

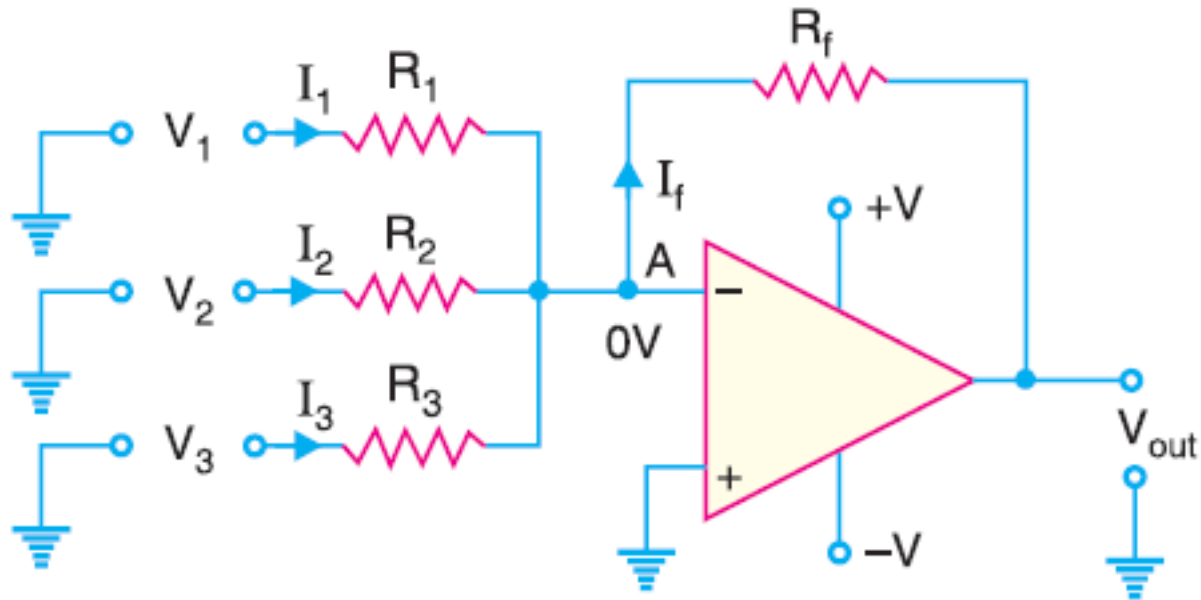
# **Basic Electronic Circuits**

## **(IEC-103)**

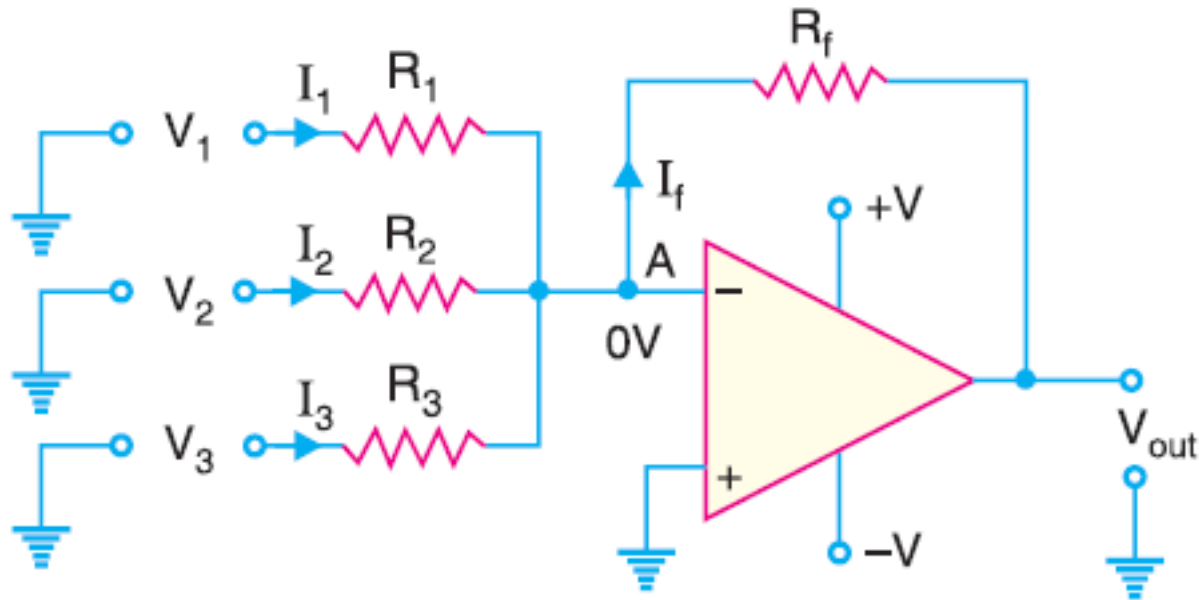
### **Lecture-05**

# **Operational Amplifier Circuits**

# Summing Amplifier



# Summing Amplifier



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

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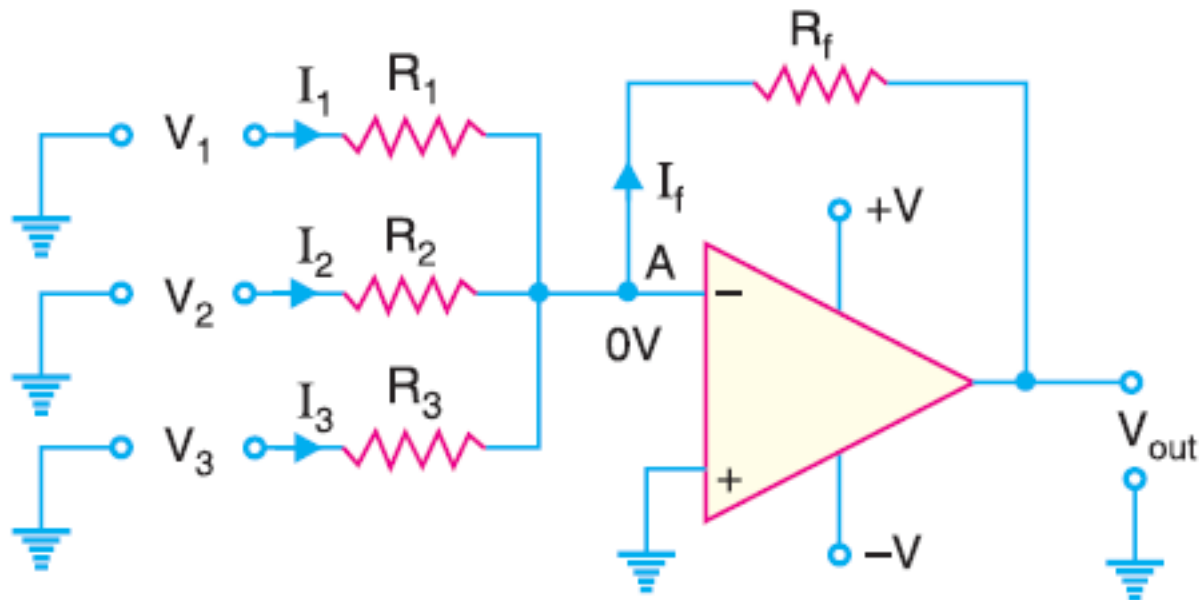
$$V_{out} = -\frac{R_f}{R} (V_1 + V_2 + V_3)$$

