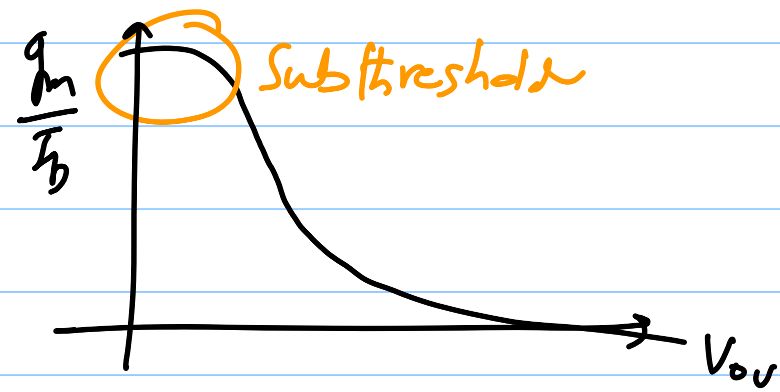
ECE 511 - Lecture 9

Note Title 2/12/2015

$$\left(\frac{g_m}{I_D}\right) = \frac{\beta V_{ov}}{\frac{\beta}{2} V_{ov}^2} \propto \frac{1}{V_{ov}} \longrightarrow 2\% \text{ of } V_{OV}$$



Short-channel

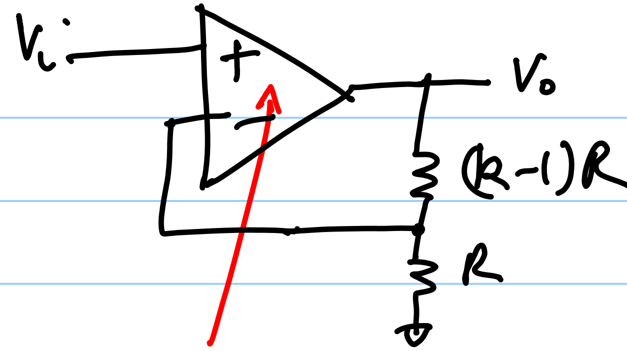
$$g_m r_o \propto \frac{L}{V_{ov}}$$

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

$$g_m r_o f_T = \text{const.}$$

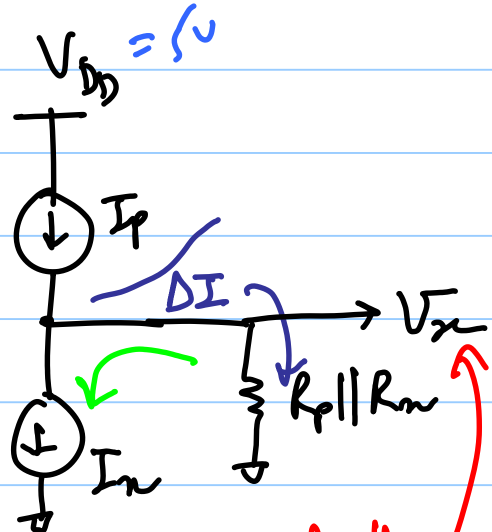
Figure of merit.

LM741



for single pole opamp

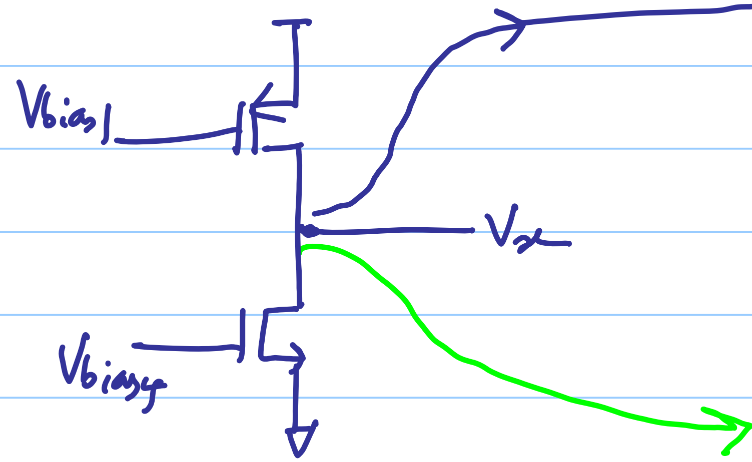
$\omega_{um} \simeq \omega_{3dB} \times A_v$

