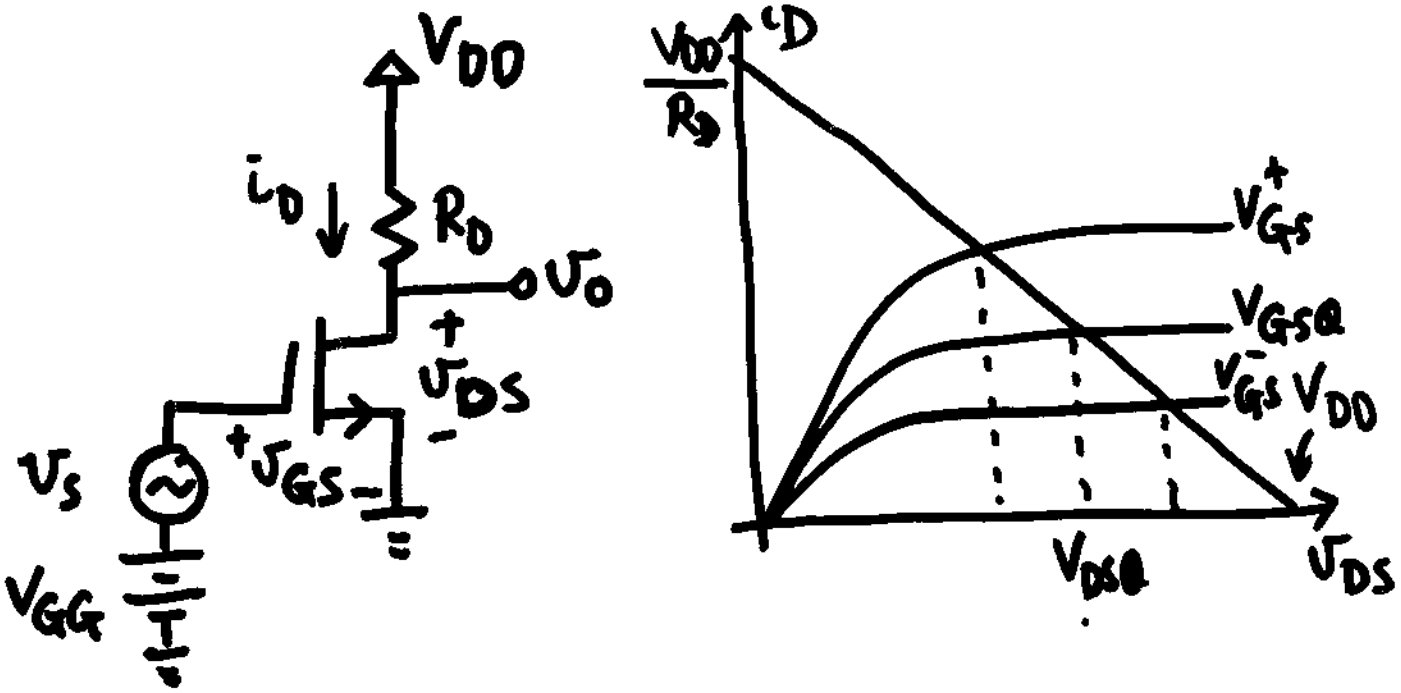
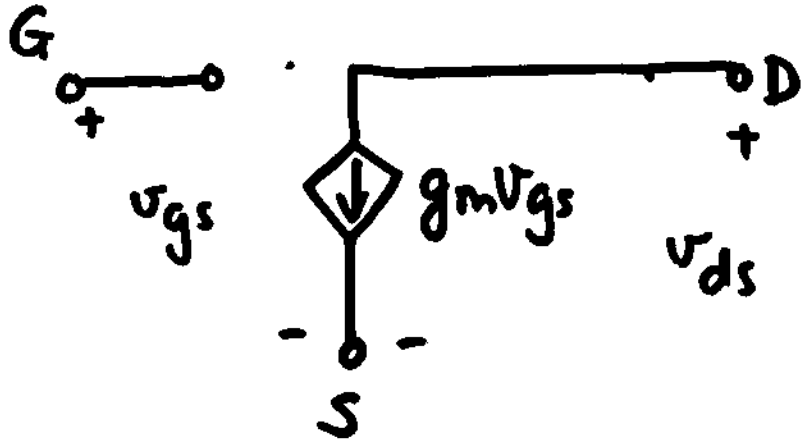
MOSFET Amplifiers



