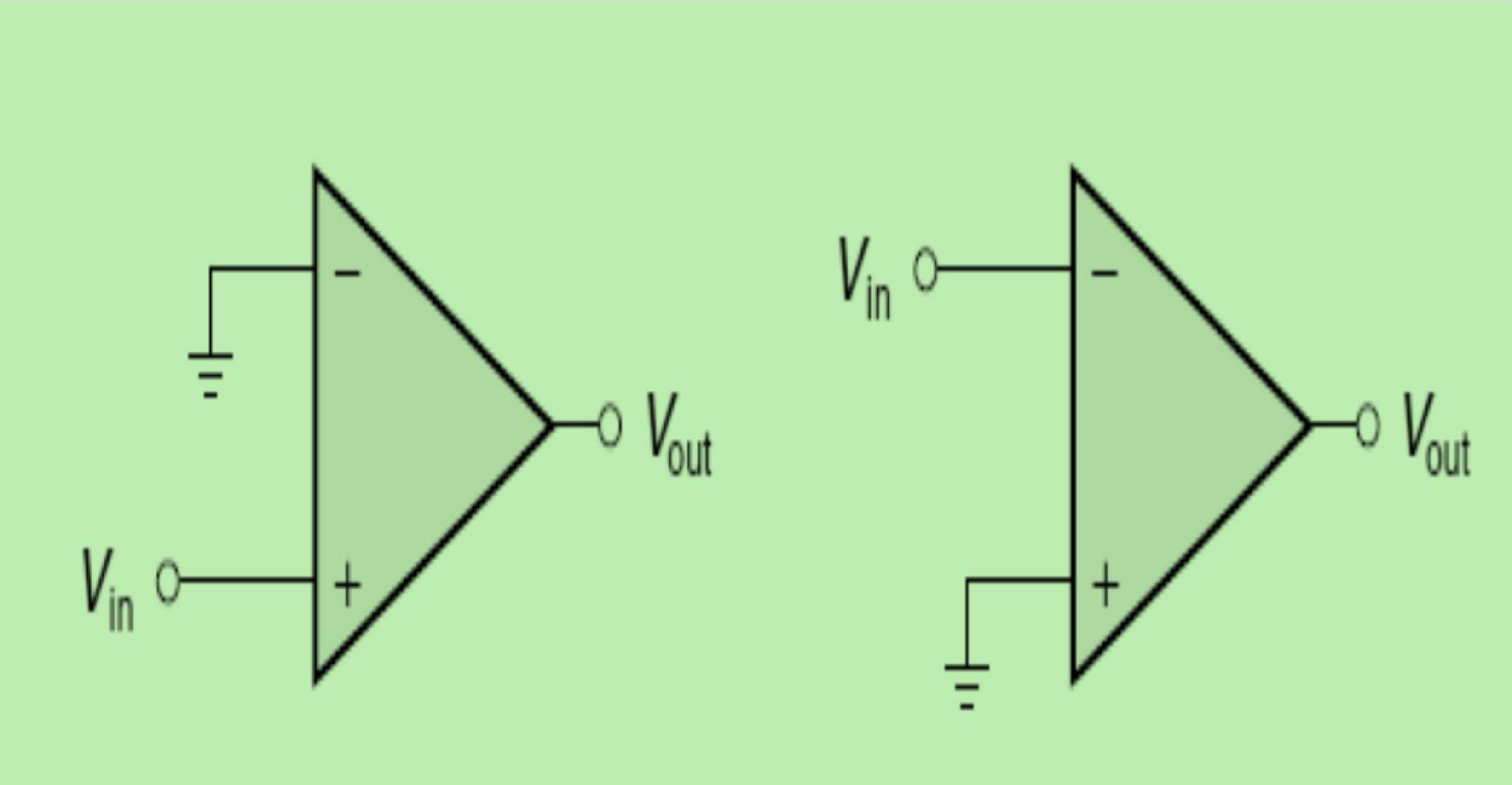
# . OP-AMP BASED SIGNAL CONDITIONING CIRCUITS

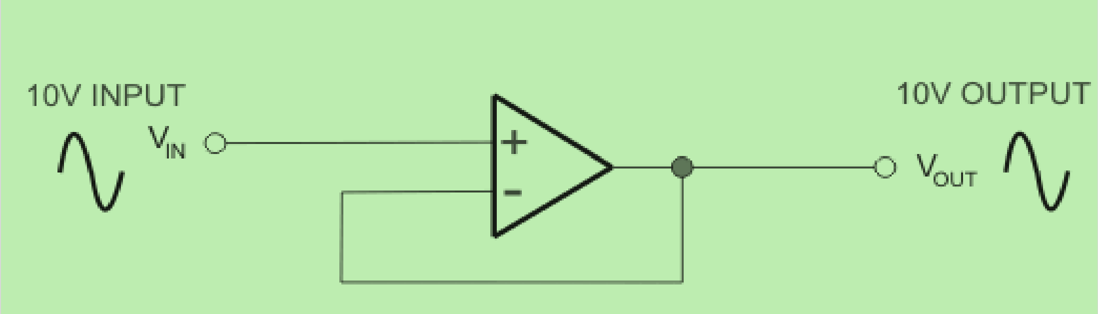
Lecture -1(B)

