# Chapter: 4

## Signal Conditioning and Processing

**Signal Conditioning:** The o/p of detector transducer stage has to be modified before it becomes usuable and satisfactory to drive the signal presentation stage. thus any processing or modification of the transduced signal in to a usuable format for the final stage of the measurement system is known as signal conditioning. The signal conditioning equipment may be required to do linear processes: amplification, attenuation, integration, differentiation, addition, subtraction, etc. It may also be required to do non linear processes: modulation, demodulation, sampling, filtering, clipping clamping, squaring, multiplication by another function, etc.

Signal Conditioning may be an amplification system for active transducer and an excitation and amplification system for passive transducer. In both the applications, the transducer o/p is brought upto a sufficient level to make it useful for conversion, processing, indicating and recording.

The excitation sources may be an alternating or dc voltage source. Accordingly, there are ac and dc signal conditioning.

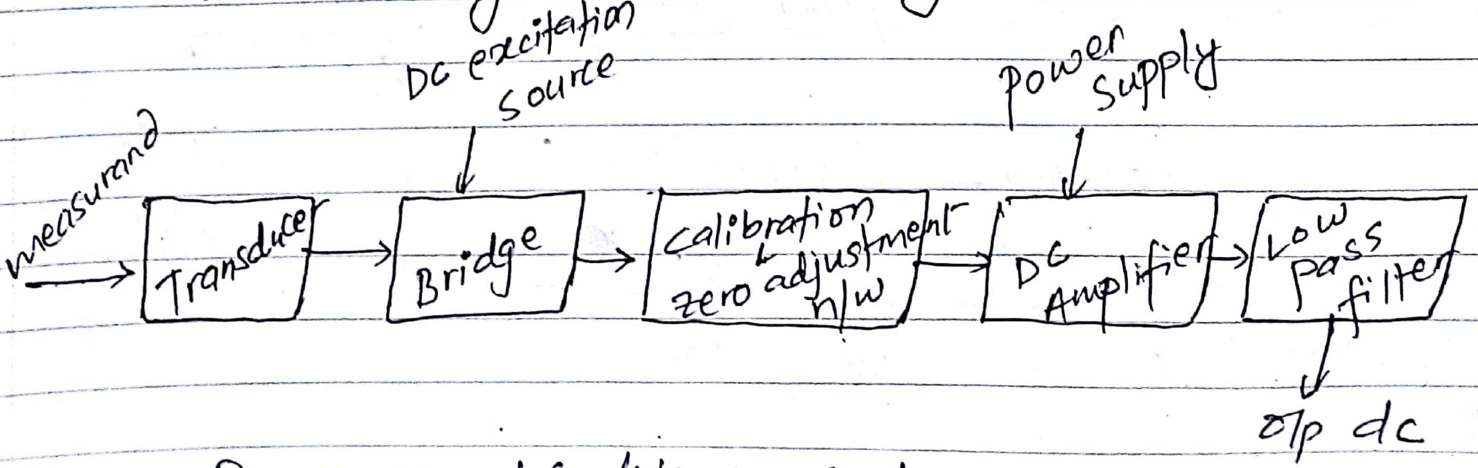


Fig: DC Signal Conditioning System.

The resistance transducers like strain gauge, constitute one arm or more than one arm of a wheatstone bridge which is excited by a dc source. The bridge can be balanced by a potentiometer and can also be calibrated for unbalanced conditions.

The desirable characteristics of dc amplifier are:
(i) It must need balanced differential i/p giving a high CMRR.
(ii) It should have an extremely good thermal and long term stability.
(iii) It must be able to recover from an overload condition unlike its counterpart.

The greatest disadvantage of a dc amplifier is that it suffers from the problem of drift.

The dc amplifier is followed by a low pass filter which eliminates high frequency components or noise from the data signal.

To overcome the problems encountered in dc systems, an ac system is used. In ac system, carrier type ac signal conditioning systems are used.

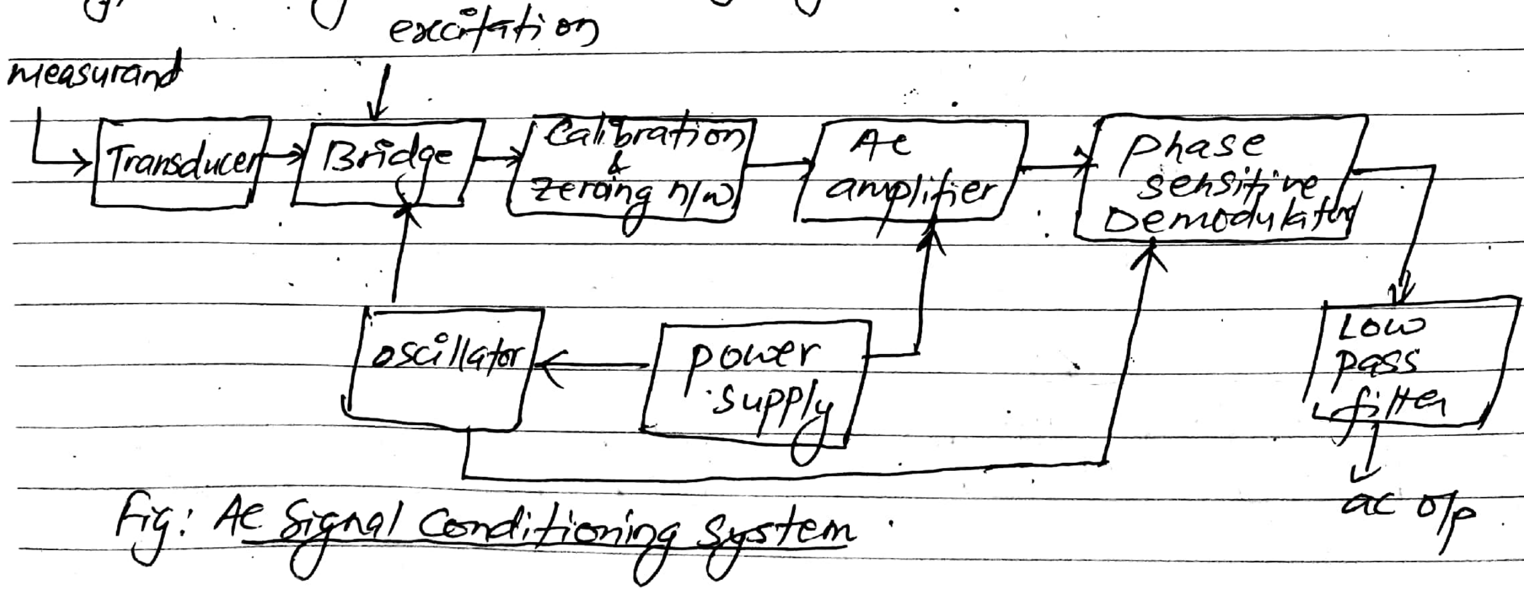


Fig: AC Signal Conditioning System

The transducers used are variable resistance or variable inductance transducers. They are employed both carrier frequencies of 50 to 200kHz. The carrier frequencies are much higher, they are at least 5 to 10 times the signal frequencies. Transducer parameter variation amplitude modulate the carrier frequencies at the bridge o/p and waveform is amplified and demodulated. The demodulation is phase sensitive so that the polarity of ac o/p indicates the dirn of the parameter changed in the bridge o/p. The phase sensitive demodulators filter out carrier frequency components of the data signal.

Advantages of ac signal conditioning system:
- there is no probability of drift in ac signal.
- telemetric (long distance carrier) thru microwave or cable is possible.

