Lab 4: Characteristics of Resistors and Diodes

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Introduction

Diodes are another fundamental electronic element. Alternative currents (voltage waveforms) are also incredibly important. Here we learn about resistance characteristic curves and the resistivity of diodes.

Exercise I

The randomly chosen resistor values are:

$$R_1 = 100\Omega,\ R_2 = 1000\Omega$$

Part 1

a) Both channels have the same range for voltage and time.

b) Channel 1 (the voltage across R2) is very close to channel 2 (the voltage across the source). It is almost the same voltage as channel 2, but it is off since it doesn't include R1 (which has much less resistance than R2 at 100 ohms vs 1000 ohms).

c) The current can be calculated using $I = \frac{V}{R}$ for the entire circuit (where $R = R_{eq}$ and $V = V_{SG}$) or one resistor ($R = R_2$, $V = V_R$). Both currents should be the same, since the circuit has no current dividers.

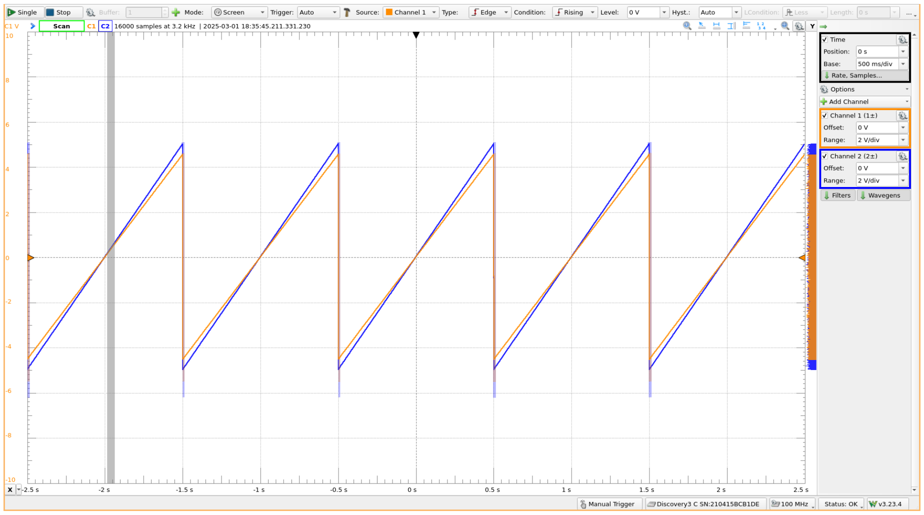
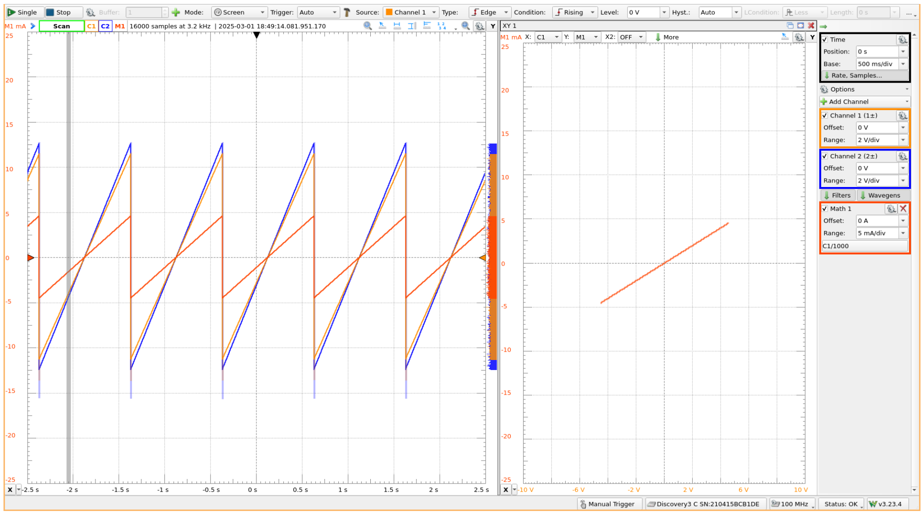


