CSE 251
Electronic Devices and Circuits

Lecture 5

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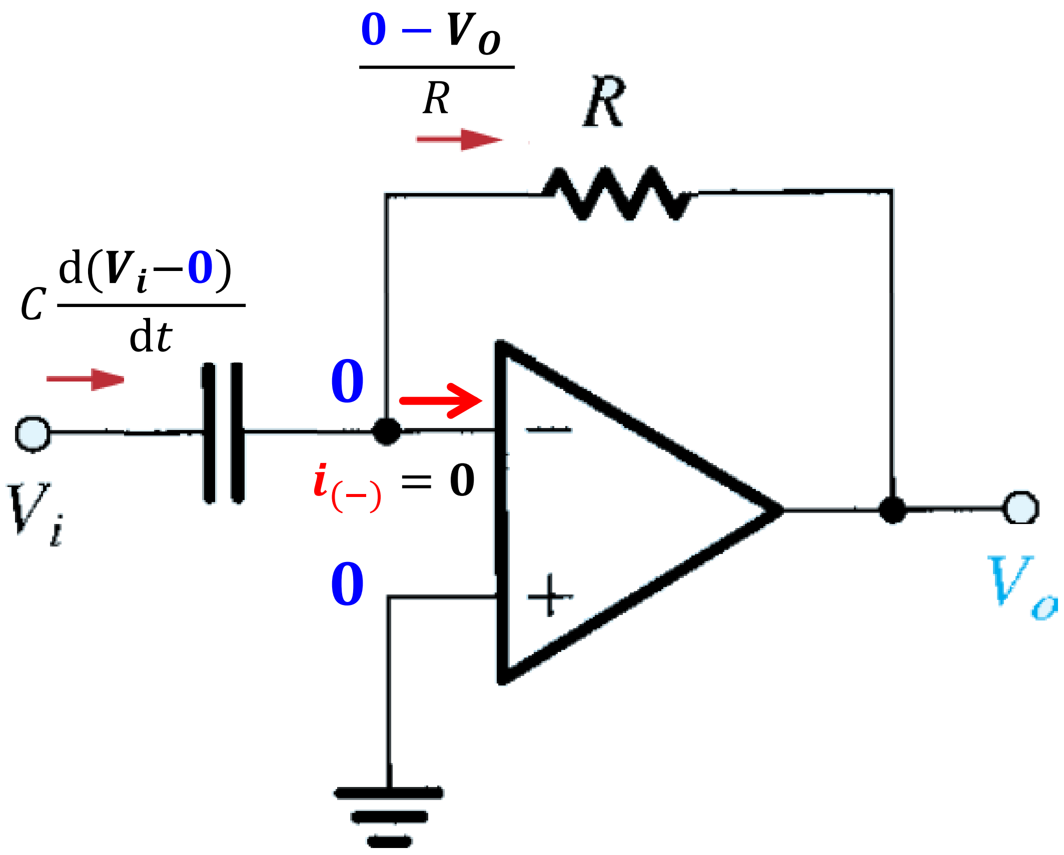
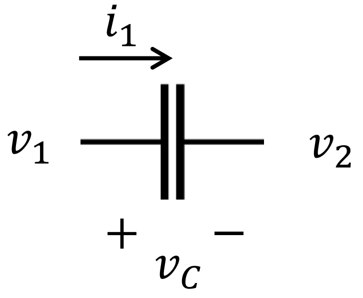
Op Amp as Inverting Differentiator

