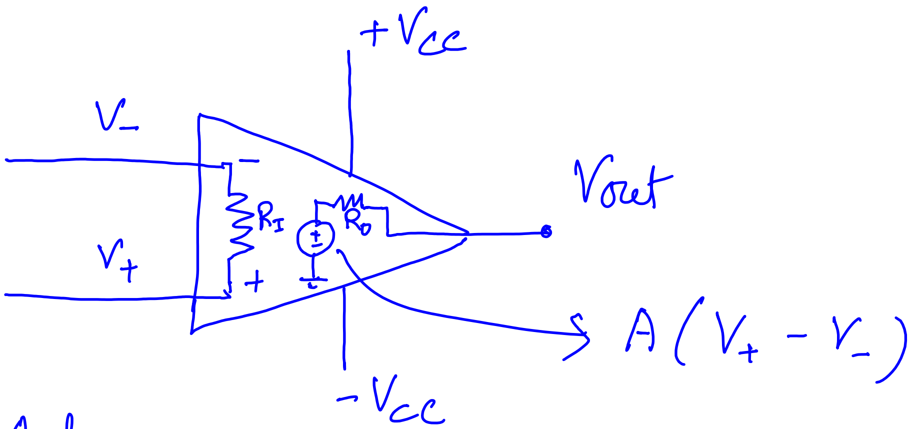
# Quick Recap

Operational Amplifier (OpAmp)

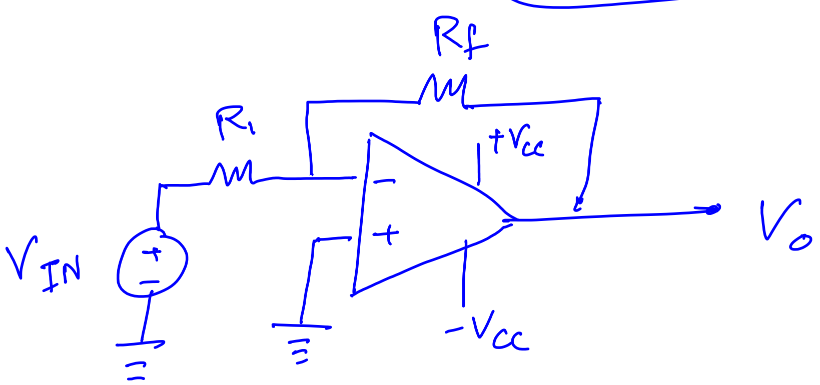



## Ideal OpAmp

$A \to \infty$ , $R_I \to \infty$, $R_o \approx 0$ ✓

$V_- = V_+$ (In closed-loop)

$$\underbrace{\left(-V_{cc} < V_{out} < V_{cc}\right)} \to \text{linear operating zone}$$



