Lab 1: Resistors and Resistive Networks

Dhara Patel
Navi Boyalakuntla
Skye Ozga
02/11/20

Experiment 1: Resistance Measurement

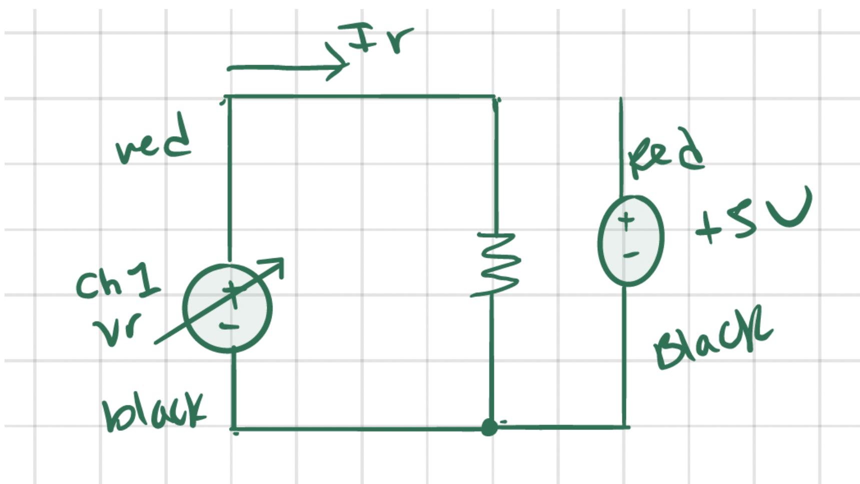

Figure 1: Schematic illustrating CH1 being used to measure the current through a resistor and CH2 being used as a reference.

We used a .25W resistor from the stockroom that was labeled as 6.04 kΩ with a 1% tolerance. We verified its value in two ways: a SourceMeter and a SMU.

To measure its resistance with a Keithley 2400 SourceMeter, we placed the probes on opposite leads of the resistor. The SourceMeter measured the resistance to be 5.96 kΩ.

Next, we used an SMU to measure the I/V characteristic of the resistor. Figure 2 is a plot of the measured current as a function of voltage. It has a slope of 1.673E-4 Amps per Volt. Using Ohm's law, we recognized that resistance would be the reciprocal of the slope of the I/V graph. The extracted resistance value from this slope is 5.97729 kΩ.

Table 1: Resistance Values

Name	Resistance Value (kΩ)
Labelled	6.04
Keithley 2400 Measured	5.96
SMU Extracted	5.977

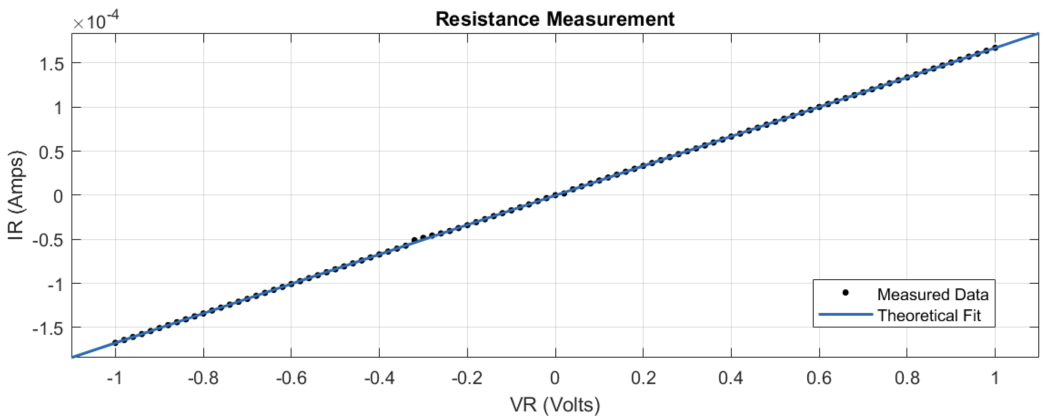

Figure 2: I-V characteristic of the resistor in question (6.04 kΩ) measured using an SMU.

