Analog Electronics

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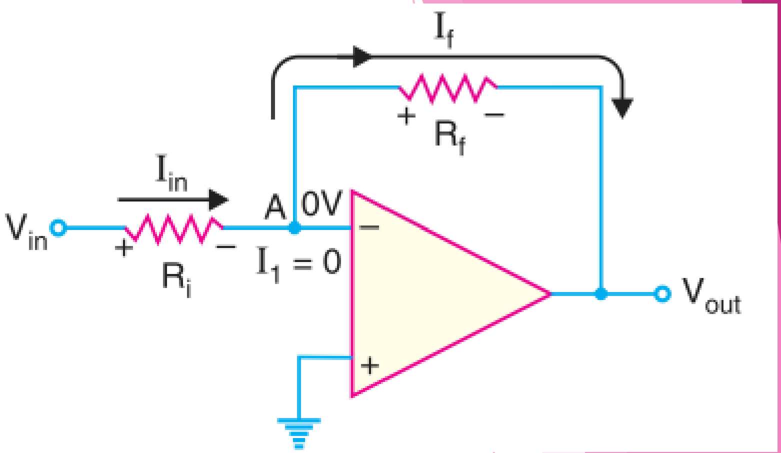
Inverting Amplifier



$$I_{in} = \frac{\text{Voltage across } R_i}{R_i} = \frac{V_{in} - V_A}{R_i} = \frac{V_{in} - 0}{R_i} = \frac{V_{in}}{R_i}$$

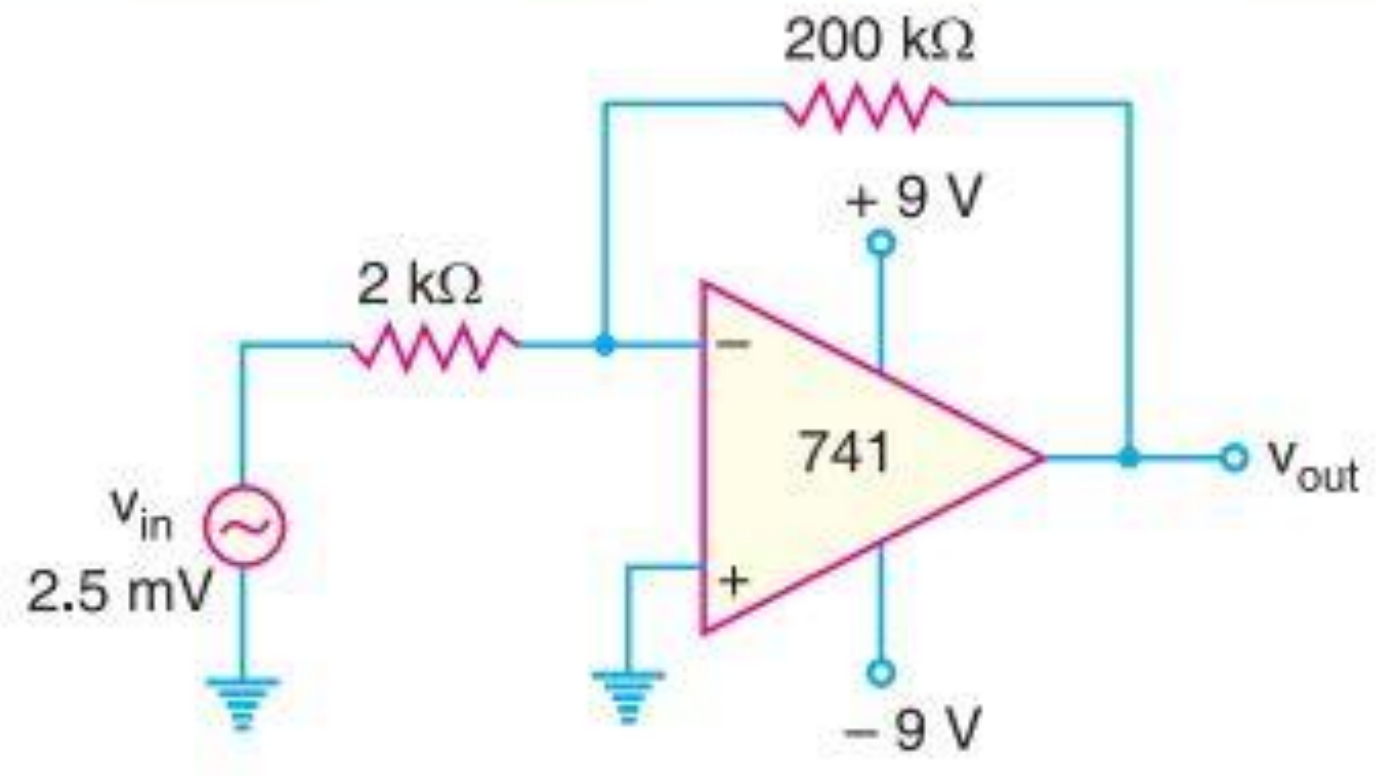
$$I_f = \frac{\text{Voltage across } R_f}{R_f} = \frac{V_A - V_{out}}{R_f} = \frac{0 - V_{out}}{R_f} = \frac{-V_{out}}{R_f}$$

