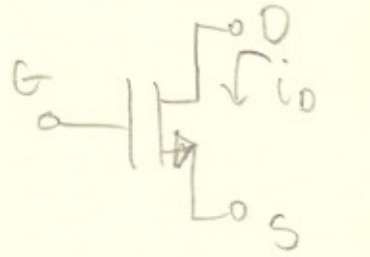
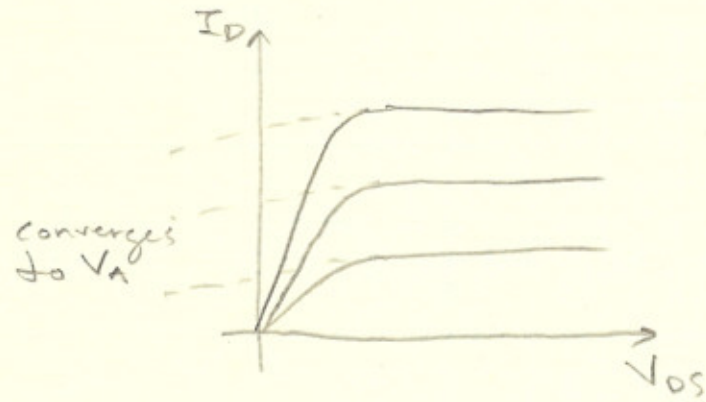
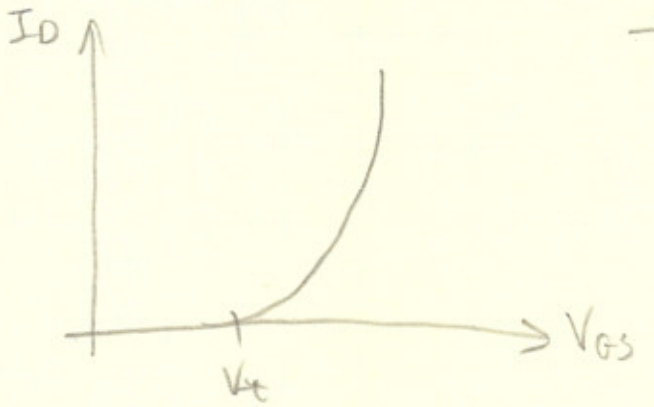
MOS FET Equations







