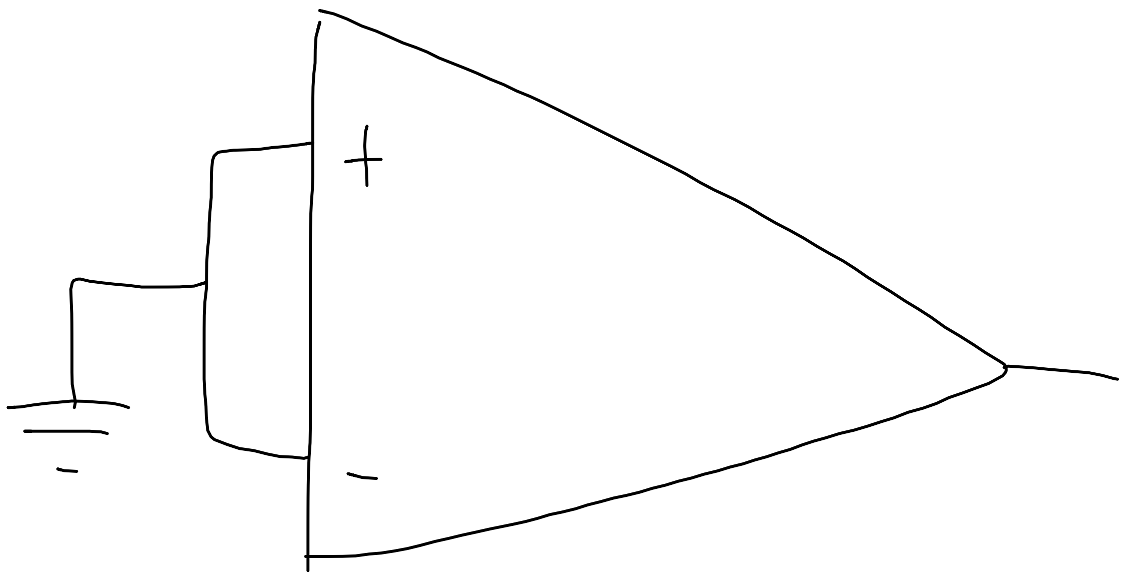
Departures from ideal op amp behavior

Golden rules:

1. No input currents
2. Output makes inputs same voltage

1. is violated if <u>any</u> curent goes in or out
2. is violated if: (assuming feedback network)
   A. If gain isn't infinite (or large enough)
   B. If response is too slow