$$\text{Since } I_f = I_{in}, \quad -\frac{V_{out}}{R_f} = \frac{V_{in}}{R_i}$$

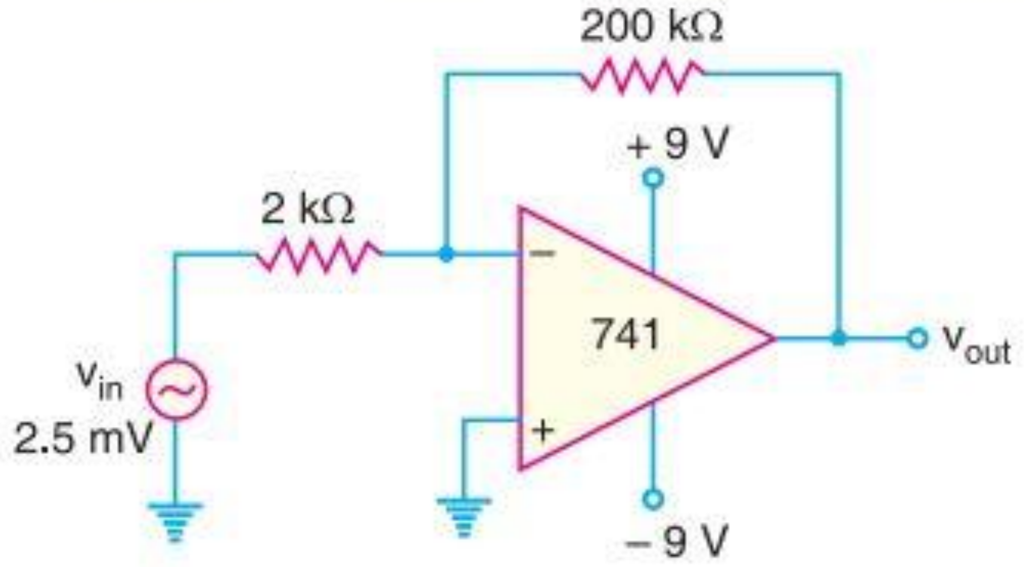
$$\text{Voltage gain, } A_{CL} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

Problem 16.1

Determine the output voltage for the circuit of Fig. 25.50.