If  $R_f = R$

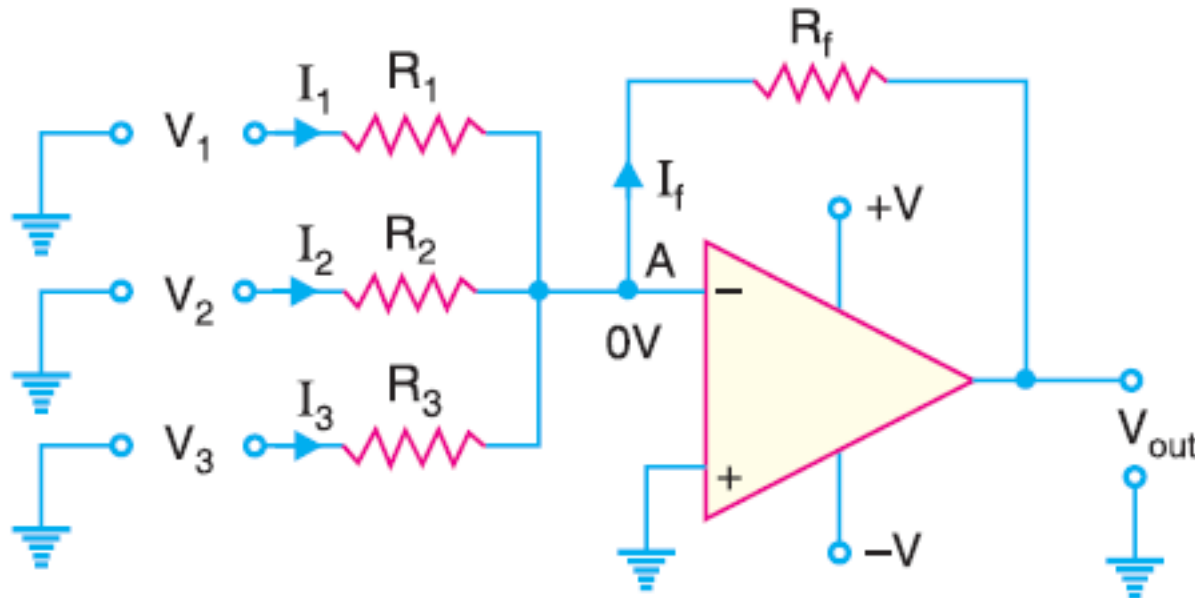
$$V_{out} = -(V_1 + V_2 + V_3)$$

# **Build an Averaging Amplifier**

# Build an Averaging Amplifier



# Build an Averaging Amplifier



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

# Averaging Amplifier

If we choose  $R_1 = R_2 = R_3 = R$

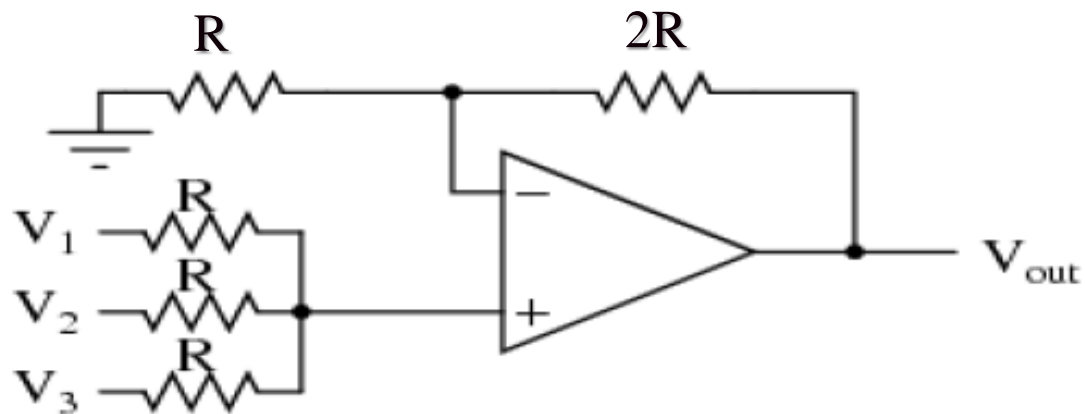
and  $R_f = R/3$

$$V_{out} = -\frac{R}{3} \left( \frac{V_1}{R} + \frac{V_2}{R} + \frac{V_3}{R} \right)$$

$$\Rightarrow V_{out} = -\frac{R}{3R} (V_1 + V_2 + V_3)$$

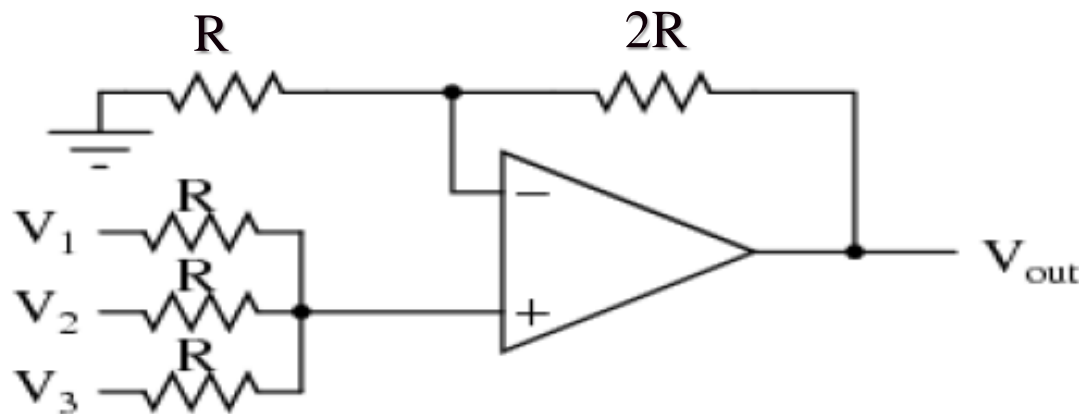
$$\Rightarrow V_{out} = -\frac{(V_1 + V_2 + V_3)}{3}$$

