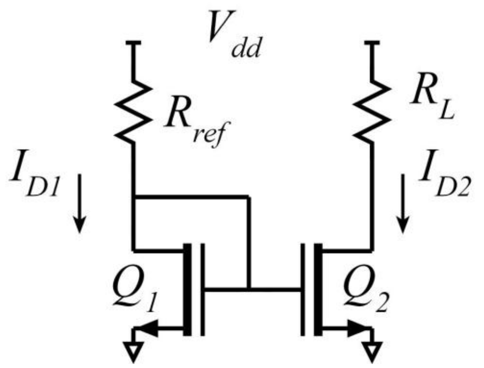
ECE2c Problem set #4:

<u>model statement</u>: 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.

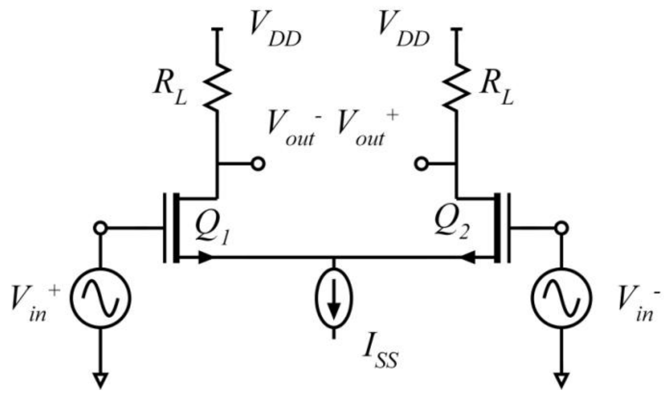
Problem 1: The MOSFETs have a +0.30 Volt threshold voltage and mobility-limited characteristics, with $(\mu C_{ox} / 2L_g) = 1\ \text{mA}/(\mu\text{m} \cdot \text{V}^2)$ and $\lambda = 0\ \text{V}^{-1}$. For Q1 the gate width W_{g1} is $1\ \mu\text{m}$. V_{dd} =3.3 Volts. Pick R_{ref} so that I_{D1} is 100 μA. (a) What value is needed for R_{ref} ? Assuming for a moment that R_L is small, pick W_{g2} so that I_{D2} is 300 μA.



(b) What value is needed for W_{g2} ? (c) over what range of V_{ds2}, and over what range of R_L is the output current I_{D2} is constant ?

Problem 2: Using the circuit of problem 1, now set $1/\lambda = 10\ \text{V}$. In this case, do not ignore λ in any calculation. (a) find the value of R_{ref} needed to set I_{D1} to 100 μA. (b) What width W_{g2} is needed if I_{D2} is to be 300 μA when V_{D2} =3.3 V ? (c) What is I_{D2} when V_{D2} =2.3 V ? Hint, brute-force solution involves solving a cubic polynomial. In your math classes, you have learned various numerical methods to solve hard problems.

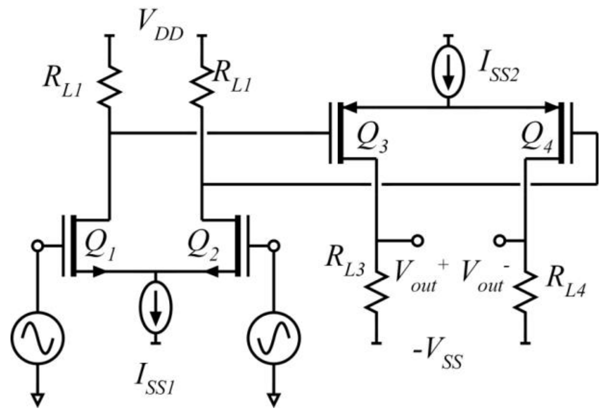
Problem 3: Q1 and Q2 are mobility-limited FETs with V_{th} =0.3V, $(\mu C_{ox} W_g / 2L_g) = 1\ \text{mA}/\text{V}^2$ and $1/\lambda = 10\ \text{V}$. V_{DD} is 2.5 V. The DC input bias voltage (as is shown) is zero volts. The DC output is at +0.5 Volts, and each FET carries 50 μA DC drain current.



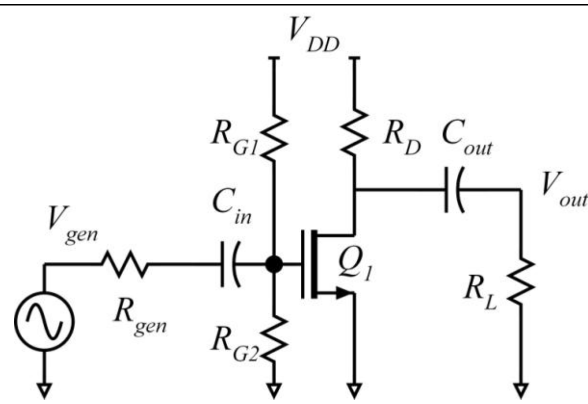
(a) Find I_{SS} and R_L. (b) Draw a circuit diagram indicating all DC node voltages and all DC branch currents. (c) Find the transconductance and output conductance of each transistor. (d) Draw a small signal equivalent circuit of each transistor. (e) Draw a small-signal equivalent circuit of the whole amplifier. (f) If $V_{in}^+ = 1\text{mV} \cdot \cos(2\pi \cdot 1\text{kHz} \cdot t)$ and

$V_{in}^{-} = 0.5\text{mV}\cdot\cos(2\pi\cdot 1\text{kHz}\cdot t)$, find $V_{out}^{+}(t)$ and $V_{out}^{-}(t)$

Problem 4: The 4FETs are mobility-limited FETs with $(\mu C_{ox}W_g/2L_g) = 1\ \text{mA/V}^2$ and $1/\lambda = 10\ \text{V}$. For the NFETs, V_{th} =0.3V, while for the PFETs, the gate must be 0.3V negative of the source in order for the FET to turn on. The DC input bias voltage (as is shown) is zero volts. The drains of Q1 and Q2 are at +0.5 Volts DC, the drains of Q3 and Q4 are at +0.0 Volts and all FETs carries 50 μA DC drain current. (a) Find the values of the 2 DC current sources and the 4 resistors. (b) Draw a circuit diagram indicating all DC node voltages and all DC branch currents. (c) Find the transconductance and output conductance of each transistor. (d) Draw a small signal equivalent circuit of each transistor. (e) Draw a small-signal equivalent circuit of the whole amplifier. (f) If $V_{in}^{+} = 1\text{mV}\cdot\cos(2\pi\cdot 1\text{kHz}\cdot t)$ and $V_{in}^{-} = 0.5\text{mV}\cdot\cos(2\pi\cdot 1\text{kHz}\cdot t)$, find $V_{out}^{+}(t)$ and $V_{out}^{-}(t)$



Problem 5: The FET a mobility-limited with $(\mu C_{ox}W_g/2L_g) = 1\ \text{mA/V}^2$ and $1/\lambda = 10\ \text{V}$ and V_{th} =0.3V. The DC drain current is 50 μA, the DC current in R_{G1} is 50 μA, V_{DD} is 3.3 V, and the DC drain voltage is 2.0 V. R_L is four times R_D, while R_{gen}= 100 kOhm. C_{in}=C_{out}= 1 microFarad.



(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. (e) Draw a small-signal equivalent circuit of the whole amplifier. (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}. (i) If $V_{gen}(t)$ is a 1 mV step-function, find $V_{out}(t)$ and make an accurate plot of this.