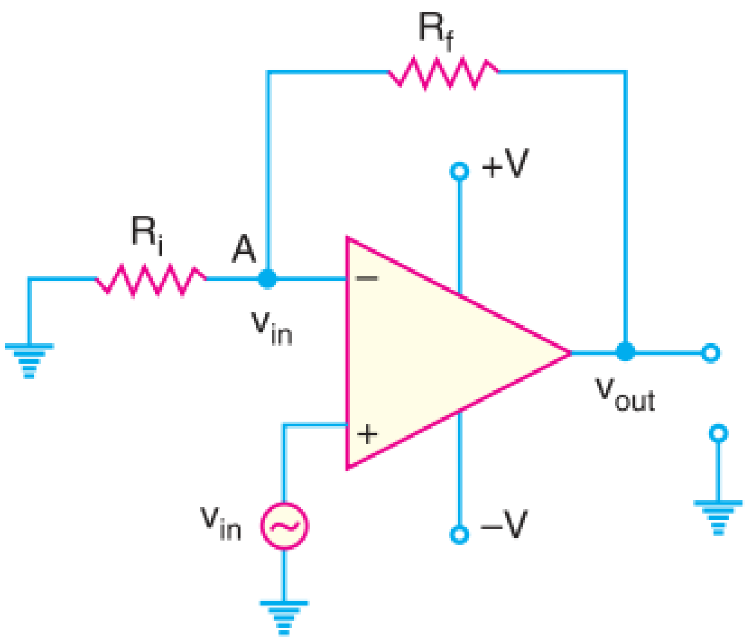
Determine the output voltage for the circuit of Fig. 25.50.



$$A_{CL} = -\frac{R_f}{R_i} = -\frac{200\ \text{k}\Omega}{2\ \text{k}\Omega} = -100$$

Output voltage, $v_{out} = A_{CL} \times v_{in} = (-100) \times (2.5\ \text{mV}) = -250\ \text{mV} = \mathbf{-0.25\ V}$

