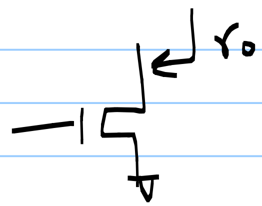
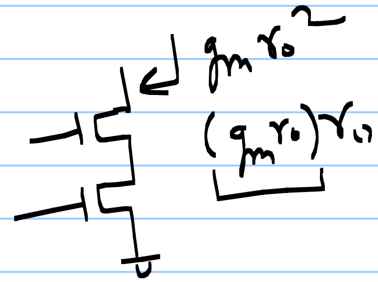
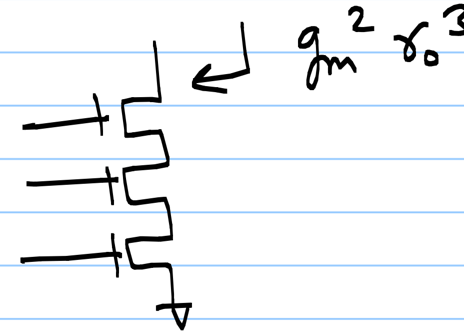
Note Title 2/28/2011

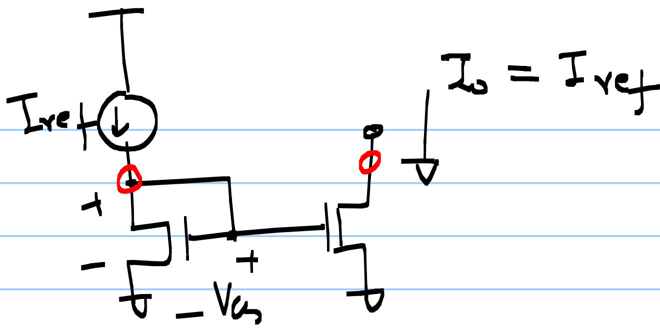
ECE 5411 – Lecture 11.



