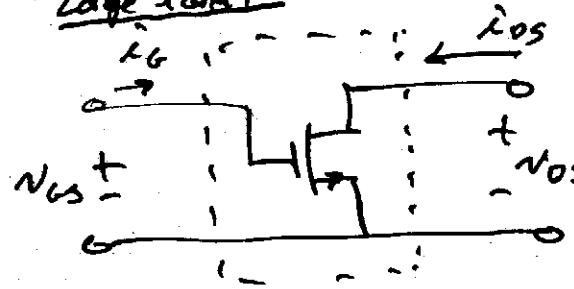
MOSFET SMALL SIGNAL MODEL

Large signal



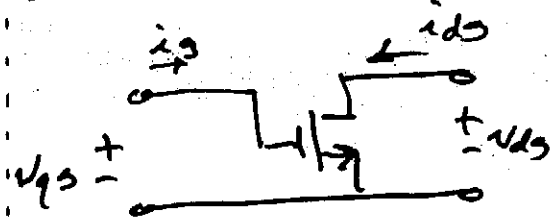
MATH MODEL

SAT mode

$$i_{DS} = \frac{K_n}{2}(v_{GS} - V_{TH})^2(1+\lambda v_{DS})$$

$$i_G = 0$$

small signal



MATH MODEL

$$i_{ds} = K_1 v_{gs} + K_2 v_{ds}$$

$$i_g = 0$$

$$K_1 \equiv \left.\frac{i_{ds}}{v_{gs}}\right|_{v_{ds}=0} = \left.\frac{\partial i_{DS}}{\partial v_{GS}}\right|_{Q} = K_n(v_{GS} - V_{TH})(1+\lambda v_{DS}) = g_m$$

(corollary : $\lambda v_{DS} \simeq 0 \rightarrow g_m = \sqrt{K_n I_{DS}} = \sqrt{2K_n' \frac{W}{L} I_{DS}}$)

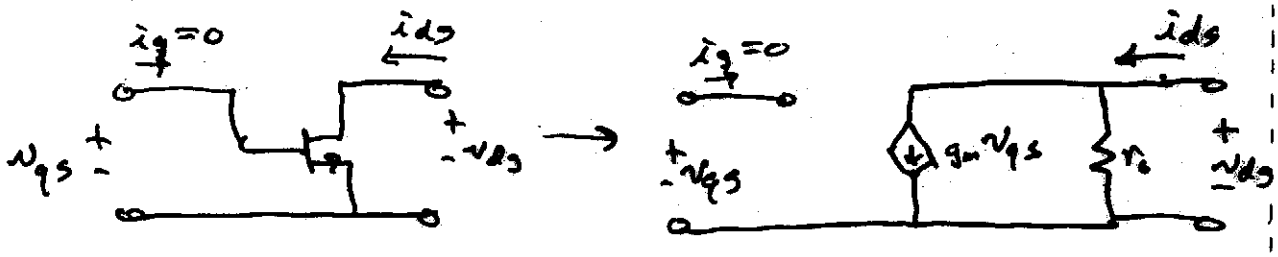
$$g_m = K_1 = K_n \sqrt{\frac{2I_{DS}}{K_n(1+\lambda v_{DS})}}(1+\lambda v_{DS})$$

$$\boxed{g_m = \sqrt{2 I_{DS} K_n (1+\lambda v_{DS})}}$$

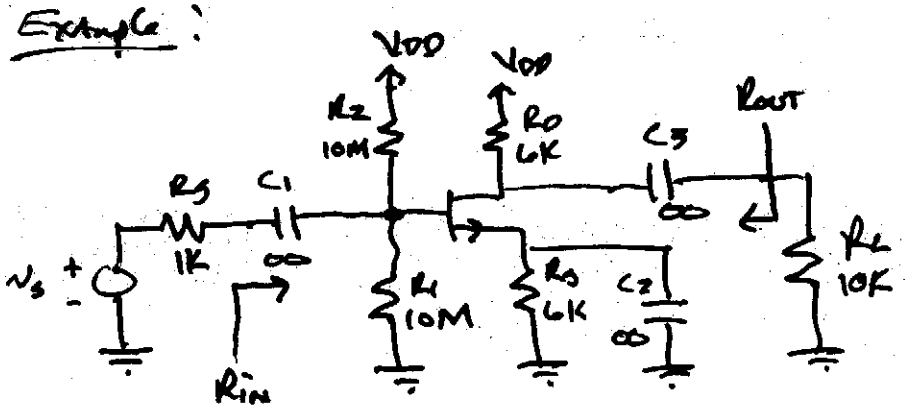
$$K_2 \equiv \left.\frac{i_{ds}}{v_{ds}}\right|_{v_{gs}=0} = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_{Q} = \lambda \frac{K_n}{2}(v_{GS} - V_{TH})^2$$