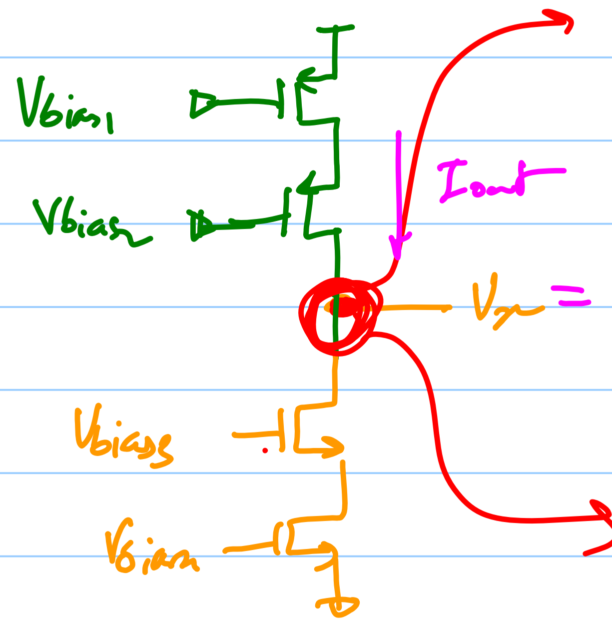


voltage is undefined

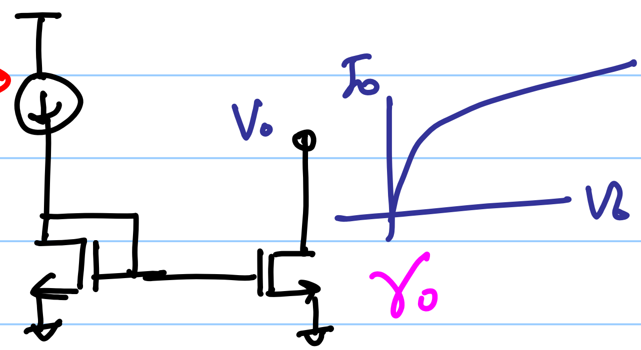
$I_p > I_n$

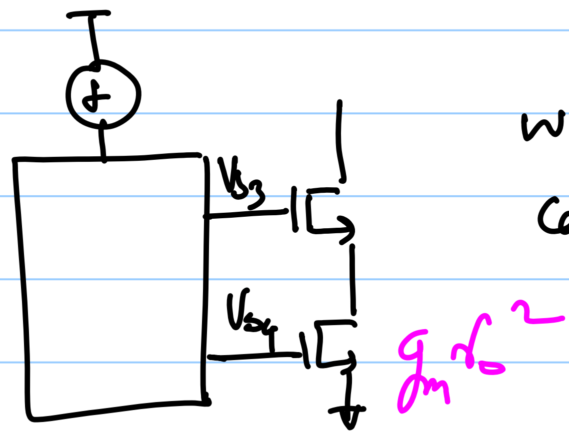
$I_p < I_n$



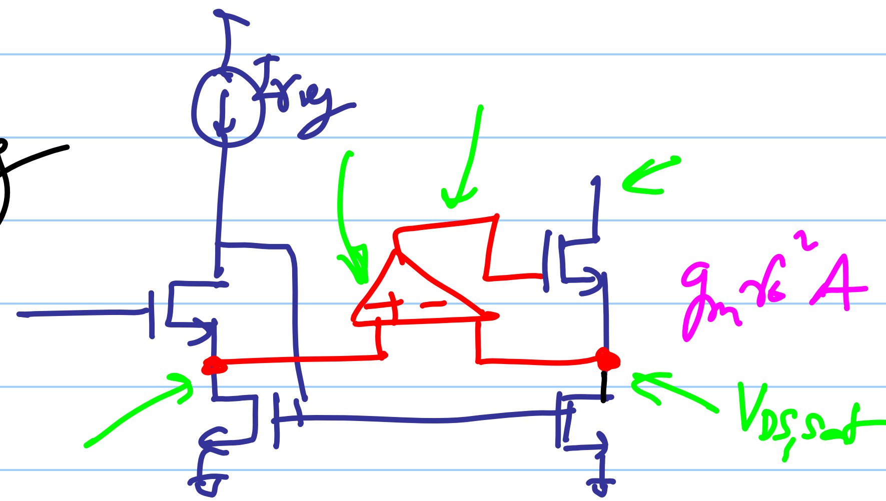


P&V independent





wide-swing cascoding



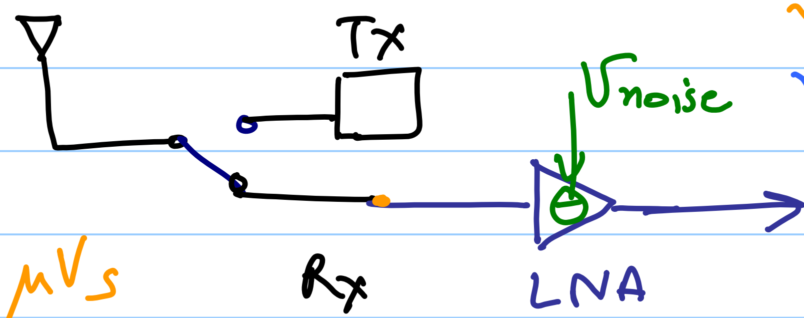
Regulated Drain CM

"Replica Biasing"

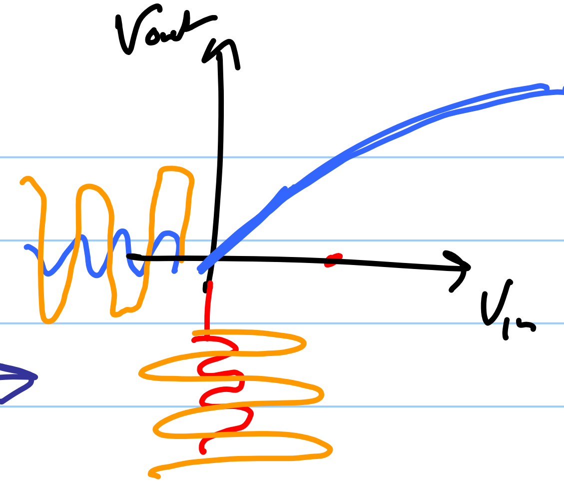
Single-Stage Amplifiers:

* amplification of small-signals

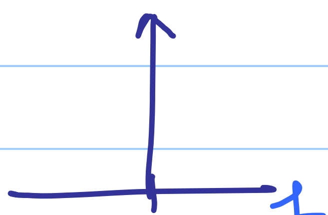
few μVs

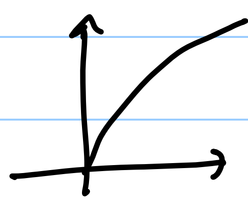


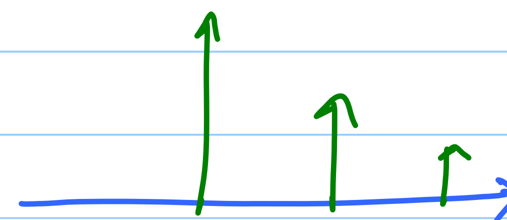
low noise amplifier



$\sin \omega_0 t$



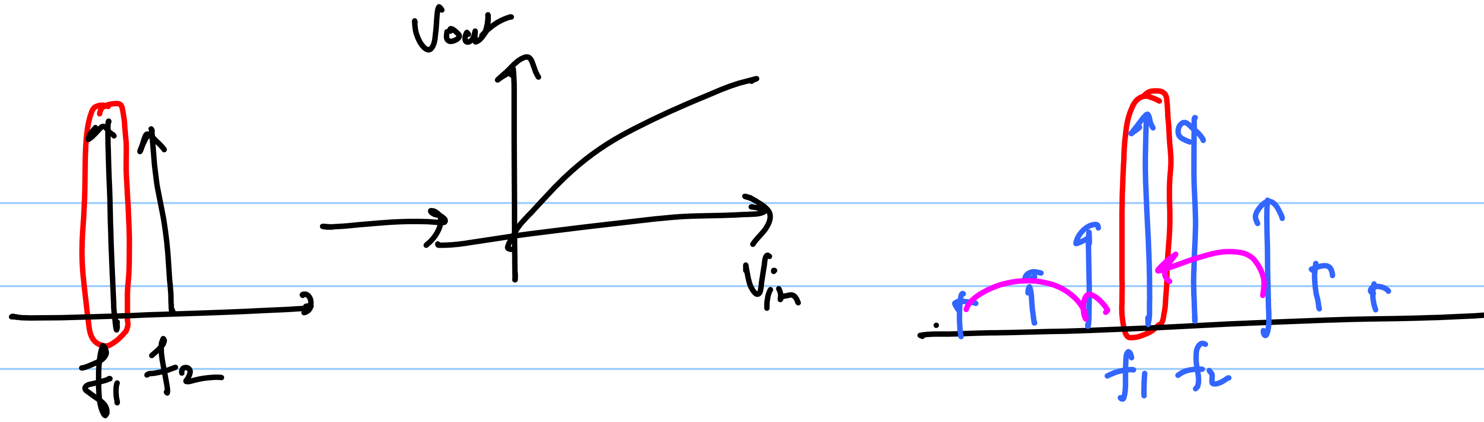




$$A_1 V_{in} - A_3 V_{in}^3 - A V_{in}^5$$

$$V_{out}(t) = A_1 \sin \omega_0 t - A_3 \sin^3 \omega_0 t$$

$\sin 3\omega_0 t$



$2f_1 - f_2$

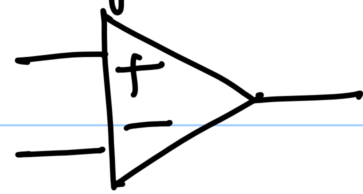
$3f_1 - f_2$

trade-off's

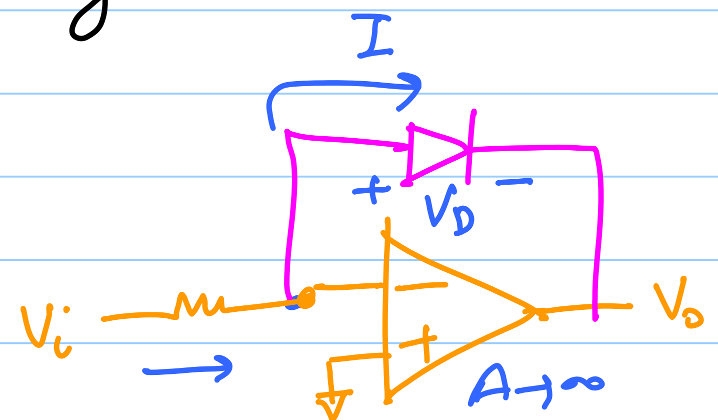
* gain
* speed / bandwidth
* headroom (voltage swing) $\longleftrightarrow$ V_{DD}
* noise
* non-linearity
* Power dissipation
* input & output impedances

