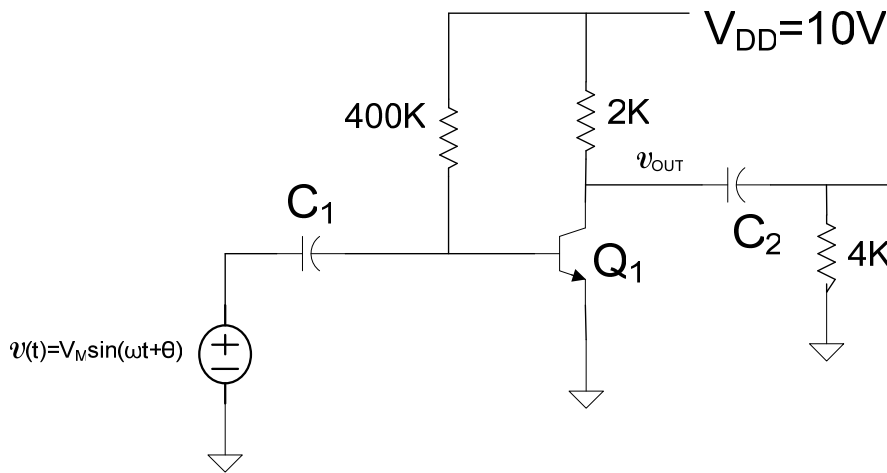


EE 230
Homework 12
Spring 2010

Assume all MOS transistors have model parameters $\mu_n C_{OX}=100\mu\text{A}/\text{V}^2$, $V_{Th}=1\text{V}$, and $\lambda=0$. Correspondingly, assume all BJT transistors have model parameters $J_S A=10^{-12}\text{A}$, $\beta=100$, and $V_{AF}=\infty$. For the data converter problems, use the CAD tool of choice. EXCEL, Matlab, or C are some tools you have available that should be useful for solving these problems.

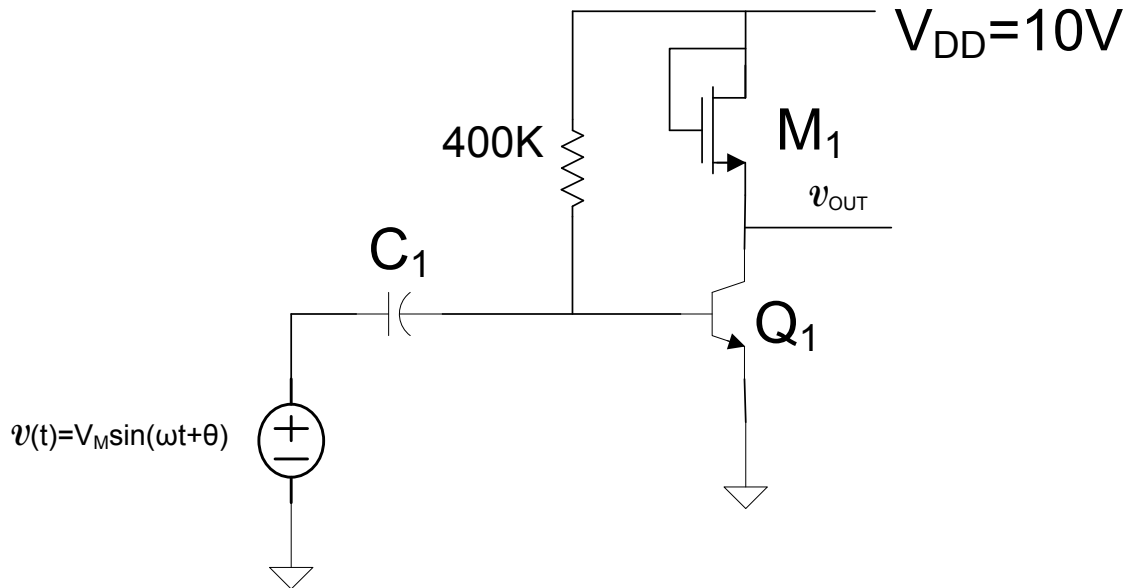
Problem 1

- Draw the small signal equivalent circuits. Assume Q_1 is in the Forward Active region, the capacitors are large, and V_M is small.
- Determine the quiescent output voltage
- Determine the small signal voltage gain.



