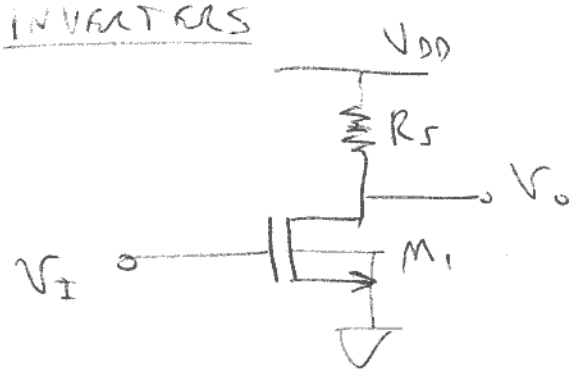
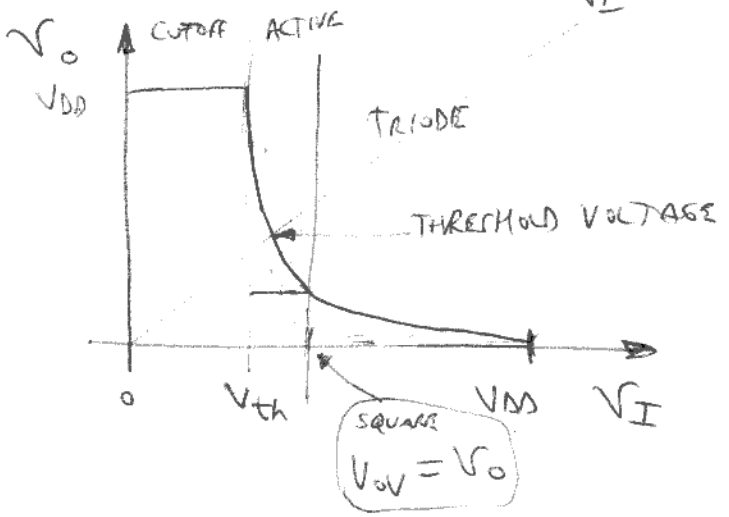
INVERTERS





$$V_o = V_{DD} - i_D R_S$$

$$V_o = V_{DD} - \frac{k'}{2}\frac{W}{L} V_{OV}^2 R_S \quad \text{(ACTIVE MODE)} \quad (\text{SINCE } V_{GS} = V_{DS})$$

$$V_o = V_I \Rightarrow V_{OV} = V_I - V_{th} = V_o - V_{th}$$

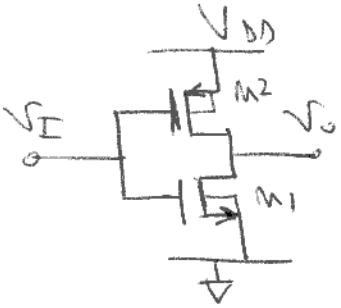
$$V_o = V_{DD} - \frac{k'}{2}\frac{W}{L}\left(V_o - V_{th}\right)^2 R_S \longrightarrow \text{SOLVE QUADRATIC EQ.}$$

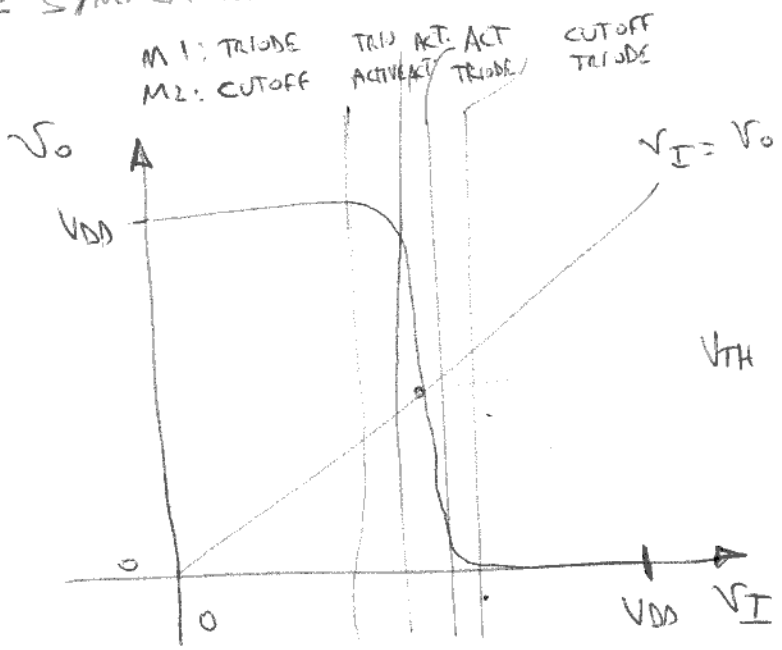
$$\frac{\partial V_o}{\partial V_I} = -\frac{k'}{2}\frac{W}{L} 2\left(V_I - V_{th}\right) R_S = -k'\frac{W}{L} R_S V_{OV} \quad \text{(SMALL-SIGNAL GAIN)}$$