# Operational Amplifier (op-Amp) :-

The op-amp manufactured with integrated ckt technology contains transistors, diodes, resistors and capacitors. It is an extremely versatile device that does countless jobs in many electronic ckts such as isolation, inversion, addition, subtraction, multiplication, division, integration, differentiation, etc.

One of the most popular op-Amp is the 741 which is an eight pin device.

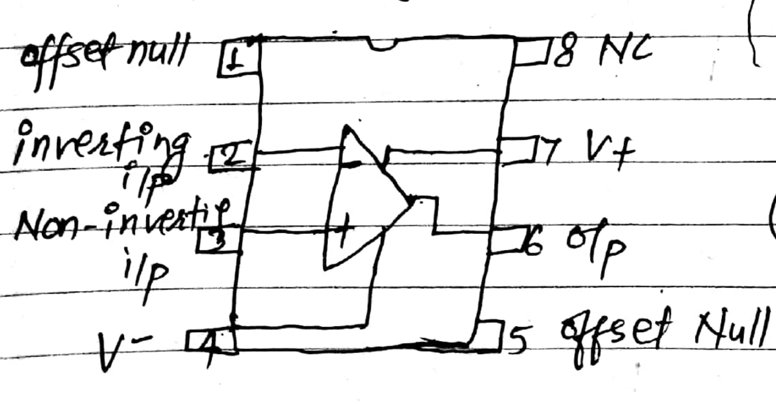


Fig: Pin Connection of 741

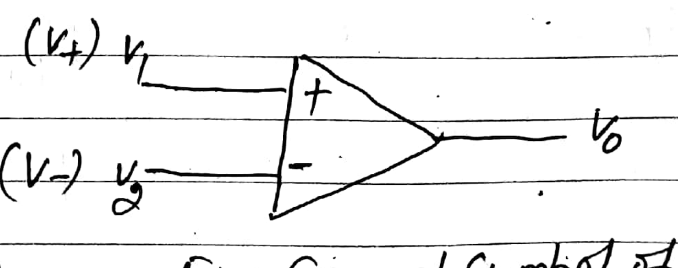


Fig: General Symbol of an op-Amp

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# Properties of operational Amplifiers:

The op-Amp without any feedback paths connected to it is described as being operated in an open loop mode. (ie. feedback loop is not closed). The ideal characteristics of the op-amp in this open loop mode are:

(i) Gain $= \infty$
(ii) Bandwidth $= \infty$
(iii) Input impedance $= \infty$
(iv) o/p impedance $= 0$
(v) o/p signal, $V_0 = 0$, when $V_2 = V_1$.

The op-amp can accomodate both +ve and -ve i/ps Simultaneously or one at a time.

$$V_0 = A_{vol}(V_+ - V_-) = A_{vol} \cdot V_d$$

where $V_d$ = net i/p differential voltage

As $V_d$ is the net i/p differential voltage and $A_{vol}$ is the open loop gain which is about 1,00,000. This means that the net differential voltage is increased at the o/p terminals by this factor. Clearly, if the overloads are to be avoided, it is necessary to restrict $V_d$ to those values that will keep $V_0$ at least below the magnitude of supply voltage. So,

$$V_d = \frac{V_0}{A_{vol}} = \frac{15}{1,00,000} = 150\mu V.$$ This voltage is known as threshold value. If $V_d$ is above this value, it will cause saturation.

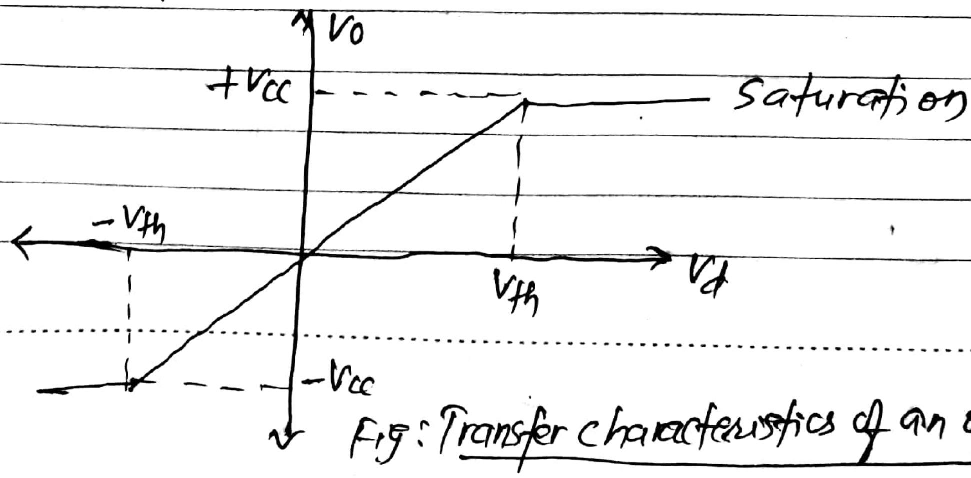


Fig: Transfer characteristics of an op-Amp

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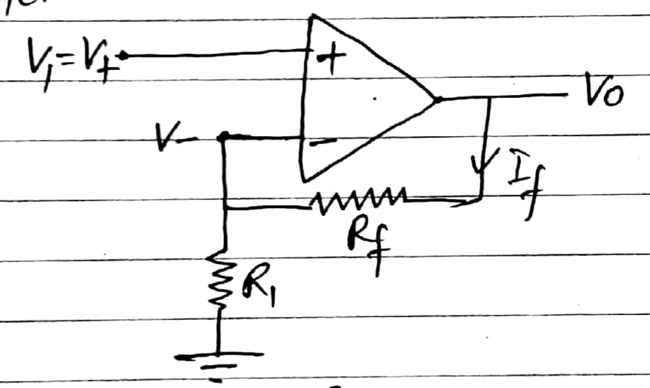
the saturation value is approximately taken to be a supply voltage Vcc for convinience. the transfer characteristics indicate that the amplifier region for the op-Amp in which $V_o = A_{vol} \cdot V_d$ is restricted to an o/p voltage range of $V_{omin} \leq V_o \leq V_{omax}$. Similarly, the range for amplifier region is given by

$$\frac{V_{o\,min}}{A_{vol}} \leq V_d \leq \frac{V_{o\,max}}{A_{vol}}$$

# Non-Inverting Amplifier Configuration :-

In this ckt, the o/p voltage is seen to have the same polarity as the i/p voltage. The i/p signal is applied to the +ve terminal while the -ve terminal is connected to ground thru resistor.




from fig, $V_- = V_o \times \left(\frac{R_1}{R_1+R_f}\right)$

Now,

$$V_o = A_{vol} \times V_d$$

$$\text{or, } V_o = A_{vol}(V_+ - V_-)$$

$$\text{or, } \frac{V_o}{A_{vol}} = V_1 - V_o\left(\frac{R_1}{R_1+R_f}\right)$$

$$\text{or, } 0 = V_1 - V_o\left(\frac{R_1}{R_1+R_f}\right) \quad (\because A_{vol} = \infty)$$

$$\text{or, } \frac{V_o}{V_1} = \frac{R_1+R_f}{R_1}$$

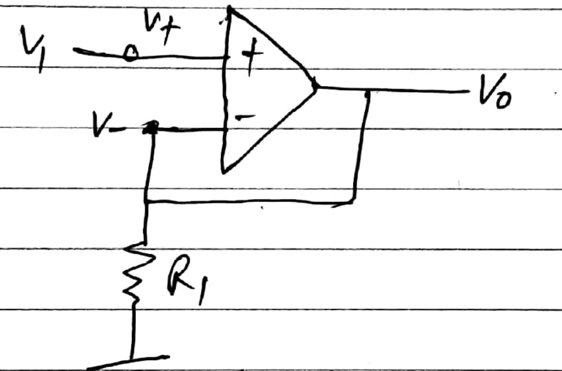
$\therefore$ $\boxed{A_v = 1 + \frac{R_f}{R_1}}$ — (1) is the closed loop gain

Hence, the o/p voltage is controlled by properly selecting the values for resistors $R_1$ and $R_f$.

