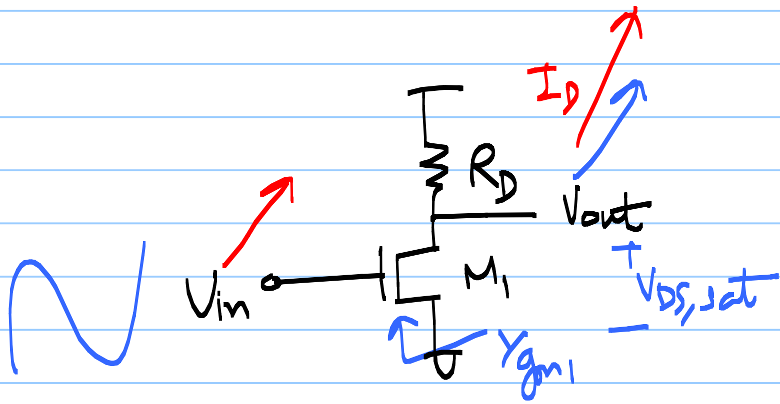
ECE541 – Lecture 12

Note Title 3/2/2011



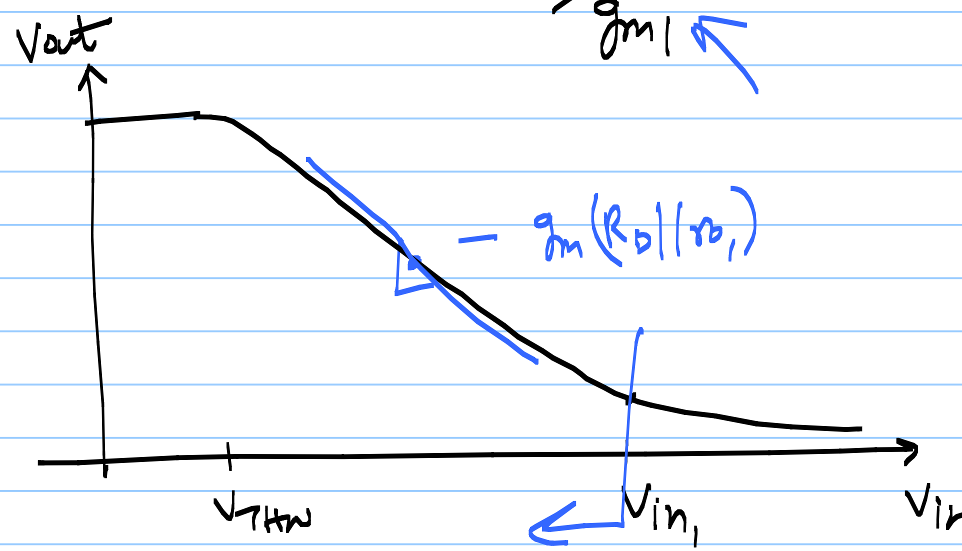
$$A_v = -g_{m1}(R_D \| r_{o1})$$

$$= -\frac{(R_D \| r_{o1})}{1/g_{m1}}$$

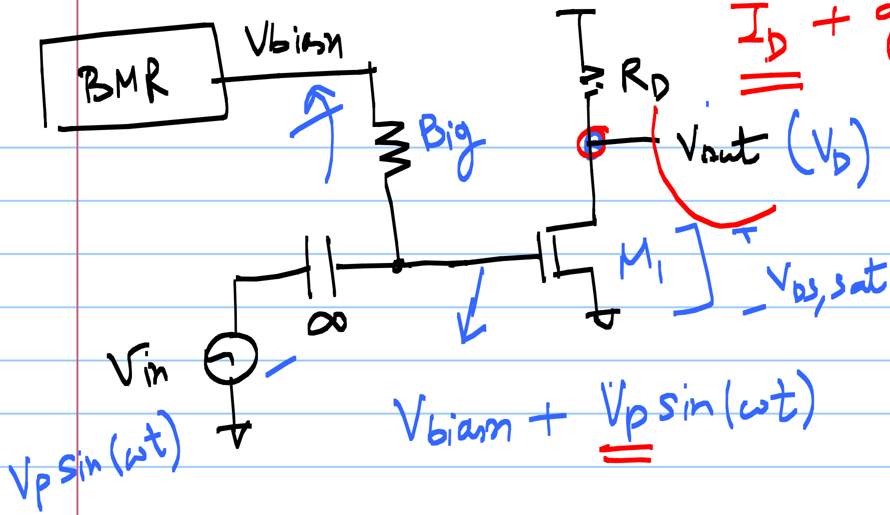
$V_{in} \uparrow \Rightarrow I_D \uparrow$