Aside

operational amplifier



large gain

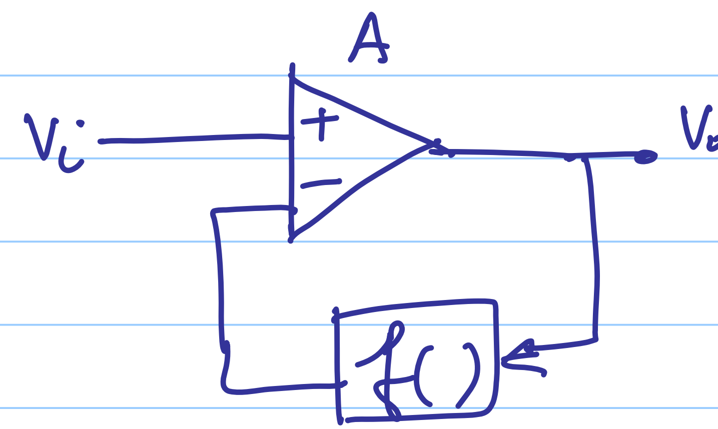


$V_o = -V_D$

$$I = I_0 e^{\frac{V_D}{V_T}} = \frac{V_i}{R}$$

$\frac{V_i}{R}$

$$e^{v_D/nV_T} = \frac{V_i}{I_0 R}$$

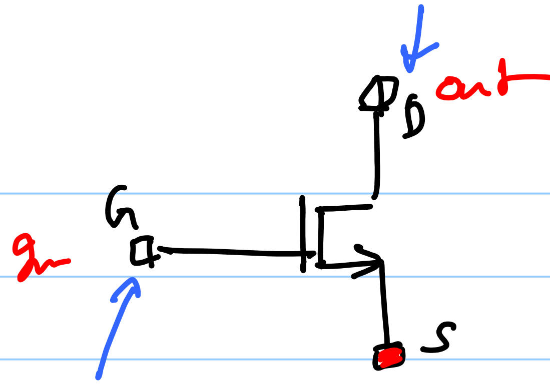


$$v_D = nV_T \ln\left(\frac{V_i}{I_0 R}\right)$$

$$v_{out} = -nV_T \ln\left(\frac{V_i}{I_0 R}\right)$$

$$V_o = f^{-1}(V_{in})$$

Δ

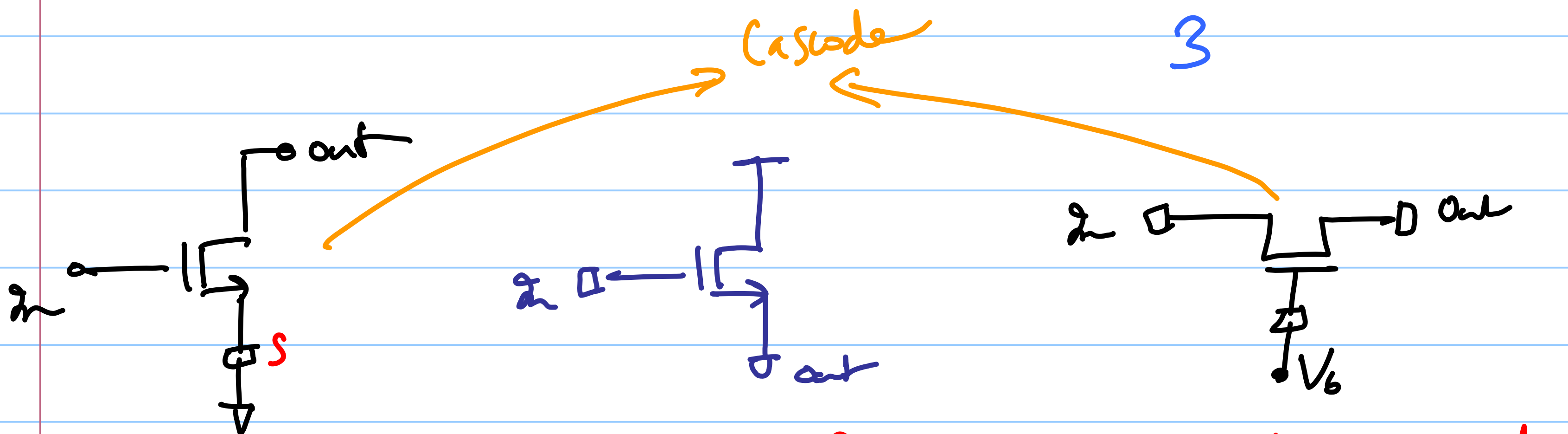


VCCS

$^3P_2$ possibilities