Since ideal op-amp, $i_- = i_+ = 0$, so $i_1 = i_2$



Review – Capacitor



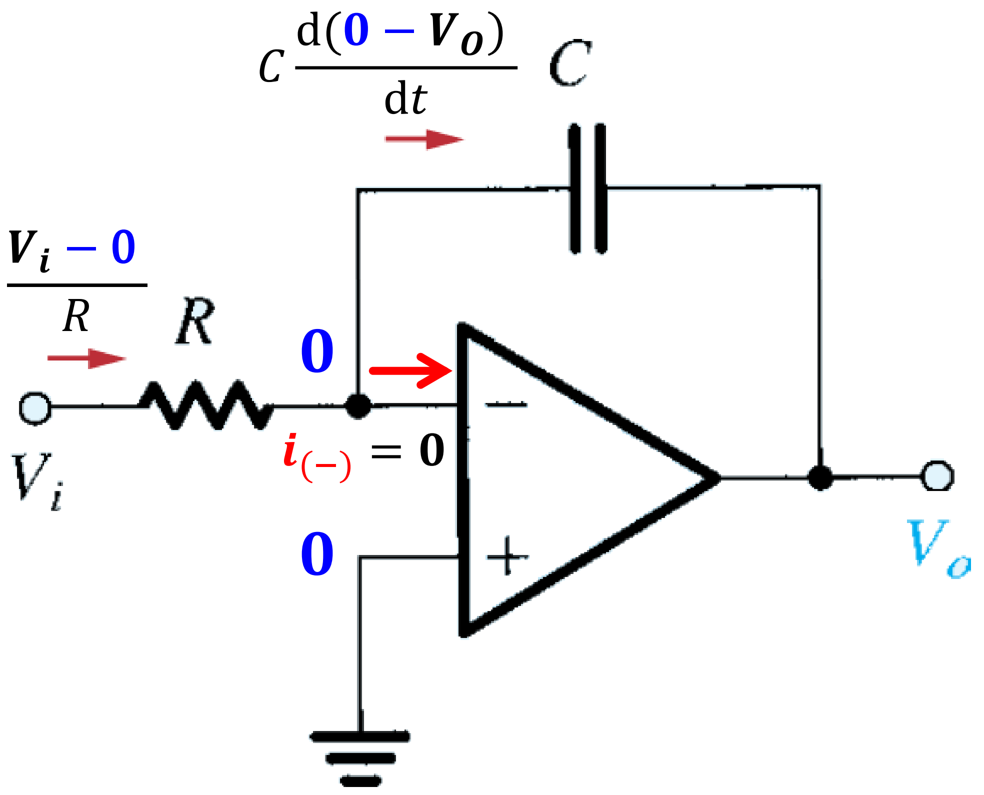
$$i_1 = C\frac{dv_C}{dt} = C\frac{d(v_1 - v_2)}{dt}$$

$$\Rightarrow -\frac{V_o}{R} = C\frac{dV_i}{dt}$$

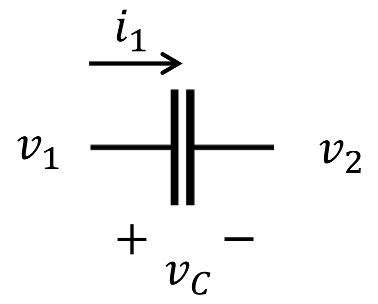
$$\boxed{\Rightarrow V_O = -RC\frac{dv_i}{dt}}$$

Op Amp as Inverting Integrator

Since ideal op-amp, $\boldsymbol{i_- = i_+ = 0}$, so $\boldsymbol{i_1 = i_2}$



Review – Capacitor



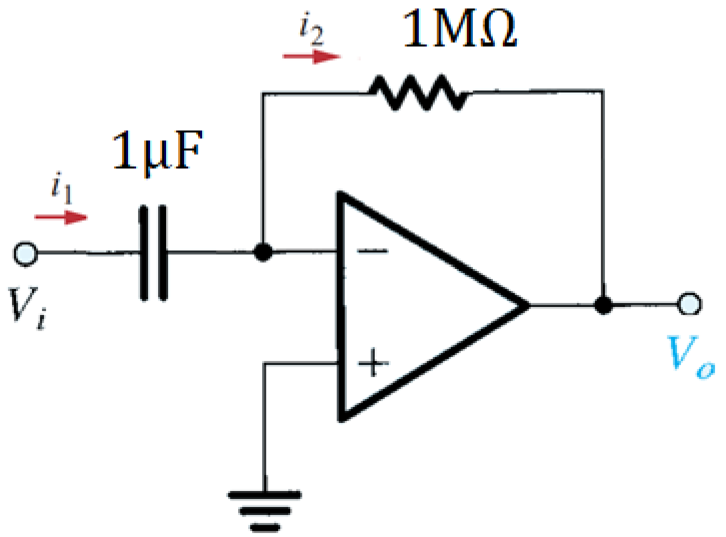
$$i_1 = \mathrm{C}\frac{dv_C}{dt} = C\frac{d(v_1 - v_2)}{dt}$$

$$\Rightarrow \frac{\boldsymbol{V_i}}{R} = -C\frac{\mathrm{d}\boldsymbol{V_O}}{\mathrm{d}t}$$

$$\boxed{\Rightarrow \boldsymbol{V_O} = -\frac{1}{RC}\int \boldsymbol{V_i}(t)\mathrm{d}t}$$

Example 10

Observe the following Figure. If $V_i = 5 \cdot \sin(6t)$, Find the value of $\boldsymbol{V_0}$



Solution:

This is a **differentiator**.