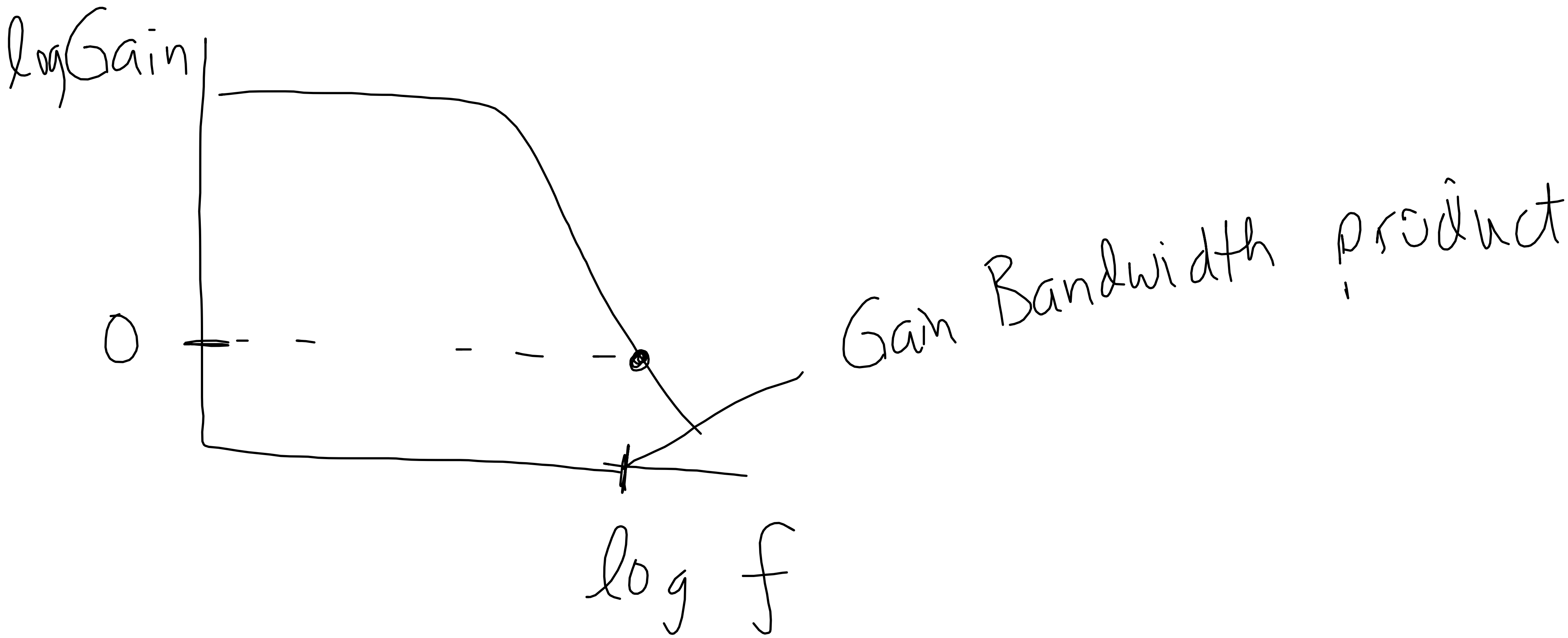
Input offset voltage



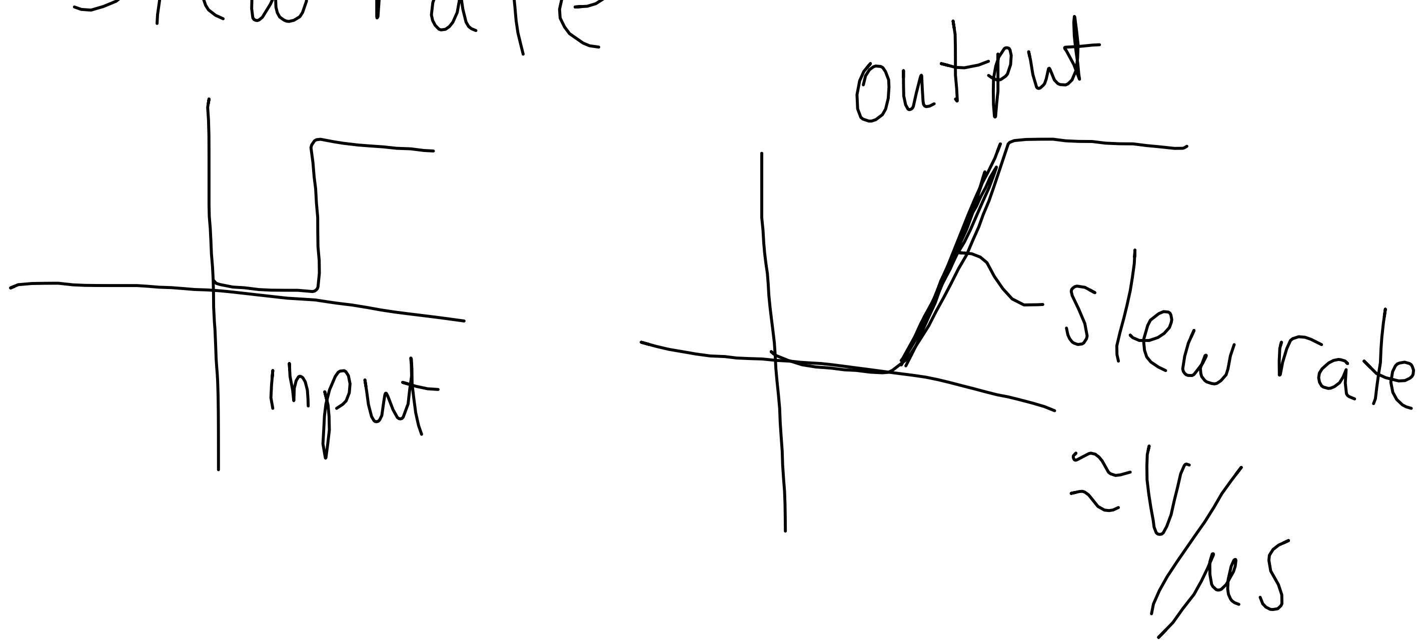
V_{out} should be zero!

