Operational Amplifier

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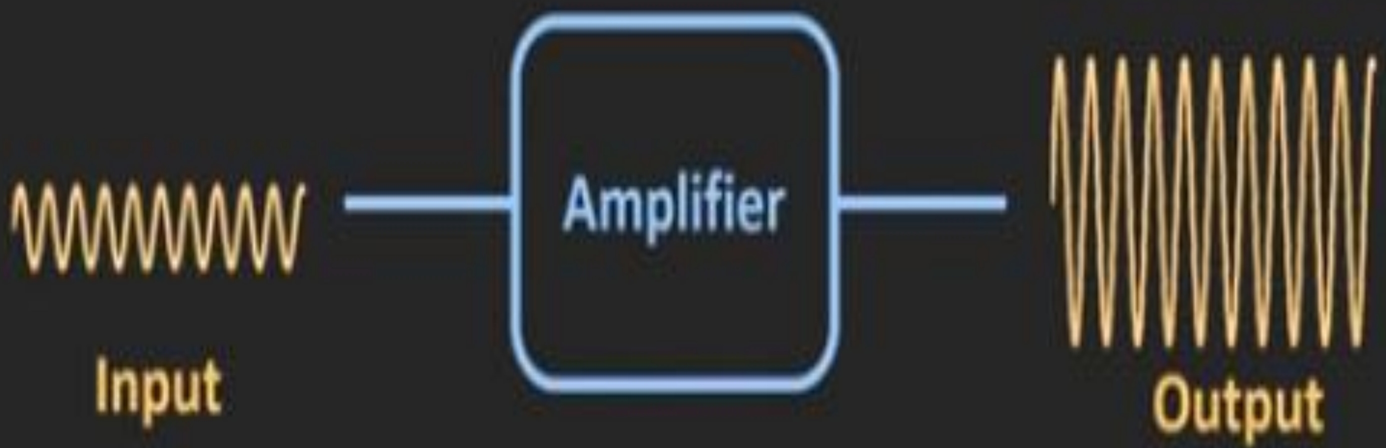
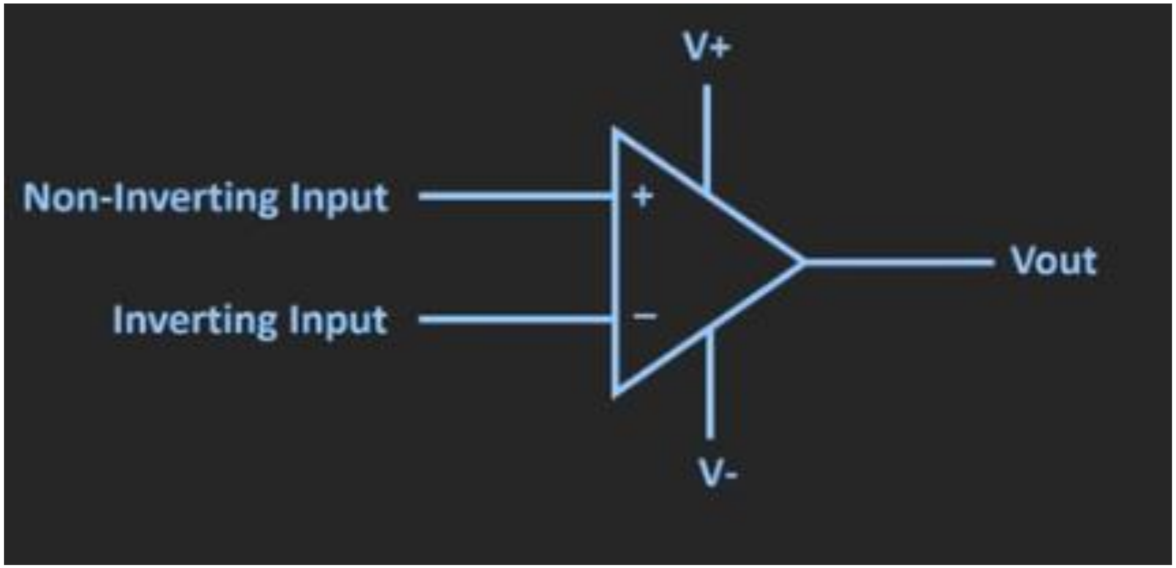


Applications:

- Addition
- Subtraction
- Integration
- Differentiation

- Active Filters
- Oscillator
- Waveform Converter
- ADC and DAC

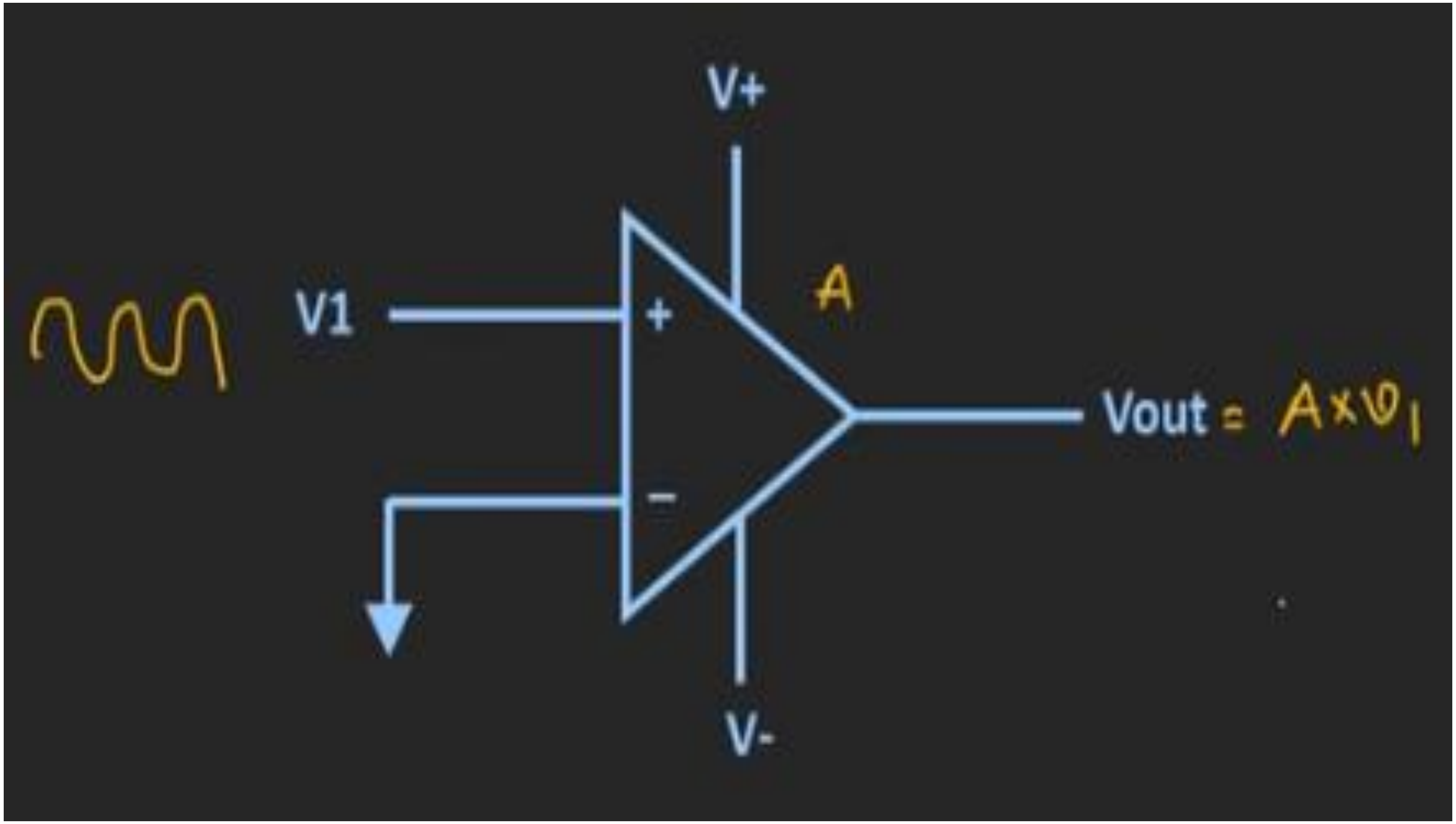
Basic Op-Amp



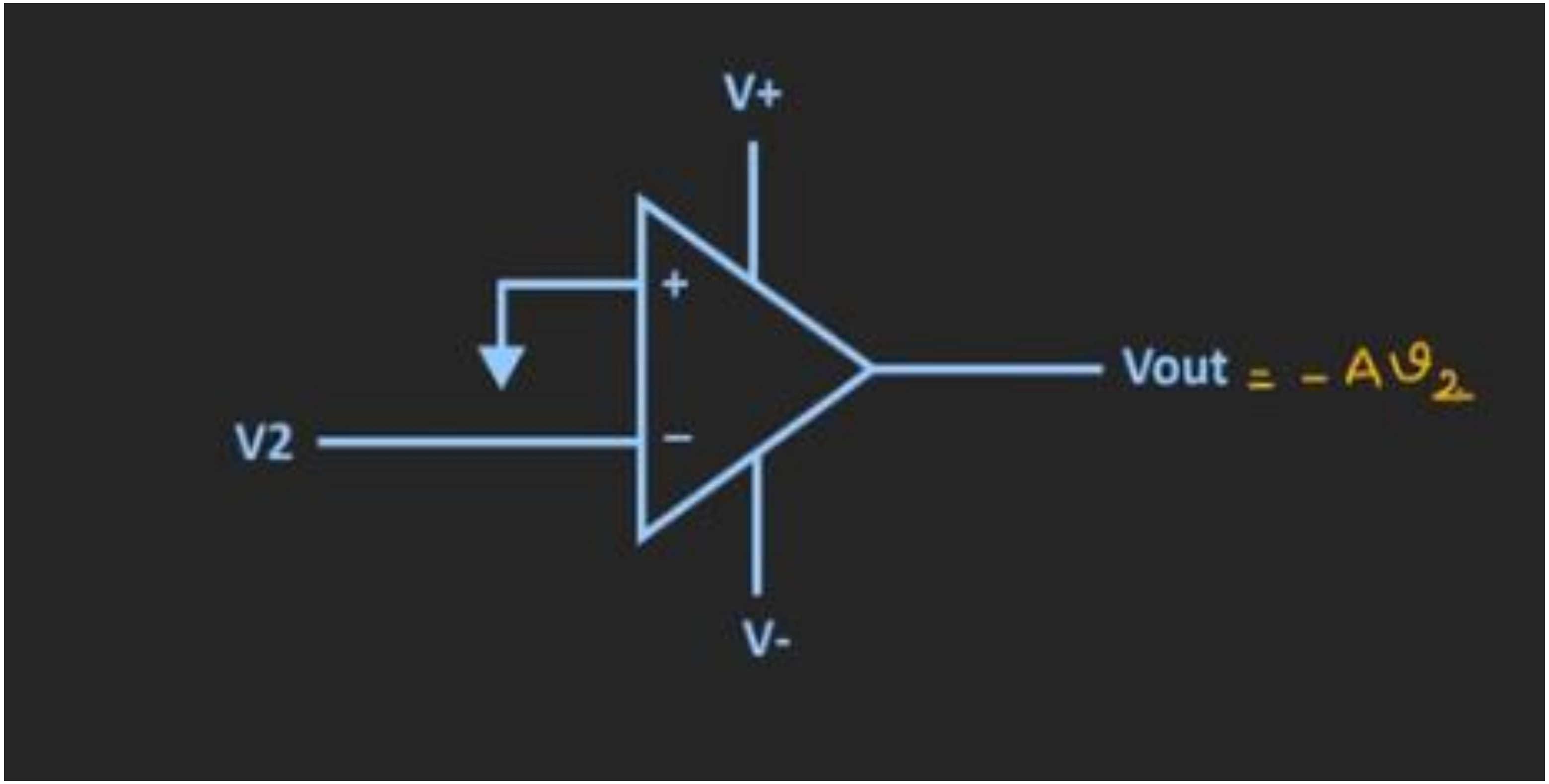
Operational amplifier or op-amp, is a very high gain differential amplifier with a high input impedance (typically a few meg-Ohms) and low output impedance (less than 100 Ω).