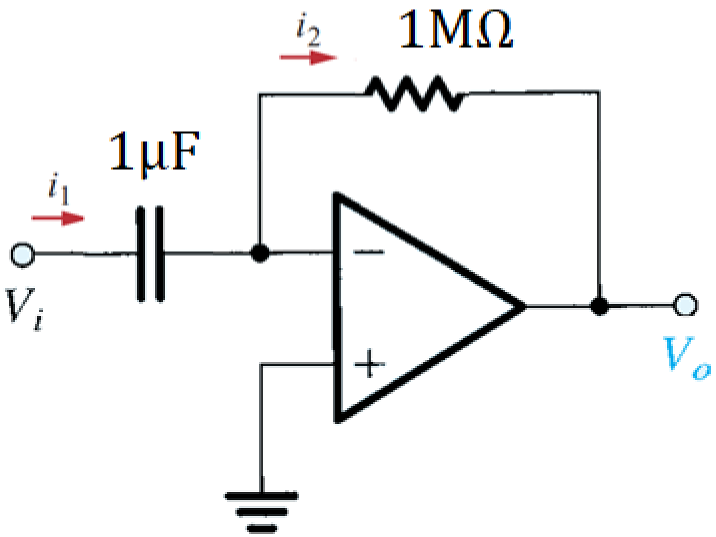
$$v_o = -RC\frac{\mathbf{d}V_i}{\mathbf{d}t}$$

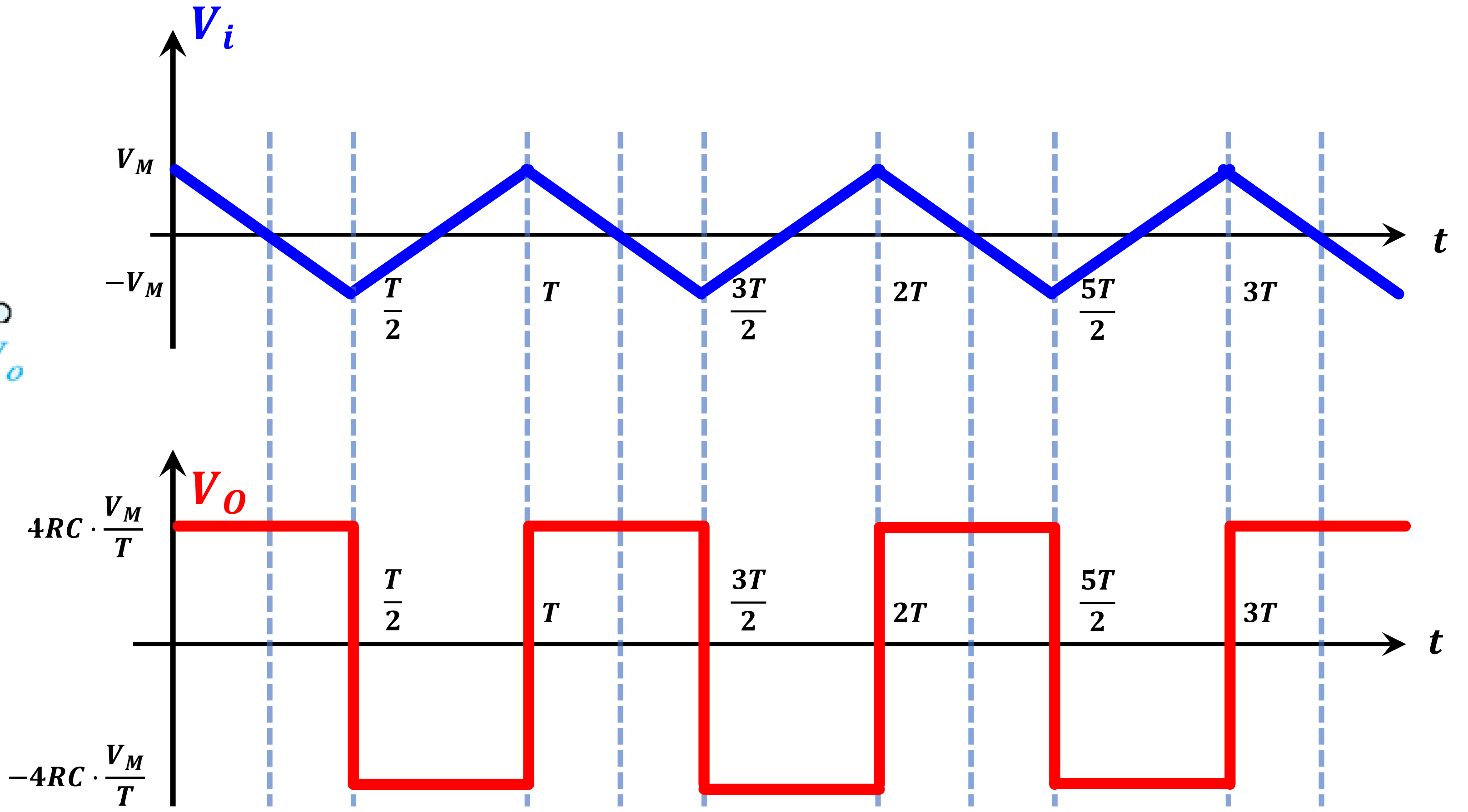
$$= -(1 \times 10^6) \cdot (1 \times 10^{-6}) \times \frac{\mathbf{d}(5 \cdot \sin(6t))}{\mathbf{d}t}$$