Non-inverting Amplifier



$$\text{Current through } R_i = \text{Current through } R_f$$

$$\frac{V_{in} - 0}{R_i} = \frac{V_{out} - V_{in}}{R_f}$$

$$V_{in} R_f = V_{out} R_i - V_{in} R_i$$

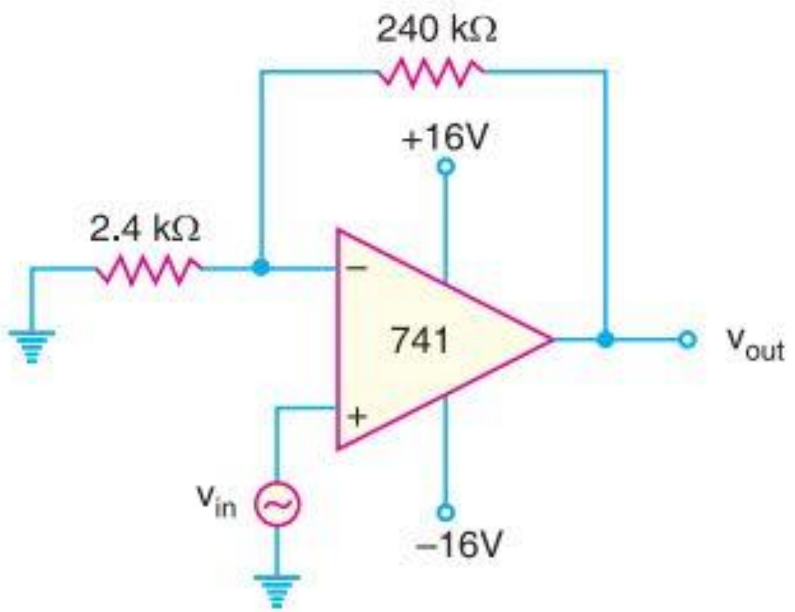
$$V_{in}(R_f + R_i) = V_{out} R_i$$

$$\frac{V_{out}}{V_{in}} = \frac{R_f + R_i}{R_i} = 1 + \frac{R_f}{R_i}$$

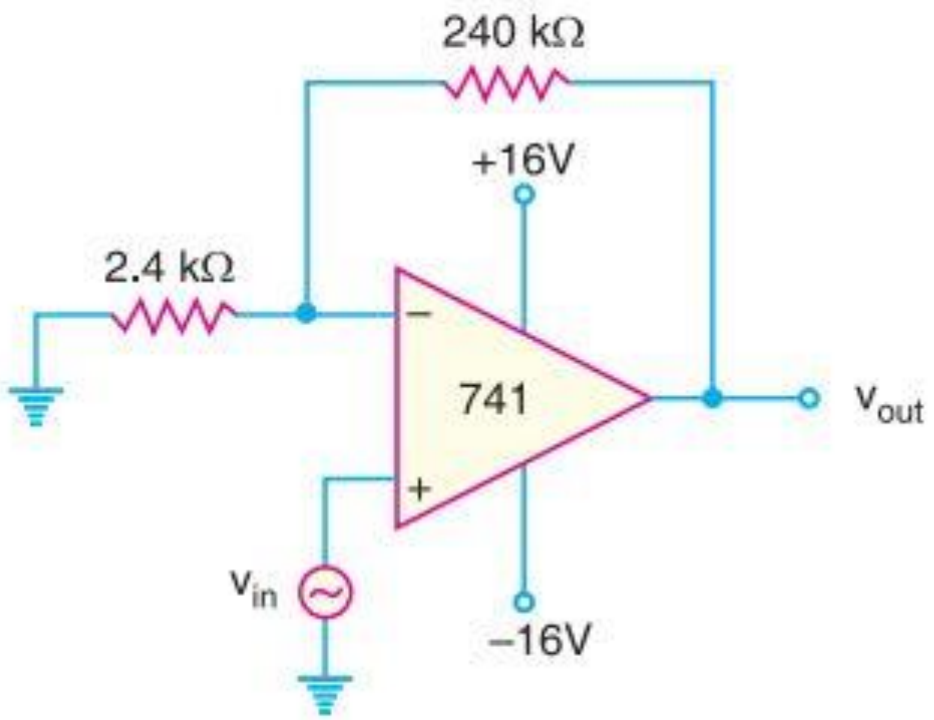
$$\text{Closed-loop voltage gain, } A_{CL} = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_i}$$

Problem 16.2

Example 25.32. *Calculate the output voltage from the noninverting amplifier circuit shown in Fig. 25.57 for an input of 120 μV.*



Example 25.32. *Calculate the output voltage from the noninverting amplifier circuit shown in Fig. 25.57 for an input of 120 μV.*

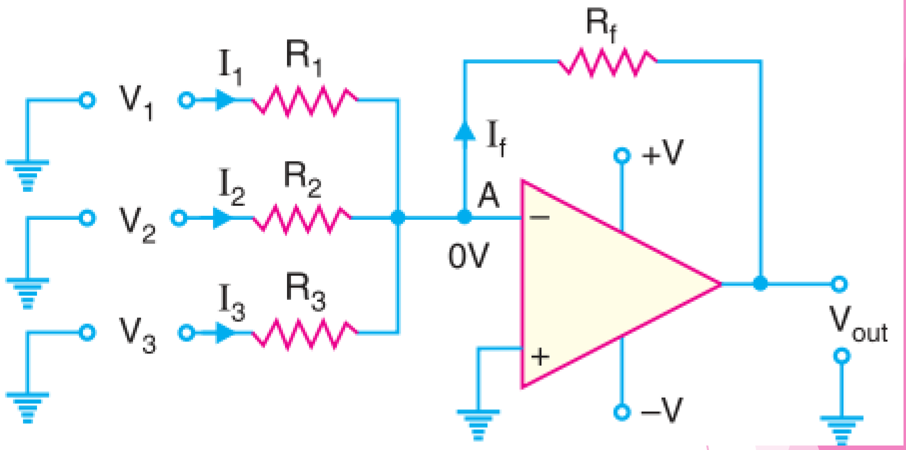


$$\text{Voltage gain, } A_{CL} = 1 + \frac{R_f}{R_i} = 1 + \frac{240\ \text{k}\Omega}{2.4\ \text{k}\Omega} = 1 + 100 = 101$$

$$\text{Output voltage, } v_{out} = A_{CL} \times v_{in} = (101) \times (120\ \mu\text{V}) = \mathbf{12.12\ mV}$$

