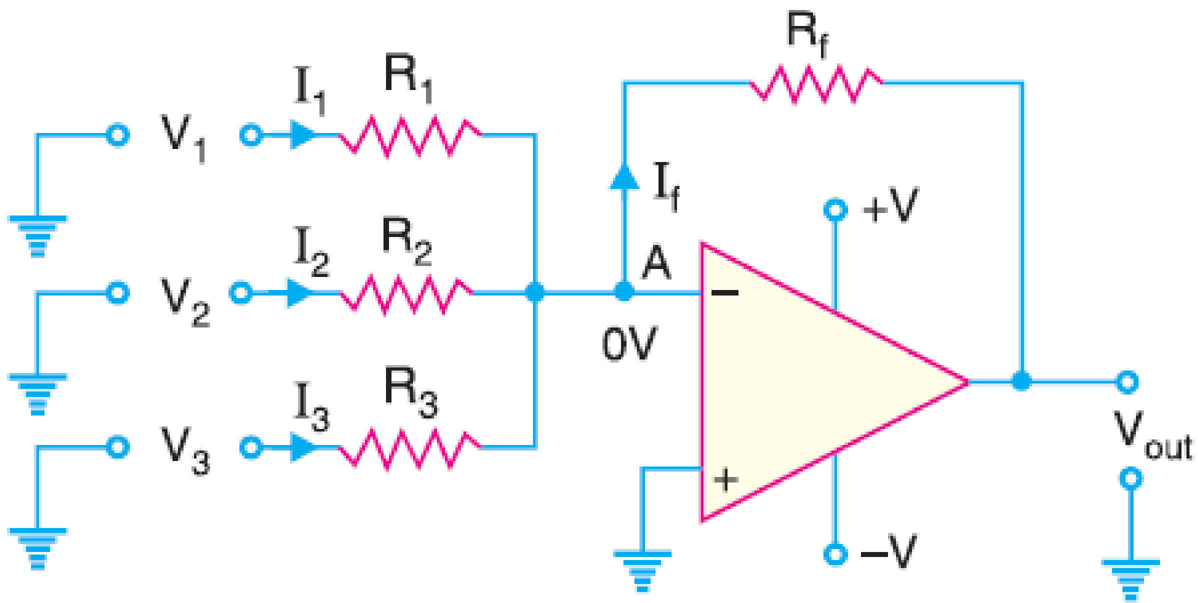
Basic Electronic Circuits
(IEC-103)

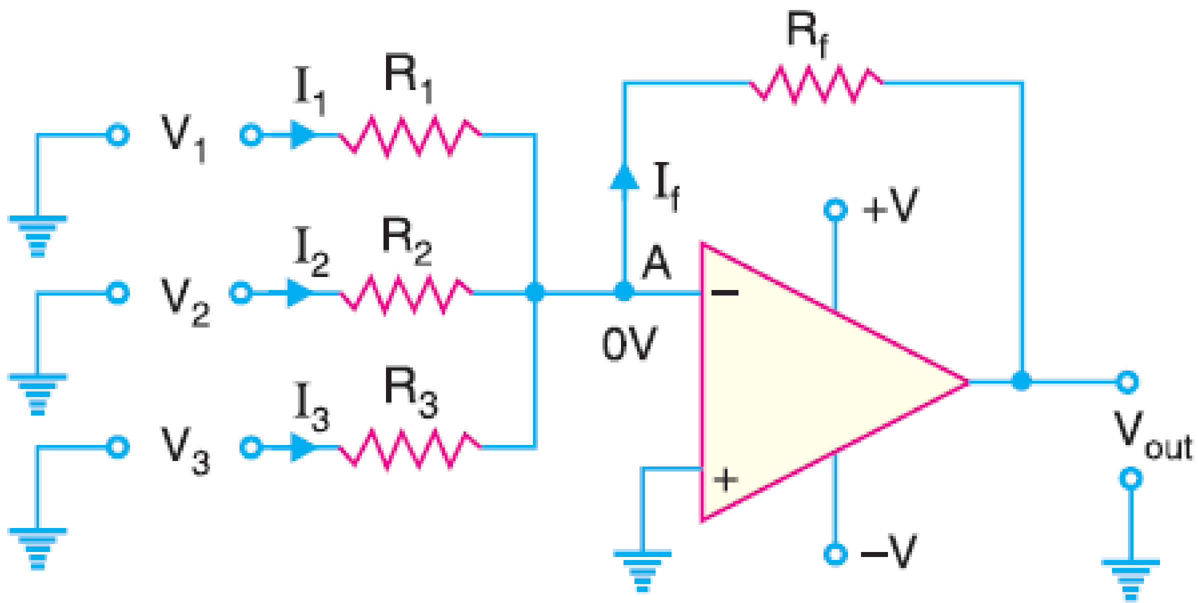
Lecture-05

Operational Amplifier Circuits

Summing Amplifier



Summing Amplifier



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Build an Averaging Amplifier

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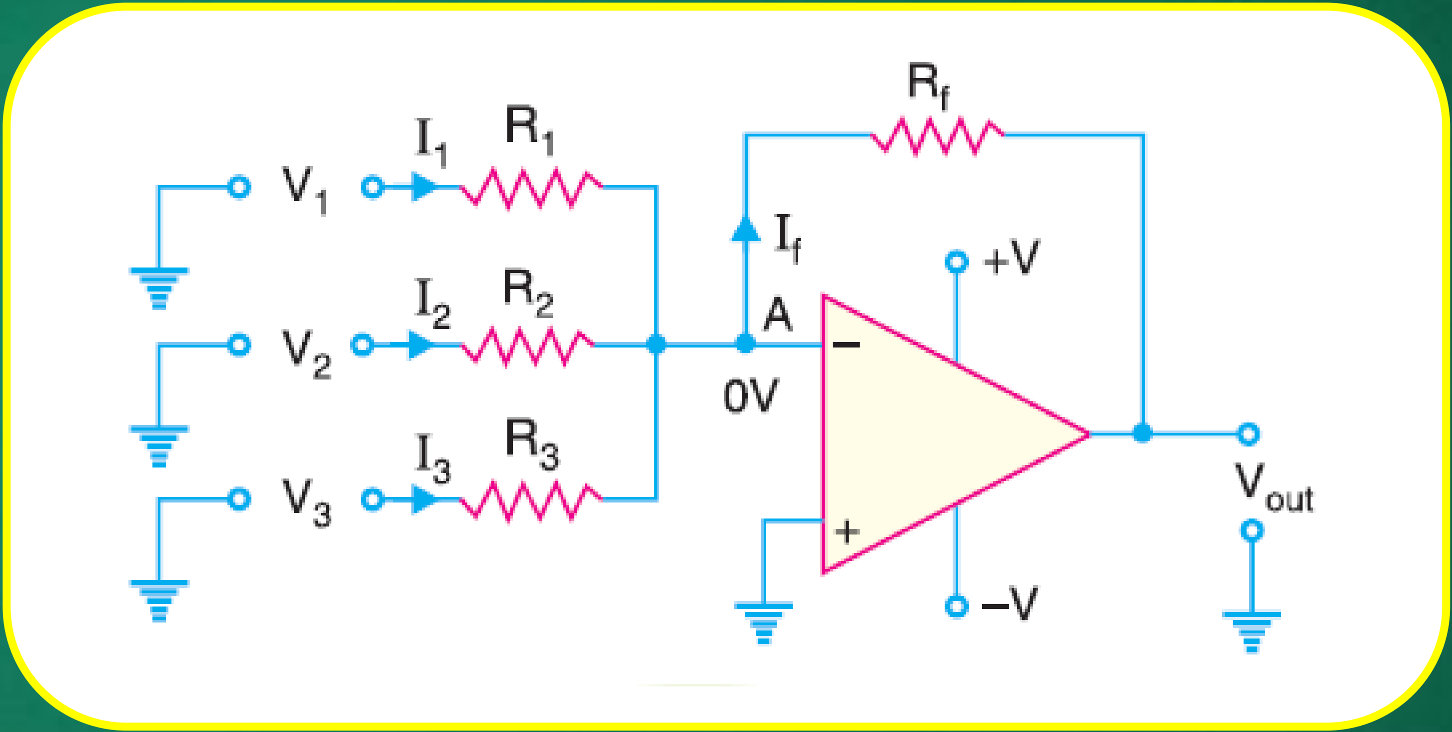

