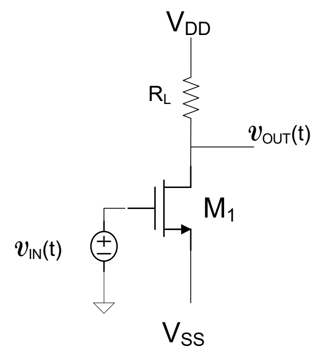
EE 330
Homework 10
Spring 2019
Due on Fri March 29th

Unless specified to the contrary, assume all n-channel MOS transistors have model parameters $\mu_n C_{OX} = 350\mu A/V^2$ and $V_{Tn} = 0.5V$, all p-channel transistors have model parameters $\mu_p C_{OX} = 70\mu A/V^2$ and $V_{Tp} = -0.5V$. Correspondingly, assume all npn BJT transistors have model parameters $J_S = 10^{-14} A/\mu^2$ and $\beta=100$ and all pnp BJT transistors have model parameters $J_S = 10^{-14} A/\mu^2$ and $\beta = 25$. If the emitter area of a transistor is not given, assume it is $100\mu^2$. If parameters are needed for CMOS process characterization beyond what is given, use the measured parameters from the TSMC 0.18μ process given in previous assignmentsv as model parameters. Assume all diodes are characterized by the model parameters J_{SX}=0.5 fA/μm², V_{G0}=1.17V, and m=2.3.

Problem 1 The amplifier shown below is called a common source amplifier. You can assume the transistor is operating in saturation.

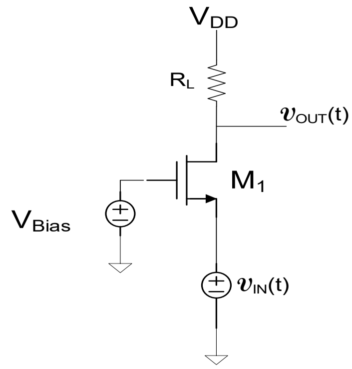


a) Draw the small signal equivalent circuit (showing g_m and g_0), and solve for the small signal gain.

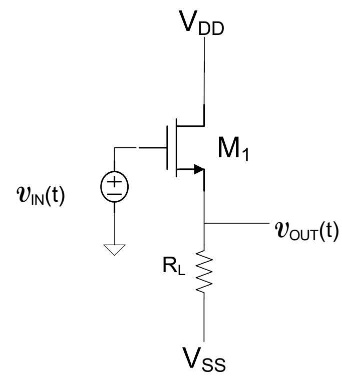
b) Solve for the input resistance of this amplifier by shorting the output terminal and applying a test voltage source V_T at the input terminal, then solving for $R_{in} = \frac{V_T}{I_T}$, where I_T is the test current supplied by V_T. Redraw the small signal equivalent circuit (showing g_m and g_0) and apply the appropriate changes.

c) Solve for the output resistance of this amplifier by shorting the input terminal and applying a test voltage source V_T at the output terminal, then solving for $R_{out} = \frac{V_T}{I_T}$, where I_T is the test current supplied by V_T. Redraw the small signal equivalent circuit (showing g_m and g_0) and apply the appropriate changes.

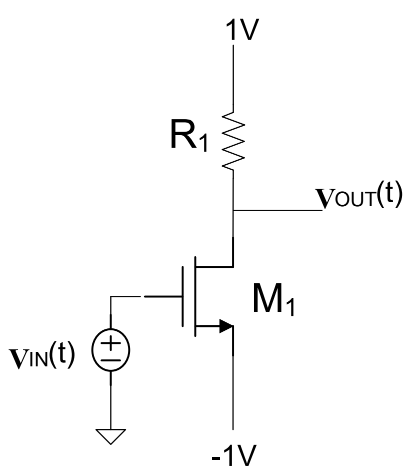
Problem 2 Repeat **Problem 1** but for the amplifier shown below. This amplifier is called a common gate amplifier.



Problem 3 Repeat **Problem 1** but for the amplifier shown below. This amplifier is called a common drain amplifier.

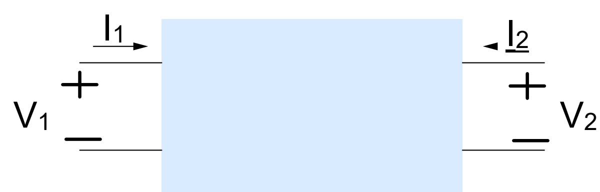


Problem 4 Consider the following circuit where R1=20K. Size the device so that the amplifier has a voltage gain of -10. Assume M_1 is in saturation.



Problem 5 Consider a device characterized by the equations

$$I_1 = V_1 V_2^{\,3}$$
$$I_2 = 0.25\, e^{0.2 V_1^{\,2} V_2}$$



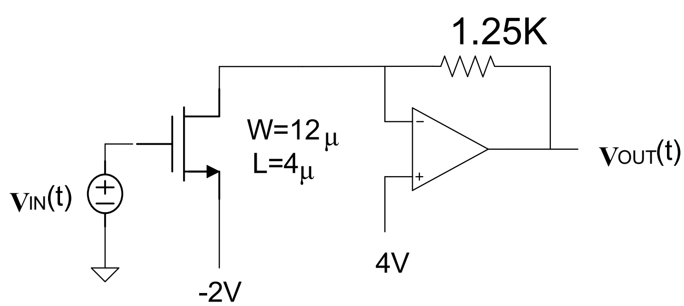
a. Determine the small signal model for a two-terminal device characterized by the equations given above

b. Determine the numerical values for the small signal model parameters if the quiescent value of the port voltages are V_1=5V, V2=1V.

c. Determine the quiescent currents at the Q-point established in part b.

d. Determine the small signal currents i_1 and i_2 if the small signal voltages v_1 and v_2 were measured to be $1mV_{RMS}$ and $2mV_{RMS}$ respectively. Assume the same Q-point as established in part b.

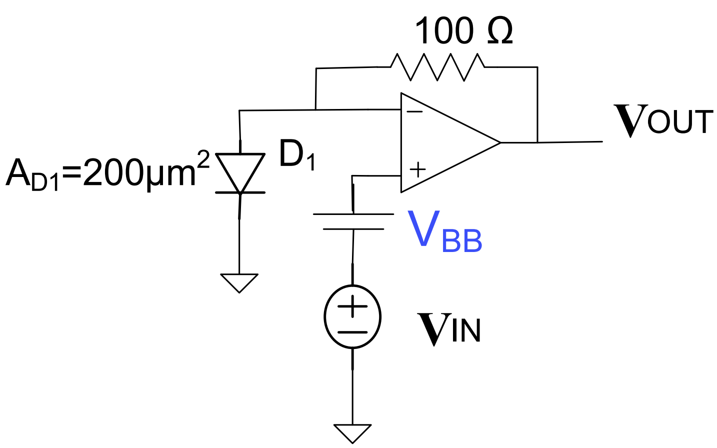
Problem 6 Determine the small signal output voltage if the small signal input voltage is a sinusoidal 1 KHz signal with 0-P amplitude of 25mV.



Problem 7 Consider the following circuit operating at T=300K. Assume $\mathbf{V_{IN}}$ is a small-signal voltage source.

a) If the voltage V_{BB} is adjusted so that the quiescent diode current is 1mA, determine the small signal voltage gain.

b) Repeat part a) if V_{BB} is adjusted so that the quiescent diode current is 10mA



Problem 8 Using ModelSim create a circuit that takes in 2 4-bit inputs and computes their sum or product depending on a select signal S. If S is 0, the output should A + B, if S is 1, the output should be A * B. Choose the output size so it won't overflow.