ECE 255 ELECTRONIC ANALYSIS AND DESIGN Fall 2009

SPICE Homework

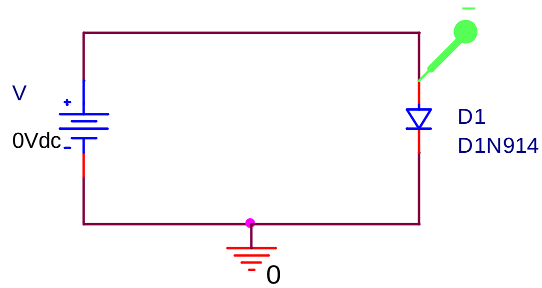
Due Friday, September 11
5:00 p.m. Room MSEE 180 Drop Box

Based on ECE 208 Lab 3

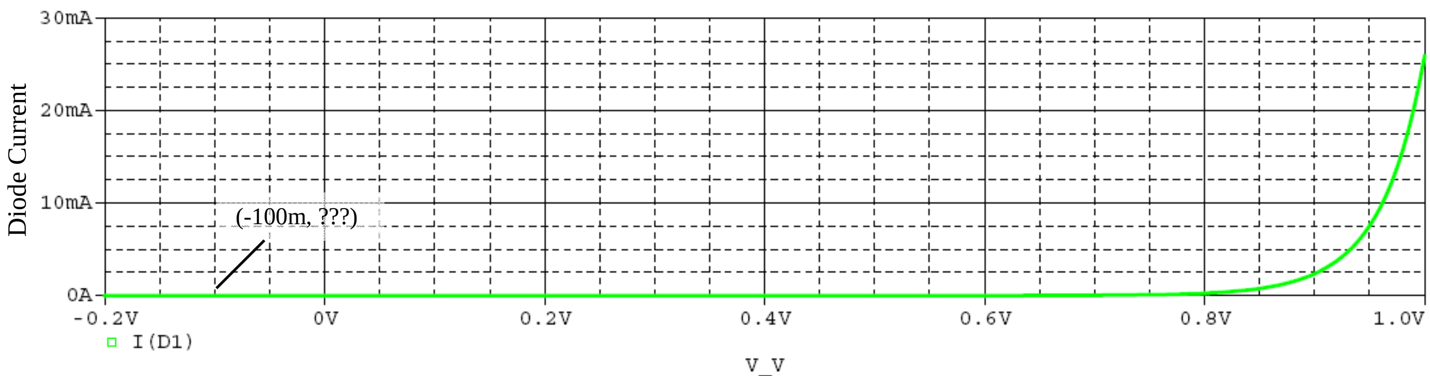
1. Using any SPICE based simulation system, plot the V-I characteristics of a 1N914 diode. Most PC based programs already contain the 1N914 diode model; however, if you are using http://www.nanohub.org/ you will need to input model parameters. Below are the model parameters used by the Cadence PSpice program.

```
.model D1N914   D(Is=168.1E-21 N=1 Rs=.1 Ikf=0 Xti=3 Eg=1.11 Cjo=4p M=.3333
+               Vj=.75 Fc=.5 Isr=100p Nr=2 Bv=100 Ibv=100u Tt=11.54n)
```

The V-I characteristics are obtained by performing a D.C. Voltage Sweep using the following circuit.

