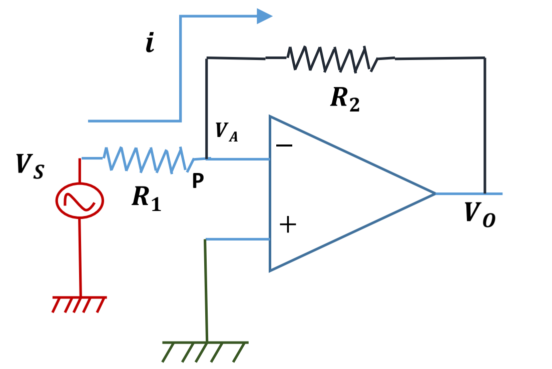
APLICATIONS OF OPAMP

INVERTING



INVERTING AMPLIFIER:- Practically no current enters into the OPAMP as input resistance is infinite. Then from figure, $i = \frac{V_S - V_A}{R_1} = \frac{V_A - V_0}{R_2}$

Or, $V_S R_2 - V_A R_2 = V_A R_1 - V_0 R_1$

Or, $V_0 R_1 - V_A (R_1 + R_2) = -V_S R_2$

Or, $V_0 R_1 - (-\frac{V_0}{A})(R_1 + R_2) = -V_S R_2$ **{ Say here open loop gain is A}**

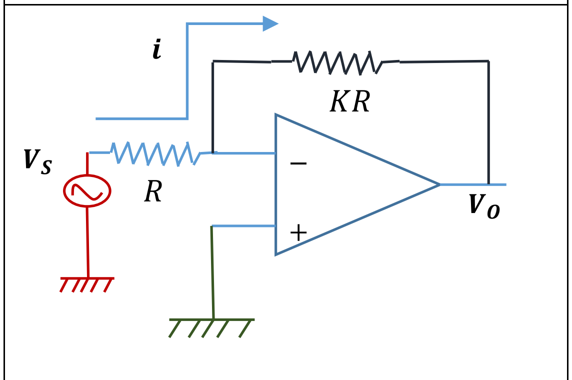
Or, $V_0 \left\{R_1 + \frac{(R_1+R_2)}{A}\right\} = -V_S R_2$

Then close loop gain (gain with feedback) $A_{Vf} = \frac{V_0}{V_S} = -\frac{R_2}{R_1\left(1+\frac{(R_1+R_2)}{AR_1}\right)} = -\frac{R_2}{R_1\left(1+\frac{1}{\beta A}\right)}$

Where $\beta = \frac{R_1}{R_1+R_2}$. For ideal case A→ ∞ Then $A_{Vf} = -\frac{R_2}{R_1}$

From virtual ground concept: for ideal case **A**→ ∞ **then** for finite output voltage the voltage difference between the inverting and non-inverting terminal must be very small. Then for ideal case we may say that there is a virtual ground at point P.

Then $V_A = 0$ then from figure $i = \frac{V_S - 0}{R_1} = \frac{0 - V_0}{R_2}$. Hence $A_{Vf} = \frac{V_0}{V_S} = -\frac{R_2}{R_1}$



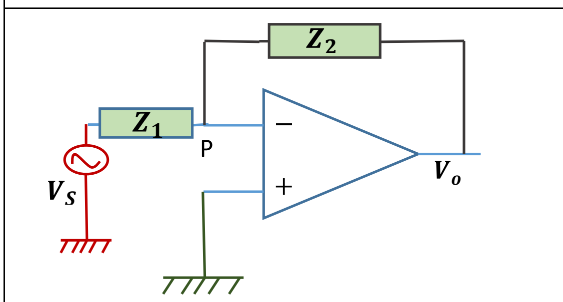
1.a). SCALE CHANGER:-

If we choose $\frac{R_2}{R_1} = K$ then $V_0 = -KV_S$

That means output is obtained by multiplying input voltage scale by $-K$

1.b). VOLTAGE CONTROLLED VOLTAGE SOURCE:- $V_0 = -\frac{R_2}{R_1} V_S$

Then output voltage is controlled by input voltage



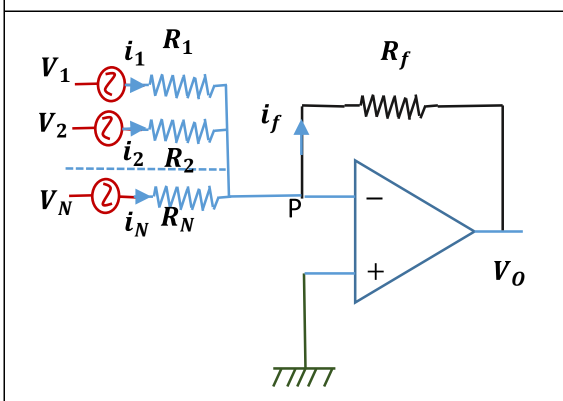
1.c).PHASE SHIFTER:-

Here $\frac{V_0}{V_S} = -\frac{Z_2}{Z_1} = -\frac{|Z_2|e^{j\Phi_2}}{|Z_1|e^{j\Phi_1}}$ **where $|Z_1|, \Phi_1$ & $|Z_2|, \Phi_2$ are magnitude and phases of Z_1 & Z_2**

