ECE 2100 Lecture Notes 4/11/03

HW #20, due: W, 4/9 — ans change: last problem: $1.16 \cdot MHz$

A. Stolp 4/10/03, 4/17/03

HW # 21, due: F 4/11 Ex5.1 - Ex5.8
ans: Ex5.7: V_{SB}=4V, i_D=0.182mA, r_c=578ohm

HW # 22, due: W 4/16 Ex5.9 - Ex5.16
Check assumptions, esp saturation on 15 & 16

Spice #S3, due: F, 4/18 handout

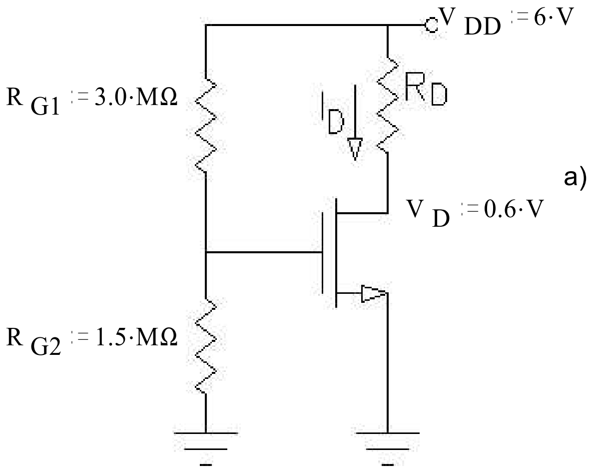
HW # 23, due: F 4/18 Ex5.17 - Ex5.23

HW # 24, due: M 4/21 Ex5.24 - Ex5.34
Ex 5.28 Ans: ...128kΩ, 192kΩ,...
May need for Ex5.33: V_{DD}= 5V, V_{tn}= 0.8V

Ex1 The transistor in the circuit shown has the following characteristics.

$\mu_n \cdot C_{ox} = k'_n := 90 \cdot \frac{\mu A}{V^2}$ $\qquad \frac{W}{L} = 12$

$V_t := 0.8 \cdot V \qquad \lambda := 0 \qquad W := 12 \cdot L$



a) Find I_D

$V_G := \frac{R_{G2}}{R_{G1} + R_{G2}} \cdot V_{DD} \qquad V_G = 2 \cdot V$

$V_{GD} := V_G - V_D \qquad V_{GD} = 1.4 \cdot V > V_t = 0.8 \cdot V$ Triode region

OR:

$V_{GS} := V_G$

$V_{DS} := V_D \qquad V_{DS} = 0.6 \cdot V < V_{GS} - V_t = 1.2 \cdot V$ Triode region

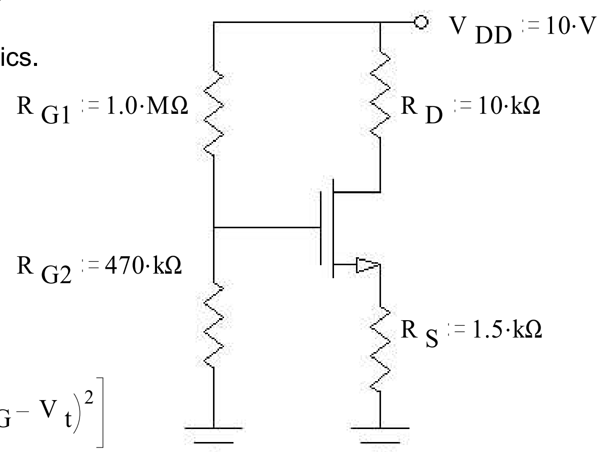
$I_D := k'_n \cdot \frac{W}{L} \cdot \left[\left(V_{GS} - V_t \right) \cdot V_{DS} - \frac{1}{2} \cdot V_{DS}^2 \right] \qquad I_D = 0.583 \cdot mA$

b) What is the value of R_D?

$R_D := \frac{V_{DD} - V_D}{I_D} \qquad R_D = 9.26 \cdot k\Omega$

Ex2 The transistor in the circuit shown has the following characteristics.

$k'_n \cdot \frac{W}{L} = K := 3.0 \cdot \frac{mA}{V^2} \qquad V_t := 1.8 \cdot V \qquad \lambda := 0$



a) $V_{DD} = 10 \cdot V$ Find V_G

$V_G := \frac{R_{G2}}{R_{G1} + R_{G2}} \cdot V_{DD} \qquad V_G = 3.197 \cdot V$

$V_G = 3.2 \cdot V$

b) Find I_D $\quad 0 = \left[R_S^2 \cdot I_D^2 - 2 \cdot \left[\left(V_G - V_t \right) \cdot R_S + \frac{1}{K} \right] \cdot I_D + \left(V_G - V_t \right)^2 \right]$

$a := R_S^2 \qquad b := -2 \cdot \left[\left(V_G - V_t \right) \cdot R_S + \frac{1}{K} \right] \qquad c := \left(V_G - V_t \right)^2$

$I_{D1} := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a} \qquad I_{D1} = 1.626 \cdot mA \qquad I_{D2} := \frac{-b - \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a} \qquad I_{D2} = 0.534 \cdot mA$

Try: $V_{GS1} := V_G - I_{D1} \cdot R_S \qquad V_{GS1} = 0.759 \cdot V < V_t = 1.8 \cdot V$ Doesn't make sense

