

Instructions: There are 8 short questions and 5 problems. The points allocated to each of the questions are as indicated. The problems are all equally weighted with an assigned weight of 16 points each. All work should be included on the exam itself. Attach additional sheets only if you run out of space on a problem. Students may bring 3 pages of notes to the exam. Calculators are permitted but can not be shared.

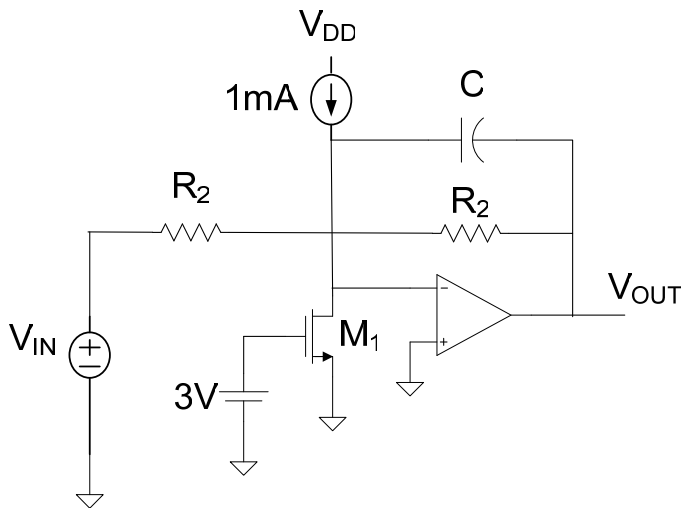
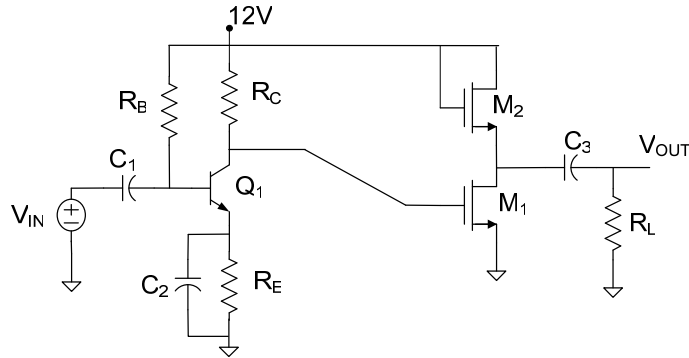
If characteristics of MOS or Bipolar transistors are needed, assume they are characterized by the model parameters $\mu_n C_{OX}=100\mu A/V^2$, $V_{Th}=1V$, $\mu_p C_{OX}=33\mu A/V^2$, $V_{Tp}=-1V$ and $\lambda=0$. Correspondingly, assume all BJT transistors have model parameters $J_S A_E=10^{-12}A$, $\beta=100$, and $V_{AF}=\infty$ and all diodes with parameter $I_S=10^{-14}A$.

Questions:

1. (2pts) What advantage does the precision rectifier circuit offer over the simple diode rectifier circuit?
2. (2pts) If a 12-bit ADC has $V_{REF}=5V$, what is V_{LSB} ?
3. (2pts) What terminal in the Bipolar transistor is the counterpart to the Drain terminal in the MOS transistor?
4. (3pts) Determine the ratio of the transconductance of a bipolar transistor to that of a MOS transistor at room temperature (300K) if both are biased to operate at a Q-point output current of 5mA. Assume the MOS transistor has dimensions $W=25\mu$, $L=1\mu$ and the bipolar transistor has an emitter area of $100\mu^2$.
5. (2 pts) When the MOS transistor is used as a Voltage Variable Resistor, what region of operation is the transistor operating in?
6. (2 pts) When the Bipolar transistor is used to build analog amplifier circuits, what region of operation is the device usually operated in?

- 7 (3 pts) What are the resolution requirements for an ADC if it is to be used in a multimeter that displays 4 decimal digits and all 4 decimal digits are to be significant?
- 8 (2pts) The small-signal transconductance of a bipolar transistor increases with the quiescent collector current. If the collector current is increased by a factor of 100, by what factor will the transconductance be increased?
- 9 (2pts) The small-signal transconductance of a MOS transistor increases with the quiescent drain current. If the drain current is increased by a factor of 100, by what factor will the transconductance be increased?

Problem 1 Draw the small-signal equivalent circuit for the following circuits. Assume the capacitors C_1 , C_2 , and C_3 are very large and C is not particularly large. Do not solve.

