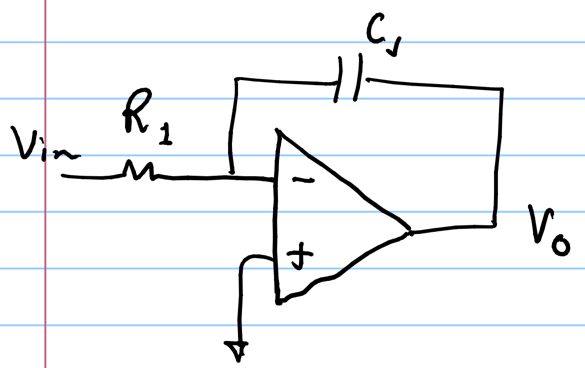
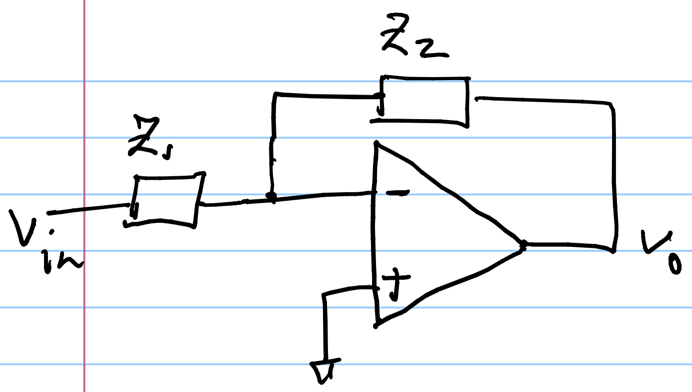


$$\frac{V_o}{V_{in}} =$$

$$\frac{V_{in} - 0}{R_1} = (0 - V_o) s C_1$$

$$\frac{V_o}{V_{in}} = -\frac{1}{R_1 C_1} \cdot \frac{1}{s} \rightarrow \text{Integrator}$$

$$\omega_u = \frac{1}{R_1 C_1}$$, R_1 & C_1 is external and can be changed to control ω_u



$$\frac{V_0}{V_{in}} = -\frac{Z_2}{Z_1}$$

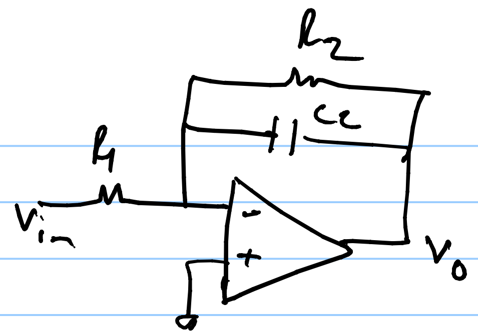
if $Z_2 = R_2$ & $Z_1 = R_1$

$$\frac{V_0}{V_{in}} = -\frac{R_2}{R_1}$$

if $Z_2 = \frac{1}{sC_1}$ → Capaciter

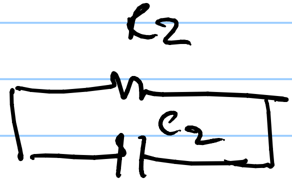
$$\frac{V_0}{V_{in}} = -\frac{1}{R_1C_1} \cdot \frac{1}{s}$$ → Integrator

$Z_1 \rightarrow$ Capacitor & $Z_2 \rightarrow$ resistor



$$\frac{V_o}{V_{in}} = -R_2 C_1 s \rightarrow \text{Differentiator}$$

$Z_2 \rightarrow$

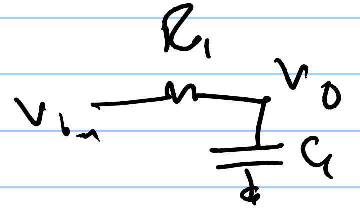


$$= \frac{1}{sC_2 + 1/R_2}$$

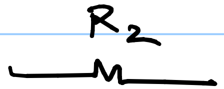
$Z_1 \rightarrow$

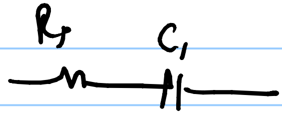
$$\frac{V_o}{V_{in}} = -\frac{1}{R_1(sC_2 + 1/R_2)} = -\frac{R_2}{R_1} \cdot \frac{1}{1 + R_2 C_2 s}$$

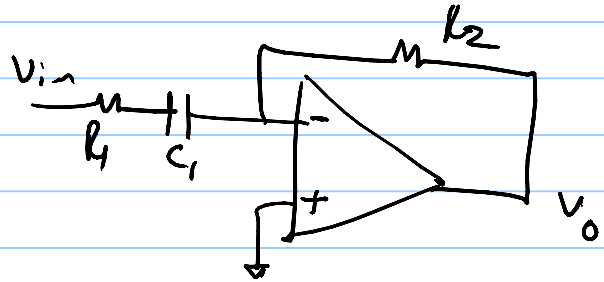
$$\omega_p = \frac{1}{R_2 C_2}, \quad \text{Gain} = \frac{R_2}{R_1}$$