$\cancel{3!}$

3



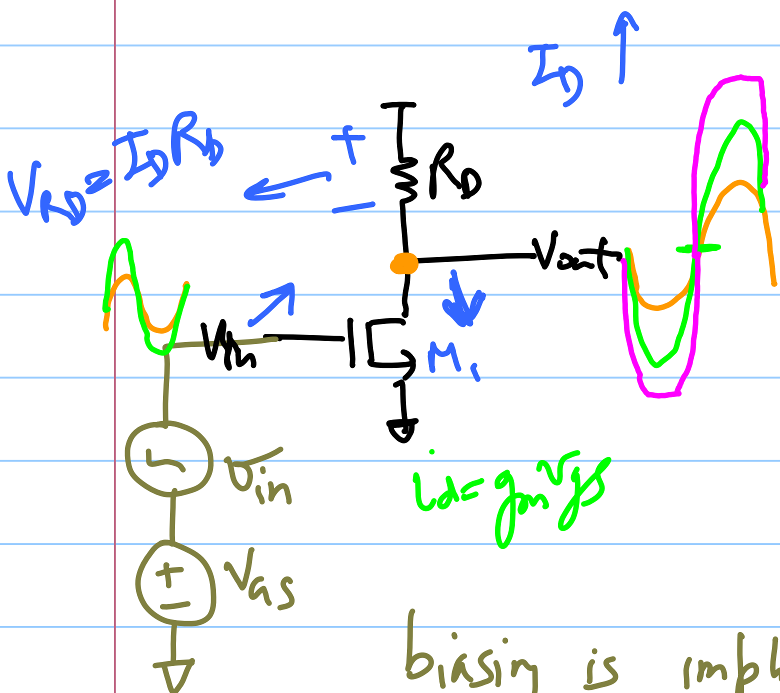
Common Source

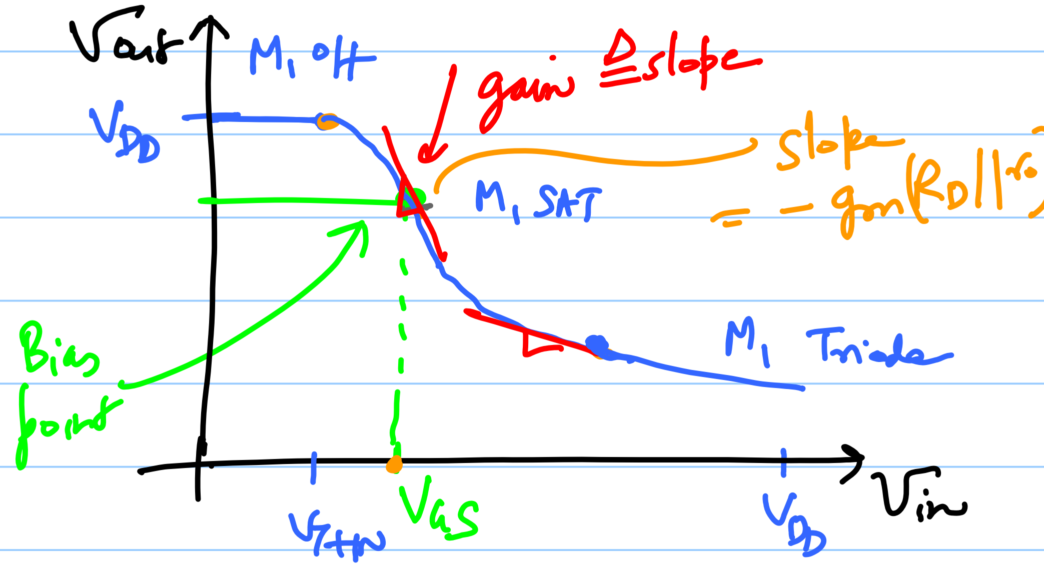
Common Drain
(Source follower)

Common gate

Common Source :

inverting gain





biasing is implicit

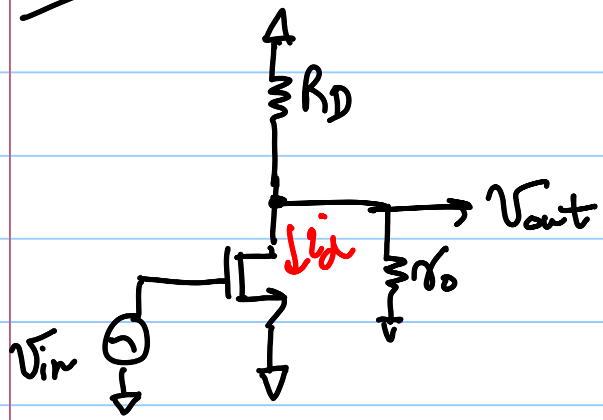
$V_{GS} \rightarrow V_{ov} \Rightarrow g_m r_o$, f_T

May Bias V_{DS} at

$V_{DS} > V_{DS,sat}$

$$\frac{V_{DS,sat} + V_{DD}}{2}$$ for max swing

Small signal



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

