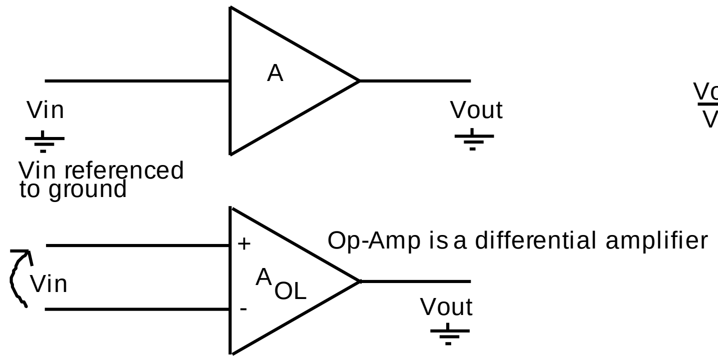
# A Review of Analog Concepts Required in Control

| Ideal Op Amp | Practical Op Amp |
| --- | --- |
| $R_{IN} = \infty\Omega$ | $R_{IN} = \rangle 10M\Omega$ |
| $R_{OUT} = 0\Omega$ | $R_{OUT} = \langle 100\Omega$ |
| $A_{V_{OL}} = GAIN_{OPENLOOP} = \infty$ | $GAIN_{OPENLOOP} = \rangle 100.dB(100,000)$ |

***Memorize these characteristics of op amps.***



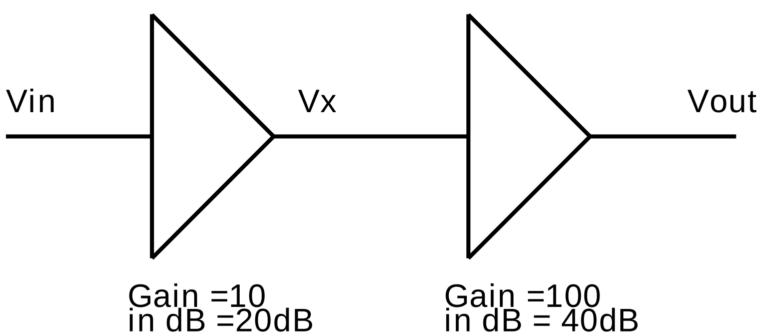

$$\frac{Vout}{Vin} = A$$

Vin is a voltage difference between + and -,
it is not referenced to ground

Gain in decibel of an amplifier is :

$$20 \ Log_{10}A_{Open\ Loop} = \text{Gain in dB}$$

For amplifiers in series, the gains in dB are added to get overall gain
Example:

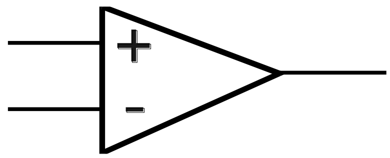



$\frac{Vx}{Vin} = 10$ $\quad$ $\frac{Vout}{Vx} = 100$

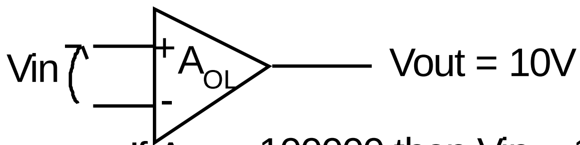
$Vx = 10Vin$ $\quad$ $Vout = 100Vx = 100(10Vin) = 1000Vi$

$$\boxed{\frac{Vout}{Vin} = 1000 \quad \text{or } 60DB}$$

Op Amp Inputs




If the (+) input is in positive with respect to the (-) input  the output of the op amp will be positive. If the (+) input is in negative with respect to the (-) input  the output of the op amp will be negative.