# Example



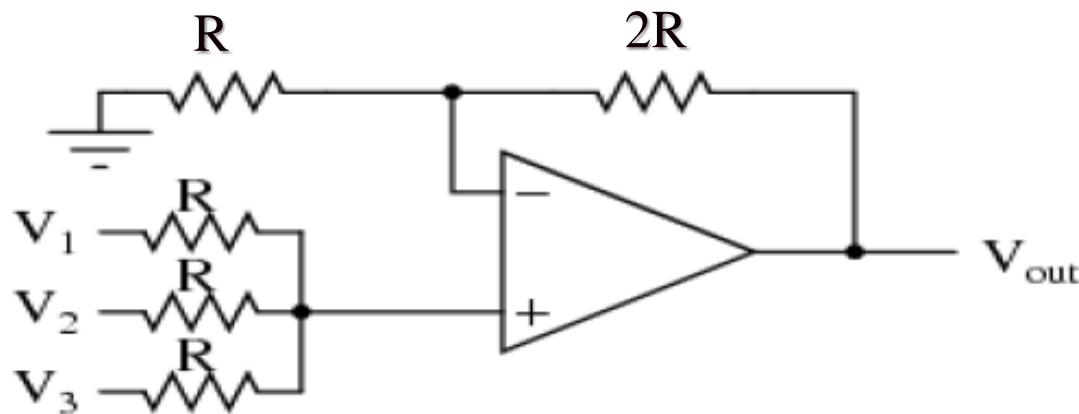


# Example (continued)



**Output voltage(  $V_{out1}$  ) due to source  $V_1$  alone**

# Example (continued)



**Output voltage(  $V_{out1}$  ) due to source  $V_1$  alone**

$$V_{out1} = \left( V_1 \times \frac{R/2}{R + R/2} \right) \left( 1 + \frac{2R}{R} \right)$$

# Example (continued)

$$\Rightarrow V_{out1} = \left( V_1 \times \frac{1}{3} \right) (3) = V_1$$

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**Similarly output voltage due to sources  $V_2$  and  $V_3$  acting alone are  $V_2$  and  $V_3$  respectively.**

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**Therefore, output voltage due to all the sources is**

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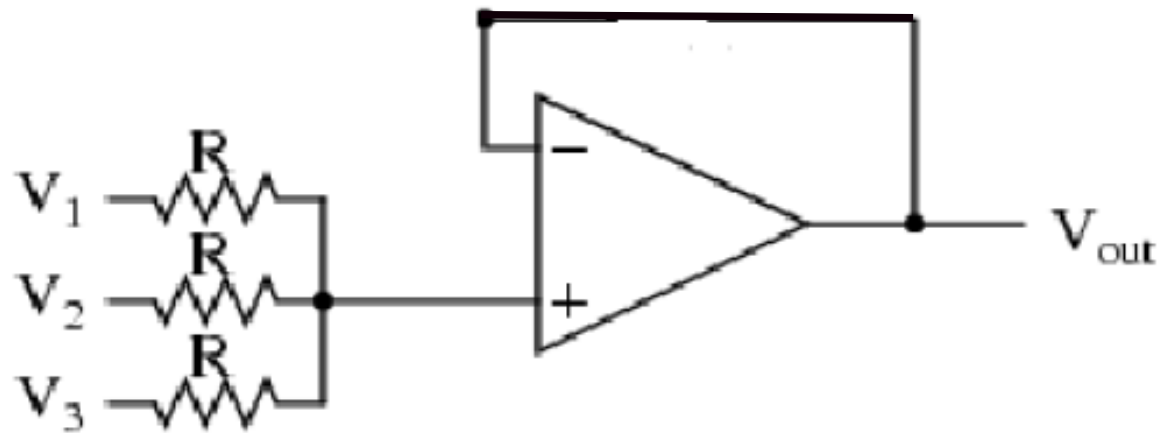
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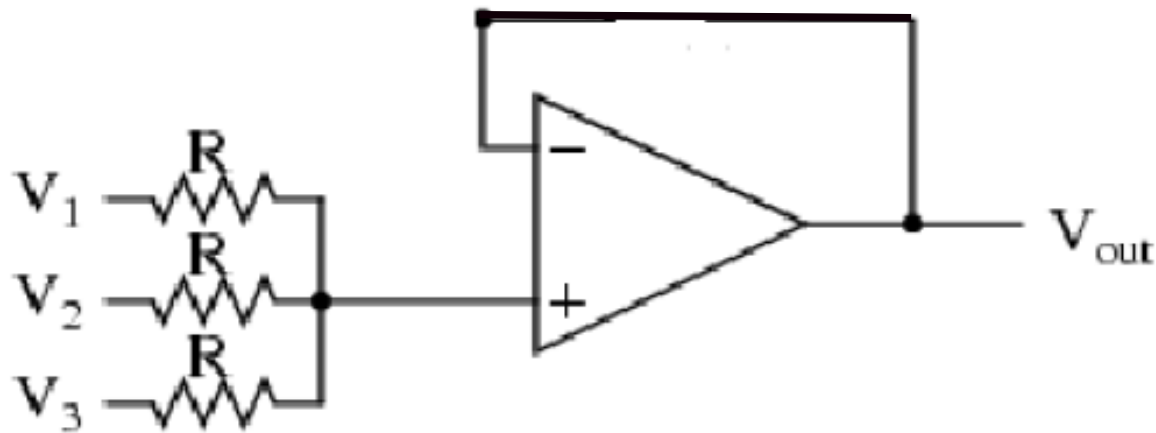
$$V_{out} = V_1 + V_2 + V_3$$

**This is summing amplifier without inversion.**

# Example

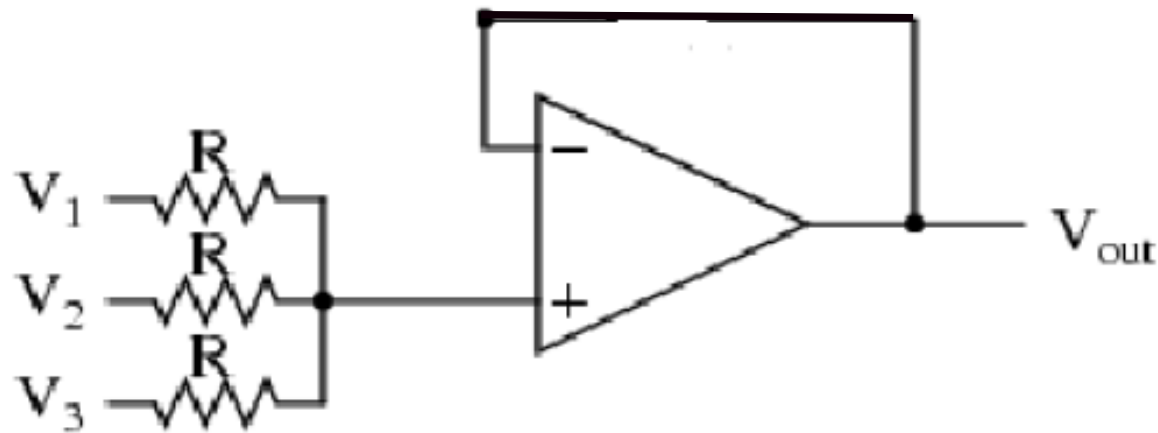


# Example (continued)



**Output voltage(  $V_{out1}$  ) due to source  $V_1$  alone**

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**Output voltage(  $V_{out1}$  ) due to source  $V_1$  alone**

$$V_{out1} = \left( V_1 \times \frac{R/2}{R + R/2} \right) (1)$$

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$$\Rightarrow V_{out1} = \left( V_1 \times \frac{1}{3} \right) (1) = \frac{V_1}{3}$$

