Semiconductor Diodes

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Introduction

1. Diodes

3.1

We connected the 1N4448 diode to the DMM in one direction and measured a resistance of $0.61572k\Omega \pm 0.1138864\ \Omega$. When we reversed direction of the diode and connected the positive grabber to the black band of the diode (Cathode) and the grounding grabber to the red end of the diode(anode), the DMM measured resistance overload.

This shows that diode conducts only unidirectionally, since if there is a non-overloading resistance reading, it means that the tiny test current passed by the DMM actually pass through to the other end of the terminal, resulting in a forward voltage drop across the diode. [1]

3.2

In the conducting direction, the plastic-stick mounted 1NN4448 diode has a forward voltage drop of 4.419 mV$\pm$ 4.53μV. When we squeezed the diode with our fingers, the measured forward voltage drop is 8.215. When we submerged the diode in liquid nitrogen — Squeezing the diode with our finger causes slight temperature increase in the diode. We can clearly see the increasing trend of —— as the we change the temperature of the diode.

Diodes do not follow the linear Ohmic behaviour relating voltage and current, but these results still correspond to the semiconductor physics at play. As we decrease the temperature, the conduction electrons has less kinetic energy and therefore slower thermal velocities. Therefore, it requires more work to transport them through the pn junction, since voltage is work per change, the results in a higher voltage drop measured.

3.3

We connect the offset adder to the DMM to measure the output voltage and varied it from -8 to 8 V. Turning the knob clockwise increases the voltage and vice versa for counterclockwise. We loaded up different resistors, since the output current is kept below 24 mA, the circuit is relatively stiff as shown in the slope of in 1.

3.4

We setup the circuit as shown in Fig.2, using the offset adder, we vary the voltage and measure the current using ammeter in

[1]The minigabbers and BNC cable were connected to the INPUT pairs on the right which had a diode symbol below it.

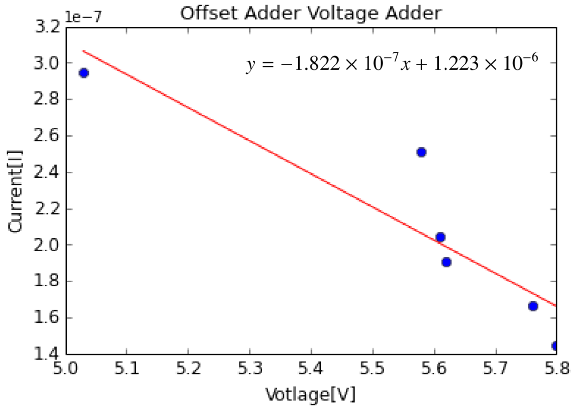

Figure 1: By plotting the VI curve, since $Z = \frac{\partial V}{\partial I}$, the output impedance relatively low, at around $-1.822 \times 10^{-7}\Omega$.

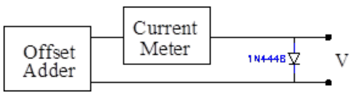

Figure 2: Setup for measuring the characteristic curve of a diode.

series and the voltage across the diode. This manual method used to obtain the characteristic curve yields the plots shown in Fig.3 and 4.

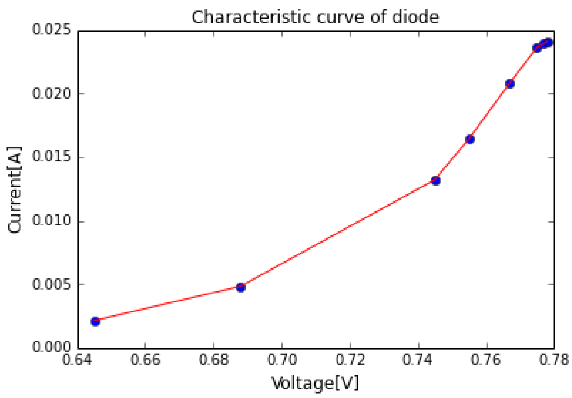

Figure 3: The VI curve on a linear scale.

