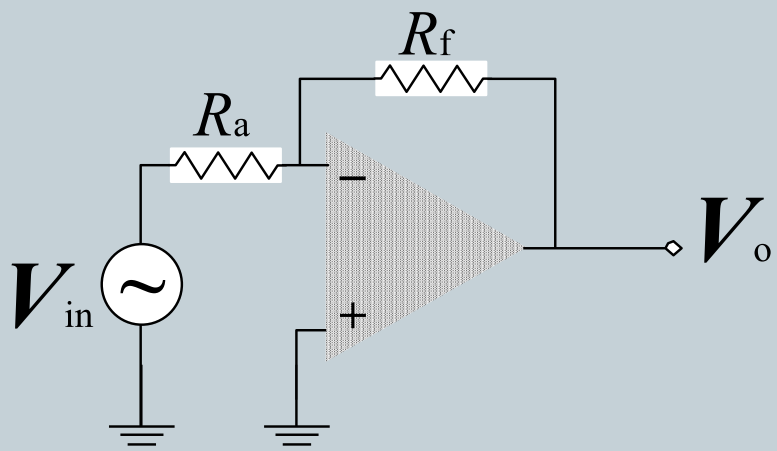
Inverting Amplifier

(1) Kirchhoff node equation at V_+ yields, $V_+ = 0$



(2) Kirchhoff node equation at V_- yields,

$$\frac{V_{in} - V_-}{R_a} + \frac{V_o - V_-}{R_f} = 0$$

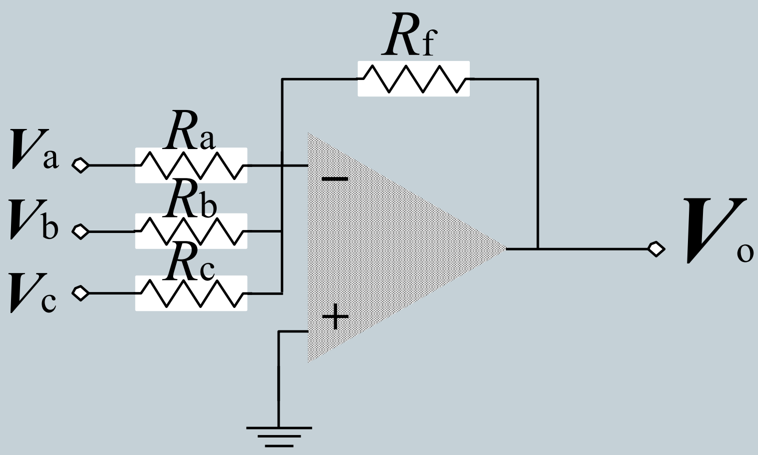
(3) Setting $V_+ = V_-$ yields

$$\frac{V_o}{V_{in}} = \frac{-R_f}{R_a}$$

Notice: The closed-loop gain V_o/V_{in} is dependent upon the ratio of two resistors, and is independent of the open-loop gain. This is caused by the use of feedback output voltage to subtract from the input voltage.

Multiple Inputs

(1) Kirchhoff node equation at V_+ yields, $V_+ = 0$



(2) Kirchhoff node equation at V_- yields,

$$\frac{V_- - V_o}{R_f} + \frac{V_- - V_a}{R_a} + \frac{V_- - V_b}{R_b} + \frac{V_- - V_c}{R_c} = 0$$

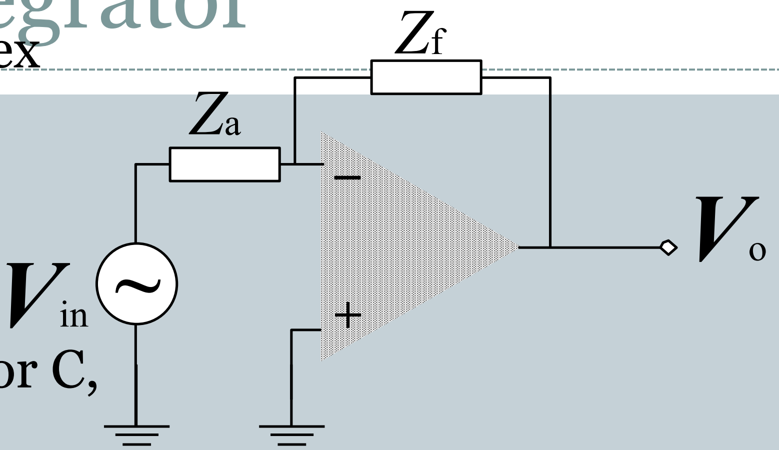
(3) Setting $V_+ = V_-$ yields

$$V_o = -R_f\left(\frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c}\right) = -R_f \sum_{j=a}^{c} \frac{V_j}{R_j}$$