Summing Amplifier

$$I_f = I_1 + I_2 + I_3$$



$$\text{Output voltage, } V_{out} = -I_f R_f = -R_f(I_1 + I_2 + I_3)$$

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

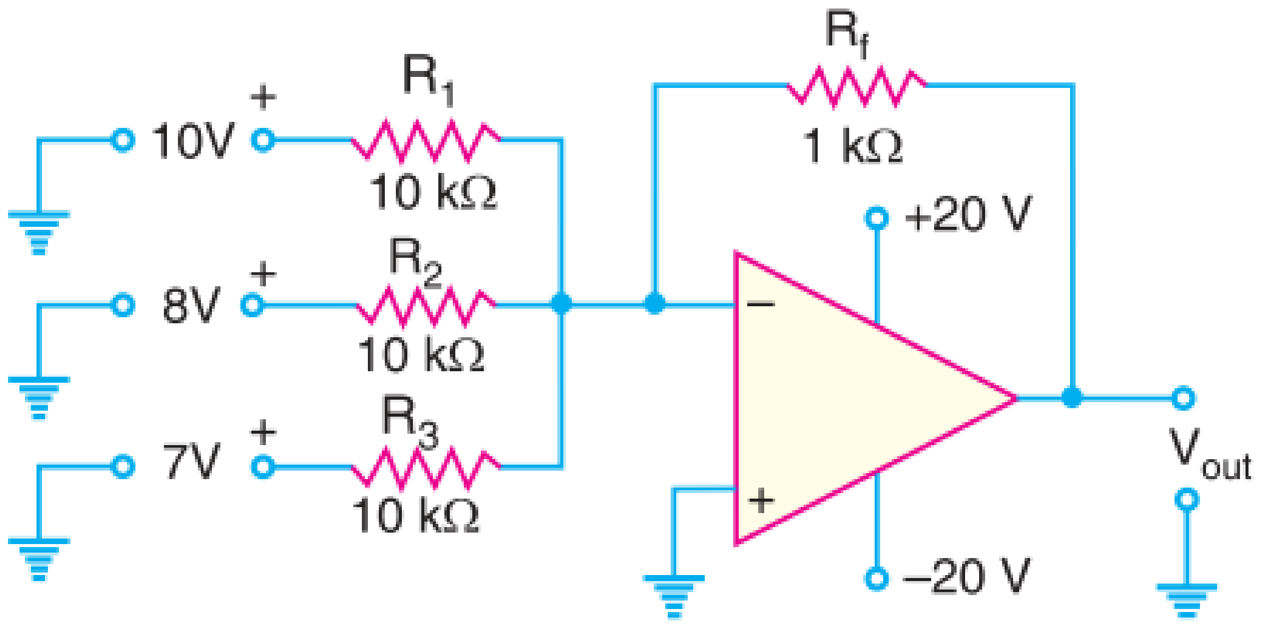
$$\therefore \quad V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

If $R_1 = R_2 = R_3 = R$, then, we have,

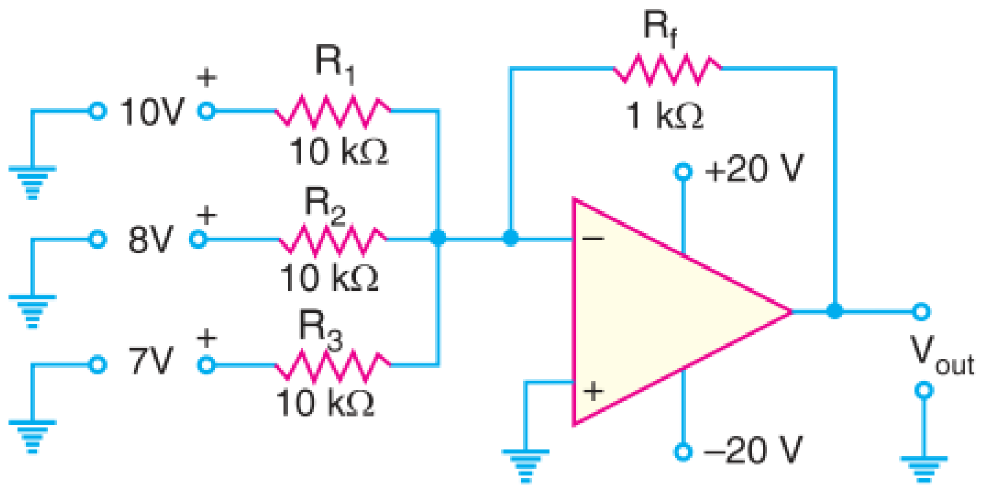
$$V_{out} = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

