HW#4, Electronic Circuit, Spring semester 2020

April 10, 2020

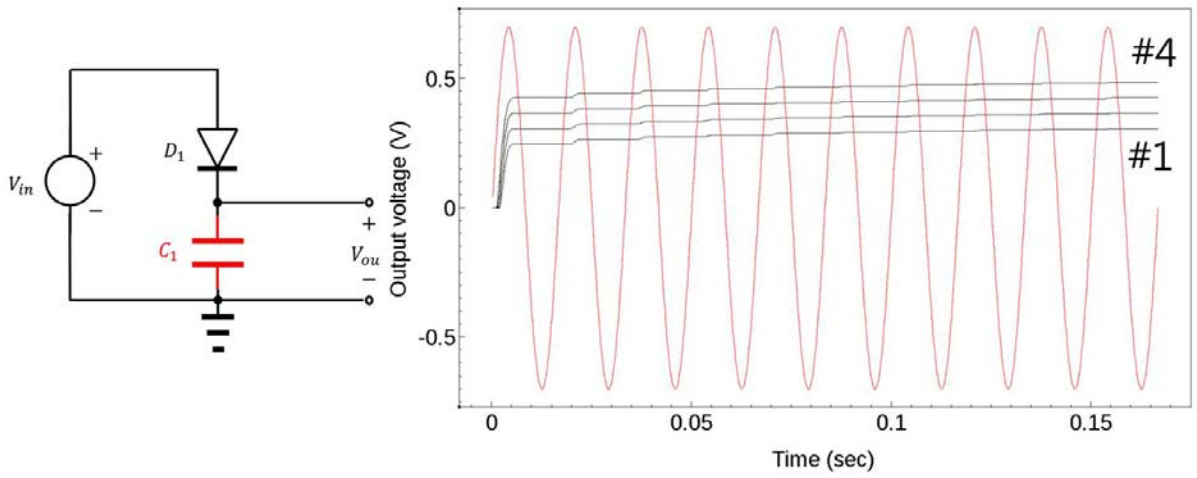
Due: 23:55, April 15 (Wednesday night)

We have 8 problems.

In your answer file, specify both the **SOLUTION PROCEDURE** and the **FINAL SOLUTION**.

1. In the lecture, it has been stressed that the diode current-voltage graph shows a slope of 60 mV/dec. (It is drawn in the semi-log scale.) However, as we already know, "60 mV" is a rough value valid only at room temperature. In this problem, write the EXACT expression for "60 mV", in terms of the thermal voltage.

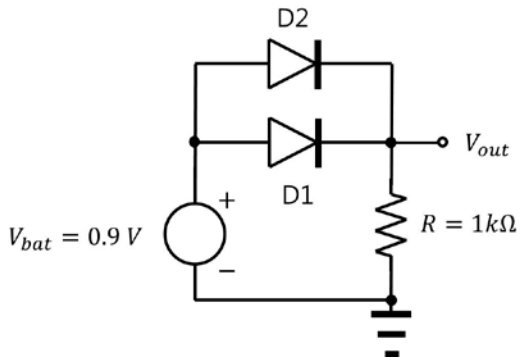
2. The left figure shows the circuit schematic. Four cases for the capacitance are considered. 1 pF, 10 pF, 100 pF, and 1 nF. The output voltages are shown in the right figure as black lines. They are labeled with #1, #2, #3, and #4, from the bottom to the top. (The red line in the right figure shows the sinusoidal input voltage.) Among the four black curves, which one is for 10 pF? Specify the correct curve index.



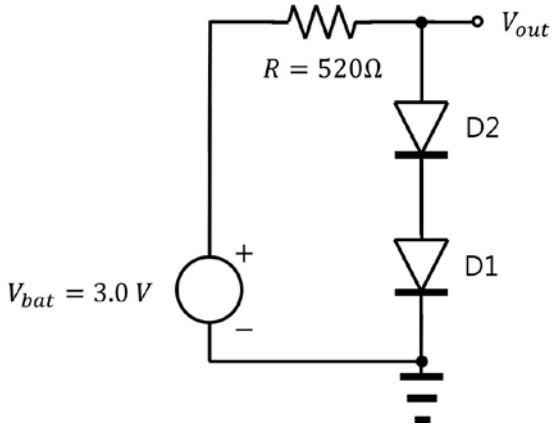
3. Consider a diode whose reverse saturation current is 1.0 fA. A researcher performs the small-signal analysis on the diode biased as 0.4 V. The small-signal resistance is extracted. After extracting it, the researcher calculates the diode current at 0.7 V by using the small-signal resistance. Of course, this is wrong and the result is not correct. Let us call this wrong current I_{wrong}. Calculate the following ratio:

$$\text{Ratio} = \frac{I_D(0.7\text{ V})}{I_{wrong}}$$

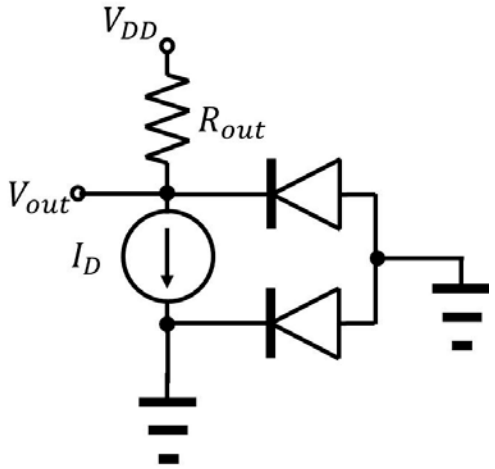
4. Consider the circuit shown below. Two diodes (D1 and D2) have different reverse saturation currents, I_S and $10^2 I_S$, respectively. The diode with I_S (D1) conducts 30 pA, when the diode voltage is 0.3 V. Estimate the output voltage. The voltage of the battery is 0.9 V



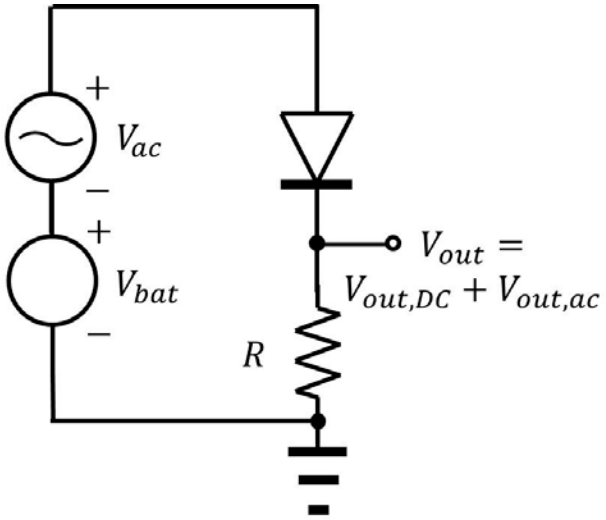
5. Consider the circuit shown below. Two diodes (D1 and D2) have different reverse saturation currents, I_S and $10^2 I_S$, respectively. The diode with I_S (D1) conducts 30 pA, when the diode voltage is 0.3 V. Estimate the output voltage.



6. Consider the circuit shown below. A current source is introduced. Assume that the magnitude of the current source is small but not zero. Also V_{DD} has a sufficiently large, positive value. Calculate the output voltage.



7. Consider the circuit shown below. The voltage required to turn on the diode is $V_{D,on}$. Assume that V_{bat} is either sufficiently larger than $V_{D,on}$. In addition to the DC battery voltage, a sinusoidal voltage source is introduced. Its amplitude is $\mathrm{V_{ac}}$, which is assumed to be small. Its frequency is 1 kHz. Therefore, the output voltage, V_{out}, can be decomposed into two terms, its DC component, $V_{out,DC}$, and its ac component, $V_{out,ac}$. Find out the relation between V_{ac} and the magnitude of $V_{out,ac}$.



8. Consider a capacitor made of two parallel metal plates. Between the metal plates, a 10-nm-thick silicon dioxide layer is found. Area of each metal plate is 400 nm^2. Calculate the capacitance. Remember that the vacuum permittivity is approximately 8.85×10^{-12} F/m. The relative permittivity of the silicon dioxide is 3.9.