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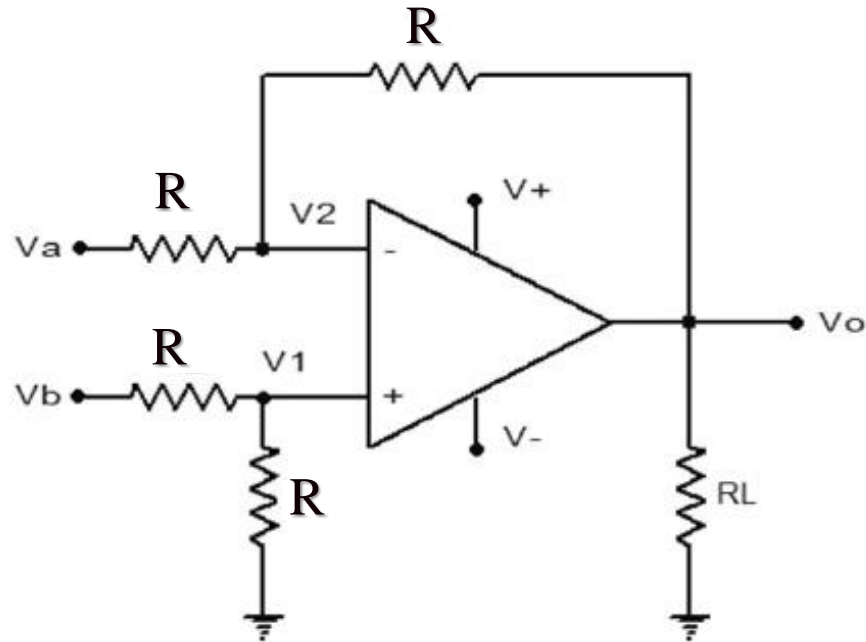
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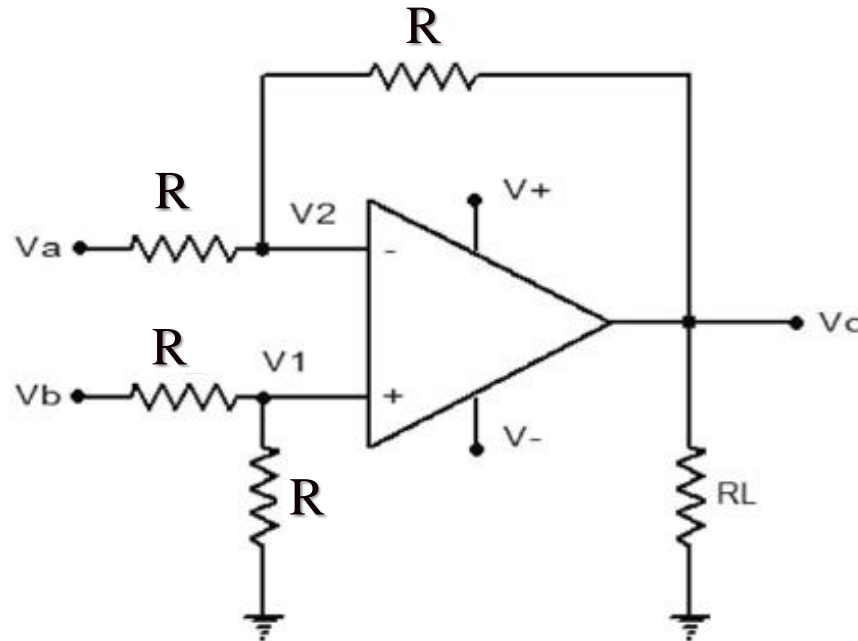
$$V_{out} = \frac{V_1 + V_2 + V_3}{3}$$

**This is an averaging amplifier without inversion.**

# Example



# Example



**Output voltage ( $V_{outa}$ ) due to source  $V_a$  alone**

$$V_{outa} = \left( -\frac{R}{R} \right) V_a = -V_a$$



# Example (continued)

**Output voltage ( $V_{outb}$ ) due to sources  $V_b$  is**

$$V_{outb} = \left(1 + \frac{R}{R}\right) \times \left(V_b \times \frac{R}{R + R}\right) = 2 \times \frac{V_b}{2} = V_b$$



# Example (continued)

**Output voltage ( $V_{outb}$ ) due to sources  $V_b$  is**

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**Therefore, output voltage due to both the sources is**