Problem 16.3

Determine the output voltage for the summing amplifier shown



Determine the output voltage for the summing amplifier shown

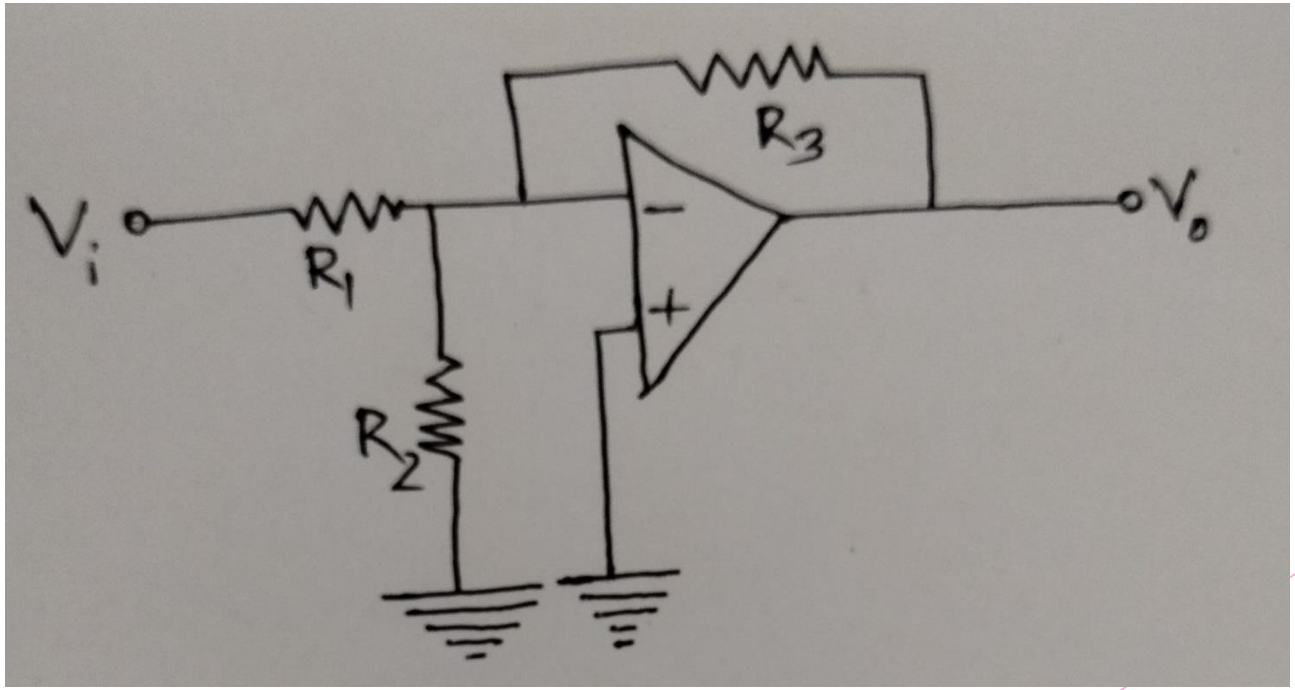


Solution. $R_f = 1\ k\Omega$ and $R_1 = R_2 = R_3 = R = 10\ k\Omega$. Therefore, gain of the amplifier $= -R_f/R = -1\ k\Omega/10\ k\Omega = -1/10$.