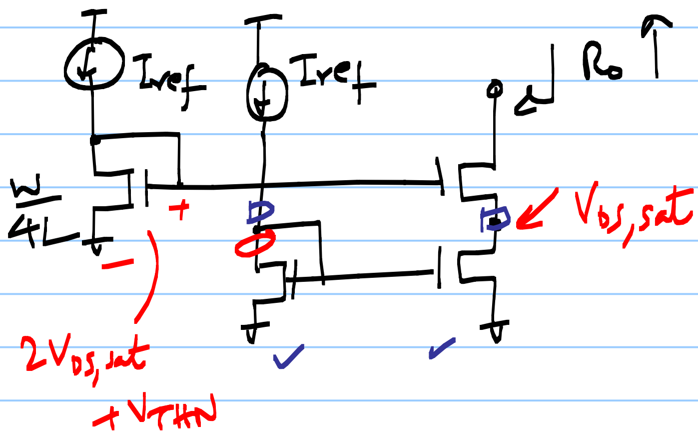




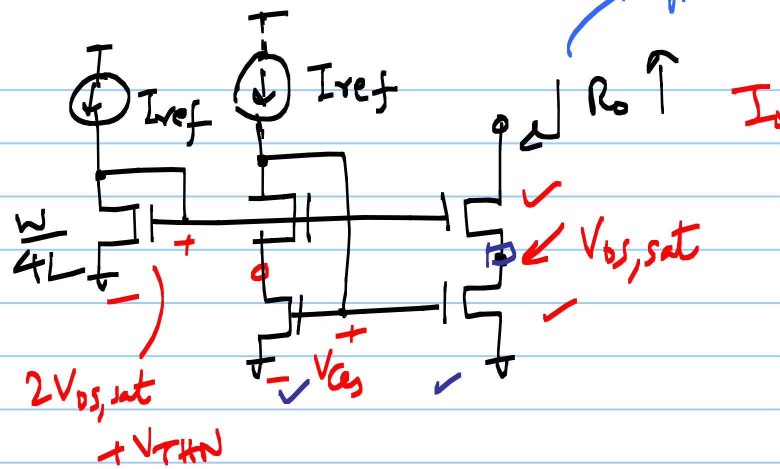
(−) swing



Iref
+
−
+
− VGS
Io = Iref

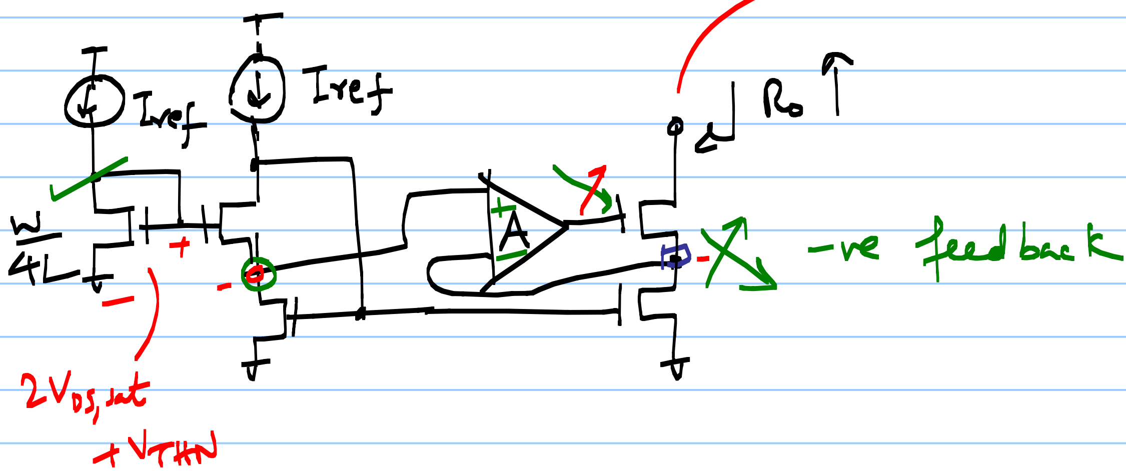


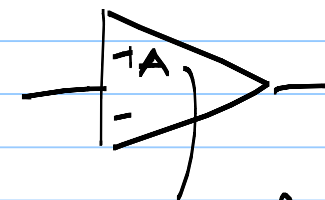
Iref
Iref
Ro
W
4L
+
−
2VDS,sat
+ VTHN
VDS,sat



$I_o \cong I_{ref}$

$R_o = A g_m r_o^2$





$$A(s) = \frac{A_0}{(1 + s/\omega_p)}$$

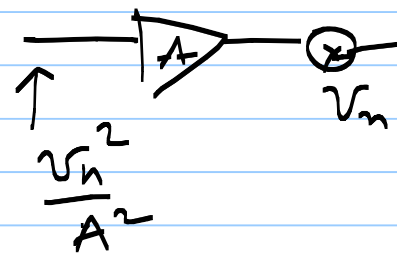
"Later"

Single-Stage Amplifiers.

amplify an analog or digital signal

↳ drive a load

↳ overcome noise of a subsequent stage



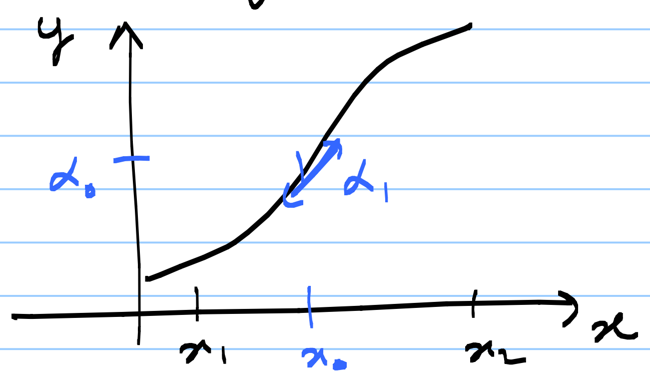
↳ provide logic levels to a digital gate

↳ in feedback systems

* Single-Stage amplifiers → low-frequency behavior

* input-output characteristics of an amplifier

$$y(t) = \alpha_0 + \alpha_1 x(t) + \alpha_2 x^2(t) + \cdots + \alpha_n x^n(t), \quad x_1 \le x \le x_2$$



Small-signal amplitude

$$y(t) \simeq \underbrace{\alpha_0}_{\text{operating point}} + \underbrace{\alpha_1 x(t)}$$

Small-signal gain

for $\alpha_1 x(t) \ll \alpha_0$, the bias point is disturbed negligibly.