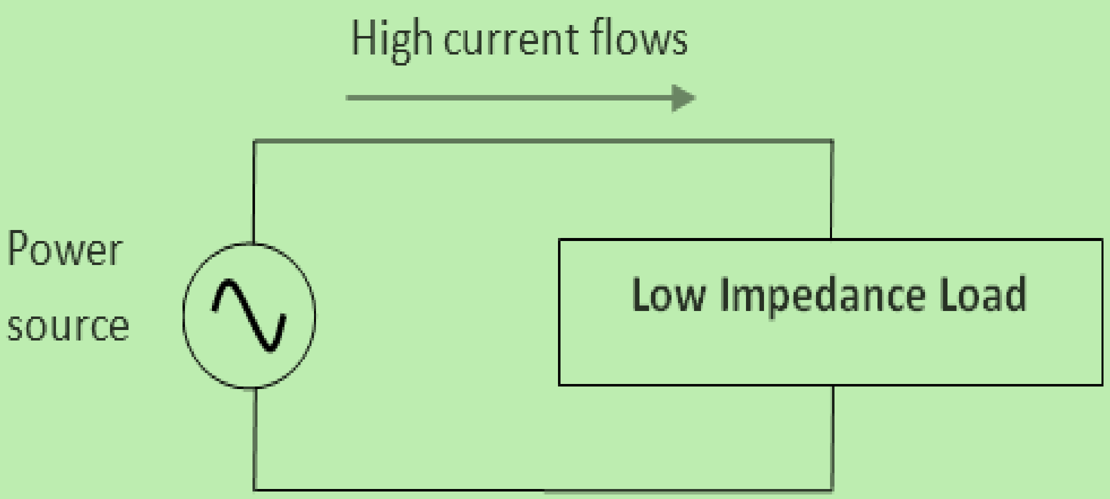
# OP AMP CKTS

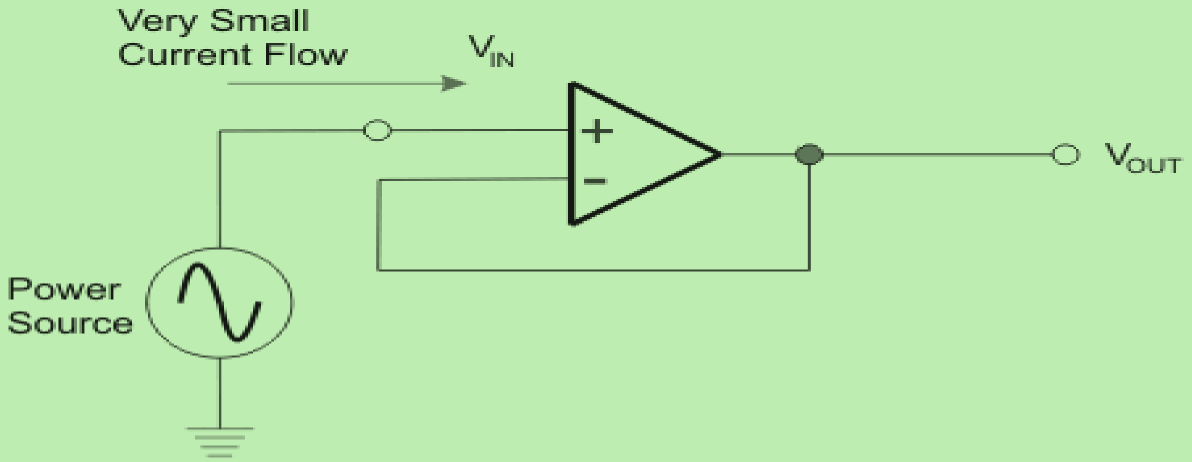


# **Voltage follower (**Isolation Amplifier, Buffer Amplifier, and Unity-Gain Amplifier**)**

- when resistance increases, the current drawn from the power source decreases.
- When Op-amp is connected, the major part of voltage will drop across it due to high impedance.
- So, if we use voltage follower in voltage divider circuits, it will let adequate voltage to be supplied across the load.