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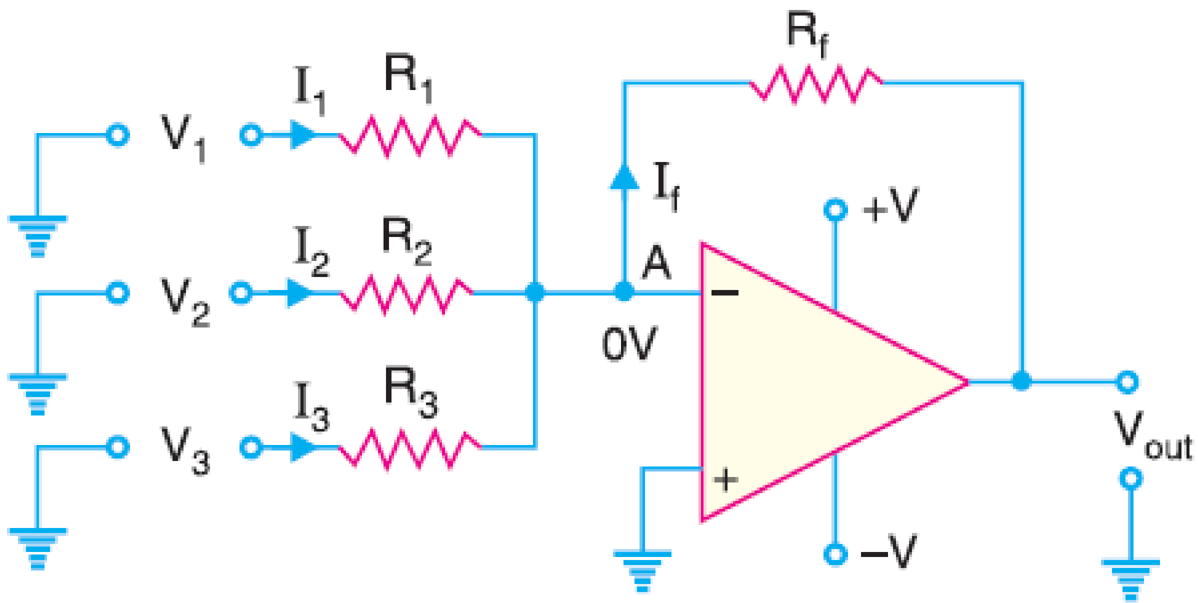


$$V_{out} = -R_f\left(\frac{V_1}{R_1}+\frac{V_2}{R_2}+\frac{V_3}{R_3}\right)$$

Averaging Amplifier

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

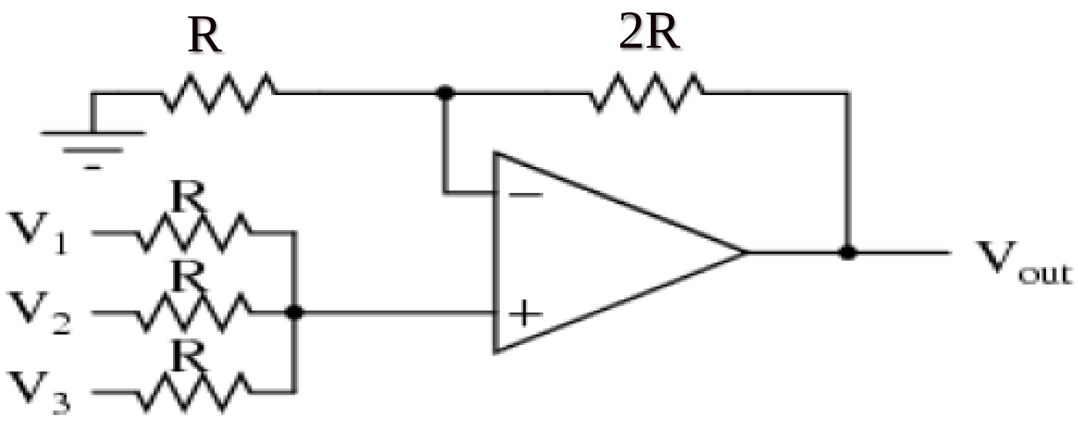
and $R_f = R/3$

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

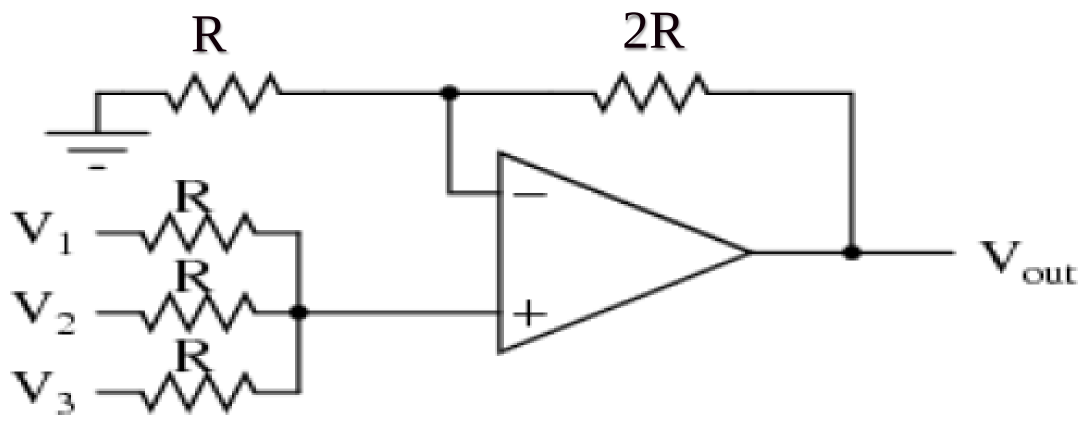
$$\Rightarrow V_{out} = -\frac{R}{3R}\left(V_1 + V_2 + V_3\right)$$