3.5

As shown in Fig.5, the curve tracer is a more reliable way of finding the characteristic curve of a diode compared to the measurements done in 3.4. This is because the automated adjustment varies the voltage faster to eliminate possible temperature dependent effects due to slow measurement and voltage adjustment. By selecting the Ohmic (linear) region on the Curve Tracer program, we obtain the i_{sat} and voltage coefficient.

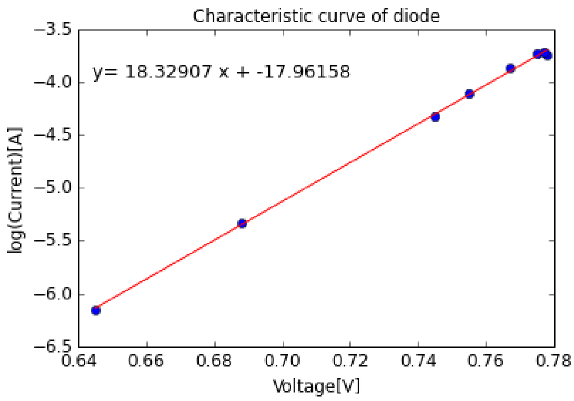

Figure 4: The characteristic curve on with current on a log scale and voltage on a linear scale.

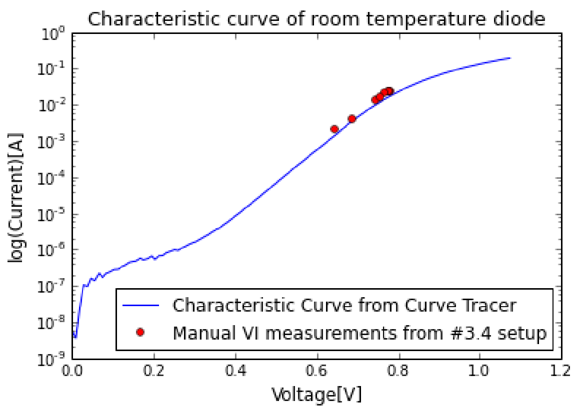

Figure 5: Characteristic curve for diode at room temperature. (T =298K; $i_{sat} = 2.37 \times 10^{-9}$, voltage coefficient = 16.49)

We rearrange the diode equation as shown in Eq. 1 and solve for n as in Eq.2

$$i(V) = i_{sat}\left[exp(\frac{eV}{nkT}) - 1\right] \qquad (1)$$

$$n = \frac{eV}{kT}\frac{1}{ln[\frac{i(V)}{i_{sat}}+1]}$$
$$= \frac{(1.60\times10^{-19}C)(0.212V)}{1.38\times10^{-23}\frac{m^2kg}{s^2K}(298K)}\frac{1}{ln(\frac{6.639\times7A}{2.37\times10^{-9}A}+1)} \quad (2)$$

and obtain n= 1.463. Indeed, we do find that the constant n fall within the reasonable range between 1 and 2, depending on the particular diode. Likewise,for the diode in liquid nitrogen, then we get a n value of 1.427, which is close to the n at room temperature. The n value is characteristic of a diode and should not be significantly affected by the temperature. The characteristic curve of the diode in liquid nitrogen is shown in 6, where we could see that the Ohmic region on the LN2 curve is shifted rightward compared to the room temperature diode.

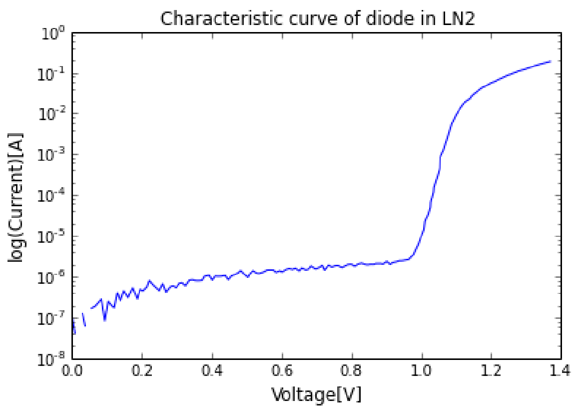

Figure 6: Characteristic curve for diode in liquid nitrogen. (T =170K; $i_{sat} = 5.22\times10^{-8}$, voltage coefficient =9.59)

3.6

We setup the experiment by connecting the 1N4448 diode in series with a 1MΩ resistor and a 12V voltage supply. In order to find the current thoruhg the diode, we measure the value of the voltage drop across the resistor as 327 mV. Using the diode equation (Eq.1), we compute the current through the diode, i(V=327mV), as:

$$(4.00\times10^{-8}A)e^{\frac{(1.6\times10^{-19}C)(327\times10^{-3}V)}{(1.4315)(1.38\times10^{-23}m^2kgs^{-2}K^{-1})(298K)}}$$

and obtain current value of 0.2896 mA.