## # Voltage follower (Isolation) Mode :-

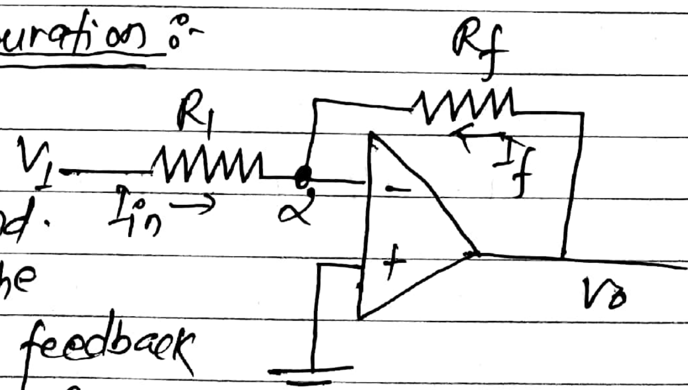
When the feedback resistor $R_f = 0$ then from the above relation (from eqn (1)), $V_1 = V_0$.
The o/p of the op-Amp exactly tracks the i/p voltage in both magnitude and polarity. This is the reason why this circuit is called a voltage follower.

* It has large i/p impedance.
* It has unity gain.
* It has very low o/p impedance.




→ works as an ideal buffer.

## # Inverting Amplifier Configuration :-




In this ckt, the +ve i/p terminal is connected to ground. The signal is applied to the -ve i/p terminal thru $R_1$ and feedback is returned from the o/p thru $R_f$.

Applying KCL at $\alpha$,

$$I_{in} + I_f = 0$$

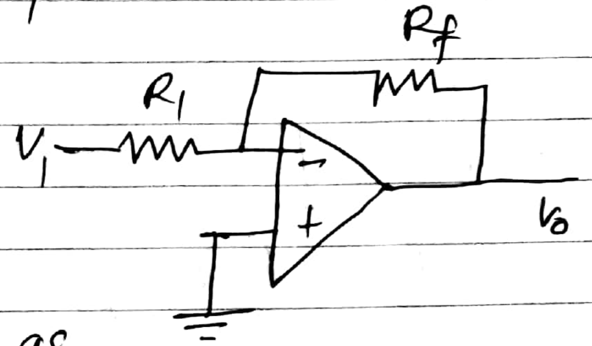
$$\text{or, } \frac{V_1}{R_1} = -\frac{V_0}{R_f}$$

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

$\therefore$ Closed loop gain $(A_v) = -\frac{R_f}{R_1}$

# Application of op-Amp :

(i) Inverter



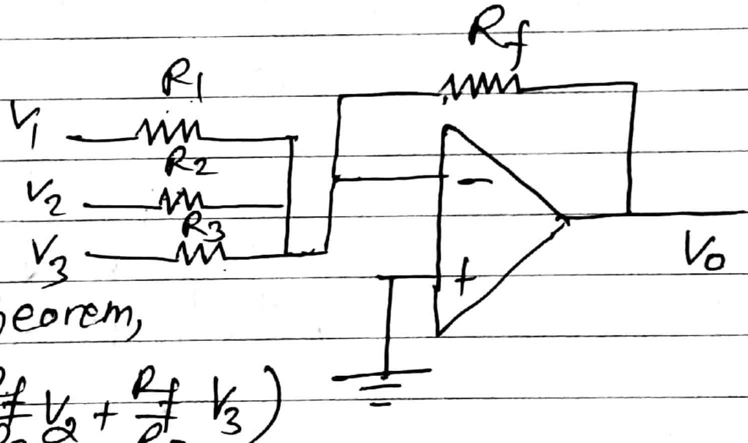

For this ckt,

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

If $R_1 = R_f$ then it acts as an inverter.

And the o/p is $V_o = -V_1$ which is 180° out of phase.

(ii) Adder :



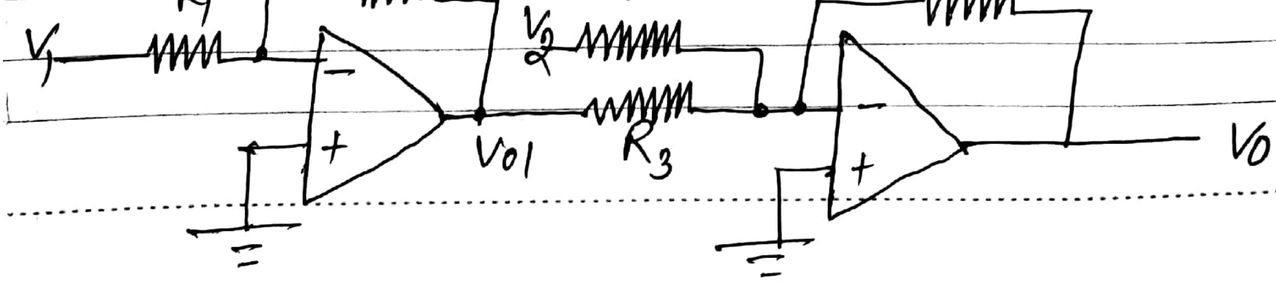

Using superposition theorem,

$V_o = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right)$

if $R_1 = R_2 = R_3 = R_f$,

$V_o = -(V_1 + V_2 + V_3)$

(iii) Subtractor :-



$$V_{01} = \left(-\frac{R_f}{R_1}\right)V_1 \quad \text{—— (1)}$$

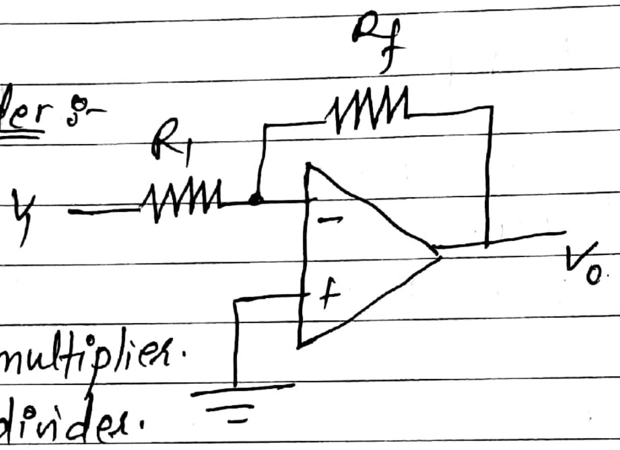
then, $V_0 = \left(-\frac{R_f}{R_1}\right)V_2 + \left(-\frac{R_f}{R_3}\right)V_{01}$

$$= \left(-\frac{R_f}{R_1}\right)V_2 + \left(-\frac{R_f}{R_3}\right)\left(-\frac{R_f}{R_1}\right)V_1$$

if $R_1 = R_2 = R_3 = R_f$ then

$$\boxed{V_0 = V_1 - V_2}$$

(iv) Multiplier and divider :-

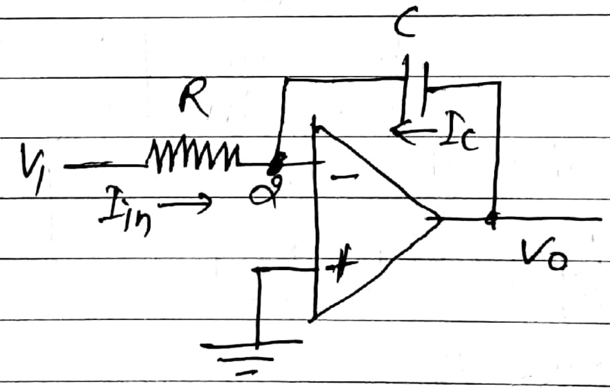



we have,

$$V_0 = \left(-\frac{R_f}{R_1}\right)V_1$$

if $R_f > R_1$, the ckt acts as multiplier.
if $R_f < R_1$, " " " " divider.