$$V_{out} = V_b - V_a$$

# Example (continued)

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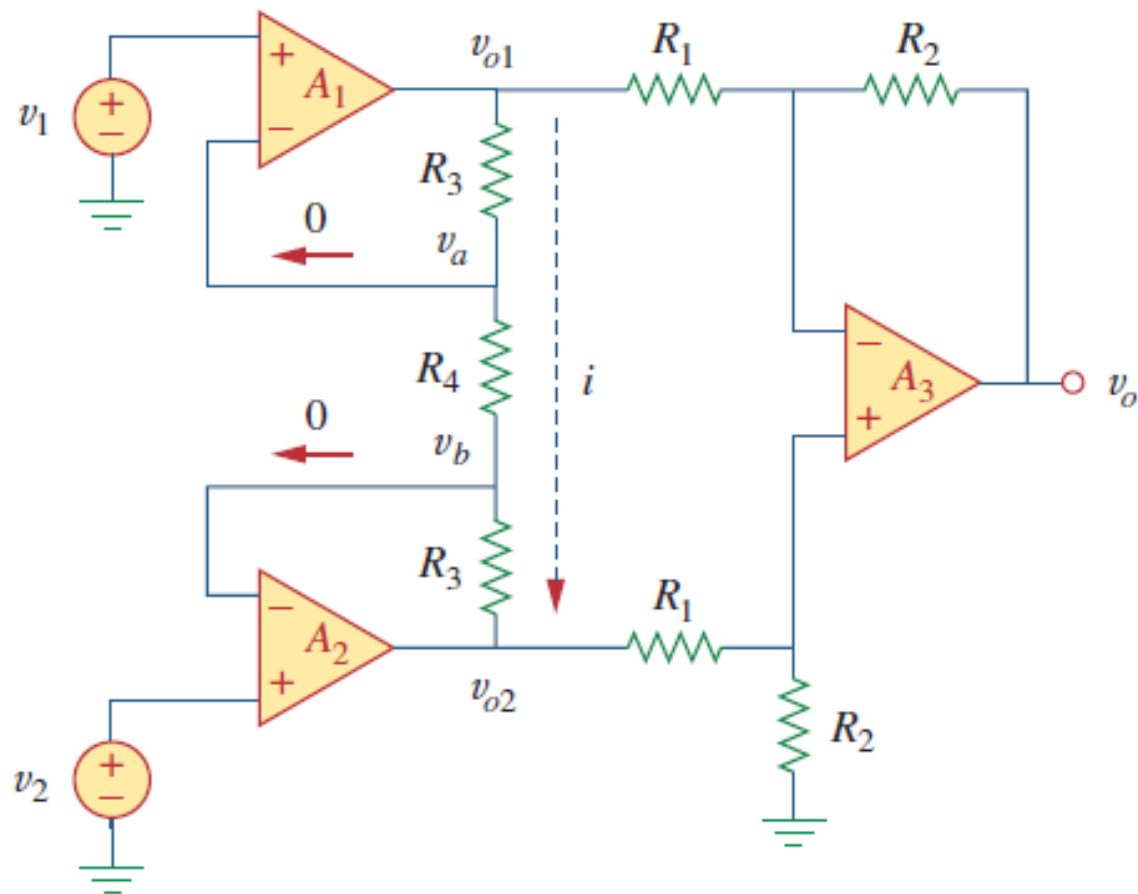
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**Therefore, output voltage due to both the sources is**

$$V_{out} = V_b - V_a$$

**This is a difference amplifier.**

# Example



# Example (continued)

$$v_o = -\frac{R_2}{R_1} v_{o1} + \frac{R_2}{R_1} v_{o2} = \left( \frac{R_2}{R_1} \right) (v_{o2} - v_{o1}) \quad (1)$$

## Example (continued)

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and

$$v_{o1} - v_{o2} = i(R_3 + R_4 + R_3) = (2R_3 + R_4)i$$

# Example (continued)

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Also

$$i = \frac{v_a - v_b}{R_4}$$



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Also

$$i = \frac{v_a - v_b}{R_4}$$

**But**  $v_a = v_1$  and  $v_b = v_2$  **(Assuming op-amps to be ideal)**

## Example (continued)

$$\therefore v_{o1} - v_{o2} = (2R_3 + R_4) \left( \frac{v_1 - v_2}{R_4} \right) = \left( 1 + \frac{2R_3}{R_4} \right) (v_1 - v_2)$$

## Example (continued)

$$\therefore v_{o1} - v_{o2} = (2R_3 + R_4) \left( \frac{v_1 - v_2}{R_4} \right) = \left( 1 + \frac{2R_3}{R_4} \right) (v_1 - v_2)$$

**Substituting  $v_{o1} - v_{o2}$  from the above equation in (1)**

$$v_o = \left( \frac{R_2}{R_1} \right) (v_{o2} - v_{o1}) = \left( \frac{R_2}{R_1} \right) \left( 1 + \frac{2R_3}{R_4} \right) (v_2 - v_1)$$

## Example (continued)

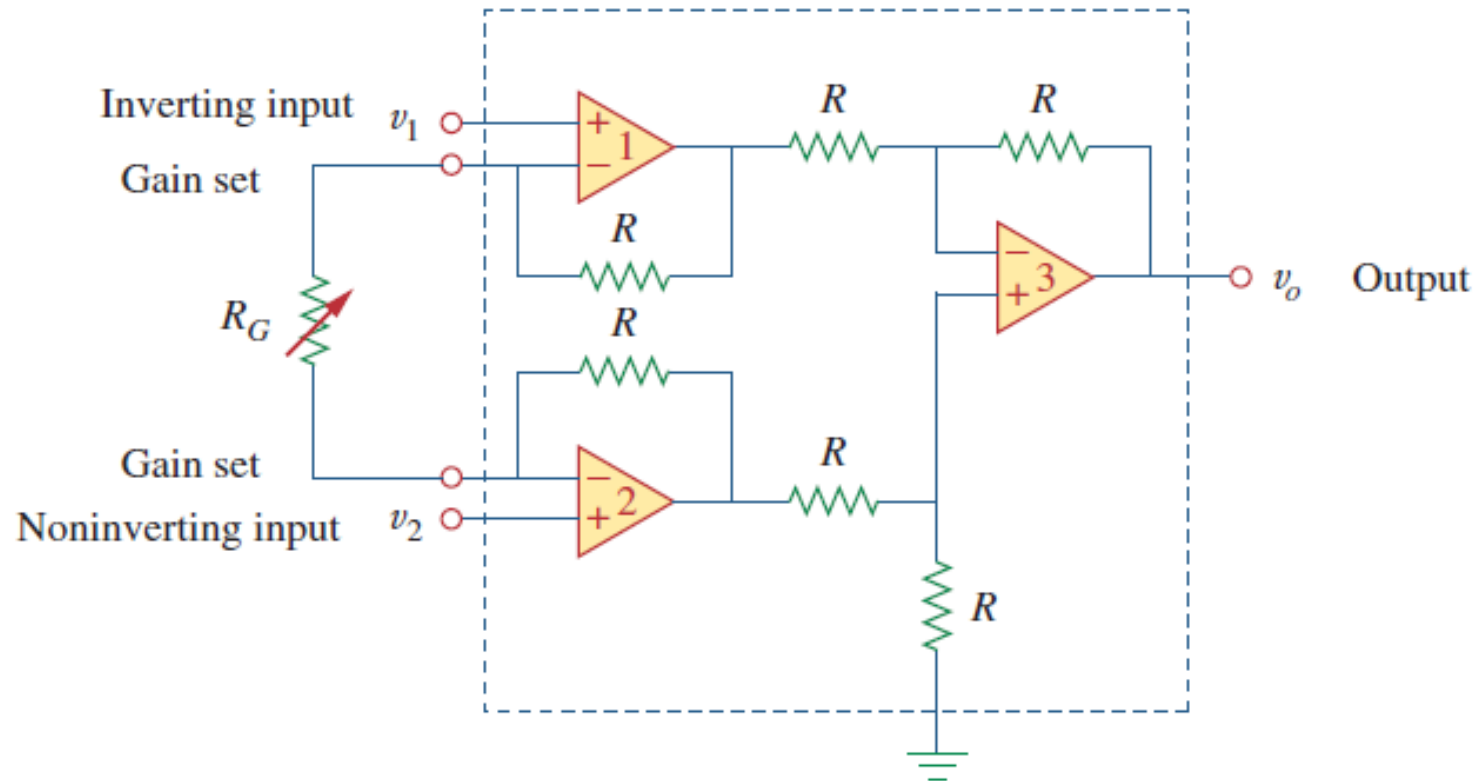
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**Substituting  $v_{o1} - v_{o2}$  from the above equation in (1)**