$g_m \uparrow$

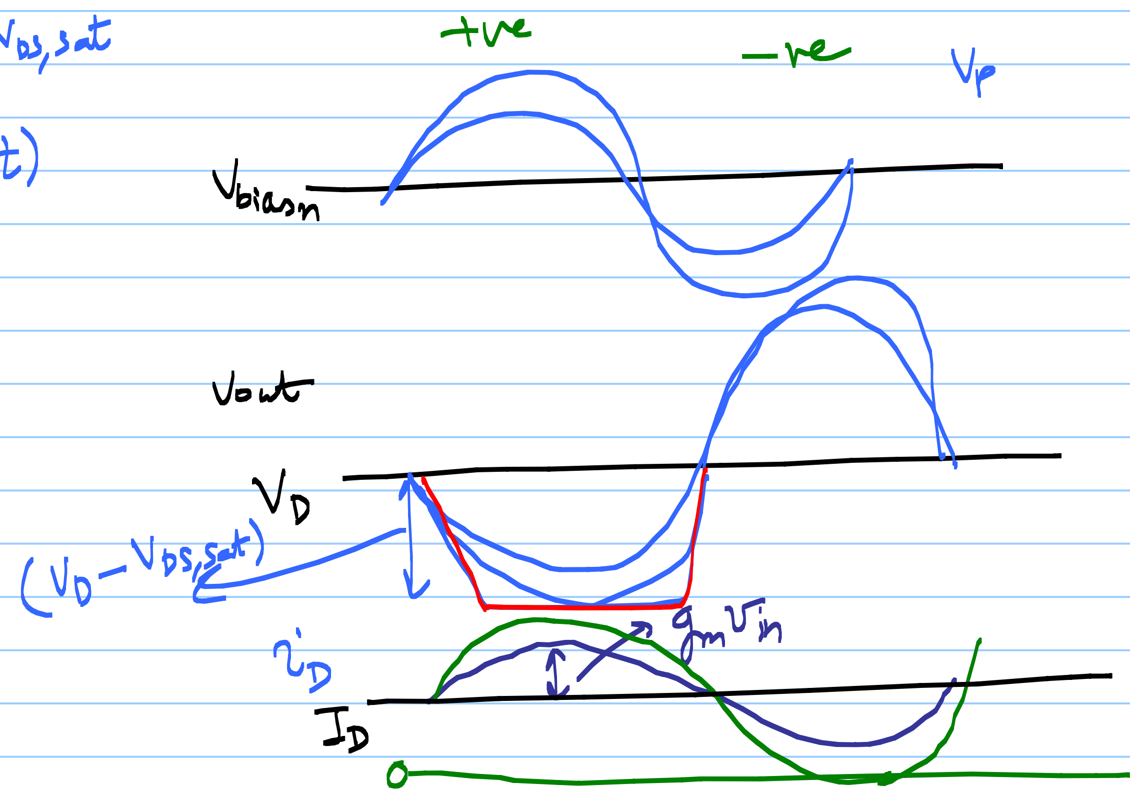
$$g_m = f(V_{in})$$



$$I_D + g_m v_{in} = i_D$$



$$A_v = -g_{m_1}(R_D \| R_L \| r_{o_1})$$



* +ve input cycle

  * M_1 can enter triode

$$V_{pmax,1} \le \frac{(V_{DS} - V_{DS,sat})}{|A_v|}$$

$|A_v| \rightarrow g_m(R_D \| r_{o1})$

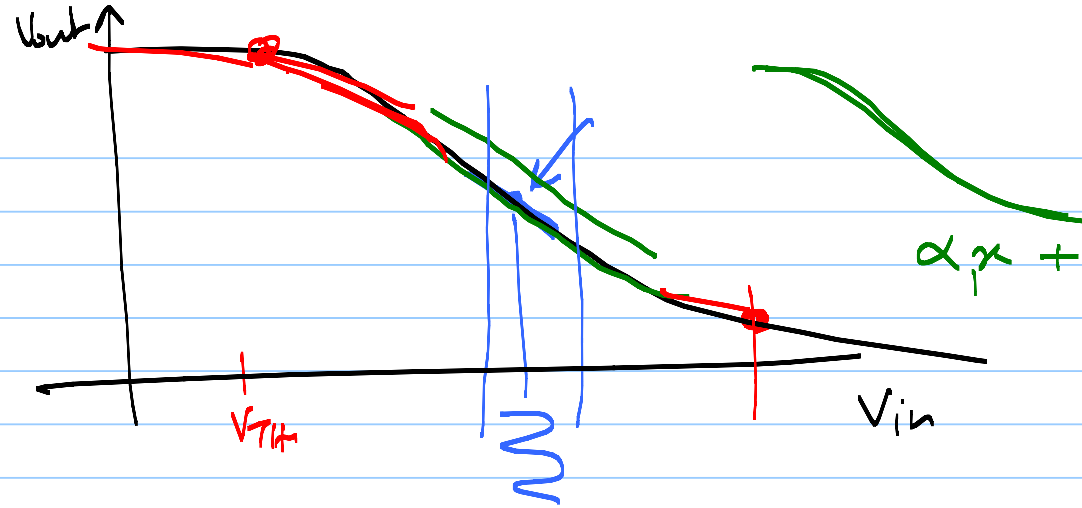
* −ve input cycle

  * M_1 can enter cutoff $\Rightarrow$ $i_d = -I_D$

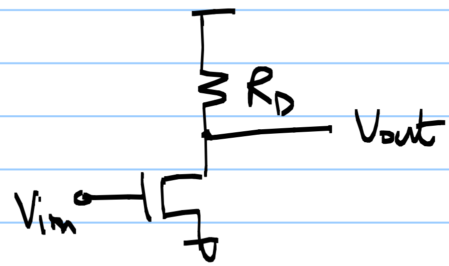
$$V_{pmax_2} \le \frac{I_D}{g_m}$$

* maximum permissible input signal amplitude