(v) Integrator :-




Applying KCl at α

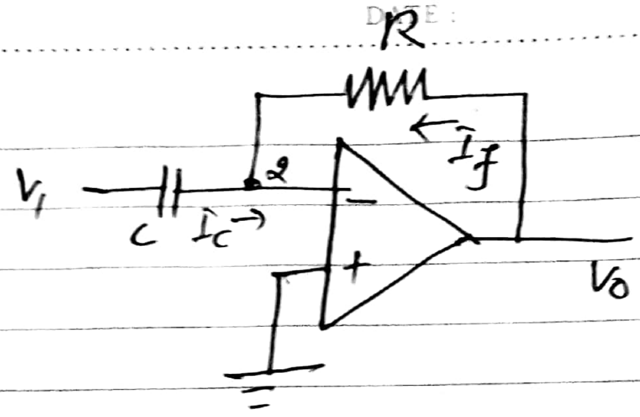
$$I_{in} + I_C = 0$$

or, $\frac{V_1}{R} = -C\frac{dv_0}{dt}$

or, $\frac{dv_0}{dt} = -\frac{V_1}{RC}$

or, $V_0 = \left(-\frac{1}{RC}\right)\int V_1\,dt$

(vi) Differentiator




Here, $I_f + I_c = 0$

or, $\frac{V_0}{R} = -C\frac{dV_1}{dt}$

or, $V_0 = (-RC)\frac{dV_1}{dt}$

# Some limiting factors of op-Amp :-

(i) o/p offset voltage :-
When an op-amp is used as dc amplifier, Vout should be zero when the i/p voltage Vin is zero. In fact, a dc voltage still appears at the o/p of real op-amp even when no i/p voltage signal is present, which is called o/p o/p offset voltage.
There are two principal components which makes up the o/p offset voltage, each caused by a different effect: Input offset voltage & i/p bias current.

I/p offset voltage :- It is a small, relatively const but temperature dependent voltage that exists between the i/p terminals of an op-amp even when no i/p signal is present. It is caused by the imperfect matching of component characteristics within the i/p stage of the op-Amp. (specially due to the mismatch in the base to emitter voltage of the i/p differential transistor amplifier).

I/p bias Current :- It is the current that flows into the i/p of a non ideal (i.e. $Z_{in} \neq \infty$) amplifier due to leakage currents, gate currents and so on of the amplifier components.

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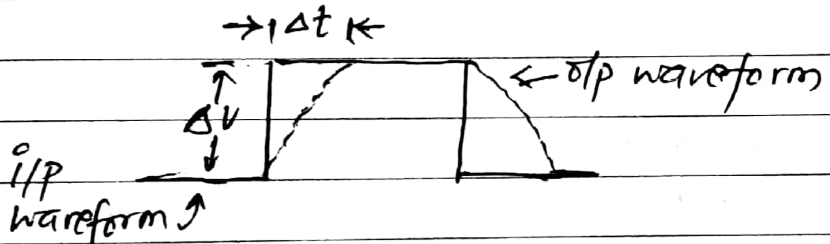
(ii) I/p offset Current :- The two i/p transistors forming op-Amp are not perfectly matched and a different bias current is required at each i/p. the difference between the two bias currents is reffered to as i/p offset current ($I_{os}$)

$$I_{os} = I_{B1} - I_{B2}$$

(iii) Slew Rate :- It represents the maximum rate of change of amplifier o/p voltage. It is measured in terms of volt/sec. Due to finite slew rate of real op-Amps, the amplifier will be unable to change the value of its o/p voltage instantaneously.

$$SR = \left.\frac{\Delta V}{\Delta t}\right|_{max}$$




(iv) CMRR (Common Mode Rejection Ratio) :-
It is defined to be the ratio of differential gain ($K_D$) to the common mode gain ($K_C$) of the amplifier

$$\text{ie. } CMRR = \frac{K_D}{K_C}$$

An ideal differential amplifier would have an infinite CMRR.

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# Filter :-

The signal originating from a transducer is fed to the signal conditioning equipment. For faithful reproduction of the signal from the transducer originating on account of variation of a physical change, it becomes necessary to eliminate any kind of unwanted signal which may get introduced into the system either at the transduction stage or at the signal conditioning stage.

The filters are designed to pass the signals of wanted frequencies and to reject the signals of unwanted frequencies which may be unwanted harmonics and noise. The harmonics or noise may be due to some form of distortion.

# Types of Filters :-

Filters may be classified as (i) Active (ii) Passive filter.

Passive filters :- They only use passive ckt elements like capacitors, inductors, resistors.

Active filters :- They use active elements like op-Amp in addition to the passive elements.

Both passive and active filters may be further classified as:

(i) Low pass filter
(ii) High pass filter
(iii) Band pass filter
(iv) Band stop filter

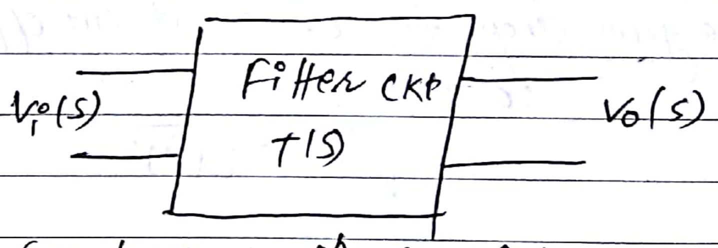
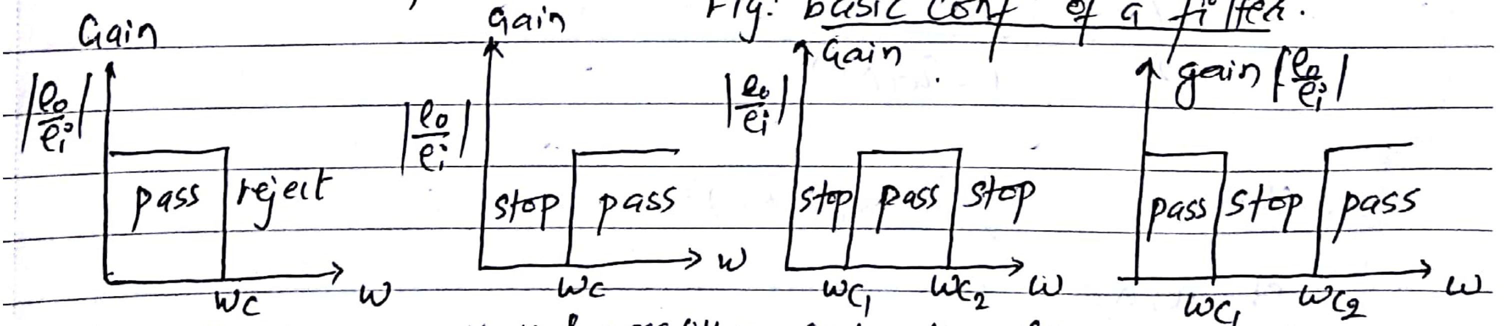



Fig: basic conf^n of a filter.




(a) low pass filter (b) High pass filter (c) band pass filter d) Band stop filter

Fig: Ideal characteristics of filters.

