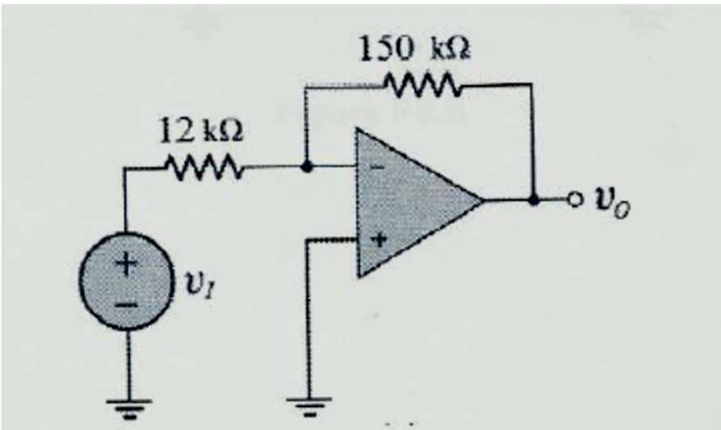
Operation Amplifier - Examples

Example: Inverting Amplifier



(a)

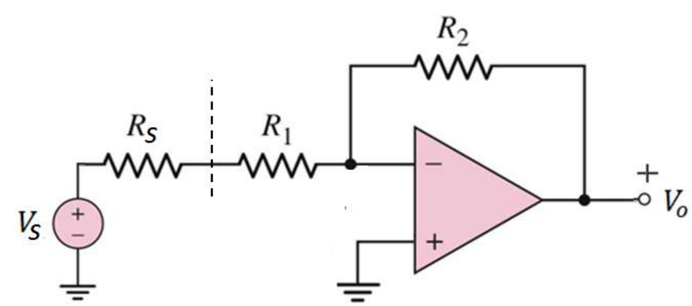
Gain = - (R_2 / R_1) = -(150/12) = **-12.5**

Example 2: Inverting Amplifier

A voltage source V_S with source resistance $R_S = 1.5\ k\Omega$ is connected to the input of an op-amp inverting amplifier circuit

(a) If the $R_1 = 1.0\ k\Omega$ and $R_2 = 15.0\ k\Omega$, then calculate the voltage gain, V_O / V_S

(b) Determine the output voltage V_o for the source voltage $V_S = 45$ mV



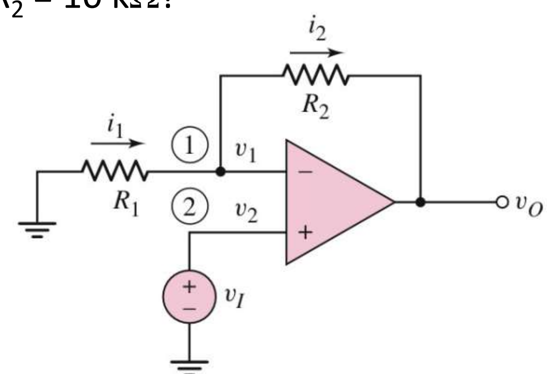
Answers:
(a) - 6
(b) - 0.27 V

Example 1: Non-Inverting Amplifier

What is the gain of the circuit when R_1 = 1 kΩ, R_2 = 10 kΩ?

$$A_v = 1 + \frac{R_2}{R_1}$$

$$A_v = 1 + \frac{R_2}{R_1} = 1 + \frac{10\,k\Omega}{1\,k\Omega} = 11$$

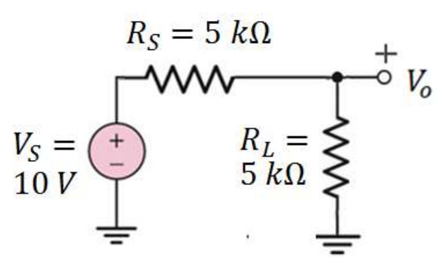


Noninverting amplifier

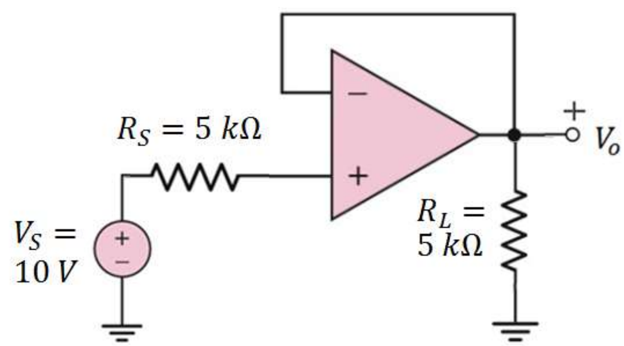
Example 1: Buffer Amplifier (Voltage Follower)

A voltage source V_S with source resistance $R_S = 5\ k\Omega$ is connected to a load resistance input of $R_L = 5\ k\Omega$ directly and through a buffer amplifier as shown in the figures below.