SATURATION:

$$i_D = K_N (v_{GS} - V_{TH})^2$$

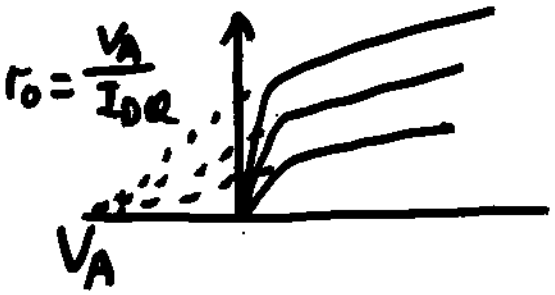
$$\simeq \underbrace{K_N (V_{GSQ} - V_{TH})^2}_{I_{DQ}} + \underbrace{2K_N (V_{GSQ} - V_{TH}) v_{gs}}_{i_d = g_m v_{gs}}$$



Channel length modulation

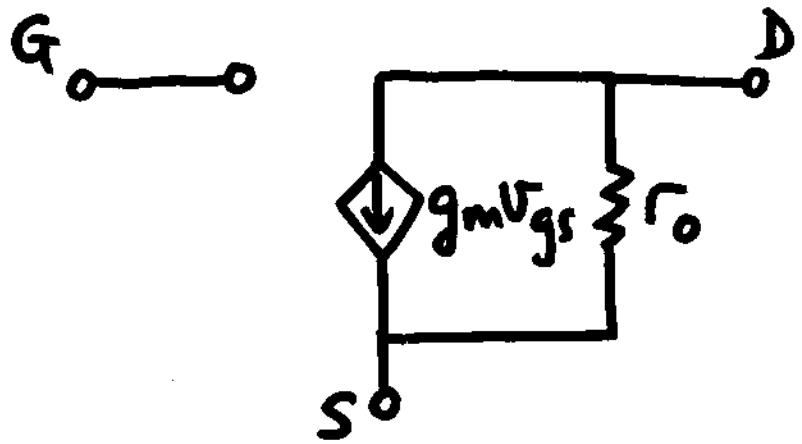
$$I_D = K_N (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS})$$

channel length modulation factor



Incremental drain-to-source resistance

$$r_o = r_{ds} = \left.\frac{\partial V_{DS}}{\partial I_D}\right|_{V_{GSQ}} = \frac{1}{\lambda K_N (V_{GSQ} - V_{TH})^2}$$



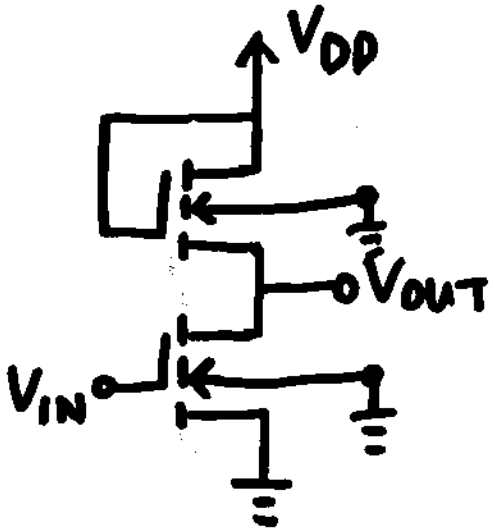
Should g_m change according?