$$= \min(V_{pmax_1}, V_{pmax_2})$$



$$\alpha_1 x + \alpha_3 x^3$$



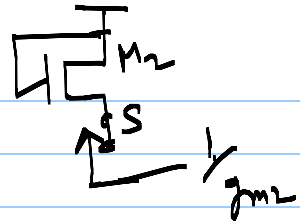
$$A_v = -g_m(R_D \| r_{o1})$$

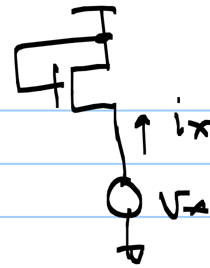
$R_D \ll r_{o1}$

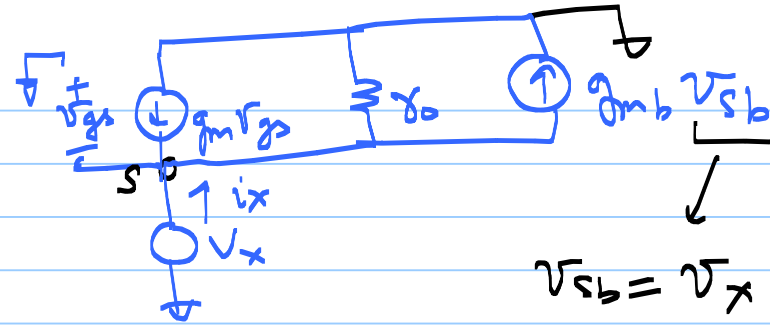
$$\simeq -g_m R_D$$

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

$$g_m r_o \propto \frac{L}{V_{ov}}$$







$v_{sb} = v_x$

$v_{gs} = -v_x$

$v_{sb} = v_x$

$$g_m v_{gs} - g_{mb} v_{sb} - \frac{v_x}{r_o} + i_x = 0$$

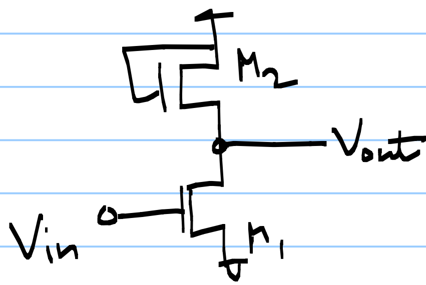
$$-g_m v_x - g_{mb} v_x - \frac{v_x}{r_o} + i_x = 0$$