$$= -1 \times (5 \times 6\cos(6t))$$

$$= \boldsymbol{-30\cos(6t)}$$

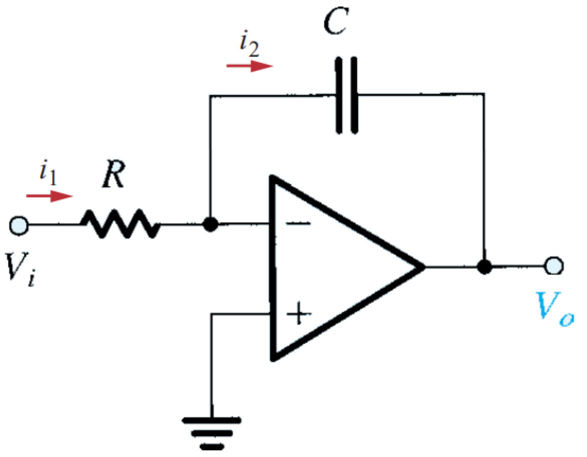
Example 11

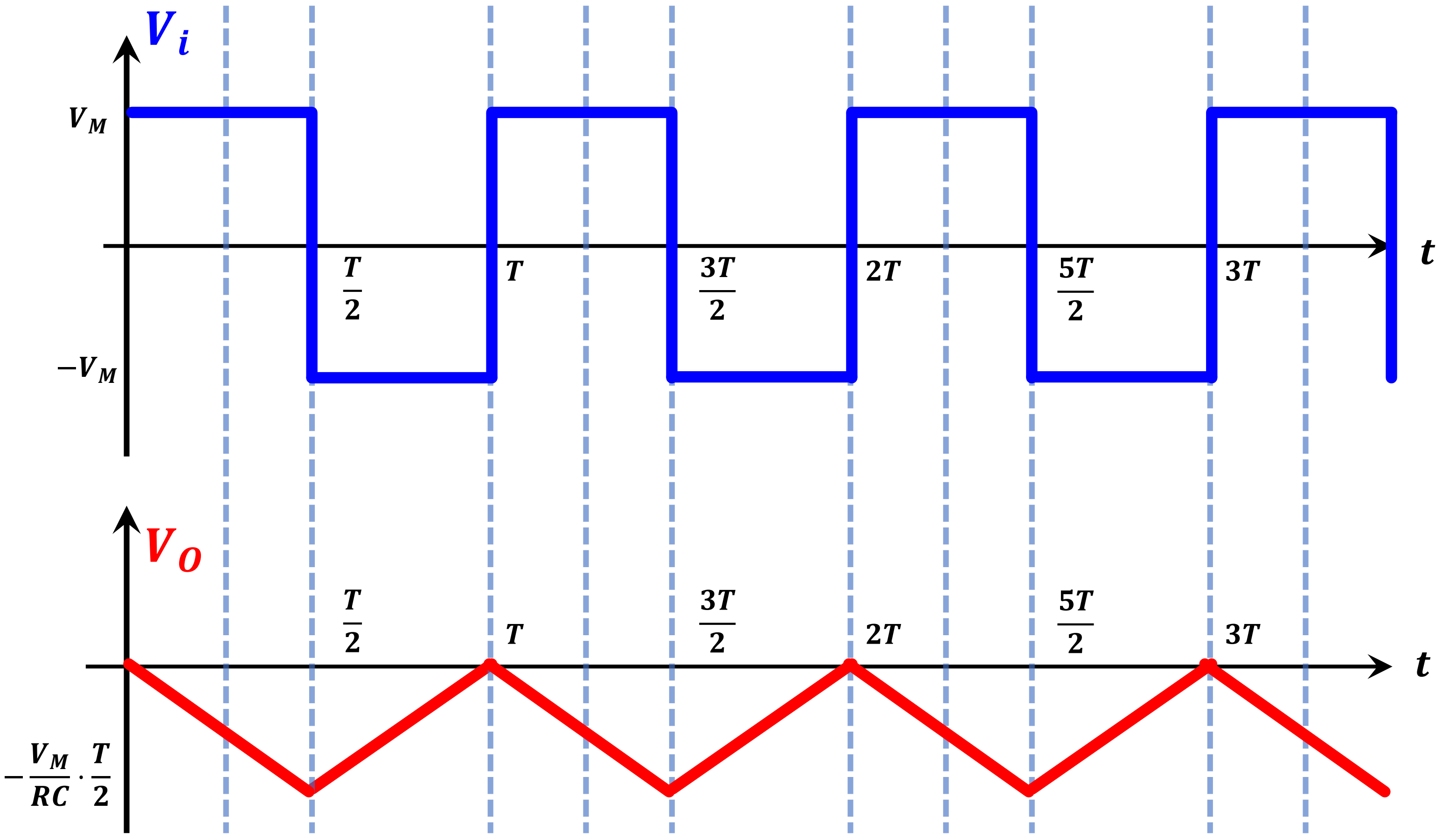




Slope: $\left|\frac{\mathrm{d}v}{\mathrm{d}t}\right| = \frac{V_M-(-V_M)}{T/2} = \frac{4V_M}{T}$