$$V_o = -\frac{R_f}{R_1} V_{IN} \quad ( -V_{cc} \leq V_o \leq V_{cc})$$

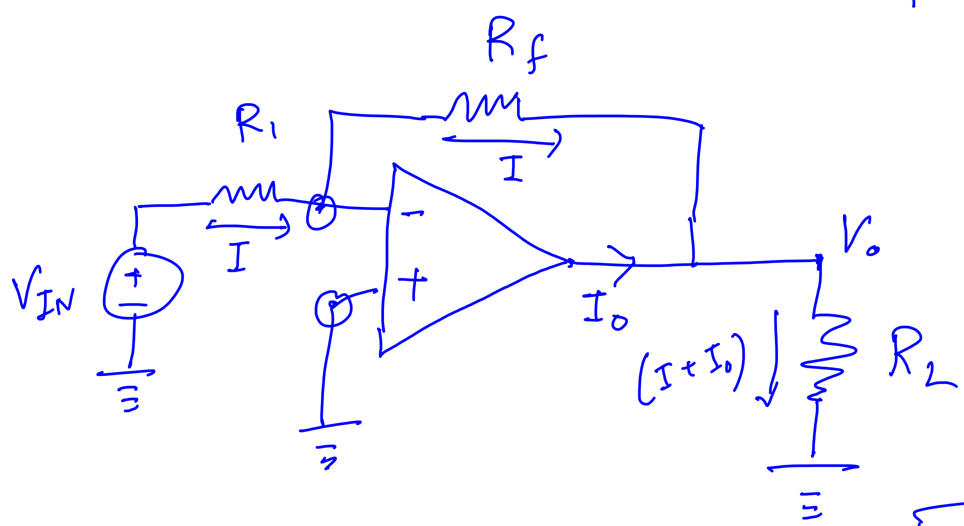
Ex

$R_f = 10\,\Omega$, $R_1 = 1\,\Omega$

$V_{cc} = 5\,V$

$V_{IN} = 1\,V$

$V_o = -5\,V$ (saturation property)




$\boxed{V_- = V_+ = 0}$

✓ $$\frac{V_{IN}}{R_1} = \frac{-V_o}{R_f} = I$$

$$V_o = -\frac{R_f}{R_1} V_{IN}$$

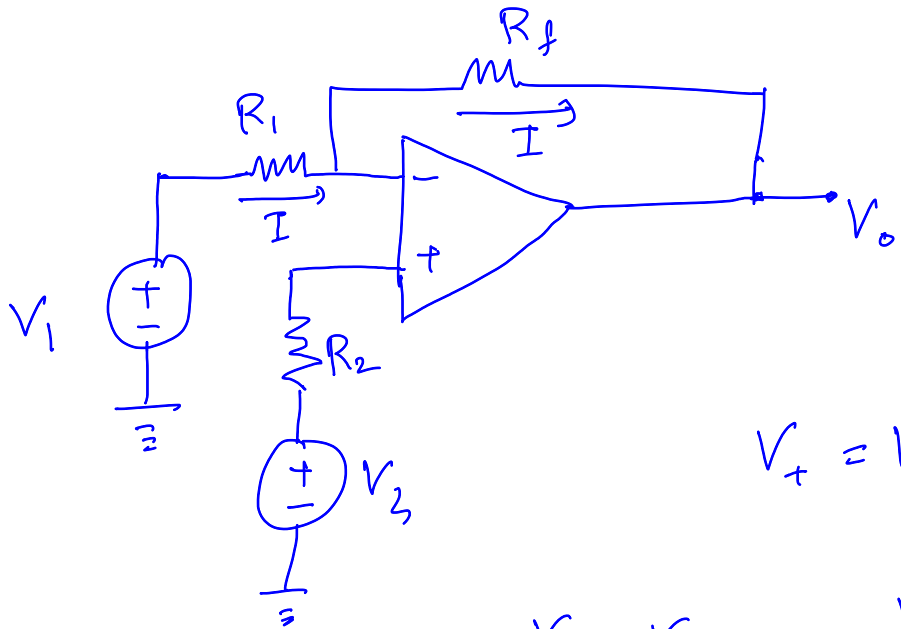
$$I + I_o = \frac{V_o}{R_L} \Rightarrow I_o = \frac{V_o}{R_L} - I$$