Note the op-amp has two inputs and one output.

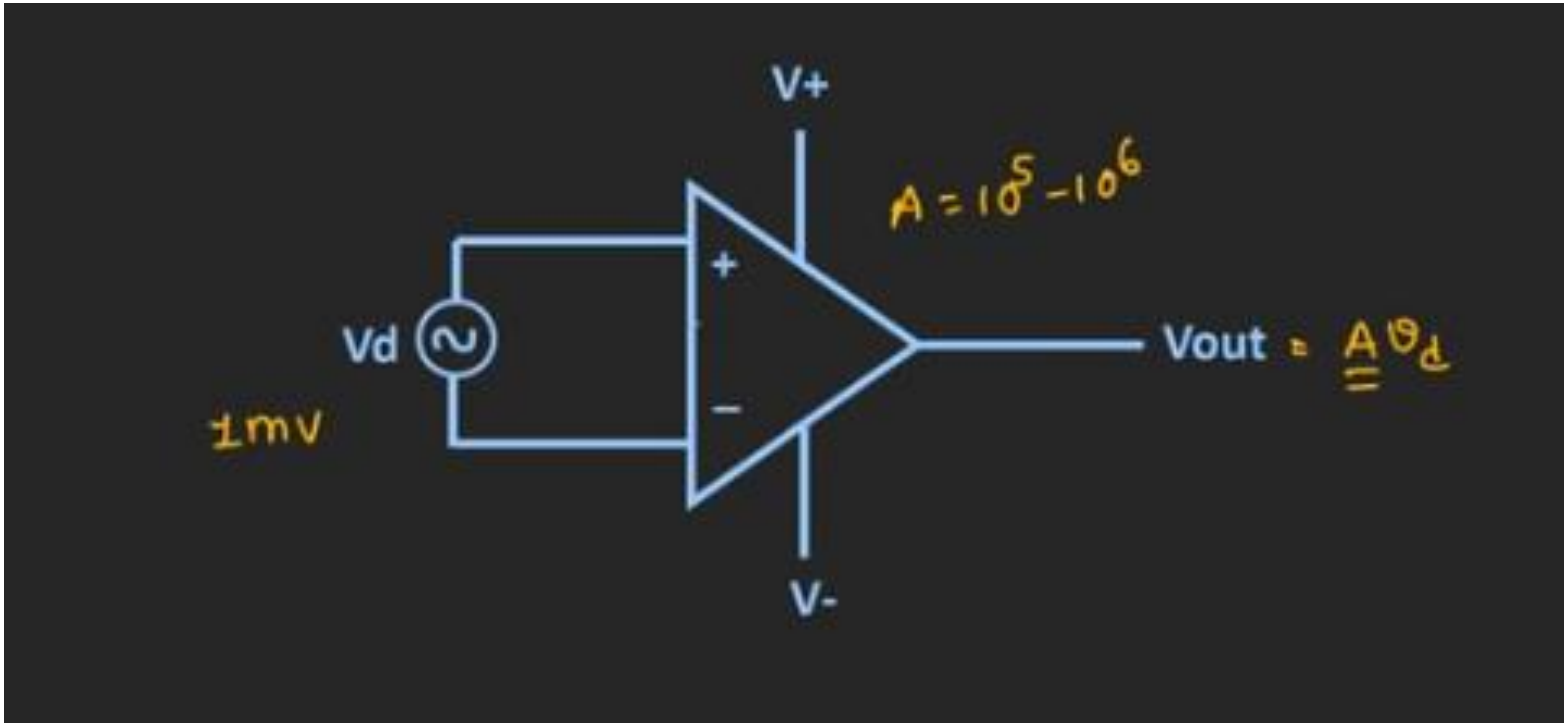
Non-Inverting Op-AMP



Inverting Op-AMP



Differential Op-AMP



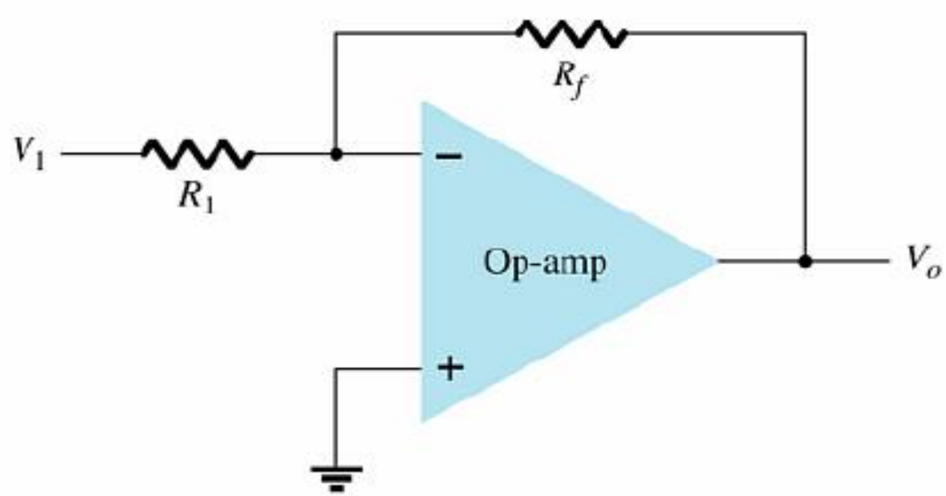
Inverting/Noninverting Op-Amps

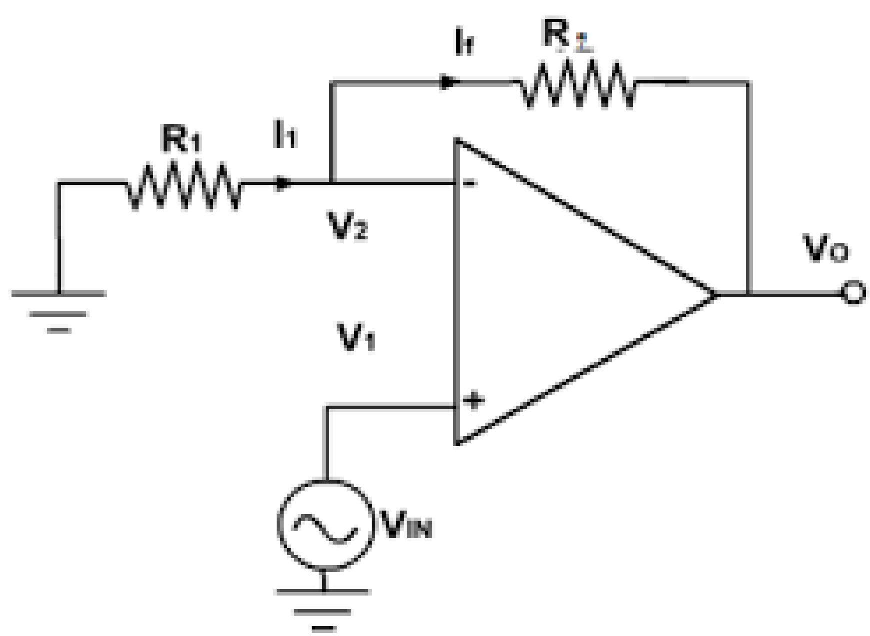
Inverting Amplifier

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

