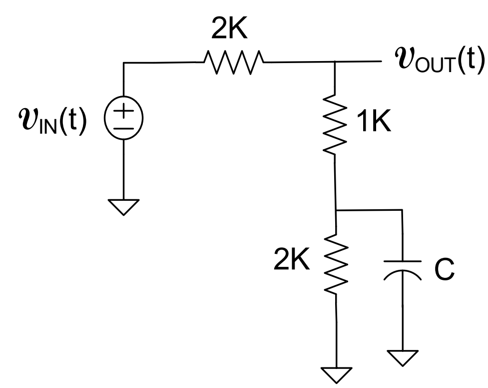
EE 330
Homework 9
Fall 2024
Due Wednesday October 23 at noon (no late submissions will be accepted this week).

Unless specified to the contrary, assume all n-channel MOS transistors have model parameters $\mu_n C_{OX} = 250\mu A/V^2$ and $V_{Tn} = 0.4V$, all p-channel transistors have model parameters $\mu_p C_{OX} = \mu_n C_{OX}/3$ and $V_{Tp} = -0.4V$. 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 $J_{SX}=0.5A/\mu m^2$, $V_{G0}=1.17V$, and m=2.3.

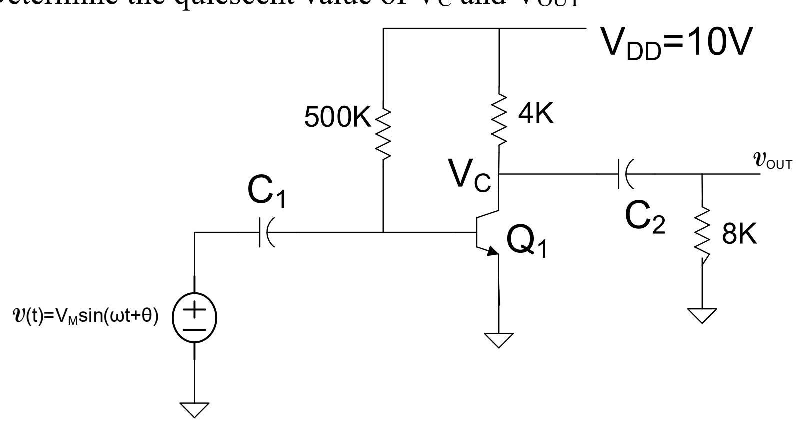
Problem 1 Assume the capacitor C is very large.

a) Draw the small-signal equivalent circuit
b) Determine the quiescent output voltage
c) Determine the small-signal voltage gain.
d) Determine the output voltage if $v_{IN}(t)=2\sin 500t$

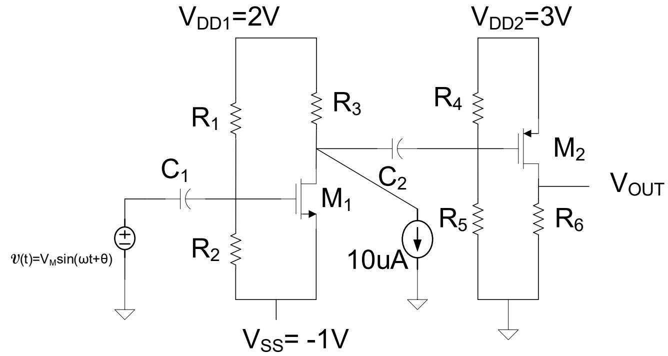


Problem 2 Assume the capacitors are very large, the emitter area of Q_1 is $20\mu m^2$, and V_M is small.

a) Draw the small signal equivalent circuit for the amplifier shown
b) Determine the quiescent value of V_C and V_{OUT}



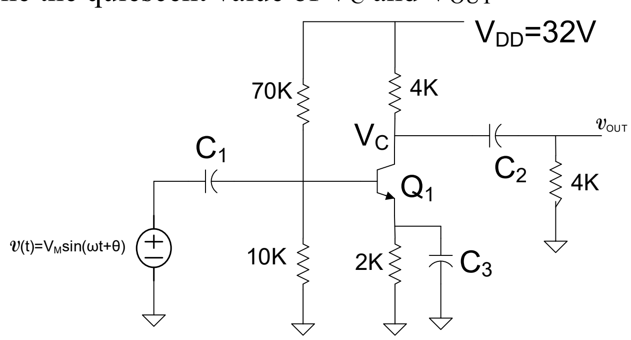
Problem 3 Obtain the small signal equivalent circuit for the following network. Assume the transistors are operating in the saturation region, all capacitors are large, and V_M is small. You do not need not solve the circuit for the output voltage.



