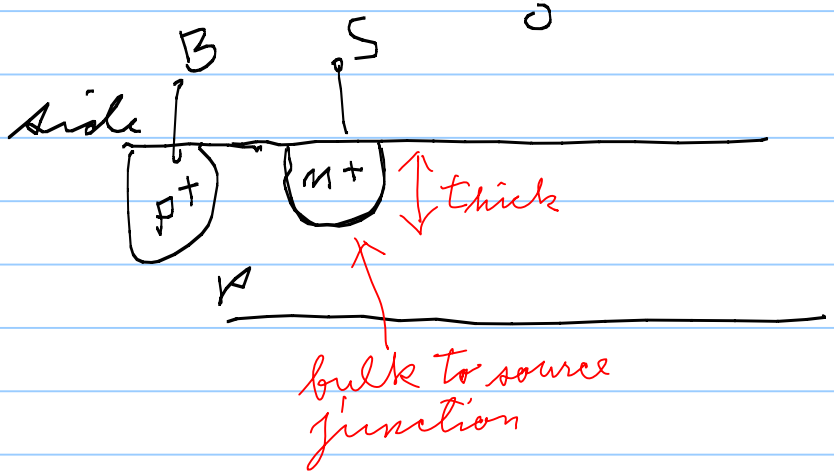
EE 302

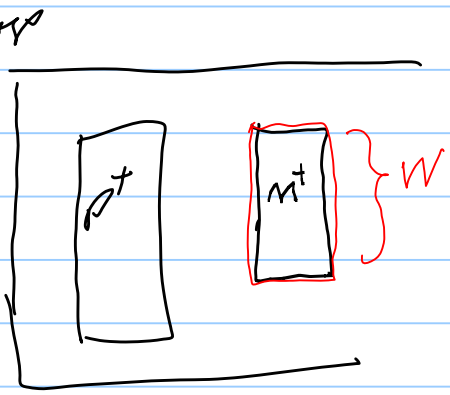
Note Title 2/17/2004

diode

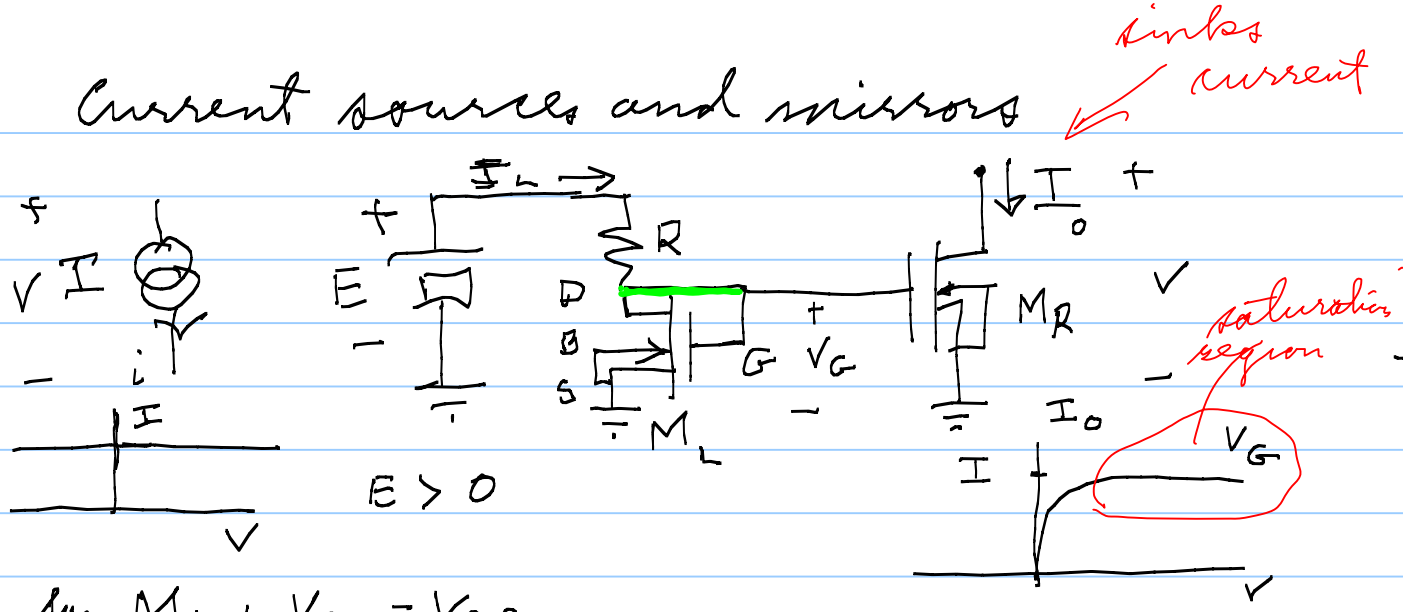
$I_D \Rightarrow IS \cdot (e^{V_{BS}/VT} - 1)$; IS (model 1)