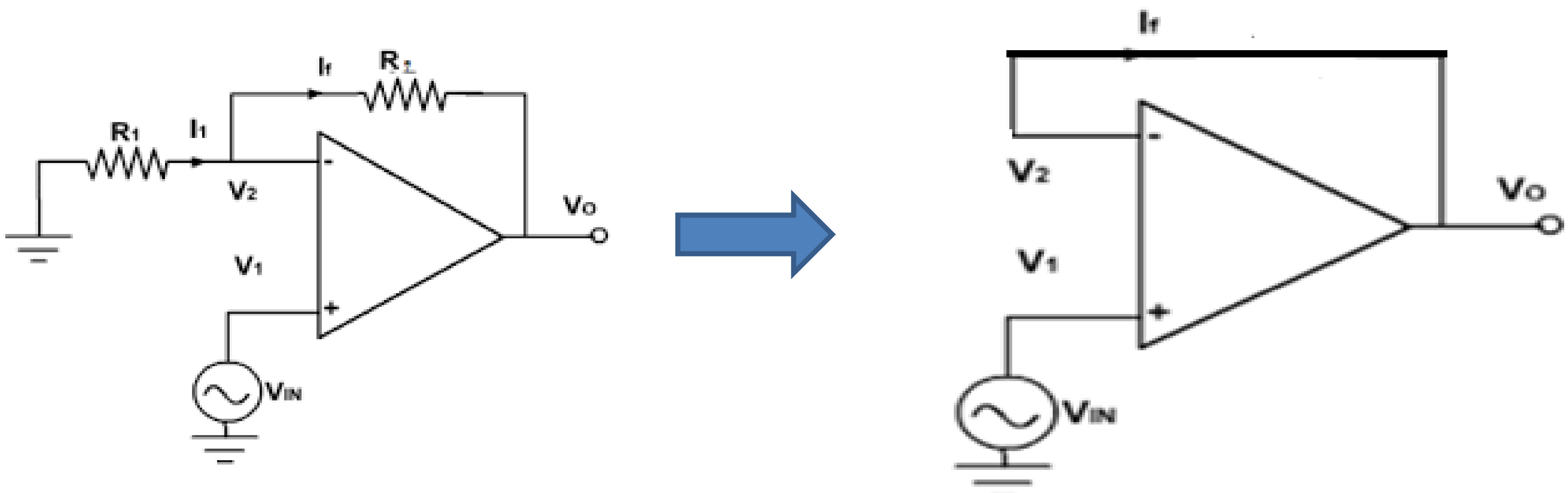
Noninverting Amplifier

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





Voltage Follower or Unity Gain Amplifier

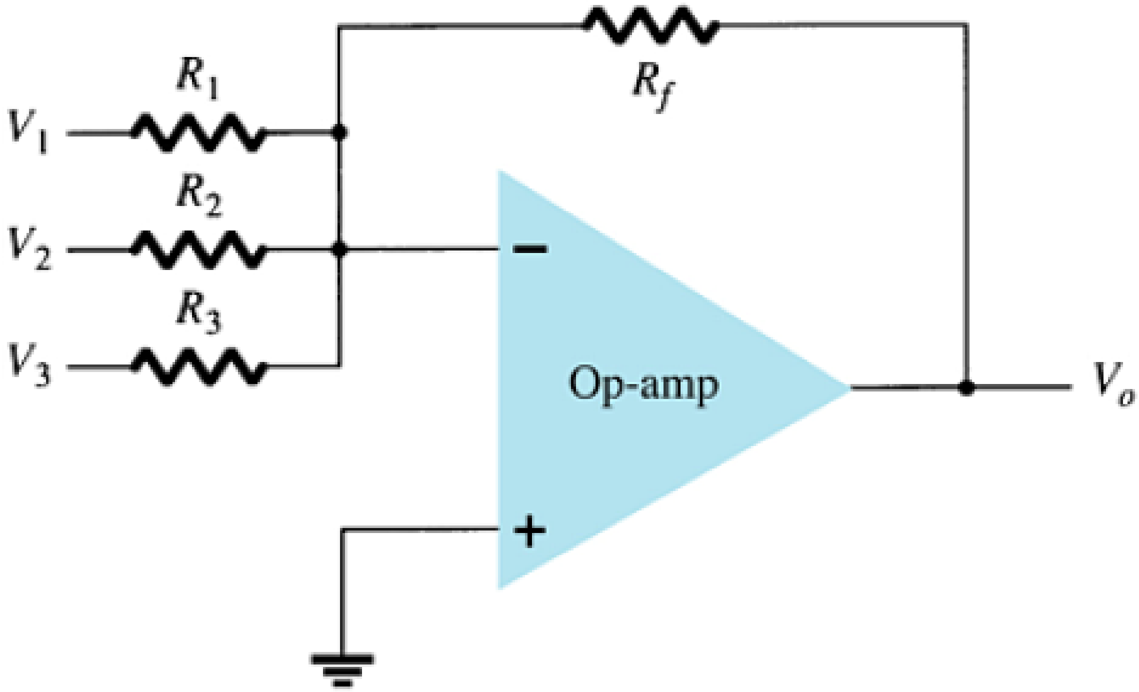


$$A = 1 + \frac{R_f}{R_1}$$

$$A = 1 + \frac{0}{\infty}$$

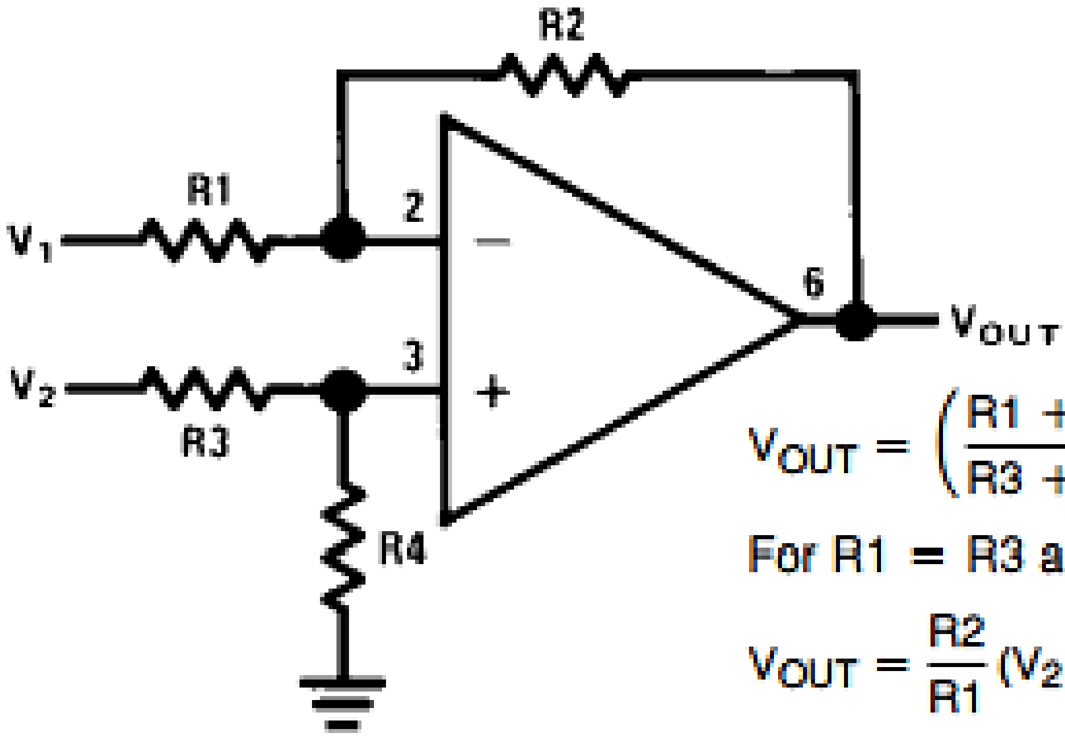
$$V_o = V_{in}$$