Figure 1: Oscilloscope of V_R (C1) and V_{SG} (C2)

Part 2

d-e) 

f)

g) Both M1 plots show the same current, which makes sense. The C1 curve when measured across R1 is much less than when measured across R2, which makes since since the voltage drop across R2 (1000 ohms) is greater than across R1 (100 ohms). Both characteristic curves are unique, since they have different slopes (resistance).

h) All four graphs, made using Python:

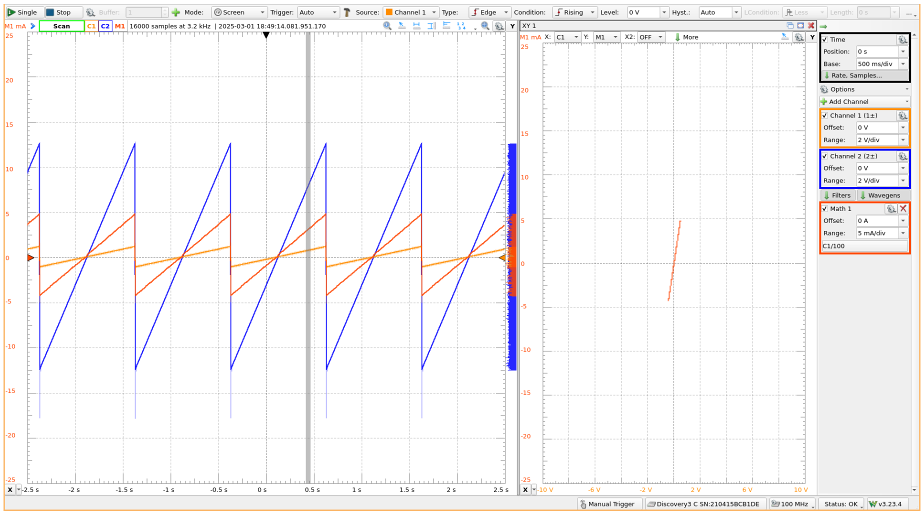


Figure 2: Oscilloscope of the Calculated Current (mA) across R1 and Characteristic Curve of R1

```
import matplotlib.pyplot as plt
import numpy as np
from numpy import genfromtxt

r1_data = genfromtxt("resistor_1.csv", delimiter=",", names=True)
r2_data = genfromtxt("resistor_2.csv", delimiter=",", names=True)

r1_voltage = r1_data["Channel_1_V"]
r2_voltage = r2_data["Channel_1_V"]

r1_current = r1_data["Math_1_A"]
r2_current = r2_data["Math_1_A"]

r1_power = r1_voltage * r1_current
r2_power = r2_voltage * r2_current

# Data sliced at certain chunks for plot clarity

plt.title("Resistor 1: Power vs Current")
plt.xlabel("Current [mA]")
plt.ylabel("Power [mW]")
plt.grid()
plt.plot(r1_current[0:2100] * 1000, r1_power[0:2100] * 1000)

plt.title("Resistor 1: Power vs Voltage")
```

```
plt.xlabel("Voltage [V]")
plt.ylabel("Power [mW]")
plt.grid()
plt.plot(r1_voltage[0:2100], r1_power[0:2100] * 1000)

plt.title("Resistor 2: Power vs Current")
plt.xlabel("Current [mA]")
plt.ylabel("Power [mW]")
plt.grid()
plt.plot(r2_current[1500:2450] * 1000, r2_power[1500:2450] * 1000)

plt.title("Resistor 2: Power vs Voltage")
plt.xlabel("Voltage [V]")
plt.ylabel("Power [mW]")
plt.grid()
plt.plot(r2_voltage[6000:7550], r2_power[6000:7550] * 1000)
```