(i) Low Pass filter :-

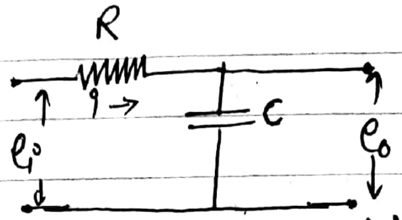



fig (a)

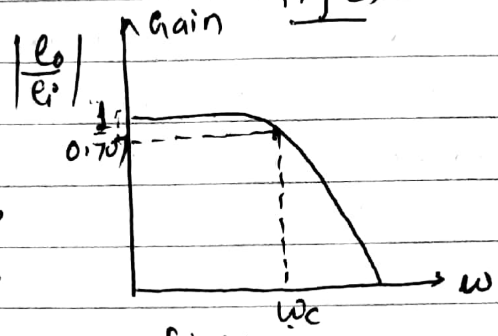



fig (b)

fig: (a) Low pass RC filter (b) its characteristics.

At low frequencies the capacitive reactance is very high and therefore the capacitor ckt can be considered as an open ckt. Under these conditions, $e_o = e_i$ or the voltage gain is unity. At very high frequencies, the capacitive reactance is very low and therefore the o/p voltage is very small as compared with the i/p voltage. Thus the gain is low and drops gradually as the frequency is increased.

The transfer function is, $\frac{E_o(s)}{E_i(s)} = \frac{1/sC}{R+1/sC} = \frac{1}{1+sRC} = \frac{1}{1+s\tau}$

The sinusoidal transfer function of a LPF is

$$\frac{e_o(j\omega)}{e_i(j\omega)} = \frac{1}{1+j\omega RC} = \frac{1}{1+j\omega\tau}$$

$$\text{Gain, } A = \left|\frac{e_o(j\omega)}{e_i(j\omega)}\right| = \frac{1}{\sqrt{1+(\omega RC)^2}}$$

The gain drops to 0.707 at cut off frequency $\omega_c$,

$$\therefore 0.707 = \frac{1}{\sqrt{1+(\omega_c RC)^2}}$$

$$\text{or, } \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1+(\omega_c RC)^2}}$$

$$\text{or, } 1/2 = 1/\,1+(\omega_c RC)^2$$

$$\text{or, } \omega_c RC = 1$$

$$\text{or, } \omega_c = 1/RC$$

$\therefore$ the cut off frequency, $f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi\tau}$

(ii) **High Pass filter :-**

The transfer function of a high pass filter is given by

$$\frac{E_o(s)}{E_i(s)} = \frac{R}{R+1/cs} = \frac{sRC}{1+sRC} = \frac{\tau s}{1+\tau s}$$

Sinusoidal tranfer function,

$$\frac{e_o(j\omega)}{e_i(j\omega)} = \frac{j\omega RC}{1+j\omega RC} = \frac{j\omega\tau}{1+j\omega\tau}$$

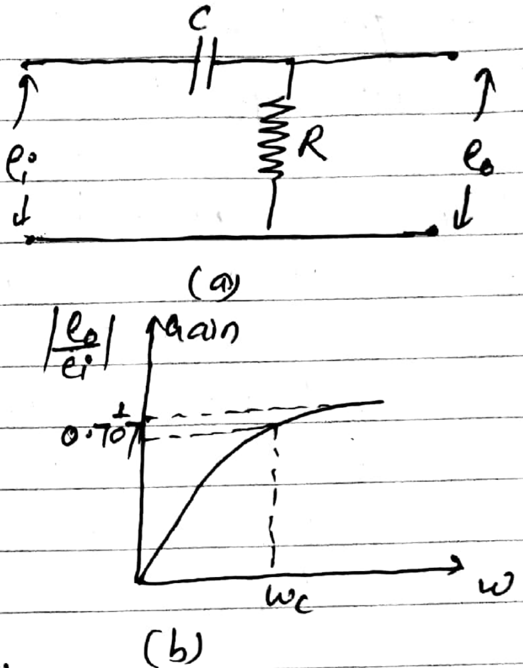



fig: (a) high pass RC filter (b) its characteristics

$$\text{Gain, } A = \left|\frac{e_o(j\omega)}{e_i(j\omega)}\right| = \frac{\omega RC}{\sqrt{1+(\omega RC)^2}}$$

At cut off frequency $\omega_c$, the gain drops to 0.707 i.e.

$$0.707 = \frac{\omega_c RC}{\sqrt{1+(\omega_c RC)^2}}$$

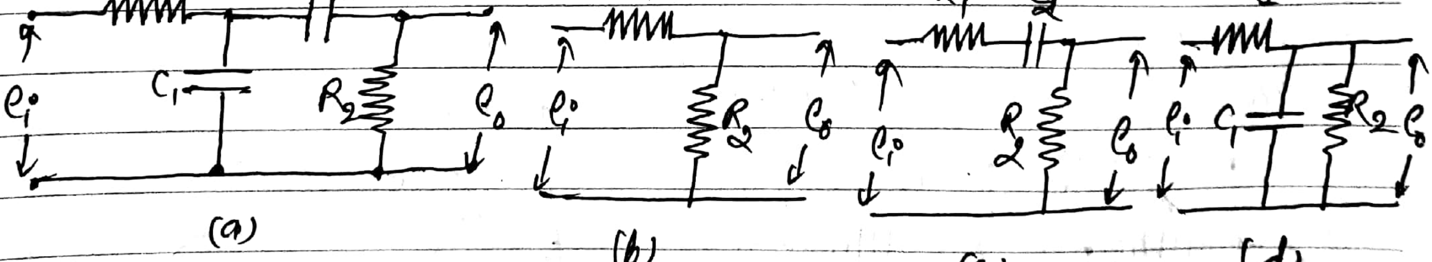
or, $1+(\omega_c RC)^2 = 2(\omega_c RC)^2$

or, $\omega_c RC = 1$

or, $\omega_c = 1/RC$

$\therefore$ cut off frequency $= f_c = 1/2\pi RC = 1/2\pi\tau$

(iii) **Band Pass filter :-** A simple band pass filter can be constructed by cascading a low pass and a high pass filter.



In the pass band with lower cut off frequency $f_{c_1}$ and upper cut off frequency $f_{c_2}$, the ckt behaves like a voltage divider n/w as in fig (b).

At frequencies below the pass band, it behaves like a high pass filter as shown in fig (c) (since capacitor $C_1$ is short circuited and capacitor $C_2$ behaves as an open ckt). Above pass band frequencies, the capacitor $C_2$ behaves as a short ckted element and the ckt behaves like a low pass filter as shown in fig (d).