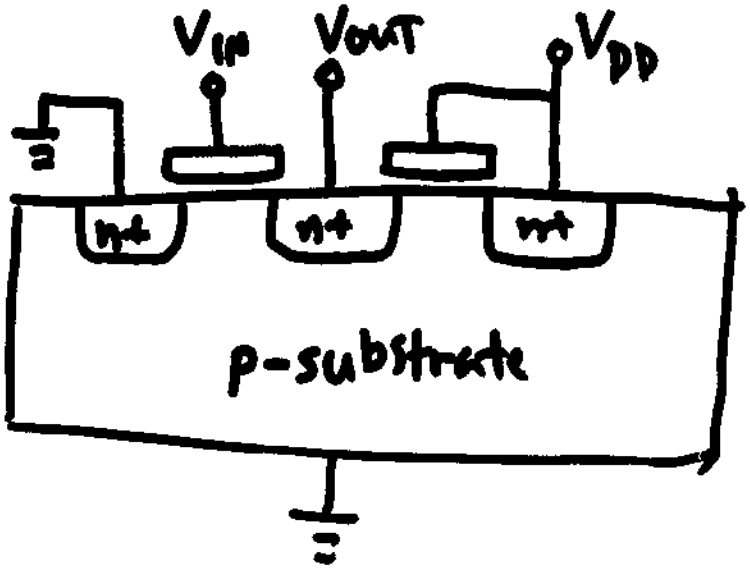
YES : $g_m = 2K_N (V_{GSQ} - V_{TH})(1 + \lambda V_{DSQ})$

