2.6- Cascaded Op Amp:

- A cascade connection is a head-to-tail arrangement of two or more op amp circuits such that the output of one is the input of the next.
- Figure 5.28 displays a block diagram representation of three op amp circuits in cascade.
- The output of one stage is the input to the next stage, the overall gain of the cascade connection is the product of the gains of the individual op amp circuits.

$$A = A_1 A_2 A_3 \qquad (5.22)$$

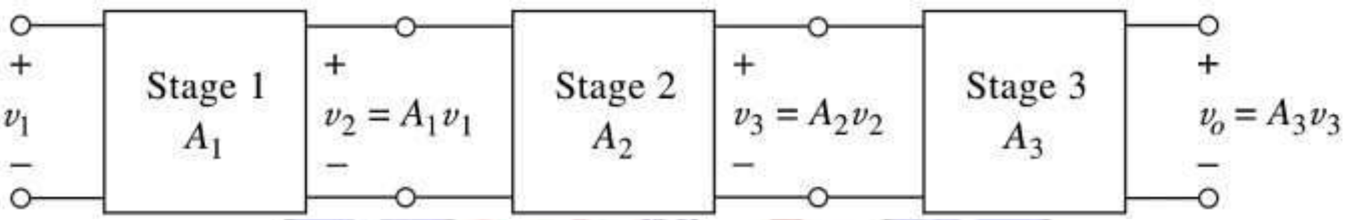

Figure 5.28
A three-stage cascaded connection.

Example 5.9:

Find v_o and i_o in the circuit in Fig. 5.29.

Solution:
This circuit consists of two noninverting amplifiers cascaded. At the output of the first op amp,

$$v_a = \left(1 + \frac{12}{3}\right)(20) = 100 \text{ mV}$$

At the output of the second op amp,

$$v_o = \left(1 + \frac{10}{4}\right)v_a = (1 + 2.5)100 = 350\text{ mV}$$

The required current i_o is the current through the 10-kΩ resistor.

$$i_o = \frac{v_o - v_b}{10}\text{ mA}$$

But $v_b = v_a = 100$ mV. Hence,

$$i_o = \frac{(350 - 100) \times 10^{-3}}{10 \times 10^3} = 25\ \mu\text{A}$$

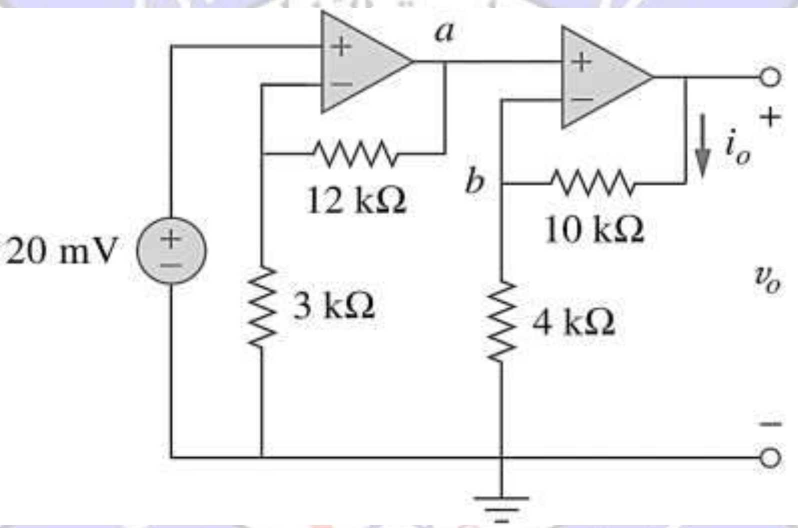

Figure 5.29
For Example 5.9.

2.7- Integrator Op Amp:

- An integrator is an op amp circuit whose output is proportional to the integral of the input signal.
- If the feedback resistor R_f in the familiar inverting amplifier of Fig. 6.35(a) is replaced by a capacitor, we obtain an ideal integrator, as shown in Fig. 6.35(b).

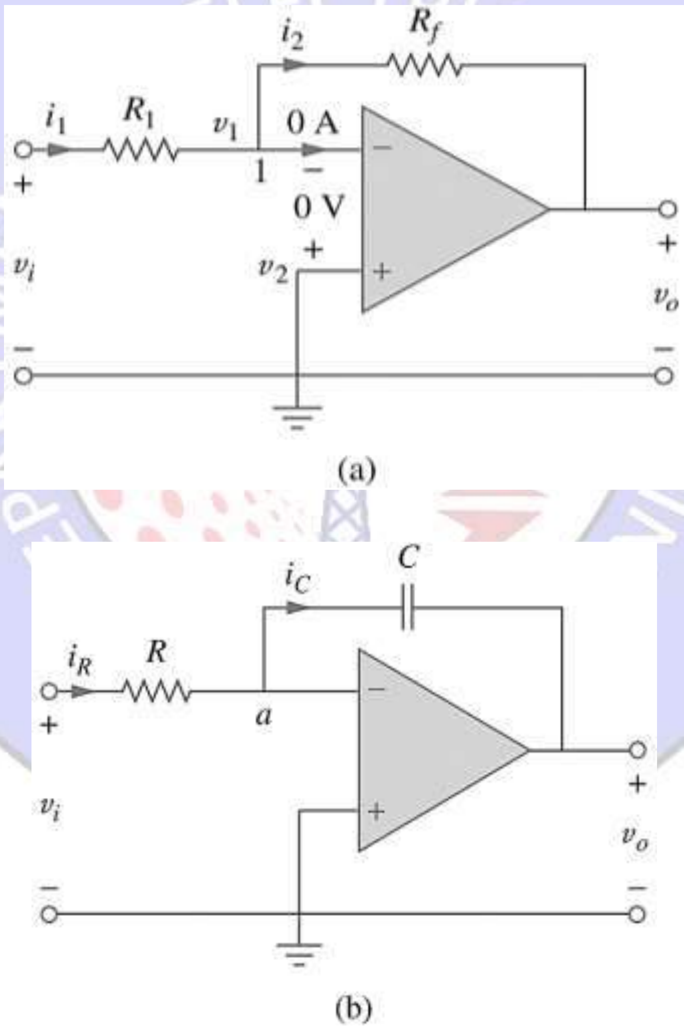

Figure 6.35
Replacing the feedback resistor in the inverting amplifier in (a) produces an integrator in (b).