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

Example

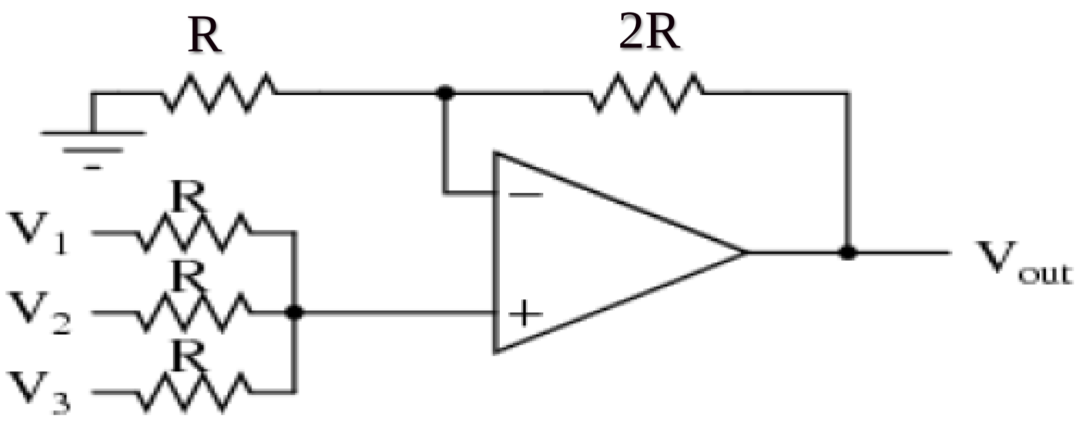


Example (continued)



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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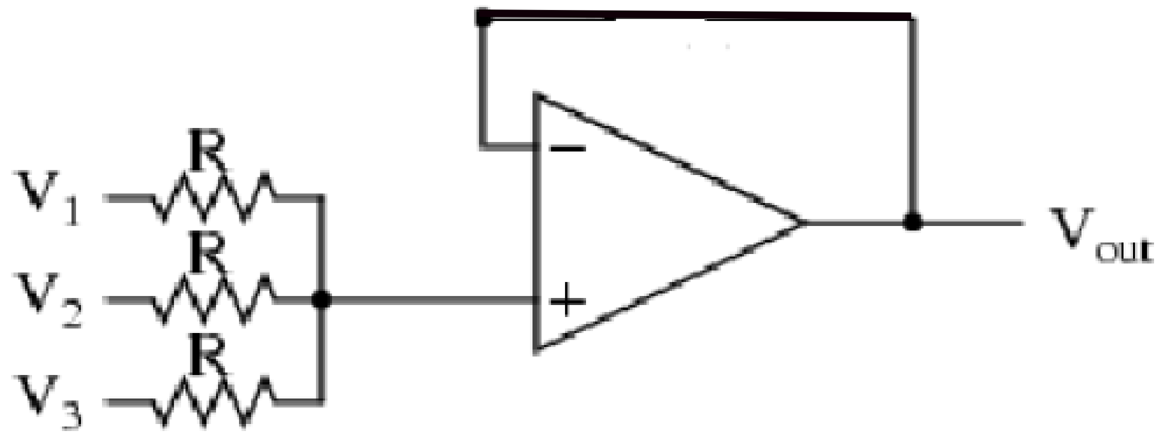
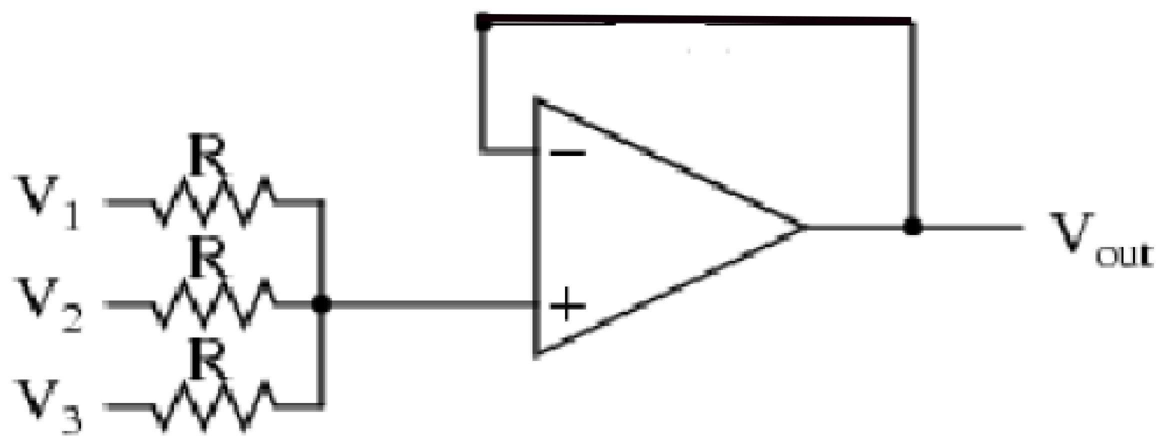
This is summing amplifier without inversion.

Example

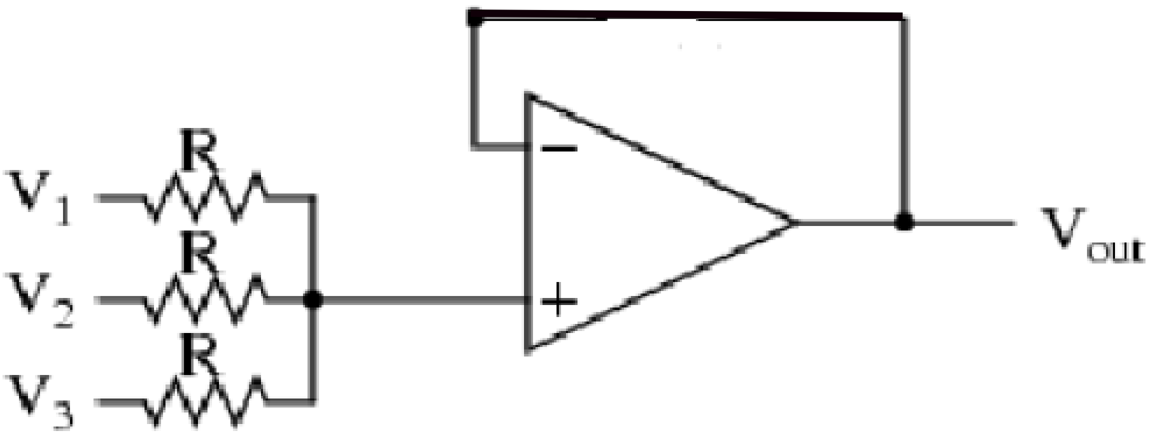


Example (continued)



