Electronics Circuits

CTE 204

Lecture 9

- OP-AMP CIRCUITS II -

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Summing Amplifier

- Besides amplification, the op amp can perform addition and subtraction.

- The addition is performed by the summing amplifier covered in this section; the subtraction is performed by the difference amplifier covered in the next section.

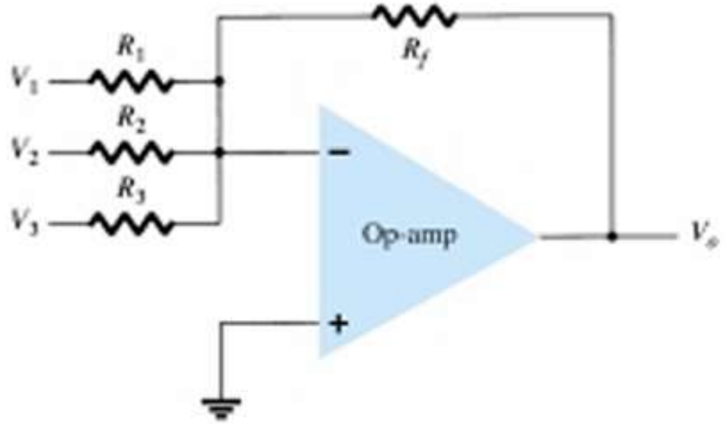
- A summing amplifier is an op amp circuit that combines several inputs and produces an output that is the weighted sum of the inputs.

Summing Amplifier

- The summing amplifier, shown in Figure below, is a variation of the inverting amplifier.

- It takes advantage of the fact that the inverting configuration can handle many inputs at the same time.

- We keep in mind that the current entering each op amp input is zero.



Summing Amplifier

Applying KCL at node a gives

$$i = i_1 + i_2 + i_3$$

But

$$i_1 = \frac{v_1 - v_a}{R_1}, \quad i_2 = \frac{v_2 - v_a}{R_2}$$

$$i_3 = \frac{v_3 - v_a}{R_3}, \quad i = \frac{v_a - v_o}{R_f}$$

$$v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} v_3\right)$$

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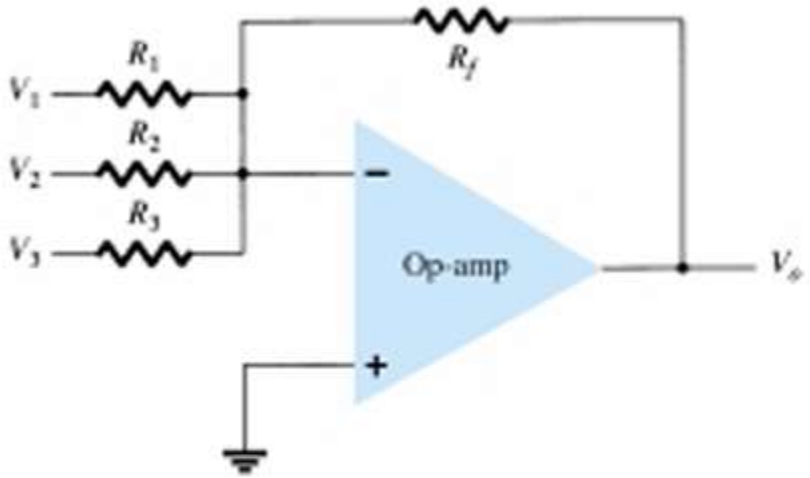
Example

Calculate the output voltage of an op-amp summing amplifier for the following sets of voltages and resistors. Use $R_f = 1\ \text{M}\Omega$ in all cases.

(a) $V_1 = +1\ \text{V}$, $V_2 = +2\ \text{V}$, $V_3 = +3\ \text{V}$, $R_1 = 500\ \text{k}\Omega$, $R_2 = 1\ \text{M}\Omega$, $R_3 = 1\ \text{M}\Omega$.

(b) $V_1 = -2\ \text{V}$, $V_2 = +3\ \text{V}$, $V_3 = +1\ \text{V}$, $R_1 = 200\ \text{k}\Omega$, $R_2 = 500\ \text{k}\Omega$, $R_3 = 1\ \text{M}\Omega$.



