EE 330

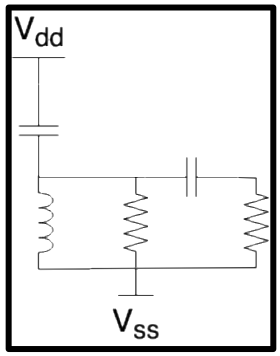
Homework 8

Fall 2020

Due Friday October 16

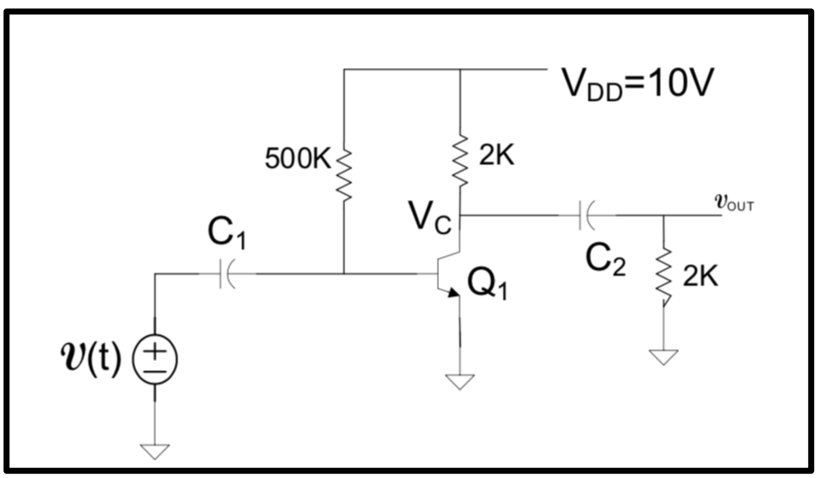
Problem 1

Draw the small-signal equivalent of the following circuit. Assume all capacitors and inductors are large.



Problem 2

Assume the capacitors in the circuit below are very large. Determine the quiescent value of V_{OUT}.

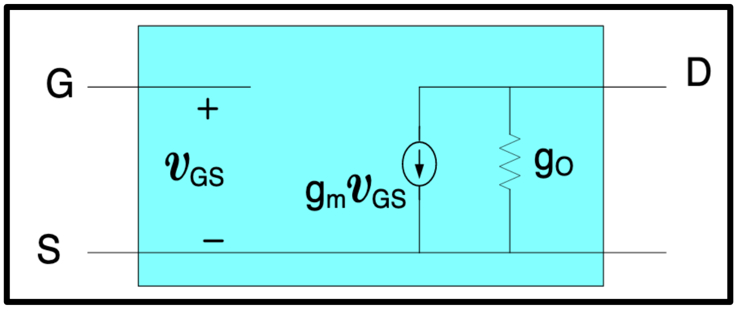


Problem 3

Assume you have an NMOS with its Gate tied to its Drain. Derive this device's small signal equivalent resistance. How does this device behave as the voltage across it changes? What happens as the input voltage increases? Do you know any devices that act the same? Is this a better version of that device?

Problem 4

Recall from lecture that a saturated NMOS can be modelled in the small-signal domain as follows:

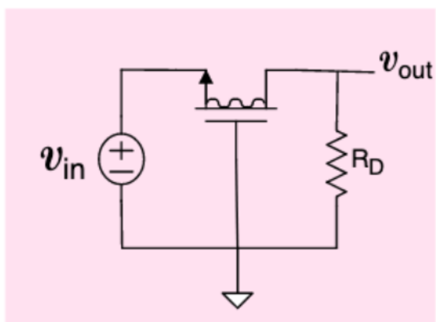


Where $g_m = \mu_n C_{ox} \frac{W}{L}(V_{GSQ} - V_T)$ and $g_o \approx \lambda I_{DQ}$.

Using the square-law model of an NMOS, show the step-by-step derivation of g_m and g_o. Then, derive the small-signal model of a saturated PMOS device **assuming that $\boldsymbol{\lambda = 0}$**.