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$$v_o = A_v (v_2 - v_1)$$

# Instrumentation Amplifier



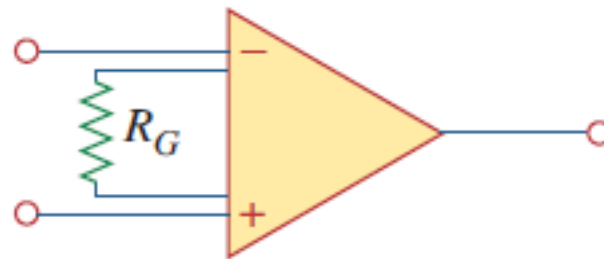
# Instrumentation Amplifier

$$A_v = \left( 1 + \frac{2R}{R_G} \right)$$



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- ☐ **Widely used in instrumentation for measurement of signals.**

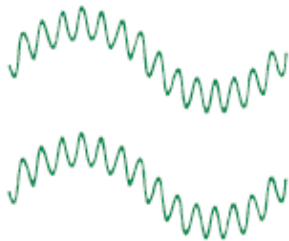
# **Instrumentation Amplifier**

- ☐ **It is difference amplifier with input buffer amplifiers.**
- ☐ **Very high input impedance and common mode rejection makes it suitable for measurement applications.**
- ☐ **Widely used in instrumentation for measurement of signals.**
- ☐ **Low DC offset, low noise, high open-loop gain, very high CMRR, and high input impedance.**