$$\Delta y = \alpha_1 \Delta x$$

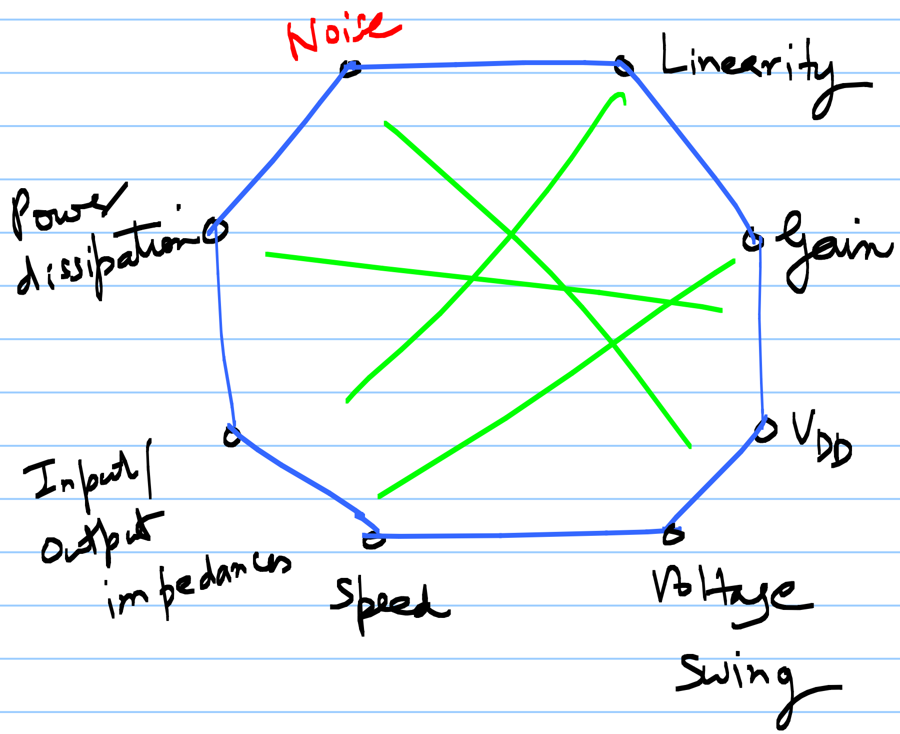
As $x(t)$ increases in magnitude

$\Rightarrow$ large-signal behavior

$\Rightarrow$ higher-order terms start manifesting

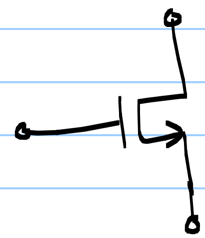
$\hookrightarrow$ distortion

"Analog design Octagon"



- variability
- mismatch

multidimentional design "trade offs" problem.



