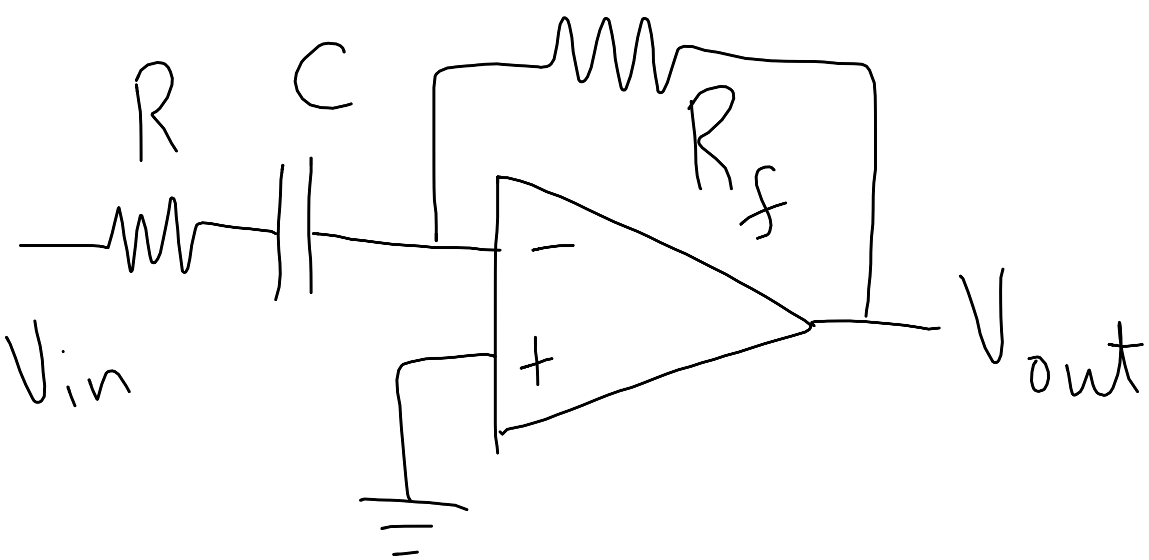
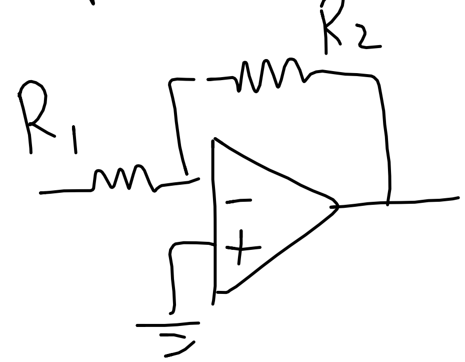