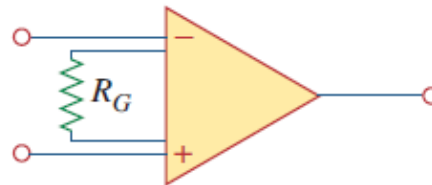


# Instrumentation Amplifier

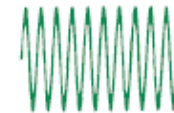
## Common Mode Rejection



Small differential signals riding on larger common-mode signals



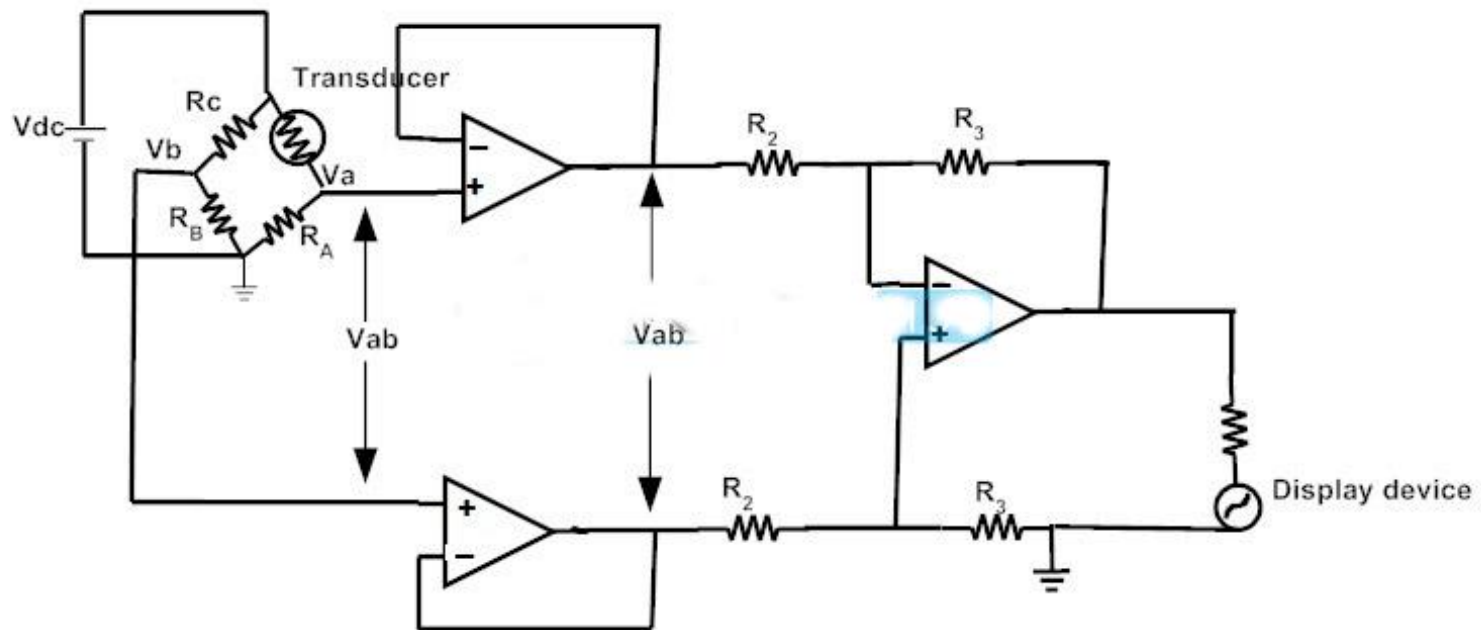
Instrumentation amplifier



Amplified differential signal,  
no common-mode signal



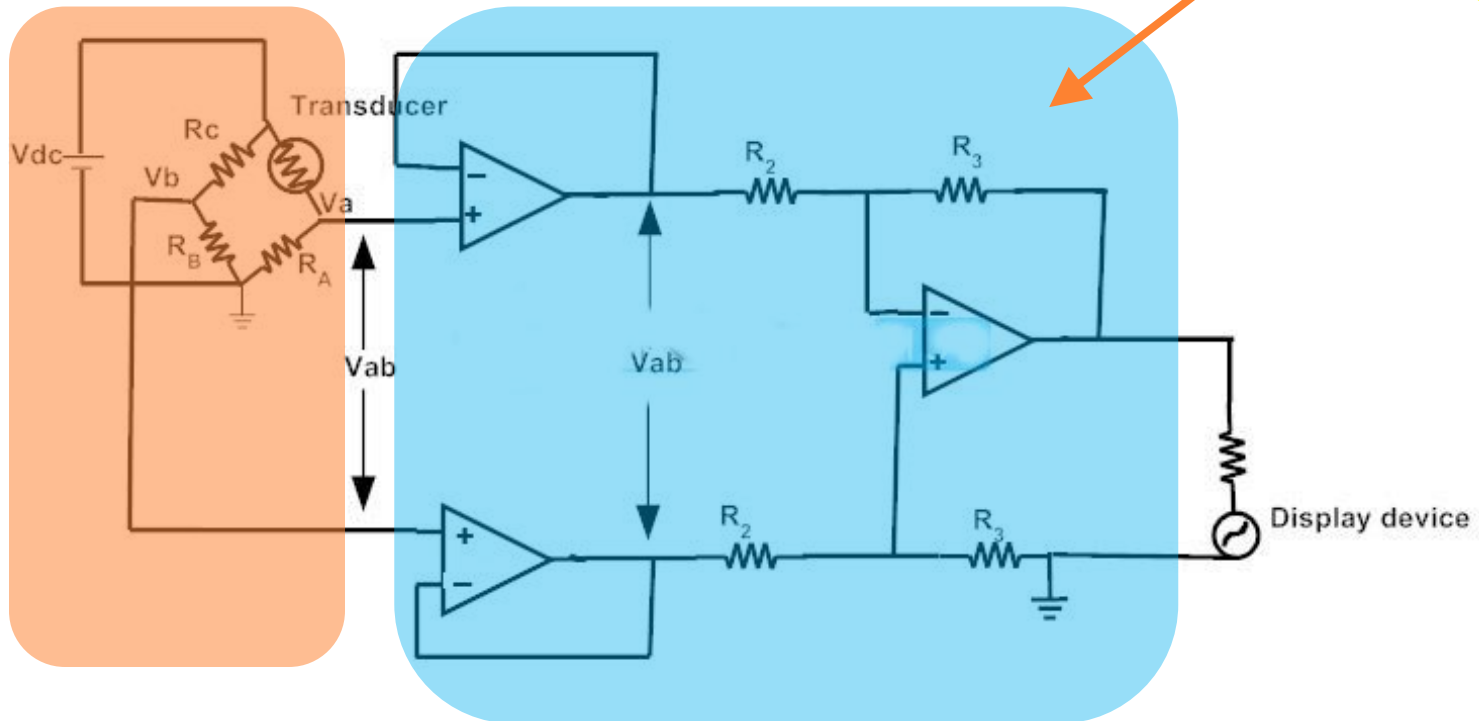
# Transducer Bridge Instrumentation Amplifier



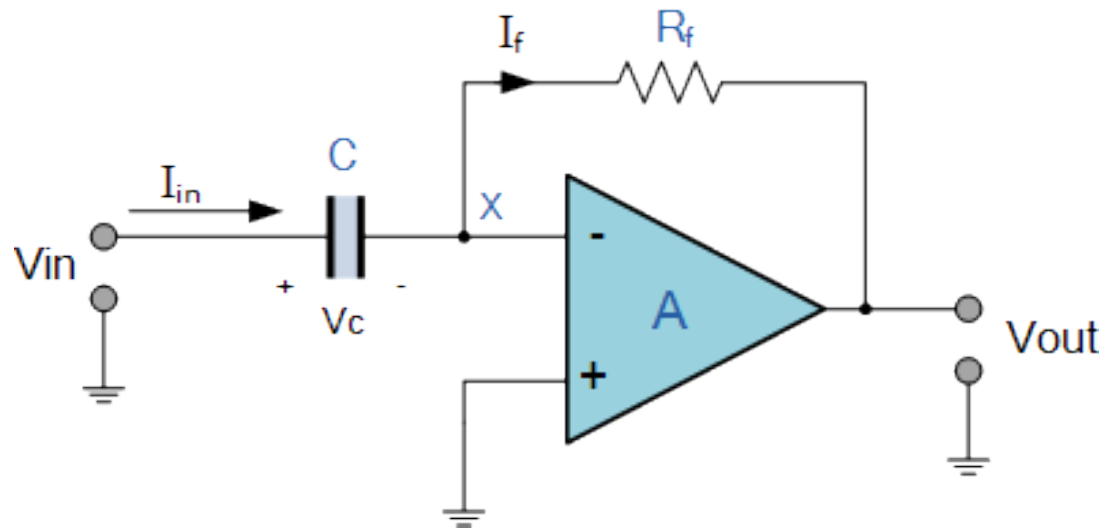
The diagram illustrates a Wheatstone bridge circuit for strain measurement. The bridge is powered by a DC voltage source  $V_{dc}$ . The bridge resistors are  $R_A$ ,  $R_B$ ,  $R_C$ , and a Transducer. The bridge output voltage  $V_{ab}$  is measured across the transducer. This signal is then amplified by an instrumentation amplifier. The instrumentation amplifier consists of two op-amp buffers (one inverting, one non-inverting) that provide a high input impedance to the bridge. The outputs of these buffers are connected to a third op-amp configured as a differential amplifier, which uses resistors  $R_2$  and  $R_3$  to produce the final output signal. This output signal is then connected to a Display device.