If $|Z_1| = |Z_2|$ then $\frac{V_0}{V_S} = -\frac{e^{j\Phi_2}}{e^{j\Phi_1}} = e^{(\pi+\Phi_2-\Phi_1)}$

Hence $V_0 = V_S e^{(\pi+\Phi_2-\Phi_1)}$

Hence the circuit can shift input phase by an amount $(\pi + \Phi_2 - \Phi_1)$



1.d)/(i)INVERTING ADDER OR SUMMING AMPLIFIER:-

Since point P may be treated as virtual ground then

$$i_f = i_1 + i_2 \ldots\ldots + i_N$$

Or, $\frac{0-V_0}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} \ldots\ldots\ldots + \frac{V_N}{R_N}$

Now if $R_N = \ldots = R_2 = R_1 = R$ then, $\frac{-V_0}{R_f} = \frac{1}{R}(V_1 + V_2 \ldots\ldots + V_N)$

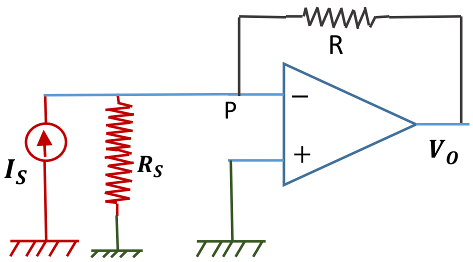
Again if $R_f = R$ then, $V_0 = -(V_1 + V_2 \ldots\ldots + V_N)$

Hence output voltage is sum of the inputs with a change in sign.

1.d)/(ii)AVARAGE AMPLIFIER:-

If $\frac{R_f}{R} = \frac{1}{N}$ Then, $V_0 = -\frac{(V_1+V_2 \ldots\ldots + V_N)}{N}$

Hence output is average of input signals

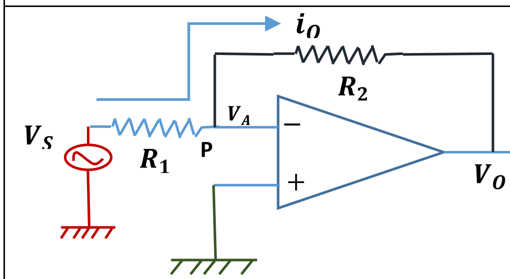


1.e).CURRENT TO VOLTAGE CONVATER/CURRENT CONTROLLED VOLTAGE SOURCE:-

Since point P is virtual ground no current passes through R_S

Hence whole current passes through feedback resistance R. therefore output voltage is $V_0 = -I_S R$

Hence output voltage is proportional to input current

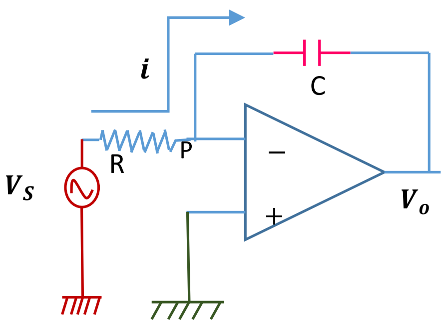


1.f). VOLTAGE Controlled CURRENT source: -

As here $A_{Vf} = \frac{V_0}{V_S} = -\frac{R_2}{R_1}$ **then** $\frac{V_0}{R_2} = -\frac{V_S}{R_1}$

Or, $i_O = -\frac{V_S}{R_1}$

Then output current is controlled by input voltage.



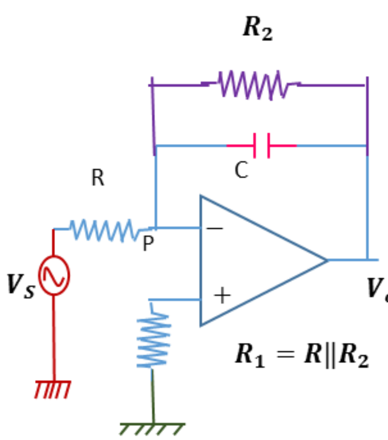
1.g). INVERTING INTEGRATOR

Since Point P is virtual ground then, $\frac{V_S - 0}{R} = \frac{dq}{dt} = \frac{d(-CV_0)}{dt} = -C\frac{dV_0}{dt}$

Hence $V_0 = -\frac{1}{CR}\int V_S\, dt + K$

Hence output voltage is proportional to time integral of input signal.

If input is cosine wave output is sine, and when input is square wave output is triangular wave.



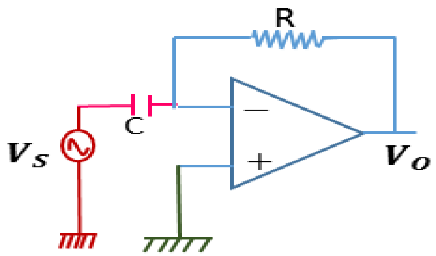
NOTE THAT: Since capacitor is open to DC signals the DC gain of the amplifier is infinite and any offset voltage may drive the OPAMP output to saturation.