Assume V_{in} is AC

Recall



Gain $= -R_2/R_1$

$$\text{Gain} = \frac{-Z_f}{Z_{in}}$$

$$Z_f = R_f \qquad Z_{in} = R - \frac{i}{\omega C}$$

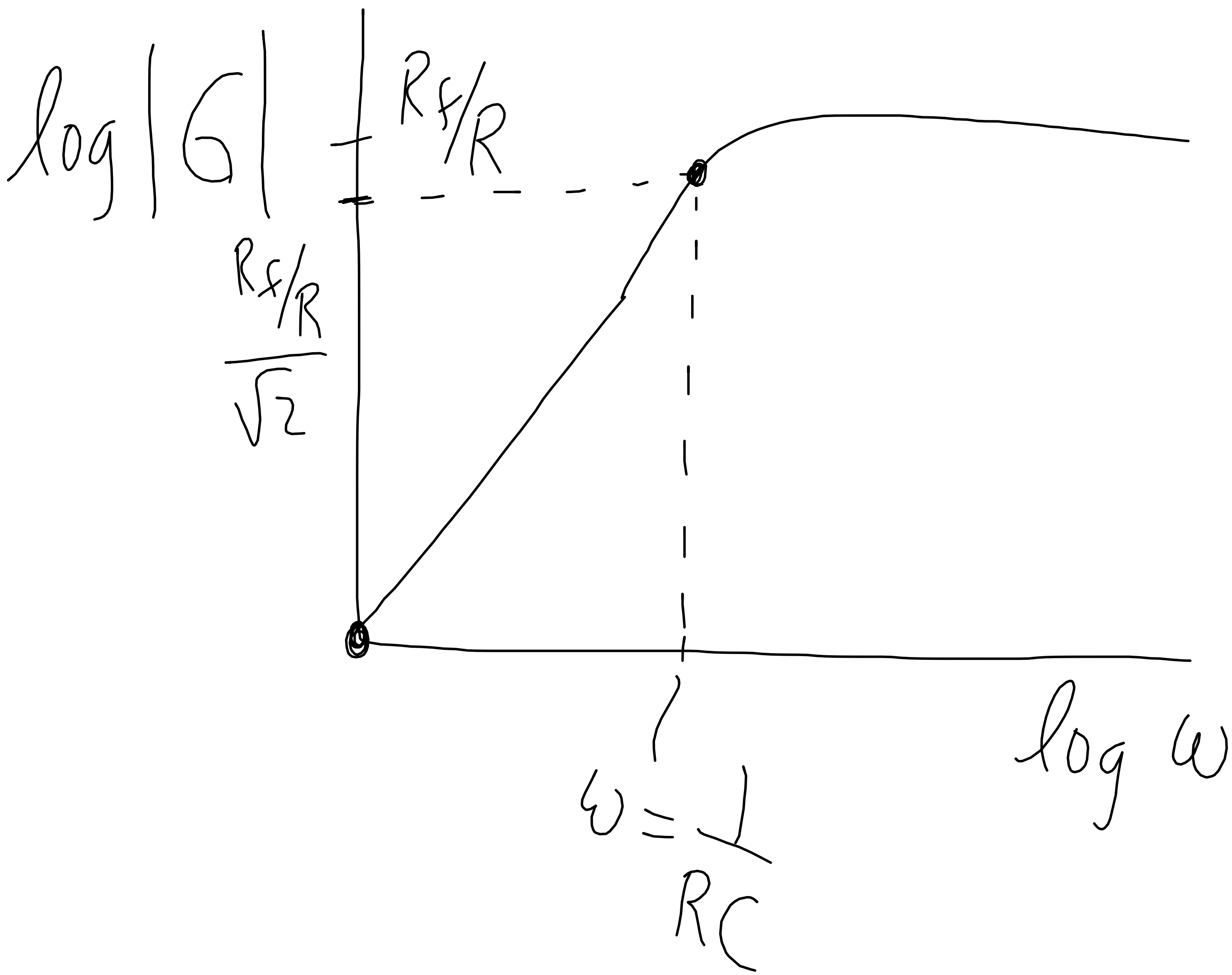
$$\text{Gain} = \frac{-R_f}{R - \frac{i}{\omega C}} \cdot \frac{R + i/\omega C}{R + i/\omega C} = \frac{-R_f R - \frac{iR_f}{\omega C}}{R^2 + \frac{1}{\omega^2 C^2}}$$

$$\text{Gain} = -\frac{R_f}{R} \frac{R^2 + \frac{iR}{\omega C}}{R^2 + \frac{1}{\omega^2 C^2}}$$

$$= -\frac{R_f}{R} \frac{1 + \frac{i}{\omega RC}}{1 + \frac{1}{\omega^2 R^2 C^2}}$$