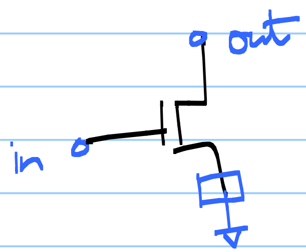
3- terminals

1- input

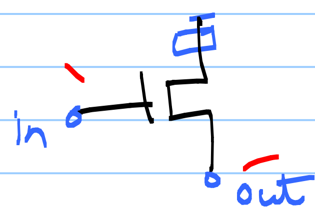
2- output

$^3C_2 = 3$

$\cancel{^3P_2}$

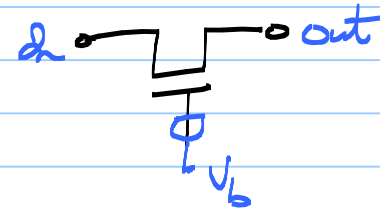


CS



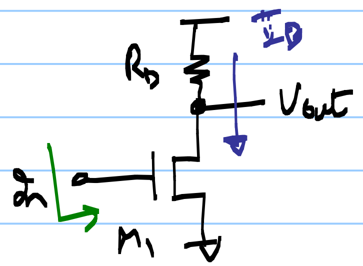
CD

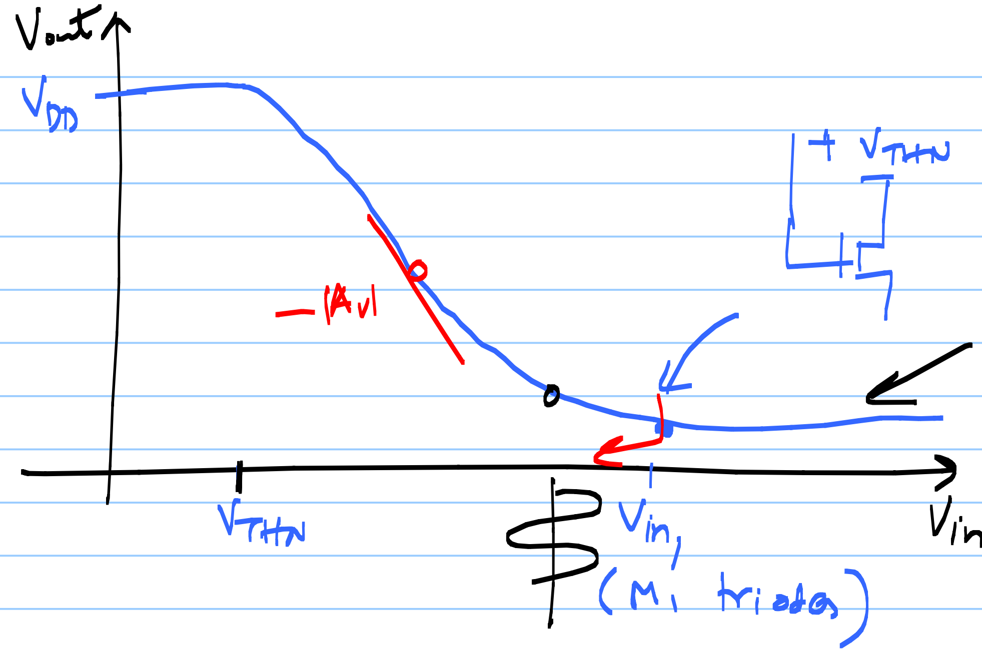
(Source-follower)



CG

Common Source Stage





@ low-freq

Z_{in} is very high

initially $V_{in} = 0$, $V_{out} = V_{DD}$

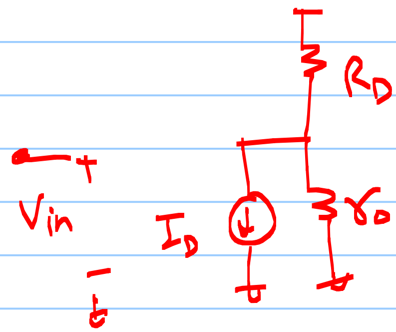
$V_{in} \geq V_{THN}$, V_{DD} is sufficiently large

$$V_{out} = V_{DD} - I_D \cdot R_D$$

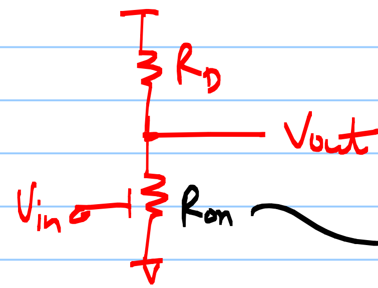
$$V_{out} = V_{DD} - R_D \cdot \frac{KP_n}{2} \frac{W}{L} (V_{in} - V_{THN})^2 \longrightarrow (1)$$

If we increase V_{in} further, M_1 triodes

$$V_{out} = V_{DD} - R_D \cdot KP_n \frac{W}{L} \left[(V_{in} - V_{THN}) V_{out} - \frac{V_{out}^2}{2} \right] \rightarrow (2)$$



SAT



TRIODE

$$R_{on} \sim \frac{1}{KP_n \frac{W}{L} (V_{GS} - V_{THN})}$$

in deep triode

In triode:

$$V_{out} = V_{DD}\,\frac{R_D}{R_D+R_{on}} = \frac{V_{DD}}{1+KP_n\frac{W}{L}(V_{in}-V_{THN})}$$

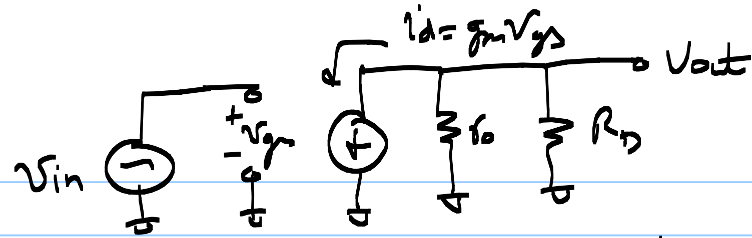
In saturation:

$$V_{out} = V_{DD} - R_D \cdot \frac{KP_n}{2}\,\frac{W}{L}\,(V_{in}-V_{THN})^2 , \qquad \lambda = 0$$