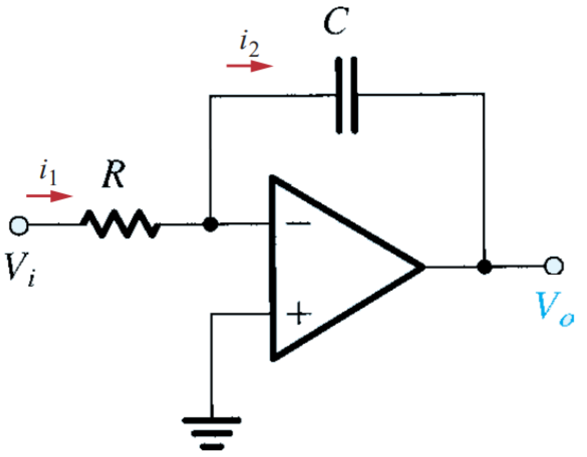
Example 12

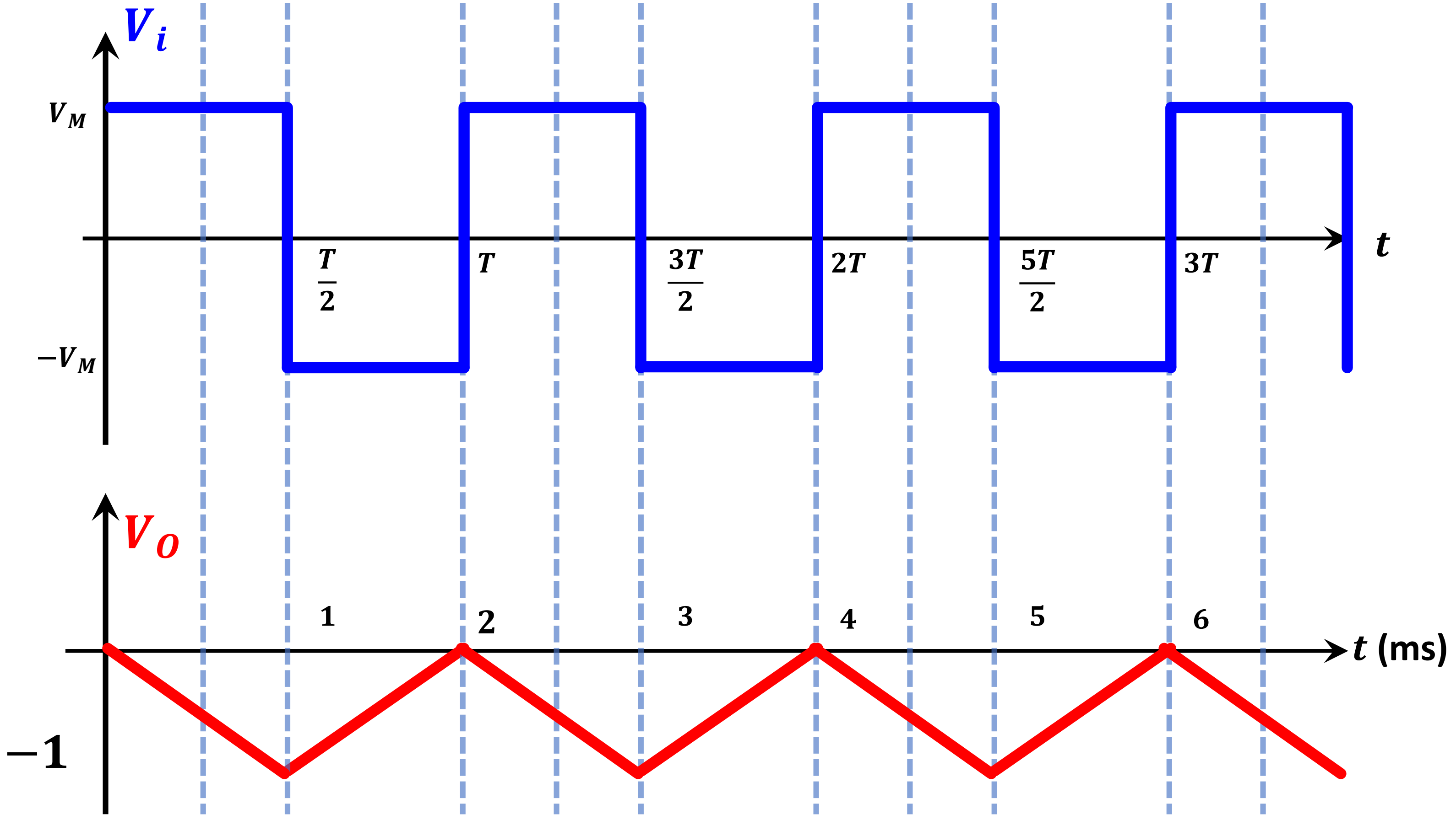




$$\int_0^t v_I \, dt = V_M \cdot t$$

Example 12





$$\int_0^t v_I \, dt = V_M \cdot t$$

APPLICATIONS:

Implementing operational functions

- $f = -2x - 3y$
- $f = -4x + 5y$
- $f = -7x + \frac{d}{dt}y$
- $f = -3\frac{d}{dt}z + 6x + 9\int y \cdot dt$
- $f = \frac{d^2x}{dt} + 10y + \int (10z - 9)dt$
- $f = -\frac{1}{3}\int x \cdot dt + 2\ln y + 4z$