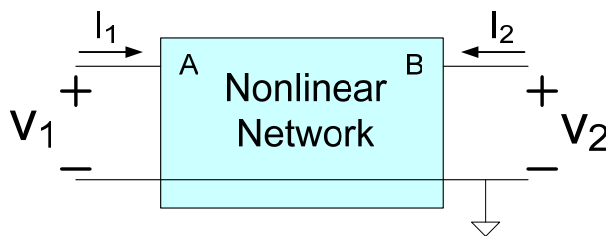


Problem 2

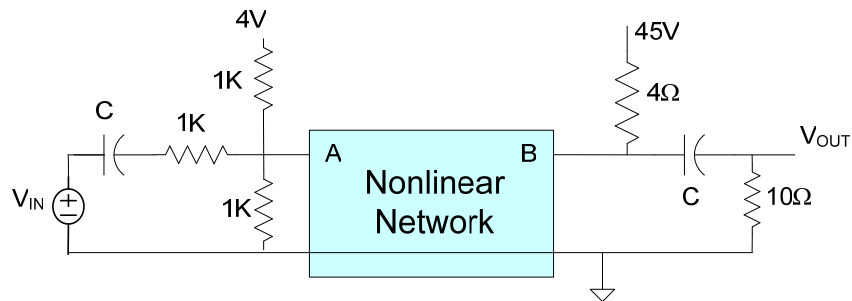
Assume the Nonlinear Network shown is characterized by the equations

$$I_1 = 0$$

$$I_2 = 18 \frac{1}{(1 + V_1)^2} V_2$$



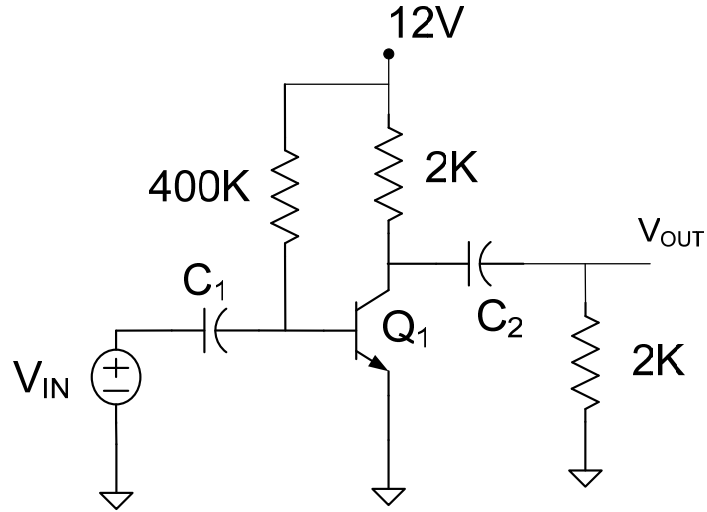
- Determine a small signal model for the device at the Q-point defined by the $V_{1Q}=2V$, $V_{2Q}=5V$
- Draw a small-signal equivalent circuit
- If this nonlinear network is connected in the circuit shown below, determine the quiescent voltages V_{1Q} , V_{2Q} , I_{1Q} and I_{2Q} where these variables are defined as indicated in the previous figure
- Determine the small-signal voltage gain for the following circuit. Assume C's are large.



(Provide Solutions on the Following Page)

Solution for Problem 2 goes here

Problem 3 Assume the transistor is characterized by model parameters given at the top of this exam and assume that the capacitors are very large. Assume V_{IN} is a small-signal input.



- Determine the quiescent output voltage
- Determine the quiescent collector current
- Obtain a small-signal model for Q_1 at the operating point determined by this circuit
- Draw a small-signal equivalent circuit for the whole circuit.
- Determine the small signal voltage gain for this circuit?

Problem 4 Assume the input to a 12-bit ADC is a 1KHz sinusoidal signal with a p-p amplitude of 3 V centered around 2.5V. Assume the reference voltage to the ADC is 5V. Assume there is an additive unwanted sinusoidal signal at 22.5KHz and of amplitude 1V p-p that is added to the desired signal. Assume further that the sampling rate of the ADC is 4KHz.

- a) The sampling frequency is higher than the Nyquist rate for this application. What is the ratio of the actual sampling frequency to the Nyquist sampling frequency?
- b) There will be aliasing of the unwanted signal into the passband of the ADC. What will be the aliased frequency of the unwanted 22.5KHz signal?
- c) What will be the magnitude of the aliased 22.5KHz signal?
- d) If the signal to noise ratio is the ratio of the desired signal to the aliased 22.5KHz signal, what will be the SNR.
- e) If an anti-aliasing filter is added at the ADC input and if the antialiasing filter has transfer function of

$$T(s) = \frac{1}{\left(\frac{s}{4\pi 10^3} + 1\right)}$$

Determine the magnitude of the aliased 22.5KHz component.

- Problem 5 Assume the Op Amp and Diode in the following circuit are ideal.
- a) Determine an expression for and plot the transfer characteristics of this circuit.
 - b) If the input is $V_{IN}=2\sin(1000t)$, plot the output for one period of the input.

