Jack Hong 30935134
Partner: Omar Mrani
February 19, 2015

PHYS 229: Experiment 2— Diodes and Transistors

Diodes

We test the I-V characteristic of a silicone diode using the circuit shown in Figure 1 and verify that it matches the equation:

$$I = I_0(e^{eV/k_BT} - 1)$$

where I is the current through the diode, I_0 is the saturation current, e is the charge of an electron (-1.602e-19 C), k_B is the Boltzmann constant, and T is the absolute temperature. Since this is a silicone diode, we expect to see the current to increase quickly when voltage reaches 0.6V.

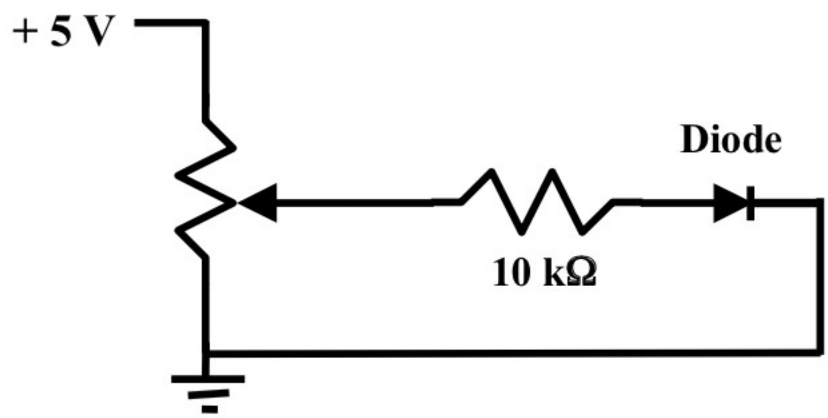
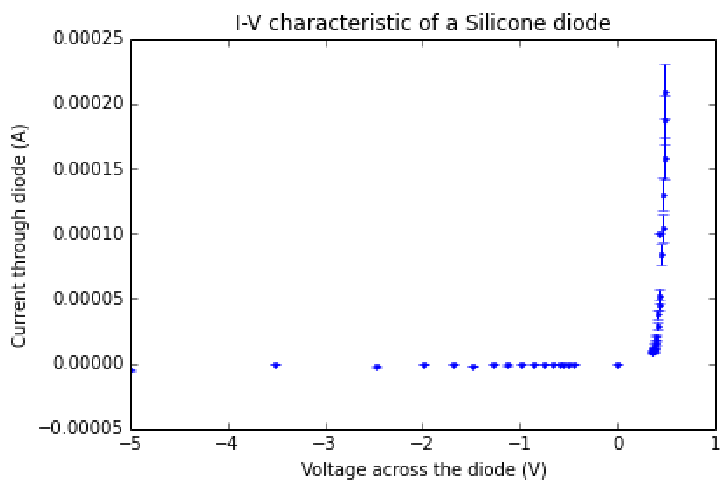


Fig. 1

The resistor used is a 10kΩ ± 5%. The current through the diode is measured as V/R where V is the voltage across the 10kΩ resistor and R is 10kΩ. Voltage across the resistor was measured with the HP DMM and the voltage across the diode was measured with the Keithly DMM at the same time. The diode was simply reversed to measure negative voltages. Our data is plotted below and we see the expected I-V characteristic for a diode, including the sudden rise at about 0.6V.



To analyze the graph, I first made it linear by plotting ln(I) vs ln(I_0) + (qV)/(kBT). Calculations shown below:

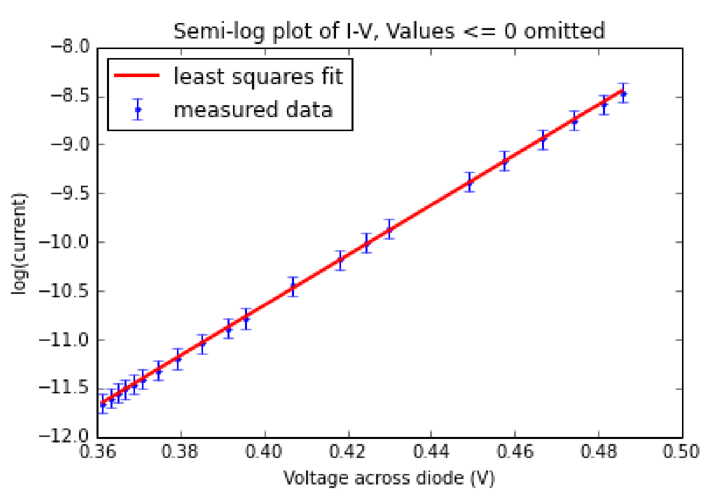
I = I_0 * (e^(qV/kBT) – 1)

ln (I + I_0) = ln(I_0) + (qV)/(kBT)

Since I_0 is << I, we make the approximation:

ln(I) = ln(I_0) + (qV)/kBT)

Note that since the ln function only takes positive numbers, all numbers less than or equal to 0 has been omitted.



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Goodness of fit - chi square measure:

Chi2 = 0.3, Chi2/dof = 0.016

Values of fit parameters:

slope = 2.571e+01 +/- 5.155e-01

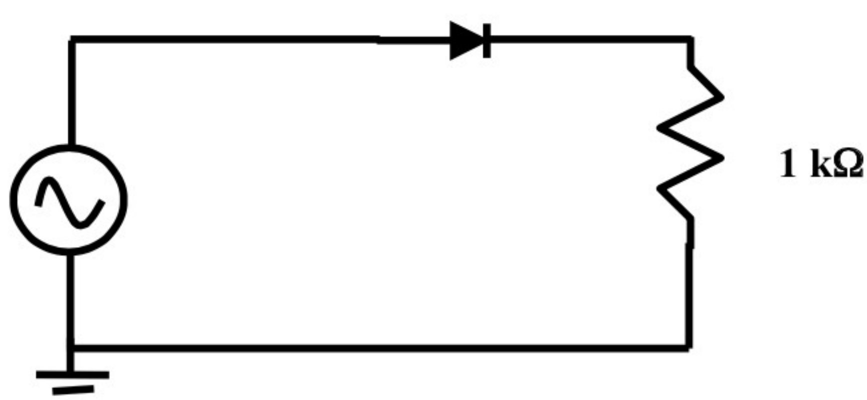
y_intercept = -2.094e+01 +/- 2.126e-01

from the equation of the line we have, slope = q/(kB*T)

kB = q/(slope*T) = 2.13 * 10^-23, which is in the same order of magnitude as the accepted value of 1.38 * 10^-23. Unfortunately, this is 54% off the accepted value. This could be explained by the observations that we made an approximation in the equation and that we omitted all the negative points. Also, from the Boltzmann constant lab, we note that there is a parameter that we did not take into account in this lab. This factor accounts for additional contributions to the diode current that we have neglected. According to the lab, the correct equation for the Boltzmann constant is kB=q/(m*slope*T) where m is the additional factor. The lab states that m varies between 1 and 2.5. If m is approximately 2, then that would bring my estimate of the Boltzmann constant much closer to the accepted value.

Diode as a Rectifier

We set up the following circuit on the breadboard:



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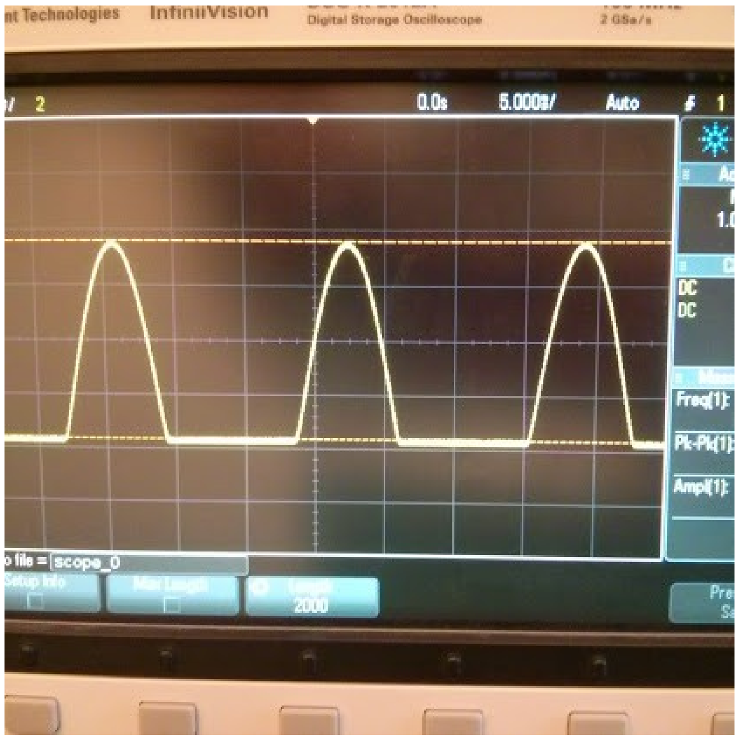
Using the wave generator, we initially ran an ac current of 60Hz (sine wave, 0 offset, 1V Vpp).

We used the oscilloscope to measure the voltage across the diode and verified that the diode passed the positive voltages, but not the negative ones.



Next, we put a capacitor in parallel with the resistor to make a DC voltage supply. We chose R = 100kΩ and C = 3uF (3 x 1uF capacitors in parallel) to get a time constant of 0.3s. This allowed us to get an overall DC voltage of 96.875mV and a ripple of approximately 4.50mV, which is a ripple of 4.6% of the overall voltage. (We were aiming for below 5%).