The 6.04kΩ label is likely not the true resistance value. Although it is the manufacturing specification, there is also a band of manufacturing tolerances that are included in the labeling as a range, and the true value could fall anywhere in that range.

The Keithley 2400 has normal source accuracy and a measured voltage accuracy of 0.10% + 0.003 Ω for resistance values between 2 kΩ and 20 kΩ. There is a very small amount of error. Therefore, it is safe to say that the Keithley is an accurate way of measuring the resistance value.

> 💡 Because the SMU measures an average of the resistor's I/V across 100 different voltage values, it gives a broader image of the true resistance value.

The SMU is likely the most accurate measurement because resistors are not perfectly linear (nothing is!) so a single measurement I/V does not provide a super accurate picture of how the resistor will behave across its whole operating range.

We aren't sure if the Keithley does the same thing, but if it does, then the Keithley is the more accurate measuring tool.

Experiment 2: Resistive Voltage Division

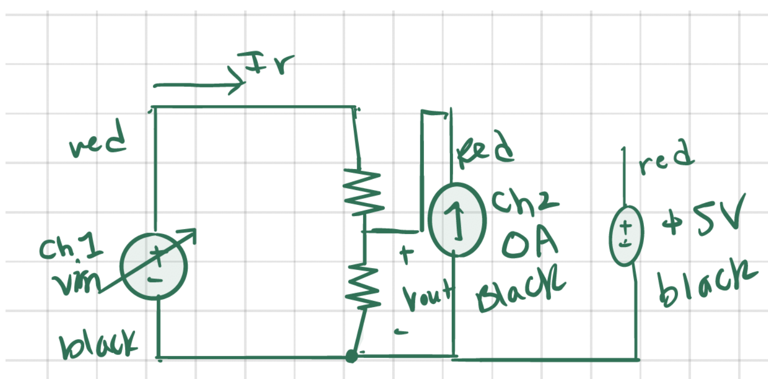

Figure 3: Schematic of the experiment set up for experiment 2.

We used two resistors in a Bourns resistor array chip and wired them in series with each other to create a voltage divider. Between these two resistors, we connected the positive lead of channel 2 and provided an input voltage from the positive lead of channel 1. The voltage drop across the first resistor was measured as a function of input voltage that ranged from -1V to 1V.

```
Table 2: Resistance within Bourns resistor array chips
Chip 1    | Chip
----------|----------
9.9475 kΩ | 9.9464 kΩ
9.9491 kΩ | 9.9343 kΩ
9.9431 kΩ | 9.9351 kΩ
9.9404 kΩ | 9.9426 kΩ
9.9602 kΩ | 9.9373 kΩ
9.9393 kΩ | 9.9320 kΩ
9.9309 kΩ | 9.9272 kΩ
9.9716 kΩ | 9.9354 kΩ
```

The labeled resistance value was 10kΩ with a tolerance of +/- 2%. This gives us a range of resistances from 9.8kΩ to 10.2kΩ. All of our measured values fall within this range as shown by Table 2. The calculated tolerance is +/- 2.38% for chip 1 and +/- 1.01% for chip 2.

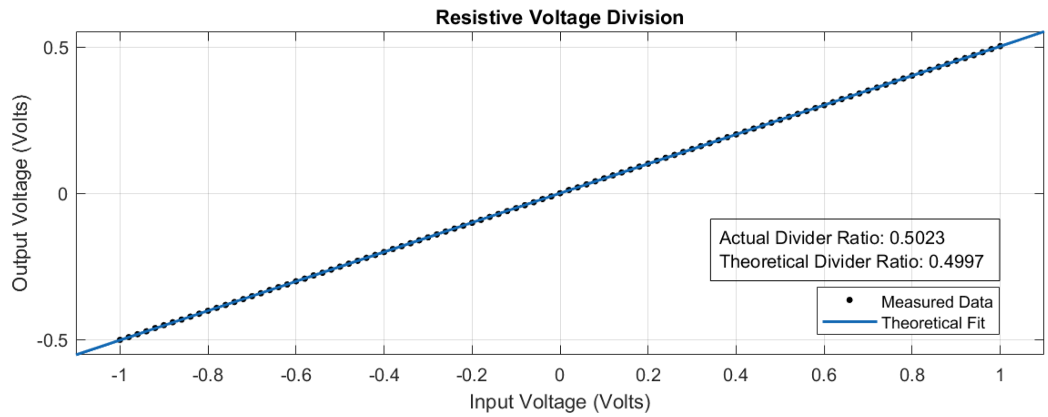

Figure 4: The voltage divider's voltage transfer characteristic graph.