If $A_{OL}$ = 100000 then Vin = 100 $\mu V$

If $V_o$ = 10V, then the input voltage is

$$\text{Vin} = \frac{10}{100,000} \quad ,$$

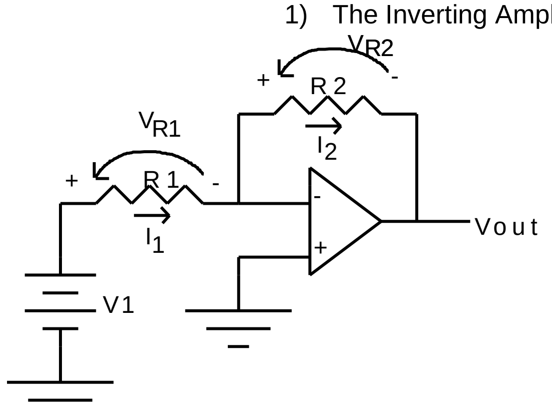
$$\text{Vin} = 100\,\mu\text{V}$$

Since $V_{in}$ is so small, it can be said that $V_{IN}$ is virtually 0 Volts.  The current would be very small into the op amp because of the small $V_{IN}$ and the high $Z_{IN}$.  Current could be as small as be 10 pA.

Inverting Amplifier

## Basic Op Amp Circuits

1) The Inverting Amplifier




$$V_{R1} = V_1$$

$$I_1 = \frac{V_{R1}}{R_1} = \frac{V_1}{R_1}$$

$$I_2 = I_1$$

$$V_{R2} = I_2 R_2$$

$$V_{R2} = I_1 R_2$$

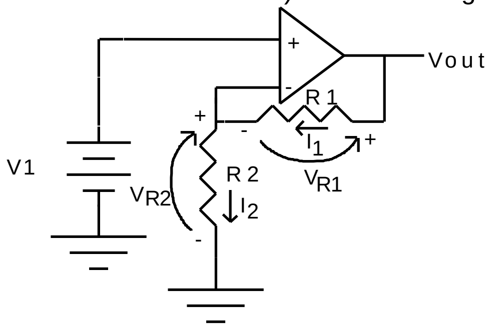
$$V_{R2} = \frac{V_1}{R_1} R_2$$

$$V_{out} = -V_{R2}$$

$$V_{out} = -\frac{V_1}{R_1} R_2$$

$$\boxed{\text{GAIN} = \frac{V_{out}}{V_1} = -\frac{R_2}{R_1}}$$

2) Non Inverting Amplifier




$$V_{R2} = V_1$$

$$I_2 = \frac{V_{R2}}{R_2} = \frac{V_1}{R_2}$$

$$I_1 = I_2$$

$$V_{R1} = I_1 R_1 = I_2 R_1 = \frac{V_1}{R_2} R_1$$

$$V_{out} = V_{R2} + V_{R1}$$

$$= V_1 + \frac{V_1}{R_2} R_1$$

$$= V_1 \left(1 + \frac{R_1}{R_2}\right)$$

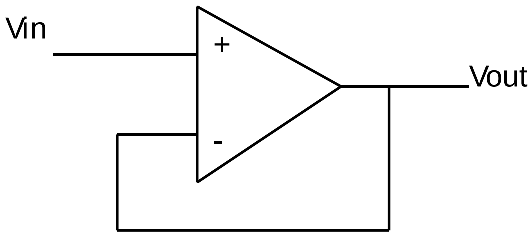
$$\text{GAIN} = \frac{V_{out}}{V_1} = \left(1 + \frac{R_1}{R_2}\right)$$

Remember the GAIN described above is the ***closed loop*** gain.

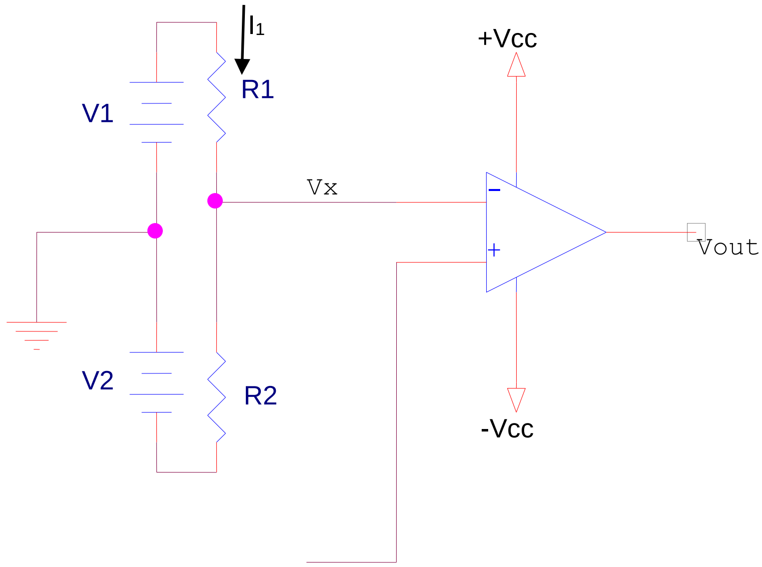
In any linear application the (+) and (-) terminals of any op amp are at zero potential.