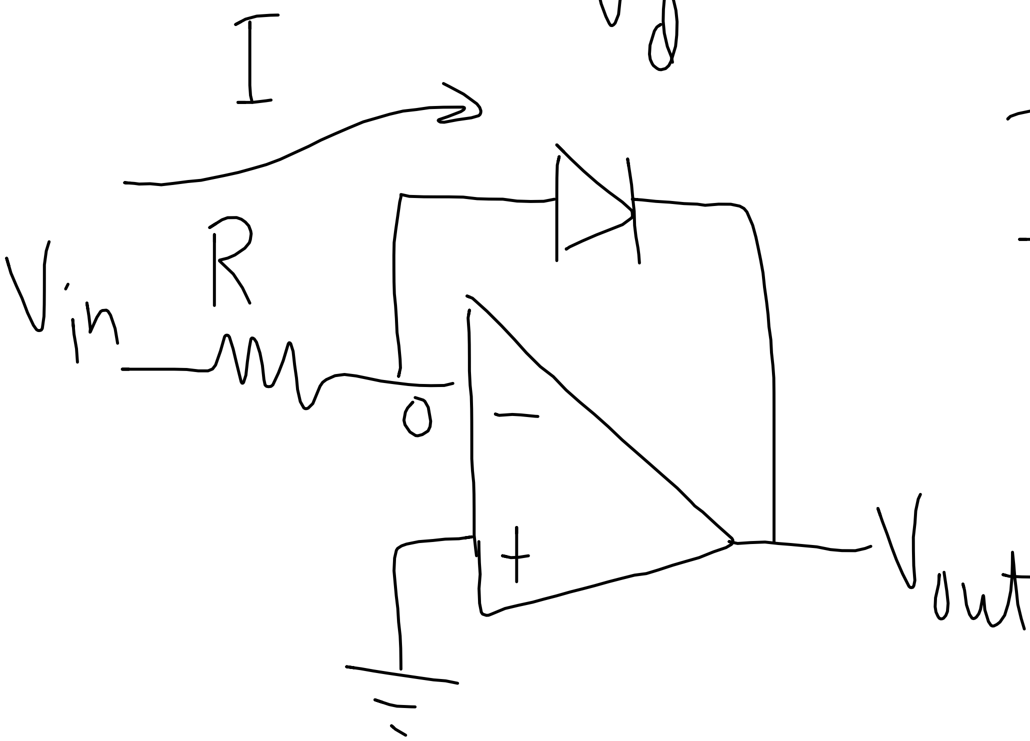
let $x = \omega RC$

$$= -\frac{R_f}{R} \frac{1 + i/x}{1 + 1/x^2} \xrightarrow[\text{value}]{\text{Abs}} \frac{R_f}{R} \frac{\sqrt{1 + \frac{1}{x^2}}}{1 + \frac{1}{x^2}} = \frac{R_f/R}{\sqrt{1 + \frac{1}{x^2}}}$$


log |G|
Rf/R
Rf/R / √2
log ω
ω = 1/RC

Ebers-Moll model

$$I_d \simeq I_{sat}\, e^{V_d/V_T}, \quad V_T = \frac{k_B T}{e}$$



$$I = \frac{V_{in}}{R} = I_d$$

$$V_{out} = -V_d$$

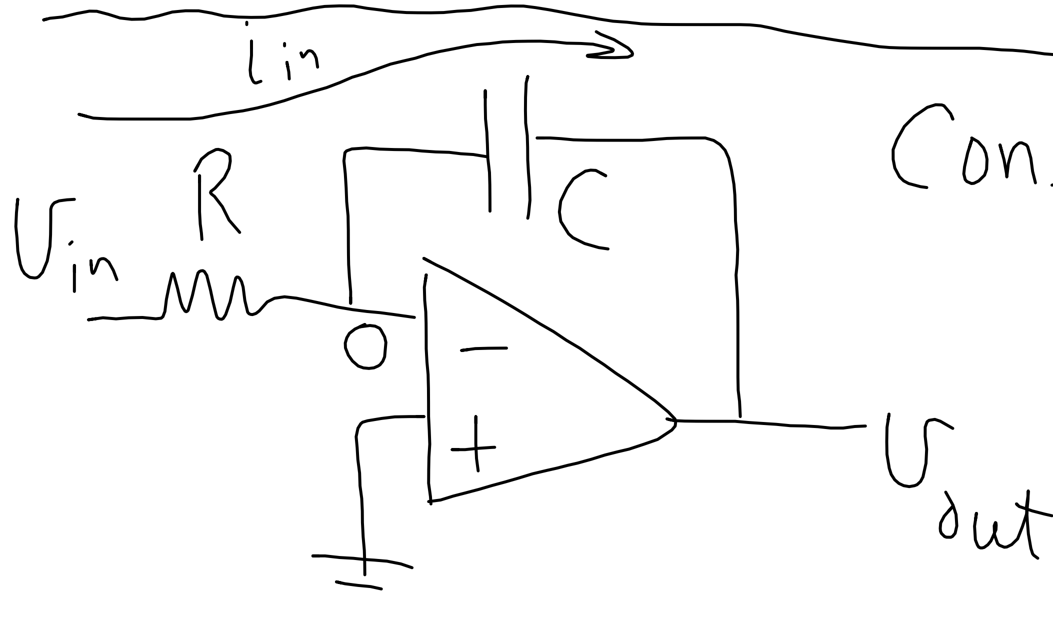
$$I_d \approx I_{sat}\, e^{V_d/V_T}, \quad V_T = \frac{k_B T}{e}$$

$$V_d = V_T \ln \frac{I_d}{I_{sat}}$$

$$V_{out} = -V_T \ln \frac{I_d}{I_{sat}}$$

$$= V_T \left[\ln I_{sat} - \ln I_d\right] = V_T \left[\ln I_{sat} - \ln \frac{V_{in}}{R}\right]$$