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

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

$$\simeq -g_m R_D \qquad R_D \ll r_o$$

* How do we maximize the voltage gain

$$A_v \simeq -g_m \cdot R_D$$

$$= -\sqrt{2\beta_n I_D} \cdot R_D \rightarrow \frac{V_{R_D}}{I_D}$$

$$= -\sqrt{2\beta_n I_D} \cdot \frac{V_{R_D}}{I_D}$$

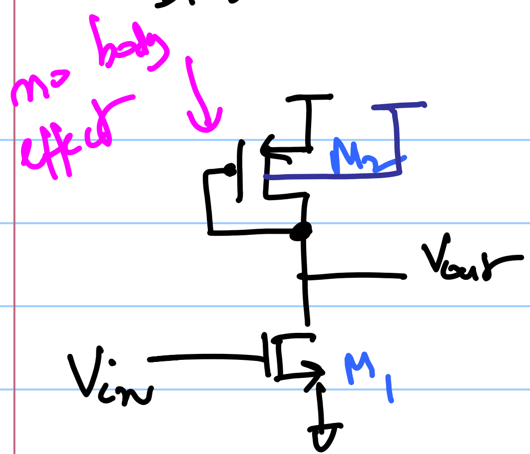
$$= -\sqrt{2\beta_n} \cdot \frac{V_{R_D}}{\sqrt{I_D}}$$