Summing Amplifier



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

Difference Amplifier or Subtractor

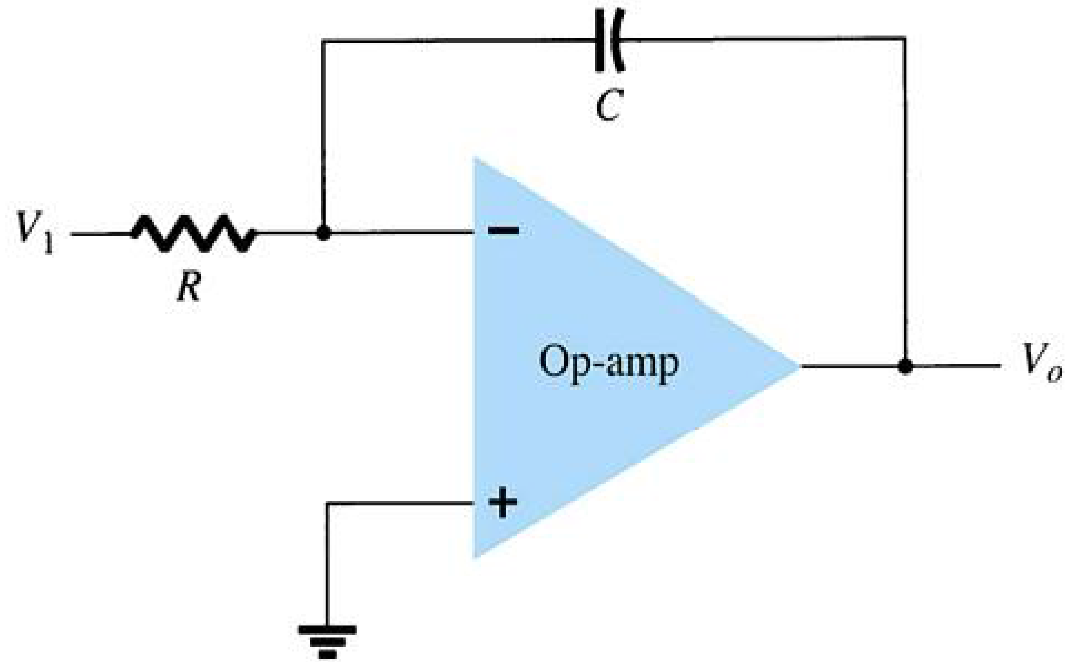


$$V_{OUT} = \left(\frac{R1 + R2}{R3 + R4}\right)\frac{R4}{R1}V_2 - \frac{R2}{R1}V_1$$

For R1 = R3 and R2 = R4

$$V_{OUT} = \frac{R2}{R1}(V_2 - V_1)$$

Integrator