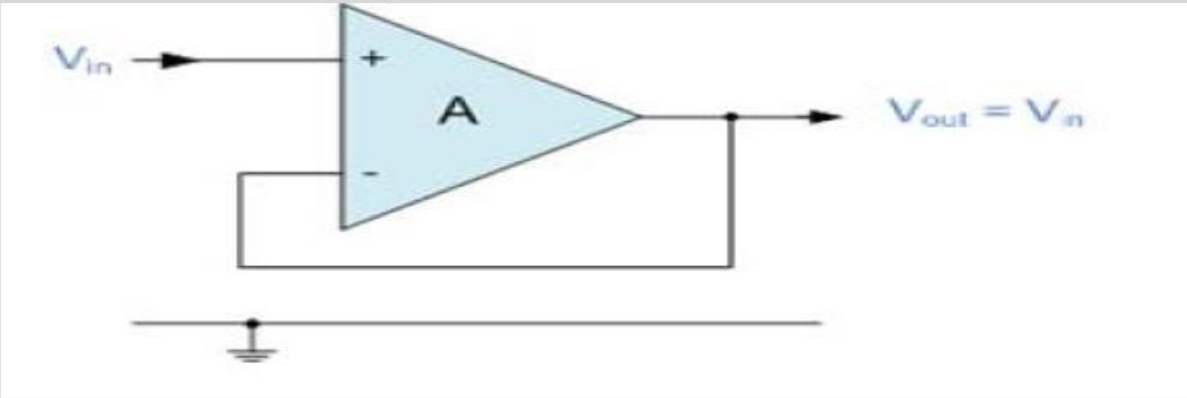


# Voltage Follower (Unity Gain Buffer)

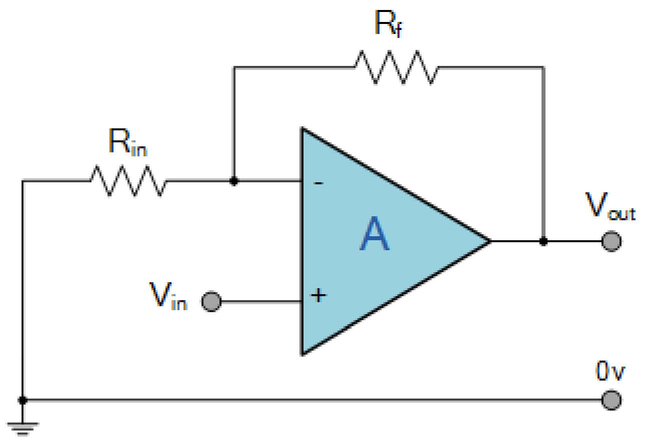
- When the circuit will have a fixed gain of "1" and would be classed as a **Voltage Follower**.
- As the input signal is connected directly to the noninverting input of the amplifier the output signal is not inverted resulting in the output voltage being equal to the input voltage, $V_{out} = V_{in}$.
- This then makes the Voltage Follower circuit ideal as a *Unity Gain Buffer* circuit because of its isolation properties as impedance or circuit isolation is more important than amplification.



# Contd..

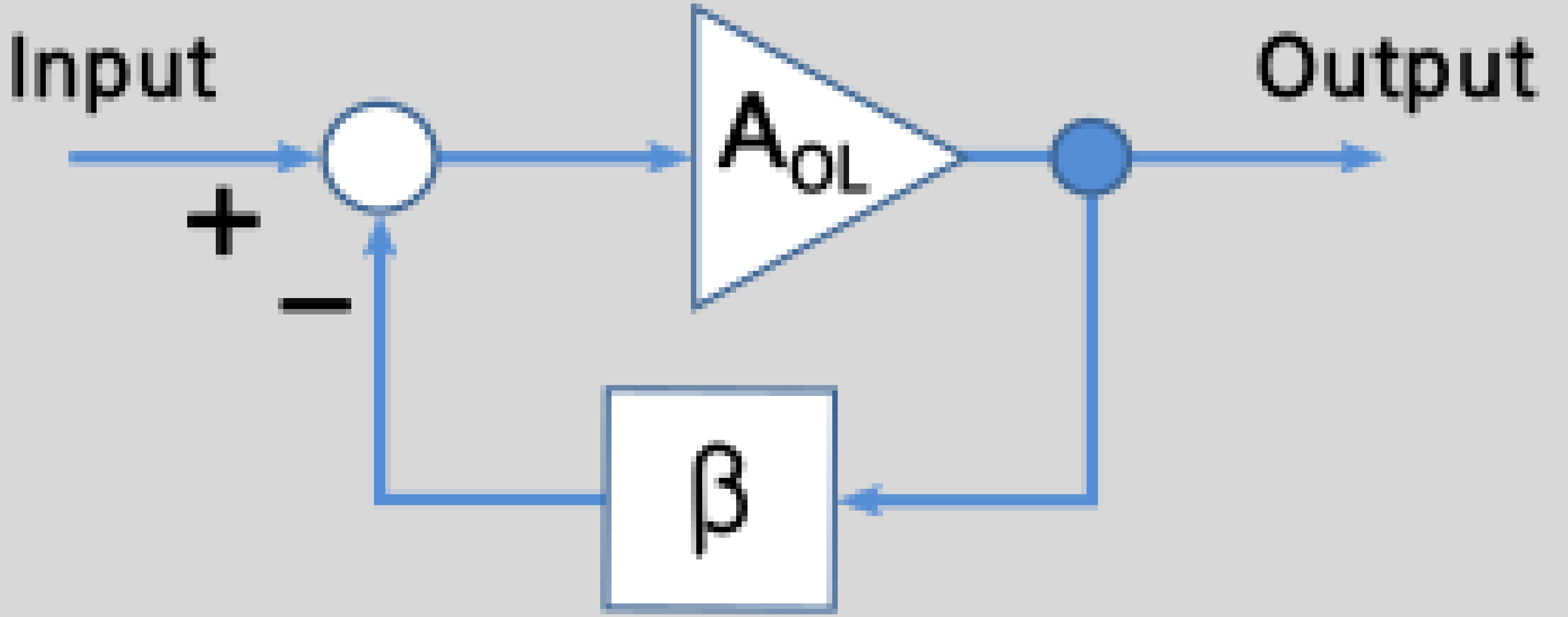
- As the input voltage $V_{in}$ is applied to the non-inverting input the gain of the amplifier is given as:

- $A_{CL} = 1 + (R_{in} / R_f)$
- So $V_{out}=A_{CL}*V_{in}$
- $V_{out}=V_{in}$




- The voltage follower or unity gain buffer is a special and very useful type of **Noninverting amplifier** circuit that is commonly used in electronics to isolate circuits from each other especially in High-order state variable.