$$= \frac{V_o}{R_L} + \frac{V_o}{R_f}$$

$$= V_o \left( \frac{1}{R_L} + \frac{1}{R_f} \right)$$

$$= -\frac{R_f}{R_1} V_{IN} \left( \frac{1}{R_L} + \frac{1}{R_f} \right)$$

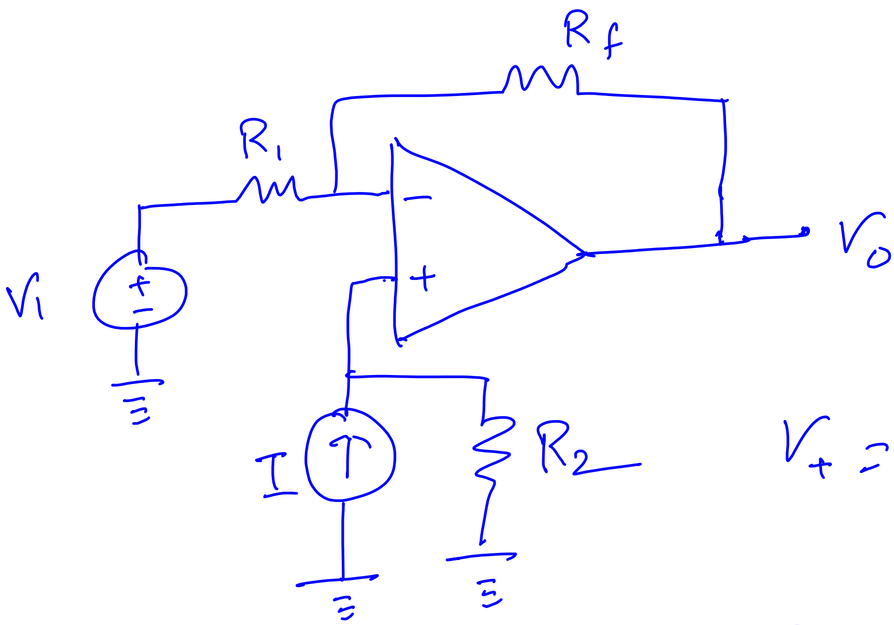
$$I_o = -V_{IN} \frac{R_2 + R_f}{R_1 R_2}$$ (dependent on the load resistance)




$$V_+ = V_2 = V_-$$

$$\frac{V_1 - V_2}{R_1} = \frac{V_2 - V_o}{R_f}$$

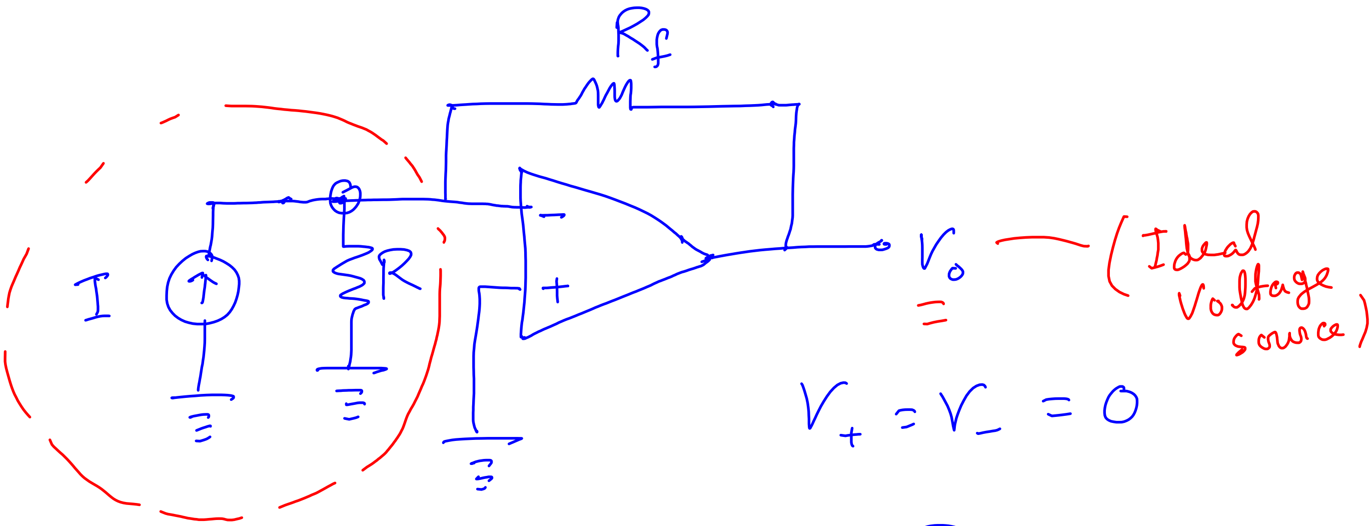
$$V_o = \underbrace{-\frac{R_f}{R_1} V_1}_{\text{contribution from inverting amplification}} + \underbrace{V_2 \left(1 + \frac{R_f}{R_1}\right)}_{\text{contribution from non-inverting amplification}}$$