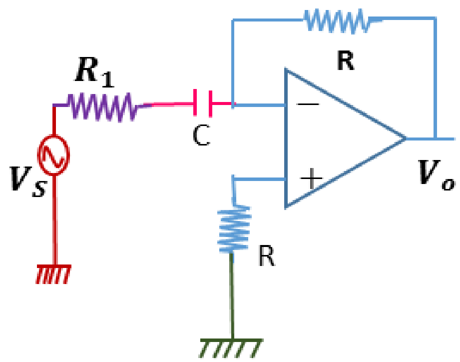
The way out of this difficulty is to decrease the DC gain by inserting a resistance R_2 in parallel with C. the value of R_2 is so chosen that the time constant CR_2 becomes large compared to the period of input signal. This requires that $R_2 \gg \frac{1}{\omega C}$

Where ω is the angular frequency of the input signal.

Also to minimize the error due to offset a resistance $R_1 = R||R_2$ may be added between the non-inverting terminal and the ground.

USES:- In digital voltmeter, sweep or ramp generator and in simulation studies in analog computer.





1.h)/(i)DIFFERENTIATOR

Point P may be treated as virtual ground then $i = \frac{dq}{dt} = C\frac{d(V_S-0)}{dt} = \frac{0-V_0}{R}$

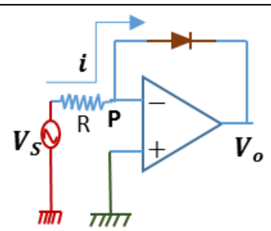
$\therefore \boldsymbol{V_0 = -CR\frac{dV_S}{dt}}$. Hence output voltage is proportional to time derivative of input signal.

If input is sine wave output is cosine, if input is square wave output is spike and when input is triangular wave output is square wave.

NOTE THAT- the ckt has high gain at high frequency thus amplify high frequency noise and switching spikes hence ckt is very much unstable. This situation can be avoided by connecting a resistance $R_1(\frac{R}{100} \le R_1 \le \frac{R}{10})$ in series with the capacitor this practical differentiator is useful for frequencies well below of frequency $\frac{1}{2\pi CR_1}$

1.h)/(ii) FREQUENCY TO VOLTAGE CONVARTER:-

If $V_S = v_0 \sin \omega t$ then $V_0 = \omega(-CR)v_0 \cos \omega t$. That means output voltage depends upon frequency. Then differentiator behaves as a simple frequency to voltage converter.



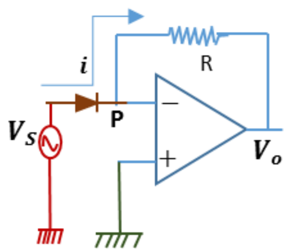
1.(i) LOGARITHMIC AMPLIFIER: -

Since point P may be treated as virtual ground then, $I_s = I_f$.

$\therefore \frac{V_S-0}{R} = I_0\left(e^{\frac{eV_f}{\eta kT}}-1\right) \approx I_0 e^{-\frac{eV_0}{\eta kT}}$ [Here voltage across diode is $V_f = (0-V_0) = -V_0$]

$\therefore V_0 = -\frac{\eta kT}{e}\ln\frac{V_S}{I_0R}$ [Here η=1 for Ge & η=2 for Si]

∴ Output voltage is proportional to logarithmic of input voltage.



1.(j) EXPONENTIAL OR INVERSE LOG OR ANTILOGARITHMIC AMPLIFIER:-

Since point P may be treated as virtual grounded, then, $I_D = I_R$ then,

$\therefore \frac{0-V_0}{R} = I_0\left(e^{\frac{eV_D}{\eta kT}}-1\right) \approx I_0 e^{-\frac{eV_D}{\eta kT}} \Rightarrow V_0 \approx -I_0Re^{\frac{eV_S}{\eta kT}}$

[Here voltage across diode is $V_D = (V_S - 0) = V_S$]

$\therefore V_0 = -I_0R\ln^{-1}\frac{eV_S}{\eta kT}$ [Here η=1 for Ge & η=2 for Si]

∴ Output voltage is proportional to anti-logarithmic of input voltage.

1.k). MULTIPLIER: -

$V_{A_1} = - - -\frac{\eta kT}{e}\ln\frac{V_1}{I_0R}$

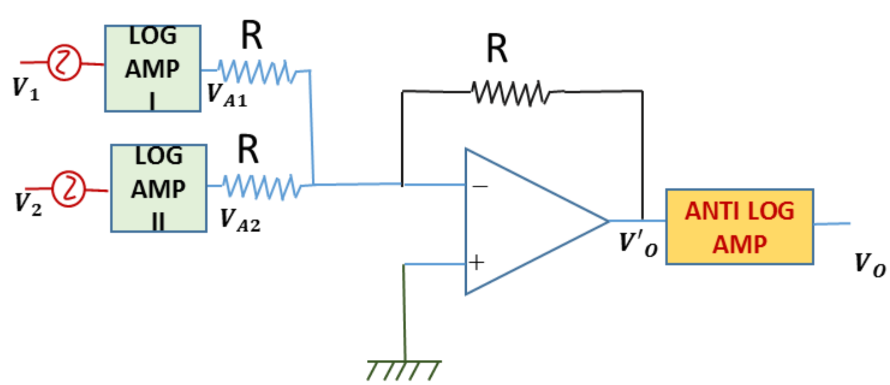
$V_{A_2} = - - -\frac{\eta kT}{e}\ln\frac{V_2}{I_0R}$