Problem 4 Assume the capacitors are all very large, A_E=10μm^2, and V_m is small.

a) Draw the small signal equivalent circuit for the amplifier shown

b) Determine the quiescent value of V_C and V_{OUT}



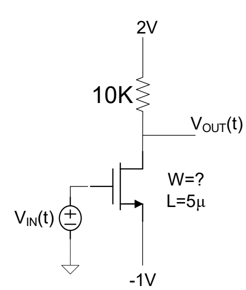
Problem 5 Consider the following circuit

a) Determine the width W so that the quiescent drain current is 0.1mA

b) Draw the small-signal equivalent circuit

c) With the drain current specified in part a), determine the small-signal voltage gain (do not use small-signal device models to solve this part of the problem)

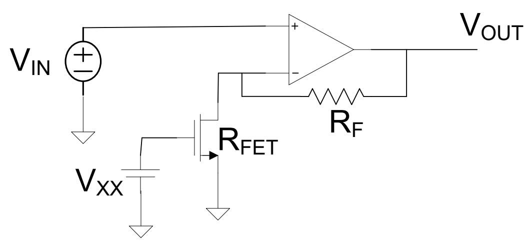
d) Determine the THD if the input is a 1KHz sinusoidal signal of amplitude 200mV 0-p



Problem 6 Assume V_{IN} is a low frequency sinusoidal waveform that is below 10mV 0-P and that W=12µm, L=1µm for the MOSFET.

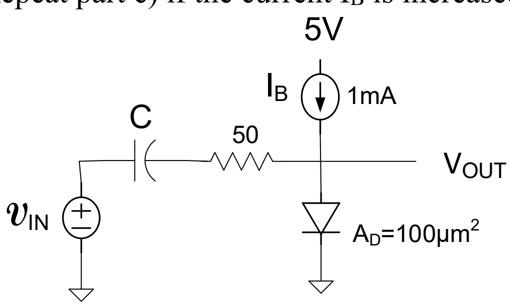
a) Determine the voltage gain of this circuit as a function of R_F if V_{XX}=1V.

b) How does the voltage gain change if V_{XX} is swept between 0.4V and 1.6V?



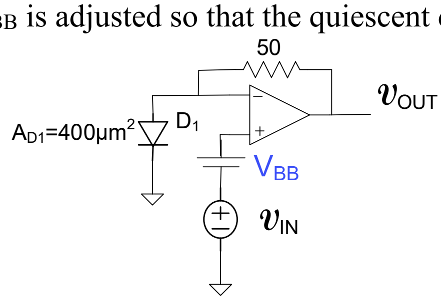
Problem 7 Consider the following circuit operating at T=300K. Assume the capacitor C is very large and the v_{IN} is a small-signal input.

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 if the input is a sinusoidal waveform.
d) Repeat part c) if the current I_B is increased to 5mA



Problem 8 Consider the following circuit operating at T=300K. Assume v_{IN} is a small-signal voltage source.

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

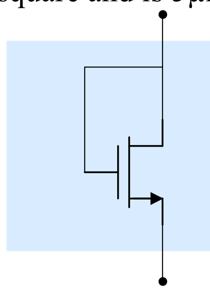


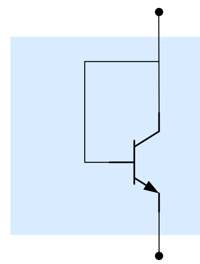
Problem 9

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 10

a) Determine the maximum value of R_1 that will keep M_1 in saturation. M_1 has dimensions W=18u and L=2u.

b) If R_1 is 1/3 of the value determined in Part a), determine the small signal voltage gain of this circuit (do not use small-signal device models which have not yet been introduced in this course to solve this problem)

c) With the value of R_1 used in part b), determine the total output voltage if $v_{IN}(t)=.001\sin(5000t+75°)$.