CUTOFF: $I_D = 0 \quad V_{GS} < V_t$

TRIODE: $I_D = K\left[2(V_{GS} - V_t)V_{DS} - V_{DS}^2\right]$

$V_{DS} < V_{GS} - V_t$

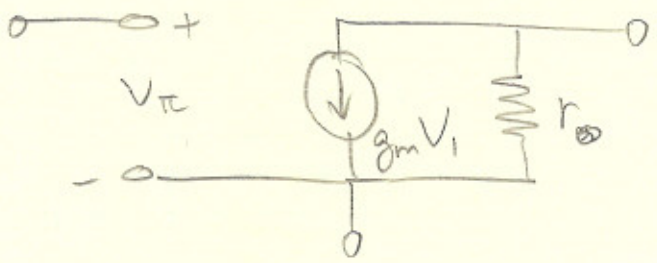
ACTIVE: $I_D = K(V_{GS} - V_t)^2$

$V_{DS} \geq V_{GS} - V_t$

For output resistence

$$\lambda = \frac{1}{V_A}$$

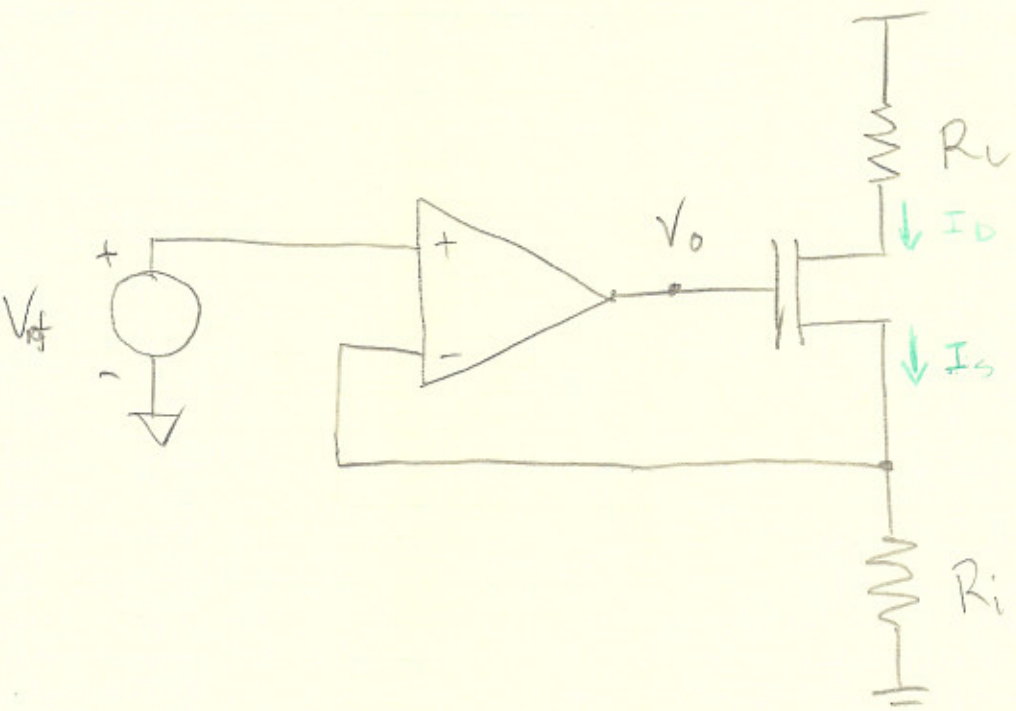
Small signal



$$g_m = \frac{\partial I_S}{\partial V_{GS}}$$

$$r_o = \frac{\partial I_D}{\partial V_{DS}}$$

Current Source



$$I_S = \frac{V_{ref}}{R_1} \Rightarrow I_D$$

$$I_D = I_D = k(V_{GS} - V_t)^2$$

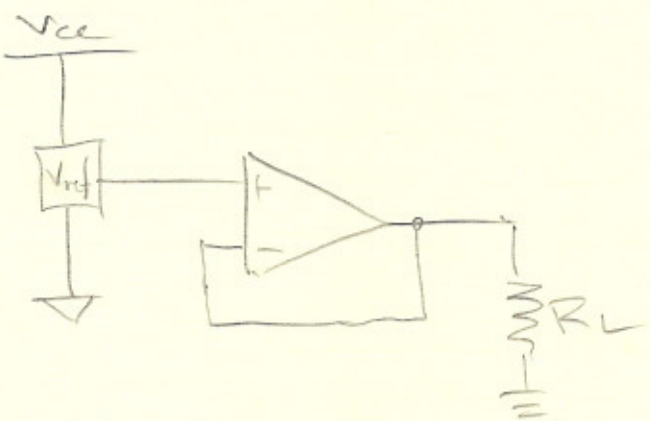