If $R_2 > 10R_1$ & $f_{c_2} > 10 f_{c_1}$

The lower cut off frequency is

$$f_{c_1} = \frac{1}{2\pi R_2 C_2}$$

and the upper cut off frequency is $f_{c_2} = \dfrac{1}{2\pi R_1 C_1}$

The low pass and high pass filters are connected in cascade, the transfer function is

$$\frac{E_o(s)}{E_i(s)} = \left(\frac{1}{1+s\tau_1}\right) \times \left(\frac{\tau_2 s}{1+s\tau_2}\right)$$

where $\tau_1 = R_1C_1$, $\tau_2 = R_2C_2$ with $\tau_2 > \tau_1$

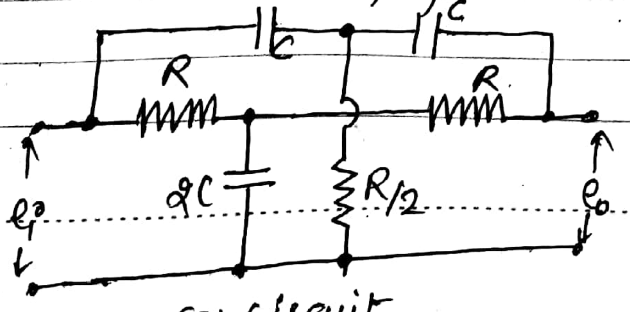
In the pass band, the ckt behaves almost as a resistive n/w and therefore the gain in the pass band is

$$A = \left|\frac{e_o}{e_i}\right| = \frac{R_2}{R_1+R_2}$$

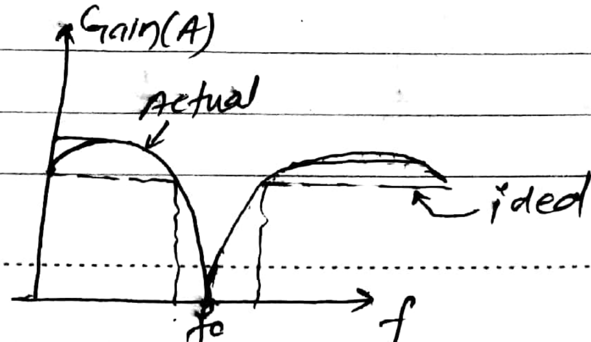
(iv) Band Reject (or band stop) filter :-

A simple RC band rejection (band stop) filters are either a Wien bridge ckt or a Twin 'T' circuit.

Twin 'T' Band stop filter :-




(a) Circuit




b) actual & ideal response

The above figures are (a) ckt of twin 'T' Notch filter and (b) actual and ideal response of the ckt.
At very low and very high frequencies, the gain is almost unity. Somewhere, in both there is frequency where the gain becomes zero. The o/p at frequency $f_o$ is equal to zero. This type of filter is often called Notch filter because it completely rejects a particular frequency and attenuates a range of frequencies greatly while passing the frequencies below and above the notch. ~~frequency fo~~. Frequency fo is called notch frequency.

$$\text{Notch frequency } (f_o) = \frac{1}{2\pi RC}$$

# Single Op-Amp (difference Amplifier):-

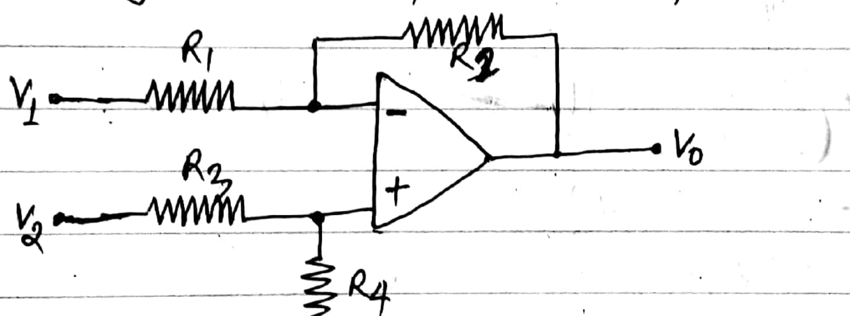
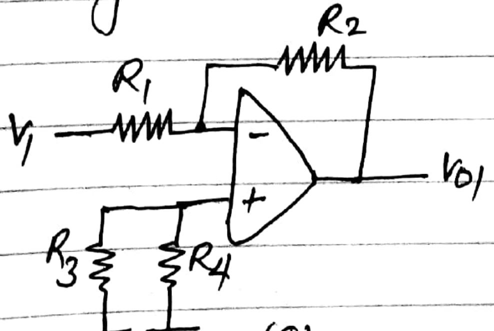
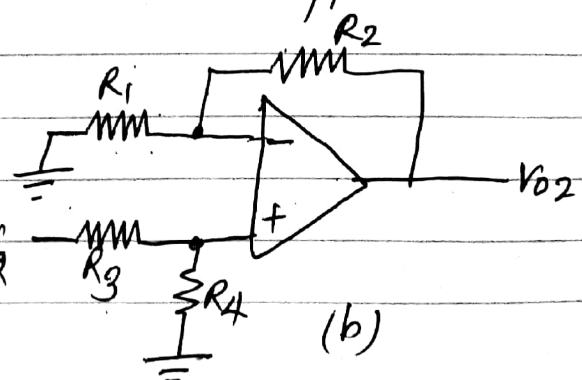



Fig: A difference Amplifier.

In order to analyze the ckt let us ~~consider~~ use principle of superposition. To apply superposition we first reduce $V_2$ to zero ie. ground the terminal to which $V_2$ is applied then the ckt becomes




(a)




(b)

as shown in fig(a). we recognize the resulting ckt as that of the inverting configuration, where the existence of $R_3$ and $R_4$ does not affect the gain expression since no current flows thru either of them.

thus, $V_{o1} = -\frac{R_2}{R_1} V_1$

Next we reduce $V_1$ to zero and evaluate the corresponding o/p voltage $V_{o2}$. The ckt becomes as shown in fig(b) which we recognize as the non inverting configurations with an additional voltage divider made up of $R_3$ and $R_4$

$$V_{o2} = V_2\left(\frac{R_4}{R_3+R_4}\right)\left(1+\frac{R_2}{R_1}\right)$$

$$\therefore V_0 = -\frac{R_2}{R_1} V_1 + V_2\left(\frac{R_4}{R_3+R_4}\right)\left(1+\frac{R_2}{R_1}\right) \text{———} (i)$$

In order to act the amplifier as differential amplifier, when $V_1 = V_2$ then ideally $V_0 = 0$

$$\therefore 0 = -\frac{R_2}{R_1} V_1 + \left(\frac{1+R_2/R_1}{1+R_3/R_4}\right) V_2 \qquad [\because V_1 = V_2]$$

or, $R_4(R_1+R_2) = R_2(R_3+R_4)$

or, $R_1R_4 + R_2R_4 = R_2R_3 + R_2R_4$

or, $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ ——— (ii)

from (i) and (ii)

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

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# Instrumentation Amplifier Using 3 op-Amps

This 3 op-amp instrumentation amplifier provides improved performance because of its higher i/p impedance and CMRR over the ~~sig~~ single op-Amp.