# Contd…

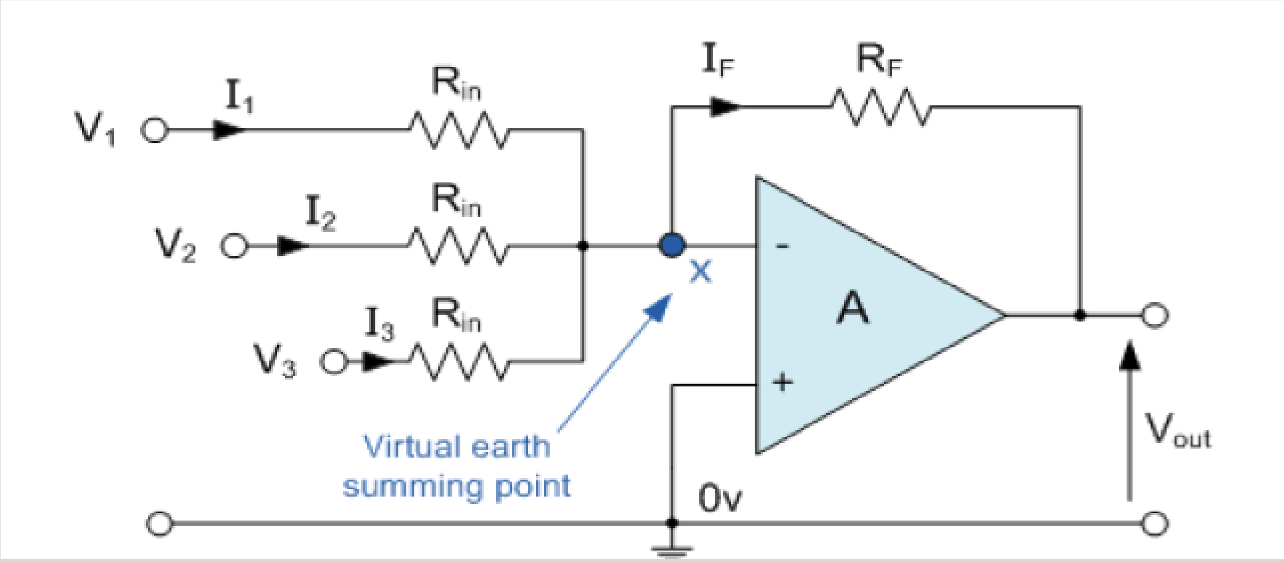


# Advantages of Voltage Follower

- **The Op-amp takes zero current from the input.**
- **Loading effects can be avoided.**
- **Provides power gain and current gain.**
- **Low output impedance to the circuit which uses the output of the voltage follower.**

# Summing Amplifier

- The **Summing Amplifier** is a very flexible circuit based upon the standard *Inverting Operational Amplifier* configuration.
- If add another input resistor equal in value equal to the original input resistor, a new configuration of another operational amplifier circuit called a **Summing Amplifier**, "*Summing Inverter*" or "*Voltage Adder*" circuit.



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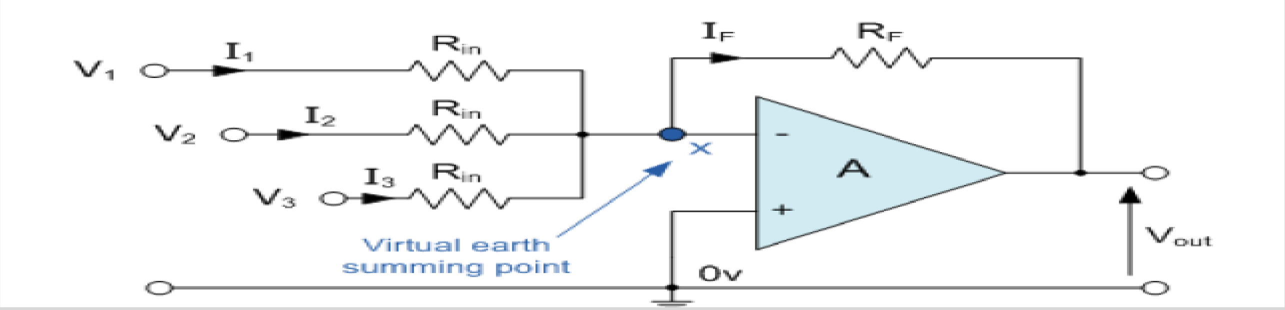