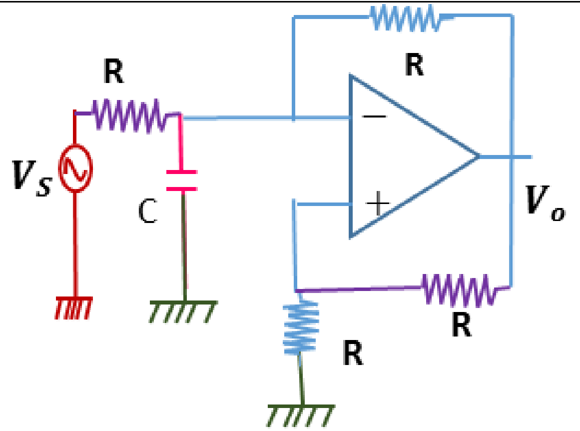
$V_0' = (-)\left(-\frac{\eta kT}{e}\right)\left\{\ln\frac{V_1}{I_0R} + \ln\frac{V_2}{I_0R}\right\}$

$= \frac{\eta kT}{e}\ln\frac{V_1V_2}{{I_0}^2R^2}$

Then $V_0 = -I_0Re^{\frac{eV_0'}{\eta kT}} = -I_0Re^{\ln\frac{V_1V_2}{{I_0}^2R^2}}$

$\therefore V_0 = -\frac{V_1V_2}{I_0R}$





Problem 1

Here $V_+ = \frac{V_0}{R+R}R = \frac{V_0}{2}$ then , $V_- \approx \frac{V_0}{2}$

Then $\frac{V_0 - \frac{V_0}{2}}{R} = \frac{\frac{V_0}{2} - V_S}{R} + C\frac{d(\frac{V_0}{2})}{dt}$

Or, $\frac{V_0}{2R} = \frac{V_0}{2R} - \frac{V_S}{R} + C\frac{d(\frac{V_0}{2})}{dt}$ or, $\frac{V_S}{R} = C\frac{d(\frac{V_0}{2})}{dt}$

Then $V_0 = \frac{2}{RC}\int V_S dt$

Problem 2

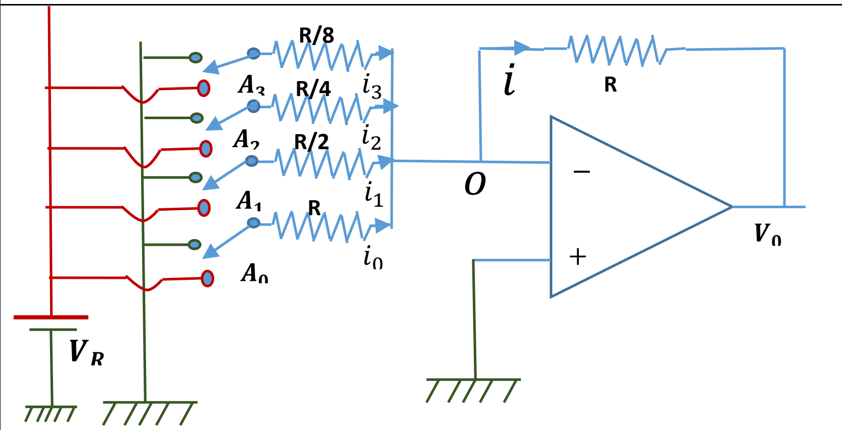
As there is a virtual ground at 'O' then

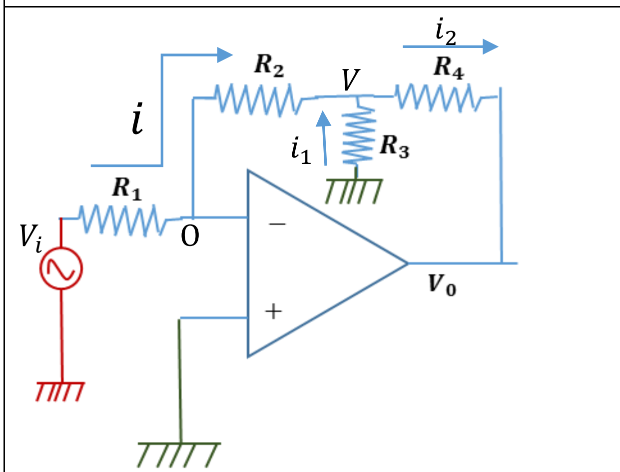
$$i = i_0 + i_1 + i_2 + i_3$$

OR, $\frac{0-V_0}{R} = \frac{V_R A_0 - 0}{R} + \frac{V_R A_1 - 0}{R/2} + \frac{V_R A_2 - 0}{R/4} + \frac{V_R A_3 - 0}{R/8}$

OR, $-\frac{V_0}{R} = \frac{V_R A_0}{R} + 2\frac{V_R A_1}{R} + 4\frac{V_R A_2}{R} + 8\frac{V_R A_3}{R}$