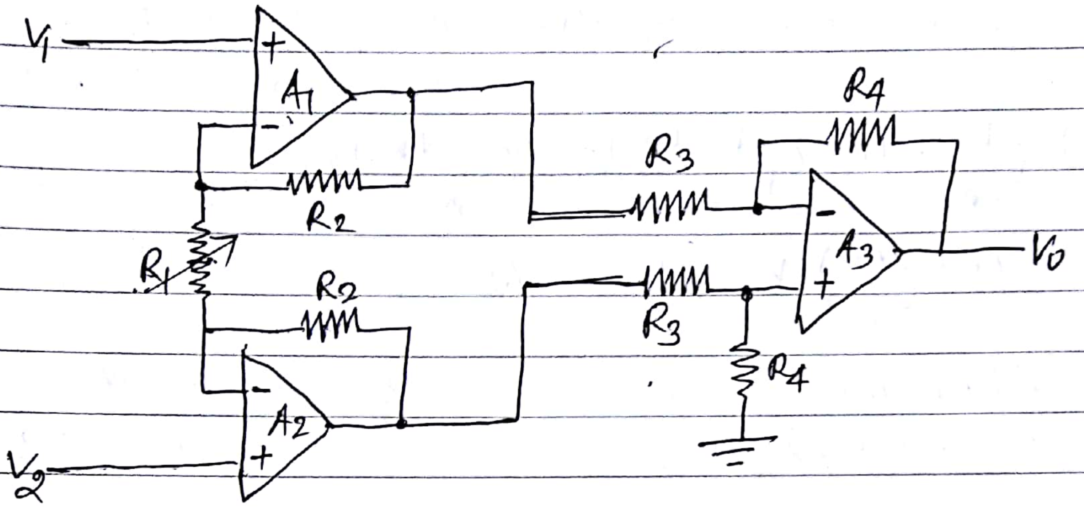
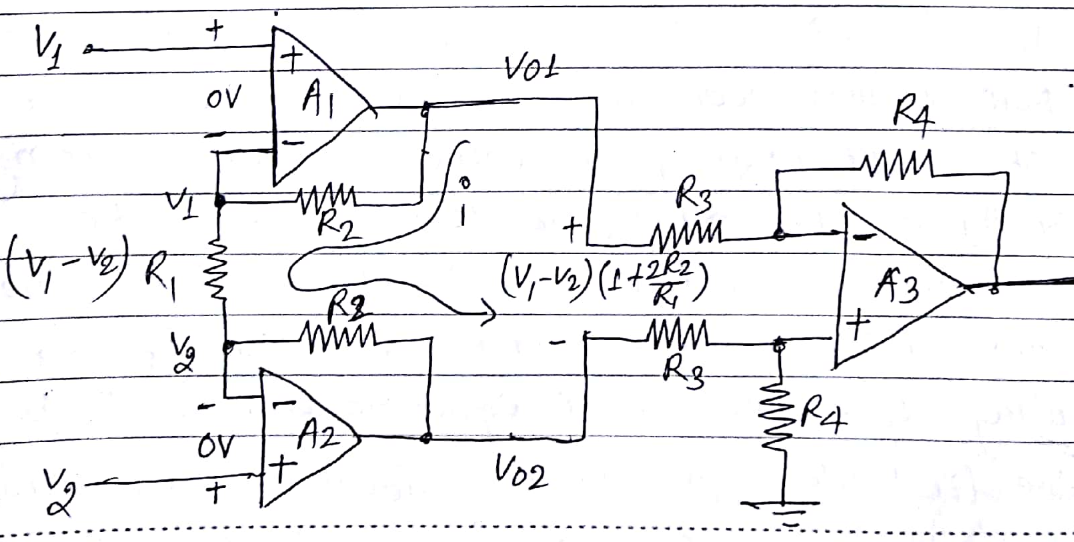



Fig: Instrumentation Amplifier using 3 op-Amp

In this configuration, the gain can be changed by varying only one resistor $R_1$.

This ckt consists of two stages: the first stage is formed by op-Amps $A_1$ and $A_2$ and their associative resistors and the second stage is is formed by op-Amp $A_3$ together with its four associative resistors. We recognize the 2nd stage as that of the difference amplifier.




$$V_0 = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)(V_2-V_1)$$

Fig: Analysis of ckt

The virtual short circuits at the inputs of op-Amps $A_1$ and $A_2$ cause the i/p voltages $V_1$ and $V_2$ to appear at the two terminals of resistor $R_1$. Thus the differential i/p voltage $(V_1 - V_2)$ appears across $R_1$ and causes current $i = \frac{(V_1 - V_2)}{R_1}$ to flow thru $R_1$ and the two resistors labeled $R_2$. This current in turn produces a voltage difference between the o/p terminals of $A_1$ and $A_2$ given by

$$(V_{01} - V_{02}) = \left(\frac{V_1 - V_2}{R_1}\right) R_2 + \left(\frac{V_1 - V_2}{R_1}\right) R_1 + \left(\frac{V_1 - V_2}{R_1}\right) R_2$$

$$\text{or, } (V_{01} - V_{02}) = \left(1 + \frac{2R_2}{R_1}\right)(V_1 - V_2) \quad \text{——— (1)}$$

The difference amplifier formed around op-Amp $A_3$ senses the voltage difference $(V_{01} - V_{02})$ and provides a proportional o/p voltage.

$$V_0 = -\frac{R_4}{R_3}(V_{01} - V_{02}) \quad \text{——— (2)}$$

from (1) and (2),

$$V_0 = -\frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)(V_1 - V_2)$$

$$\text{or, } V_0 = \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)(V_2 - V_1)$$

Thus the instrumentation amplifier has a differential voltage gain

$$A_d = \frac{V_0}{V_2 - V_1} = \left(1 + \frac{2R_2}{R_1}\right)\left(\frac{R_4}{R_3}\right) \quad \text{——— (3)}$$

Now consider pure common mode signal i.e. $V_1 = V_2 = V_{cm}$. Due to the virtual short ckt property, the voltage at the inverting i/p terminals of $A_1$ and $A_2$ both equals to $V_{cm}$. Hence the voltage across the series connected resistor is also zero and no current flows thru $R_1$. Therefore no current flows thru $R_2$ also. Thus the o/p voltage of $A_1$ and $A_2$ are equal to $V_{cm}$ and it is evident that the first stage gain is unity for the common mode signal. Thus if the 2nd stage difference amplifier is properly balanced it will produce a zero o/p voltage in response to $V_{cm}$, indicating that common mode gain of the instrumentation amplifier has the ideal value of zero.

From the differential gain expression (3) we observe that the gain value can be varied by varying the single resistor $R_1$. Since both of the i/p stage op-Amps are connected in the non-inverting configuration, the i/p impedance seen by each of $V_1$ and $V_2$ is infinite (ideally). This is the major advantage of this instrumentation amplifier configuration.

# Interference :-

The phenomenon by which it degrades the performance of the measurement system by the external or internal noise sources is known as interference.

There are generally two types of interference:

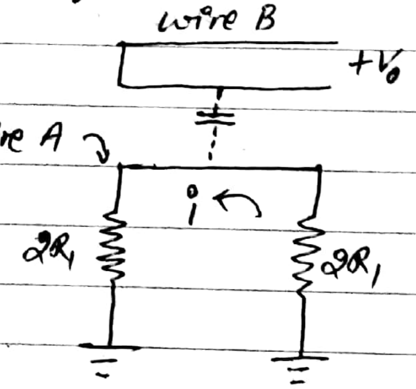
(i) External Interference
(ii) Internal Interference

(i) External Interference :-

The interference which is due to unwanted noise signals generated by the introduction of external magnetic and electric field to the measurement system is known as external interference. These signals may be coupled into the systems in various ways. External interference signals can be classified according to the physical phenomena that are responsible for their generation and transmission. The five major types of external interference signals are:

(a) Capacitive (or electrically coupled) Interference :-

Nearby power cables, the earth and conductors in the measurement system are separated from each other by a dielectric air. There can thus be capacitance betn the power cable and the conductors, and both conductors and earth. these capacitors couple the measurement system conductors to the other systems and thus signals in the other systems ~~offering~~ affecting the charges on these capacitors can result in interference in the measurement system.



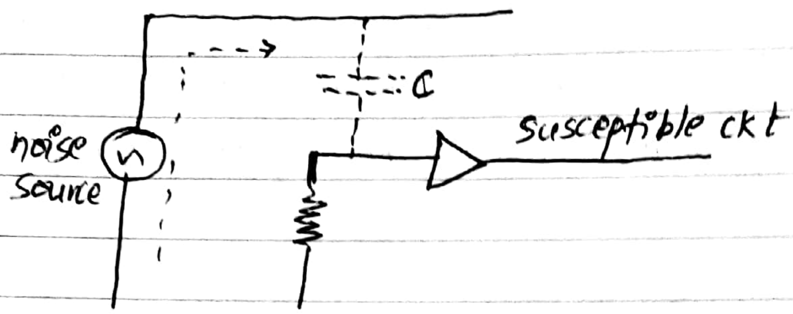




Fig. Capacitive Interference

Fig: Capacitive Coupling [coupling from stray capacitance completes the circuit of a noise source in to a susceptible ckt].