$$V_{out} = V_T \left[\ln I_{sat} - \ln \frac{V_{in}}{R} \right]$$



Consider AC $\Rightarrow$ lower case $v + i$

$$v_{out} = -v_C$$

$$= \frac{-q}{C}$$

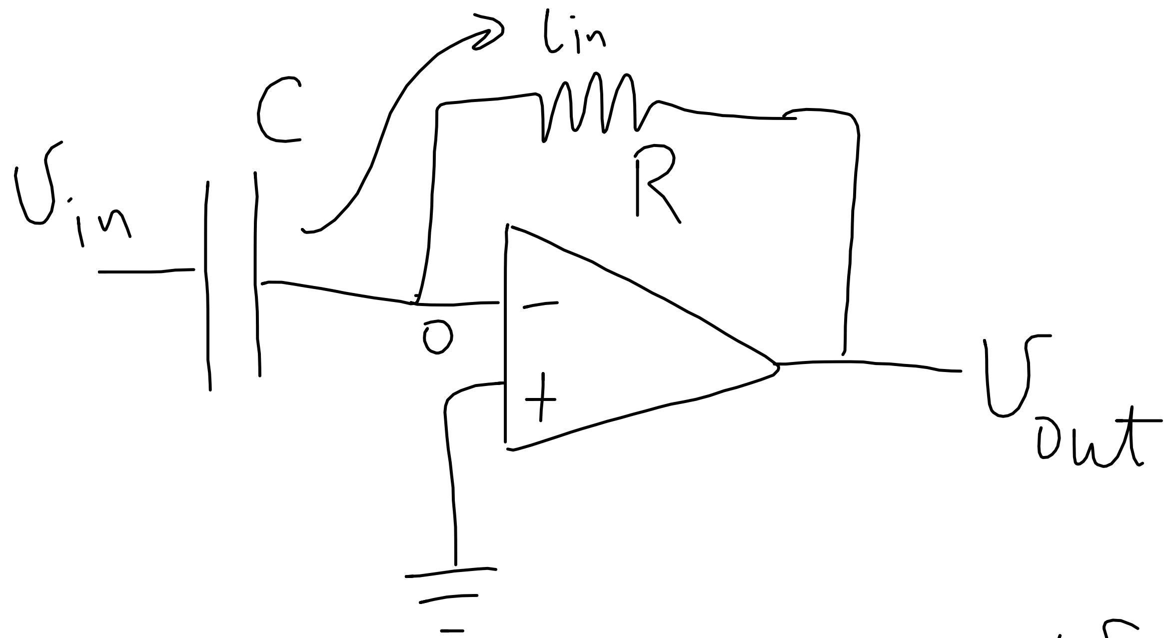
$$i_{in} = \frac{v_{in}}{R}$$

$$\frac{dv_{out}}{dt} = \frac{-dq/dt}{C} = \frac{-i_{in}}{C}$$

$$\frac{dv_{out}}{dt} = \frac{-v_{in}}{RC}$$

$$v_{out} = -\frac{1}{RC}\int v_{in}\,dt + C$$

Integrator



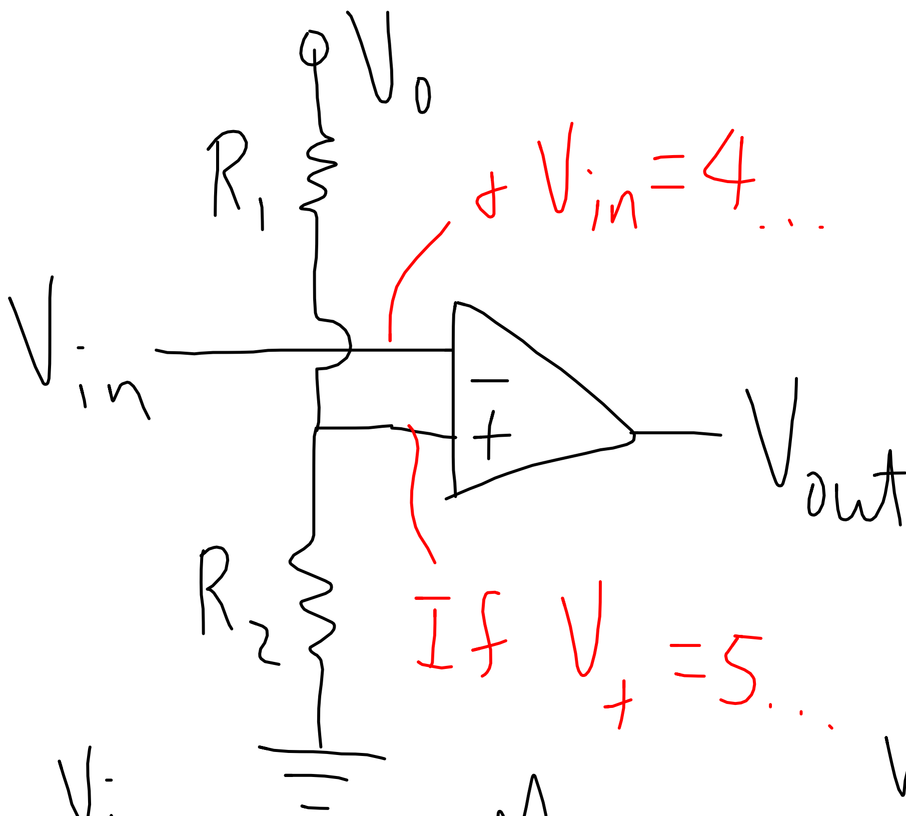
$$V_{out} = -i_{in} R$$

$$V_{in} = V_c = \frac{q}{C}$$

$$\frac{dV_{in}}{dt} = \frac{dq/dt}{C} = \frac{i_{in}}{C} = \frac{-V_{out}}{RC}$$