OR, $V_0 = -V_R(2^0 A_0 + 2^1 A_1 + 2^2 A_2 + 2^3 A_3)$





Problem 3

From figure $i = \frac{V_i - 0}{R_1} = \frac{0-V}{R_2}$ then $V = -\frac{R_2}{R_1}V_i \ldots.(i)$

$$i_1 = \frac{0-V}{R_3} \;\&\; i_2 = \frac{V-V_0}{R_4}$$

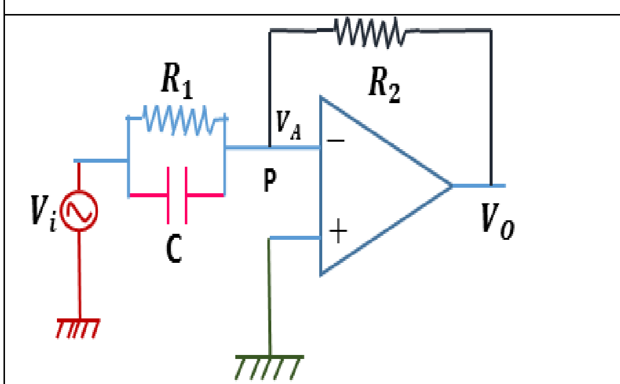
As there is a virtual ground at 'O' then $i_2 = i + i_1$

Or, $\frac{V-V_0}{R_4} = \frac{0-V}{R_2} + \frac{0-V}{R_3}$

Then $\frac{V}{R_4} + \frac{V}{R_2} + \frac{V}{R_3} = \frac{V_0}{R_4}$ then $\frac{V_0}{R_4} = V\left(\frac{R_2R_3 + R_2R_4 + R_4R_3}{R_2R_3R_4}\right)$

From equation (i) $\frac{V_0}{R_4} = -\frac{R_2}{R_1}V_i\left(\frac{R_2R_3 + R_2R_4 + R_4R_3}{R_2R_3R_4}\right)$

Then $\frac{V_0}{V_i} = -\left(\frac{R_2R_3 + R_2R_4 + R_4R_3}{R_1R_3}\right)$



Problem 4

As there is a virtual ground at 'P' then

$$\frac{V_i - 0}{\frac{R_1 \times \frac{1}{j\omega C}}{R_1 + \frac{1}{j\omega C}}} = \frac{0 - V_0}{R_2}$$

$$Or, -V_0 = V_i\frac{R_2}{R_1 \times \frac{1}{j\omega C}}\left(R_1 + \frac{1}{j\omega C}\right) = V_i\left(R_2 j\omega C + \frac{R_2}{R_1}\right)$$

$V_0 = -\left(CR_2(j\omega)V_i + V_i\frac{R_2}{R_1}\right) = -CR_2\frac{dV_i}{dt} - V_i\frac{R_2}{R_1}$

[As for harmonic input signal $V_i = e^{i\omega t}$

$\frac{dV_i}{dt} = (j\omega)V_i$ & $\frac{d^2V_i}{dt^2} = -(\omega^2)V_i$]

Problem 5

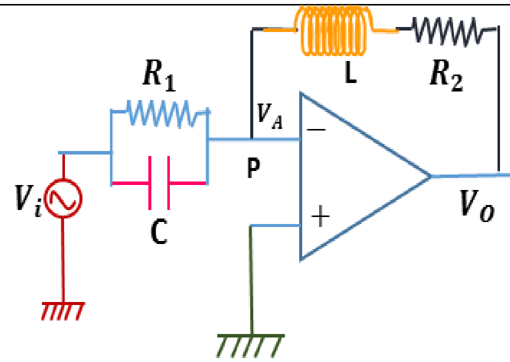
Hints $\frac{V_0}{V_i} = -\frac{Z_1}{Z_2} = -\frac{R_2 + j\omega L}{R_1 \times \frac{1}{j\omega C}}\left(R_1 + \frac{1}{j\omega C}\right)$

$$Or, V_0 = LC(\omega^2)V_i - \left(\frac{L}{R_1} + CR_2\right)(j\omega)V_i - V_i\frac{R_2}{R_1}$$

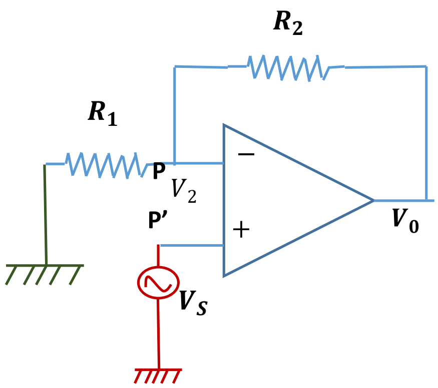
$$Or, V_0 = -LC\frac{d^2V_i}{dt^2} - \left(\frac{L}{R_1} + CR_2\right)\frac{dV_i}{dt} - V_i\frac{R_2}{R_1}$$

