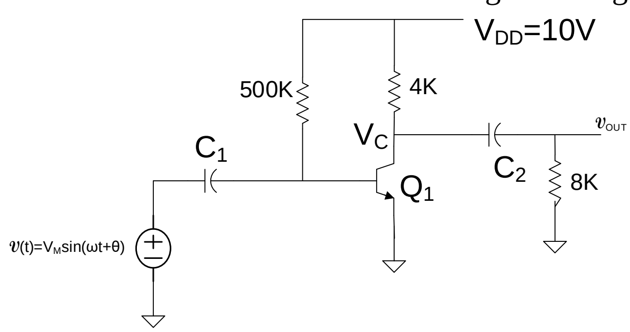
EE 330
Homework 10
Fall 2019
Due Friday Nov 1

Unless specified to the contrary, assume all n-channel MOS transistors have model parameters $\mu_n C_{OX} = 100\mu A/V^2$ and $V_{Tn} = 0.8V$, all p-channel transistors have model parameters $\mu_p C_{OX} = 33\mu A/V^2$ and $V_{Tp} = -0.8V$. 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 $100\mu^2$. Assume all diodes are characterized by the model parameters $J_{SX} = 0.1 fA/\mu m^2$, $V_{G0} = 1.17V$, and m=2.3.

Problem 1

Assume the capacitors are very large and V_M is small.

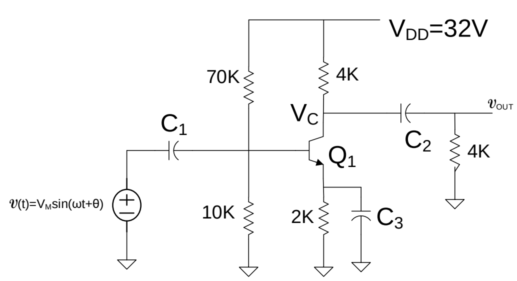
a) Draw the small signal equivalent circuit for the amplifier shown (from HW 9)
b) Determine the quiescent value of V_C and V_{OUT} (from Hw 9)
c) Determine the voltage gain in terms of the small-signal y-parameters (or equivalently the g-parameters) for the transistor. Assume the parameter y_{21} in the model of the transistor is 0.
d) Determine the numerical value for the small-signal voltage gain



Problem 2

Assume the capacitors are all very large and V_m is small.

a) Draw the small signal equivalent circuit for the amplifier shown (from HW 9)
b) Determine the quiescent value of V_C and V_{OUT} (from HW 9)
c) Determine the voltage gain in terms of the small-signal y-parameters (or equivalently the g-parameters) for the transistor. Assume the parameter y_{21} in the model of the transistor is 0.
d) Determine the numerical value for the small-signal voltage gain

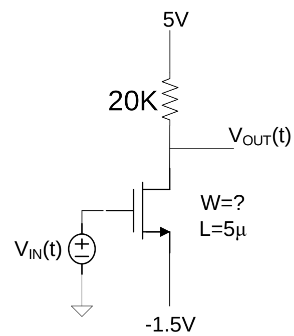


Problem 3 Consider the following circuit

a) Determine W so that the quiescent drain current is 0.1mA (from HW 9)

b) Draw the small-signal equivalent circuit (from HW 9)

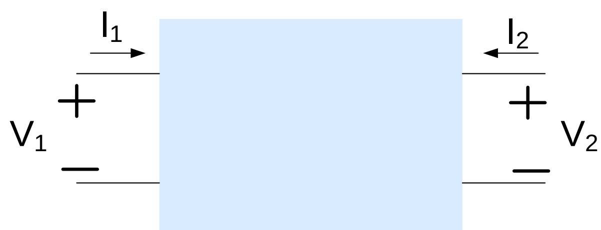
c) With the drain current specified in part a), determine the small-signal voltage gain using a small-signal analysis and compare the results with those obtained on last weeks assignment using nonlinear analysis techniques,



Problem 4 Consider a device characterized by the equations

$$I_1 = V_1 V_2^2$$

$$I_2 = 0.1e^{0.2V_1^2 V_2}$$



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_2=1V, V_1=5V.

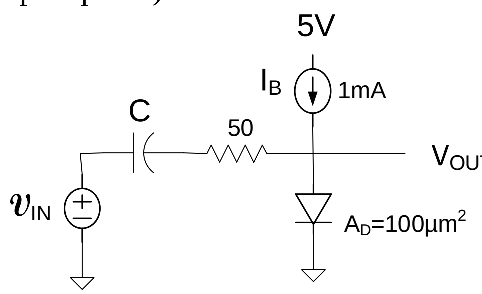
c. Determine the quiescent currents at the Q-point established in part b.