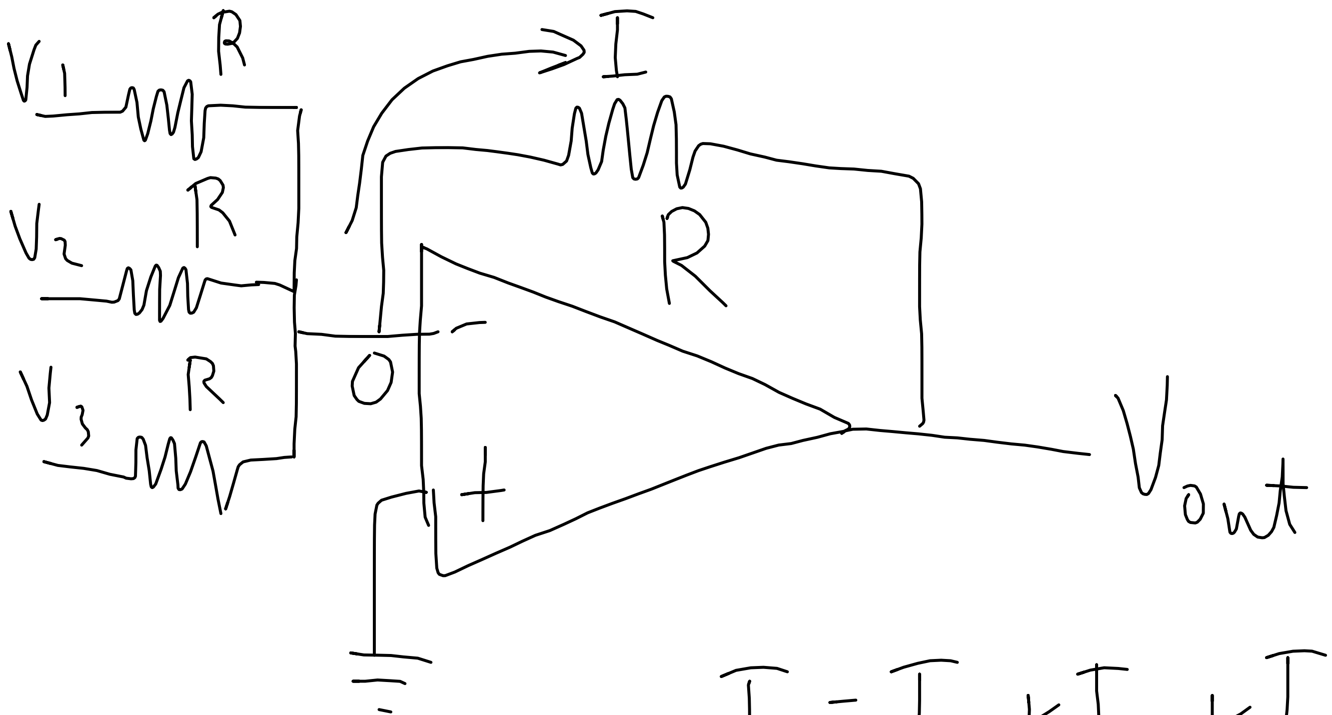
Input bias current

Input offset current


logGain
0
log f
Gain Bandwidth product

Slew rate


output
input
slew rate
≈V/µs



$$I = I_1 + I_2 + I_3$$

$$I_1 = \frac{V_1}{R}$$

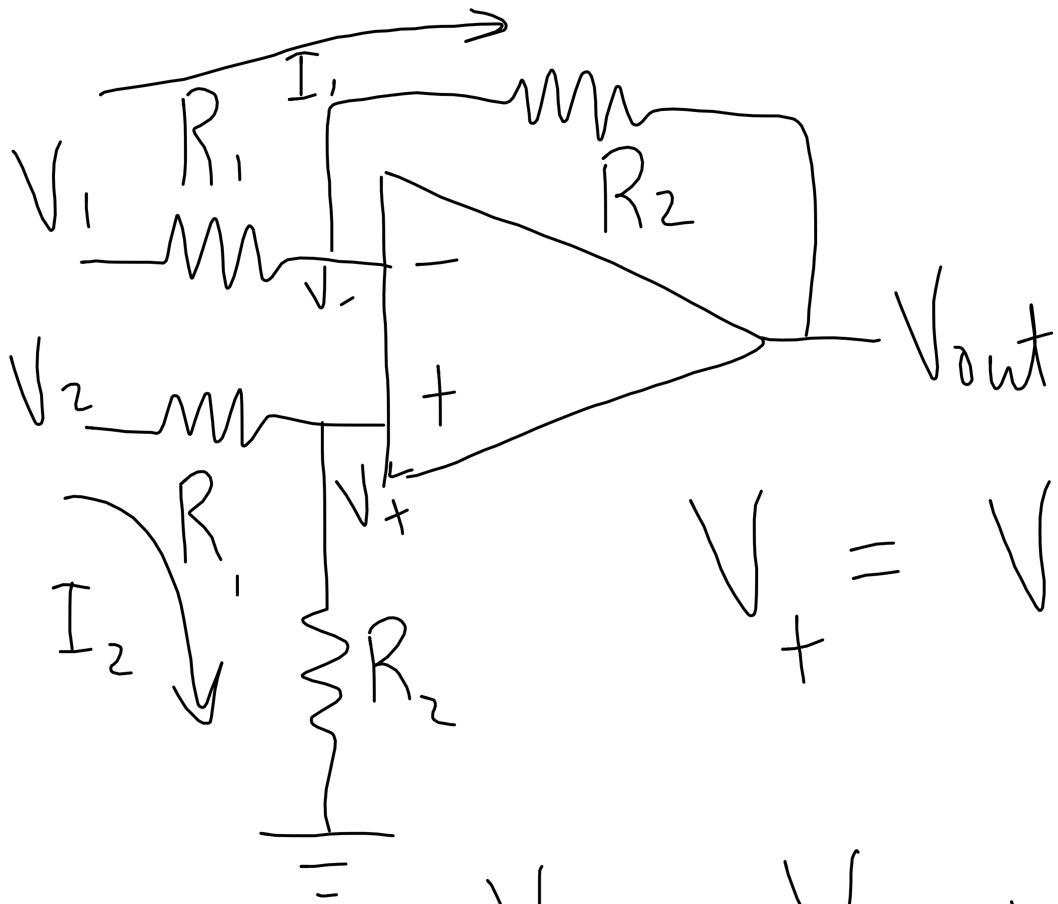
$$I_2 = \frac{V_2}{R}$$

$$I_3 = \frac{V_3}{R}$$

$$V_{out} = -IR = -\left(\frac{V_1}{R} + \frac{V_2}{R} + \frac{V_3}{R}\right)R$$

$$= -(V_1 + V_2 + V_3)$$

Summing amplifier



Think about voltage dividers....

$$V_+ = V_2 \frac{R_2}{R_1+R_2}$$

$$V_- = V_1 + (V_{out} - V_1)\frac{R_1}{R_1+R_2}$$

$$V_2 \frac{R_2}{R_1+R_2} = V_1 + \left(V_{out} - V_1\right)\frac{R_1}{R_1+R_2}$$