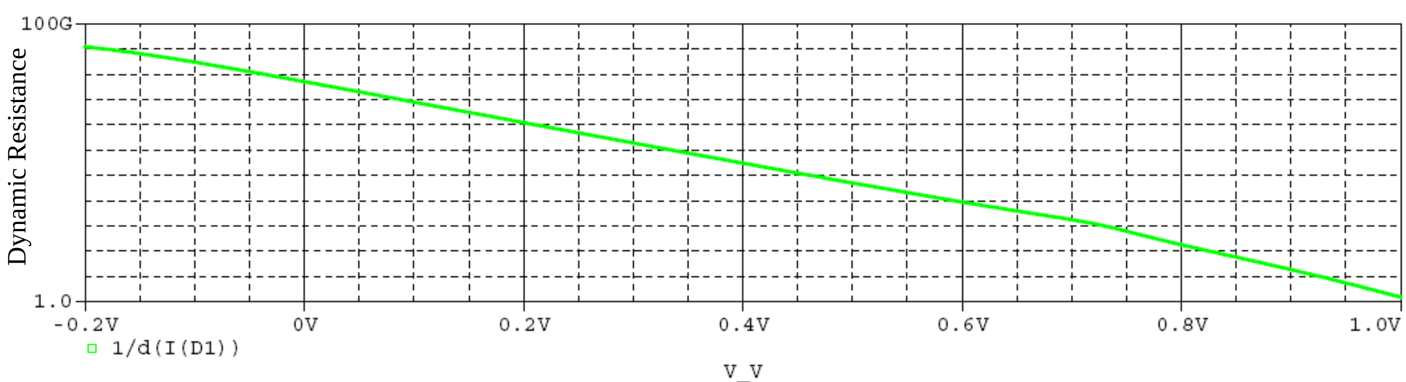


Sweep the D.C. voltage from –0.2 V to 1.0 V to obtain a plot similar to the graph below.



2. Using the cursor, mark a point at about –0.1 V to estimate the value of I_S (as shown above) and record the result on the cover sheet.

3. Plot the dynamic resistance of the diode logarithmically to obtain a plot similar to the plot below.



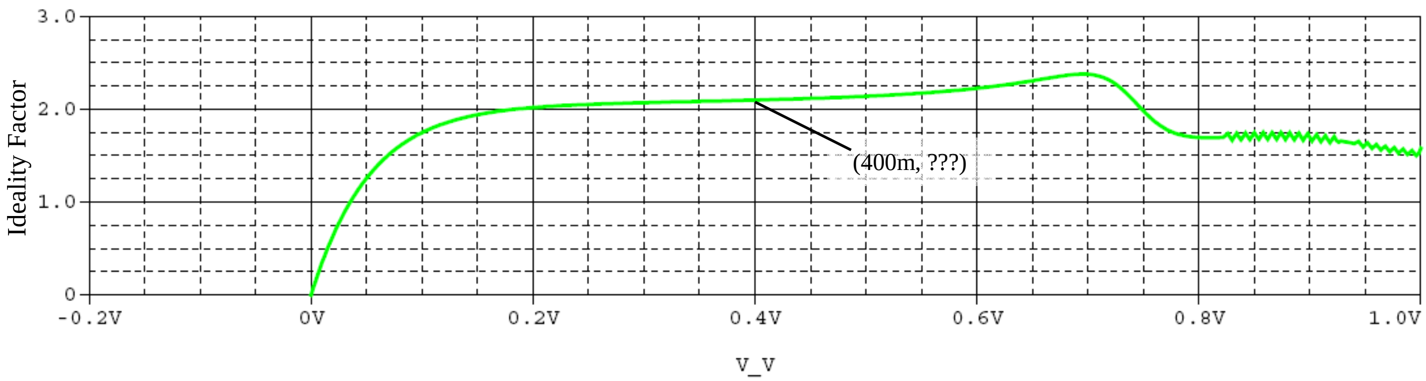
The dynamic resistance r_d is the reciprocal of the slope of the diode I-V characteristic evaluated at the operating point, Q.

$$r_d = \left.\frac{d\,V_D}{d\,I_D}\right|_Q = \frac{\eta\,V_T}{I_D + I_S} \approx \frac{\eta\,V_T}{I_D} \text{ (for forward bias)}$$

where η is the ideality factor and V_T is the thermal voltage. Since the PSpice simulation assumes a temperature of 27°C,

