ECE2c Problem set #5:

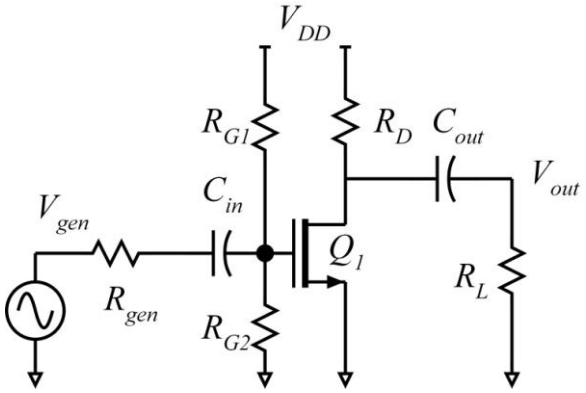
model statement: for old-fashioned mobility-limited NFETs,

$I_d = (\mu C_{ox} W_g / 2L_g)(V_{gs} - V_{th})^2 (1 + \lambda V_{ds})$ for $V_D > V_g - V_{th}$ and

$I_d = (\mu C_{ox} W_g / 2L_g)\left(2(V_{gs} - V_{th})V_{DS} - V_{DS}^2\right)(1 + \lambda V_{ds})$ for $V_D < V_g - V_{th}$.

As is discussed in the notes, for PFETs, the polarities of V_{gs} and V_{ds}, and the direction of I_D, are all reversed.

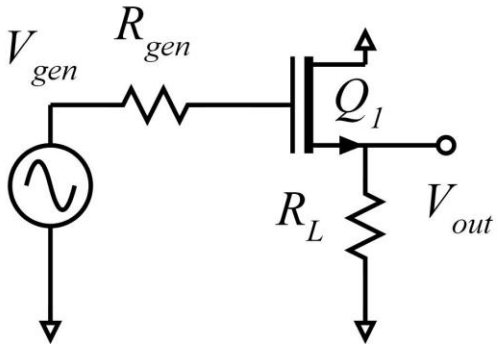
Problem 1: The FET is mobility-limited with $(\mu C_{ox} W_g / 2L_g) = 1$ mA/V^2, $1/\lambda = 10$ V and V_{th} =0.3V. The DC drain current is 100 μA, the DC current in R_{G1} is 100 μA, V_{DD} is 5 V, and the DC drain voltage is 2.5 V. R_L is four times R_D, while R_{gen} = 50 kOhm. C_{in} and C_{out} are extremely big.



The transistor has C_{gs} =0.5 fF and C_{gd} =0.25 fF.

(a) Find the values of all resistors. (b) Draw a circuit diagram indicating all DC node voltages and all DC branch currents. (c) Find the transconductance and output conductance of the transistor. (d) Draw a small signal equivalent circuit of the transistor, ***including the gate-source and gate-drain capacitances*** (e) Draw a small-signal equivalent circuit of the whole amplifier. ***We are going to ignore the effects of C_{in} and C_{out}; please replace these capacitors with short-circuits.*** (f) Compute the small-signal transfer function $V_{out}(s)/V_{gen}(s)$. (g) Find the pole and zero frequencies of the transfer function. (h) Make a Bode plot, (horizontal axis being frequency in Hz on semi log paper, vertical axis being dB) of V_{out}/V_{gen}. What is the -3 dB bandwidth ? (i) If $V_{gen}(t)$ is a 1 mV step-function, find $V_{out}(t)$ and make an accurate plot of this. (j) What is the 10%-90% risetime of the step response ? Is it predominantly controlled by one of the two poles ?

Problem 2: This is a *source-follower or common-drain amplifier*. Ignore DC bias; you don't need it (we will learn how to deal with this in ece137ab) . The transistor has C_{gd} =0 fF. It has nonzero values for G_{ds}., g_m , and C_{gs}.



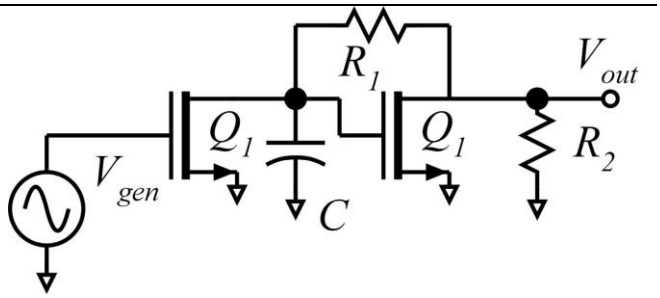
(a) Draw an accurate small-signal equivalent circuit model of the circuit. (b) Using NODAL ANALYSIS, find the transfer function Vo(s)/Vgen(s). The answer must be in standard

form:

$$\frac{V_o(s)}{V_{gen}(s)} = \frac{V_o}{V_{gen}}\bigg|_{\substack{\text{low=frequency}\\ \text{value}}} \times \frac{1+b_1 s+b_2 s^2+...}{1+a_1 s+a_2 s^2+...}$$

(c) g_m=50 mS, Rgen=100kOhm, RL=1kOhm. C_{gs} = 1 pF, Gds=1mS. Find the frequency of all poles and zeros in the transfer function, giving them in Hz. (d) Draw a quantitatively accuract plot of the root locus. (e) Make an accurate Bode plot of Vout/Vgen, labeling all slopes, and all key gain and frequency values. Make sure you draw the straight-line asymptotes, and then sketch the true curve. What is the -3 dB bandwidth ? (f) If Vin(t) is a 1 mV step-function, find and accurately plot Vout(t). Be sure to label both axes and give units. (j) What is the 10%-90% risetime of the step response ?

Problem 3: This is a *transconductance-transimpedance amplifier*. Ignore DC bias; you don't need it. (we will learn how to deal with this in ece137ab) The transistors have zero C_{gs} and C_{gd}, and have transconductance g_{m1} and g_{m2}. Both have zero G_{ds}. (a) Draw an accurate small-signal equivalent circuit model of the circuit.



(b) Using NODAL ANALYSIS, find the transfer function Vo(s)/Vgen(s). The answer must be in standard form (as defined in problem 2) (c) g_{m1}=10 mS, g_{m2}=20 mS. R_1=1,000 Ohms. R_2=1,000 Ohms. C = 1 pF. Given an numerical form of the transfer function with all pole and zero frequencies identified. How many poles are there in the transfer function ? Give its frequency / their frequencies. (d) Draw a quantitatively accuract plot of the root locus. (e) Make an accurate Bode plot of Vout/Vgen, labeling all slopes, and all key gain and frequency values. Make sure you draw the straight-line asymptotes, and then sketch the true curve. What is the -3 dB bandwidth ? (f) If Vin(t) is a 1 mV step-function, find and accurately plot Vout(t). Be sure to label both axes and give units. (j) What is the 10%-90% risetime of the step response ?