PROBLEMS ENCOUNTERED

The main problems I encountered while working through the pre-lab was how to properly set-up the circuit such that it would provide the correct measurements. I did not realize that I had to set the voltage in waveforms until I read another student having this issue so I would recommend making this more obvious that the voltage is not normally set to 5V for +V. Along with this, finding the correct resistor took a while and made the process feel more tedious.

INTRODUCTION

The purpose of this lab is to introduce resistors, how they work, and how to apply them in any circuit. This will be utilized to find the effects that resistors have on circuits when in series, parallel, simple resistor ladders, and the effects of real-world resistors. Lab 4 should leave the student with the ability to measure voltages, measure currents, calculate resistances, and develop our understanding in forming the resistor divider for the final project.

DISCUSSION

4.5 Pre-lab Requirements

4.5.1Resistor Ladders

This section of the lab is used to get students used to measuring resistances in simple circuits using WaveForms and calculating estimated voltages.

Nodes	Calculated Voltage (V)	Actual Voltage (V)
A	4.404 V	4.382 V
B	3.135 V	3.100 V
C	1.865 V	1.844 V
D	0.596 V	0.590 V

***Table 1**: This table shows the calculated and measured voltage of the circuit shown in Figure 1.*

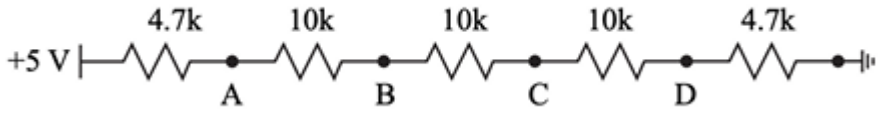


***Figure 1**: Circuit layout that was utilized to tabulate information in Table 1. This contains 5 resistors and 4 nodes.*

4.5.2 Two-bit R-2R Ladder

This section of the lab is used to get students used to using the wavegen portion of waveforms to generate changing input voltages to then find the actual voltages afterwards.

Combinations	Ideal Voltage (V)	Actual Voltage (V)
V_0=0V & V_1=0V	0 V	0 V
V_0=5V & V_1=0V	1.269 V	1.274 V
V_0=0V & V_1=5V	2.462 V	2.453 V
V_0=5V & V_1=5V	3.731 V	3.722 V

***Table 2**: This table shows the ideal and measured voltage of the circuit shown in Figure 2.*

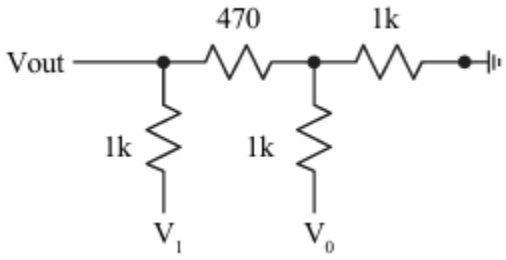


***Figure 2**: Circuit layout that was utilized to tabulate information in Table 2. This contains 4 resistors, 2 waveform inputs, and 1 measured voltage*