$$V_T = \frac{k\,T}{q} = 25.87\,\text{mV}\,.$$

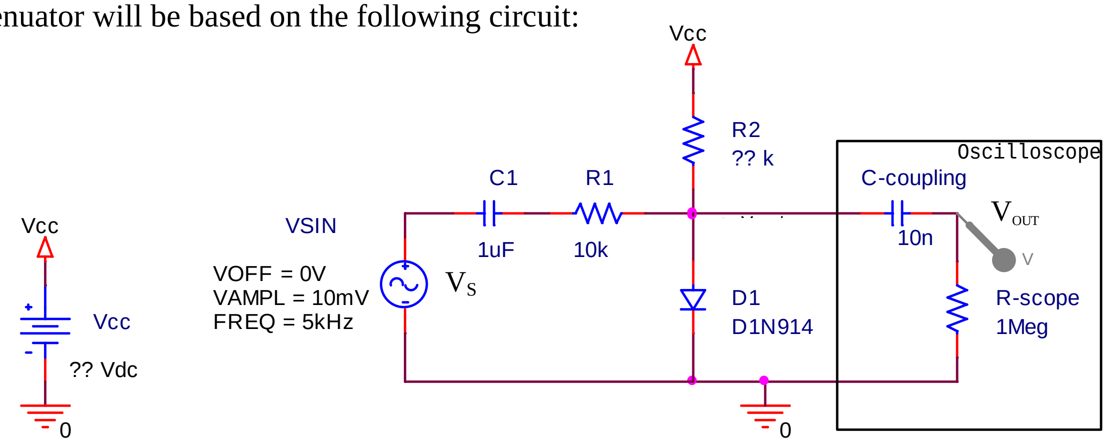
4. Modify your plot to provide an estimate of the ideality factor. That is, plot $\eta = \dfrac{I_D\,r_d}{V_T}$.



5. Using the cursor mark a point at about 0.4 V to estimate the value of η (as shown above) and record the result on the cover sheet.
   NOTE: Our approximation requires that the diode be forward biased but we note that the diode behavior begins to deviate from that of an ideal diode at both very low and high currents.

Now that we know all about our diode's characteristics, let's build something!
How about a variable attenuator? (This is known as a rhetorical question.)

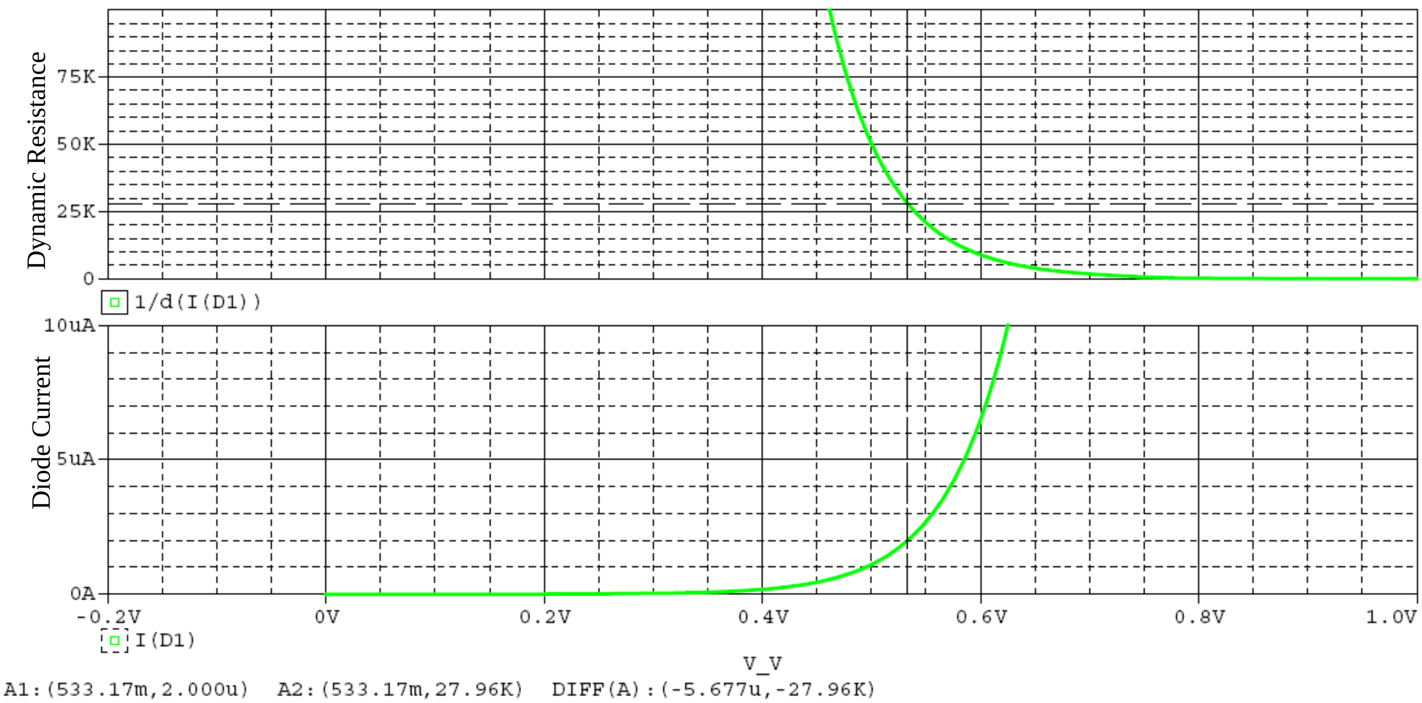
The attenuator will be based on the following circuit:



NOTE: The elements in the box at the right are added to simulate the effect of the oscilloscope set to A.C. coupling and should not affect (or be included in) your hand calculations.

6. Determine the value of r_d at 2μA from the diode V-I characteristics.

   The plots below suggest how this can be easily accomplished. Using "Add Plot to Window", both the V-I characteristics and dynamic resistance can appear in the same view. Simply place one cursor on the desired current and the other cursor at the corresponding voltage on the dynamic resistance plot to directly read the dynamic resistance.



7. Assuming that I_D = 2μA, determine a value for R_2 such that the attenuation ratio $\frac{\text{Vout}}{\text{Vs}} = \frac{1}{2}$.

   You can neglect the effect of the oscilloscope input impedance in this and the following calculations.

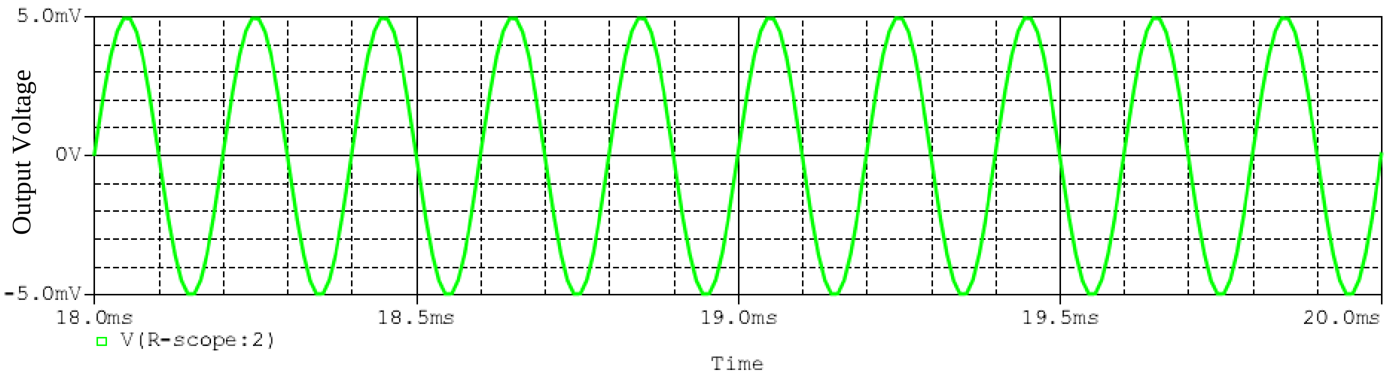
8. Since we want to actually build the attenuator, we need to select a real resistor value. The table on page 1164 of the text shows the values of 5% tolerance resistors that are available. Select a **single** 5% resistor value to use for R_2.

9. Since you probably can not use the exact value of R_2 you calculated in Part 7, you may need to slightly adjust your operating point to achieve an attenuation ratio of exactly $\frac{1}{2}$. Assuming that the value of your **single** 5% resistor is exactly equal to the **nominal value**, calculate the new value of the dynamic resistance, r_d, that will produce an attenuation ratio of $\frac{1}{2}$.

10. Determine the diode operating point that will produce this new value of dynamic resistance, r_d, and record the values of I_D and V_D on the cover sheet.

11. Determine the value of V_{CC} required to achieve the operating point that will produce the value of r_d required to produce an attenuation ratio of $\frac{1}{2}$ with the value of R_2 that you have selected.