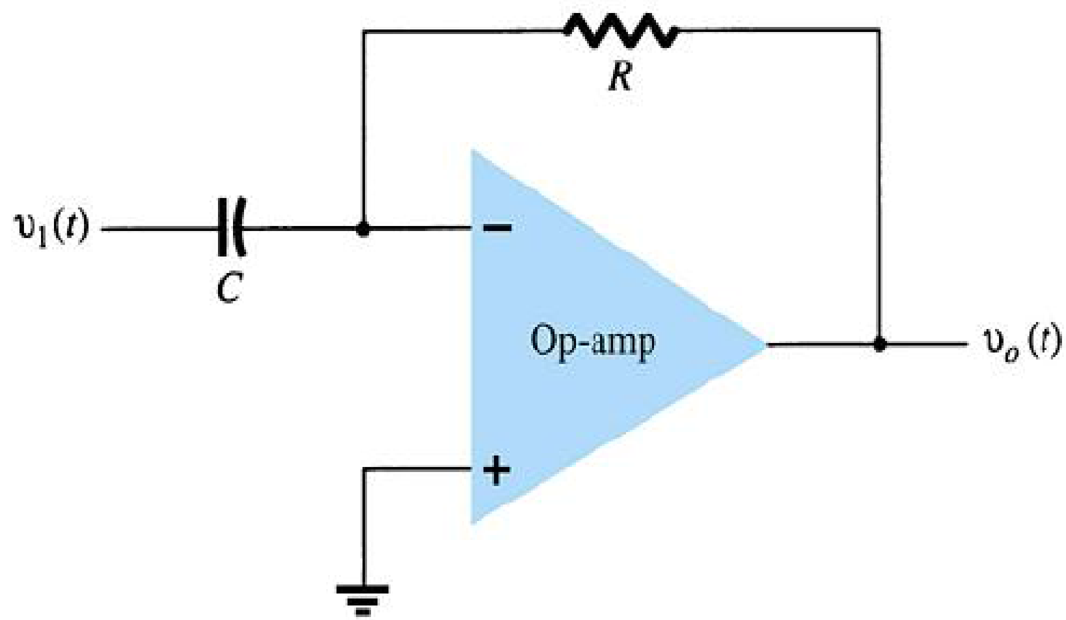


- The output is the integral of the input.
- This circuit is useful in low-pass filter circuits.

$$v_o(t) = -\frac{1}{RC}\int v_1(t)dt$$

Differentiator

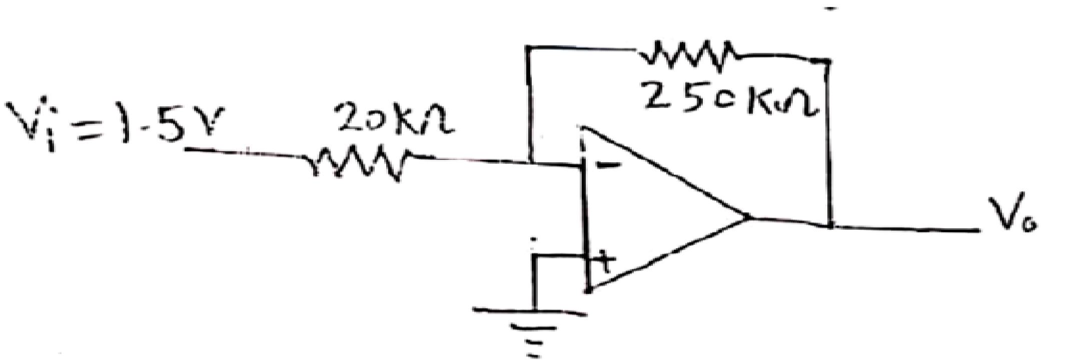
- The differentiator takes the derivative of the input.
- This circuit is useful in high-pass filter circuits.