$$V_+ = IR_2 = V_-$$

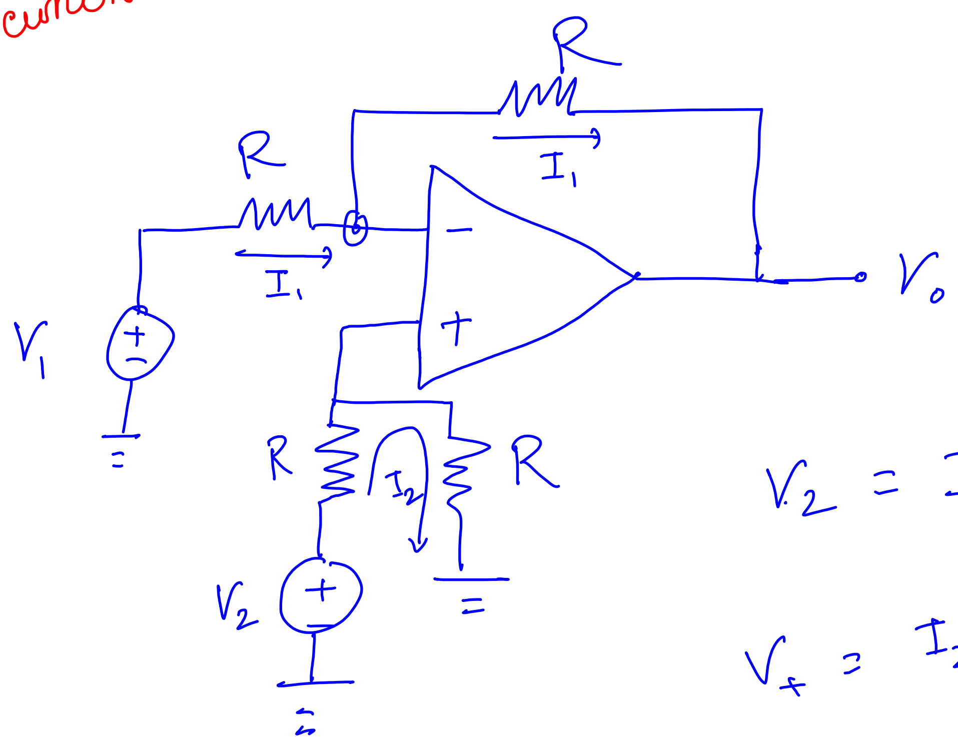
$$\frac{V_1 - IR_2}{R_1} = \frac{IR_2 - V_o}{R_f}$$