12. Place the computed values of R_2 and V_{CC} in the attenuator circuit shown above and perform a transient simulation (of duration 2ms) to produce a plot as shown below.



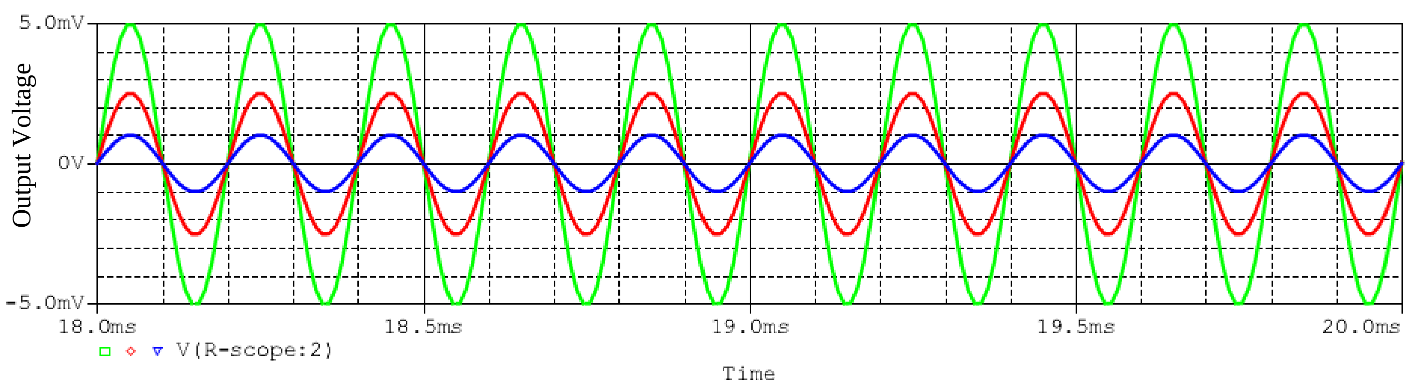
NOTE: If your initial output trace is "lumpy" adjust the **maximum step size** to produce a smooth output trace. You may also notice that your output plot is not quite symmetric about zero volts. The reason is that the capacitors are initially uncharged. You can compensate for this by either applying an initial charge to the capacitors (using the IC property) or by simply skipping the first few milliseconds of the output to allow the charging transients to die out.

12.5 If your output trace does not have a peak value of nearly 5 mV reexamine your work in Parts 6–11 and determine new values of R_2 and V_{CC} to produce plot shown above in Part 12.

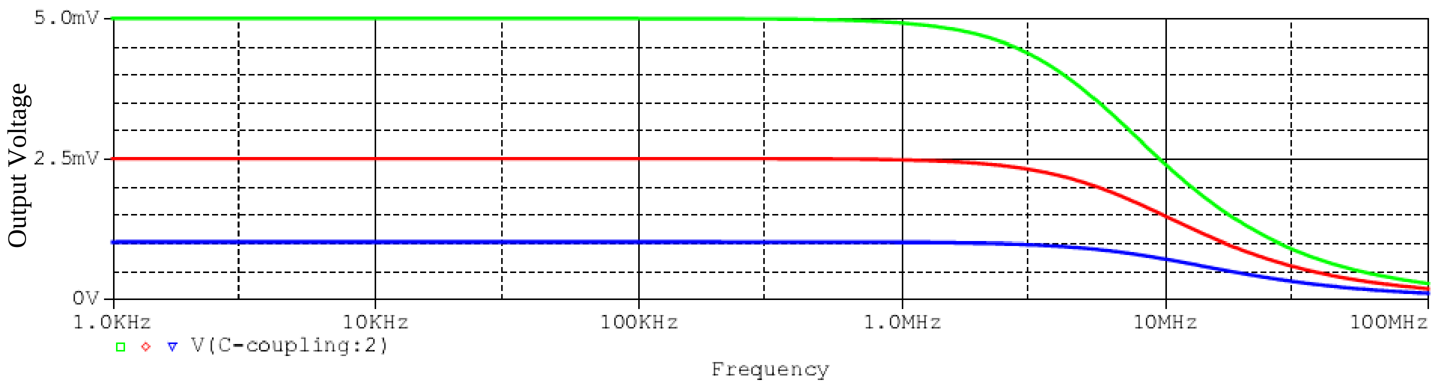
13. Determine the two values of the dynamic resistance (r_d) required to obtain attenuation ratios of $\frac{1}{4}$ and $\frac{1}{10}$ while keeping R_2 fixed at the value determined above in Parts 7and 8. List the two values of r_d required on the cover sheet.