Solution:

$$(a)\quad V_o = -\left[\frac{1000\ \text{k}\Omega}{500\ \text{k}\Omega}(+1\ \text{V}) + \frac{1000\ \text{k}\Omega}{1000\ \text{k}\Omega}(+2\ \text{V}) + \frac{1000\ \text{k}\Omega}{1000\ \text{k}\Omega}(+3\ \text{V})\right]$$

$$= -[2(1\ \text{V}) + 1(2\ \text{V}) + 1(3\ \text{V})] = \mathbf{-7\ V}$$

$$(b)\quad V_o = -\left[\frac{1000\ \text{k}\Omega}{200\ \text{k}\Omega}(-2\ \text{V}) + \frac{1000\ \text{k}\Omega}{500\ \text{k}\Omega}(+3\ \text{V}) + \frac{1000\ \text{k}\Omega}{1000\ \text{k}\Omega}(+1\ \text{V})\right]$$

$$= -[5(-2\ \text{V}) + 2(3\ \text{V}) + 1(1\ \text{V})] = \mathbf{+3\ V}$$

Differentiator

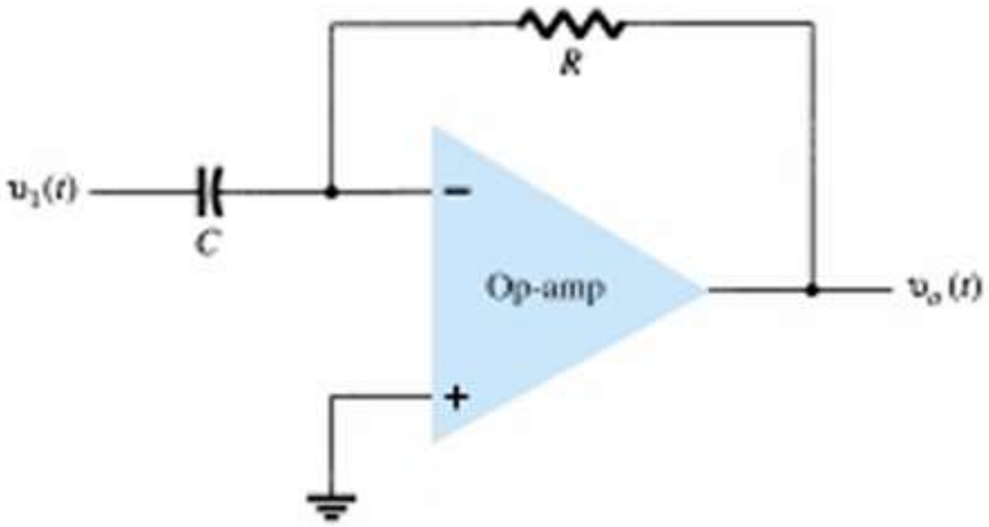
- A differentiator circuit is shown in Figure below.

- While not as useful as the circuit forms covered above, the differentiator does provide a useful operation, the resulting relation for the circuit being

$$v_o(t) = -RC \frac{dv_1(t)}{dt}$$

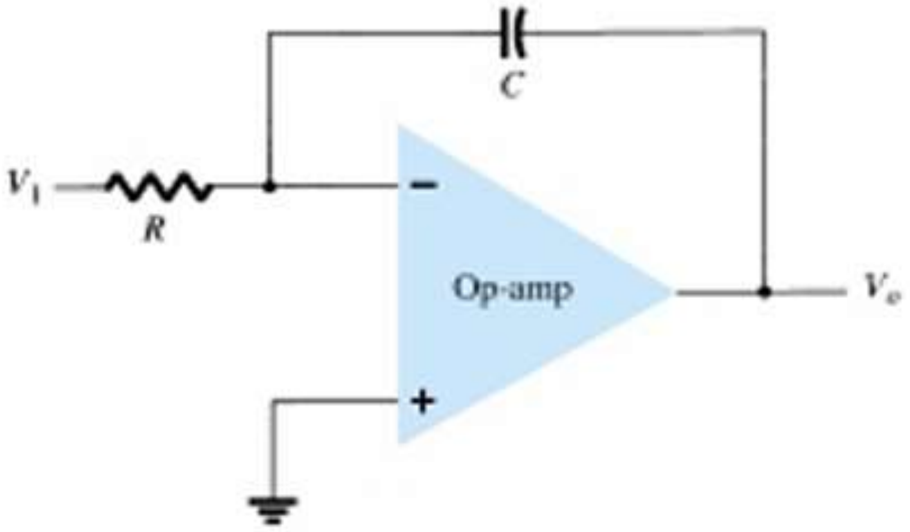
Differentiator

where the scale factor is $-RC$.



Integrator

- So far, the input and feedback components have been resistors.
- If the feedback component used is a capacitor, as shown in Figure below, the resulting connection is called an integrator.