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 5

Consider the following circuit operating at T=300K. Assume the capacitor C is very large and the v_{IN} is a small-signal input.

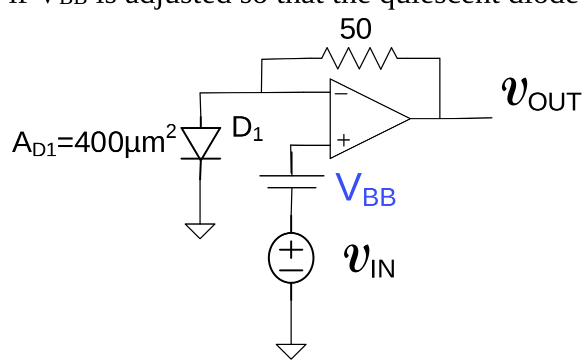
a) Determine the quiescent output voltage.
b) Draw the small-signal equivalent circuit
c) Determine the small-signal voltage gain from the input to the output.
d) Repeat part c) if the current I_B is increased to 5mA



Problem 6

Consider the following circuit operating at T=300K. Assume v_{IN} is a small-signal voltage source.

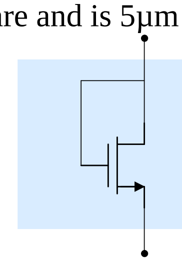
a) If the voltage V_{BB} is adjusted so that the quiescent diode current is 1mA, determine the small signal voltage gain $A_V = \frac{v_{OUT}}{v_{IN}}$
b) Repeat part a) if V_{BB} is adjusted so that the quiescent diode current is 10mA

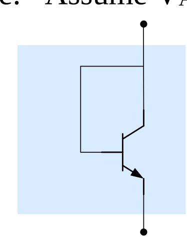


Problem 7

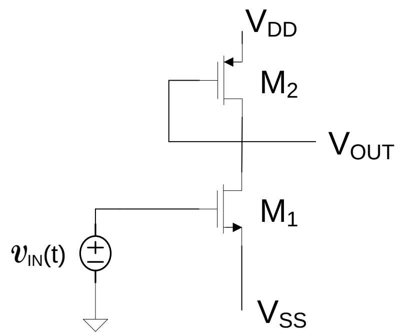
Consider the following circuits.

a) Obtain the small signal impedance between the two terminals exiting the box in terms of the small-signal model parameters. Assume the MOSFET is operating in the Saturation region and the BJT in the Forward Active region
b) Numerically determine the small-signal impedances if the quiescent currents are both 1mA, the width and length of the MOSFET are both 5µm, and the emitter of the BJT is square and is 5µm on a side. Assume $V_{AF}=\infty$ and $\lambda=0$.

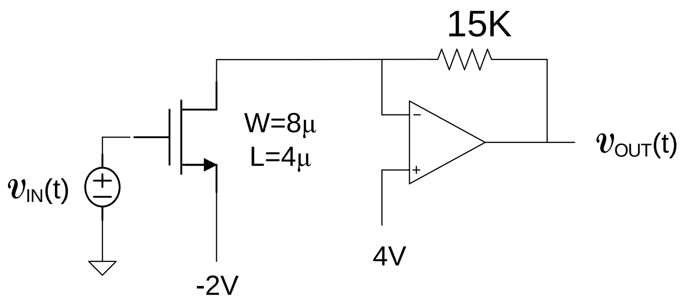




Problem 8 Obtain an expression for the small signal output voltage in terms of the small signal parameters if the input is given by the expression $v_{IN}(t)=V_M\cos(\omega t+\theta)$. Assume M_1 is operating in the saturation region.



Problem 9 Determine the small signal output voltage if the small signal input voltage is a sinusoidal 1KHz signal with 0-P amplitude of 25mV.



Problem 10 Determine the total output voltage for the circuit in Problem 10 if V_{DD}=5V, V_{SS}=-2V, W_1=10u, L_1=2u, W_2=6u and L_2=1u. Assume the devices are from a process with parameters $\mu_n C_{OX}=100\mu A/v^2$, $\mu_p C_{OX}=30\mu A/v^2$, V_{TNO}=0.5V, V_{TPO}= - 0.5V, $C_{OX}=2fF/\mu^2$, $\lambda = 0$, $\gamma = 0$.

Problem 11 Design an amplifier using only BJT transistors, resistors, capacitors and voltage sources that has a voltage gain of -5 when driving a 2K resistor.

Problem 12 Design an amplifier using only MOS transistors, capacitors, and voltage sources that has a voltage gain of -10 when driving an external 10K resistor.