Inverting Integrator

Now replace resistors R_a and R_f by complex components Z_a and Z_f, respectively, therefore

$$V_o = \frac{-Z_f}{Z_a} V_{in}$$



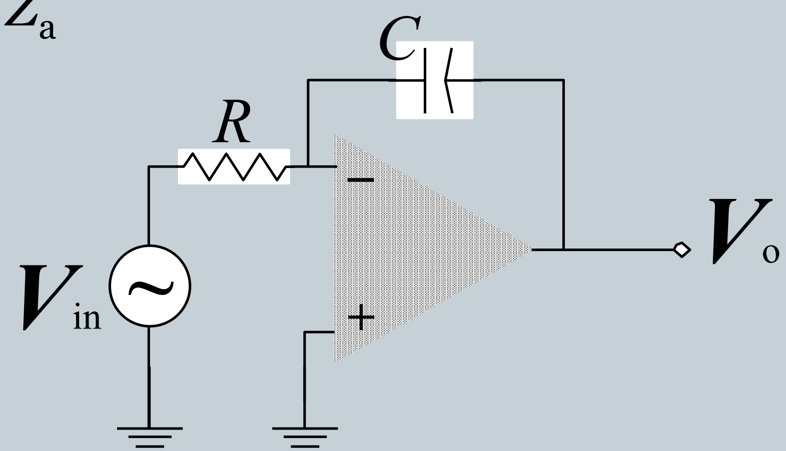
Supposing

(i) The feedback component is a capacitor C, i.e., $Z_f = \frac{1}{j\omega C}$

(ii) The input component is a resistor R, $Z_a = R$

Therefore, the closed-loop gain (V_o/V_{in}) become:

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



where

$$v_i(t) = V_i e^{j\omega t}$$

What happens if $Z_a = 1/j\omega C$ whereas, $Z_f = R$?

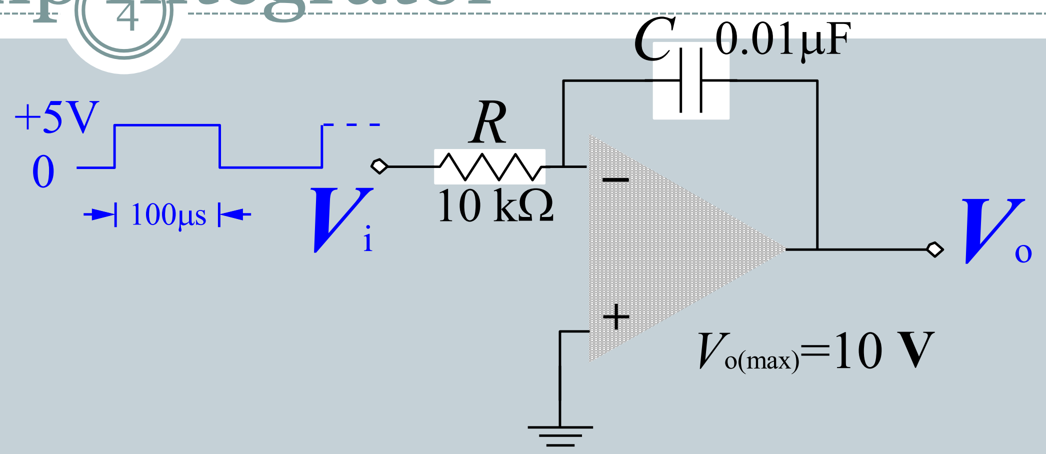
Inverting differentiator

Op-Amp Integrator

Example:

(a) Determine the rate of change of the output voltage.

(b) Draw the output waveform.