$V_{GS2} := V_G - I_{D2} \cdot R_S \qquad V_{GS2} = 2.397 \cdot V > V_t = 1.8 \cdot V$ OK, $I_D := 0.5338 \cdot mA$

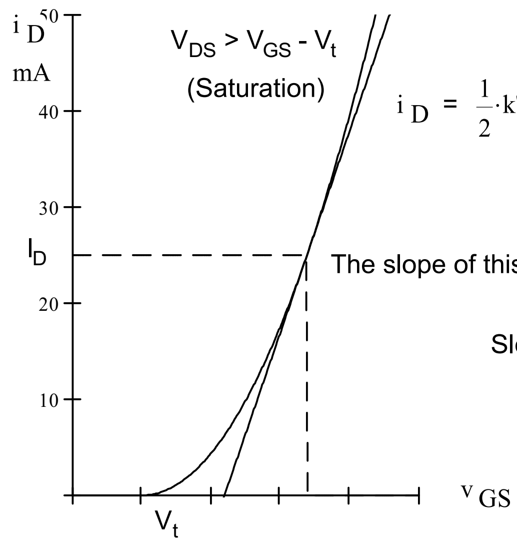
The equation only works in the SATURATION region, so check. $V_D := V_{DD} - I_D \cdot R_D \qquad V_D = 4.662 \cdot V$

$V_{GD} := V_G - V_D \qquad V_{GD} = -1.465 \cdot V < V_t = 1.8 \cdot V$ Saturation region

OR:

$V_S := I_D \cdot R_S \qquad V_S = 0.801 \cdot V \qquad V_{GS} := V_G - V_S \qquad V_{GS} = 2.397 \cdot V$

$V_{DS} := V_D - V_S \qquad V_{DS} = 3.861 \cdot V > V_{GS} - V_t = 0.597 \cdot V$ Saturation region



$$i_D = \frac{1}{2}\cdot k'_n\cdot\frac{W}{L}\cdot\left(v_{GS} - V_t\right)^2$$

The slope of this line at the bias point is the "linearization" about the bias point.

$$\text{Slope} = \frac{d}{dv_{GS}} i_D = \frac{d}{dv_{GS}}\left[\frac{1}{2}\cdot k'_n\cdot\frac{W}{L}\cdot\left(v_{GS} - V_t\right)^2\right]$$

$$= \left[k'_n\cdot\frac{W}{L}\cdot\left(V_{GS} - V_t\right)\right]\cdot 1 = g_m = \frac{i_d}{v_{gs}}$$

small signal values

$$g_m = k'_n\cdot\frac{W}{L}\cdot\left(V_{GS} - V_t\right) = \sqrt{k'_n\cdot\frac{W}{L}\cdot 2\cdot I_D}$$

$$= \sqrt{\frac{4\cdot I_{DSS}\cdot I_D}{V_t^{\,2}}}$$ Depletion-type parts

Also called "transfer admittance, y_f"

Use $\frac{1}{g_m}$ in gain equations like r_e for BJT's

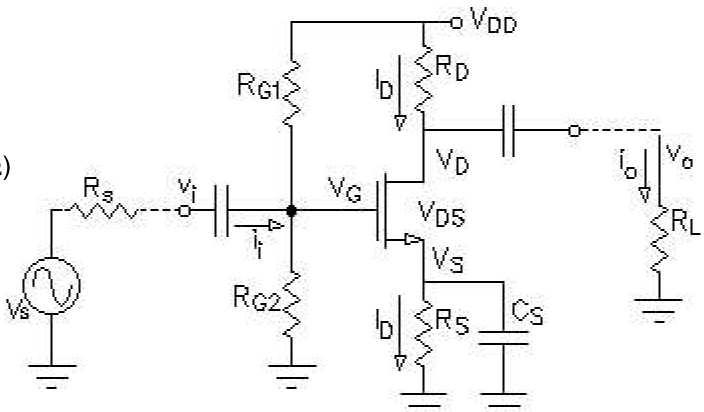
Common-source amp

DC bias: $V_G = \frac{R_{G2}}{R_{G1} + R_{G2}}$

$I_G = 0$, so R_{G1} and R_{G2} can be very large (typ $\geq$ 1 MΩ)

$V_S = R_S\cdot I_D$

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



Input impedance: $R_i = R_{G1} \| R_{G2}$

Except at high frequencies, the input impedance to the MOSFET itself can be considered ∞

Output impedance: $R_o = R_D \| r_o$ <---- Often neglected: $r_o = \frac{V_A}{I_D} = \frac{1}{\lambda\cdot I_D}$ (Early voltage.)

AC collector resistance: $r_d = R_D \| R_L \| r_o$

Voltage gain: $A_v = \frac{v_o}{v_g} = g_m\cdot r_d$

Unloaded voltage gain: $A_{v0} = g_m\cdot R_o$

This is not a very linear amplifier, especially with large output signals, however, the swing limits are:
Clipping
Maximum output swings before clipping: + swing: $L+ = I_D\cdot r_d$ - swing: $L- = \frac{V_D - V_G + V_t}{1 + \frac{1}{A_v}}$

V_{oppmax} is smaller of: 2L + or 2L -