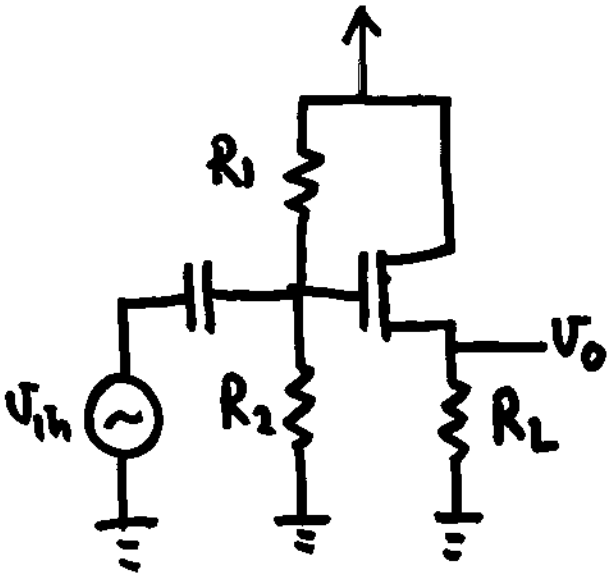
But typically ignored

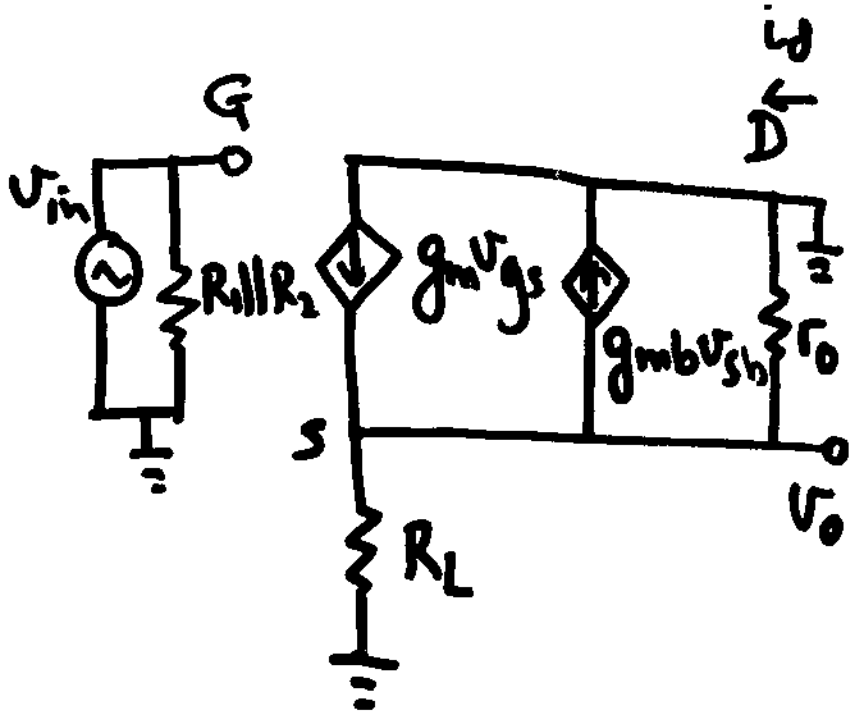
Body effect

$$V_{TH} = V_{THO} + \gamma\left[\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right]$$









$$g_{mb} = \left.\frac{\partial I_D}{\partial V_{SB}}\right|_{Q\text{-pt}}$$

$$= \left.\frac{\partial I_D}{\partial V_{TH}} \cdot \frac{\partial V_{TH}}{\partial V_{SB}}\right|_{Q\text{pt}}$$