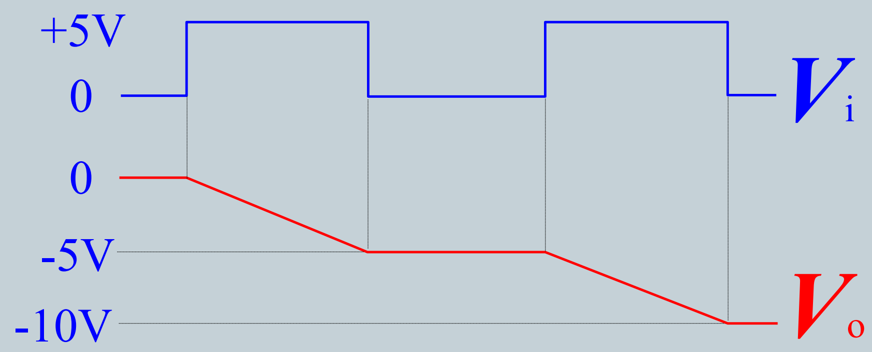


Solution:

(a) Rate of change of the output voltage

$$\frac{\Delta V_o}{\Delta t} = -\frac{V_i}{RC} = \frac{5\ \mathbf{V}}{(10\ \mathbf{k\Omega})(0.01\ \mu\mathbf{F})}$$

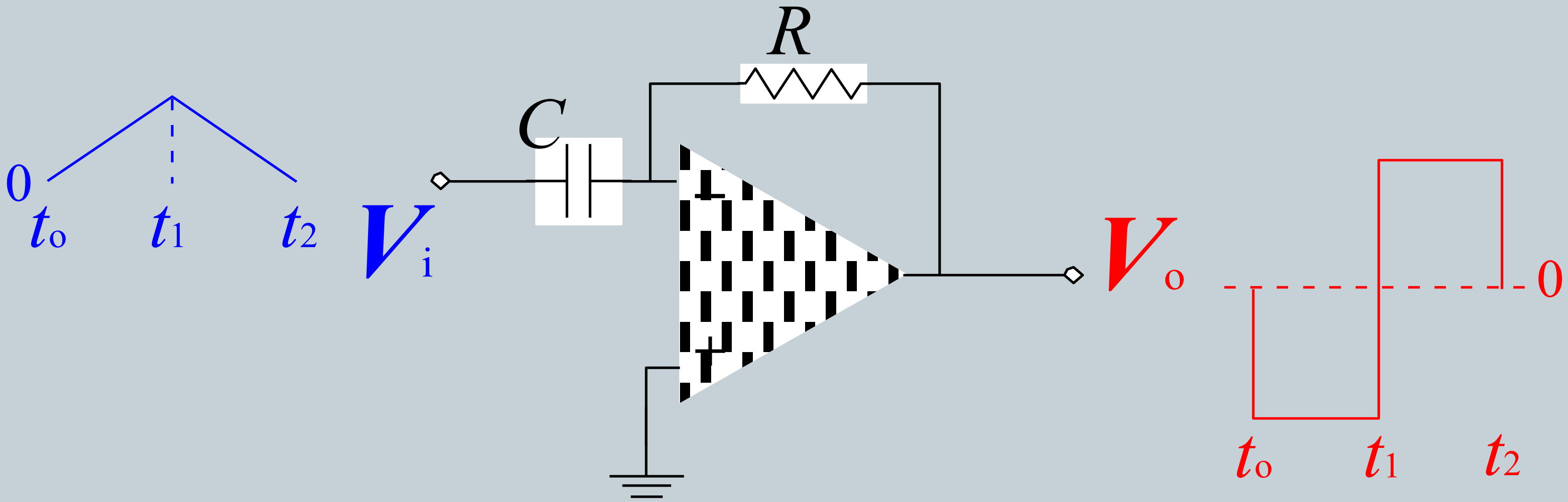
$$= -50\ \mathbf{mV}/\mu\mathbf{s}$$



(b) In 100 µs, the voltage decrease

$$\Delta V_o = (-50\ \mathbf{mV}/\mu\mathbf{s})(100\ \mathbf{\mu s}) = -5\mathbf{V}$$

Op-Amp Differentiator



$$v_o = -\left(\frac{dV_i}{dt}\right)RC$$