$$V_{out} = -RC \frac{dV_{in}}{dt}$$ differentiator

Suppose we construct

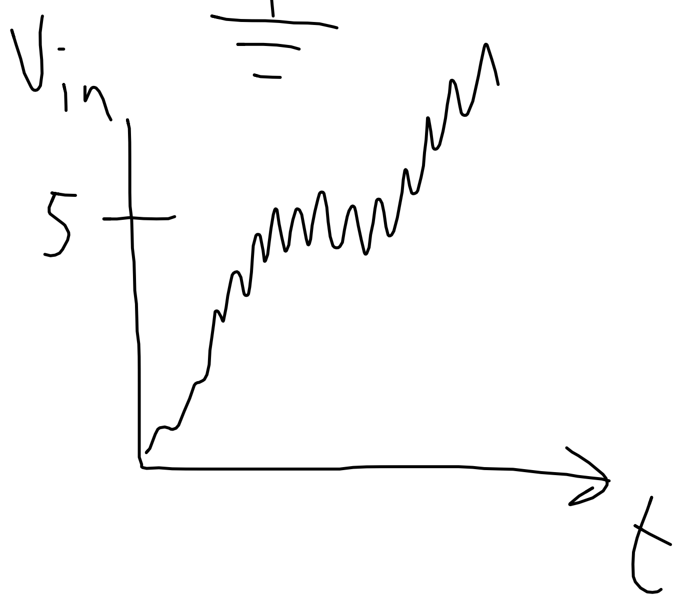