- Determine the output voltage across the load and the current in the resistance R_L for each circuit configuration



Load directly connected to the source



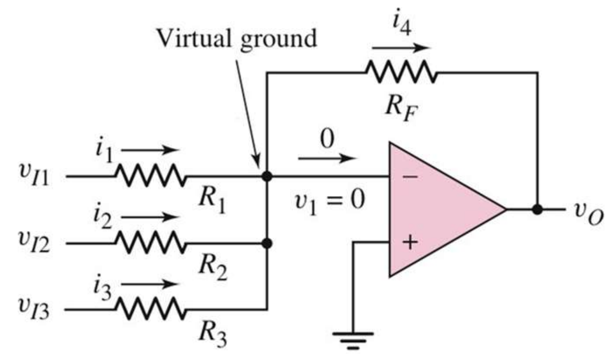
Load connected to the source via a buffer

Answers:
Vo = 5 V, Current = 1 mA
Vo = 10 V, current = 2 mA

Example 1: Summing Amplifier

Design a summing amplifier as shown in figure to produce a specific output signal, such that **$v_o = 1.25 - 2.5\cos\omega t$** volt. Assume the input signals are **$v_{I1} = -1.0$ V, $v_{I2} = 0.5\cos\omega t$** volt. Assume the feedback resistance $R_F = 10\ k\Omega$

Solution: output voltage



$$v_0 = -R_F\left(\frac{v_{I1}}{R_1} + \frac{v_{I2}}{R_2} + \frac{v_{I3}}{R_3}\right) = -R_F\left[\frac{(-1)}{R_1} + \frac{0.5\cos\omega t}{R_2}\right]$$

$$\text{Or,} \qquad 1.25 - 2.5\cos\omega t = R_F\left[\frac{1}{R_1} - \frac{0.5\cos\omega t}{R_2}\right]$$

$$\text{Or,} \qquad \boxed{1.25} - \boxed{2.5\cos\omega t} = \boxed{\frac{R_F}{R_1}} - \boxed{\left(\frac{R_F}{R_2}\right)(0.5\cos\omega t)}$$

$$\frac{R_F}{R_1} = 1.25 \quad \text{or} \quad R_1 = \frac{R_F}{1.25} = \frac{10k\Omega}{1.25} = 8k\Omega$$

$$\frac{R_F}{R_2}\left(0.5cos(\omega t)\right) = 2.5cos(\omega t) \quad \text{or} \quad R_2 = R_F\frac{0.5cos(\omega t)}{2.5cos(\omega t)} = 10\times\frac{0.5}{2.5} = 2k\Omega$$

Example 1: **Integrator**

The integrator circuit as shown in figure has an initial voltage $V_x = -1.4$ V across the capacitor at time $t = 0$. A step input voltage $V_S = -2$V is applied at time $t = 0$. Determine the *RC* time constant necessary such that the output voltage reaches +10.2 V at time $t = 5.0$ ms.