$$V_{GS} = V_{OA} - V_{ref}$$

$$\frac{V_{ref}}{R_1} = k(V_{GS} - V_t)^2$$

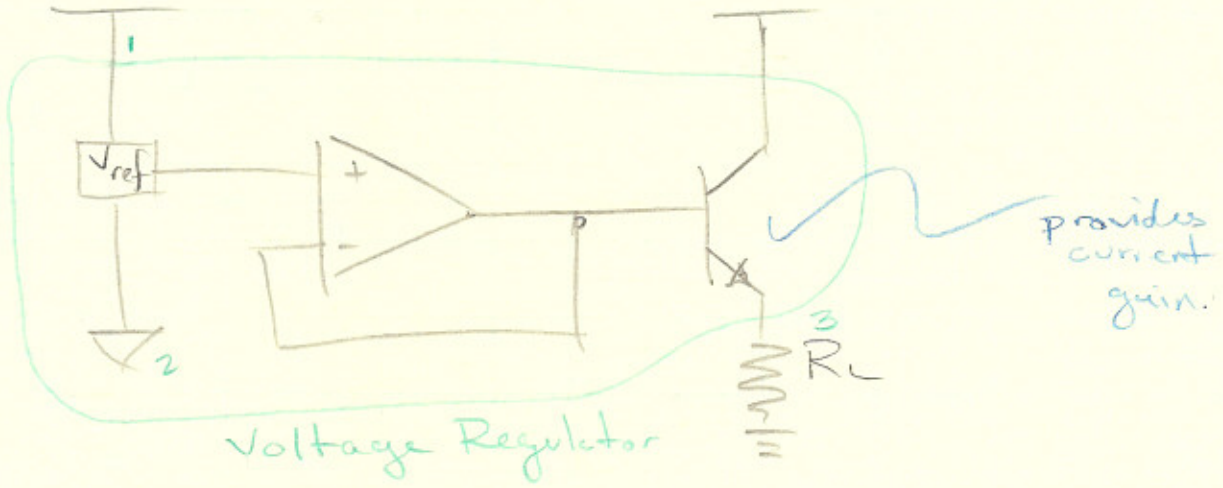
$$\frac{V_{ref}}{R_1} = k\left(V_{OA} - V_{ref} - V_t\right)^2$$

$$V_{OA} = V_{ref} + V_t \pm \sqrt{\frac{V_{ref}}{kR_1}}$$

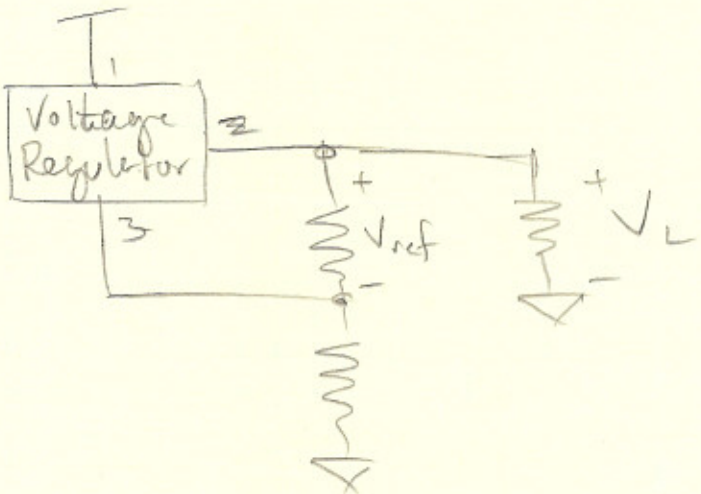
Voltage Regulators



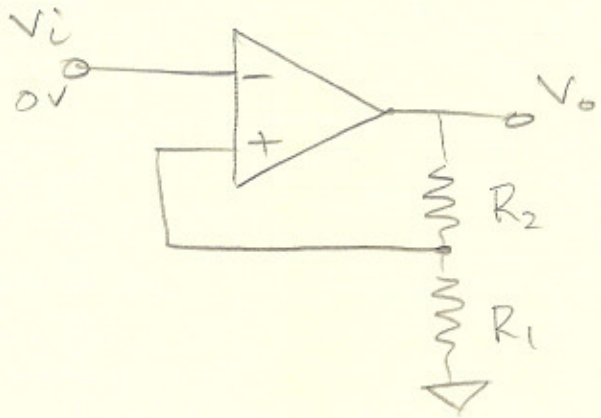
When the load requires more current.



Adjustable Voltage divider ($V_{out} > V_{ref}$)

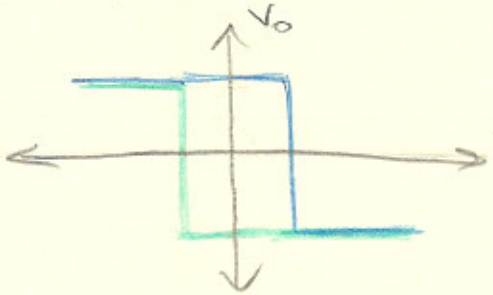


Comparator



$$V^+ = V_{cc}\frac{R_1}{R_2+R_1} > 0$$

then the circuit is saturated positive there is positive feedback.