14. Determine the two values of V_{CC} required to achieve the required operating points that will produce the two additional attenuation ratios $\left(\frac{Vout}{Vs} = \frac{1}{4} \text{ and } \frac{1}{10}\right)$. List these two values of required V_{CC} (along with the V_{CC} value from Part 11) on the cover sheet.

15. Show the result of the attenuator in operation by doing a **parametric** sweep in the transient analysis mode (using the **list** of the three values of V_{CC} you have chosen) to produce a plot like the one below.



16. The A.C. model of the diode contains a capacitor which will be important at high frequencies. Investigate the performance of the attenuator at high frequencies by creating an A.C. sweep (with a **parametric** sweep of the **list** of values of V_{CC}). You will need to replace the VSIN source with a VAC source of amplitude 10 mV. If you sweep from 1 kHz to 100 MegHz, your output should appear as shown below.



NOTE: In PSpice, both ‘m’ and ‘M’ are interpreted as milli. ‘Meg’ is used to represent mega.

Below is a list of the material to be turned in for this assignment:

1. **REQUIRED:** Completed cover page provided as the last page of this assignment.

2. A **single** page containing the plots of the diode V-I characteristics (showing the 'Mark'ed cursor designated value of the diode current at –100 mV) **and** the dynamic resistance of the diode. This page which represents your results from Parts 1, 2, and 3 is to be produced directly from the probe display (i.e., not cut and pasted to another application).

3. A plot showing your determination of the ideality factor (displaying the '**Mark**'ed cursor designated value of the ideality factor). This represents your results from Parts 4 and 5.

4. The schematic of the attenuator circuit you are using to perform the transient analysis in Part 12 (including all component values). Enable the **bias point current display** on the schematic to show that the bias current is approximately 2 μA.
   If your are using the NanoHub, hand draw the schematic – label the nodes with the node numbers you have assigned and include a listing of your source code.

5. A plot of the transient response of the completed attenuator (similar to that shown in Part 15).

6. A plot of the attenuator performance as a function of frequency (similar to that shown in Part 16).

7. **REQUIRED:** The output file produced when performing the transient analysis of Part 12. (You may remove page breaks, blank lines, and reduce font size to no smaller than 8 points if you wish to conserve paper; however, do not alter any text in the output file)

Although you are encouraged to work with your classmates, each student is required to create their own simulation and produce their own plots and other results from their own unique simulations. Potential sanctions are provided on the course website.

Name ______________________________

ECE 255 **ELECTRONIC ANALYSIS AND DESIGN**
Fall 2009 SPICE Homework

My results for the design of an attenuator using a 1N914 diode:

Measured value of the reverse saturation current for a 1N914

I_S = ________________________

Measured value of the ideality factor for a 1N914

η = ________________________

Dynamic resistance a 1N914 at $I_D = 2\mu A$

r_d = ________________________

Attenuator resistor R_2 (actual 5% value)

R_2 = ________________________

Revised operating point to produce the dynamic resistance that will yield an attenuation ratio of $\frac{1}{2}$.

r_d = ________________ , I_D = ______________ , V_D = ________________

Dynamic resistance necessary to achieve attenuation ratios of $\left(\frac{Vout}{Vs} = \frac{1}{4} \text{ and } \frac{1}{10}\right)$

r_d for $\frac{1}{4}$ = ____________________ r_d for $\frac{1}{10}$ = ____________________

Values of power supply voltage, V_{CC}, used to produce the required attenuation ratios

V_{CC} for $\frac{1}{2}$ = _____________ V_{CC} for $\frac{1}{4}$ = _____________ V_{CC} for $\frac{1}{10}$ = _____________