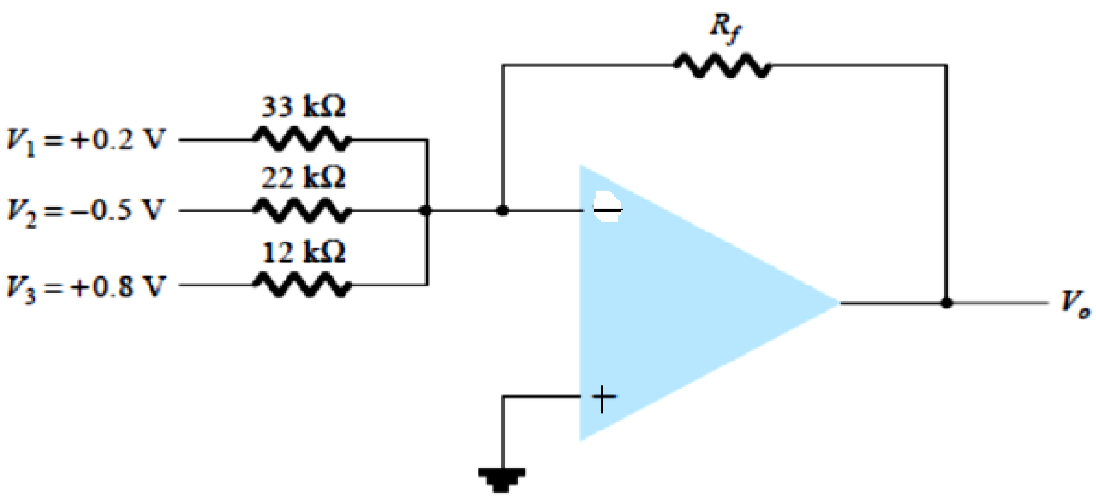
$$v_o(t) = -RC\frac{dv_1(t)}{dt}$$

Tutorial Sheet

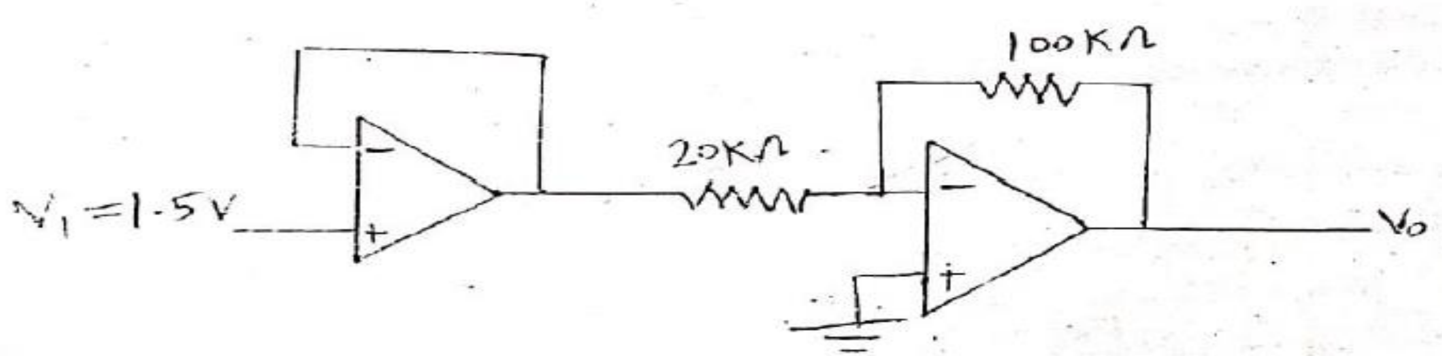
Q1. Calculate the output voltage of the following op-amp circuit.



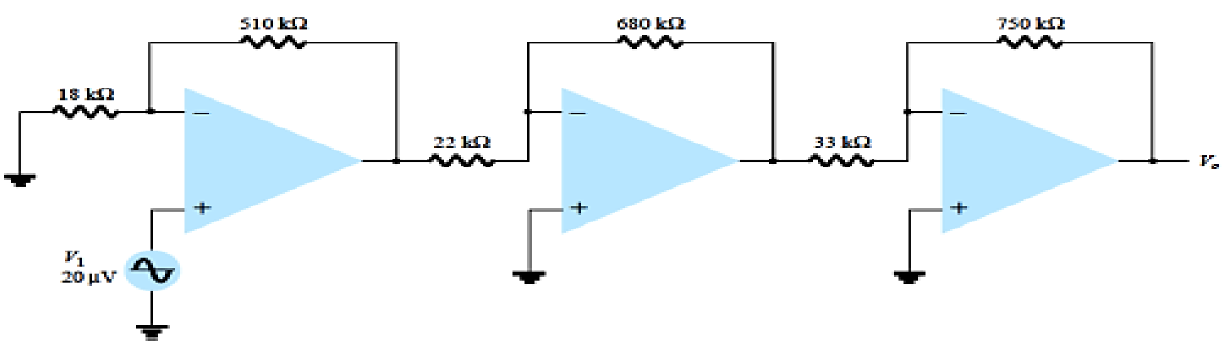
Q2 Calculate the output voltage of summing amplifier for a)R_f= 330 K, b) R_f=68 K.



Q3. Calculate the output voltage of the following op-amp circuit.

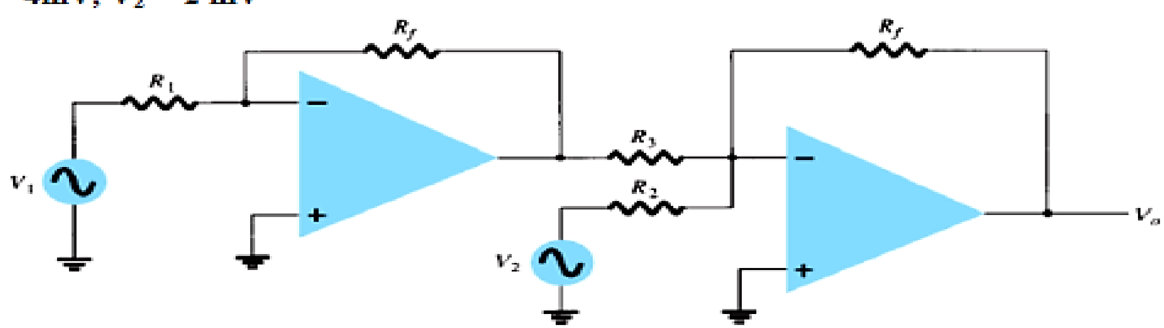


Q4. Calculate the output voltage V_o of the following op-amp circuit.

