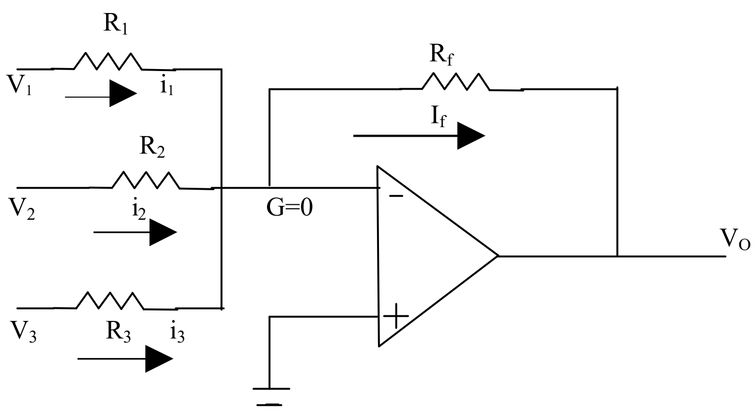
3. For an inverting amplifier R_1=10KΩ and V_i =1V. Calculate $i_1$and $V_{O.}$
Soln:

Given: R_1 = 10KΩ, R_f=100KΩ V_i =1 V



4. Desing an amplifier with a gain of +9 and R_f =12 KΩ using an op-Amp
Soln:
Since the gain is positive:
Choose a non-inverting amplifier

6. **In the figure shown if V_1=+1V, V_2=+3V and V_3=+2V with R_1=R_2=R_3=2KΩ. Determine the output voltage.**



Soln: We have ,

$$V_o = -\frac{R_f}{R}\left[V_1 + V_2 + V_3\right]$$

7. Design an Adder using Op-Amp to give the output voltage $V_O = -[2V_1+3V_2+5V_3]$

Soln:

Equating eqn 1 and 2 we get,

$$\frac{R_f}{R_1} = 2 \quad ; \quad \frac{R_f}{R_2} = 3 \quad ; \quad \frac{R_f}{R_3} = 5$$

Assuming R_f =100KΩ, We get,

$$R_1 = \frac{R_f}{2} \quad \therefore \; R_1 = 50K\Omega$$

$$R_2 = \frac{R_f}{3} \quad \therefore \; R_2 = 33.33K\Omega$$

$$R_3 = \frac{R_f}{5} \quad \therefore \; R_3 = 20K\Omega$$

Note: If design is asked after finding the values of R_f and R_1 circuit diagram should be written.

8.Design a summing amplifier to add three input voltages. The output of the amplifier should be twice the negative sum of the inputs.

Solution:

$$V_O = -2(V_1 + V_2 + V_3)$$

$$we\ have \quad V_O = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

Equating we get,

$$\frac{R_f}{R} = 2 \quad \therefore \; R_f = 2R$$

$$Let\ R = 10K\Omega \quad then\ R_f = 20K\Omega$$

9. A 5 mV peak voltage, 1 KHz signal is applied to the input of an Op-Amp integrator for which R=100KΩ and C=1µF. Find the output voltage.

Soln: Given R=100KΩ
C=1µF
V_m =5mV
F=1KHz
V_0 =?

We have $V_i = V_m \text{Sinwt} = V_m \text{Sin}2\pi ft$

$V_i = 5\sin 200\pi t$ mV

For an integrator,

$$V_O = -\frac{1}{RC}\int V_i dt$$

on solving,

$$V_O = \frac{1}{40\pi}\cos 200\pi\, t \quad mV$$

10.The input to a differentiator is a sindusoidal voltage of peak value 5mV and frequency 2KHz . Find the output if R = 100KΩ and C=1µF.

Given:
$V_i = 5\sin 400\pi\, t \quad mV$

for differentiator $V_O = -RC\dfrac{dV_i}{dt}$

on solving $V_O = -2000\pi \ \cos 4000\pi\, t \quad mV$

SINUSOIDAL OSCILLATORS

" An electronic device that generates sinusoidal oscillations of desired frequency is known as sinusoidal oscillator"

Types of Sinusoidal Oscillations

1. Damped Oscillations
2. Undamped Oscillations

1. **Damped Oscillations-**The electrical oscillations whose amplitude goes on decreasing with time are called damped oscillations.
2. **Undamped Oscillations-** The electrical oscillations whose amplitude remains constant with time are called undamped oscillations.