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

Example (continued)



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

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

Example (continued)

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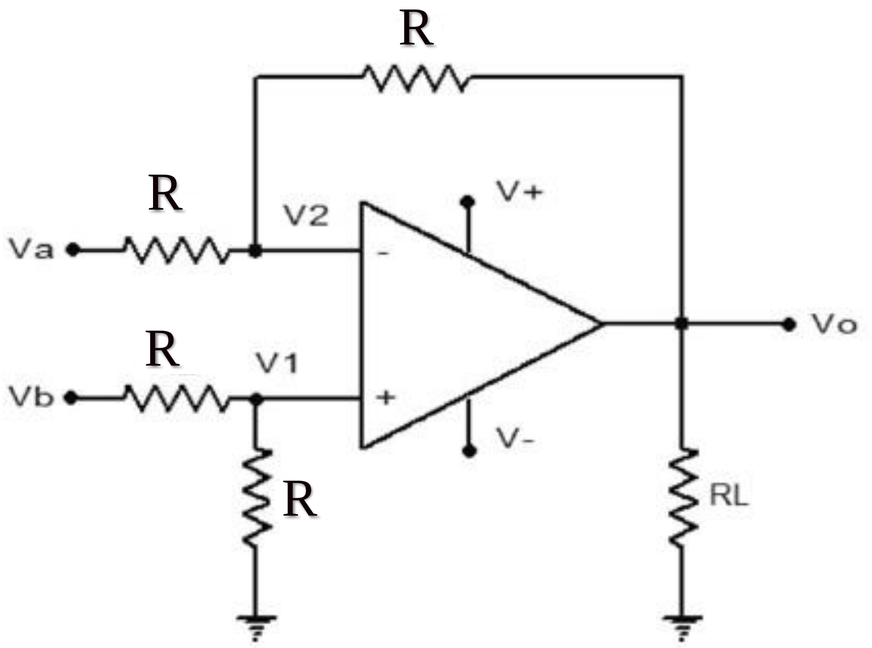
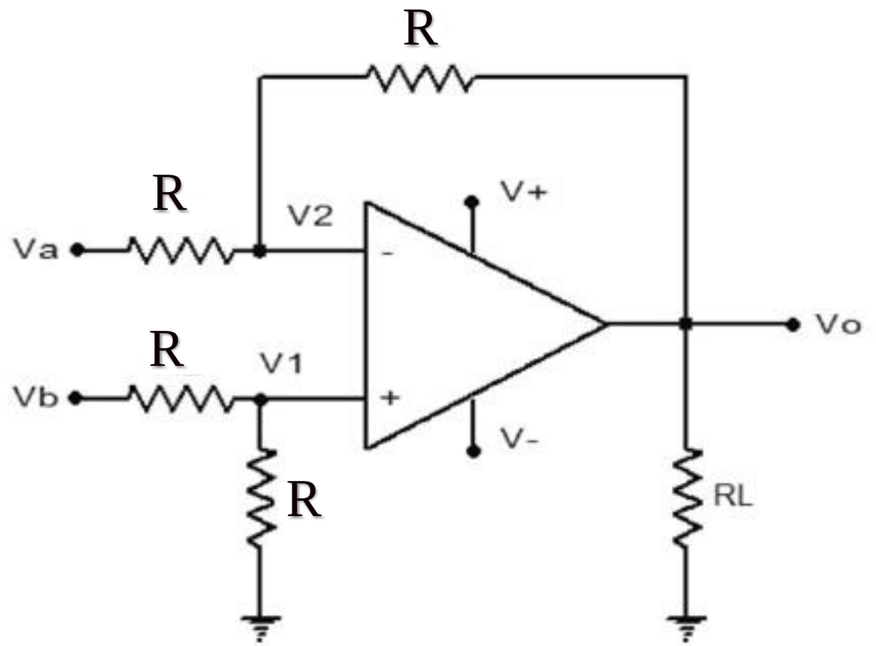
$$V_{out} = \frac{V_1 + V_2 + V_3}{3}$$

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

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

Therefore, output voltage due to both the sources is

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

Example (continued)

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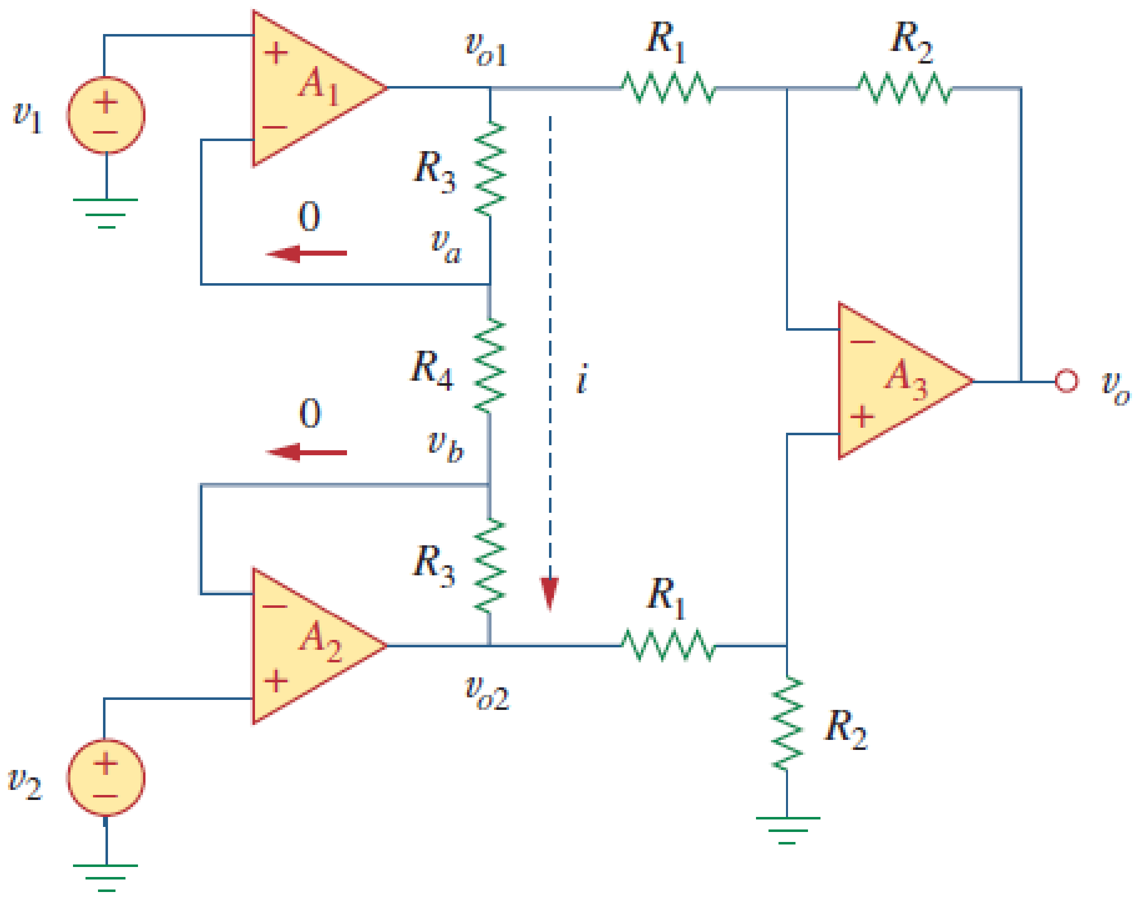
Therefore, output voltage due to both the sources is