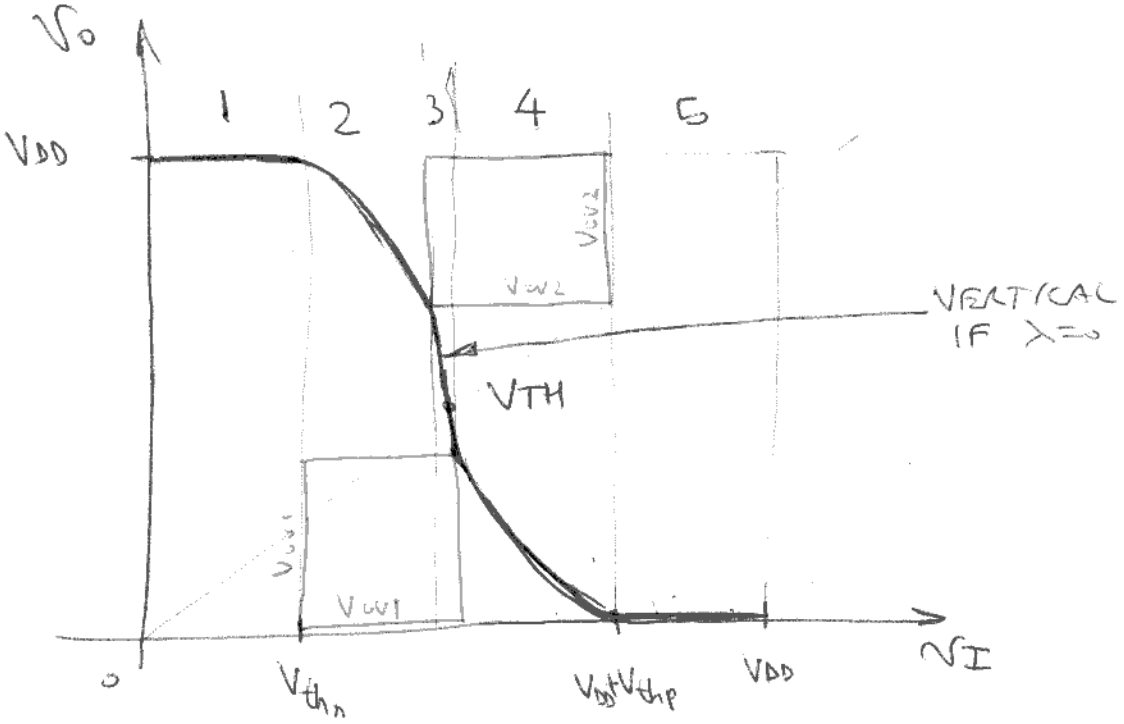
$$\left|\frac{\partial V_o}{\partial V_I}\right| \gg 1 \quad \text{FOR SIGNAL REGENERATION}$$

(INTRODUCE SYMPLYFIED S.S. MODEL HERE)

CMOS INVERTER







	M1	M2
1.	CUTOFF	TRIODE
2.	ACTIVE	TRIODE
3.	ACTIVE	ACTIVE
4.	TRIODE	ACTIVE
5.	TRIODE	CUTOFF

NOTE: M1, M2 ARE BOTH ACTIVE @ V_{TH} SINCE $|V_{DS}|=|V_{GS}|$ FOR BOTH TRANSISTORS AT ~~THAT~~ POINT.

$$I_{D1} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 (V_{TH}-V_{thn})^2$$

$$i_{D2} = \frac{\mu_p C_{ox}}{2}\left(\frac{W}{L}\right)_2 (V_{DD}-V_{th}+V_{thp})^2$$

$i_{D1} = i_{D2} \longrightarrow$ FIND V_{th}

$$V_{th} = \frac{V_{thn} + (V_{DD}+V_{tp})\sqrt{\mu_p\left(\frac{W}{L}\right)_2 / \mu_n\left(\frac{W}{L}\right)_1}}{1+\sqrt{\mu_p\left(\frac{W}{L}\right)_2 / \mu_n\left(\frac{W}{L}\right)_1}}$$

EXAMPLE

$k'_n = 180 \frac{\mu A}{V^2}$ $V_{thn} = 0.76V$ $\frac{W}{L} = \frac{1.2\mu m}{0.6\mu m}$ FOR BOTH TRANSISTORS

$k'_p = 40 \frac{\mu A}{V^2}$ $V_{thp} = -0.66V$

$V_{DD} = 3.3V$

$$V_{TH} = \frac{0.76V + (3.3 - 0.66V)\sqrt{\frac{40\frac{\mu A}{V^2}\frac{1.2}{0.6}}{180\frac{\mu A}{V^2}\times\frac{1.2}{0.6}}}}{1+\sqrt{\frac{40\frac{\mu A}{V^2}}{180\frac{\mu A}{V^2}}}} = 1.55V$$

(NOT TOO BAD)

NOTE: $\frac{V_{DD}}{2} = 1.65V$

IF $V_{thn} = |V_{thp}|$ AND $\mu_n = \mu_p \Rightarrow V_{TH} = \frac{V_{DD}}{2}$ NOISE MARGIN MAXIMIZED.

FOR CMOS: $\begin{cases} NMH = V_{DD} - V_{TH} \\ NML = V_{TH} \end{cases}$

- FOR ASSIGNMENT → CONVERT ANALOG-DIGITAL WITH SPECIFIC VTH.