3) Non-Inverting Buffer

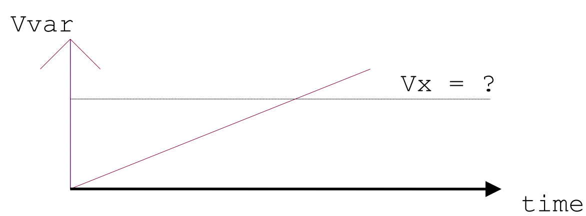
Unity Gain Buffer (Voltage Follower)

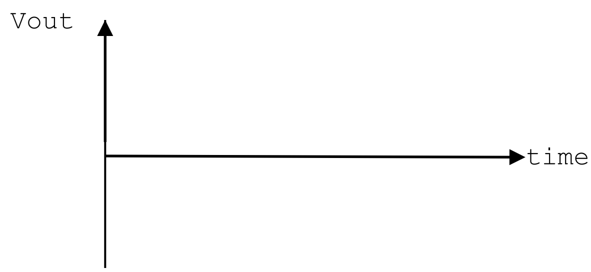


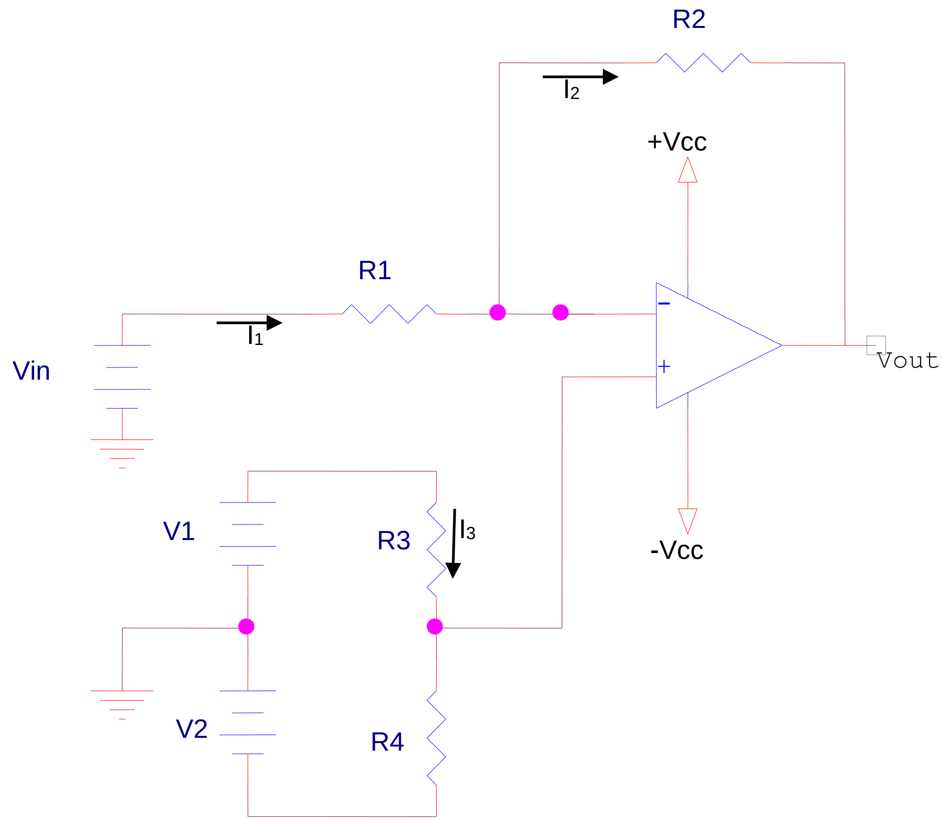
# Op Amp Circuit Analysis



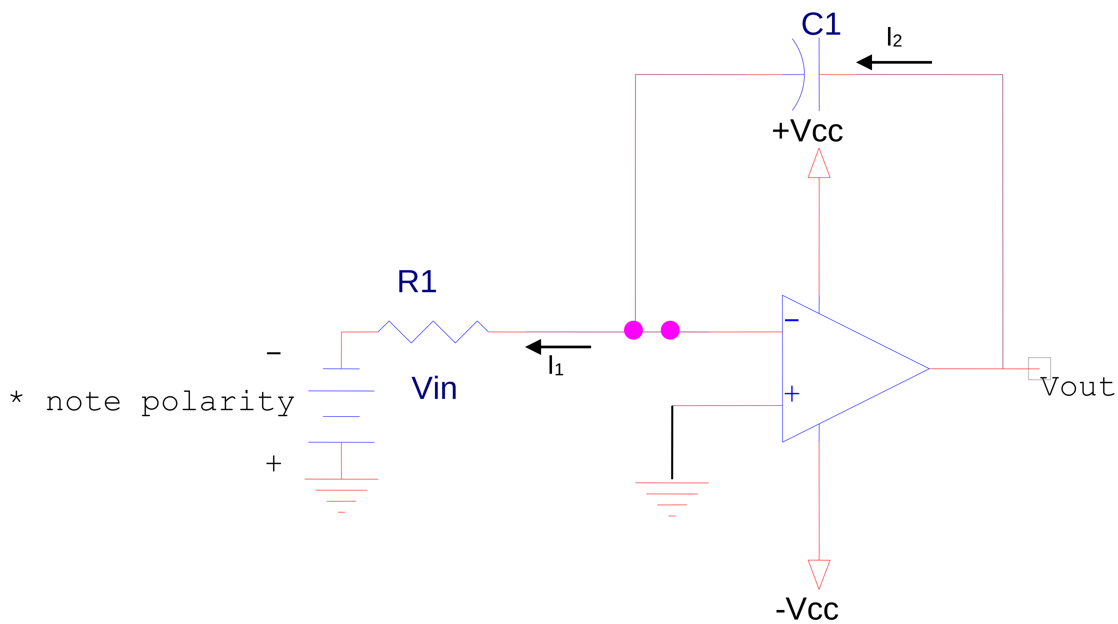

when Vvar changes as shown below
