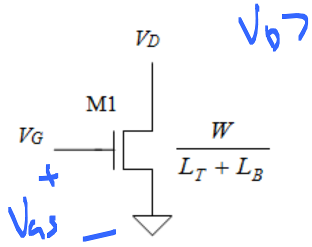
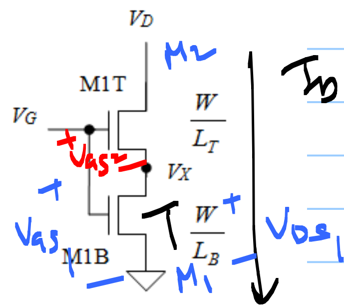
# ECE 511 – Lecture 9

Note Title 2/19/2013

$V_D > V_G - V_{THN}$




for $M_1$ in sat:

$$V_{DS_1} > V_{GS_1} - V_{THN}$$

$$\cancel{V_{GS_1}} - V_{GS_2} > \cancel{V_{GS_1}} - V_{THN}$$

$$V_{GS_2} < V_{THN}$$

$M_1$ Triode

$$I_{D_1} = k P_n \frac{W}{L_B} \cdot \left[ (V_{GS} - V_{THN}) V_x - \frac{V_x^2}{2} \right]$$

$$I_{D_1} \cdot L_B = k P_n \, W \left[ (V_G - V_{THN}) V_x - \frac{V_x^2}{2} \right] \longrightarrow (1)$$

$M_2$ T S

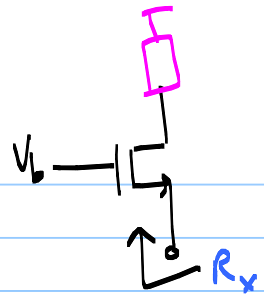
$$I_{D_2} = \frac{k P_n}{2} \frac{W}{L_A} (V_G - V_x - V_{THN})^2$$

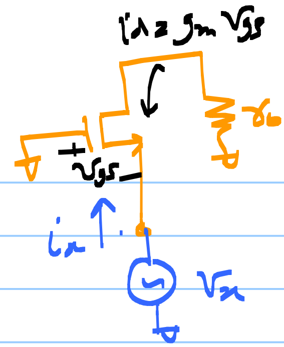
$$I_{D_2} \cdot L_A = \frac{k P_n}{2} W [ \overbrace{V_G - V_x - V_{THN}}^{(a+b)^2} ]^2 \longrightarrow (2)$$

Add (1) + (2)

$$I_D (L_A + L_B) = k P_n W \left\{ \cancel{(V_G - V_{THN})V_x} - \cancel{\frac{V_x^2}{2}} + \frac{1}{2}(V_G - V_{THN})^2 + \cancel{\frac{V_x^2}{2}} - \cancel{\frac{2}{2}(V_G - V_{THN}) V_x} \right\}$$

$$\Rightarrow I_D = \frac{k P_n \cdot W}{2(L_A + L_B)} \left[ V_G - V_{TH} \right]^2$$



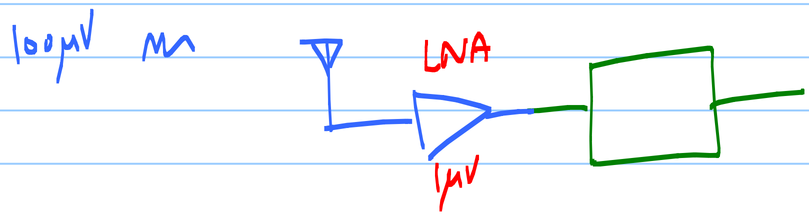

ignoring $g_{mb}$

$$KVL \Rightarrow \quad v_{gs} = -v_x \longrightarrow (1)$$

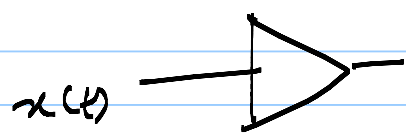
$$i_x = -i_d = -g_m v_{gs} = g_m v_x$$

$$R_x = 1/g_m \qquad \frac{1}{g_m + g_{mb}}$$

# Single-Stage Amplifiers




Input output characteristics of an amplifier




$y(t) = f(x(t))$

$$y(t) = \alpha_0 + \boxed{\alpha_1}\, x(t) + \alpha_2 x^2(t) + \alpha_3 x^3(t) + \dots$$