- $f = -3\frac{dx}{dt} + 2\exp(y) + 4z$
- $f = xy/z$

APPLICATIONS:

Implementing operational functions

- $f = -2x - 3y$

APPLICATIONS:

Implementing operational functions

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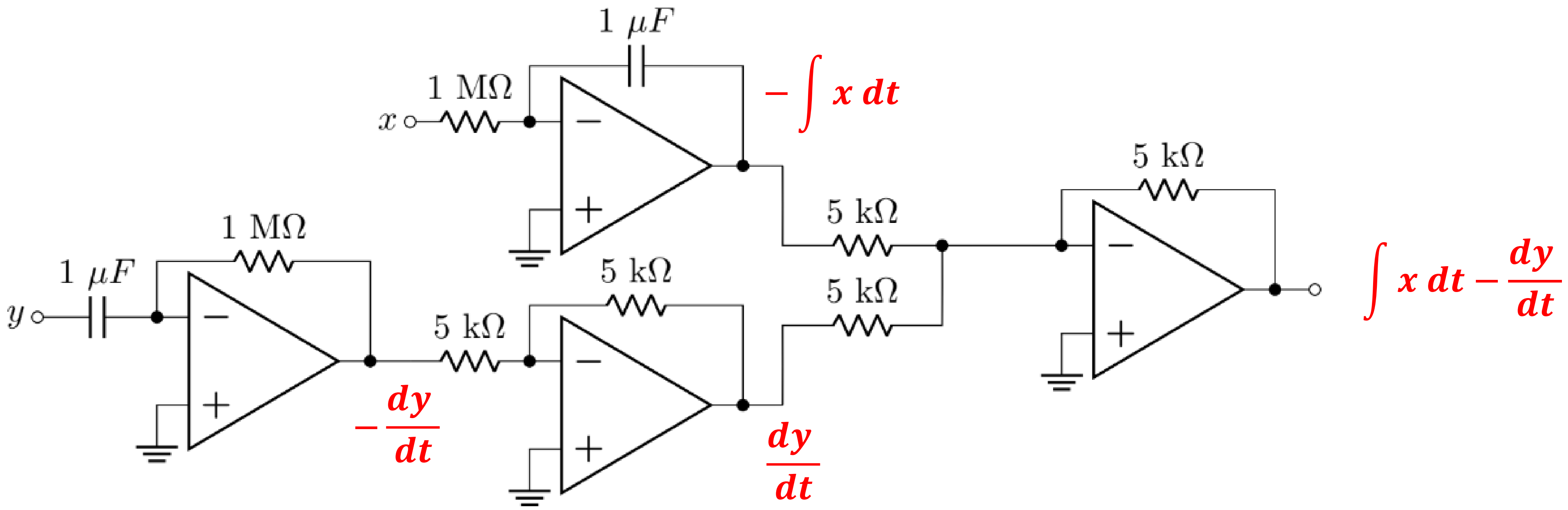
APPLICATIONS:

Implementing operational functions

- $f = -7x + \frac{d}{dt}y$

Example

Analyze the circuit below to **find** an expression of $\boldsymbol{f}$ in terms of inputs $\boldsymbol{x}$ and $\boldsymbol{y}$.