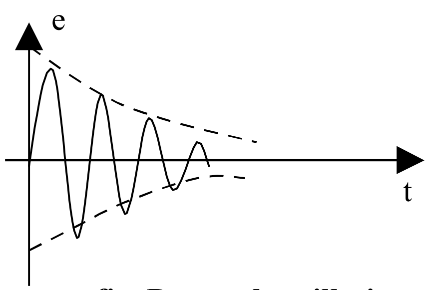


fig. Damped oscillations

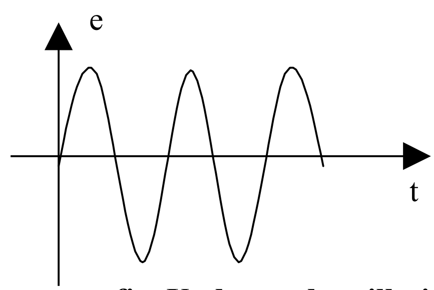


fig. Undamped oscillations

Oscillatory circuit

A circuit, which produces electrical oscillations of any desired frequency, is known as an oscillatory circuit or tank circuit.

A simple oscillatory circuit consists of a capacitor C and inductance coil L in parallel as shown in figure below. This electrical system can produce electrical oscillations of frequency determined by the values of L and C.

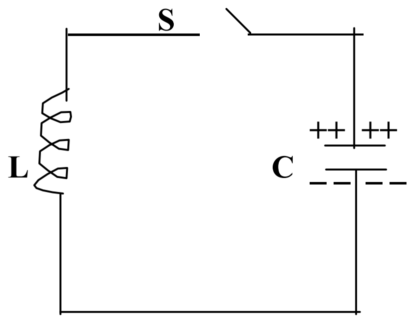


Fig.1

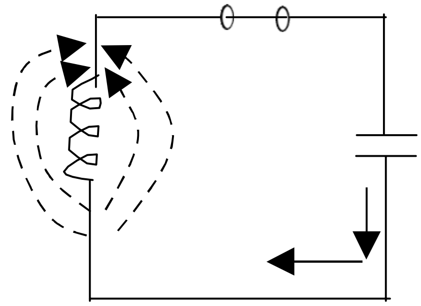


Fig. 2

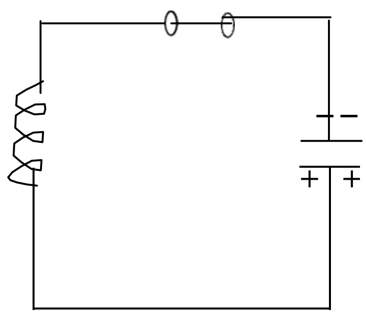


Fig. 3

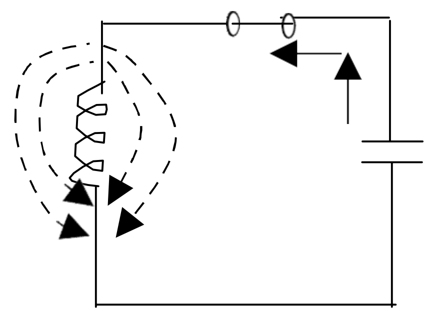


Fig. 4

Circuit operations- Assume capacitor is charged from a d. c. source with a polarity as shown in figure 1.

- When switch S is closed as shown in fig.ii, the capacitor will discharge through inductance and the electron flow will be in the direction indicated by the arrow. This current flow sets up magnetic field around the coil. Due to the inductive effect, the current builds up slowly towards a maximum value. The circuit current will be maximum when the capacitor is fully discharged. Hence the electrostatic energy across the capacitor is completely converted into magnetic field energy around the coil.

- Once the capacitor is discharged, the magnetic field will begin to collapse and produce a counter emf. According to Lenz's law the counter emf will keep the current flowing in the same direction. The result is that the capacitor is now charged with opposite polarity making upper plate of capacitor –ve and lower plate +ve as shown in fig. 3.
- After the collapsing field has recharged the capacitor, the capacitor now begins to discharge and current now flows in the opposite direction as shown in fig. iv.
- The sequence of charge and discharge results in alternating motion of electrons or an oscillating current. The energy is alternately stored in the lectric field of the capacitor C and the magnetic field of the inductance coil L . This interchange of energy between L and C is repeated over and again resulting in the production of Oscillations.

Waveform- In practical tank circuit there are resistive and radiation losses in the coil and dielectric losses in the capacitor. During each cycle a small part of the originally imparted energy is used up to overcome these losses. The result is that the amplitude of oscillating current decreases gradually and eventually it become zero. Therefore tank circuit produces damped oscillations.