# Transducer Bridge Instrumentation Amplifier

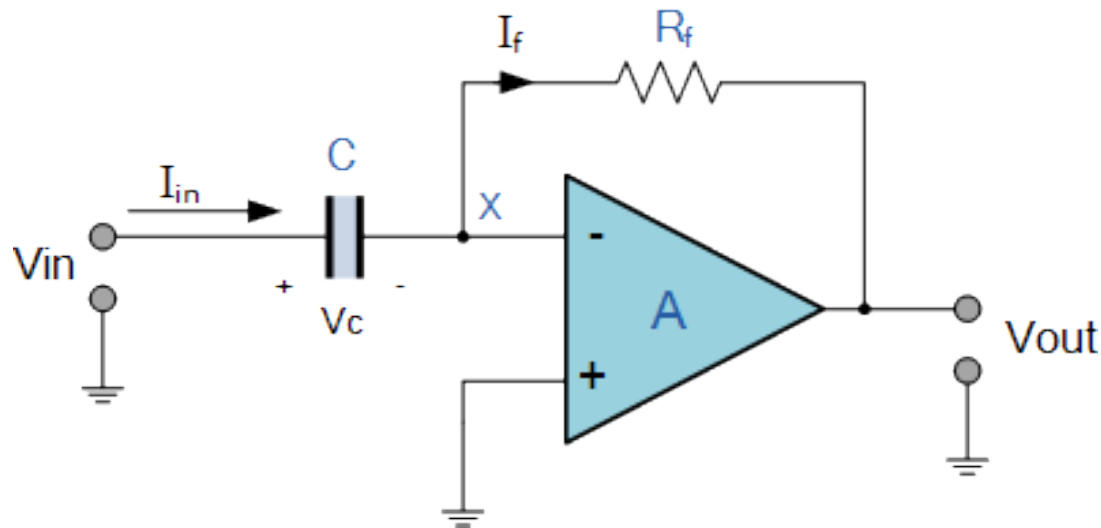
instrumentation Amplifier



# Example



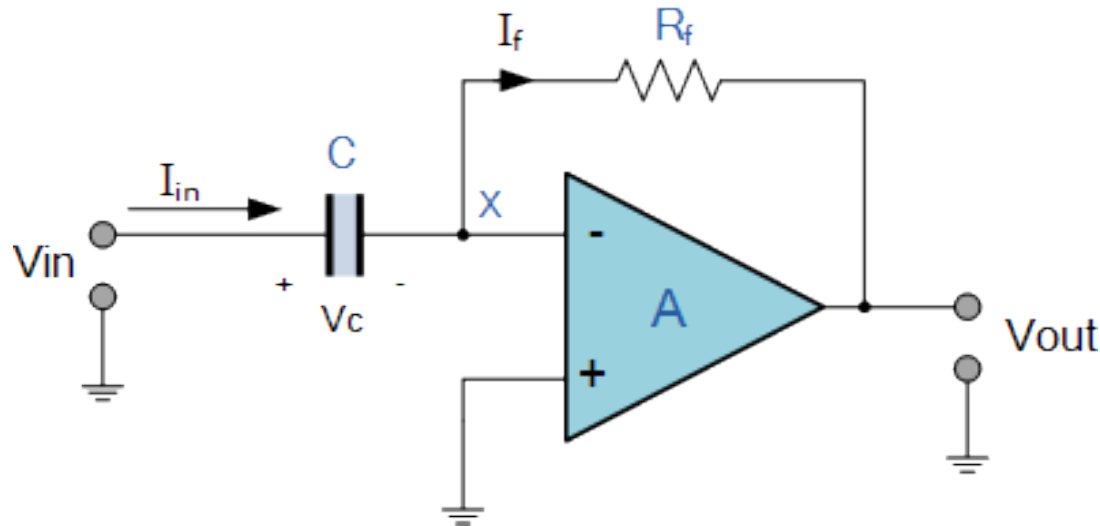
# Example (Continued)



$$V_{out} = -R_f C \frac{dV_{in}}{dt}$$



# Example (Continued)

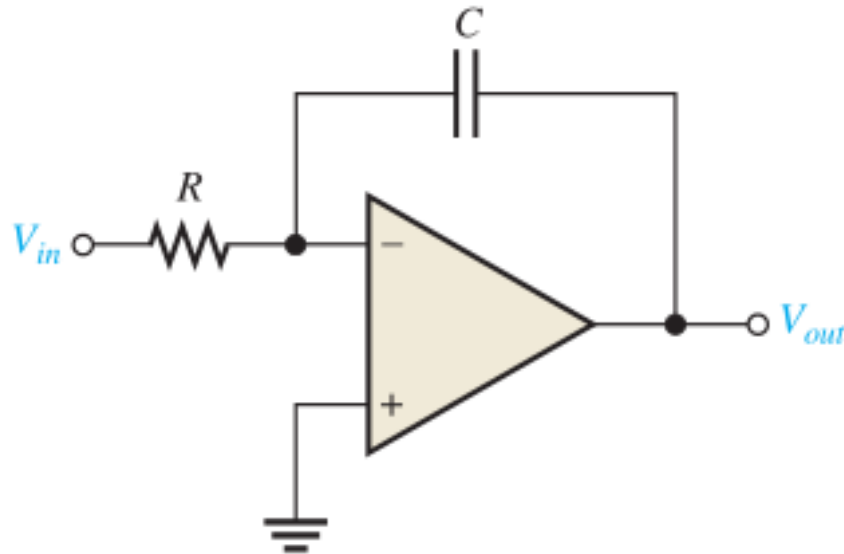


$$V_{out} = -R_f C \frac{dV_{in}}{dt}$$

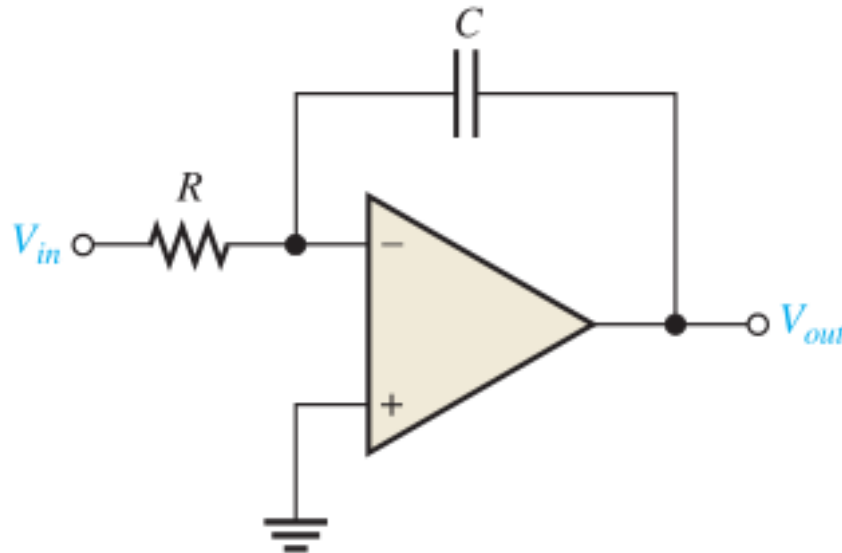
**Differentiator**



# Example

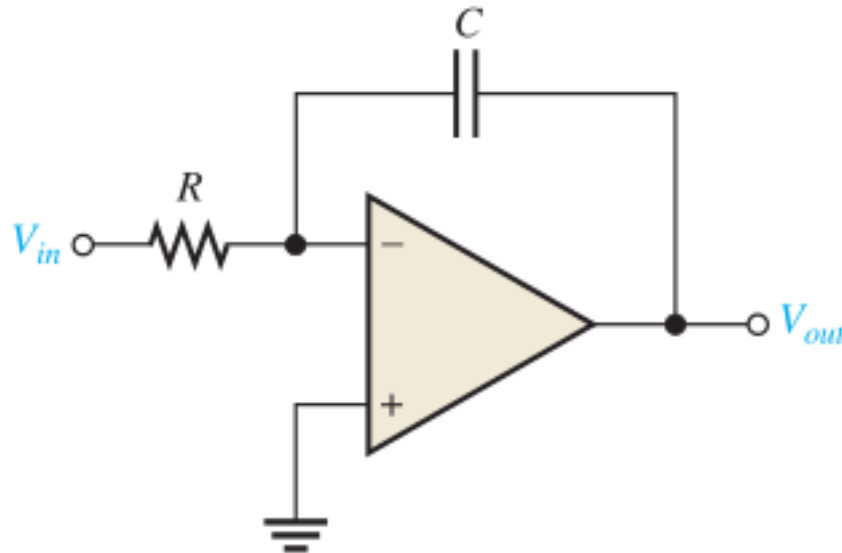


# Example (Continued)



$$V_{out} = -\frac{1}{RC} \int V_{in} dt$$

# Example (Continued)



$$V_{out} = -\frac{1}{RC} \int V_{in} dt$$

**Integrator**