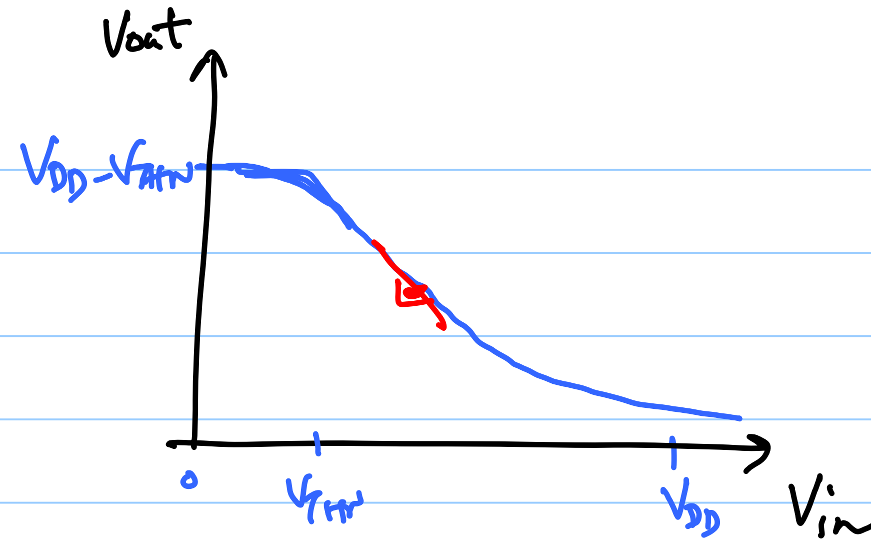
$|A_v|$ can be increased by increasing $\frac{W}{L}\uparrow \rightarrow$ more cap

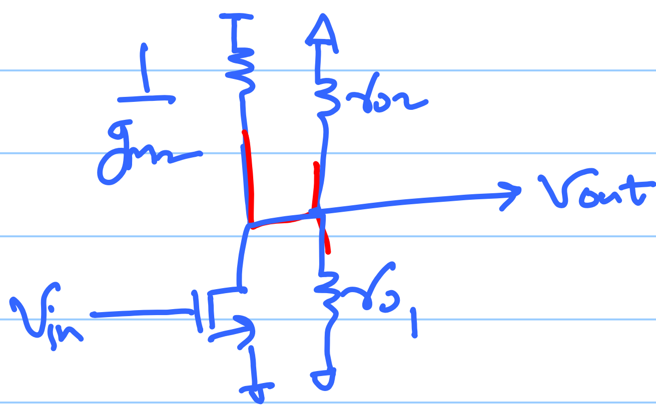
or $V_{R_D}\uparrow \Rightarrow$ lower swing

or $I_D\downarrow \Rightarrow$ lower speed

Diode connected load







$$A_v = -g_{m1} \cdot \frac{1}{g_{m2}} \| r_{o1} \| r_{o2}$$

$$\simeq -\frac{g_{m1}}{g_{m2}}$$

$$= -\sqrt{\frac{KP_n (W/L)_1}{KP_p (W/L)_2}}$$

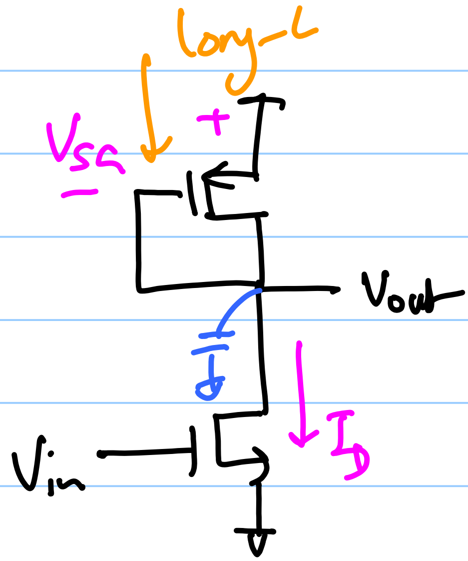
$$\frac{1}{g_m} \ll r_o$$

$$\Rightarrow g_m r_o \gg 1$$

How do we get $|A_v| >> 1$?

$$\left(\frac{W}{L}\right)_1 > \left(\frac{W}{L}\right)_2$$

$$\Rightarrow \quad L_2 = 5L_1$$



larger area

lower headroom

gains are lower