$$V_o = -\frac{R_f}{R_1}V_1 + IR_2\left(1+\frac{R_f}{R_1}\right)$$




$$V_+ = V_- = 0$$

$$V_o = -IR_f$$




$$V_2 = I_2\, 2R$$

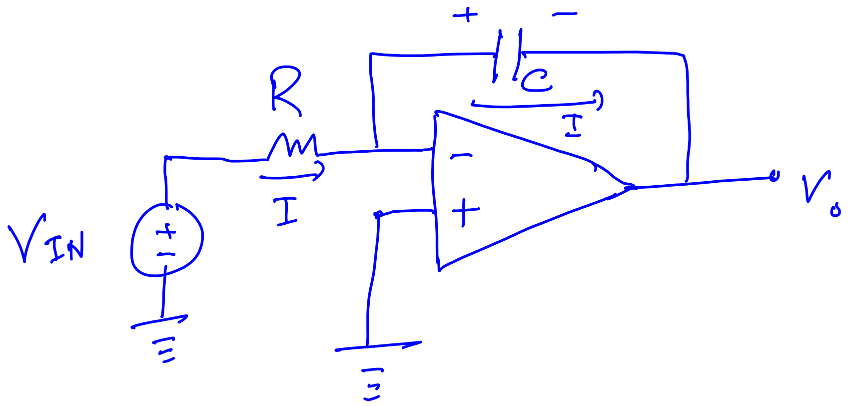
$$V_+ = I_2 R = \frac{V_2}{2R} R$$

$$= \frac{V_2}{2}$$

$$\Rightarrow V_- = \frac{V_2}{2}$$

$$\frac{V_1 - \frac{V_2}{2}}{R} = \frac{\frac{V_2}{2} - V_o}{R}$$

$$V_o = V_2 - V_1 \quad \text{( substraction)}$$



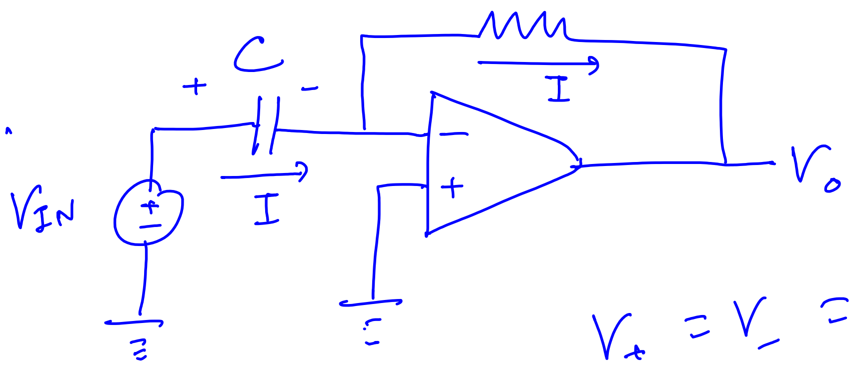

$$V_C(0) = 0$$

$$V_+ = V_- = 0$$

$$\frac{V_{IN}}{R} = -C\frac{dV_o}{dt}$$

$$V_o(t) = -\frac{1}{RC}\int_0^t V_{IN}(\tau)\,d\tau$$

(Integrator)