$$= -2K_N(V_{GSQ} - V_{TH}) \cdot \frac{\gamma}{2\sqrt{2\phi_f + V_{SBQ}}}$$

$$= -g_m \frac{\gamma}{\sqrt{2\phi_f + V_{SBQ}}}$$

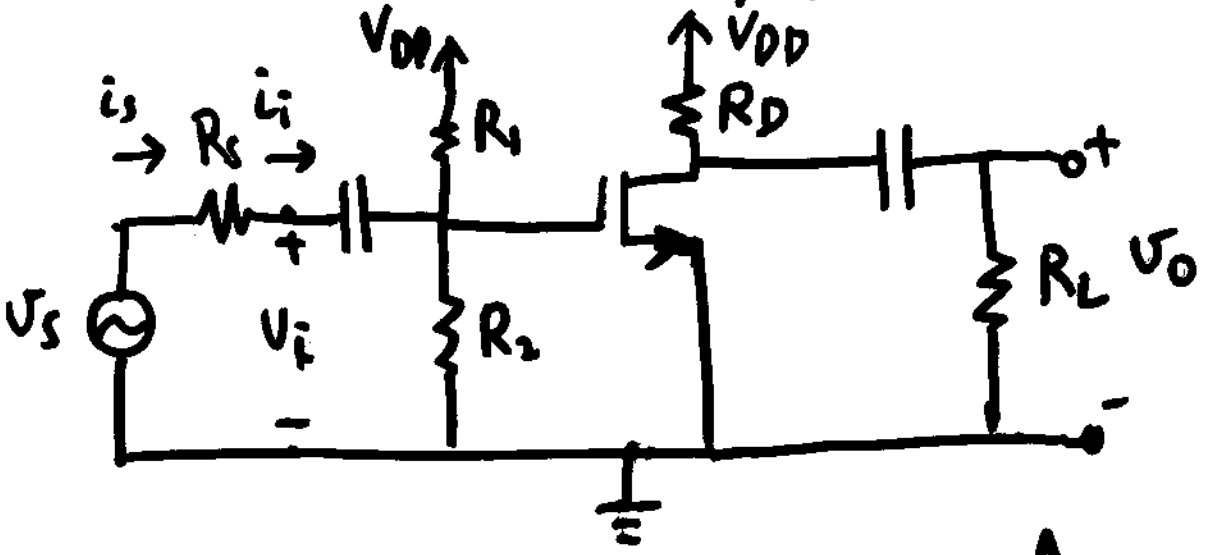
$v_{sb} > 0$

$\Rightarrow v_{SB}$ increases

$\Rightarrow v_{TH}$ increases

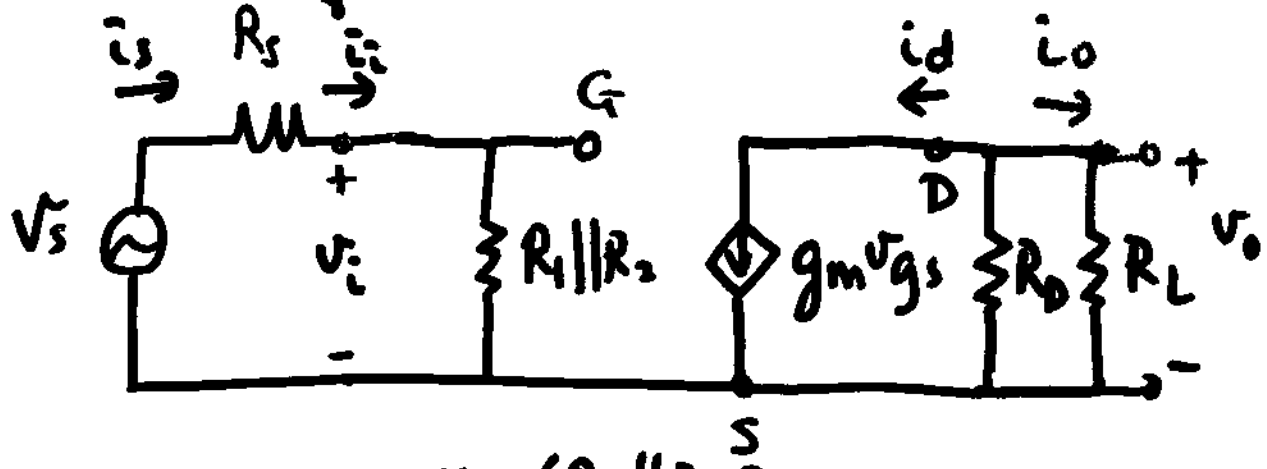
$\Rightarrow i_D$ decreases

Common-Source Amplifier



Assume $r_o = \infty$

a.c. equivalent circuit



$$v_o = -g_m v_{gs} (R_D \| R_L)$$

$$v_i = v_{gs}$$

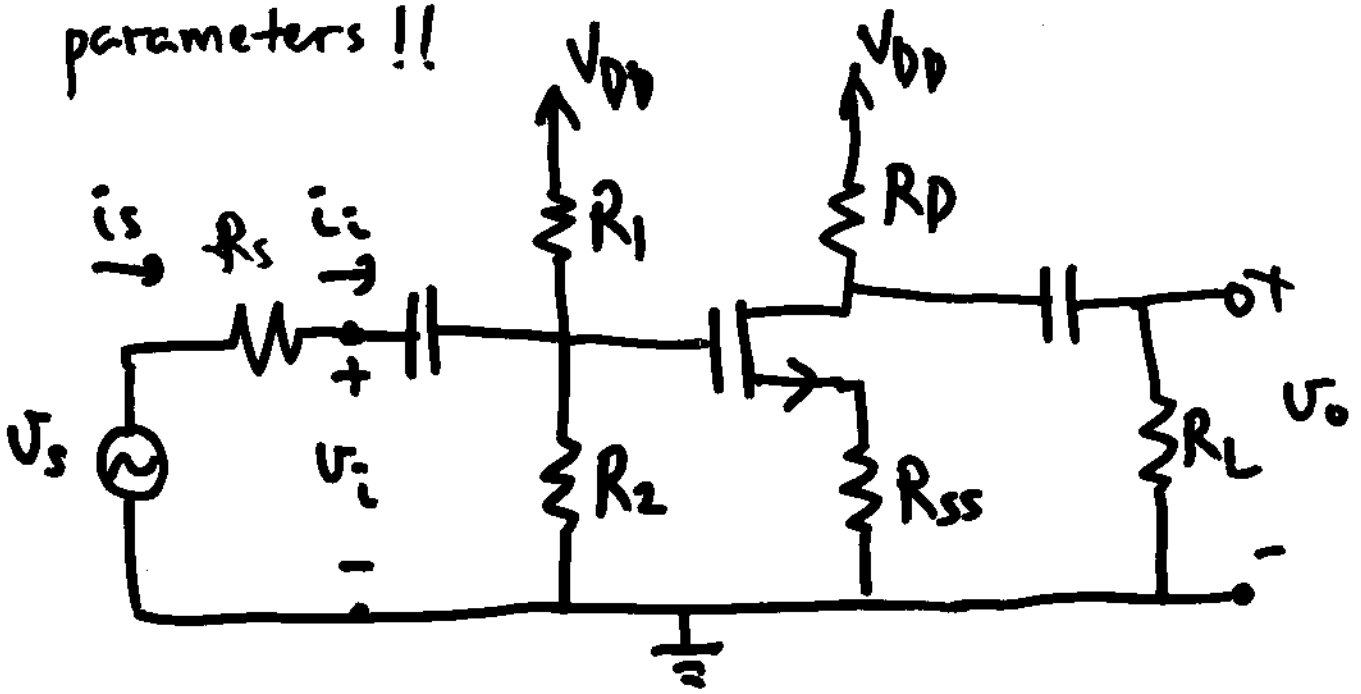
$$A_{v_i} = -g_m (R_D \| R_L)$$ ← Just like CE BJT Amp!!