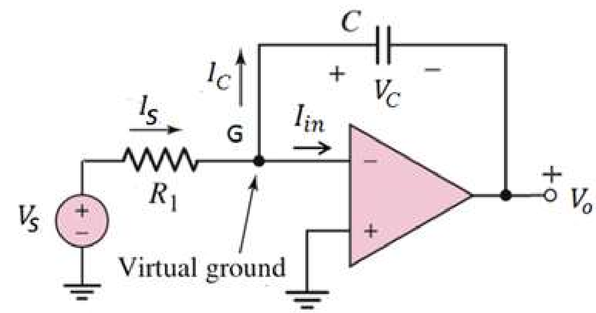
Solution: The output voltage

$$V_o = V_x - \frac{1}{R_1 C}\int V_S \, dt$$

$$= V_x - \frac{1}{R_1 C}\int_0^5 V_S \, dt$$

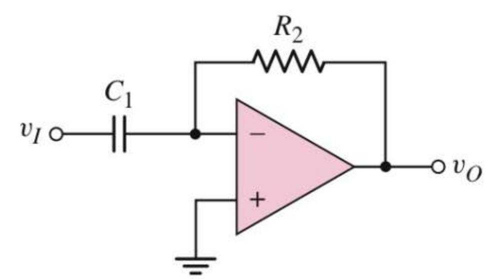
$$10.2 = -1.4 - \frac{(-2)}{R_1 C}\int_0^5 dt = -1.4 + \frac{2}{R_1 C}[5 - 0]$$

$$R_1 C = 0.862 \; ms$$



Example 1: Differentiator

Determine the output voltage of a differentiator circuit. Assume that the input voltage $v_I = 3.5\cos(100\pi t)\ V$ and the time constant R_2C_1 = 1.5 ms.



Solution:

The output voltage

$$v_O = -R_2C_1\frac{dv_I}{dt}$$

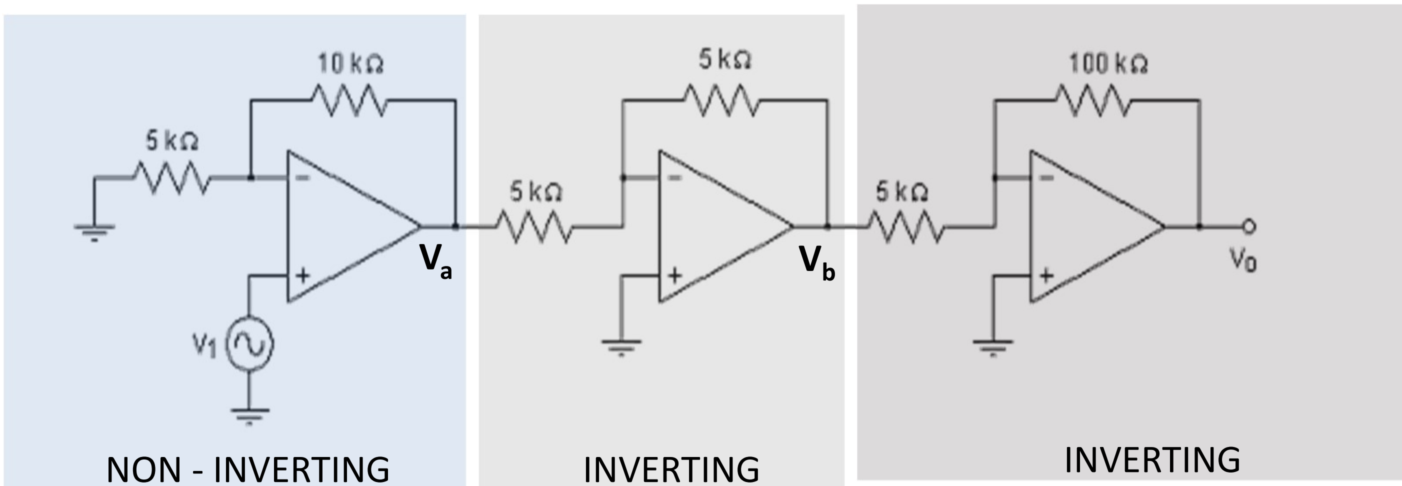
$$= -(1.5\times10^{-3})\frac{d[3.5\,cos(100\pi t)\,]}{dt}$$

$$v_O = -(1.5\times10^{-3})[-3.5\times100\pi\times\ sin(100\pi t)]$$

$$v_O = 1.65\ sin(100\pi t)\ \text{volt}$$

Example 1: Multi-Stage Amplifier

Calculate the input voltage if the final output, V_O is 10.08 V.