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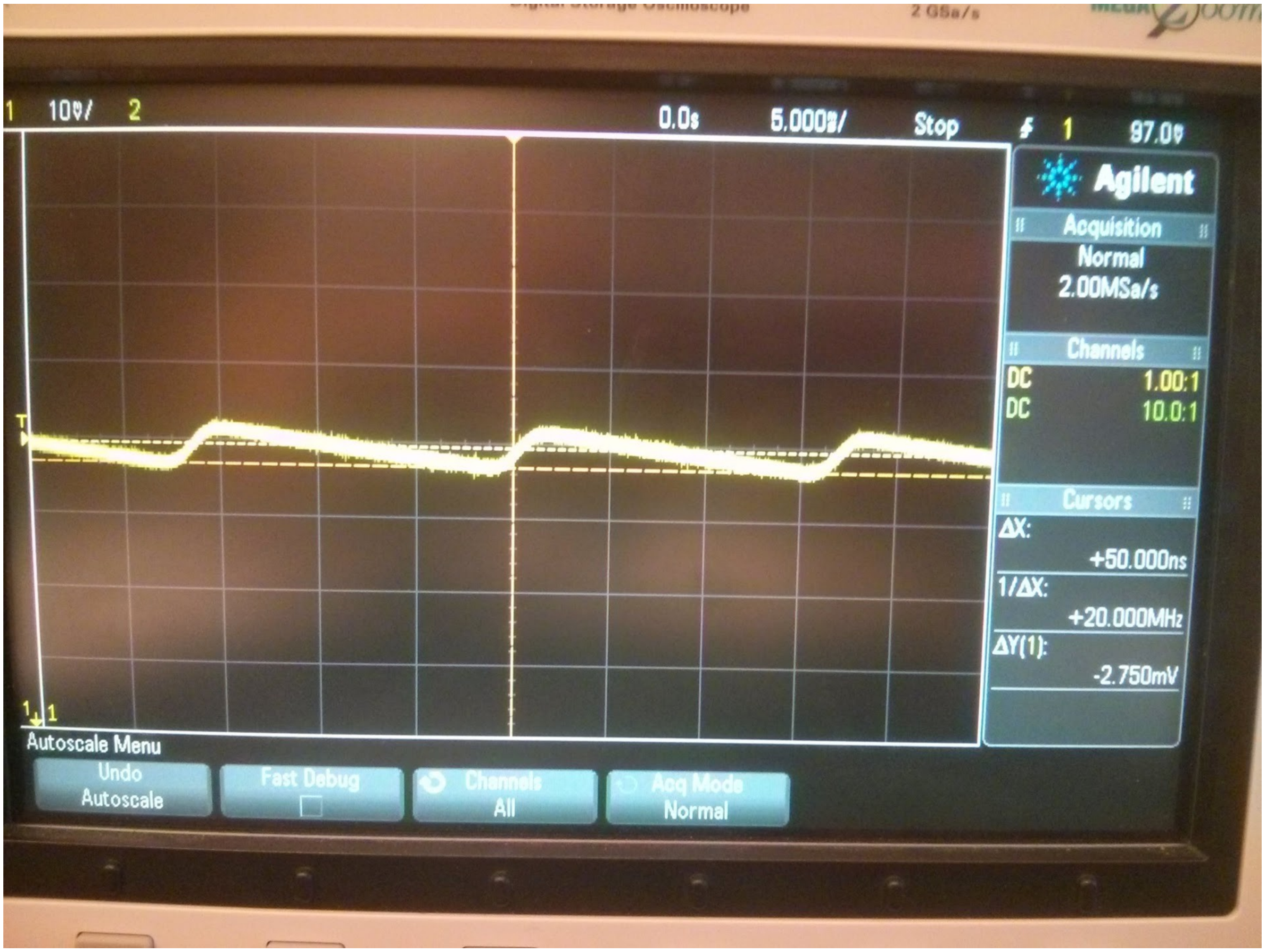
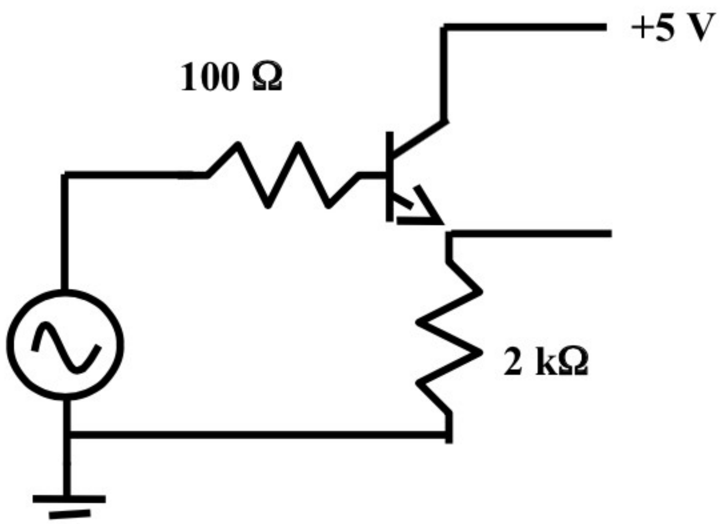


Transistors

We set up the following circuit:



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The ac output is 60Hz sine wave, 5 Vpp, 3V offset. The offset is to insure the transistor is forward biased all the time. We measure the voltage across the 100Ω resistor on channel 1 of the oscilloscope and the voltage across the 2kΩ resistor on channel 2. We learned that the probe setting on the oscilloscope must be set to 1:1 for the measurements to work properly. We note that the voltage across the 2kΩ resistor does match the ac source as long as the amplification does not surpass 5V or 0V.

We then switched to measuring both the voltages with DMM's to get the RMS voltages and we were able determine that the circuit did indeed provide amplification.

Table 1

Voltage across 2kΩ (V)	Voltage across 100 Ω (V)	Current out (A)	Current in (A)
0.03476	0.000007	0.00001738	0.00000007
0.07199	0.000008	0.000035995	0.00000008
0.10589	0.000007	0.000052945	0.00000007
0.01796	0.000009	0.00000898	0.00000009