Capacitive coupling can be avoided by completely enclosing the system in an earthed metal screen. Problem may occur if there are multiple earths. So the metal shield surrounding the test signal cable should also be connected to ground at the single source ground point thru a low impedance path to minimize the problem. [ie. Shielding with proper grounding]

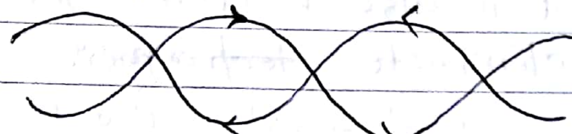
(B) Inductive Interference (or Magnetically Coupled) :-

A changing current in a nearby circuit produces a changing magnetic field which can induce emfs as a result of electro-magnetic induction, in conductors in the measurement system. The ~~magnetic~~ magnitude of induced emf depends upon the strength of magnetic field, the frequency of its variation and the area of the loop (the loop area is the factor because a large loop will encompass more magnetic flux than with smaller one). Hence the source of inductive interference is current carrying conductor in the near field.

Reduction techniques :-

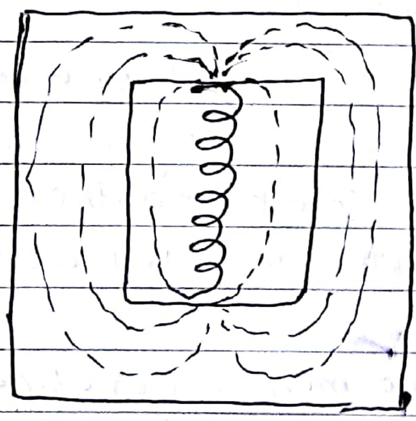
(a) Twisted pairs of wires :-

This involves the elements of the measurement system being connected by twisted wire pairs. A changing magnetic field will induce emfs in each ~~step~~ loop, but because of the twisting the directions of the emfs in a wire will be in one direction for one loop and in the opposite direction for the next loop and so cancel out.



Reducing the loop area by twisting the cable also minimizes the inductive interference.

(b) Since a magnetic field will concentrate itself in a ferro-magnetic material, by enclosing transformers and other magnetic field sources in ferromagnetic enclosures, the magnetic field outside the enclosure is weakned.




(c) Electromagnetic interference :-

At high frequencies, a part of the energy associated with the fluctuating current or charge in a conductor is radiated away from it in the form of electromagnetic (EM) radiation. The sources of EM interference may be :

- Human made sources of RF signals : transmitters (radio, radar, TV, etc), gas discharges in fluorescent lamp & x-ray tubes, arching in electric motors, generators, switches and relays, high frequency oscillators, pulse ckts, discharge ckts, etc.
- Natural sources of RF radiation include lightening and other electrical atmospheric phenomena.

**Reduction:** If either magnetic or electric field is suppressed, electromagnetic (EM) radiation is not possible. If we eliminate either the electric or the magnetic component of an EM wave, the other component is also halted. Therefore, since a shield designed to eliminate electrostatic fields can be made quite easy, this type of shield is also used to eliminate the electric field component of an EM wave. A mesh of conductor is used to cover the electronic equipments and it should be properly grounded. The external EM radiation is induced in the metallic wire but gets dumped to the ground, so it can't reach the ckt. Hence it is protected.

(d) Conductively Coupled Interference :-

Electrical fluctuation originated in other electrical devices but connected in the same ckt can cause interference, such interference signals are coupled to the measurement ckt. directly through electrical conductors called conductively coupled interference.

Three of the most common causes of conductively coupled interference in measurement systems are:

(*) the presence of common impedance ~~p~~ path in measurement system.

(*) Conductively coupled interference introduced into the system through the power transformer of measurement instruments &

(*) Power supplies that are incorrectly connected to parallel loads.

**Eliminations:**

- Separate grounding terminals for low and high signal pass or separate grounding for digital & analog ckts.
- the problem of conductively coupled noise spikes may be reduced with capacitance interference shielding (Faraday schielding) betn primary and secondary coil which attenuates the capacitive interference to the ground but permits the magnetic energy to pass.
- by the proper connection of the parallel loads to the supply.
- Unwanted conductively coupled signals can be minimised by the proper use of filters, if the range of frequencies of measured signals are known.

(e) **Ground Loop interference :-**

Ground loops are Closed electrical paths in which the sections of path consist of the ground wires of the system and the ground planes. Ground loops are created whenever the ground conductor of an electrical system is connected to the ground plane at different points. Since the ground wires of the systems and the ground plane are usually low impedance conducting paths, ground loops as a whole are conducting paths of low impedance. Thus, even if small voltage difference exist betn any points along the loop, large current will flow in them. This current may arise interference in the measurement system. Two principal causes of current flow in the ground loops are:

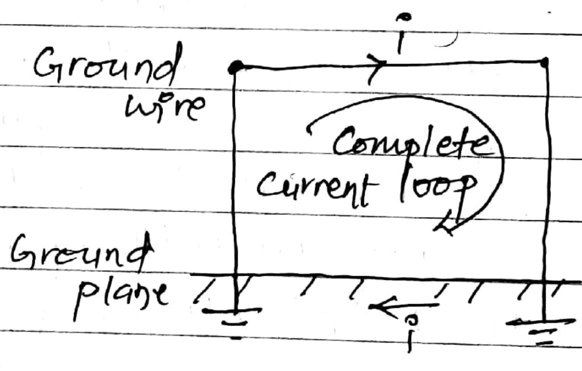



Fig:- Ground loop

(*) differences in potential both the points of the ground plane to which the ground terminals are connected.
(*) Inductive pick-up due to stray magnetic and RF fields.

Elimination:
→ Single point grounding.
→ Reducing the area of the loop.

(ii) Internal Interference :-
The interference which is internally generated i.e. arise from the inherent operation of the devices and the components that made up the system is known as internal interference. Some of the main internal internal interference signals are:

(a) Thermal (or Johnson) Noise :-
This noise is generated by the random motion of electrons and other charge carriers in resistors and s/c. It is spread over an infinite range of frequency and is thus often referred to as white noise. The rms noise voltage for a bandwith of frequency $f_1$ and $f_2$ is

rms noise voltage = $\sqrt{4KRT(f_2-f_1)}$

where, K = Boltzmann's constant
R = Resistance
T = Temp. in kelvin.

(b) Shot Noise (or Schottky Noise) :-
This noise is due to the random fluctuation in the rate at which charge carriers diffuse across potential barriers such as in pn junction diode. The rms noise ~~value~~ voltage from bandwidth from freq. $f_1$ to $f_2$ is

rms noise voltage = $\sqrt{2KTr_d(f_2-f_1)}$

where, $K$ = Boltzmann's Constant
$T$ = temp. on Kelvin
$r_d$ = the differential diode resistance $= \frac{KT}{qI}$, $q$ being the charge on an electron and $I$, the dc current thru the junction.

This noise also spreads across the all frequency spectrum, so it is also referred to as white noise.

(c) Flicker or 1/f noise : Th

This noise is exhibited by transistors and other solid state devices and its name is derived from the fact that its magnitude varies with the variation in the frequency.

(d) Burst or Popcorn Noise :-

Burst noise is due to the change in dc current level thru a s/c. It is due to the imperfection near the surface of the s/c.

(e) Partition Noise :-

This noise occurs whenever current has to divide between two or more electrodes and results from random fluctuations in the division. In BJT, the partition noise is produced when the emitter current is divided into base and collector currents. Since diode does not develop partition noise, in i/p of microwave receiver is a diode ckt.