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

This is a **difference amplifier.**

Example



Example (continued)

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

Example (continued)

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

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 $v_a = v_1 \text{ and } v_b = v_2$ (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)

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

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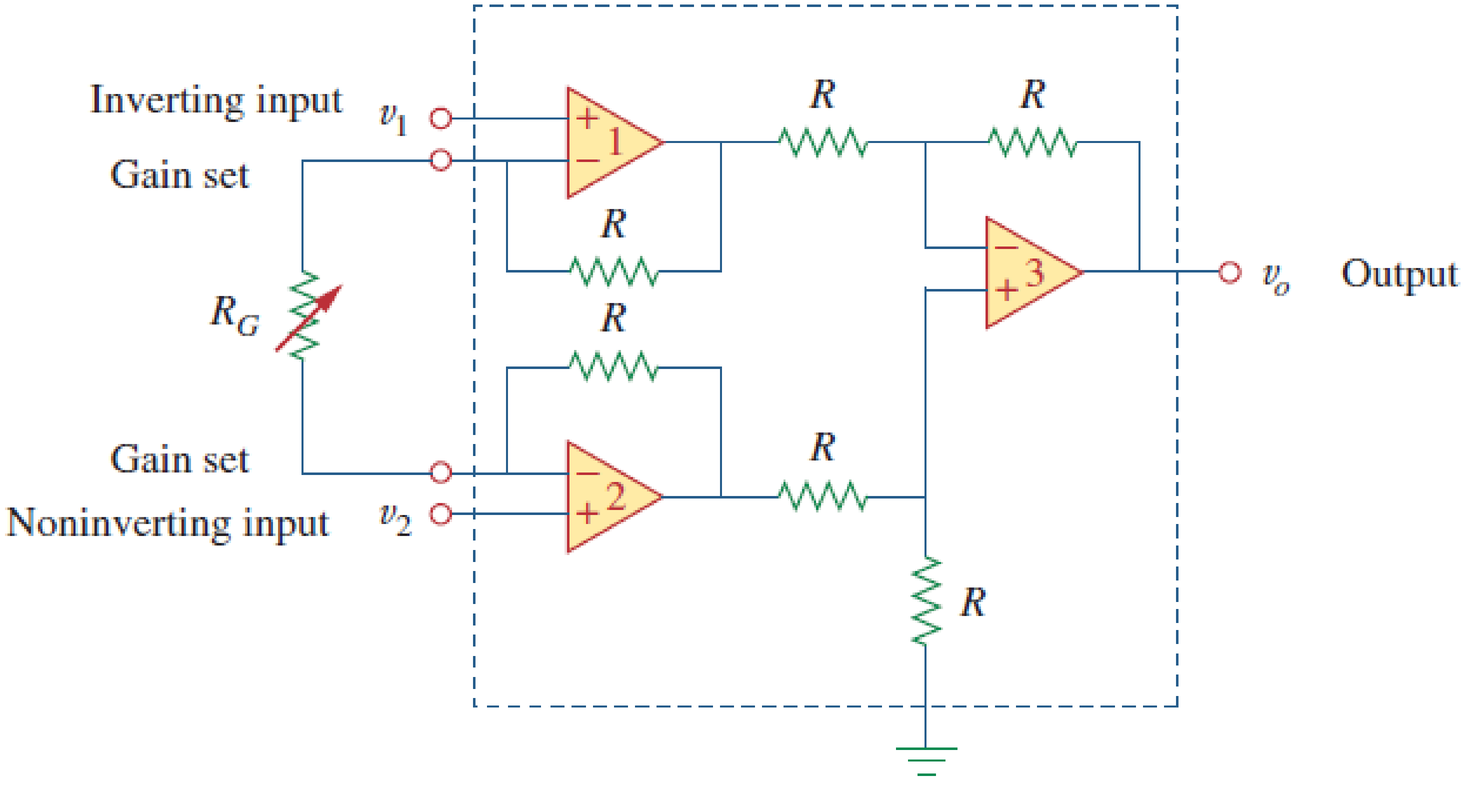
$$v_o = A_v(v_2 - v_1)$$

Instrumentation Amplifier



Instrumentation Amplifier

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

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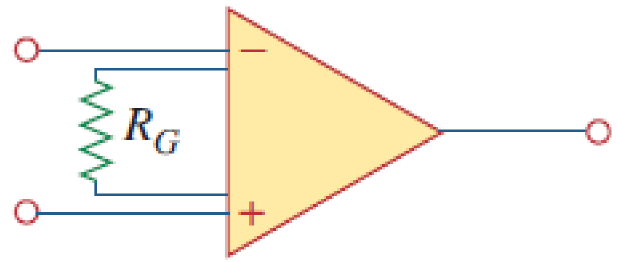

Instrumentation Amplifier

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- Very high input impedance and common mode rejection makes it suitable for measurement applications.

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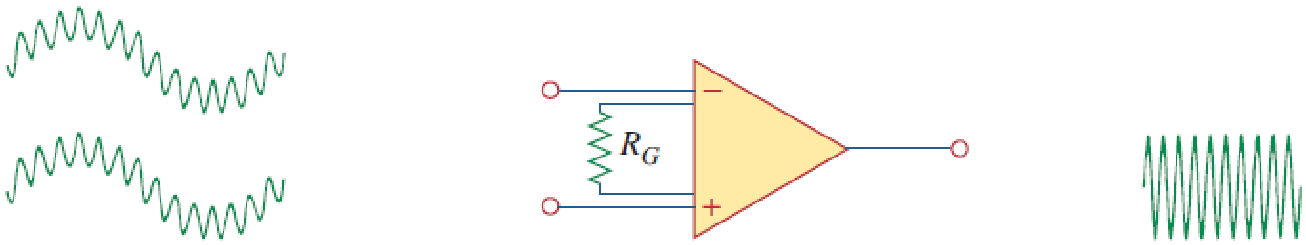
- Very high input impedance and common mode rejection makes it suitable for measurement applications.
- Widely used in instrumentation for measurement of signals.
- Low DC offset, low noise, high open-loop gain, very high CMRR, and high input impedance.