$\Rightarrow$ IJ · WT · thick $(e^{V_{BS}/V_T} - 1)$ (model 2)





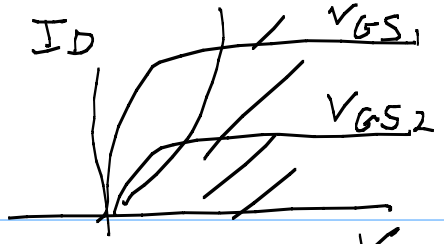
Current sources and mirrors



for M_L : $V_{DS} = V_{GS}$

if compare V_{DS} with $V_{GS} - V_{th}$ means for $I_L > 0$

we see $V_{DS} = V_{GS} > V_{GS} - V_{th}$ need $E > V_{th} > 0$

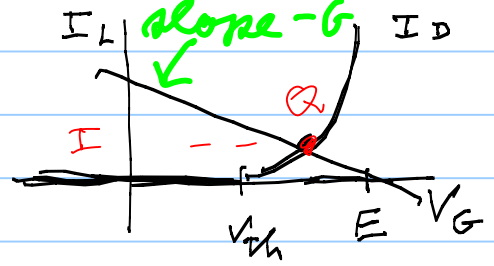


means M_L is in saturation // = saturation

$$I_D = \frac{KP}{2}\cdot\frac{W}{L}\left(V_{GS} - V_{th}\right)^2 \text{ if } V_{GS} \geq V_{th}$$

$I_D = 0$ otherwise

plot I_L vs $V_G = V_{GS} = V_{DS}$; $I_D = I_L$ by KCL



by KVL: $V_G = E - RI_L$

solve for $I_L = G(E - V_G)$; $G = \frac{1}{R}$

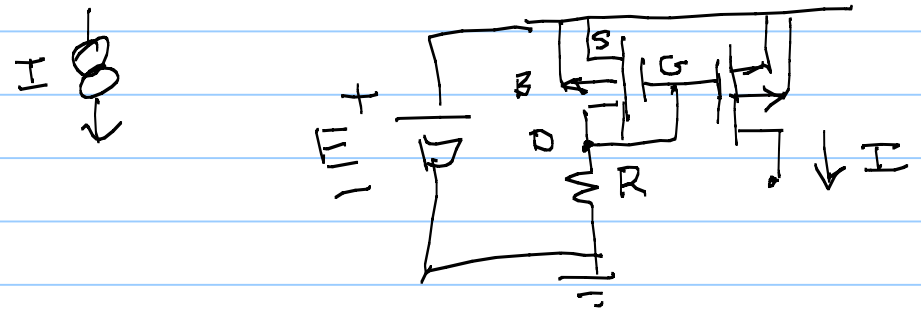
(a load line on the transistor curve)

if $M_R = M_L$ and M_R is kept in saturation

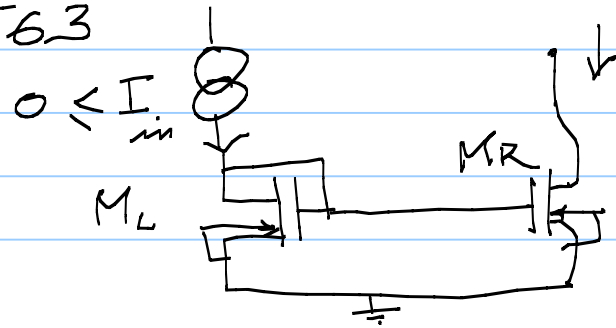
then $I_{D_{M_L}} = I_{D_{MR}} = I$ (depends on the load.)