$g_{m\,FET} < g_{m\,BJT}$

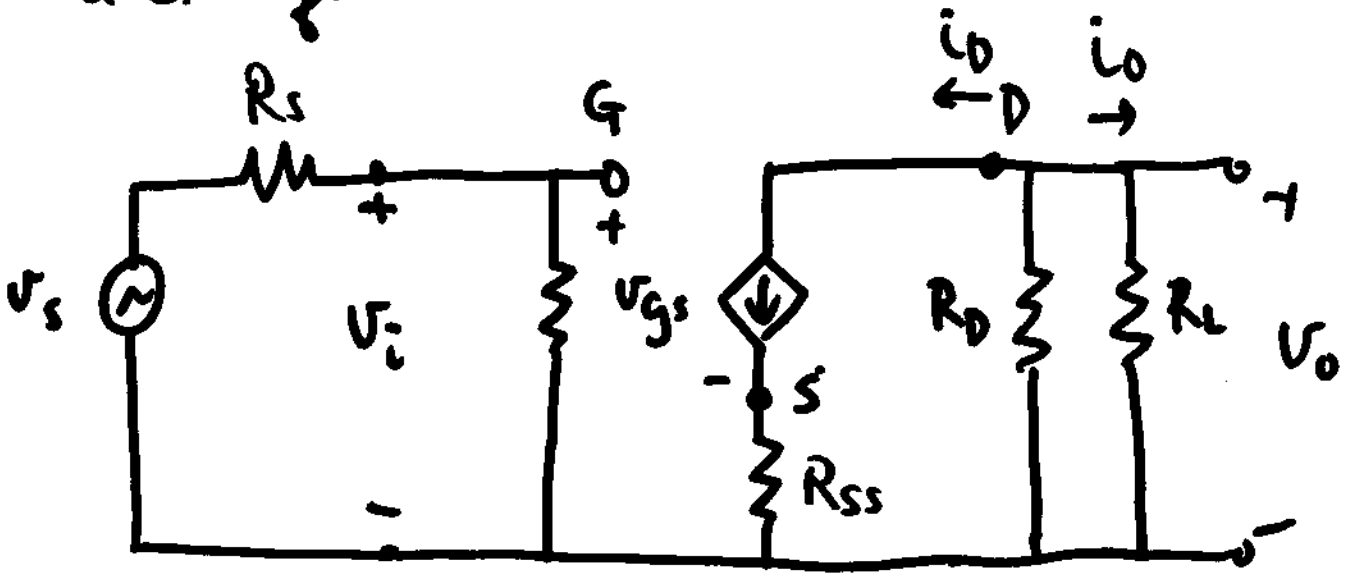
$$A_{i_i} = \frac{v_o / R_L}{v_i / R_{in}} = A_{v_i} \frac{R_1 \| R_2}{R_L}$$

$$A_{p_i} = A_{i_i} A_{v_i} = A_{v_i}^2 \frac{R_1 \| R_2}{R_L}$$

Add source degeneration resistor to stabilize against variations in transistor parameters !!