Need to work backward:

$$V_o = -\frac{100\,k\Omega}{5\,k\Omega} V_b$$

$$10.08 = -20V_b$$

$$V_b = -0.504\,V$$

Then:

$$V_b = -\frac{5}{5} V_a$$

$$-0.504 = -V_a$$

$$V_a = 0.504\ V$$

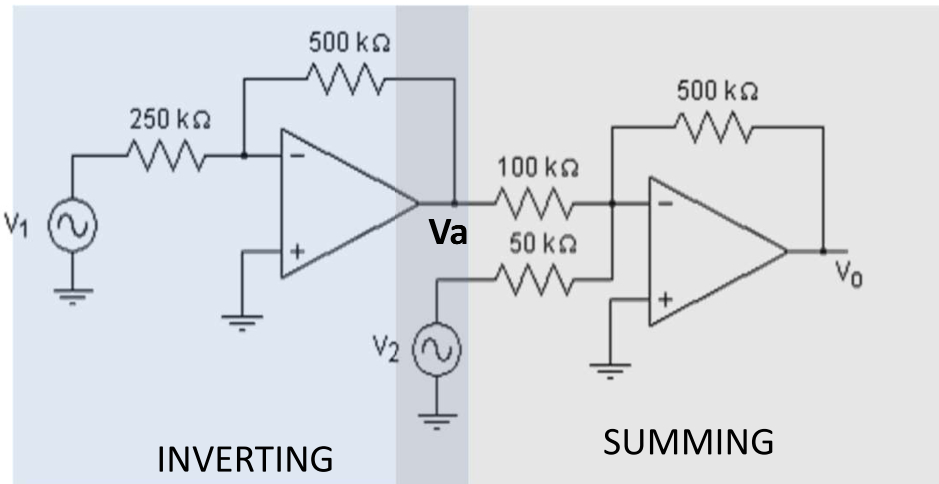
Finally:

$$V_a = \left(1 + \frac{10k\Omega}{5k\Omega}\right) V_1$$

$$0.504 = 3V_1$$

$$V_1 = 0.168\,V$$

Example 2: Multi-Stage Amplifier



Calculate the output voltage, V_O if $V_1 = V_2 = 700$ mV

Va = -(500/250) 0.7
Va = -1.4 V

→

Then:

Vo = - 500 [V_a / 100 + V_2 / 50]
Vo = - 500 [-1.4 / 100 + 0.7 / 50]
Vo = 0 V

Calculating Gain and Design Questions

INVERTING

Voltage gain, $A_v = \frac{V_0}{V_i} = -\frac{R_2}{R_1}$

NON - INVERTING

Voltage gain, $A_v = \frac{V_0}{V_i} = 1 + \frac{R_2}{R_1}$

Calculating Output and Design Questions

SUMMING AMPLIFIER

Output voltage

$$V_0 = -R_F\left(\frac{V_{i1}}{R_1} + \frac{V_{i2}}{R_2} + \frac{V_{i3}}{R_3}\right)$$

DIFFERENTIATOR AMPLIFIER

Output voltage, $v_0 = -R_2 C_1 \frac{dv_I}{dt}$

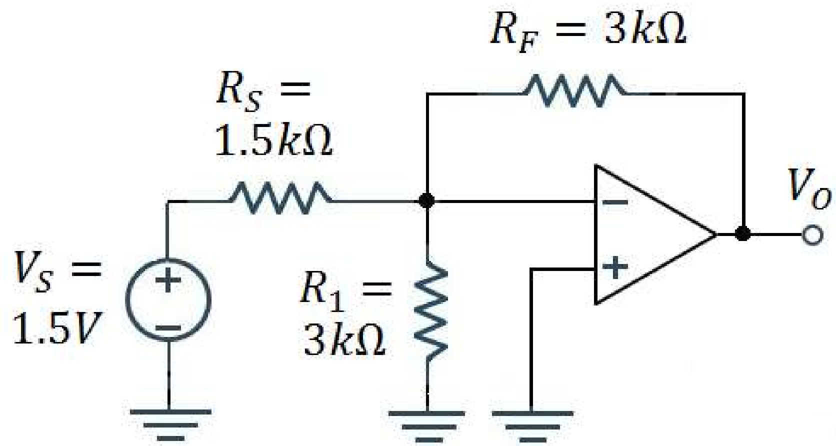
INTEGRATOR AMPLIFIER

Output voltage, $v_0 = -\frac{1}{R_1 C_2}\int v_I \, dt$

If the capacitor has some initially voltage, V_C

$$v_0 = V_C - \frac{1}{R_1 C_2}\int v_I \, dt$$

Example 3:



Calculate the output voltage V_o of the operational amplifier circuit as shown in the figure.

Answer: -3 V