Sketch the output Voltage Vout



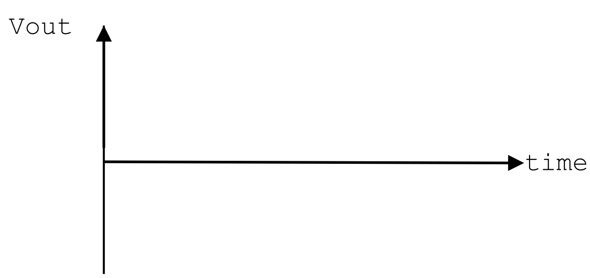



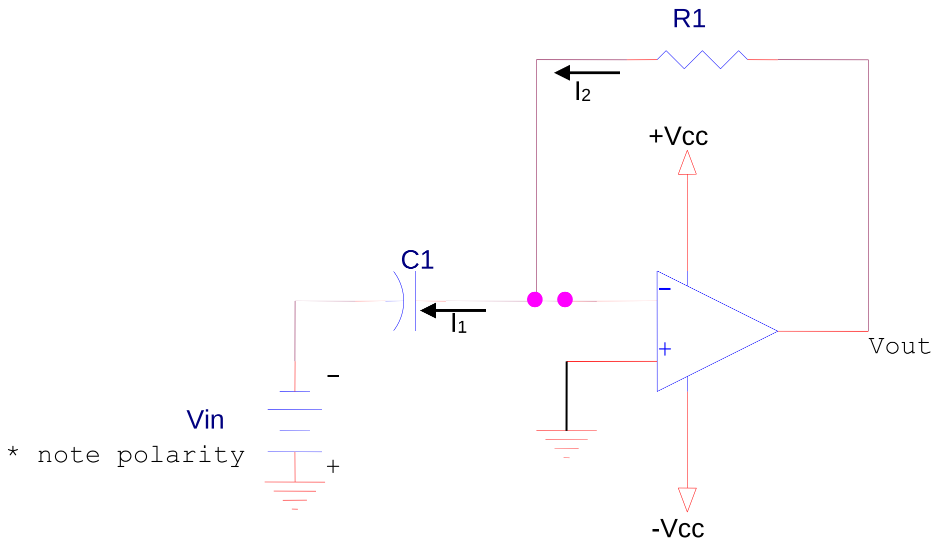



Find Vout/Vin in terms of resistors,
V1, and V2

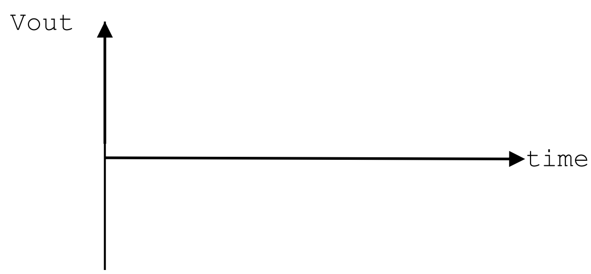


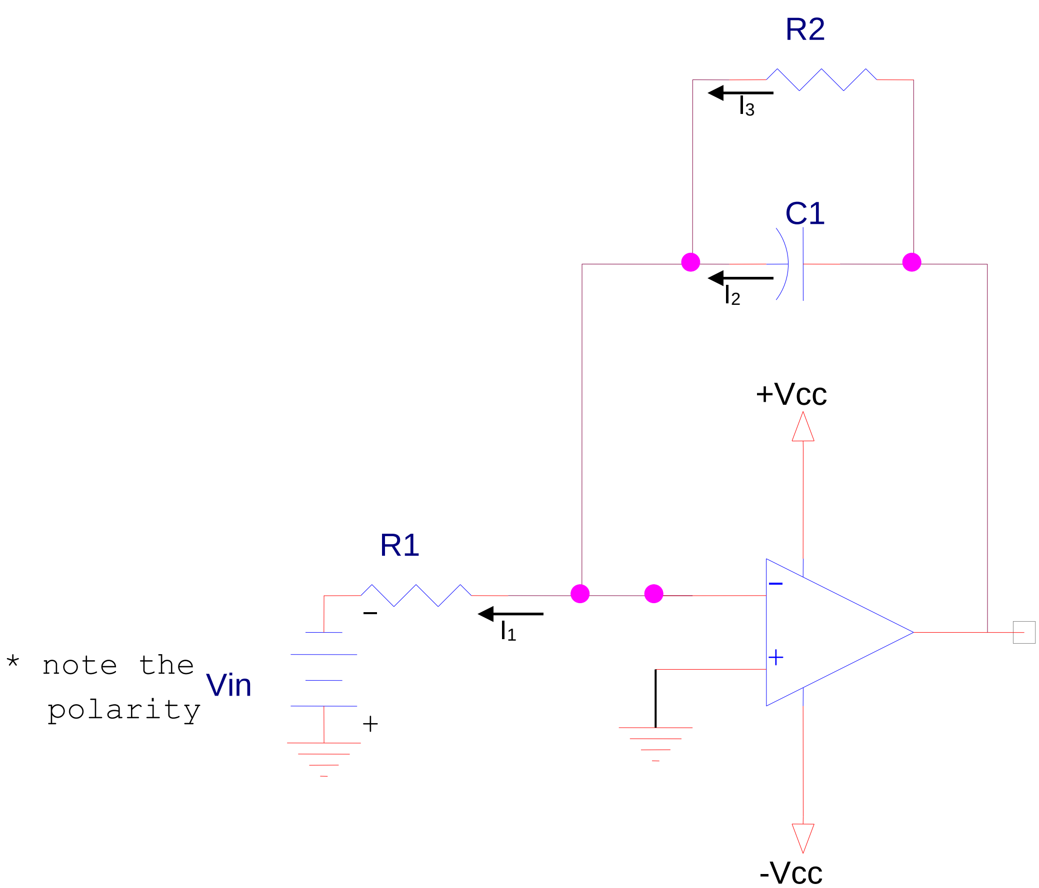

If the op amp is not saturated, describe the shape of the output voltage curve with respect to time and explain your reasons






Describe the relationship between
Vout and Vin if if the op amp is not saturated.






If the op amp is not saturated, describe
the relationship between Vout and Vin.