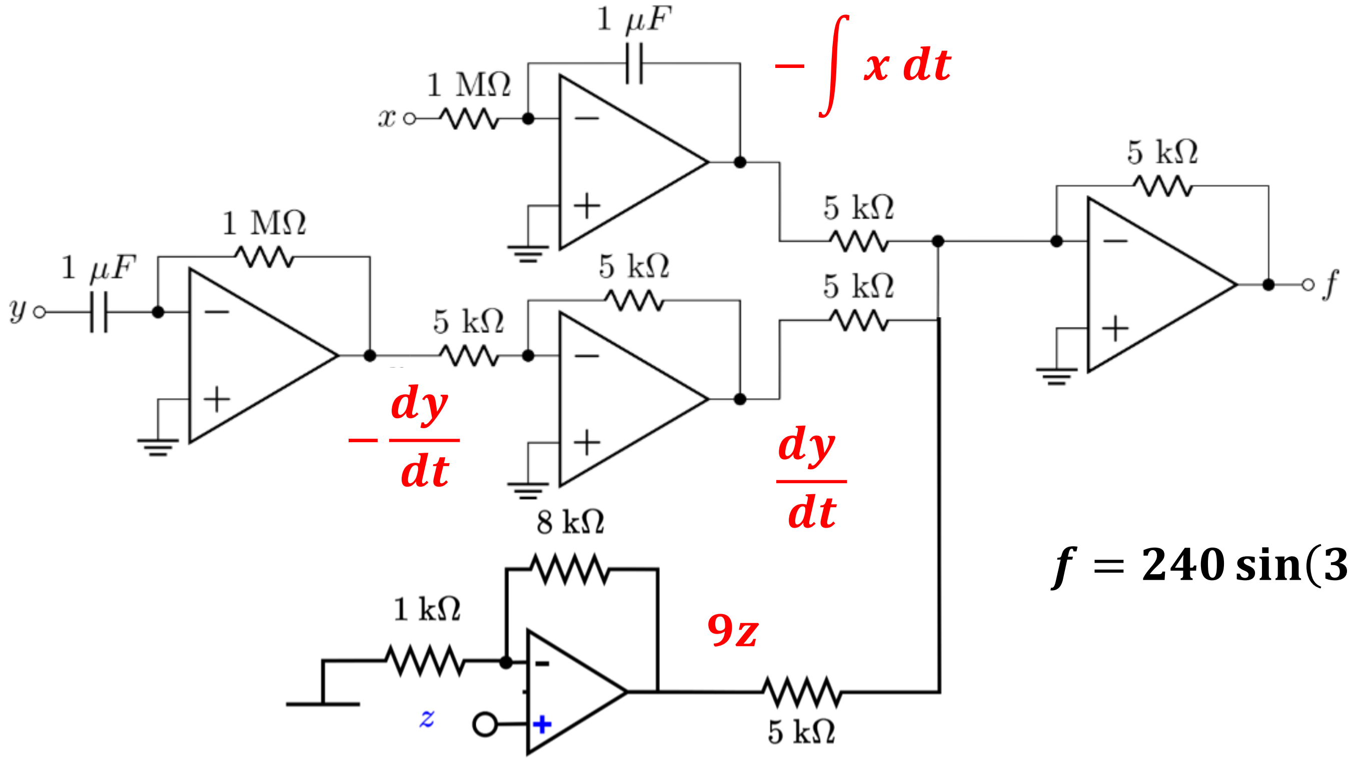
Solution:

$$v_{I_1} = -\frac{dy}{dt}\,; v_{I_2} = -\frac{1}{RC}\int x\,dt\,; v_{I_3} = -v_{I_1} = \frac{dy}{dt}\,;\ v_o = -(v_{I_2} + v_{I_3})$$

Example

Analyze the circuit below to **find** an expression of $\boldsymbol{f}$ in terms of inputs $\boldsymbol{x}$ and $\boldsymbol{y}$.