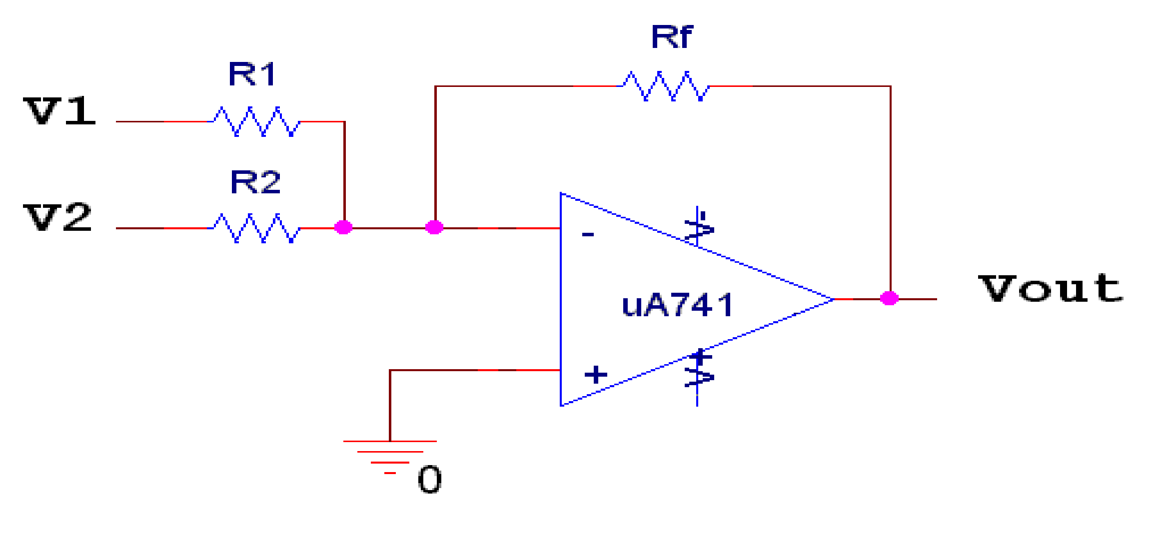

- The output voltage, (Vout) now becomes proportional to the sum of the input voltages, V1, V2, V3 etc.
- Then modify the original equation for the inverting amplifier

$$I_F = I_1 + I_2 + I_3 = -\left[\frac{V_1}{R_{in}} + \frac{V_2}{R_{in}} + \frac{V_3}{R_{in}}\right]$$

$$V_{out} = -\frac{R_F}{R_{in}}\left(V_1 + V_2 + V_3\right)$$

- The **Summing Amplifier** is a very flexible circuit indeed, enabling us to effectively "Add" or "Sum" together several individual input signals.
- If the input resistors are all equal a unity gain inverting adder can be made.
- However, if the input resistors are of different values a scaling summing amplifier is produced which gives a weighted sum of the input signals.