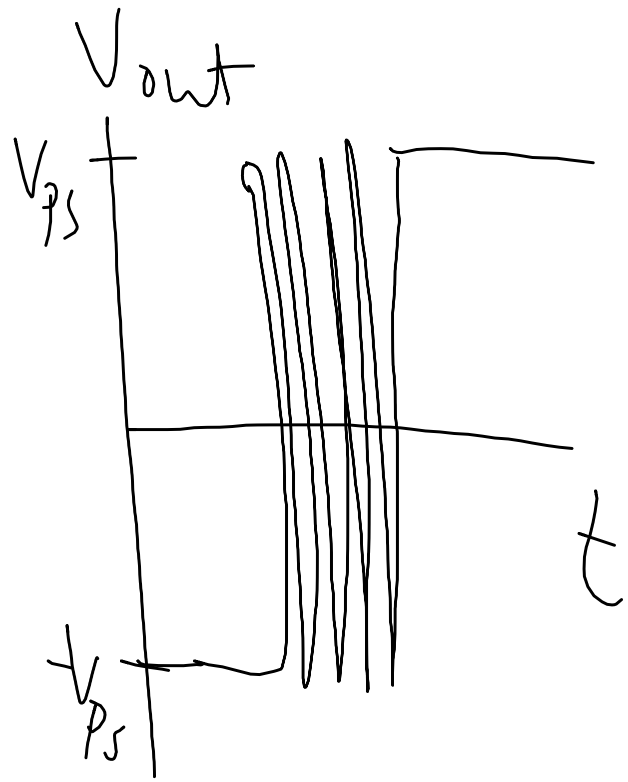
$+V_{in} = 4 \ldots$

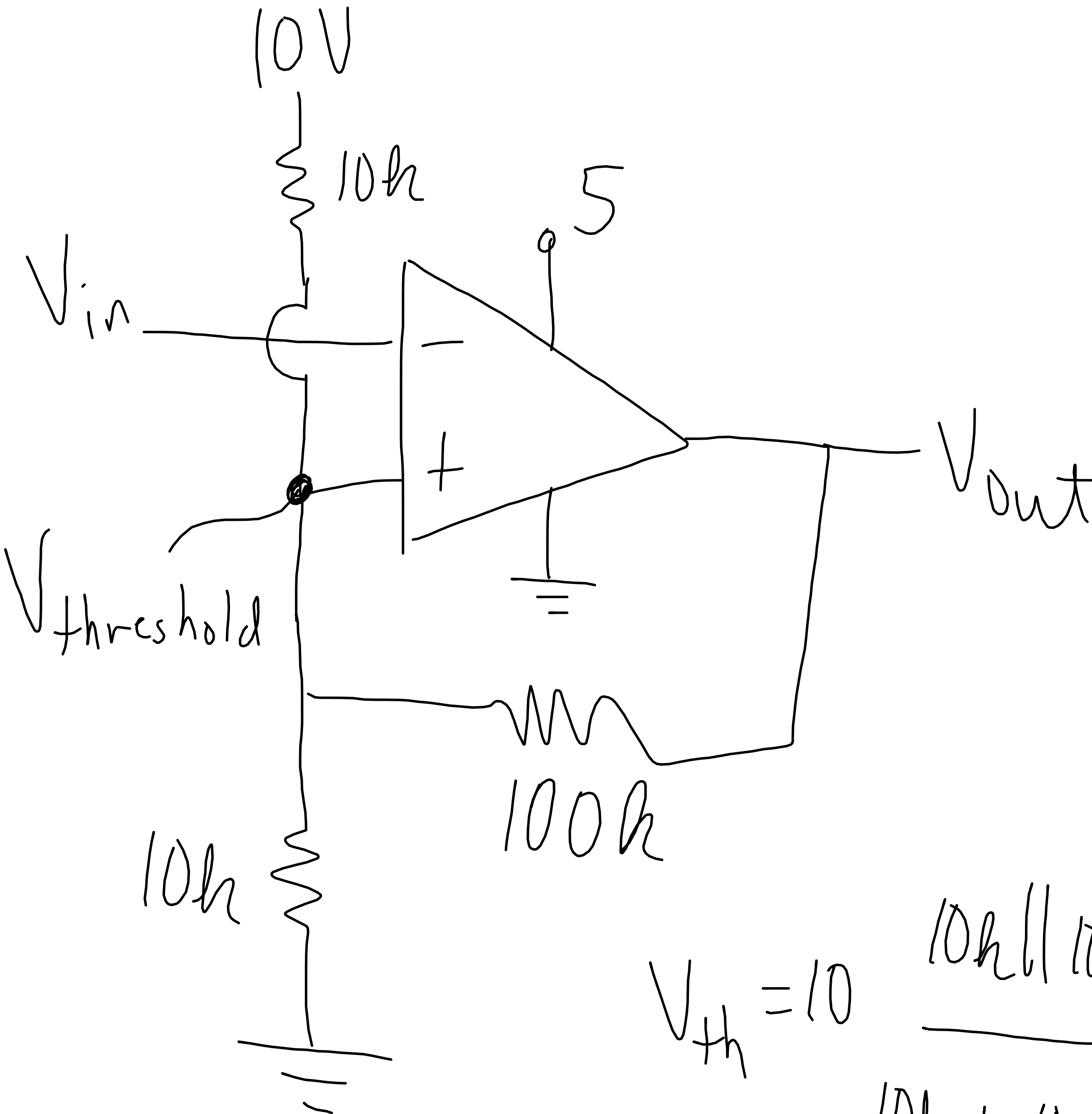
If $V_{in} = 6$, $V_{out} \Rightarrow -V_{ps}$