[As for harmonic input signal $V_i = e^{i\omega t}$

$\frac{dV_i}{dt} = (j\omega)V_i$ & $\frac{d^2V_i}{dt^2} = -(\omega^2)V_i$ **]**



NON-INVERTING



NON-VERTING AMPLIFIER: - Practically no current enters into the OPAMP as input resistance is infinite. Then from figure, $V_2 = V_0 \frac{R_1}{R_1+R_2} = \beta V_0$

Where $\beta = \frac{R_1}{R_1+R_2}$

Now the differential input to the amplifier is $V_s - V_2$

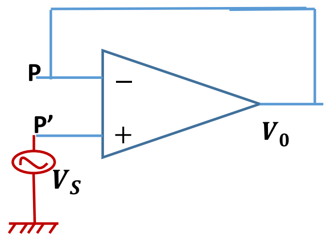
Then $V_0 = A(V_s - V_2) = A(V_s - \beta V_0)$ **{ Say here open loop gain is A}**

Then close loop gain (gain with feedback)$A_{Vf} = \frac{V_0}{V_S} = -\frac{A}{(1+A\,\beta)}$

For ideal case A→ ∞ Then $A_{Vf} = \lim_{A\to\infty} \frac{1}{\frac{1}{A}+\beta} = \frac{1}{\beta} = 1 + \frac{R_2}{R_1}$

From virtual short concept: for ideal case **A→ ∞ then** for finite output voltage the voltage difference between the inverting and non-inverting terminal must be very small. Then for ideal case we may say that there is a virtual short at point P & P'.

Then $V_2 \approx V_S$ then from figure $i = \frac{0-V_S}{R_1} = \frac{V_S-V_0}{R_2}$. Hence $A_{Vf} = \frac{V_0}{V_S} = 1 + \frac{R_2}{R_1}$

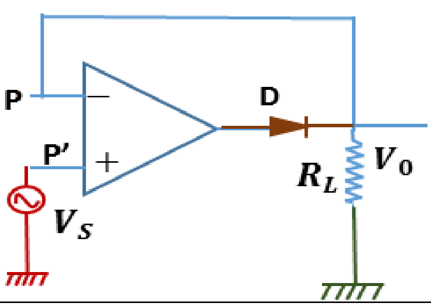


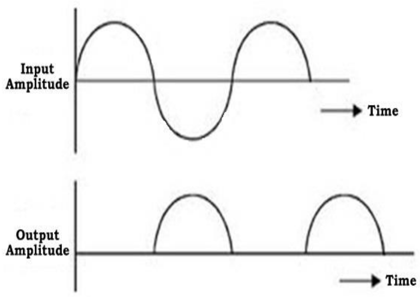
UNITY GAIN FOLLOWER: - When $R_1 = \infty$ *or*, $R_2 = 0$ then $A_{Vf} = 1$

It has practically infinite input resistance and zero output resistance. so the circuit can be used as a buffer or isolation amplifier. It allows the input voltage to be transferred to the output without any change and at the same time avoid the loading of the source.

VOLTAGE CONTROLLED VOLTAGE SOURCE:- $V_0 = (1 + \frac{R_2}{R_1})V_S$

Then output voltage is controlled by input voltage





ACTIVE HALF WAVE RECTIFIER

A sinusoidal voltage having peak value less than the cutin voltage V_γ cannot be rectified by ordinary diode rectifiers. By placing that diode in the feedback loop of an OP AMP it is possible to virtually eliminate effect of V_γ. Then the circuit will be able to rectify signals in the microvolt range. Figure shows a precision half wave rectifier using op amp and diode. The minimum input voltage that can turn on the diode is about $\frac{V_\gamma}{A}$. where A is the open loop gain. If the input V_i is greater than $\frac{V_\gamma}{A}$ diode D conducts. The circuit then acts as a voltage follower and half cycle appears across R_L .

when the input goes negative the OP AMP output goes negative. It turns off the diode D and no voltage appears across R_L.

Thus the output voltage across R_L almost a perfect half wave.

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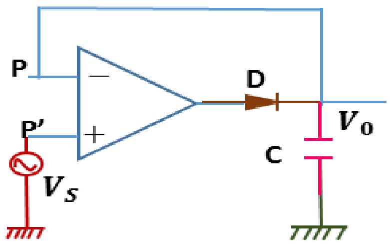

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Active peak detector.
For the peak detection of low level Signals an active peak detector using op-amp and diode can be used. When the input V_i is positive diode D is conducting and the capacitor C charges to the peak value of the input (because they circuit behaves like a voltage follower). When V_i falls below the capacitor voltage the OP AMP output goes negative the diode stops conducting and the feedback Path becomes open, the capacitor cannot discharge and retains the most positive peak voltage, even when the input signal is removed.
To reset the circuit and make it ready for another input signal very often a low leakage switch such as a MOSFET is placed across the capacitor to discharge it.
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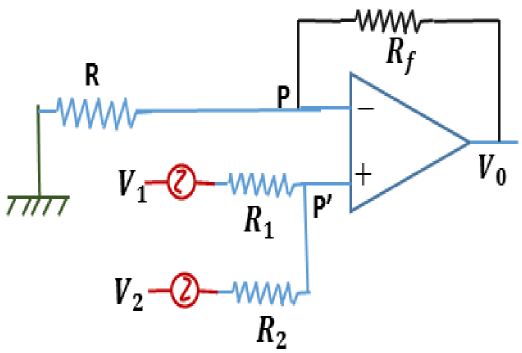