3.7

We built a half wave rectifier using the setup shown in Fig.7 and set the DC offset as zero. By measuring the input and output signal waveforms, as shown in Fig.8, we find that the peak-to-peak voltage of the rectified signal is attenuated by a factor of about 8. In addition, we can see that the half-wave rectifier passes half of the signal while blocking the other half, however, there are still some rippling in the rectified signal that requires filtering.

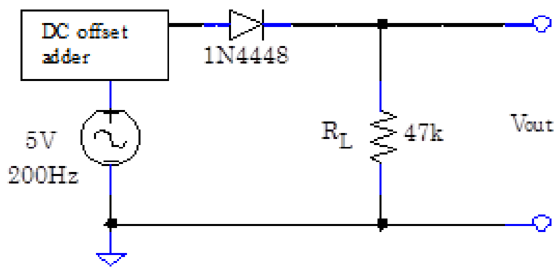

Figure 7: setup

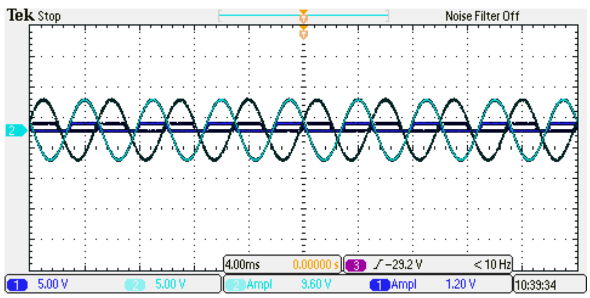

Figure 8: Scope trace of the AC signal (in cyan; Channel 2) and the rectified output signal (in blue; Channel 1)

3.8

To alleviate the rippling effect observed in Fig.??, we add a 1μF capacitor in parallel to the load resistor in the rectifier shown in Fig.7. The peak-to-peak voltage of the original input signal is 10V, without the rippling the V_{pp} is equal to the amplitude.

a) When we double the input frequency, the amplitude of the ripple decreased to 1.25V. The measured V_{pp} is 1.32V. The difference between these measurements tells us that the ripple is around 0.08V.

b) Doubling the capacitance also results in a ripple voltage of around 0.08V.

c) By doubling the load resistor, the ripple voltage is approximately 0.08.

3.9

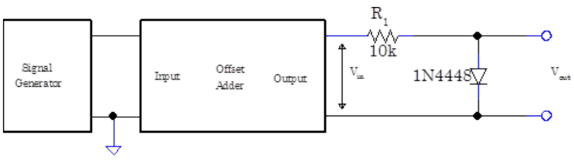

Figure 9: Diode analysis

3.10

For 3.10, Pictures 12, 13, 14 (in Dropbox) correspond to the effect of varying amplitude. These correspond to amplitudes of 2V, 5V and 10V respectively. Pictures 17 and 15 to a negative offset and at 2V peak-to-peak. Picture 16 to a positive offset at peak-to-peak amplitude of 2V as well. The offset adder basically cuts off your signal beyond a certain amplitude and offset.

3.11

3.13

When we flipped the polarity of the power supply, the forward voltage drop is close to zero because no current should be flowing through in the reverse direction of a diode. When we connected the LED to different values of resistance, we find that as we increase the resistance, the forward voltage drop increases and the LED brightness dims. When the resistance too large, the voltage drop across the diode is not enough to power the LED since it is below the LED's cutoff voltage, therefore the LED did not light up for the 30$k\Omega$ and 300kΩ trial.