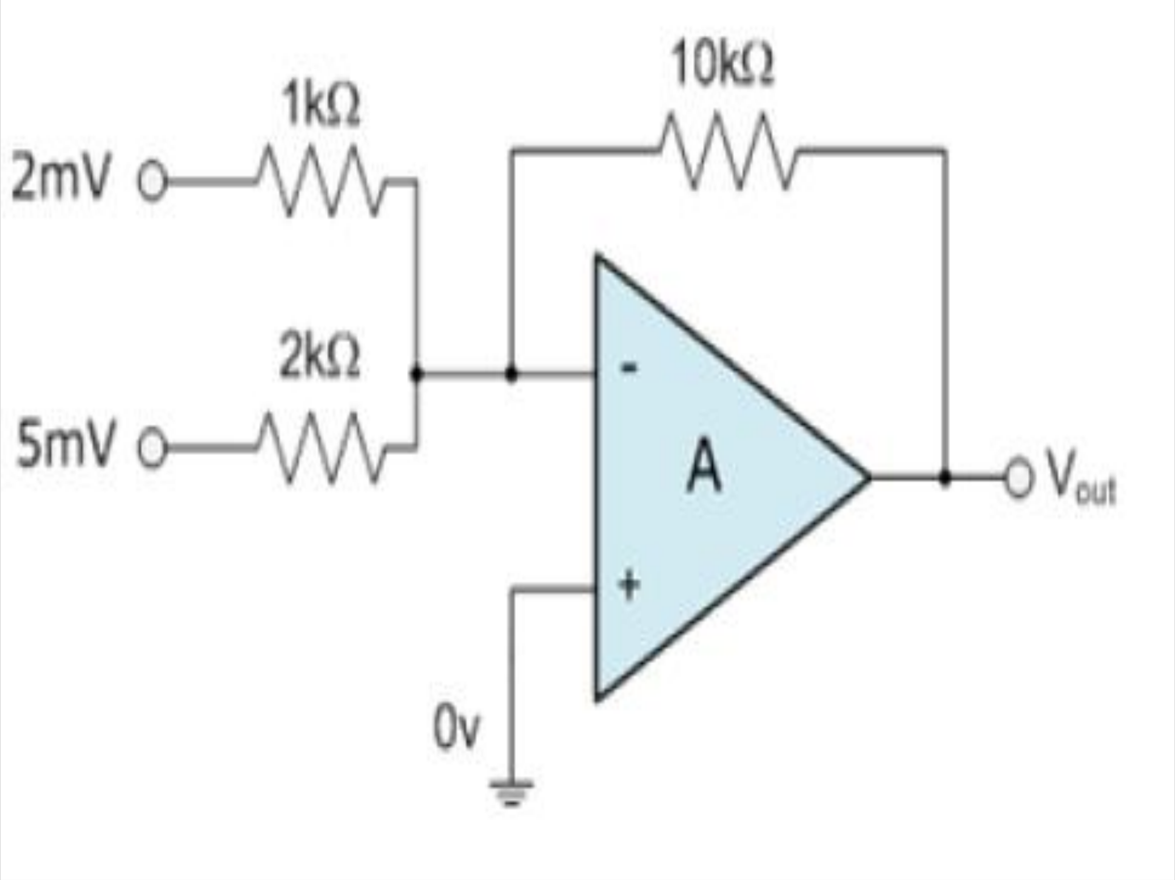
# Practical Adder circuit




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

$$if\ \ R_1 = R_2\ then\ \frac{V_{out}}{V_1 + V_2} = -\frac{R_f}{R_1}$$

# Find the output voltage of the following *Summing Amplifier* circuit



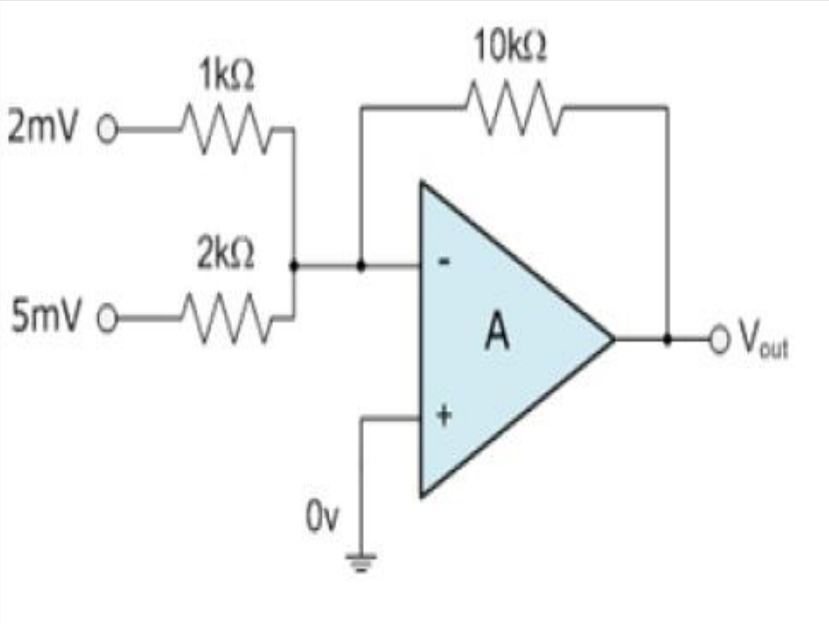
# Solution

$$Gain = \frac{V_o}{V_{in}} = -\frac{R_f}{R_{in}}$$

$$A_1 = \frac{10k\Omega}{1k\Omega} = -10, \quad A2 = \frac{10k\Omega}{2k\Omega} = -5$$

