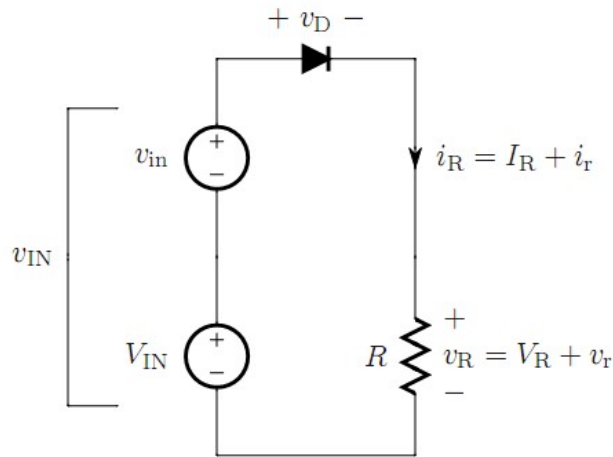


Homework #3 – February 18, 2009

Due: February 25, 2009 at recitation

No late homework accepted

1. [20 points] Problem 4.12 of Agarwal and Lang (Note, distinction between *Problem* and *Exercise*).
2. [20 points] Problem 4.13 of Agarwal and Lang.
3. [20 points] Exercise 16.2 of Agarwal and Lang.
4. [40 points] This problem studies the small-signal characteristics of a network containing a non-linear diode, comparing experimental characteristics to those based on the theory developed in class. The network to be studied is the simple source-resistor-diode network shown below. The voltage source v_{IN} is shown in two parts: its large-signal bias V_{IN} , and its small-signal variation v_{in} . Correspondingly, the resistor current i_R and voltage v_R are expanded into their large-signal and small-signal components as well. This problem will study both the large-signal and small-signal characteristics of the network as a function of the input bias V_{IN} , focusing in particular on the large-signal and small-signal components of v_R .



This problem contains a theoretical component followed by an experimental component. The theoretical component involves model development, and the experimental component tests the predictions of the model. The experimental component will be carried out using the ELVIS iLab.

Consider first the behavior of the network from a theoretical viewpoint, using the methodology for small-signal analysis introduced in class. Here assume that the diode is ideal with a saturation current I_S , and an operating temperature T .

(A) Assume that I_R is known. Derive expressions for V_{IN} and V_R in terms of I_R , and the diode and resistor parameters. These expressions establish the biases within the network.

(B) Starting from the biases determined in Part (A), derive an expression for v_r in terms of I_R , v_{in} , and the diode and resistor parameters. In doing so, assume that I_R is so large that $I_R \approx I_S e^{(qV_D/kT)}$.

(C) Rewrite the expression for v_r using V_R instead of I_R to represent the bias.

(D) Assume that v_{in} is 0.1 V, R is 10 k Ω , and the temperature kT/q is 26 mV. Using a calculator or a program of your choice, calculate v_r as a function of V_R for $V_R = 0.1, 0.2, 0.3, 0.4$ and 0.5 V. Graph v_r as a function of V_R .

You are now ready to carry out experiments to see the extent to which the results of Part (D) apply to a real network. To do so, you will use a new iLab called the ELVIS iLab. Thus, after logging in to iLab you must select and launch the *ELVIS Lab Client*. The ELVIS iLab is a versatile platform built by National Instruments that allows one to carry out simple experiments with circuits in the time domain.

When you launch the client, you will immediately see the network under test in the top half of the GUI. It comprises the function generator *FGEN*, the diode, the 10-k Ω resistor, and the oscilloscope *SCOPE* that reads the voltage across the resistor. The diode is identical to the one that you characterized in Homework #2. To perform the experiments, you must suitably program the function generator and the oscilloscope as follows.

- First, double-click on the function generator. Set the WaveForm to *SINE*. Set the Frequency of the small signal v_{in} to 100 Hz, and its Amplitude to 100 mV. The Offset is the DC bias of the function generator, and corresponds to V_{IN} . Run the first experiment with an Offset of 0.5 V. To save these settings, click *Apply* or OK.
- Next, double-click on the oscilloscope. Using its menu, set the sampling rate and the duration of the waveform to be acquired. You must think about appropriate settings for these two parameters. The sampling rate should be sufficiently greater than the frequency of the signal so that the signal can be measured with good resolution. The duration is the time period over which the waveform will be acquired by the oscilloscope. The product of the sampling rate and the duration (plus one) is the total number of samples to be acquired, and this must be less than or equal to 2001. When you are ready with the settings, click *Apply* or OK.
- The experiment can now be run. Under the *Measurement* menu, click on *Run experiment*. If everything is properly configured, your experiment will now execute. If the queue is empty, the experiment will take about 20 seconds to execute. If you try to run your experiments at a very busy time, it might take much longer. Once the data comes back, the Y1 axis (the left vertical axis) will automatically display the input voltage v_{IN} . You must program the Y2 axis (the right vertical axis) to display *VOUT* which is the total voltage v_R across the resistor. It will be easier if you leave the Y1 and Y2 axes in the *Autoscale and Linear* formats. From the results, you must read off the DC bias voltage across the resistor and the amplitude of the small-signal voltage across the resistor. To do so, you may wish to use the *Tracking* feature that the client offers at its bottom left. This feature allows you to read the coordinates of specific data points, or if you uncheck the *Snap to data points* box, the coordinates of any point on the canvas. To first order, you can assume that the bias in *VOUT* (V_R) is the middle of its range, and that its peak small-signal amplitude (peak v_r) is half of its peak-to-peak voltage difference.
- Carry out the experiment described above for the additional V_{IN} bias values of 0.4,

0.6, 0.7, 0.8, 0.9, and 1.0 V.

Now examine the experimental results as follows.

(E) Construct a table to display the results of your measurements. The table should have three columns. The first column should be the bias V_{IN} . The second column should be the bias V_R . The third column should be the peak amplitude of v_f , which corresponds to $v_{in} = 0.1$ V. Notice that the bias and small-signal amplitude of v_{IN} that you read from the canvas will not be exactly the same as those set in the function generator. The function generator is not very precise. Therefore, if you want to use information about v_{IN} , you should read it directly from the canvas. Record your measurements in the table.

(F) Graph the small-signal peak amplitude of the experimental v_f against the bias v_R on the same graph that you constructed above using the model. Comment on the results that you obtain.

(G) In all your analysis you have neglected any non-linear (distortion) terms in v_R . It turns out that the neglected non-linear response to the signal, i.e. the distortion, increases as the magnitude of the signal increases. Now, calculate the maximum magnitude of v_{IN} , for your expression in (C) above, at which the magnitude of the distortion remains below about 10% of the magnitude of the signal. (Hint - think Taylor series expansion of i_R).