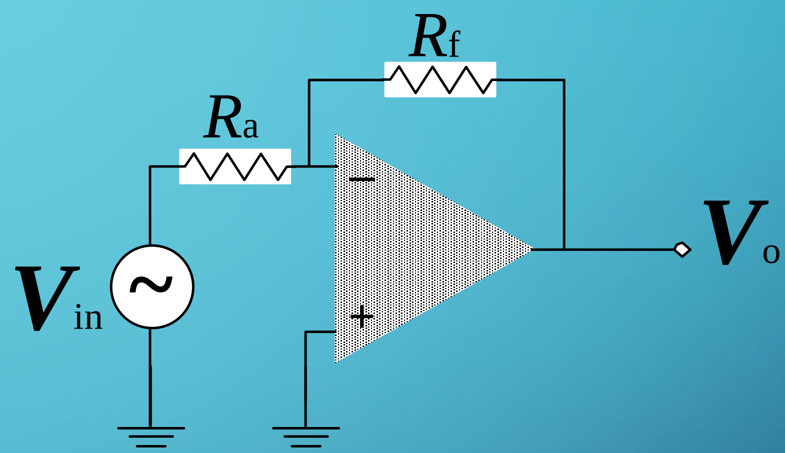
NETWORK THEORY

LECTURE 9

SECTION-D :NETWORK SYNTHESIS

INVERTING AMPLIFIER

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



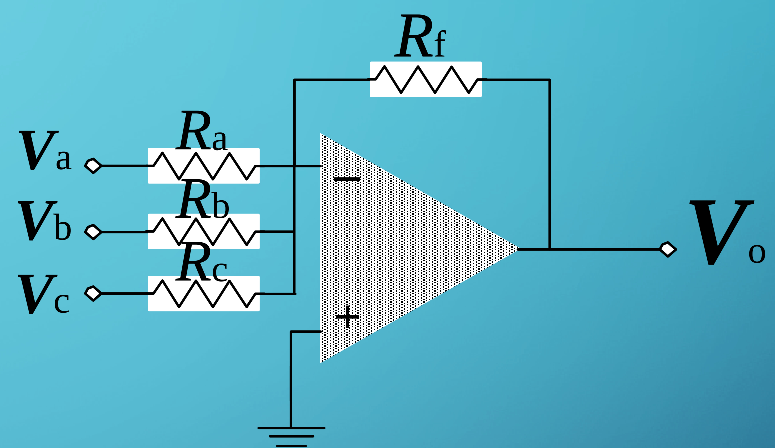
(2) Kirchhoff node equation at V_- yields, $\frac{V_{in} - V_-}{R_a} + \frac{V_o - V_-}{R_f} = 0$

(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

Supposing

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

(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:

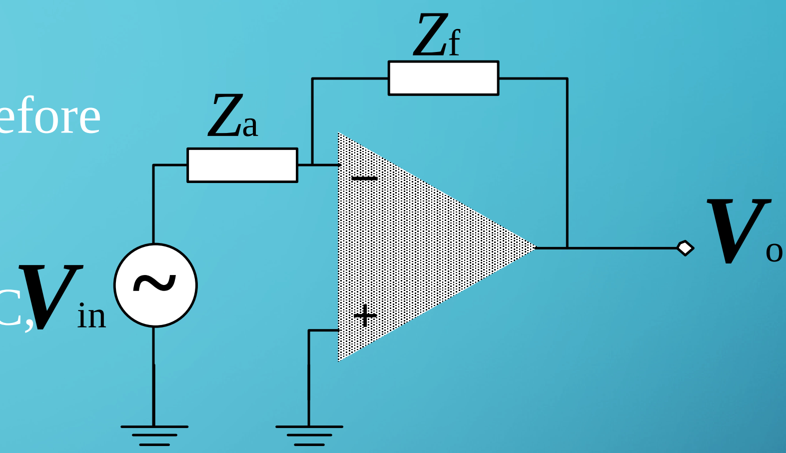
$$v_o(t) = \frac{-1}{RC}\int v_i(t)dt$$

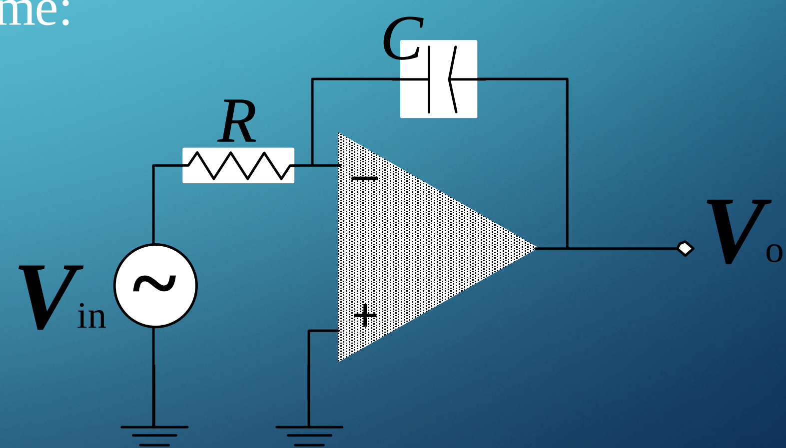
where

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

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

Inverting differentiator



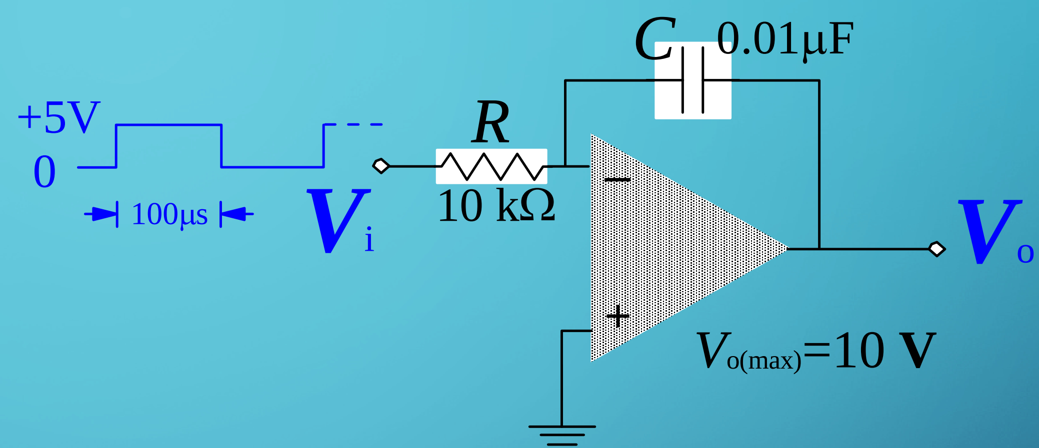


OP-AMP INTEGRATOR

Example:

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

(b) Draw the output waveform.



Solution:

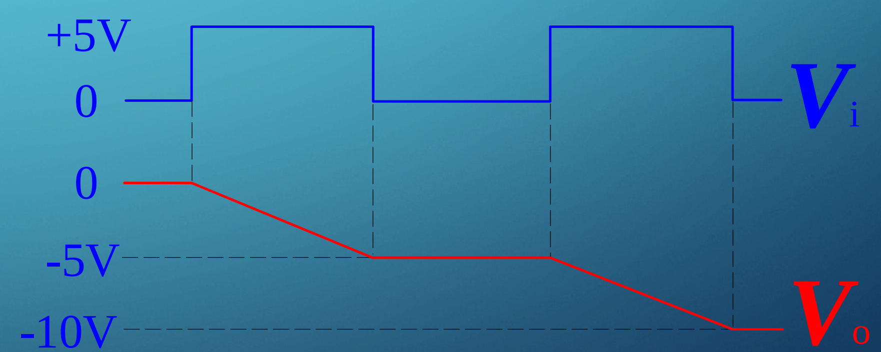
(a) Rate of change of the output voltage