Instrumentation Amplifier

Common Mode Rejection

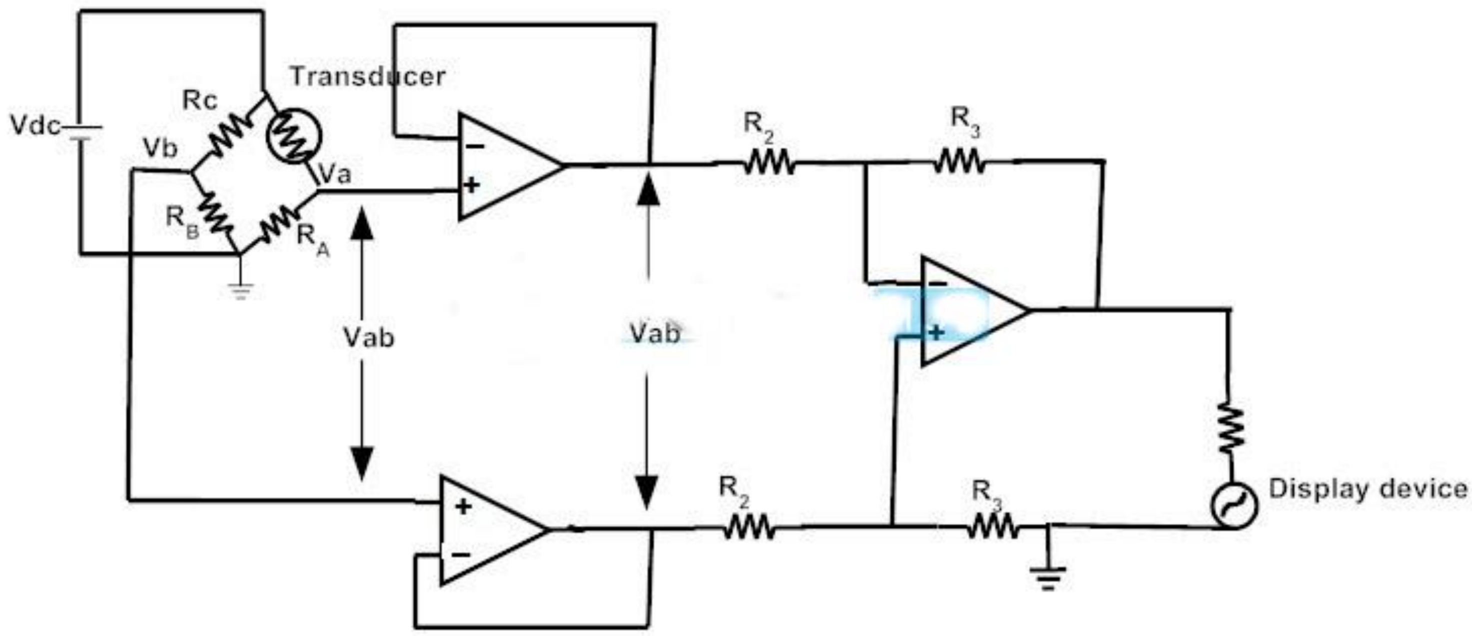


Small differential signals riding on larger common-mode signals

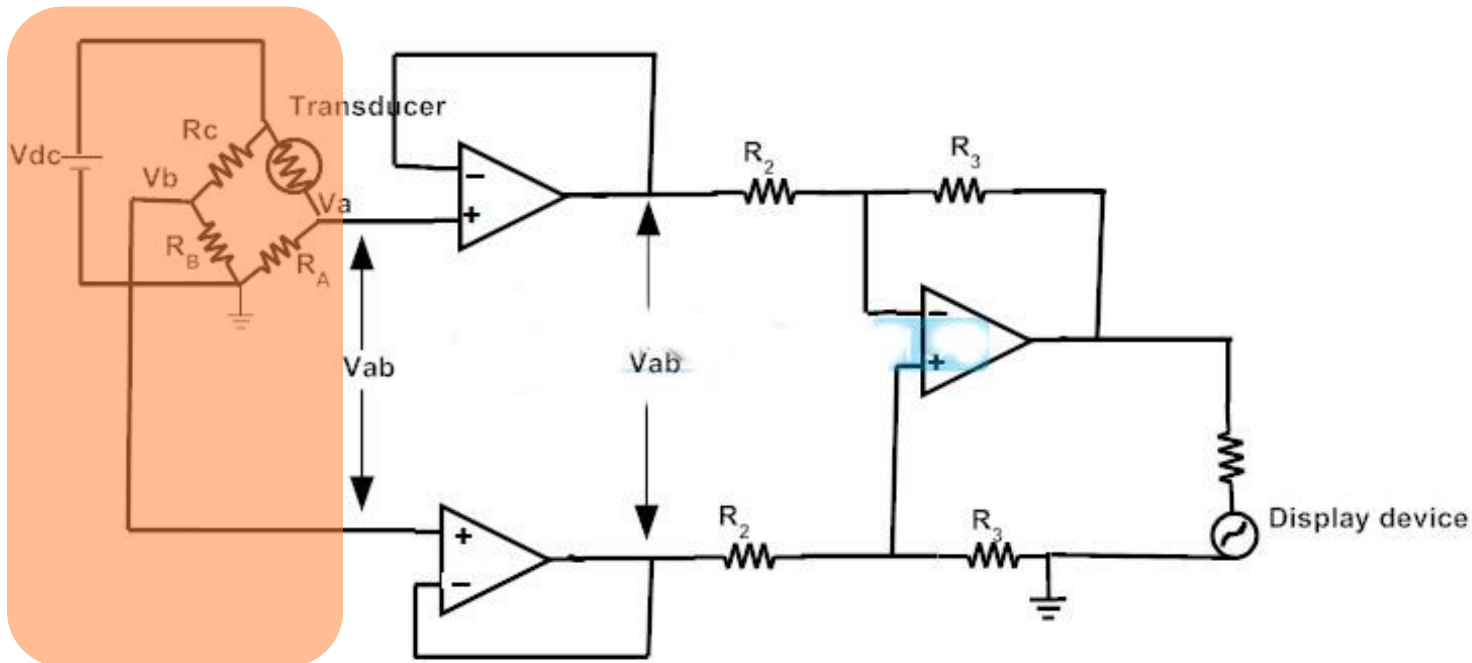
Instrumentation amplifier

Amplified differential signal, no common-mode signal