Small-signal voltage gain

$$A_V = \frac{\partial V_{out}}{\partial V_{in}} = -R_D \cdot KP_n\,\frac{W}{L}\,(V_{in}-V_{THN})$$

$$= \underline{\underline{-g_m R_D}}$$



$$V_{out} = -i_d (r_o \| R_D)$$

$$= -g_m \underbrace{v_{gs}}_{v_{in}} (r_o \| R_D)$$

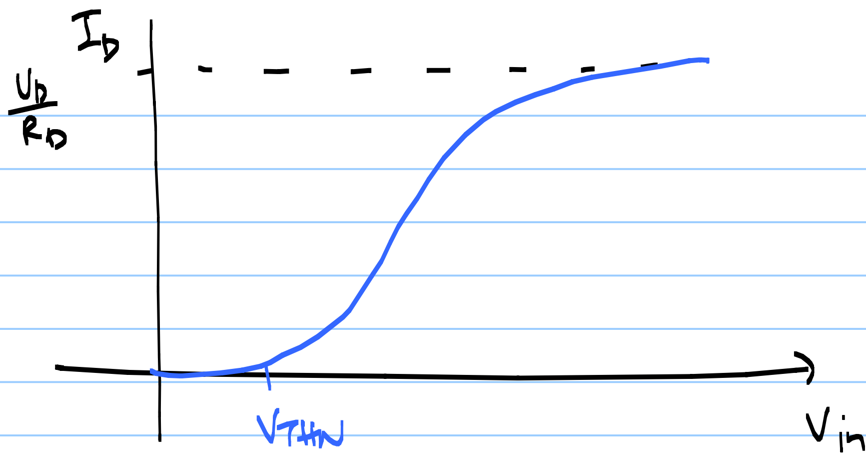
$$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = -g_m (r_o \| R_D)$$

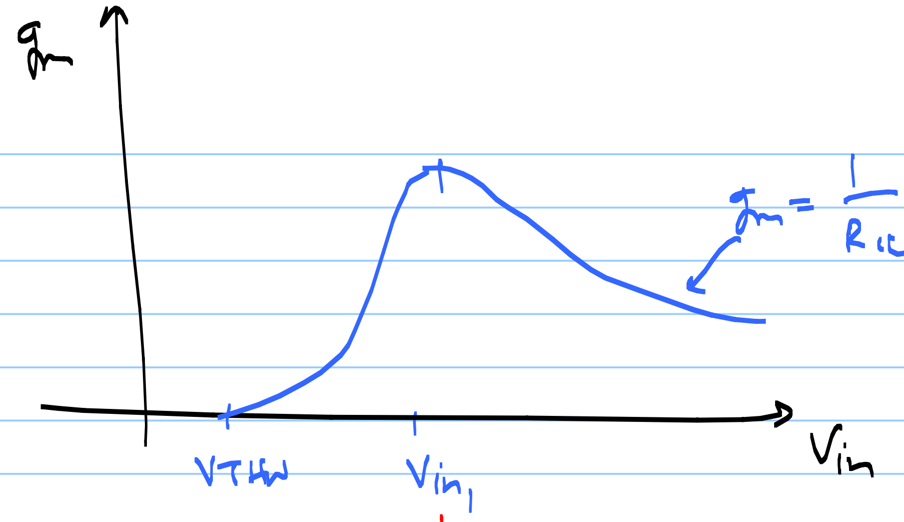
$$\approx -g_m R_D$$

$$* \quad A_v = -R_D \cdot \overbrace{KP_n \frac{W}{L} (V_{in} - V_{THN})}^{g_m}$$

* gain varies will large signal swing

* $g_m = f(V_{in})$





$$A_v = -\sqrt{2KP_n \frac{W}{L} I_D} \cdot R_D$$

V_{R_D} is the drop across R_D

$$= -\sqrt{2KP_n \frac{W}{L} \cdot I_D} \cdot \frac{V_{R_D}}{I_D}.$$

$$= -\sqrt{2KP_n \frac{W}{L}} \cdot \frac{V_{R_D}}{\sqrt{I_D}}$$

$|A_v|$

$\left(\frac{W}{L}\right)\uparrow \Rightarrow$ larger device caps

$V_{ov}\uparrow \Rightarrow$ lower swing

$I_D\downarrow \Rightarrow$ lower speed.

$f_T \propto \frac{V_{ov}}{L}$, $A_v \propto \frac{L}{V_{ov}}$