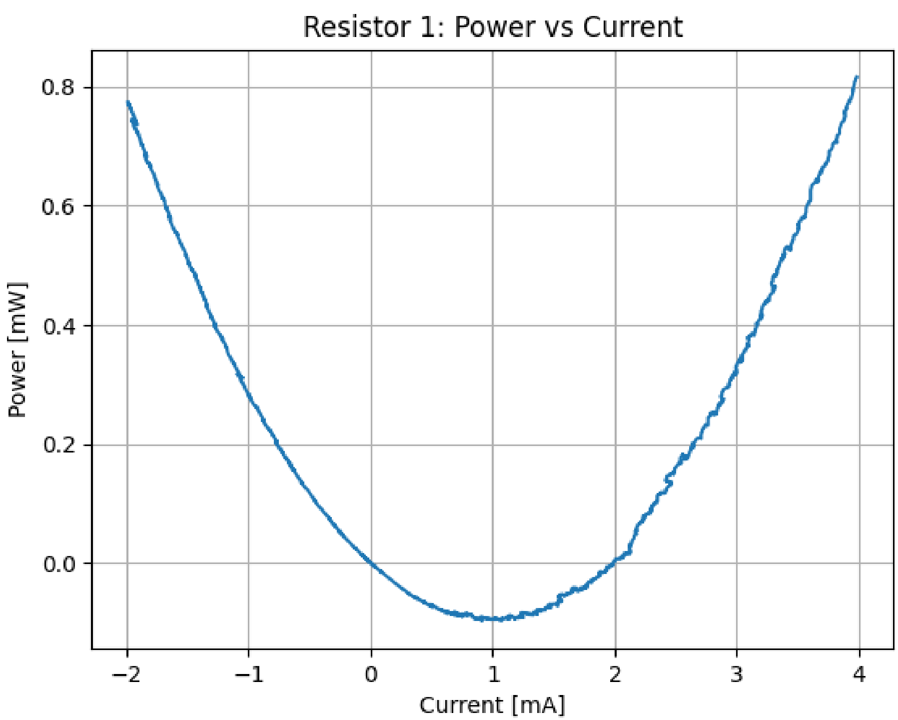


Figure 3: Resistor 1: Power vs Current

i) It is quadratic since:

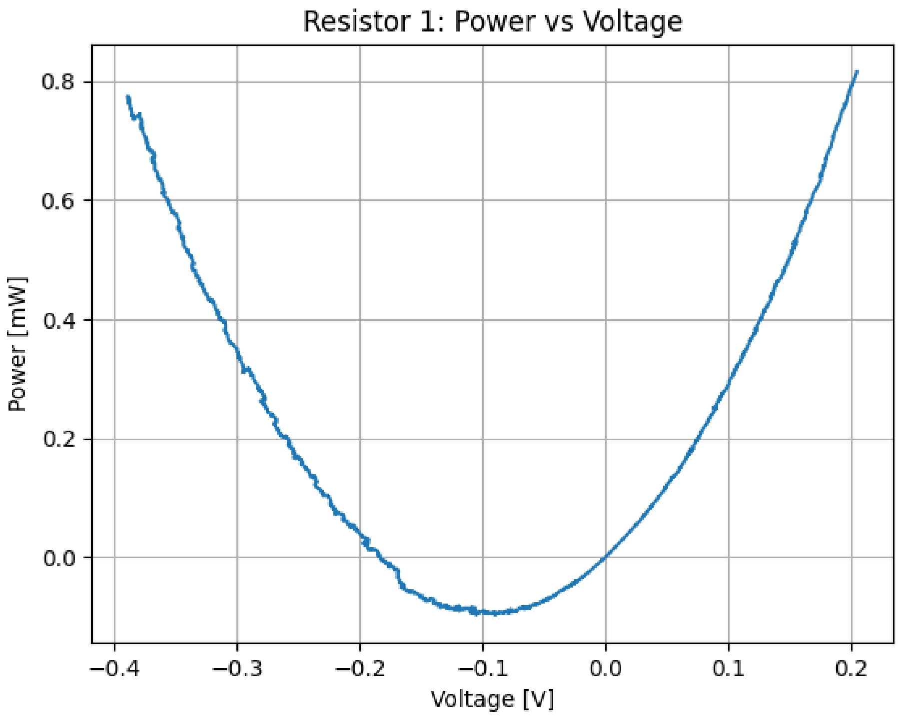


Figure 4: Resistor 1: Power vs Voltage

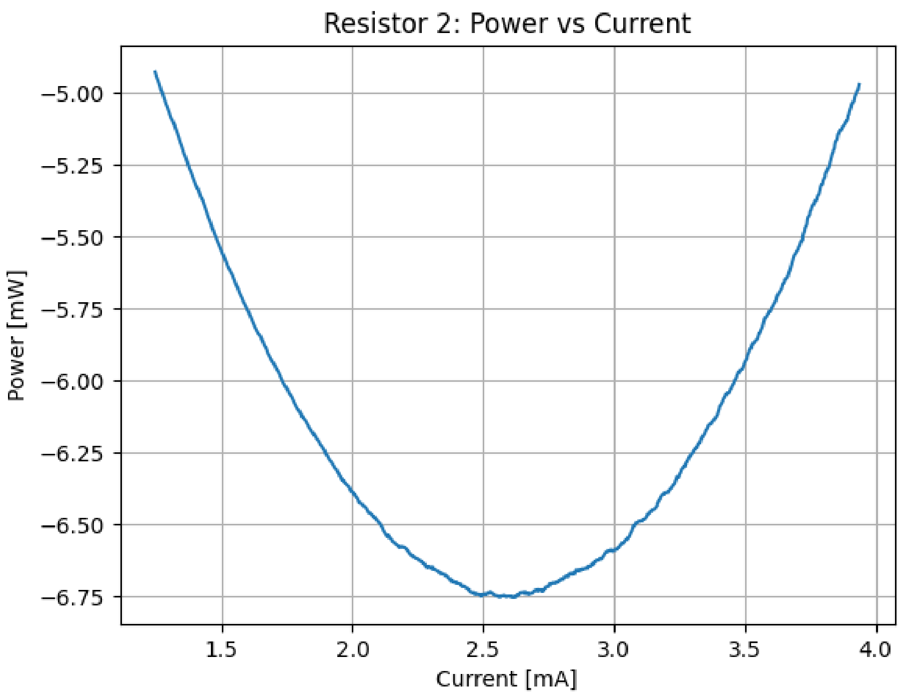


Figure 5: Resistor 2: Power vs Current

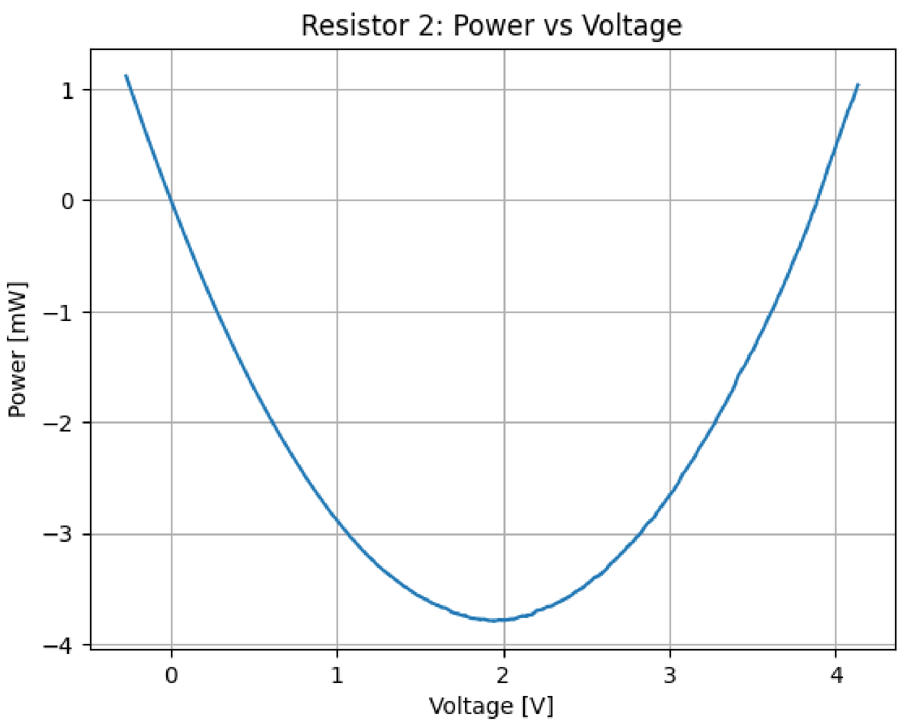


Figure 6: Resistor 2: Power vs Voltage

$$P = VI \qquad V = IR$$

$$\boxed{P = RI^2}$$

j) It is quadratic since:

$$P = VI \qquad I = \frac{V}{R}$$

$$\boxed{P = \frac{V^2}{R}}$$

Exercise II

The 1000 ohm resistor (R2) is replaced with a diode. C1 measures the voltage across the diode and C2 measures the voltage across the resistor.