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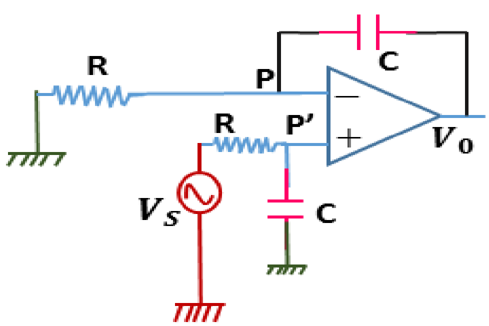

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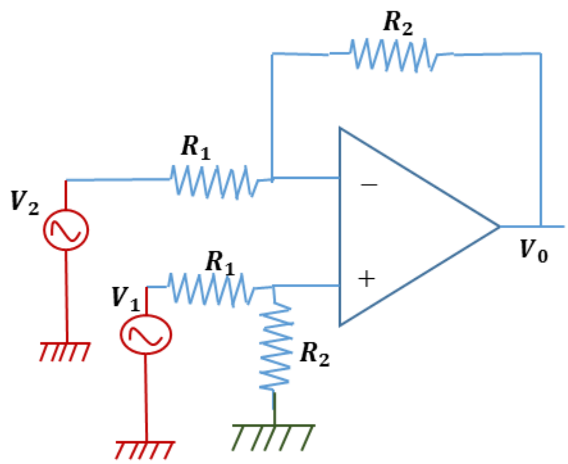
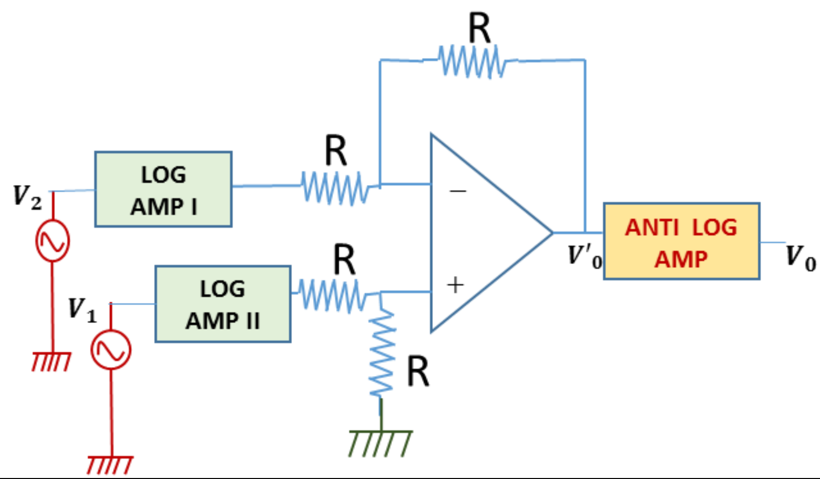
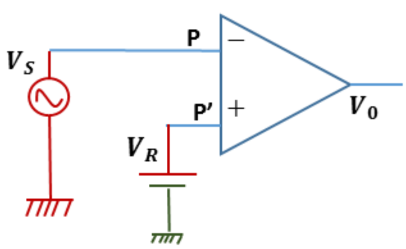
DIFFERENTIAL