$$\left[-(g_m + g_{mb}) - \frac{1}{r_o}\right] v_x - i_x = 0$$

$$-\left[(g_m + g_{mb}) + r_o^{-1}\right] v_x - i_x = 0$$

$$R_{out} = \frac{v_x}{i_x} = \frac{1}{g_m + g_{mb} + r_o^{-1}}$$

$$\boxed{R_{out} \simeq \frac{1}{g_m + g_{mb}}} \quad \text{if} \quad r_o \gg 1/g_m$$



$$A_v = - \frac{\frac{1}{(g_{m2} + g_{mb2})}}{1/g_{m1}}$$

$$g_{mb} = \eta g_m$$

$$= - \frac{g_{m1}}{g_{m2} + g_{mb2}} = - \frac{g_{m1}}{g_{m2}} \left(\frac{1}{\eta + 1} \right)$$

$$\boxed{A_v = -\frac{g_{m1}}{g_{m2}}\left(\frac{1}{\eta+1}\right)}$$

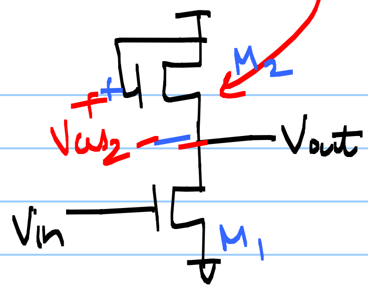
$$g_m = \sqrt{2\beta I_D}$$

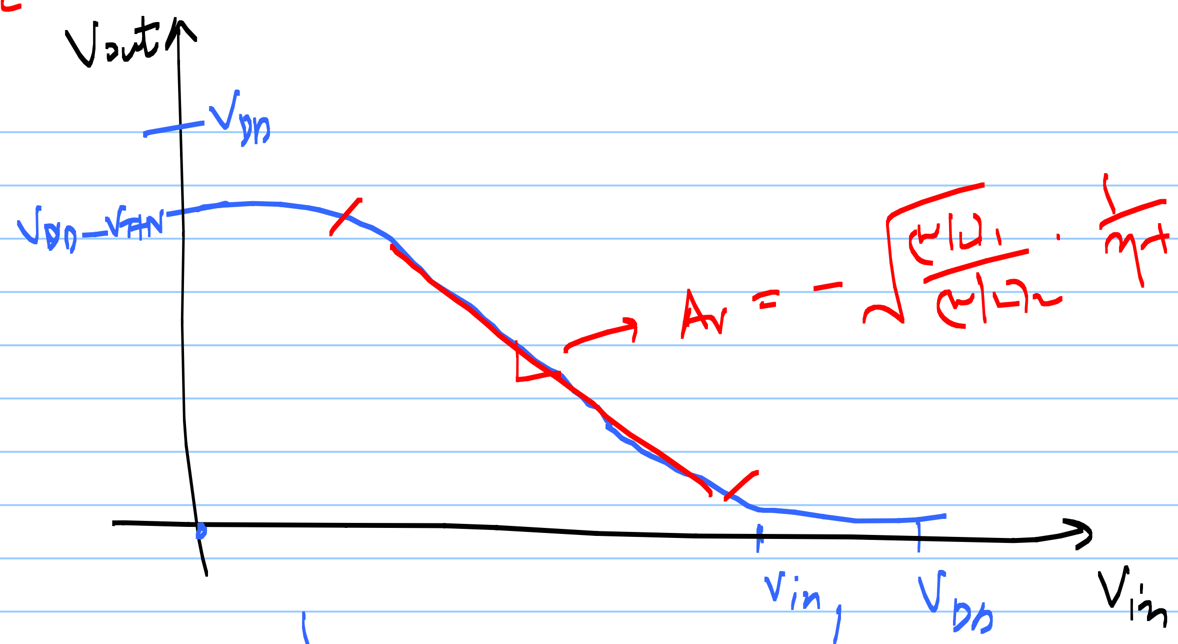
$$= -\sqrt{\frac{(W/L)_1}{(W/L)_2}} \cdot \left(\frac{1}{\eta+1}\right)$$