a-b) The current through the resistor is the same as the diode in series, so the calculated current for the resistor applies to the diode too.

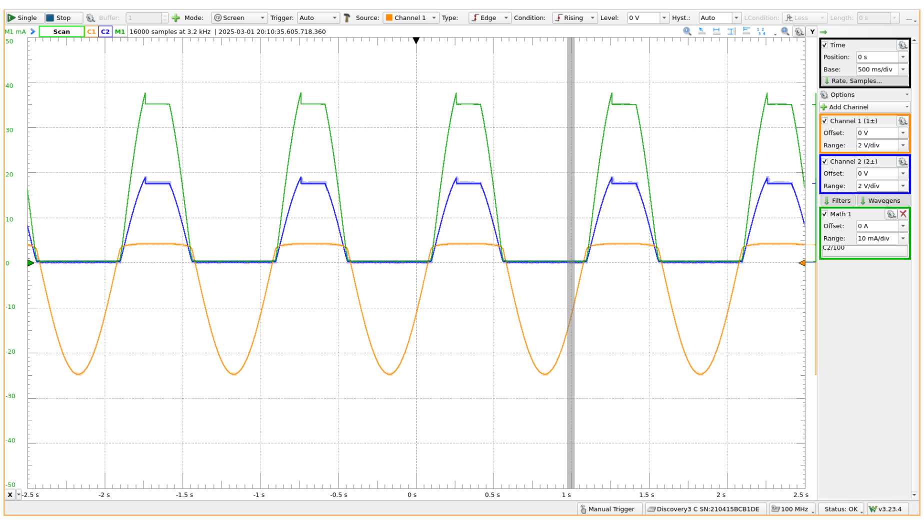


Figure 7: Diode Connected in Series with Resistor

c-d) The curve should look exponential.

e) See the previous figure for the sinusodial input. Here are three different waveform inputs (saw-tooth, square, and 50 Hz noise):