a.c. equivalent circuit



$$v_o = -g_m v_{gs} (R_D \| R_L)$$

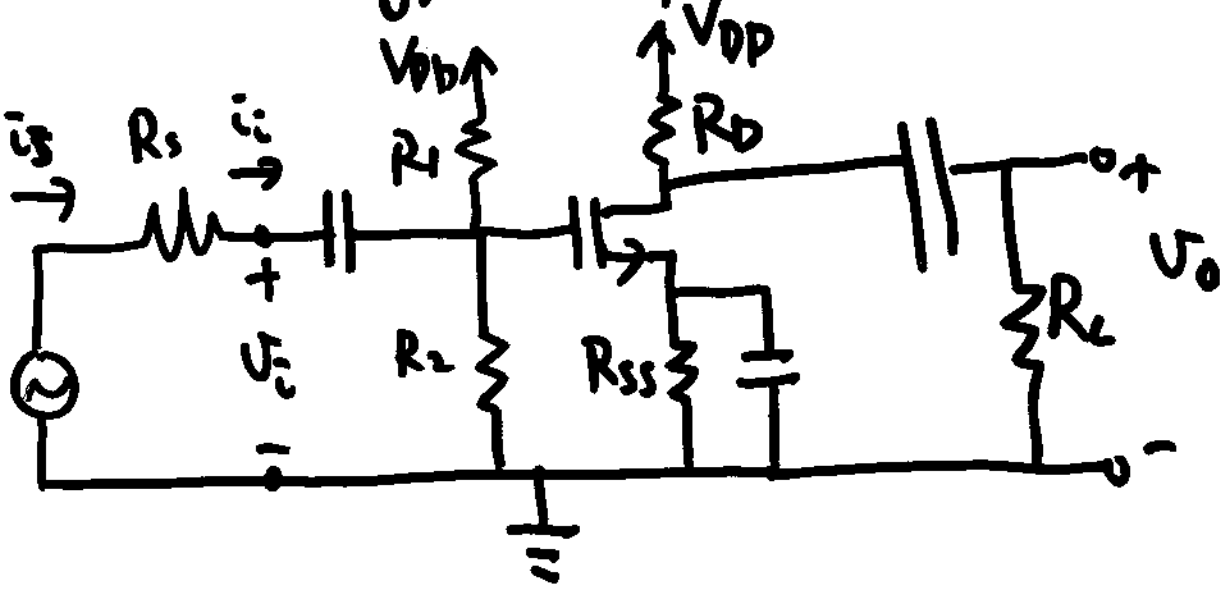
$$v_i = v_{gs} + g_m v_{gs} R_{ss}$$

$$= v_{gs} (1 + g_m R_{ss})$$

$$A_{v_i} = \frac{-g_m (R_D \| R_L)}{1 + g_m R_{ss}}$$

STABLE BUT LOW GAIN

Add a bypass capacitor



BJT - MOSFET Analogy

C.E. C.S.

BJT

$$v_o = -g_m v_\pi (R_C \| R_L)$$

$$v_i = v_\pi + (\beta+1) i_b R_E$$

$$\approx v_\pi + (\beta+1) \frac{v_\pi}{r_\pi} R_E$$

$$A_{v_i\,BJT} = \boxed{\frac{-g_m (R_C \| R_L)}{1 + \frac{(\beta+1) R_E}{r_\pi}}} \quad \text{—— ①}$$

$\beta \to \infty$, $r_\pi \to \infty$, $\beta / r_\pi \to g_m$, $R_C \to R_D$, $R_E \to R_{SS}$

① becomes $\dfrac{-g_m (R_C \| R_L)}{1 + \frac{(\beta+1) R_E}{r_\pi}}$

$$\approx \frac{-g_m (R_D \| R_L)}{1 + g_m R_E}$$