$\Rightarrow +V_{\text{Power supply}}$

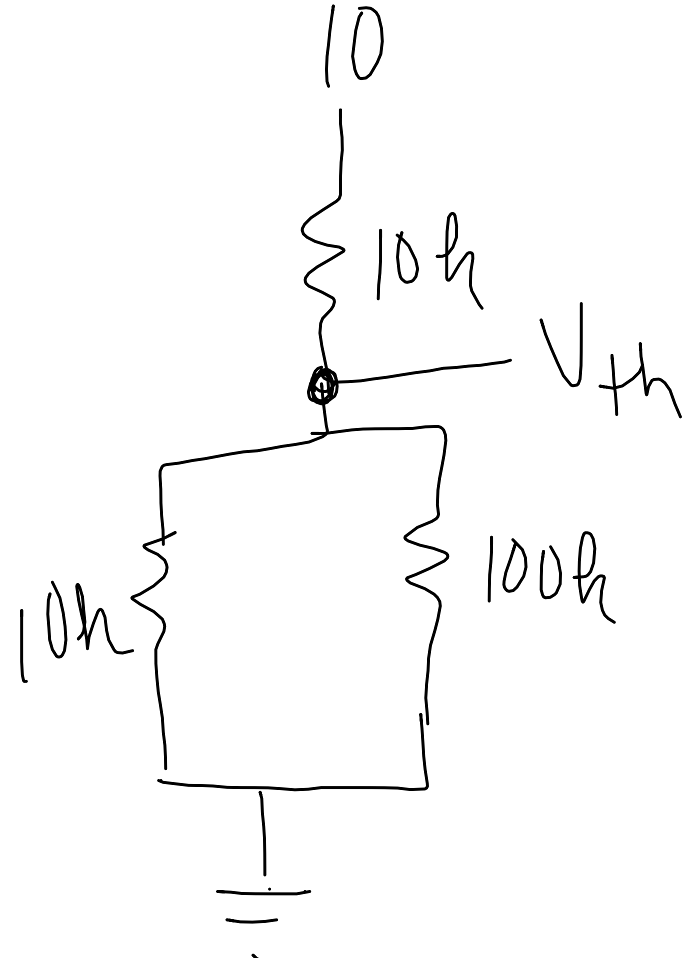
If $V_+ = 5 \ldots$







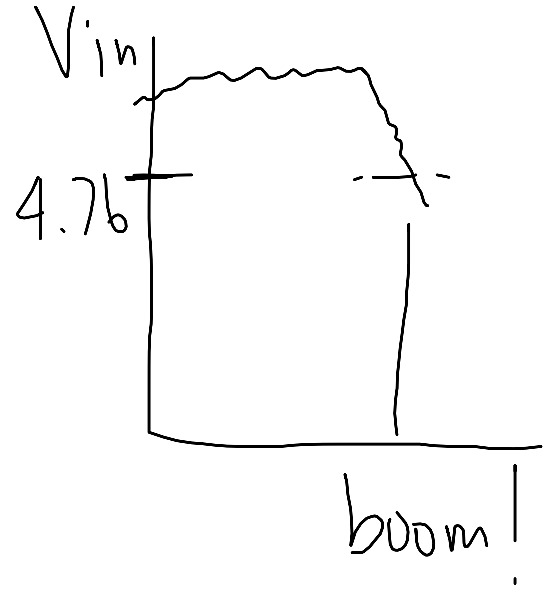
Assume V_{out} is 0.

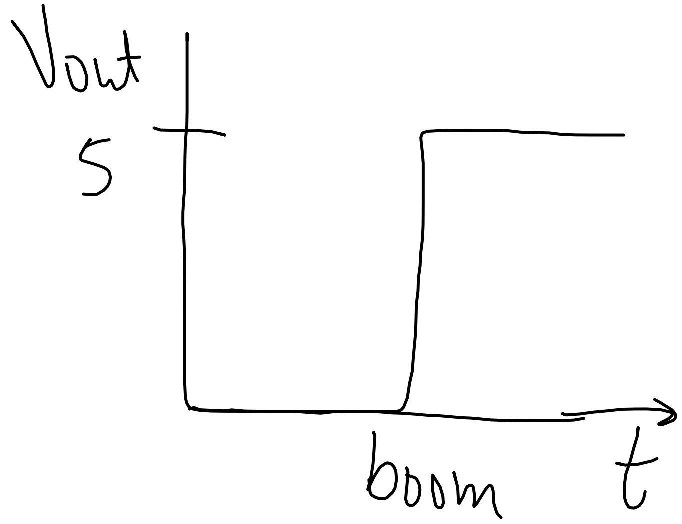


$$V_{th} = 10 \; \frac{10k \,||\, 100k}{10k + 10k \,||\, 100k}$$

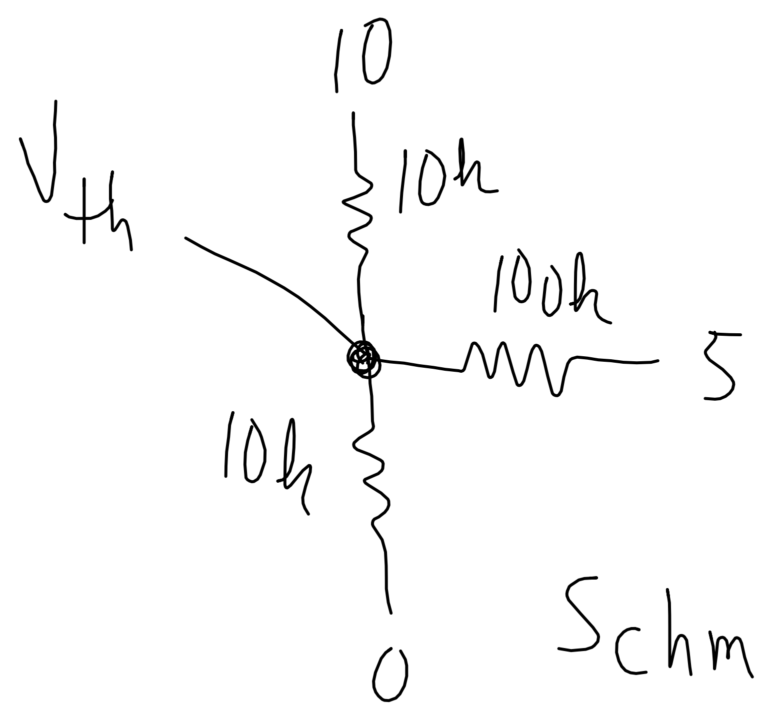
$$\frac{(10k)(100k)}{110k} = 9.\overline{09}\,k \qquad = 4.76\ V$$

So





Now $V_{out} = 5V$. where is V_{th}?