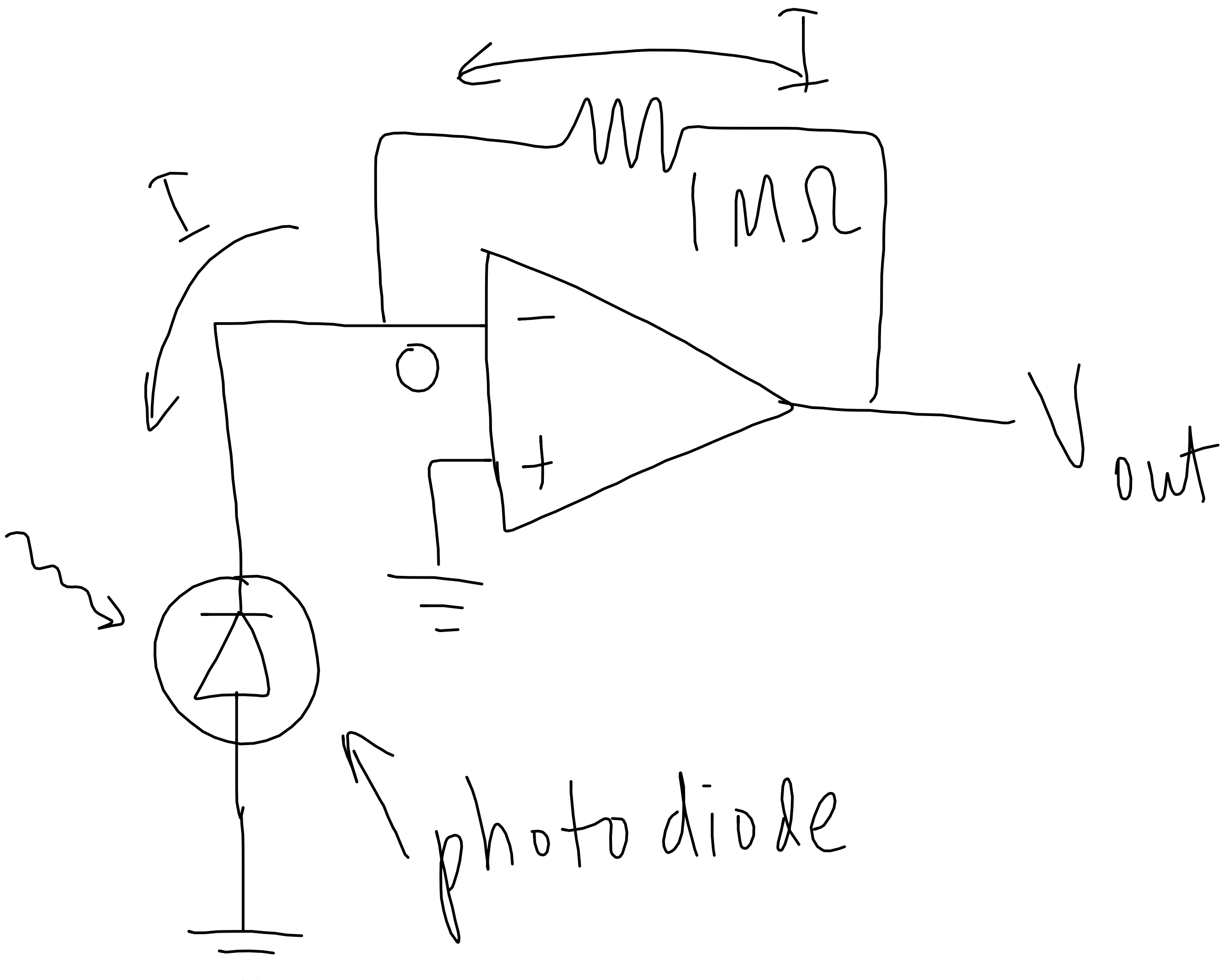
$$= V_1\left[1 - \frac{R_1}{R_1+R_2}\right] + V_{out}\left[\frac{R_1}{R_1+R_2}\right]$$

$$V_2\left(\frac{R_2}{R_1+R_2}\right) = V_1\left(\frac{R_2}{R_1+R_2}\right) + V_{out}\left(\frac{R_1}{R_1+R_2}\right)$$

$$(V_2-V_1)\left(\frac{R_2}{\cancel{R_1+R_2}}\right) = V_{out}\left(\frac{R_1}{\cancel{R_1+R_2}}\right)$$