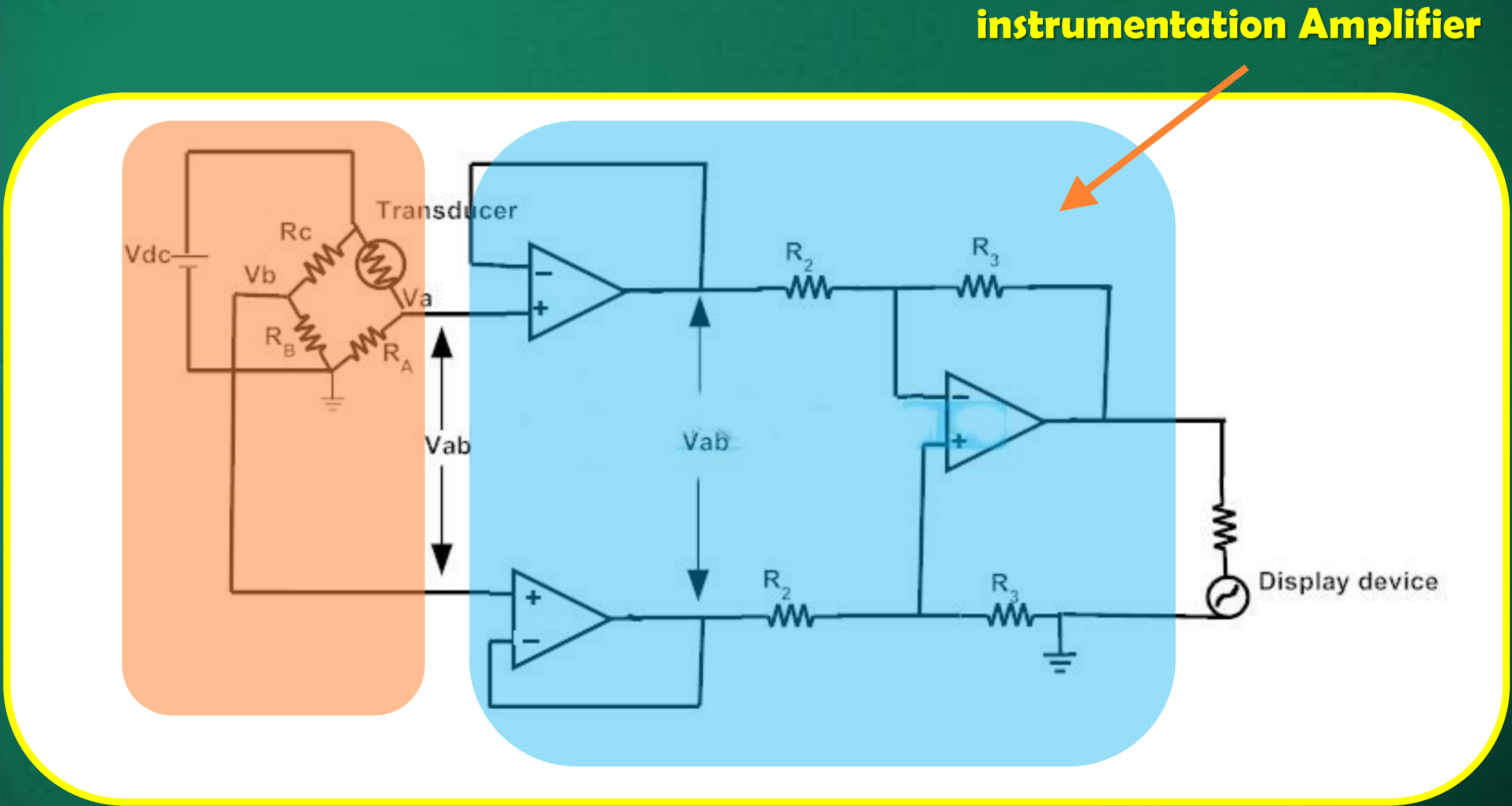
Transducer Bridge Instrumentation Amplifier



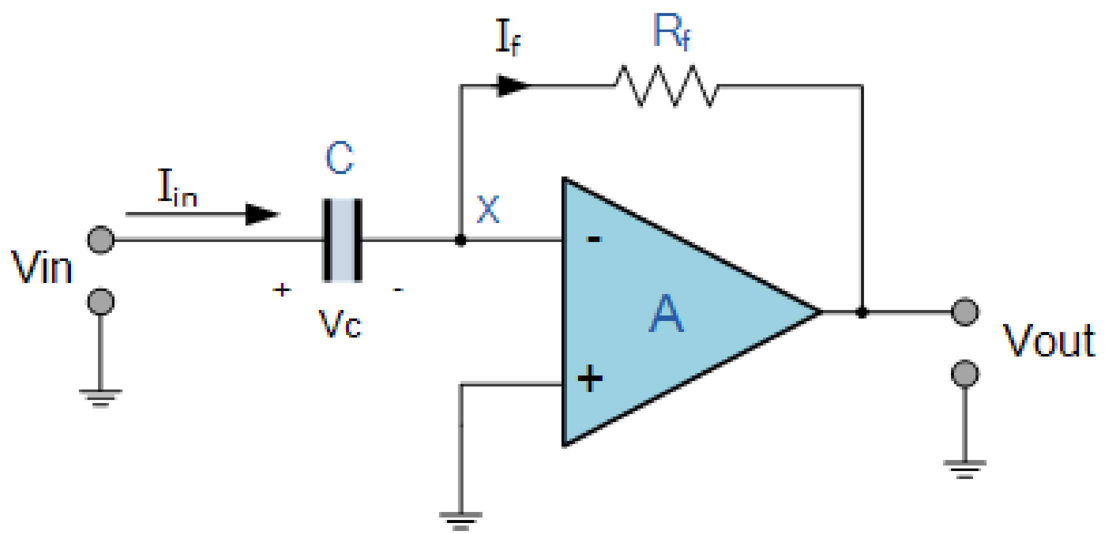
Transducer Bridge Instrumentation Amplifier



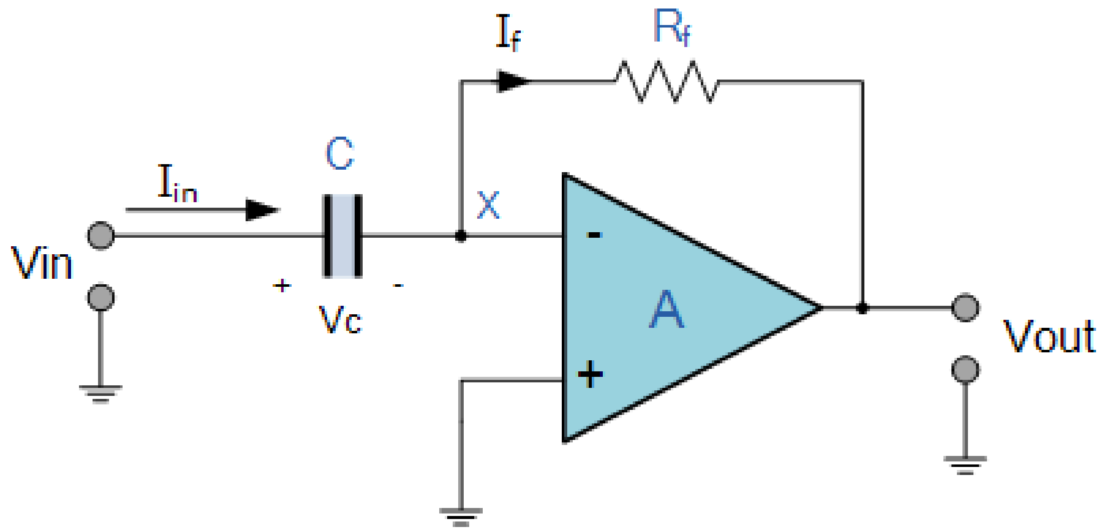
Transducer Bridge Instrumentation Amplifier