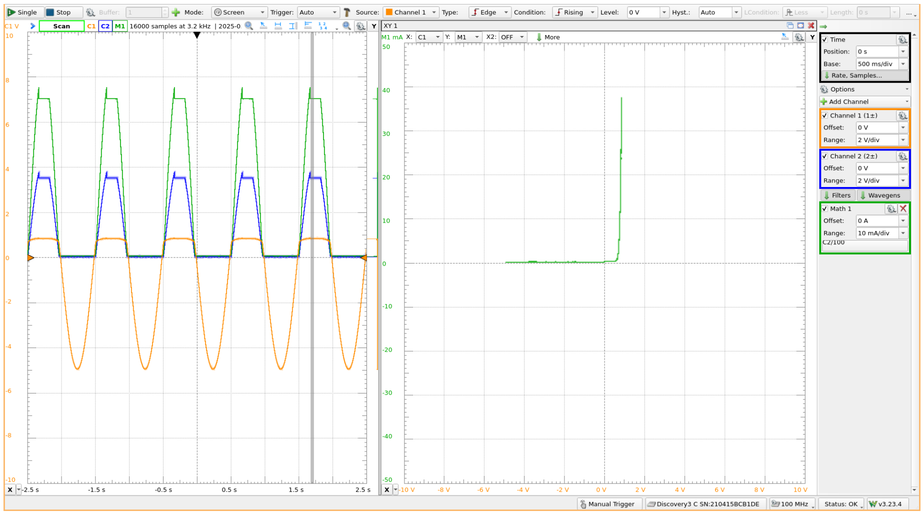


Figure 8: Characteristic of Diode

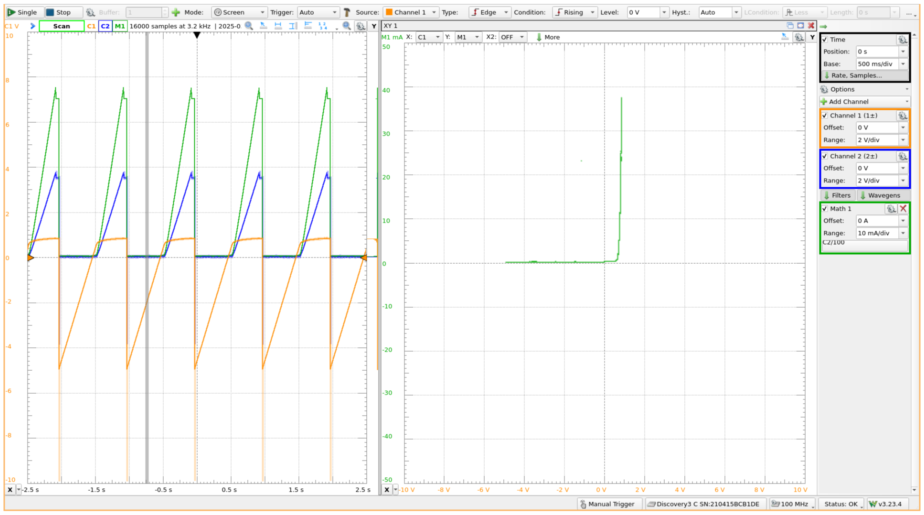


Figure 9: Saw-tooth

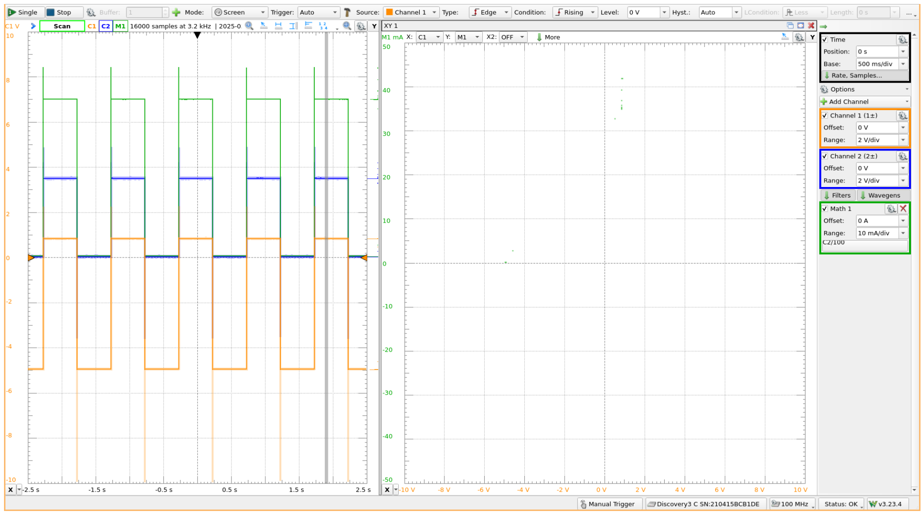


Figure 10: Square

The characteristic looks very similar, which makes sense since it is the most similar to the sinusodial waveform.

The square wave misses the voltage differences inbetween, so the characteristic curve is not full.