$$= \lambda \frac{K_n}{2}\left(\frac{2I_{DS}}{K_n(1+\lambda v_{DS})}\right)$$

$$\Rightarrow \boxed{g_o = \frac{1}{r_o} = \frac{\lambda I_{DS}}{1+\lambda v_{DS}}}$$



Example:



Given:

$K_n = \frac{0.5mA}{V^2}$

$V_{TN} = 1V$

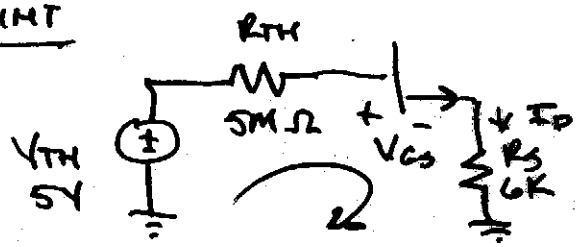
$\lambda = 0.01\ V^{-1}$

$V_{DD} = 10V$

Find

A_V, R_{in}, R_{out}

FIND Q POINT



$$5 = V_{GS} + R_S\left[\frac{K_n}{2}(V_{GS} - V_T)^2\right] \rightarrow I_D$$

$$0 = \frac{3}{2}V_{GS}^2 - 2V_{GS} - 7/2$$

$V_{GS} = 7/3$ OR -1 → $V_{GS} = 2.33V$

$$I_{DS} = \frac{0.5mA}{2}(2.33-1)^2 = 0.442mA$$

$$V_{DS} = +10 - I_D(R_D + R_S) = 4.70\ V$$

SAT MODE: $V_{DS} > V_{GS} - V_T = 1.33V$

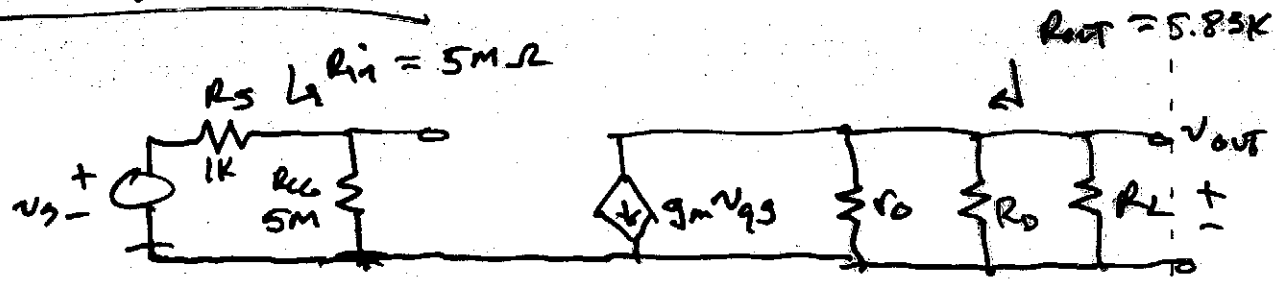
$V_{DS} = 4.707 > 1.33$ ← SAT MODE!

small signal parameters

$$g_m = \sqrt{K_n I_D (1+\lambda V_{DS})} = 0.668 mS$$

$$r_o = \frac{V_{OST} + \frac{L}{2}}{I_{DS}} = 237 K\Omega$$

small signal circuit



$$A_V = \left(\frac{v_{gs}}{v_s}\right)\left(\frac{v_{out}}{v_{gs}}\right) = -2.46 \, V/V$$