$V_o = V_{cc}$

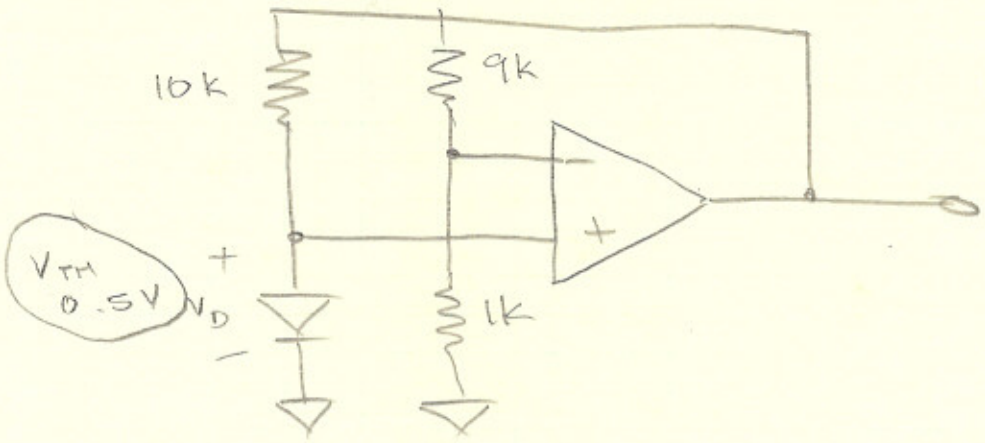
if V_I is increased until it reaches

$$V_i = V^- > V^+$$

then the output becomes $-V_{cc}$; It will stay this way until

$$V_i = V^- < V^+ = -V_{cc}\frac{R_1}{R_2+R_1}$$

EX:



Find the stable equilibrium points.

Suppose $V_o = -V_{cc}$ $\begin{cases} V^- = \frac{-V_{cc}}{10} \\ V^+ = -V_{cc} \end{cases}$

$$V_{ID} = -V_{cc} + \frac{V_{cc}}{10} = -\frac{9}{10}V_{cc} < 0$$

Therefore the out put will stay at V_{cc}

$V_o = +V_{cc}$ $\begin{cases} V^- = \frac{V_{cc}}{10} \\ V^+ = 0.5V \end{cases}$

$$\boxed{V_{ID} = V^+ - V^-}$$

$$= 0.5V - \frac{V_{cc}}{10} < 0$$

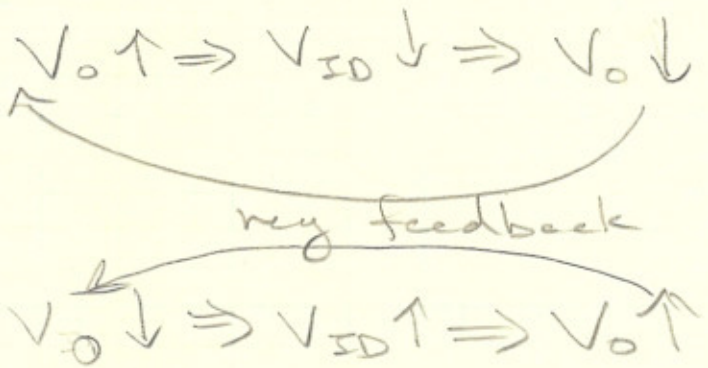
$\therefore V_o = +V_{cc}$ is not stable

However, the system does have an equilibrium point at

$$V_{ID} = 0 = 0.5V - \frac{V_o}{10}$$

$$V_o = 5V$$

Stable ?



This holds true until the diode goes in reverse bias

$$0 < V_o \leq 0.5V$$

$$V_o = V^+$$

$$V^- = V_o \frac{1}{10}$$

$$V_{ID} = V_o - V_o \frac{1}{10}$$

$\therefore$ V_o will go to V_{cc} but stop at $V_o = 5V$.