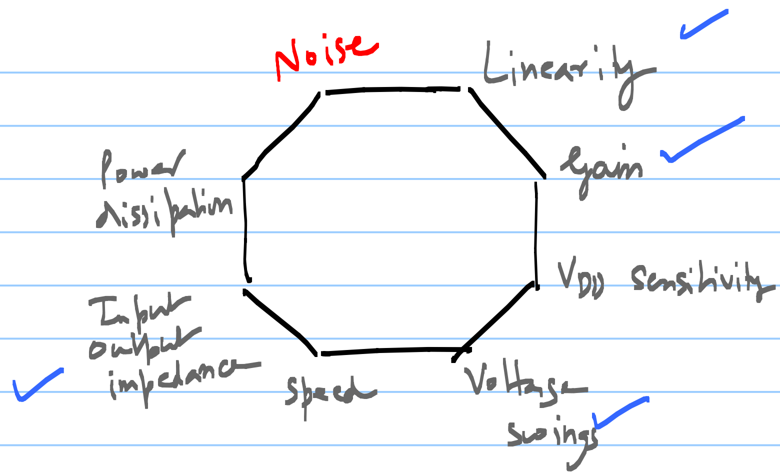
↑ o/p DC-level

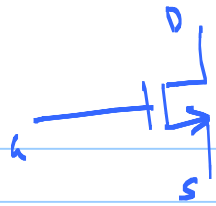
small signal gain

distortion terms

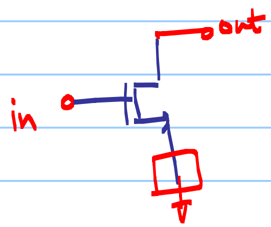
for "small-signal" $\Delta y = \alpha_1 \Delta x$ ← small signal signal

if x(t) starts increasing in Amplitude

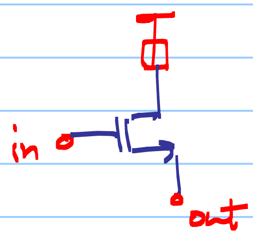

Noise
Linearity
Gain
VDD Sensitivity
Voltage swings
Speed
Input output impedance
Power dissipation



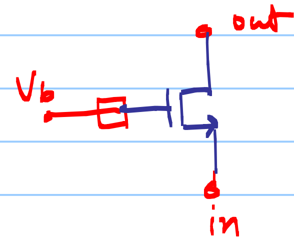

VCCS in small signal




CS




CD
(Source follower)