Frequency of oscillations- The expression for frequency of oscillation is given by,

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

<u>Undamped Oscillations from Tank Circuit</u>

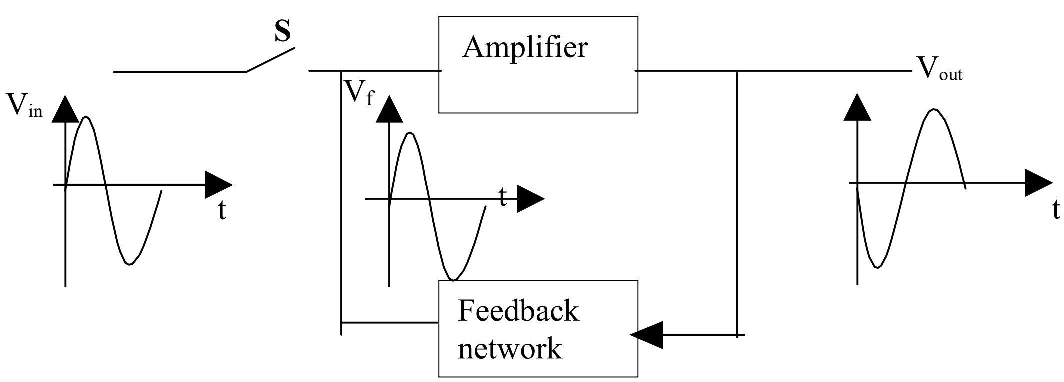
A tank circuit produces damped oscillations. In practice we need continuous undamped oscillations for the successful operation of electronics equipment. In order to make the oscillations in the tank circuit undamped it is necessary to supply correct amount of energy to the tank circuit at the proper time intervals to meet the losses.

The following conditions must be fulfilled;

1. The amount of energy supplied be such so as to meet the losses in the tank and the a.c. energy removed from the circuit by the load. For example if losses in LC circuit amount ot 5 mW and a.c. output being taken is 100 mW, then power of 105mW should be continuously supplied to the circuit.
2. The applied energy should have the same frequency as the of the oscillations in the tank circuit.
3. The applied energy should be in phase with the oscillations set up in the tank circuit.

Positive feedback Amplifier-Oscillator

1. A transistor amplifier with proper +ve feedback can act as an oscillator.



2. The circuit needs only a quick trigger signal to start the oscillations. Once the oscillations have started, no external signal source is necessary.
3. In order to get continuous undamped output from the circuit, the following condition must be met;

$$m_v A_V = 1$$

where A_V = voltage gain of amplifier without feedback.

m_v = feedback fraction.

This relation is also called Barkhausen criterion

1. RC Phase Shift Oscillator

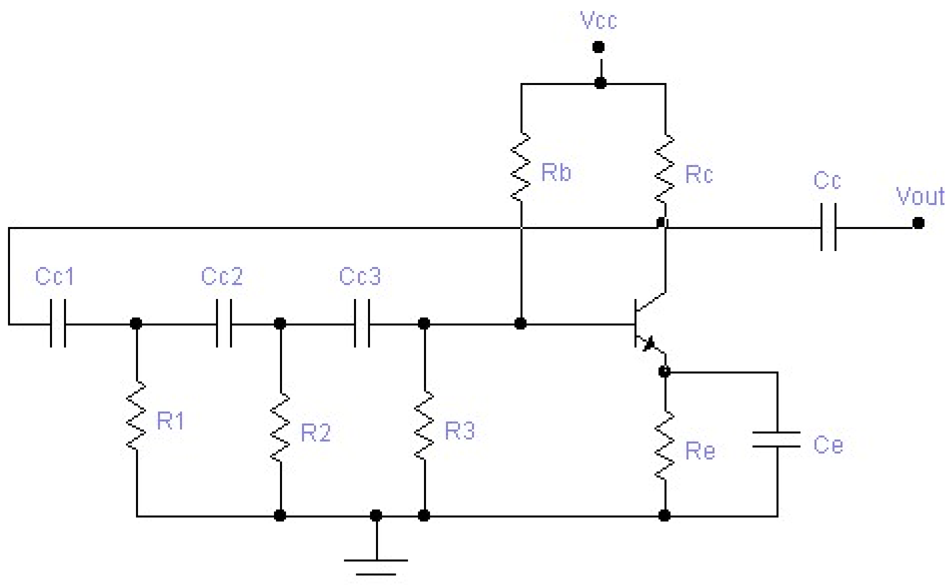


Figure: Circuit diagram of RC phase shift Oscillator

- It consists of a conventional single transistor amplifier and a RC phase shift circuit. The RC phase shift circuit consists of three sections R_1C_1, R_2C_2, and R_3C_3. At some particular frequency f_0 the phase shift in each RC section is 60^0 so that the total phase shift produced by the RC network is 180^0. The frequency of oscillation is given by

$$f_o = \frac{1}{2\pi RC\sqrt{6}} \quad \text{------------------------------------} (6)$$