Example

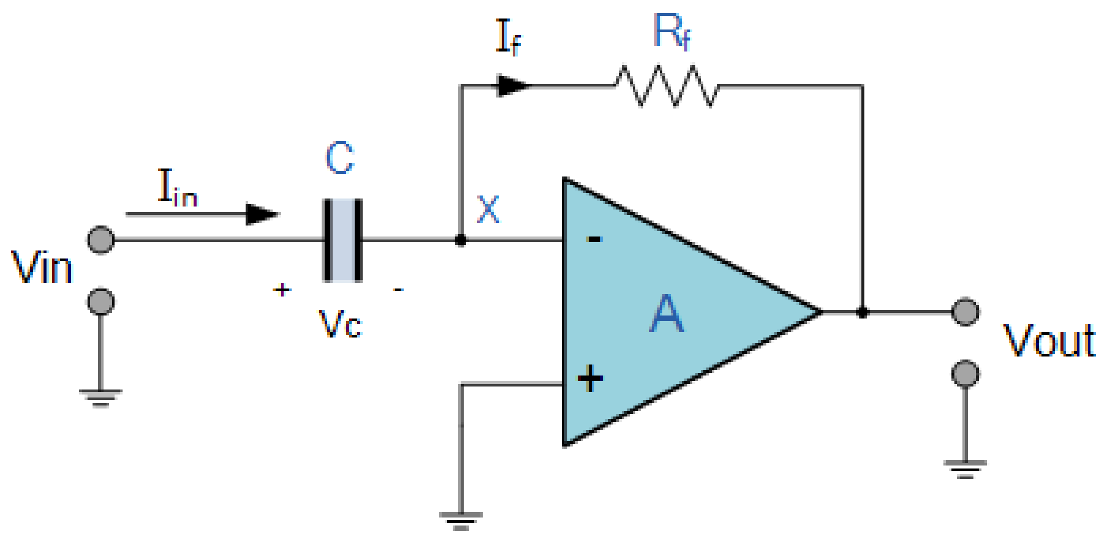


Example (Continued)



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

Example (Continued)



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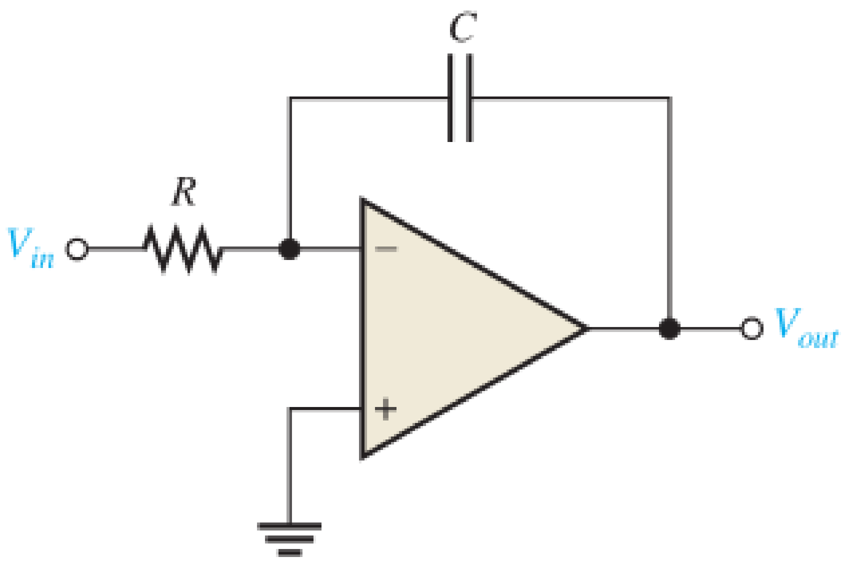
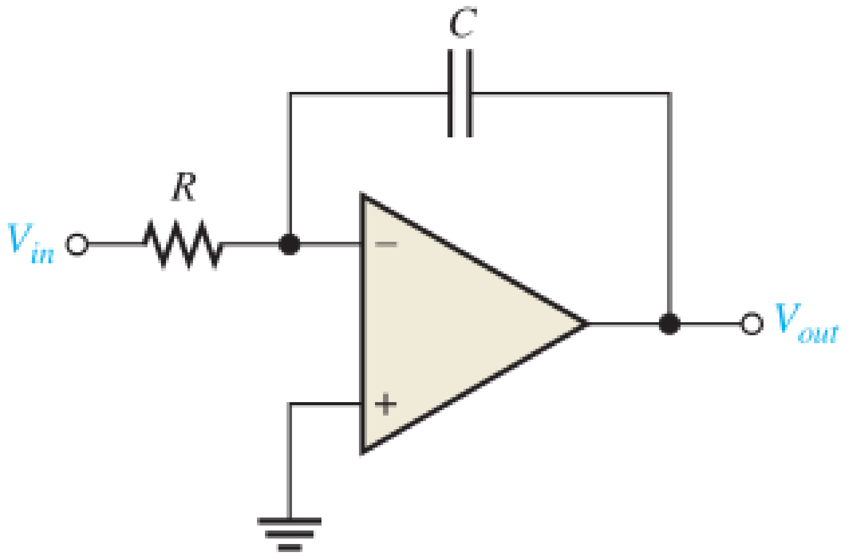
Differentiator

Example

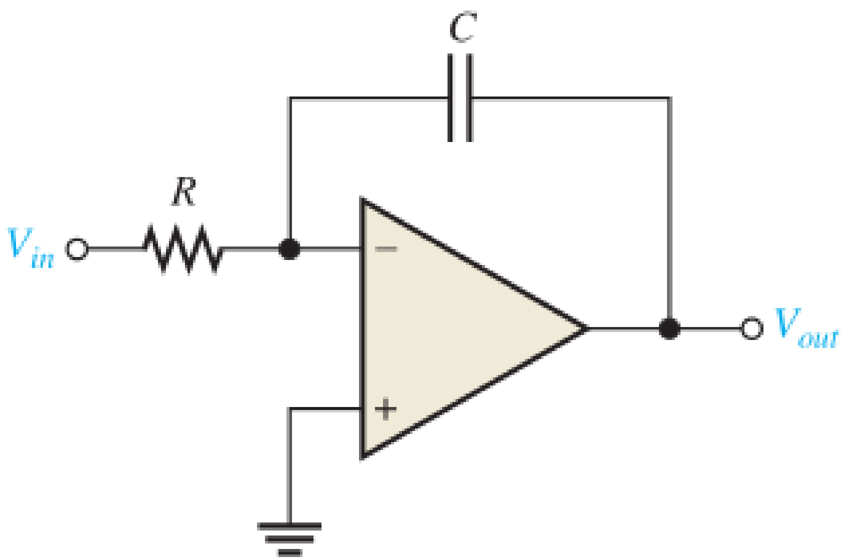


Example (Continued)



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

Example (Continued)



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Integrator