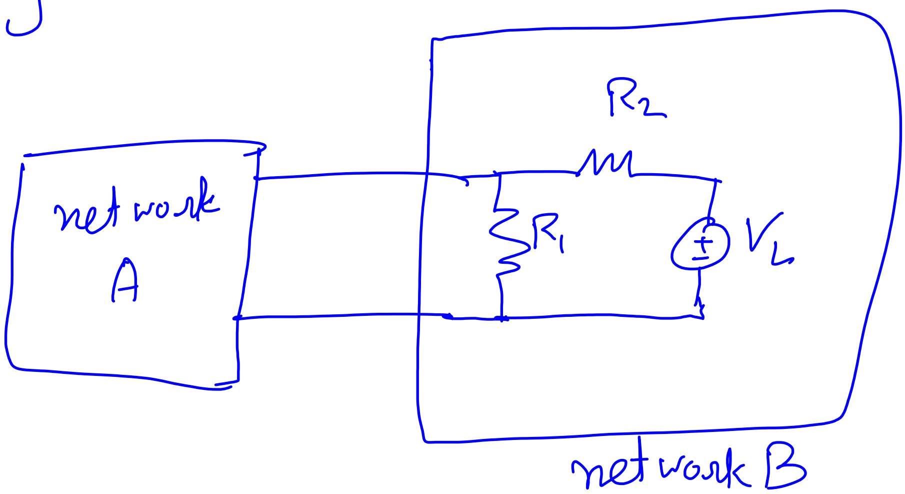

$$V_C(0) = 0$$

$$V_+ = V_- = 0$$

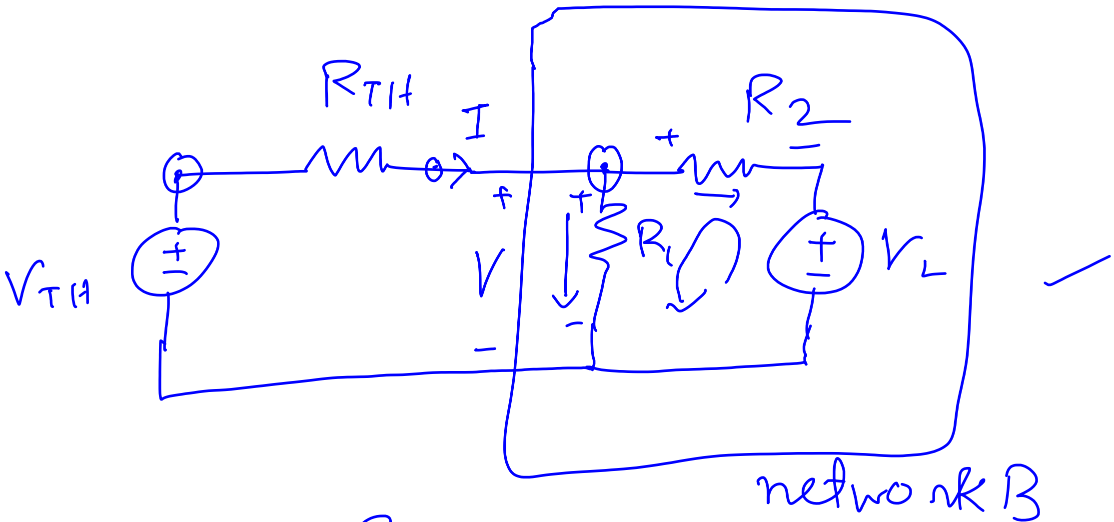
$$C\frac{dV_{IN}}{dt} = -\frac{V_o}{R}$$

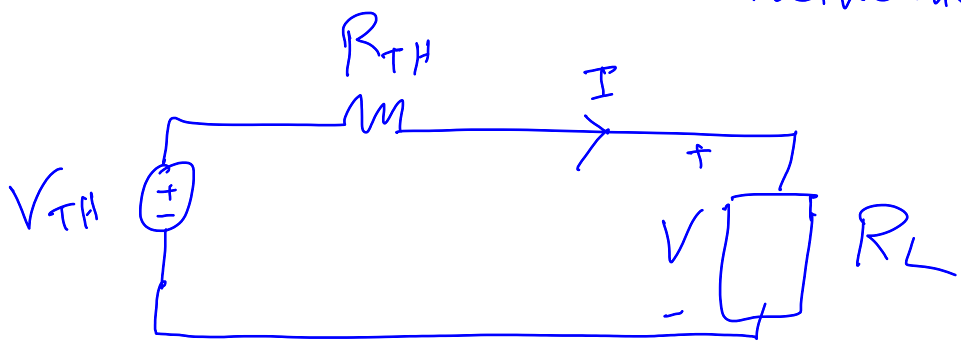
$$V_o = -RC\frac{dV_{IN}}{dt}$$ (Differentiator)

Q.3> (Assignment 1)




What should be the magnitude of $V_2$ such that maximum power is delivered to network B?




From maximum power transfer $V = \frac{V_{TH}}{2}$.

$$\Rightarrow \quad I = \frac{V_{TH}}{2R_{TH}}, \qquad I_{R1} = \frac{V_{TH}}{2R_1}$$

$$I = I_{R1} + I_{R2}$$

$$I_{R2} = I - I_{R1}$$

$$= \frac{V_{TH}}{2}\left(\frac{1}{R_{TH}} - \frac{1}{R_1}\right)$$

$$-V_L - V_{R2} + V_{R1} = 0$$

$$V_L = V_{R1} - V_{R2}$$

$$= \frac{V_{TH}}{2} - I_{R2} \cdot R_2$$

$$= \frac{V_{TH}}{2} - \frac{V_{TH}}{2}\left(\frac{1}{R_{TH}} - \frac{1}{R_1}\right) \cdot R_2$$