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

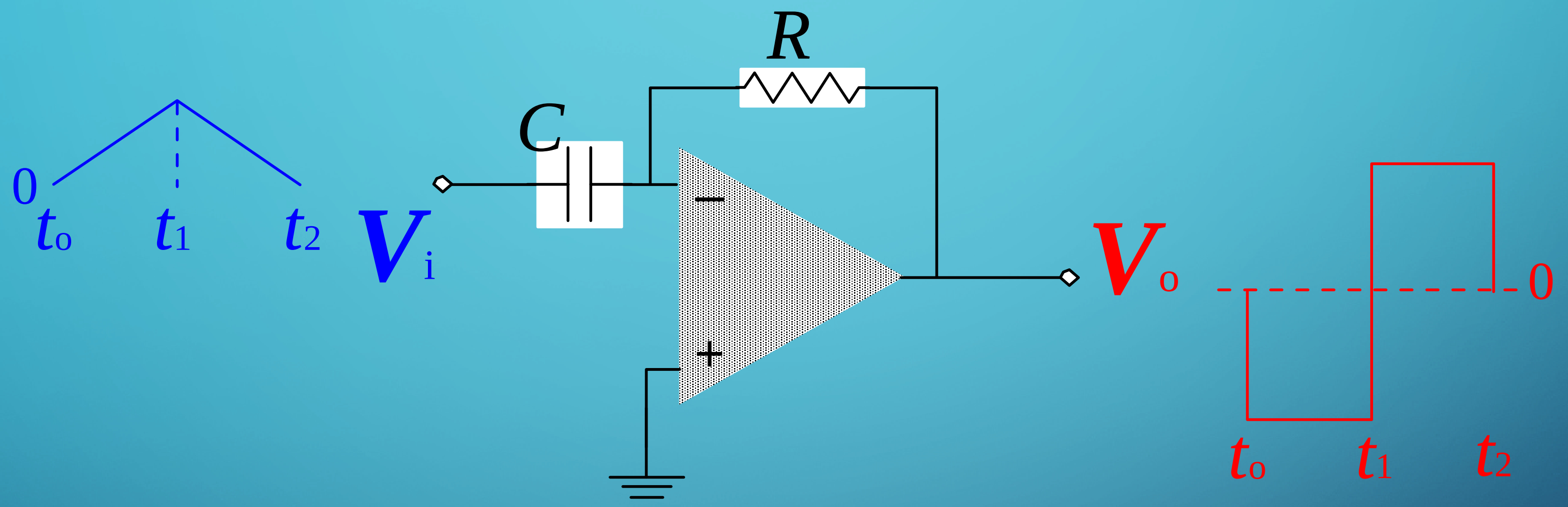
$$= -50\,\mathbf{mV}/\mu\mathbf{s}$$

(b) In 100 μs, the voltage decrease

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

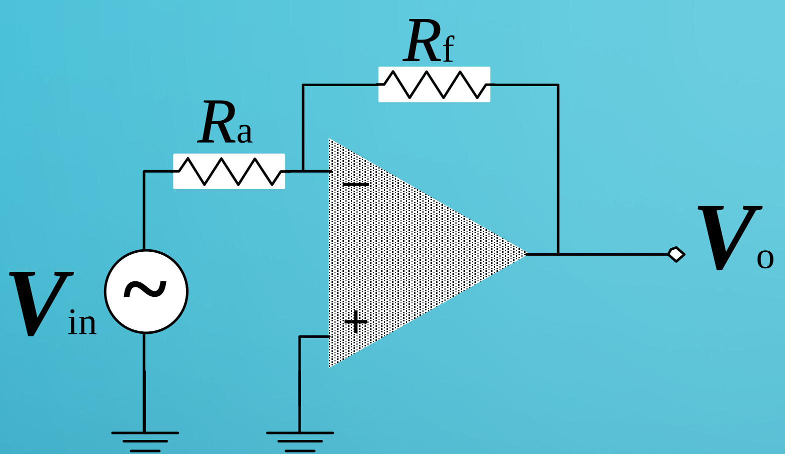


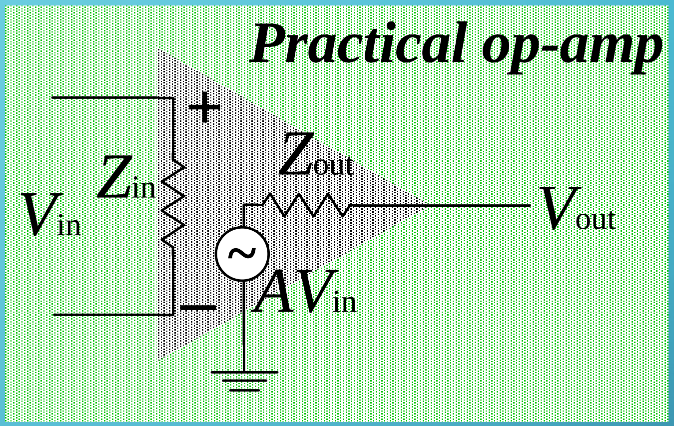
OP-AMP DIFFERENTIATOR



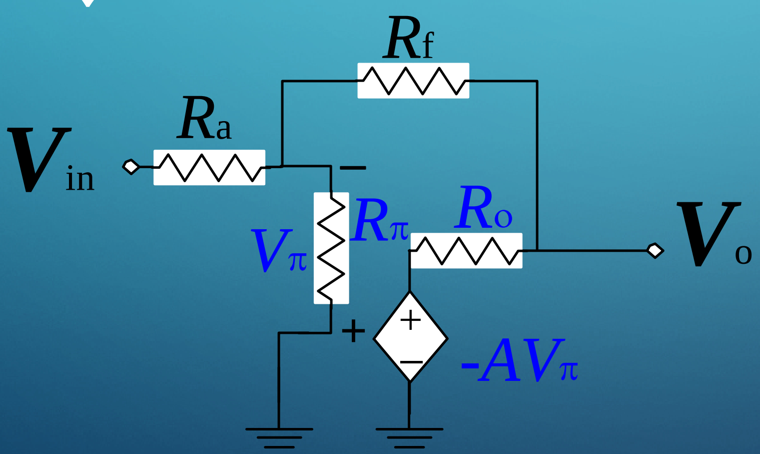
$$v_o = -\left(\frac{dV_i}{dt}\right)RC$$

NON-IDEAL CASE (INVERTING AMPLIFIER)





⇓ Equivalent Circuit



3 categories are considering

- ❑ Close-Loop Voltage Gain
- ❑ Input impedance
- ❑ Output impedance

CLOSE-LOOP GAIN

Applied KCL at V– terminal,

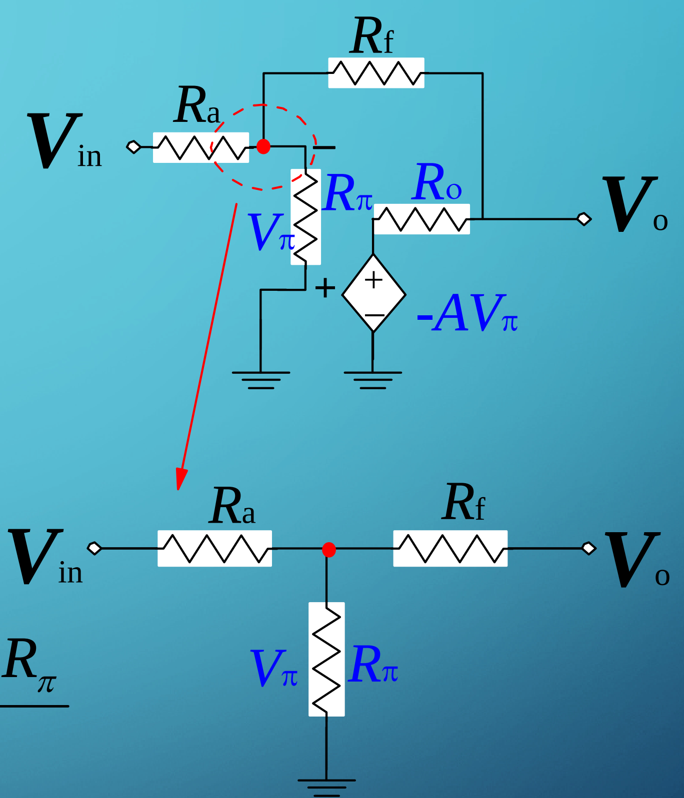
$$\frac{V_{in}-V_{\pi}}{R_a}+\frac{-V_{\pi}}{R_{\pi}}+\frac{V_o-V_{\pi}}{R_f}=0$$

By using the open loop gain,

$$V_o=-AV_{\pi}$$

$$\Rightarrow \quad \frac{V_{in}}{R_a}+\frac{V_o}{AR_a}+\frac{V_o}{AR_{\pi}}+\frac{V_o}{R_f}+\frac{V_o}{AR_f}=0$$

$$\Rightarrow \quad \frac{V_{in}}{R_a}=-V_o\frac{R_{\pi}R_f+R_aR_f+R_aR_{\pi}+AR_aR_{\pi}}{AR_aR_{\pi}R_f}$$



The Close-Loop Gain, A_v

$$A_v=\frac{V_o}{V_{in}}=\frac{-AR_{\pi}R_f}{R_{\pi}R_f+R_aR_f+R_aR_{\pi}+AR_aR_{\pi}}$$

CLOSE-LOOP GAIN

When the open loop gain is very large, the above equation become,

$$A_v \sim \frac{-R_f}{R_a}$$

Note : The close-loop gain now reduce to the same form as an ideal case