Integrator

The capacitive impedance can be expressed as

$$X_C = \frac{1}{j\omega C} = \frac{1}{sC}$$

$$I = \frac{V_1}{R} = -\frac{V_o}{X_C} = \frac{-V_o}{1/sC} = -sCV_o$$

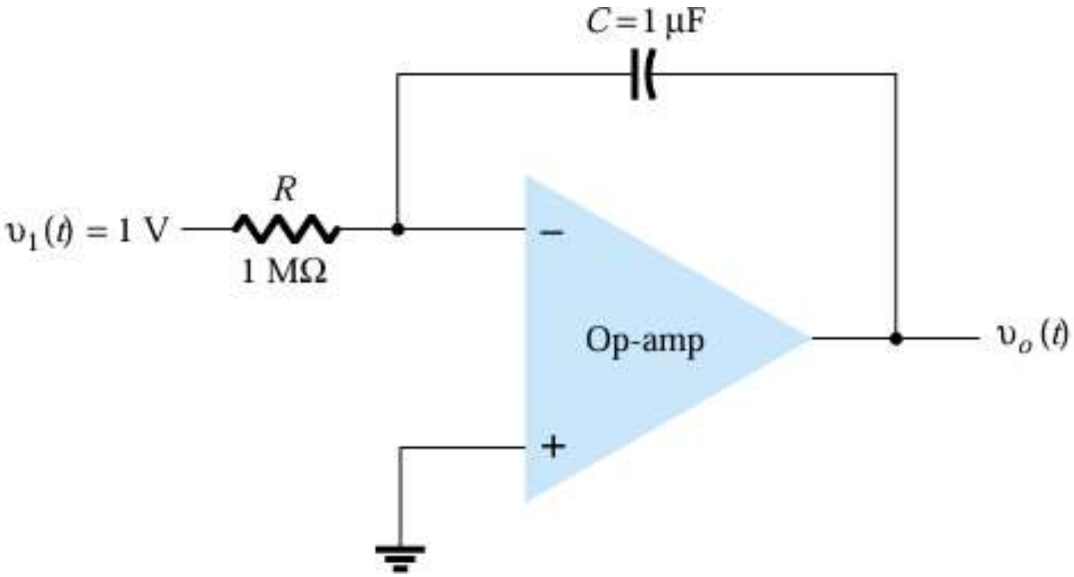
$$\frac{V_o}{V_1} = \frac{-1}{sCR}$$

The expression above can be rewritten in the time domain as

$$v_o(t) = -\frac{1}{RC}\int v_1(t)\ dt$$

Integrator

Example: consider an input voltage, V1 = 1 V, to the integrator circuit of Figure below.



Solution :

The scale factor of 1/RC is

$$-\frac{1}{RC} = \frac{1}{(1\ \text{M}\Omega)(1\ \mu\text{F})} = -1$$

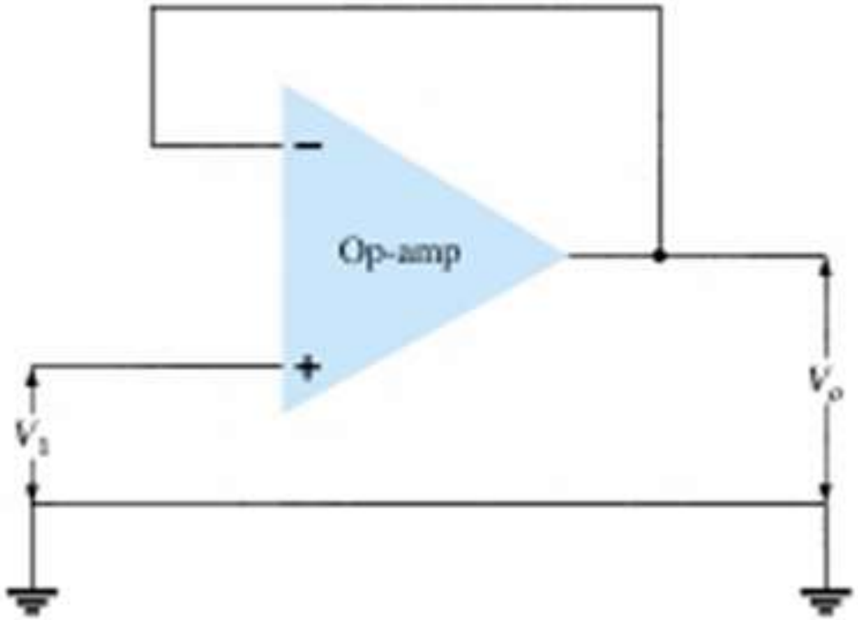
So that the output is a negative ramp voltage as shown in Figure below.

If the scale factor is changed by making R = 100 k, for example

$$-\frac{1}{RC} = \frac{1}{(100\ \text{k}\Omega)(1\ \mu\text{F})} = -10$$

Unity Follower

- The unity-follower circuit, as shown in Figure below, provides a gain of unity (1) with no polarity or phase reversal.



Unity Follower

- From the equivalent circuit that is shown in Figure below, it is clear that

- The output is the same polarity and magnitude as the input.

- The circuit operates like an emitter- or source-follower circuit except that the gain is exactly unity.