CG

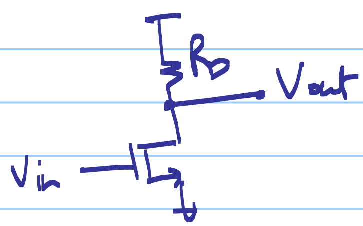
$^3P_2 = \cancel{6}$

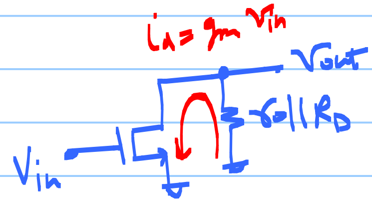
$^3C_2 = 3$

Drain can't be on input

* 3 basic configurations & their combinations

# Common Source Stage



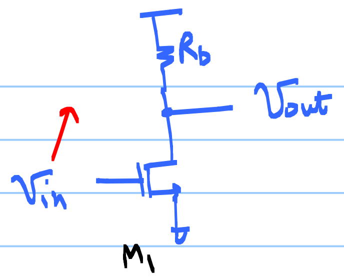



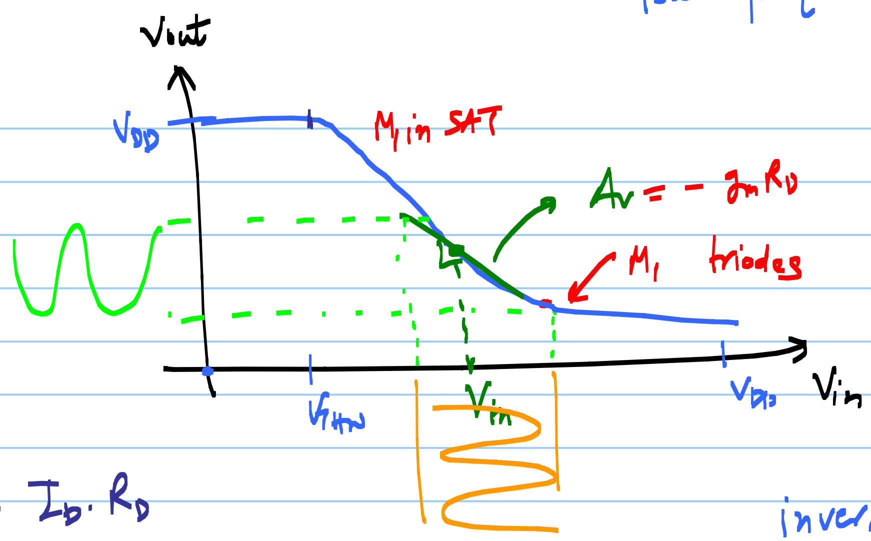

$$V_{out} = -g_m v_{in}(r_o || R_D)$$

$$A_v = -g_m(R_D || r_o)$$

$$\simeq -g_m R_D \quad \text{for } R_D \ll r_o$$

low-freq behavior




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

$$V_{out} = V_{DD} - R_D \cdot \frac{k'_n}{2} \frac{W}{L} (V_{in} - V_{thN})^2$$

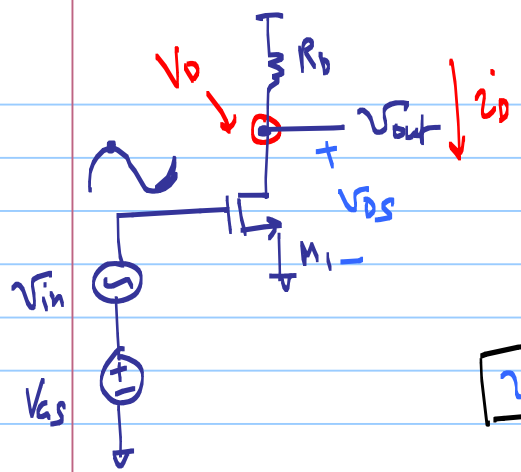
$$A_v = \frac{\partial V_{out}}{\partial V_{in}} = -g_m R_D$$