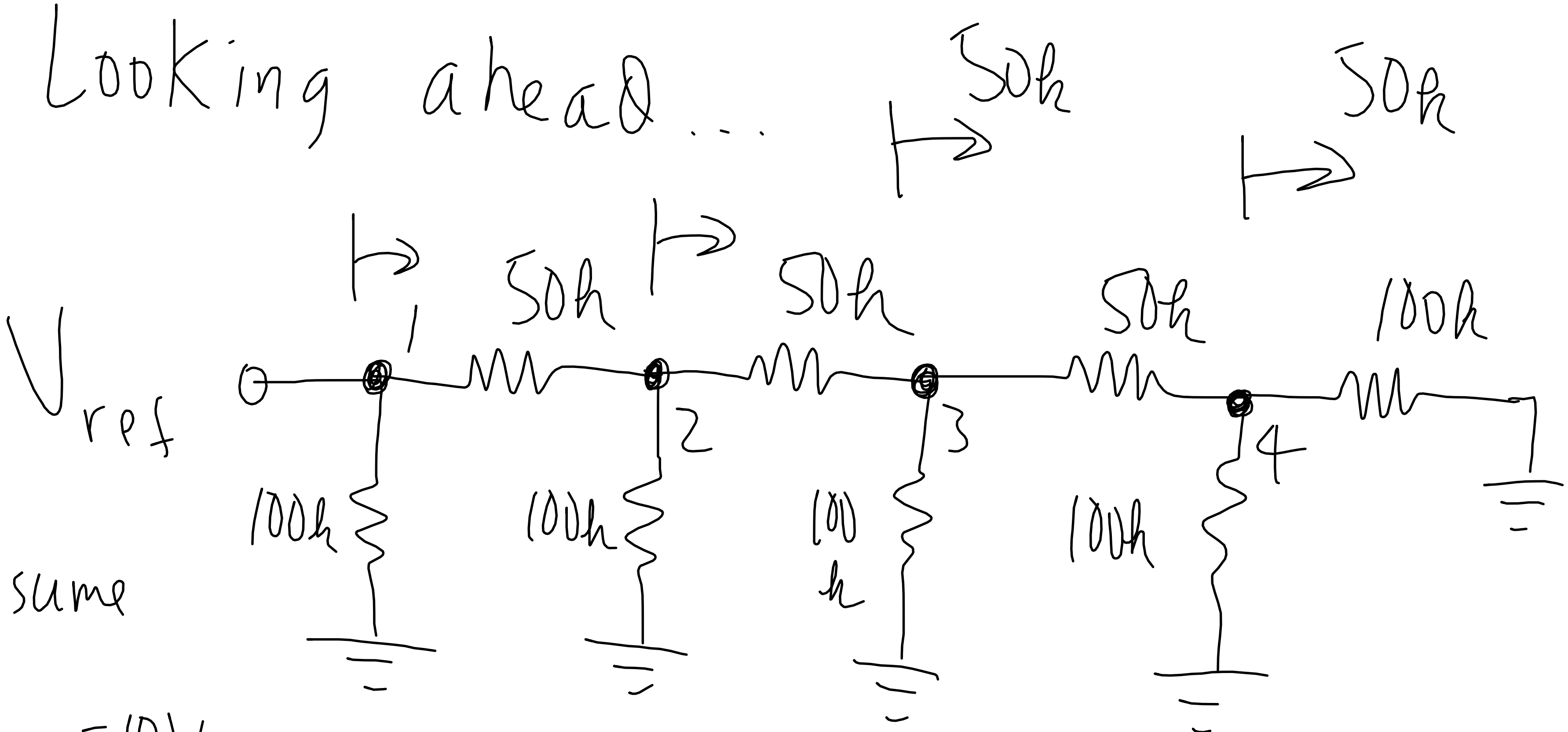
$$\frac{10 - V_{th}}{10k} + \frac{5 - V_{th}}{100k} + \frac{0 - V_{th}}{10k} = 0$$

$$10(10 - V_{th}) + 5 - V_{th} = 10 V_{th}$$

Schmitt trigger

$$105 = 21 V_{th} \quad V_{th} = 5V$$

Looking ahead...



Assume

$V_{ref} = 10V$

$V_1 = 10$ $V_2 = 5V$ $V_3 = 2.5V$ $V_4 = 1.25V$