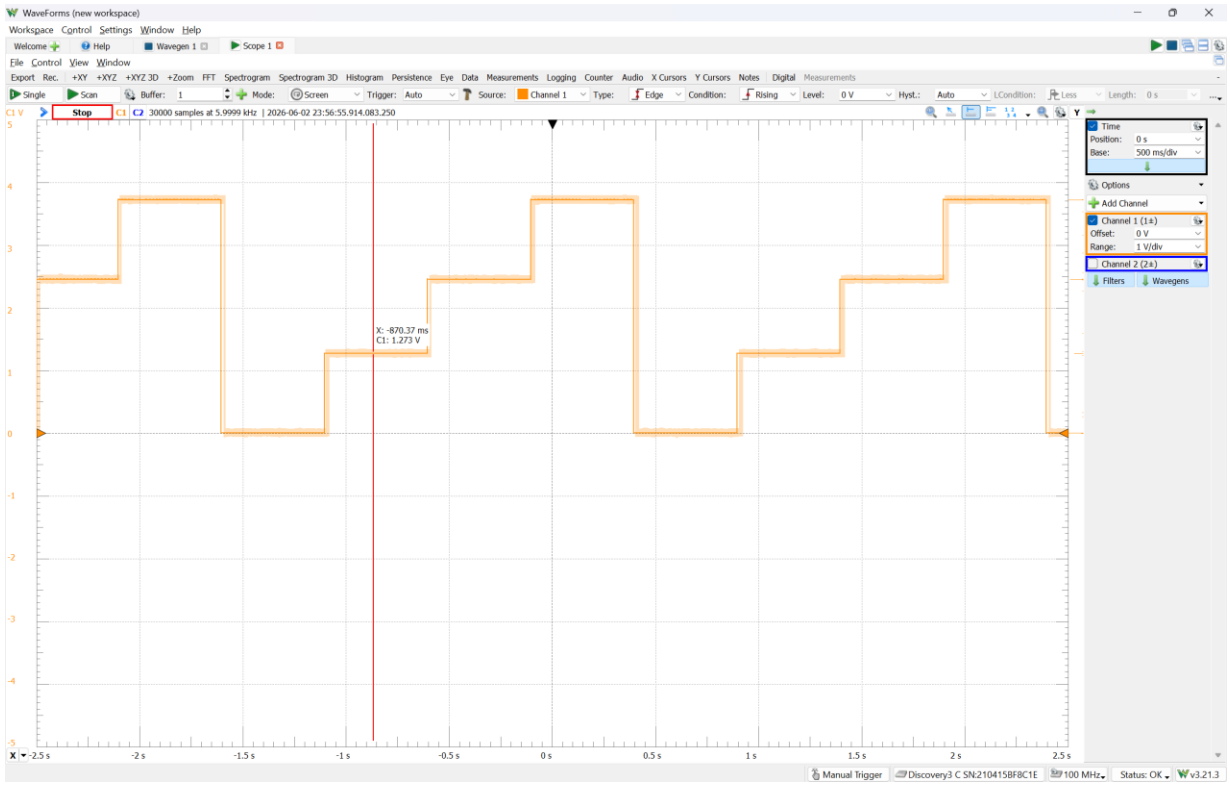


***Figure 3**: Oscilloscope output of the wavegen settings shown in Table 2 based on the circuit shown in Figure 2.*

4.6 In-Lab Requirements

4.6.1 Resistor Tolerances

This section of the lab is used to highlight how actual resistances change the measured voltages, leading to "incorrect" results compared to what the ideal would be based on the advertised resistance.

Advertised Resistance	Actual Resistance	Percent Error
470 Ω	464.9 Ω	1.09%
1k Ω	0.977 kΩ | 0.981Ω | 0.974Ω	2.30% | 1.90% | 2.60%
4.7 kΩ	4.645 Ω | 4.687Ω	1.17% | 0.28%
10 kΩ	9.81 kΩ | 9.93Ω | 9.91Ω	1.90% | 0.70% | 0.90%

***Table 3**: This table shows advertised versus actual resistances for the resistors used in Figures 1 & 2. These actual resistances were then used to calculate the ideal voltages seen in Table 4.*

Node(s)	Recalculated Voltage	Ideal Voltage from 4.5.2	Percent Error
A	4.400V	4.328 V	0.41%
B	3.133 V	3.100 V	1.05%
C	1.867 V	1.844 V	1.23%
D	0.600 V	0.590 V	1.67%
V_0=0V & V_1=0V	0.000 V	0.000 V	0.00%
V_0=5V & V_1=0V	1.265 V	1.274 V	0.71%
V_0=0V & V_1=5V	2.469 V	2.453 V	0.65%
V_0=5V & V_1=5V	3.735 V	3.722 V	0.35%

***Table 4**: This table tabulates the re-calculated voltages from Tables 1 & 2 based on the actual resistances shown in Table 3.*

4.6.2 Three-bit R-2R Ladder

This section of the lab highlights how voltages change when increasing the bits in an R-2R ladder, especially when there is an extra 5V or 0V to the circuit.

Steps	V_2 = 0V	V_2 = 5V
V_0=0V & V_1=0V	0 V	2.456 V
V_0=5V & V_1=0V	0.647 V	3.101 V
V_0=0V & V_1=5V	1.247 V	3.703 V
V_0=5V & V_1=5V	1.894V	4.348 V

***Table 5**: This table shows the measured voltages of the circuit shown in Figure 4 which then was tabulated using o-scope values seen in Figures 5 & 6.*

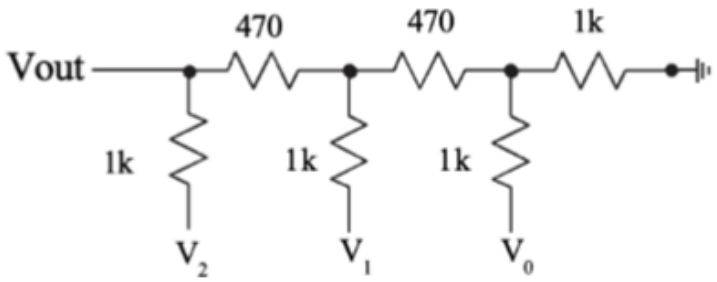


***Figure 4**: This circuit was constructed and calculated using the DAD to find the output Voltages for various steps seen in Figures 5 & 6.*