$$\frac{g_{m1}}{g_{m2}} = \sqrt{\frac{(W/L)_1}{(W/L)_2}}$$

* A_v gain is independent of bias currents & voltages

* if input signal varies, gain is constant



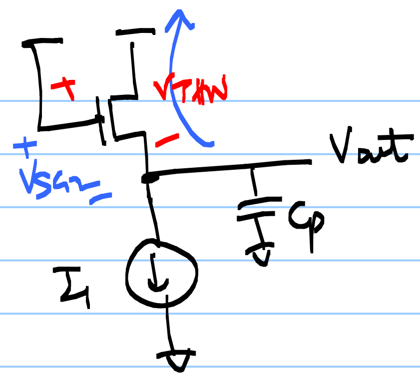


$$A_v = -\sqrt{\frac{(W/L)_1}{(W/L)_2}} \cdot \frac{1}{\eta+1}$$

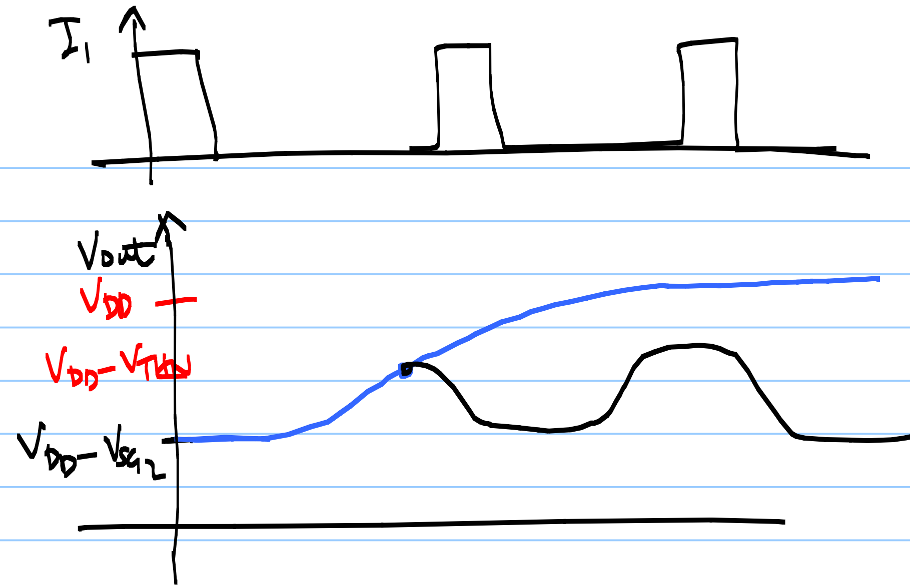
$$A_v = -\sqrt{\frac{(W/L)_1}{(W/L)_2}} \cdot \qquad 0.8 \qquad \frac{1}{1+\gamma}$$