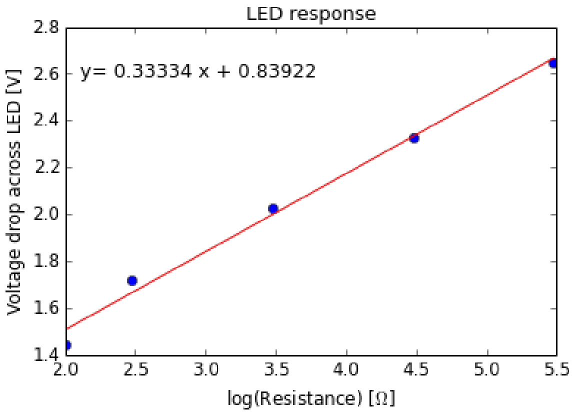

Figure 10: The LED's brightness decreases as we increase the resistance, corresponding to a larger voltage drop across the resistance.

3.14

We used the Curve Tracer to obtain the Fig. 11 characteristic curve of the blue LED used in the Problem 3.13.

3.18

We designed the zener diode voltage regulator shown in Fig.??, as a voltage divider with one resistor and the 1N5234 zener diode. We compute the resistance given that the maximum current can not exceed 15mA:

$$R_s = \frac{V_{in} - V_{out}}{I_{max}} = \frac{12 - 6.2V}{15mA} = 75.4\Omega \quad (3)$$

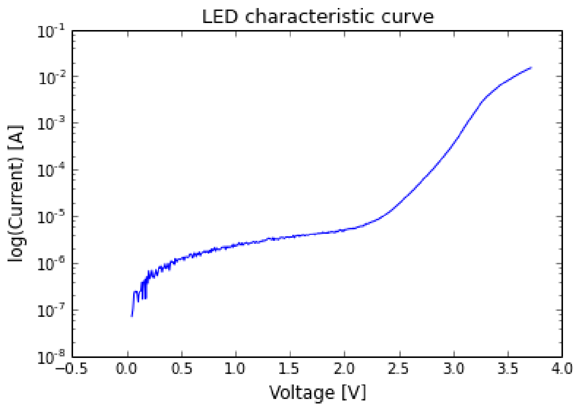

Figure 11: Characteristic curve of the light-emitting diode (LED). By selecting the Ohmic region of the characteristic curve, the fitting analysis done by Curve Tracer yielded an i_{sat} value of —— and voltage coefficient of ——.

We construct the necessary R_s by putting a 80,300, and 4Ω resistor in series. For the 12V± 1.84mV input from the breadboard box, the output voltage regulated by this circuit is measured at 6.2946 V ± 1.155 mV.

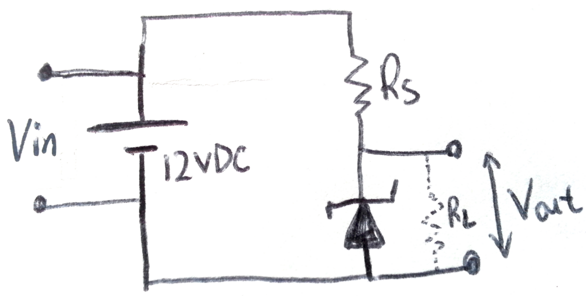

Figure 12: Schematic for the zener diode voltage regulator.

2. Conclusion

Acknowledgments

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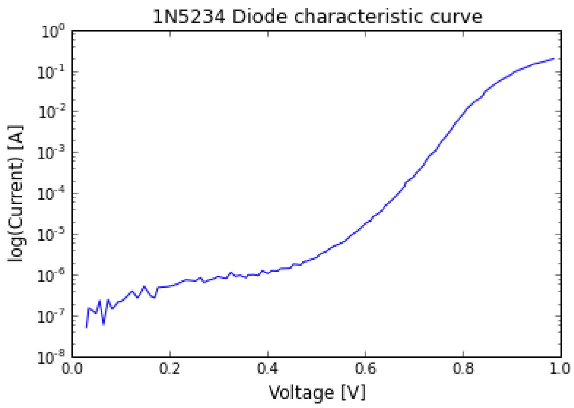

Figure 13: Characteristic curve of the 1N5234 zener diode.

that helped this work. We also appreciate Sissi Wang for providing us with guidance on question 3.2.

References

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