$V_{DS_{MR}} \geq V_G - V_{th}$

To "source" current



see p. 563



$I_{out} \approx I_{in}$ if keep right transistor in saturation if $M_R = M_L$

Eqn. for current source $I_L = I$, $V_G = V$

$$I = I_L = G(E - V) = \frac{KP}{2}\frac{W}{L}(V - V_{th})^2$$

$$V = E - RI; \quad I = \frac{KP}{2}\frac{W}{L}((E - RI) - V_{th})^2 = \beta(E - RI - V_{th})^2$$

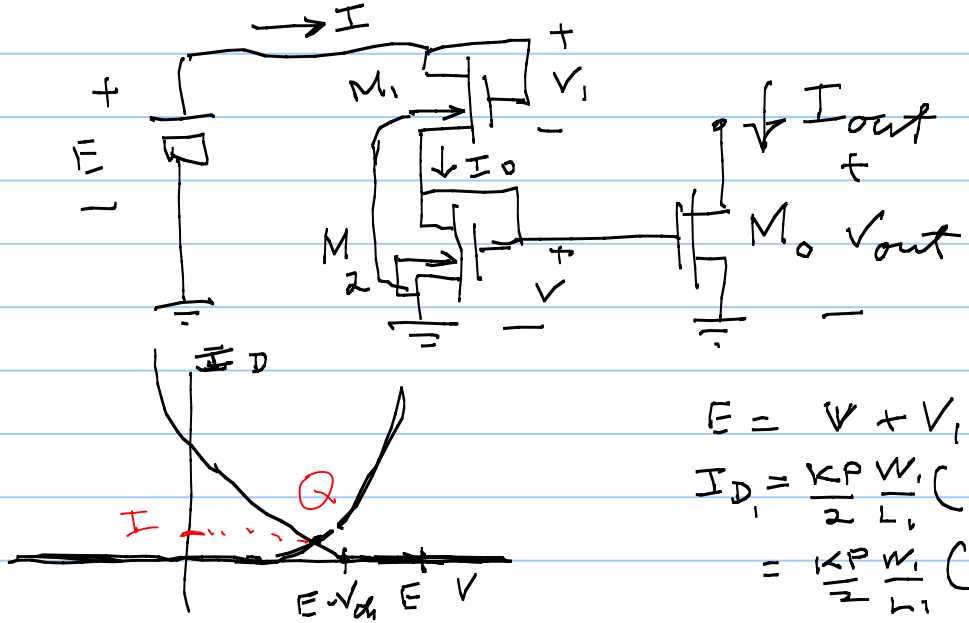
$$\beta = \frac{KP}{2}\frac{W}{L} \qquad I = \beta(R^2 I^2 - 2RI(E - V_{th}) + (E - V_{th})^2)$$

for design desire R vs I with E, KP, V_{th}, $\frac{W}{L}$ given

$$R^2 - \left(\frac{1}{\beta I} + \frac{2}{I}(E - V_{th})\right)R + \frac{(E - V_{th})^2}{I^2} = 0$$

as quadratic can solve for R vs I.

But if do not want a resistor can use a diode connected transistor



$$E = V + V_1$$

$$I_{D_1} = \frac{KP}{2}\frac{W_1}{L_1}(V_1 - V_{th})^2$$

$$= \frac{KP}{2}\frac{W_1}{L_1}(E - V - V_{th})^2$$

if $E - V = V_{th}$ then turn off M_1
at $V = E - V_{th}$

$$I_{D_2} = \frac{KP}{2}\frac{W_2}{L_2}(V - V_{th})^2 = I_{D_1} = \frac{KP}{2}\frac{W_1}{L_1}(E - V - V_{th})^2$$

$$\sqrt{\frac{\frac{W_2}{L_2}}{\frac{W_1}{L_1}}}(V - V_{th}) = E - V - V_{th}$$ gives V right away

if $\frac{W_1}{L_1} = \frac{W_2}{L_2} \Rightarrow$ $2V = E \Rightarrow V = E/2$

$$I_{out} = \frac{KP}{2}\frac{W_0}{L_0}(V - V_{th})^2 = \frac{KP}{2}\left(\frac{W_0}{L_0}\right)\left(\frac{E}{2} - V_{th}\right)^2 = I$$

needs $V_{out} > \frac{E}{2} - V_{th}$ for M_0 in saturation