increase A_v ⇒ make $(W/L)_2$ smaller ⇒ V_{SG2} ↑

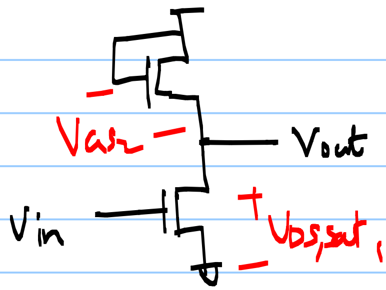
↳ reduced output swing

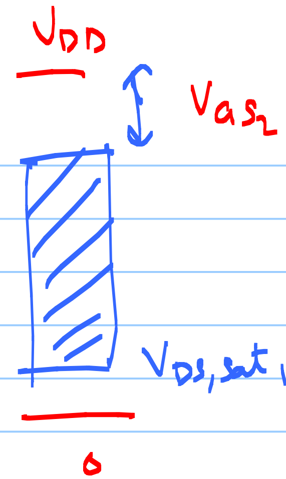


VTHN
+
-
+
VSG2
-
Vout
Cp
I1

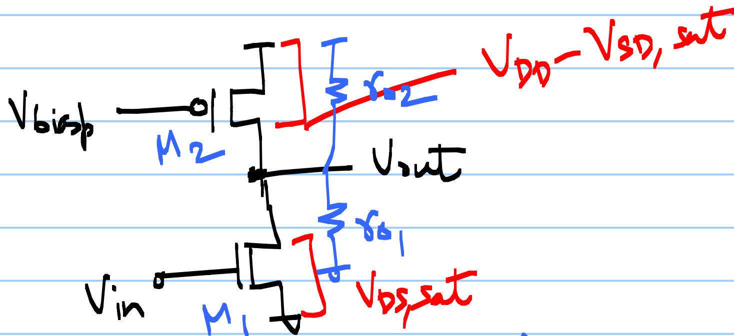


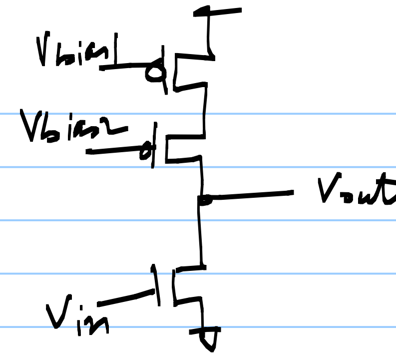
I1
Vout
VDD
VDD-VTHN
VDD-VSG2





$V_{GS_2} = V_{DS,sat_2} + \underline{\underline{V_{THN}}}$



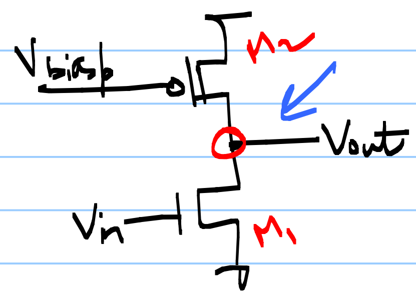


$$A_v = -\frac{(r_{o1} \| r_{o2})}{1/g_{m1}}$$

$$= -g_{m1}\underbrace{(r_{o1} \| r_{o2})}$$

* much larger gain
* better output swing / voltage headroom

* the output impedance value is no longer coupled with the drop across the load.

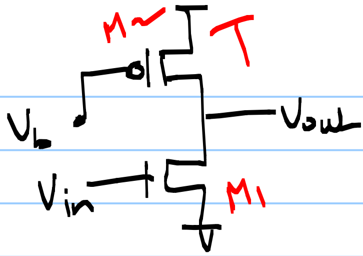


* output bias voltage in this circuit is not well defined

* Stage is reliably biased only in a feedback circuit.

$$-g_m(r_{o1} \| r_{o2}) \qquad g_m r_o \propto \frac{L}{V_{ov}}$$

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

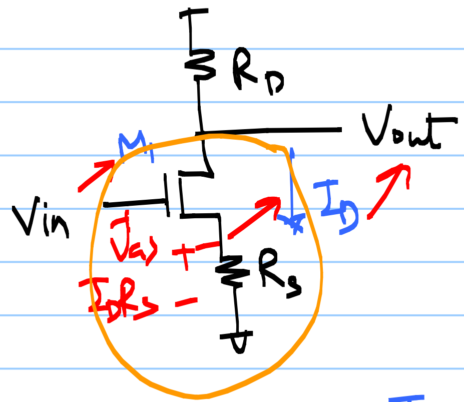


$$R_{ch} = \frac{1}{KP_p \left(\frac{W}{L}\right)_p \left(V_{DD} - \boxed{V_b} - V_{THP}\right)}$$

R_{ch} depends on PT

↳ hard to design with PT variations

CS with Source Degeneration



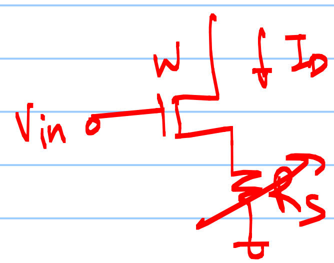
$\Rightarrow M_1 \rightarrow$ non-linear I-V characteristics

↳ Can we use feedback to linearize this CS stage

$$I_D = \frac{V_{in} - \boxed{V_{GS}}}{R_S}$$

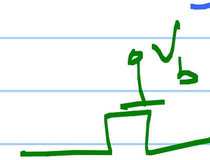
if $\Delta V_{GS} = 0$

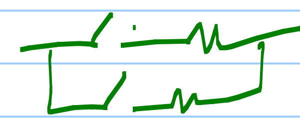
$$\Delta I_D \simeq \frac{\Delta V_{in}}{R_S}$$



$\uparrow I_D$

$$I_D \simeq \frac{V_{in}}{R_S}$$





VGA