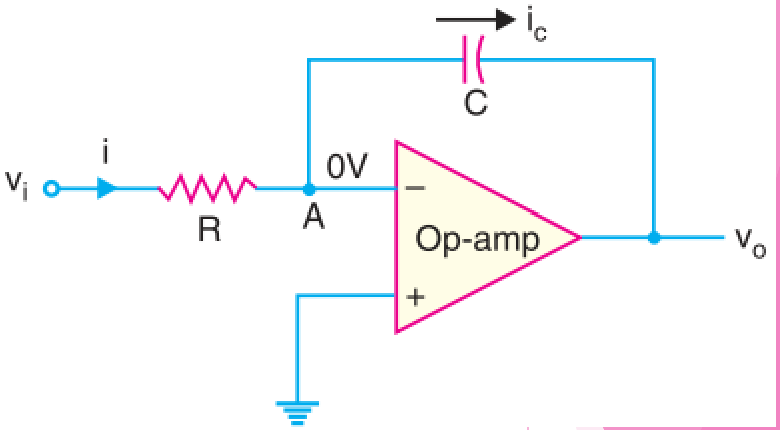
Now
$$V_{out} = -\frac{R_f}{R}(V_1 + V_2 + V_3) = -\frac{1\ k\Omega}{10\ k\Omega}(10 + 8 + 7) = \mathbf{-2.5\ V}$$

Problem 16.4

For the following op amp circuit, find the voltage gain (v_0/v_i) where R_1= 10 KΩ, R_2= 10 KΩ and R_3= 100 KΩ.



OP-Amp Integrator



$i = i_c.$

Now $\quad i = \dfrac{v_i - 0}{R} = \dfrac{v_i}{R}$

Also voltage across capacitor is $v_c = 0 - v_o = -v_o$

$\therefore \quad i_c = \dfrac{C\,dv_c}{dt} = -C\dfrac{dv_o}{dt}$

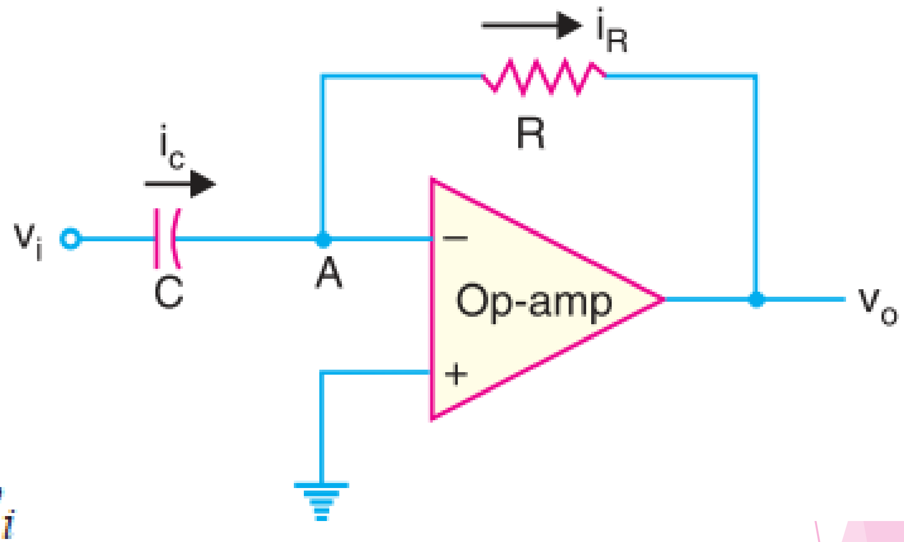
From eqs. (*i*) and (*ii*), $\quad \dfrac{v_i}{R} = -C\dfrac{dv_o}{dt}$

or $\quad \dfrac{dv_o}{dt} = -\dfrac{1}{RC}v_i$

To find the output voltage, we integrate both sides of eq. (*iii*) to get,

$$v_o = -\frac{1}{RC}\int_0^t v_i\,dt$$

OP-Amp Differentiator



$$i_R = \frac{0 - v_o}{R} = -\frac{v_o}{R} \quad \text{and} \quad v_c = v_i - 0 = v_i$$

$$i_c = C\frac{dv_c}{dt} = C\frac{dv_i}{dt}$$

$$-\frac{v_o}{R} = C\frac{dv_i}{dt}$$

$$v_o = -RC\frac{dv_i}{dt}$$