Problem 2

- Draw the small signal equivalent circuit. Assume M_1 is in the saturation region, Q_1 is in the Forward Active region, the capacitors are large, and V_M is small.
- Size the transistor M_1 so that the quiescent output voltage is 5V. Assume $L_1=2\mu$.
- With the device sizing used in part b), determine the small signal voltage gain.



Problem 3 A multimeter displays 4 decimal digits. How many bits of resolution is needed for an ADC internal to the multimeter if the full-scale output is to be accurate to 1 decimal digit.

Problem 4 What is the LSB voltage for a 14-bit ADC if the reference voltage is 2V?

Problem 5 Consider an ideal 12-bit ADC with $V_{REF}=5\text{V}$ and with the first transition point at V_{LSB} . What is the Boolean output if the input voltage is 3.333V.

Problem 6 Assume an ideal 10-bit ADC with $V_{REF}=5\text{V}$ is used to sample a 1V p-p sinusoidal signal that has a 2.5V offset.

- What percent error (relative to the magnitude of the sinusoid) can be expected in the peak voltage measurements due to the quantization effects of the ADC
- Repeat part a) if the input amplitude is increased so the p-p voltage is 5V.

- Problem 7 Assume an ideal 12-bit ADC has a reference voltage of 1V.
- If the input to the ADC is given by $V_{IN}=0.5+0.5\sin(1000t)$, give the Boolean outputs if 200 samples of the input are made 100usec apart with the first sample being taken at time $t=0$.
 - Plot the interpreted value of output samples on the same graph as the input waveform

- Problem 8 Consider an input signal $V_{IN}=0.5+0.5\sin(2\pi\bullet 1000t)$. Assume this is sampled by an ideal infinite resolution ADC. Provide a sufficient number of samples so that it becomes clear what the output waveforms look like.
- Compare the interpreted output of the ADC with the input if the samples start at $t=0$ and the samples are spaced 9usec apart? (present results graphically)
 - Repeat part a) if the samples are spaced 500usec apart
 - Repeat part a) if the samples are spaced 500usec apart but the first sample is taken at time $t=250\text{usec}$
 - Repeat part a) if the samples are spaced 550usec apart
 - In view of the previous results, make observations about how sampling rate and sampling times affect the interpreted outputs.

- Problem 9 Assume a scale for weighing agricultural commodities is designed for a maximum load of 60 tons. The State of Iowa stipulates that weight measurements must be accurate to within $\pm 0.1\%$ the maximum load of the scale. Load cells (with strain gauges as the transducers) are used to convert the weight to a voltage and that this voltage is measured with an ADC. Although there are typically 6 to 10 load cells on such scales with a separate ADC for each load cell, assume for convenience that the analog outputs of the load cells are summed and that a single ADC can be used to measure the load. Assume that the output of the load cell has a full-scale range of 5V. The platform of the scale typically weighs about 20 tons. The tare weight (empty) of a semi truck is around 13 tons. When filled with corn, the maximum load of the semi is around 750 bushels.
- Determine the resolution required for the ADC if the only errors are quantization errors if an ADC with $V_{REF}=5V$ is used.
 - With the ADC determined in part a), what will be the accuracy in percent of weighing the commodity corn if the semi is fully loaded with corn?
 - What would be the accuracy, in percent, of weighing the commodity corn if the semi only contains 50 bushels of corn?
 - Since the platform of the scale is not removed during normal operation, the contribution of the weight of the platform could be subtracted, as part of a calibration process, from the load cell output prior to taking the signal to the ADC. The difference signal could then be amplified to obtain a full-scale range of 5V that can be applied to the ADC. If the platform weight is subtracted, what would be the resolution required for the ADC if the only errors are quantization errors?

Problem 10 A local riding stable uses bales of alfalfa for feeding of the horses. Assume they are buying this alfalfa by the ton at a rate of \$120/ton and are hauling the alfalfa on a pickup that will hold 16 bales, each weighing somewhere around 40 pounds. Assume they first determine the tare weight of the pickup and then the loaded weight by using a 60 ton scale available at the local elevator. This scale has an absolute accuracy requirement stipulated by the State of Iowa ($\pm 0.1\%$ of full scale).

- a) What is the maximum error, in percent, that could result from using this method for determining the weight of the 16 bales?
- b) What is the maximum error in dollars associated with this method of measurement?