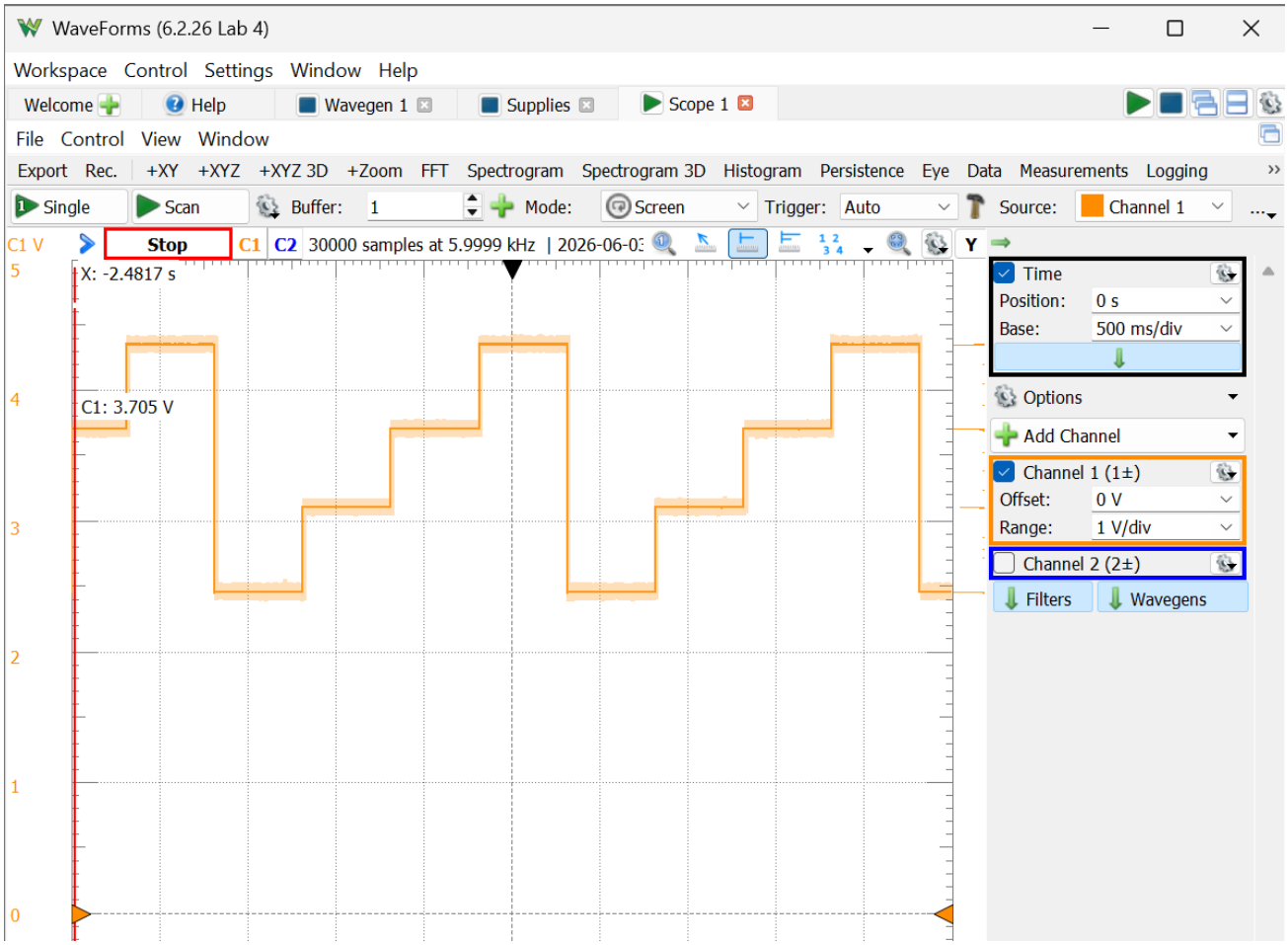


***Figure 4**: This is the output o-scope for V_2 = 5V seen in Table 5 constructed based on Figure 4.*

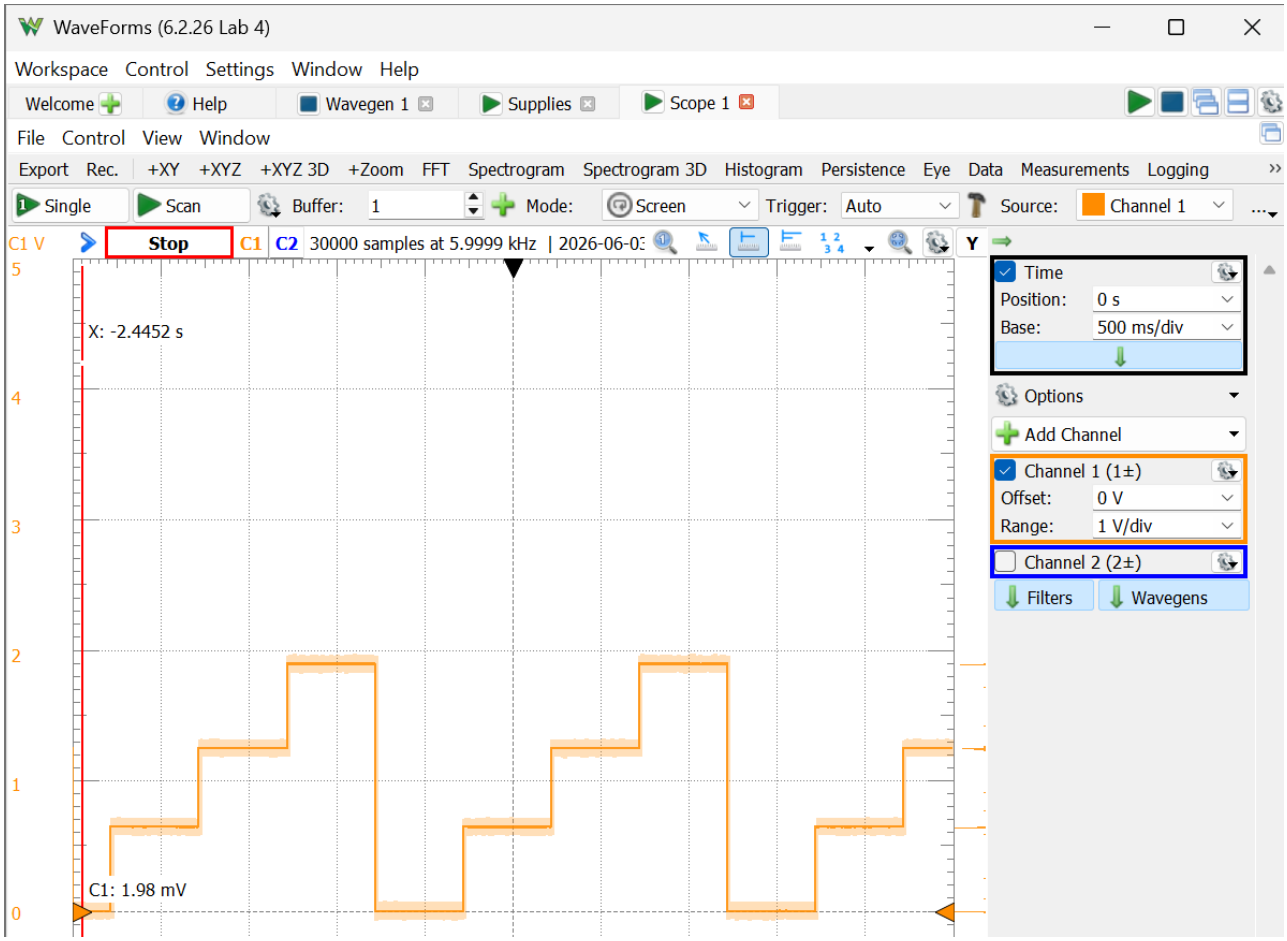


***Figure 6**: This is the output o-scope for $V_2 = 0V$ seen in Table 5 constructed based on Figure 4.*

Discussion Question:

During the teamwork section, I learned that having clear communication is extremely important to ensure that everyone in my group was recording values correctly and overall moving forward with the work properly. Collaborating with teammates helped to catch small mistakes like incorrect waveform settings before wasting a lot of time fixing these issues. Working together also made troubleshooting much easier when our values did not somewhat match one another.

I would overall rate my team's performance a 5/5 because we communicated well and completed the work efficiently while also helping each other throughout the lab. One main issue we encountered was making sure the waveform generator and supply were properly configured, especially since having these sections wrong caused unexpected measurements.

The three-bit R-2R ladder differs from the two-bit ladder because it includes an additional input bit, allowing for more voltage combinations and a larger amount of output levels. This resolution increase causes the output voltage to be more precise and capable of representing more digital values. Potential applications of a three-bit ladder includes digital to analog converters, signal generation, and audio electronics.

CONCLUSION

In this lab, I constructed and analyzed ladder circuits while measuring voltages and resistances utilizing WaveForms and the Digilent Analog Discovery Device. I compared the ideal resistor values with experimental measured resistor tolerances to see how physical components impact the circuits performance. Along with this, I constructed and tested both two-bit and 3-bit R-2R ladder circuits to help us better understand how digital inputs can influence voltage outputs with analog systems.