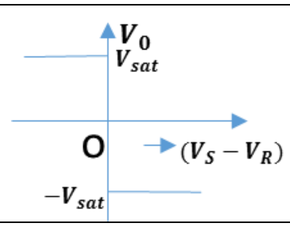


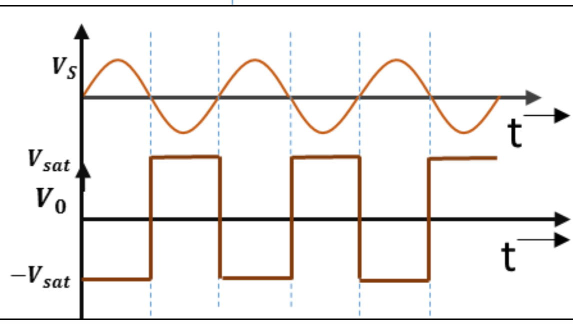
DIFFERENTIAL AMPLIFIER

SUBTRACTOR







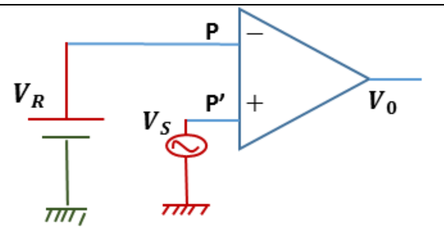


INVERTING COMPARATOR

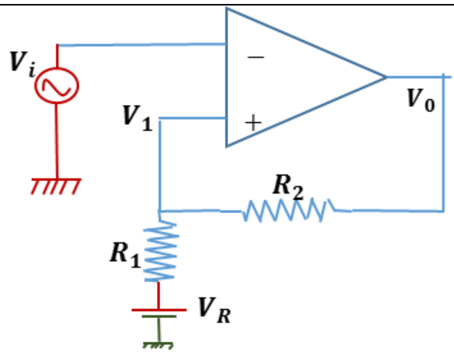
The comparator is a circuit which can compare two voltages.
An OP-AMP voltage comparator which compares the input voltage v_s with reference voltage V_R as long as $v_s < V_R$ the output voltage V_0 goes to maximum positive saturation value $(+V_{sat})$.
As v_s crosses V_R toward the region $v_s > V_R$ the OPAMP output switches the negative saturation value $(-V_{sat})$. Thus by looking at the output voltage we can instantly identify whether the voltage v_s is greater than or less than V_R. The comparetor can be used to generate a symmetric square wave from sine waves by just taking $V_R = 0$ and chossing v_s as a sinusoidal voltage.

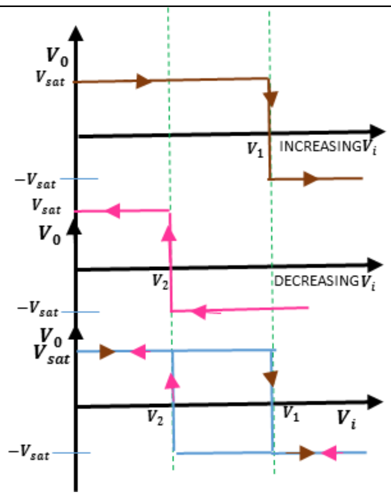
ZERO CROSSING DE TECTOR

When v_s passes through 0 towaods positive values of output V_0 is driven into negative saturation $(-V_{sat})$. On the other hand when v_s passes through 0 towaods negaitive values of output V_0 is driven into positive saturation $(+V_{sat})$. Thus if $V_R = 0$ the output changes almost discontinuously from one state to other every time the input signal passes through 0. For this such a configuration is called a zero crossing detector. It is often used to convert a sinusoidal waveform into a square waveform.



NON- INVERTING COMPARATOR





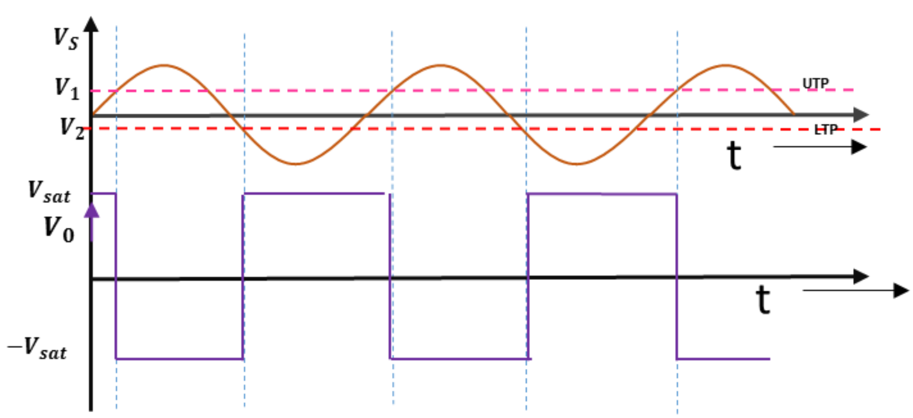
SCHMITT TRIGGER

A comparator which uses positive of regenerative feedback and exhibits the phenomenon of hysteresis is called a regenerative comparator of most commonly a Schmitt Trigger

Schmitt Trigger circuit using an OP AMP is shown in figure. The input voltage v_i is applied to the inverting terminal and the feedback voltage is applied to the non inverting terminal. when $v_i < v_1$ than the output V_0 is at positive saturation level $(+V_{sat})$. Then, using superposition principle we get

If v_i *is* now increased then the output remains constant at $(+V_{sat})$. And $v_i = V_1 =$ constant until $v_i = V_1$. At this threshold, critical or triggering voltage the output regenerative switches to $(-V_{sat})$. And remains at this value as long as $v_i > V_1$. The corresponding transfer characteristic is shown in figure.The voltage at the non-inverting terminal for $v_i > V_1$ is given by

If the voltage v_i now decreased the output remains at $(-V_{sat})$. (and $v_1 = V_2$) until $v_i = V_2$. At this voltage the output regenaratively switches to the $(+V_{sat})$. Transfer characteristic is shown in figure. the complete transfer characteristic is shown in figure. The circuit triggers and different voltages depending on whether the signal is increasing or decreasing. The circuit thus exhibits hysteresis. The two input voltages at which the output voltage changes states are called trip points. V_1 is the upper trip point (UTP) and V_2 is the lowest point.(LTP). The difference between these two points is called the hysteresis V_H. thus



Hysteresis is desirable in a Schmitt trigger because it prevents the noise from causing false triggering. We note that the Schmitt trigger can remain in one of its two stable steps indefinitely. It changes state only when a triggering signal is applied for this the circuit is known as bistable multivibrator. An important use of smith Trigger is to convert a slowly varying input into a square wave output. Smith Trigger always produces a rectangular output regardless of the shape of the input signal provided it has an amplitude larger enough to pass beyond the limit of the hysteresis range V_H

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