- We can obtain a mathematical representation of integration. At node a in Fig. 6.35(b),

$$i_R = i_C \quad (6.32)$$

But

$$i_R = \frac{v_i}{R}, \qquad i_C = -C\frac{dv_o}{dt}$$

Substituting these in Eq. (6.32), we obtain

$$\frac{v_i}{R} = -C\frac{dv_o}{dt} \quad (6.33a)$$

$$dv_o = -\frac{1}{RC}v_i\,dt \quad (6.33b)$$

Integrating both sides gives

$$v_o(t) - v_o(0) = -\frac{1}{RC}\int_0^t v_i(\tau)d\tau \quad (6.34)$$

To ensure that $v_o(0) = 0$, it is always necessary to discharge the integrator's capacitor prior to the application of a signal.

$$\boxed{v_o = -\frac{1}{RC}\int_0^t v_i(\tau)d\tau} \quad (6.35)$$

- Assuming $v_o(0) = 0$ which shows that the circuit in Fig. 6.35(b) provides an output voltage proportional to the integral of the input.
- In practice, the op amp integrator requires a feedback resistor to reduce dc gain and prevent saturation.

Example 6.13:

If $v_1 = 10\cos 2t$ mV and $v_2 = 0.5t$ mV, find v_o in the op amp circuit in Fig. 6.36. Assume that the voltage across the capacitor is initially zero.

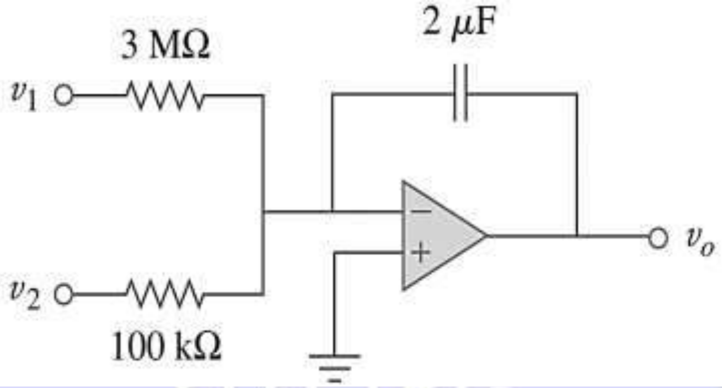

Figure 6.36
For Example 6.13.

Solution:

This is a summing integrator, and

$$v_o = -\frac{1}{R_1C}\int v_1\,dt - \frac{1}{R_2C}\int v_2\,dt$$

$$= -\frac{1}{3\times 10^6 \times 2\times 10^{-6}}\int_0^t 10\cos(2\tau)d\tau$$

$$-\frac{1}{100\times 10^3 \times 2\times 10^{-6}}\int_0^t 0.5\tau\,d\tau$$

$$= -\frac{1}{6}\frac{10}{2}\sin 2t - \frac{1}{0.2}\frac{0.5t^2}{2} = -0.833\sin 2t - 1.25t^2 \text{ mV}$$

2.8- Differentiator Op Amp:

- A differentiator is an op amp circuit whose output is proportional to the rate of change of the input signal.
- In Fig. 6.35(a), if the input resistor is replaced by a capacitor, the resulting circuit is a differentiator, shown in Fig. 6.37.

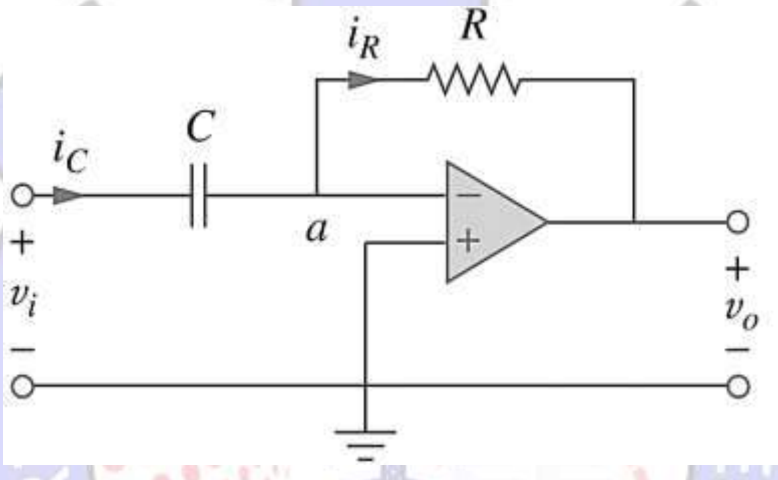

Figure 6.37
An op amp differentiator.

Applying KCL at node a,

$$i_R = i_C \qquad (6.36)$$

But

$$i_R = -\frac{v_o}{R}, \qquad i_C = C\frac{dv_i}{dt}$$

Substituting these in Eq. (6.36) yields

$$v_o = -RC\frac{dv_i}{dt} \qquad (6.37)$$

- Above equation shows that the output is the derivative of the input.