Gain = 1

$Z_2 \rightarrow$ 

$Z_1 \longrightarrow$ 

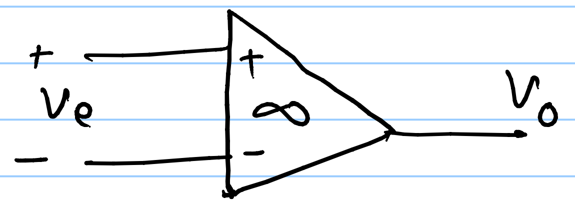


$$Z_1 = R_1 + \frac{1}{sC_1}$$

$$Z_2 = R_2$$

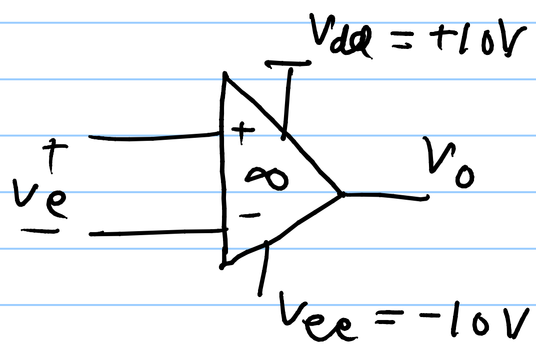
$$\frac{V_o}{V_{in}} = -\frac{R_2}{R_1 + \frac{1}{sC_1}} = \frac{R_2 C_1 s}{1 + R_1 C_1 s}$$

Supply Limited op-amp



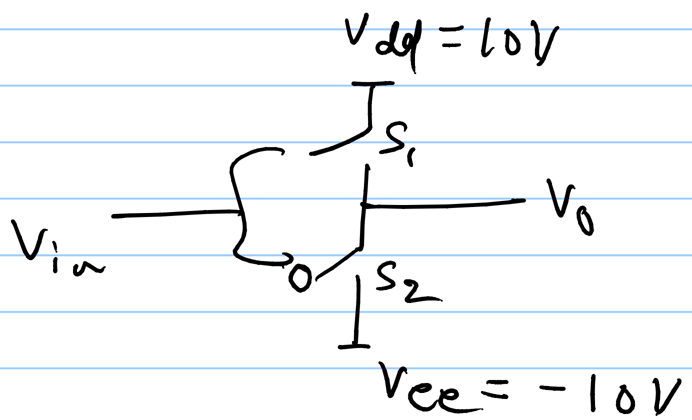
if $V_e > 0$, $V_o = \infty$

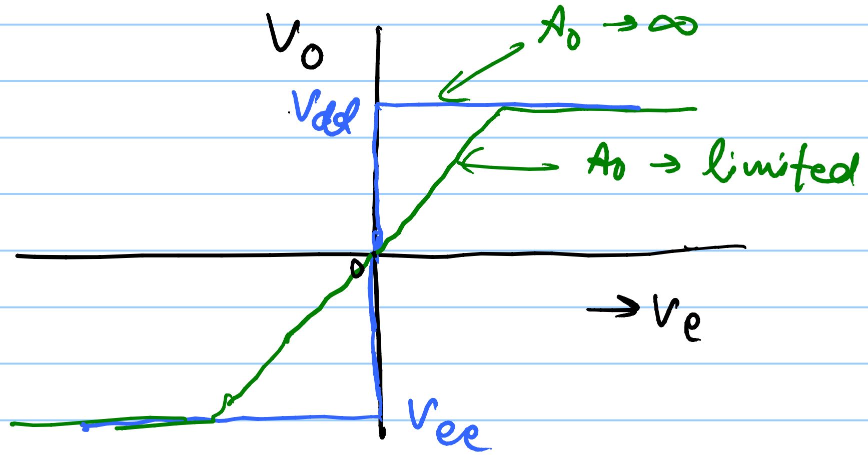
if $V_e < 0$, $V_o = -\infty$

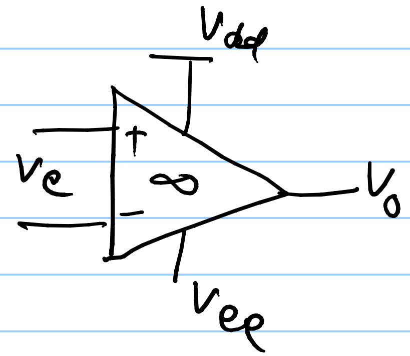


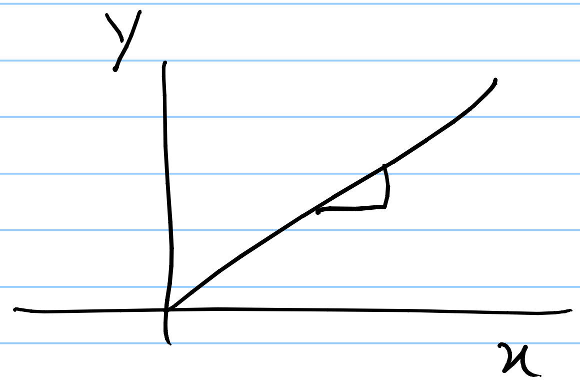
if $V_e > 0$, $V_o = +10V$ → logic high (1)

if $V_e < 0$, $V_o = -10V$ → logic low (0)









$$\frac{dy}{dx} = \text{gain}$$