The noise seems to add more random data points on the characteristic curve.

f) The waves I generated (sinusodial, saw-tooth, square, and noise) are equivelent to the recorded waves. The square wave is unique in that it only has one voltage difference unlike the other "continous" waves.

g) Yes. The characteristic plots look exponential, so to find the resistance of the diode would require fitting an exponential curve to the data.

h) Eye-balling the curves on the plot, it seems to conduct at around 800 mV.

i) The maximum current was: 37.41 mA.

j) No. If it were, current would be able to flow in both directions (since a linear relation isn't piece-wise).

Question k

(Almost all the plots are the same for the LED.)

c-d) The curve should look exponential.

e) See the previous figure for the sinusodial input. Here are three different waveform inputs (saw-tooth, square, and 50 Hz noise):

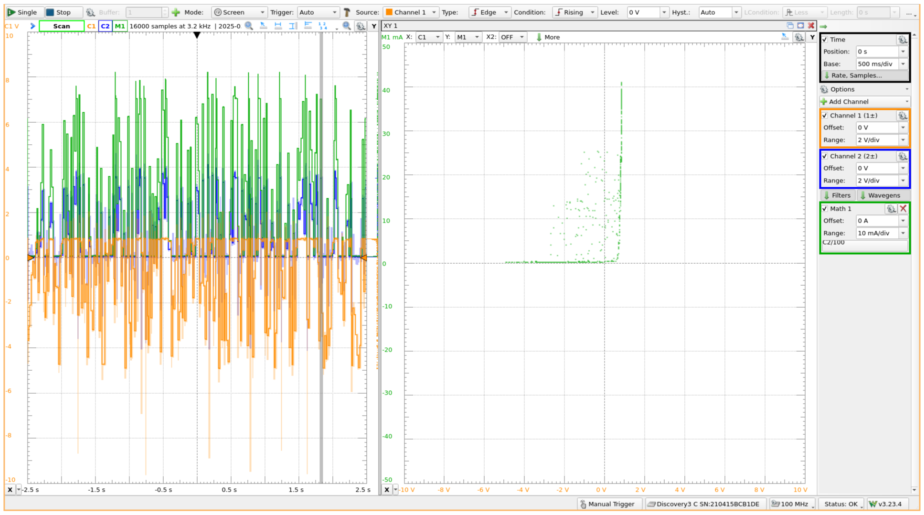


Figure 11: Noise

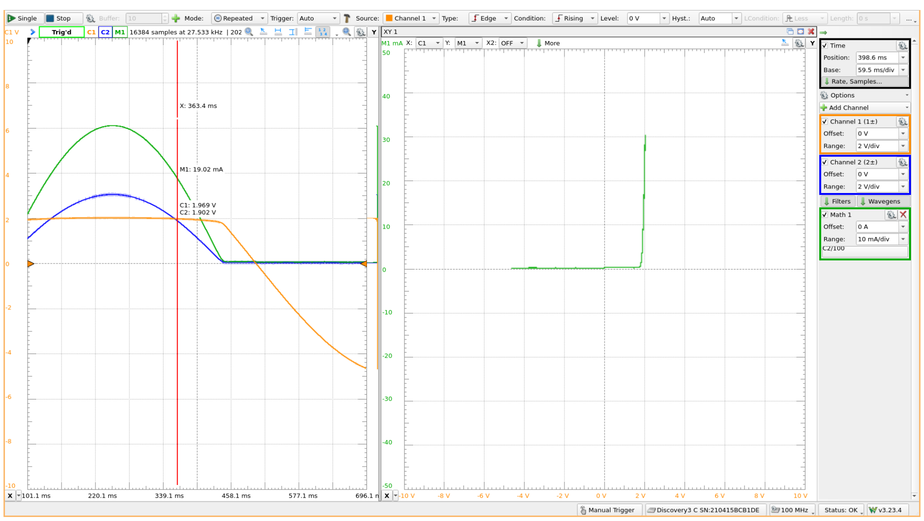


Figure 12: Characteristic of LED

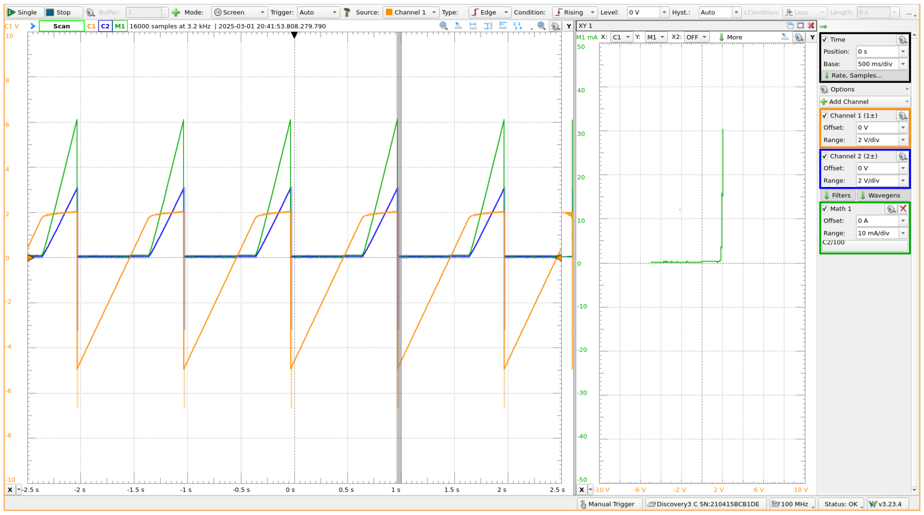