- When the circuit is switched ON it produces oscillations of frequency determined by equation 1. The output E_O of the amplifier is feedback to RC feedback network. This network produces a phase shift of 180^0 and the transistor gives another 180^0 shift. Thereby total phase shift of the output signal when fed back is 360^0

Merits-

1. They do not require any transformer or inductor thereby reduce the cost.
2. They are quite useful in the low frequency range where tank circuit oscillators cannot be used.
3. They provide constant output and good frequency stability.

Demerits –

1. It is difficult to start oscillations.
2. The circuit requires a large number of components.
3. They cannot generate high frequencies and are unstable as variable frequency generators.

2.Transistor Crystal Oscillator

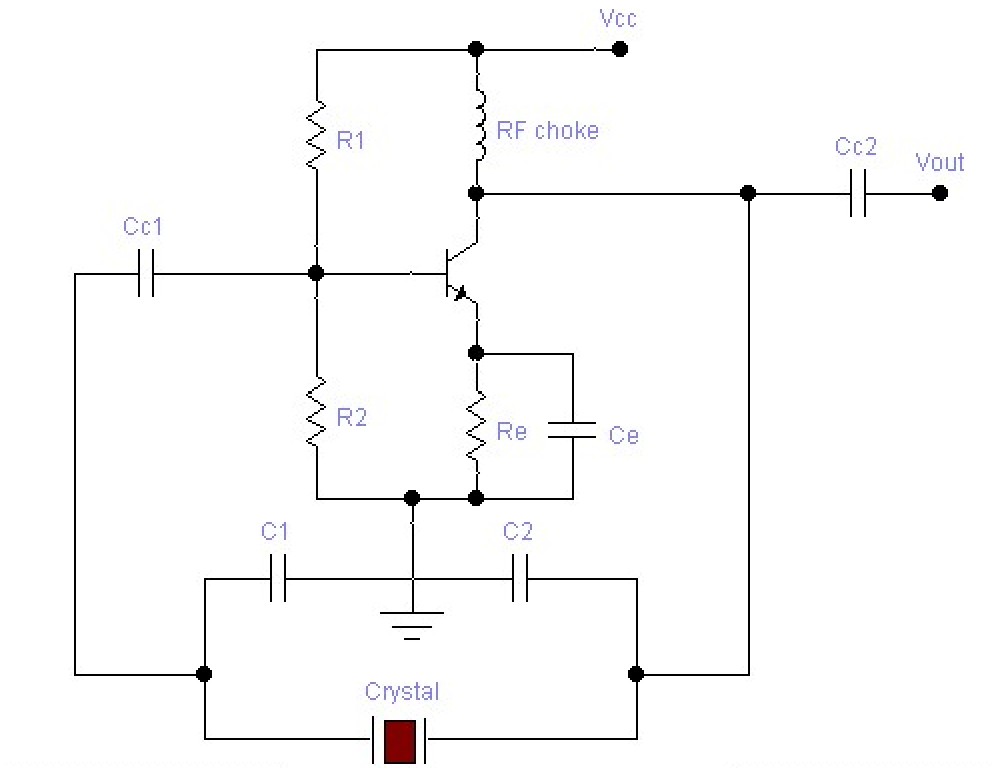


Figure: Circuit diagram of Transistor crystal oscillator

- Figure shows the transistor crystal oscillator. The crystal will act as parallel – tuned circuit. At parallel resonance, the impedance of the crystal is maximum. This means that there is a maximum voltage drop across C_2. This in turn will allow the maximum energy transfer through the feedback network.

- The feedback is +ve. A phase shift of 180^0 is produced by the transistor. A further phase shift of 180^0 is produced by the capacitor voltage divider. This oscillator will oscillate only at f_p.

  Where f_p = parallel resonant frequency ie the frequency at which the vibrating crystal behaves as a parallel resonant circuit.

$$f_p = \frac{1}{2\pi\sqrt{LC_T}}$$

--------------------------------------(7)

$$where\ C_T = \frac{CC_m}{C + C_m}$$

Advantages

1. Higher order of frequency stability
2. The Q-factor of the crystal is very high.

Disadvantages

1. Can be used in low power circuits.
2. The frequency of oscillations cannot be changed appreciably.

3.Wien Bridge Oscillator

Multivibrators