If $\boldsymbol{x} = \mathbf{8}\cos(\mathbf{30}\boldsymbol{t})\ \mathbf{V}$ and $\boldsymbol{y} = \mathbf{3}\sin(\mathbf{30}\boldsymbol{t})\ \mathbf{V}$ and $\boldsymbol{z} = \mathbf{1}\ \mathbf{V}$



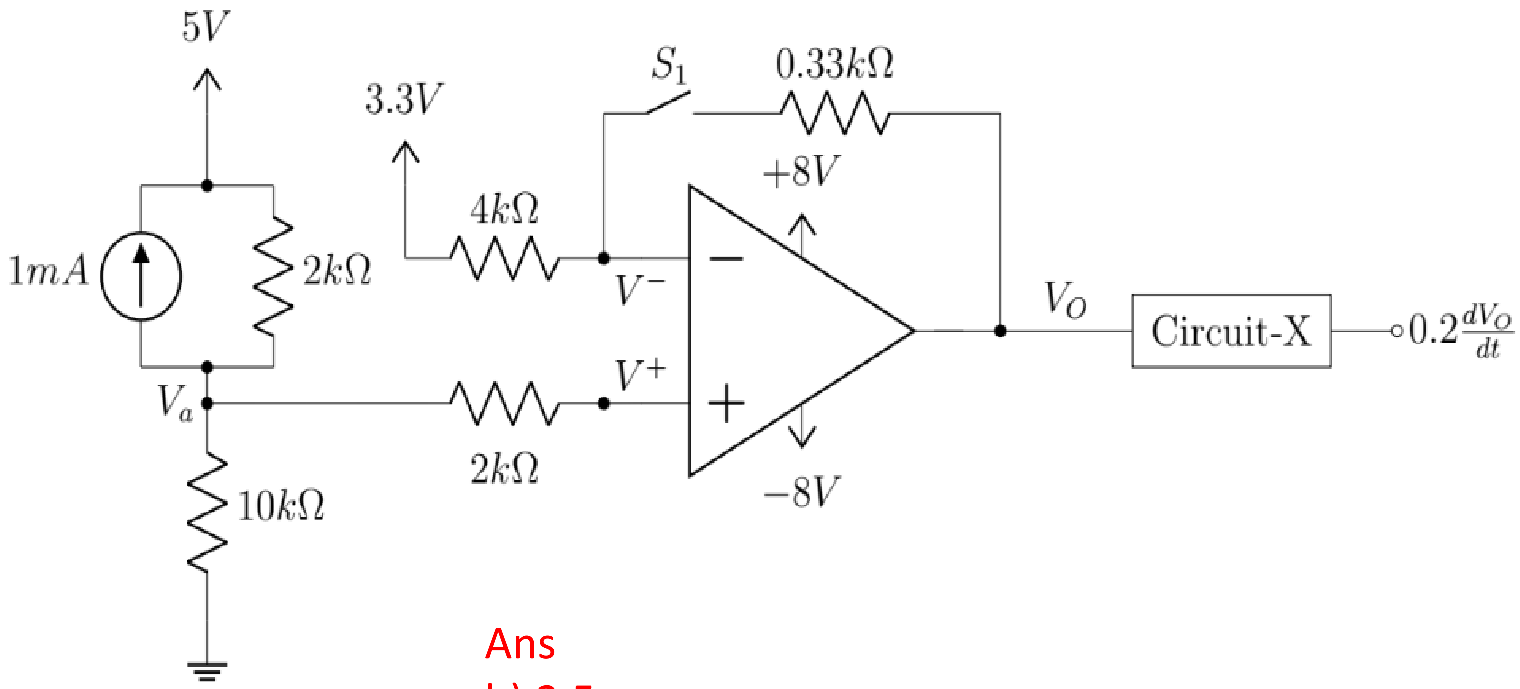
$$= \int x\,dt - \frac{dy}{dt} - 9z$$

$$\boldsymbol{f} = \mathbf{240}\sin(\mathbf{30}\boldsymbol{t}) - \mathbf{90}\cos(\mathbf{30}\boldsymbol{t}) - \mathbf{9}\ \mathbf{V}$$

Problem 1

The circuit diagram has a switch S1 which is shown to be 'open' in the figure. The output V_O is passed through an unknown block of 'Circuit-X' and a differentiated result is generated.

a) **State** the equation of gain of an inverting amplifier.
b) **Calculate** the Value of Va and V+.
c) **Determine** Vo when switch S1 is closed
d) **Determine** Vo when switch S1 is open
e) **Design** the circuit-X. Assume any value if necessary.



Ans
b) 2.5v
c) 2.434
d) -8v

Thank You!