Problem 5

Find the small-signal gain ($\frac{v_{out}}{v_{in}}$) of the circuit below assuming that the provided small-signal NMOS is operating in the saturation mode of operation. Assume that v_{in} is a small-signal input (that is, it should not be modeled as a short circuit). You may assume that $\lambda = 0$. Your final answer should be in terms of I_{DQ}, R_D, V_{GSQ}, and V_T.

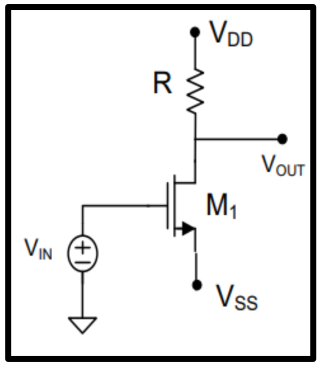


Problem 6

Based on your recent laboratory work, is g_o dependent on length? What about V_{DS}?

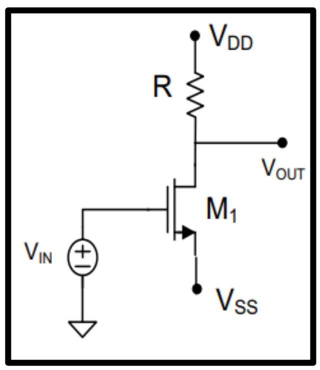
Problem 7

If M1 is a minimum sized NMOS in the AMI 06 process, what is the max value of R such that the NMOS will be in the Saturation region (Assume a very small input)? If the Resistor is a third of the value you found, what is the small signal gain of the configuration? (Assume Vss is -2.5V and Vdd is 10V)



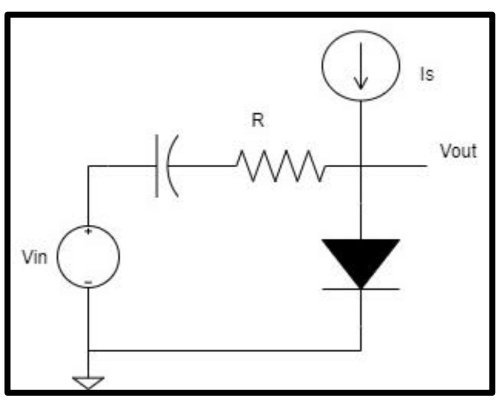
Problem 8

Find the quiescent VGSq if the small signal output is $2.5V + A_V V_{in}(t)$. The NMOS is a minimum sized transistor in the AMI06 process. Assume it is in the saturation region. (R=5kΩ) Given your answer for VGS, what is the max value for VG that would be possible?



Problem 9

Consider the following circuit operating with $Js = 18 * 10^{-3}$. Assume the capacitor C is very large and the VIN is a small-signal input. Use Vt=25mV, Is = 2mA, R=25Ω and the area of the diode is 200µm^2



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.

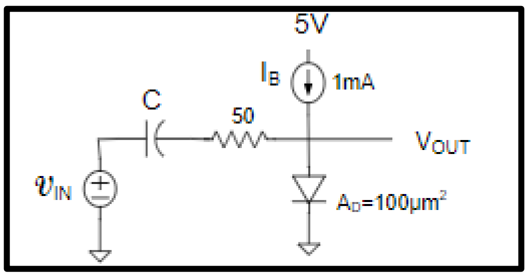
Problem 10

Consider the following circuit with $Js = 9.925 * 10^{-3}$. Assume the capacitor C is very large and the VIN 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.



Problem 11

What does the term "operating point" of a circuit mean and what is its purpose? What are the steps to solve for the operating point of a circuit?

Problem 12

Assume you have a non-linear device used in a system you created. After analyzing it and finding the output in terms of the input you get the following equation. Identify the Quiescent output and the voltage gain. (all variables used are constants from your device's parameters. Your only variables are Vout and Vin)

$$V_{out} = V_{dd} - \frac{\lambda\psi}{\rho}(V_{ss} - V_C) + \frac{\lambda\psi}{\rho}(V_{ss} - V_C)^2 R\, V_{in} + 10(\delta + V_{in})$$