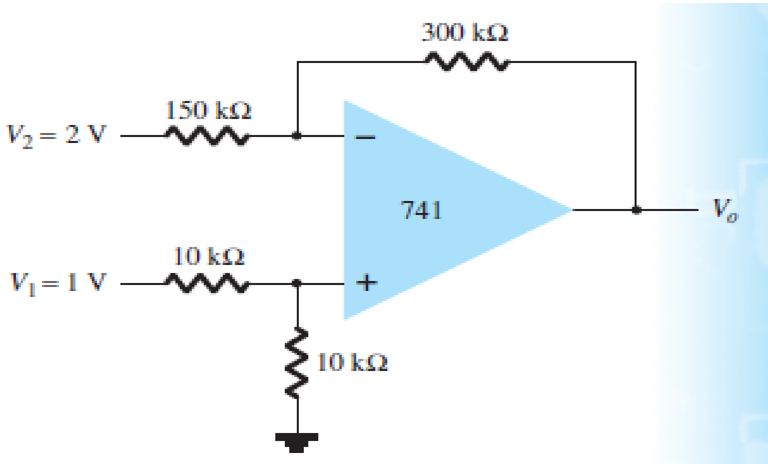


Q5. Calculate the V0 and gain of each amplifier for the following op-amp circuit.

$R_f = 1\ \text{M}\Omega$, $R_1 = 100\ \text{k}\Omega$, $R_2 = 50\ \text{k}\Omega$, and $R_3 = 500\ \text{k}\Omega$.
$V_1 = 4\text{mV}$, $V_2 = -2\ \text{mV}$

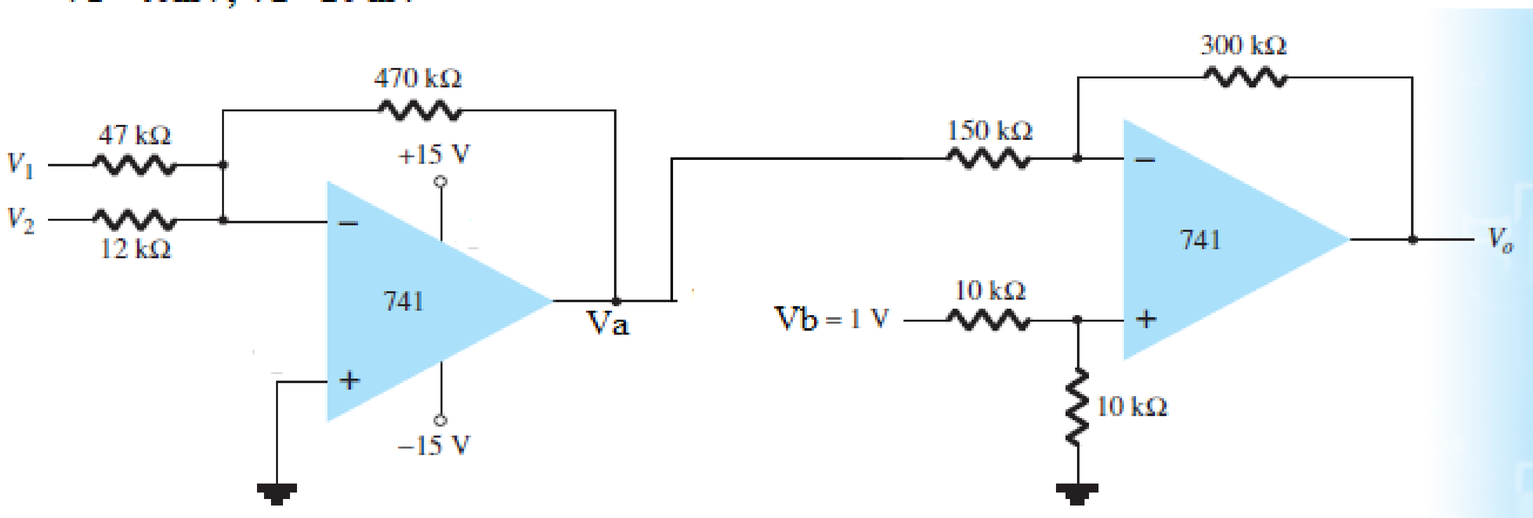


Q6.Calculate the output voltage of the following op-amp circuit.



Q7.Calculate the output voltage of the following op-amp circuit.

V1= 40mV, V2= 20 mV



OP-AMP Characteristics

- **Open loop voltage gain-**It is the differential gain of an OP-AMP in the open loop mode of operation.
- **Input resistance-**It is defined as the equivalent resistance which can be measured at either at inverting or non-inverting terminal with the other terminal connected to ground.
- **Output resistance-**It is the resistance measured by looking into the output terminal of OP-AMP, with the input source short circuited.

- **Bandwidth**-It is the range over which all signal frequencies are amplified almost equally.
- **Common mode rejection ratio**-It is defined as the ratio of differential gain to common mode gain.
- **Slew rate**-It is defined as the maximum rate of change of output voltage per unit time.
- **Power supply rejection ratio**-It is the change in an OP-AMPs input offset voltage caused by variation in the supply voltage.