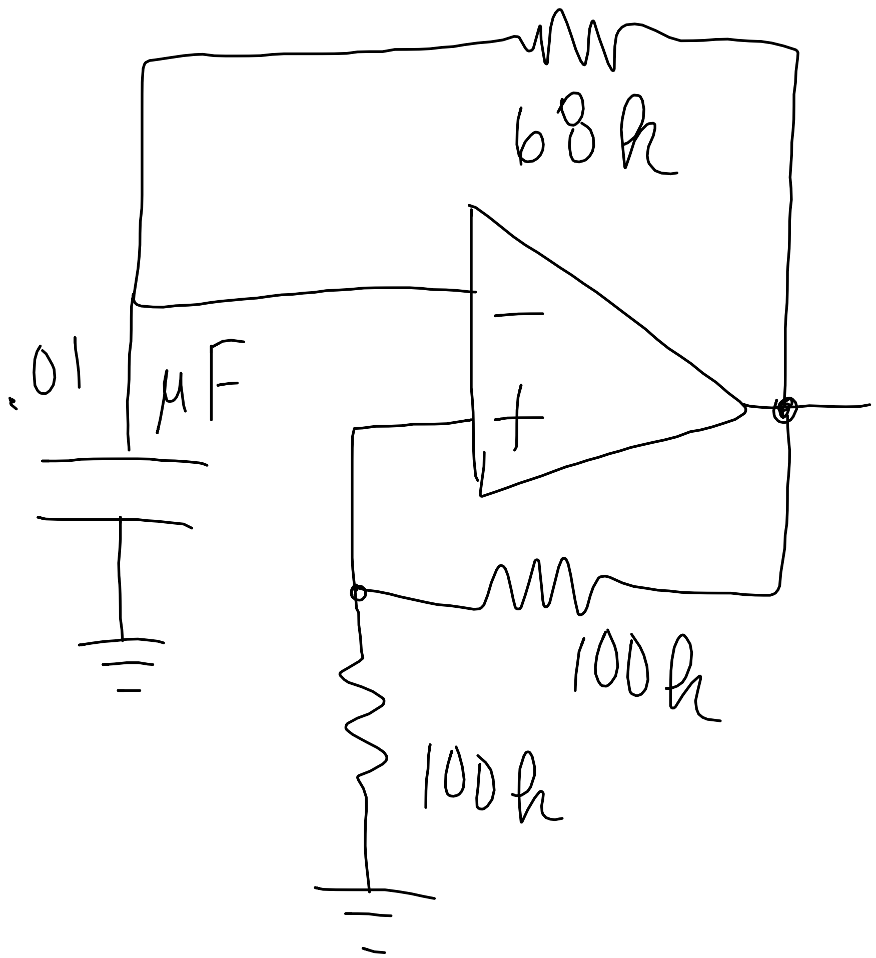
$$V_{out} = (V_2-V_1)\frac{R_2}{R_1}$$

difference amplifier



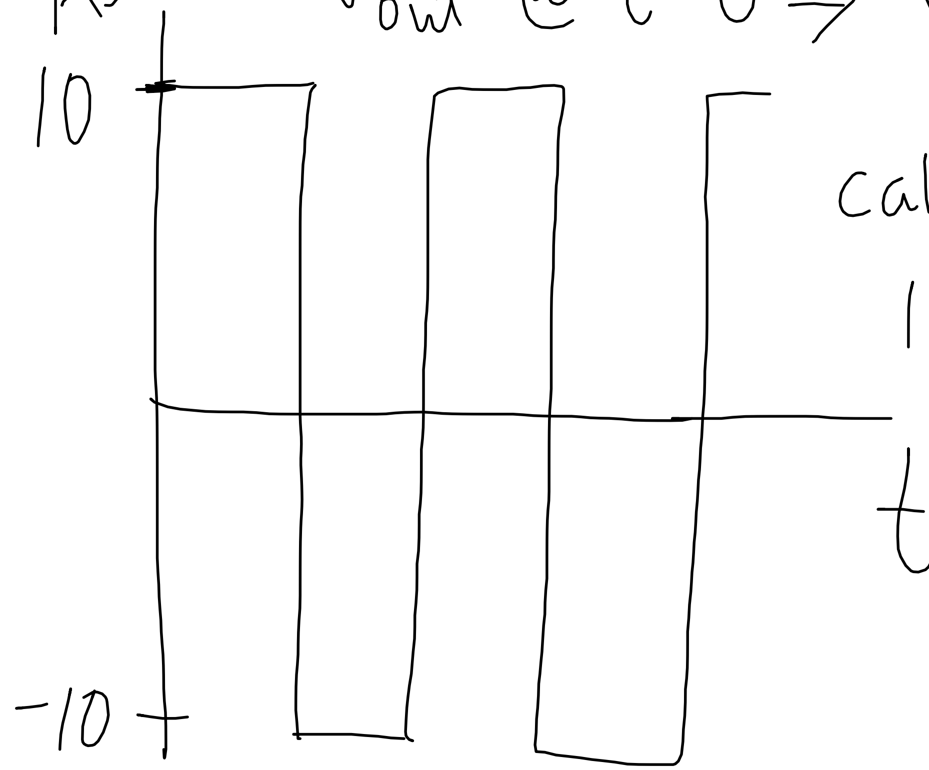
$$V_{out} = 1 \frac{V}{\mu A}$$

current-to-voltage converter



Assume V_{out} @ $t=0 \Rightarrow V_{max\ out}$

call it 10V



free running oscillator