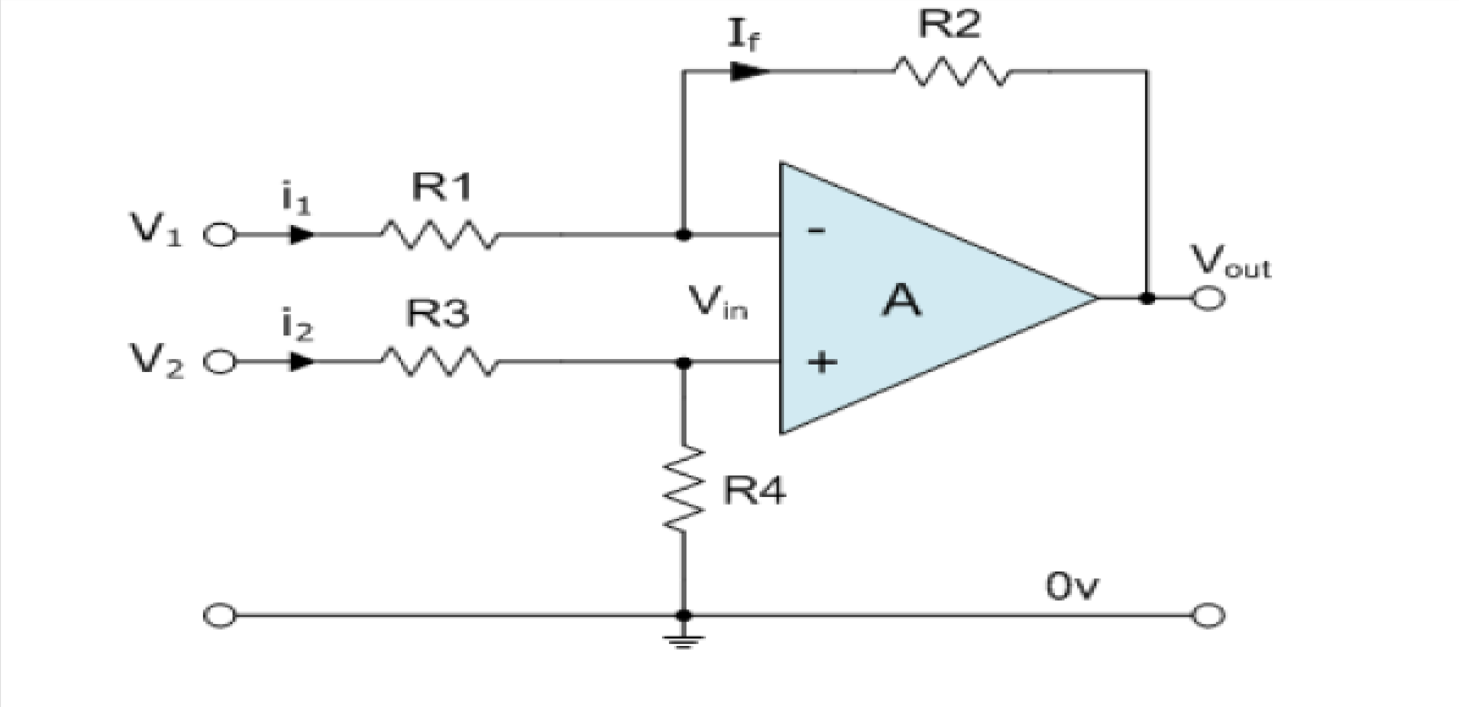
$$V_o = (-10(2mV)) + (-5(5mV))$$

$$= -45\,mV$$



# Difference Amplifier

- If connect signals to both of the inputs at the same time producing another common type of operational amplifier circuit called a differential amplifier.
- The resultant output voltage will be proportional to the "Difference" between the two input signals, V1 and V2. This type of circuit can also be used as a subtractor.



# Contd..

- The transfer function for a differential amplifier circuit is given as

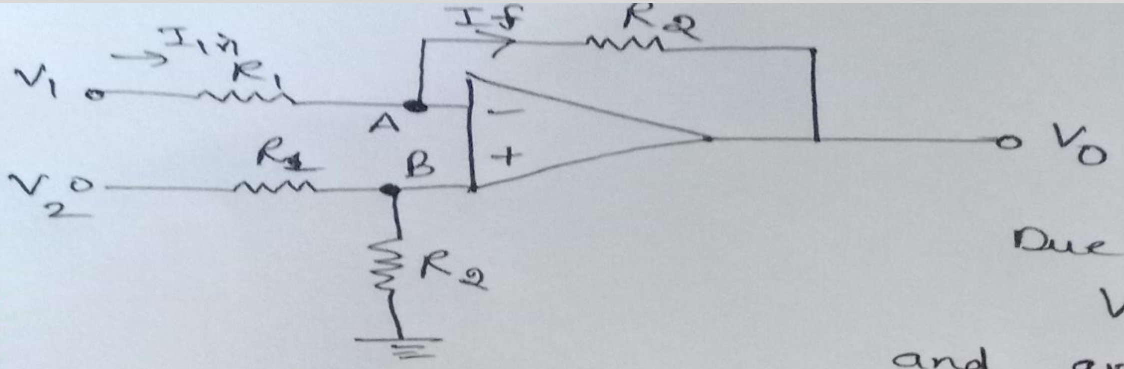
$$V_o = -\frac{R_2}{R_1}V_1 + (1+\frac{R_2}{R_1})(\frac{R_4}{R_3+R_4})V_2$$

- When R1 = R3 and R2 = R4 the transfer function formula can be modified to

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

- If all the resistors are all of the same ohmic value the circuit will become a **Unity Gain Differential Amplifier** and the gain of the amplifier will be 1 or Unity.
- One major limitation of this type of amplifier design is that its input impedances are lower compared to that of other operational amplifier configurations.
- Each input voltage source has to drive current through an input resistance, which has less overall impedance than that of the op-amps input alone.
- One way to overcome this problem is to add a *Unity Gain Buffer Amplifier* such as the voltage follower.

# Derivation




$$V_o = A_{CL}(V_1 - V_2)$$

Due to virtual Concept

$$V_A = V_B \quad -(1)$$

and apply KCL at node A

$$I_{in} = I_f \quad -(2)$$

Voltage at node B is $V_B$

$$V_B = \frac{R_2}{R_1+R_2} \cdot V_2 \quad - (3)$$

$$I_{in} = \frac{V_1 - V_A}{R_1} \qquad I_f = \frac{V_A - V_o}{R_2}$$

Put value of $I_{in}$ + $I_f$ in eq (2)

$$\frac{V_1 - V_A}{R_1} = \frac{V_A - V_o}{R_2}$$

# Contd..

$$\frac{V_1}{R_1} - \frac{V_A}{R_1} = \frac{V_A}{R_2} - \frac{V_0}{R_2}$$

$$\frac{V_1}{R_1} - \frac{V_A}{R_1} - \frac{V_A}{R_2} = -\frac{V_0}{R_2}$$

$$\frac{V_1}{R_1} - V_A\left(\frac{R_1+R_2}{R_1 R_2}\right) = -\frac{V_0}{R_2}$$

$$\frac{V_1}{R_1} - \left(\frac{\cancel{R_2}}{\cancel{R_1+R_2}}\right)\left(\frac{\cancel{R_1+R_2}}{R_1 \cancel{R_2}}\right)V_2 = -\frac{V_0}{R_2}$$