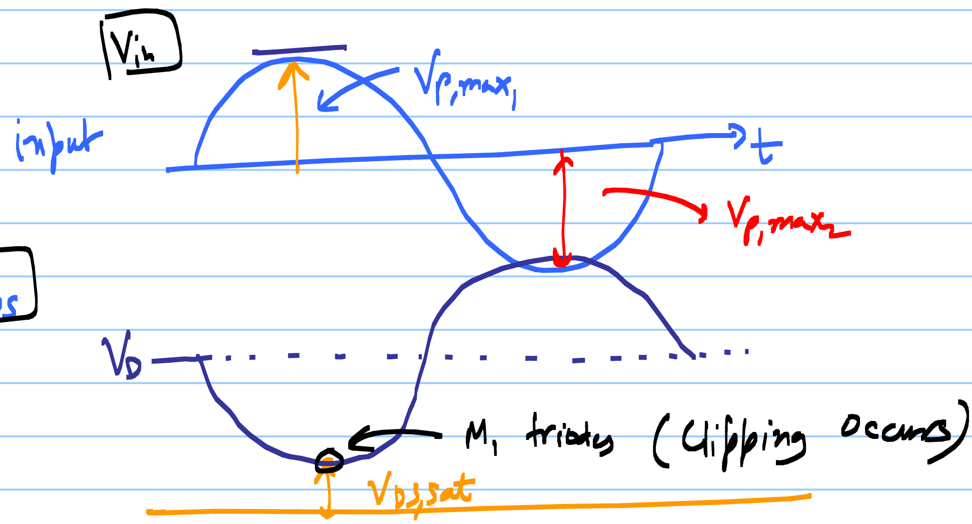
inverting amplifier

$V_{out}$ is $180^\circ$ out of phase

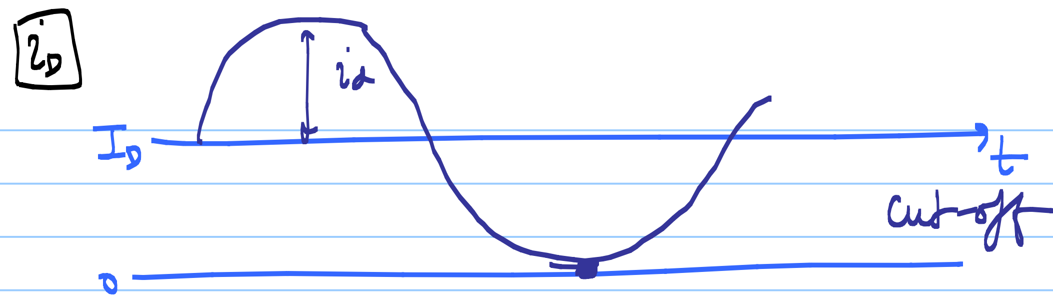
$$v_{out} = -\underbrace{g_m (R_D || r_o)}_{A_v} v_{in}$$

Assume linear behavior




$$V_{p,max} = \frac{V_D - V_{DS,sat}}{|A_v|} = \frac{(V_D - V_{DS,sat})}{g_m R_D}$$



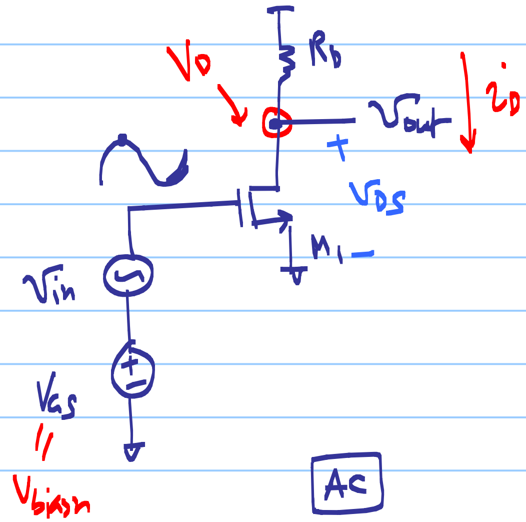

$i_d = -I_D$

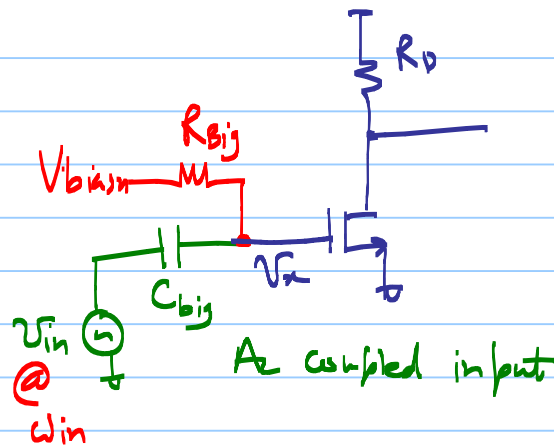
$$\overbrace{g_m V_{p,max_2}}^{i_d} = -I_D$$

$$|V_{p,max_2}| = \frac{I_D}{g_m}$$

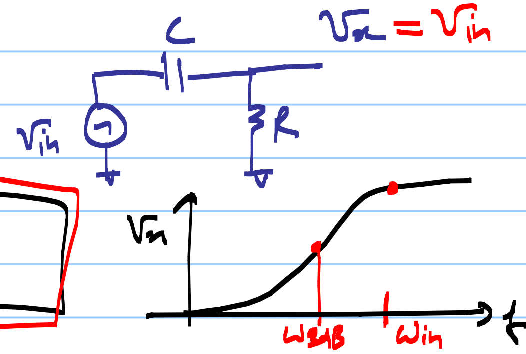
input amplitude $< \min \{ V_{p,max_1}, V_{p,max_2} \}$

Note:

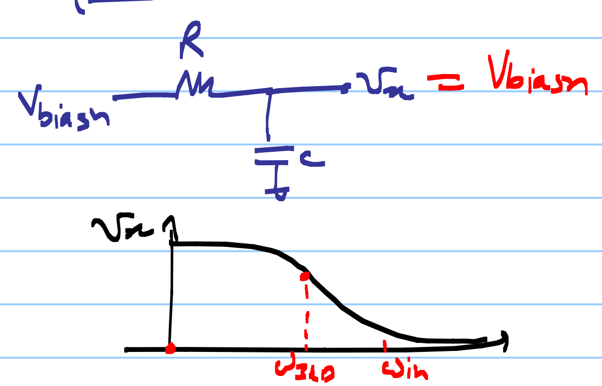



AC




DC




$$\boxed{\omega_{in} > \frac{10}{RC}}$$