Figure 13: Saw-tooth

The characteristic looks very similar, which makes sense since it is the most similar to the sinusodial waveform.

The square wave misses the voltage differences inbetween, so the characteristic curve is not full.

The noise seems to add more random data points on the characteristic curve.

f) The waves I generated (sinusodial, saw-tooth, square, and noise) are equivelent to the recorded waves. The square wave is unique in that it only has one voltage difference unlike the other "continous" waves.

g) Yes. The characteristic plots look exponential, so to find the resistance of the diode would require fitting an exponential curve to the data.

h) Eye-balling the curves on the plot, it seems to conduct at around 2 V.

i) The maximum current was: 30.47 mA.

Conclusion

The many experiments performed here showcase the uses of alternative currents in combination with diodes, especially LEDs. This lab also helped me better understand the use of the Waveforms software.

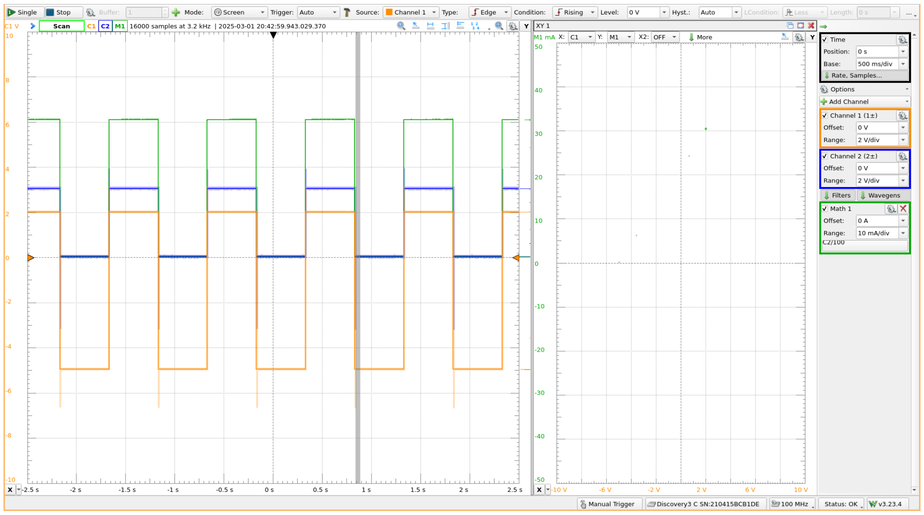


Figure 14: Square

Figure 15: Noise