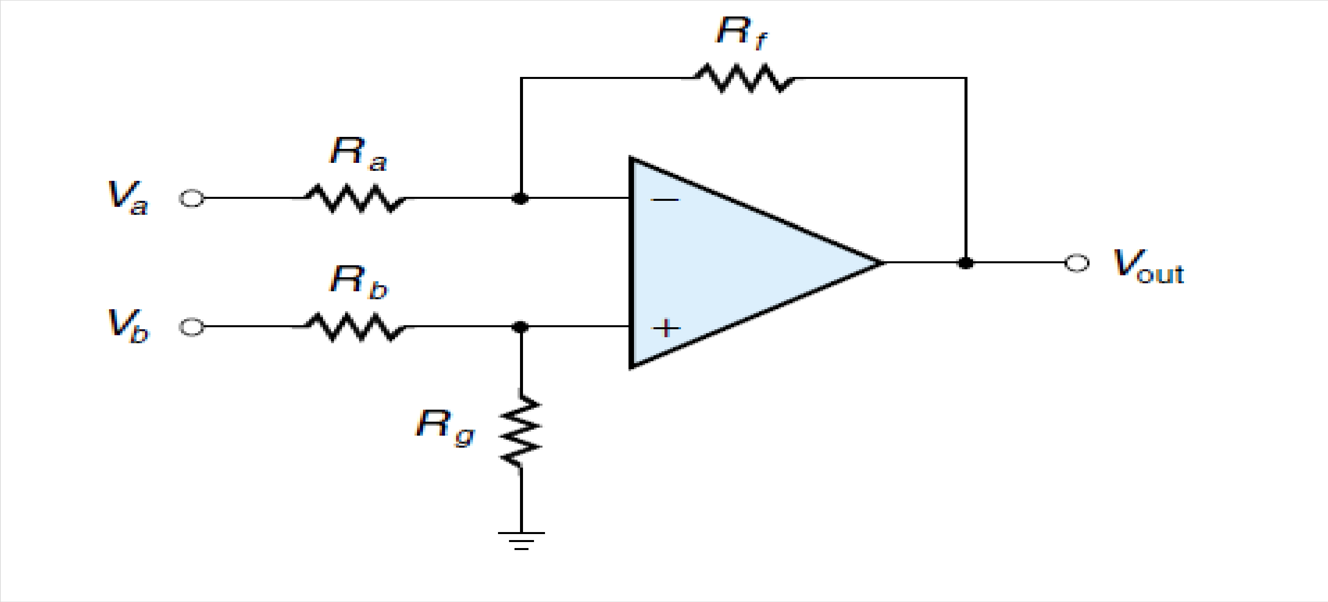
$$\frac{1}{R_1}(V_1 - V_2) = -\frac{V_0}{R_2}$$

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

Gain

Difference

Q2. A differential amp is needed to amplify the voltage difference between two temperature sensors. The sensors have an internal resistance of 50 kΩ, and the maximum voltage difference between the sensors will be 2 V. Design the differential amp circuit to have an output of 12 V when the difference the inputs is 2 V.



## Solution

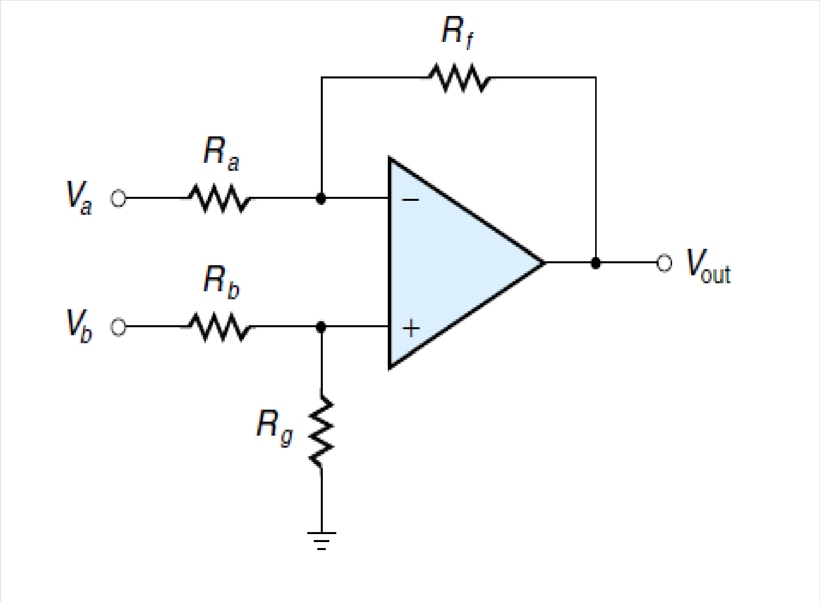
$$A_V = \frac{V_{out}}{V_{in}} = \frac{12\text{V}}{2\text{V}} = 6$$

$$R_a = R_b \text{ and } R_f = R_g$$

$$A_V = \frac{R_f}{R_a} = 6$$

$$R_f = R_a \times 6$$

$$= 50\ \text{k}\Omega \times 6 = 300\ \text{k}\Omega$$



# References


- ❖ ***Coughlin, R.F., Operational Amplifiers and Linear Integrated Circuits, Pearson Education (2006).***
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- ❖ ***Terrell, D., Op Amps Design Application and Troubleshooting, Newness (1996).***