The calculated voltage divider ratio is 0.4997 with R1 being 9.9469 kΩ and R2 being 9.9343 kΩ. The measured voltage divider ratio is 0.5023. The discrepancies between the theoretical and measured values may have been due to the parasitic impedance associated with the use of a solderless breadboard. We can use Equation 1 to find the tolerance of the nominal divider ratio based on the resistors' tolerances. We found the measured tolerance of the divider ratio to be +/- 0.51%

Equation 1

Experiment 3: Resistive Current Division

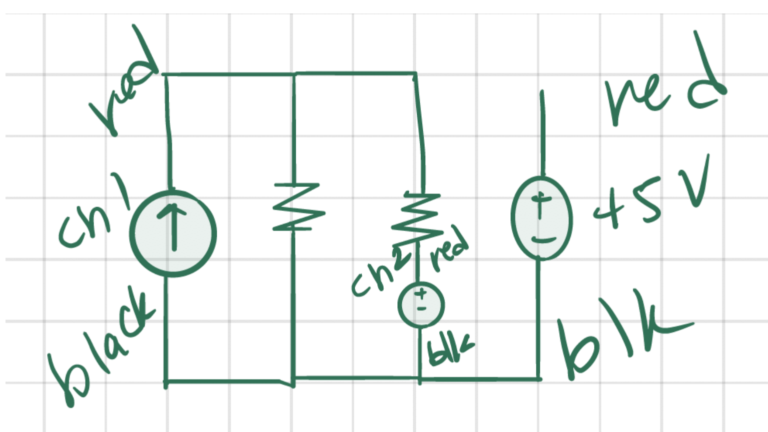

Figure 5: Schematic of the experiment set up for experiment 3

We constructed a current divider by placing two resistors of the same value in parallel. We supplied a variable current into the system using the positive lead of channel 1 and measured the current in one of the branches by placing channel two in series with it. The negative lead of the 5 volt supply was the ground.

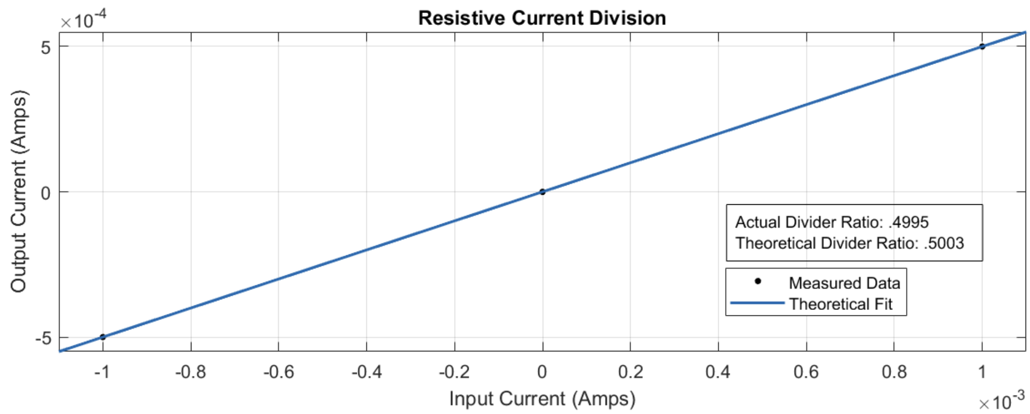

Figure 6: The current divider's current transfer characteristic graph.

The theoretical current divider ratio is .5003 while the current divider ratio is .4995. They are within 0.002% of each other. This discrepancy is consistent with the level of resistance mismatch. The resistors used were within 0.001% of each other.

Experiment 4: R-2R Ladder Network

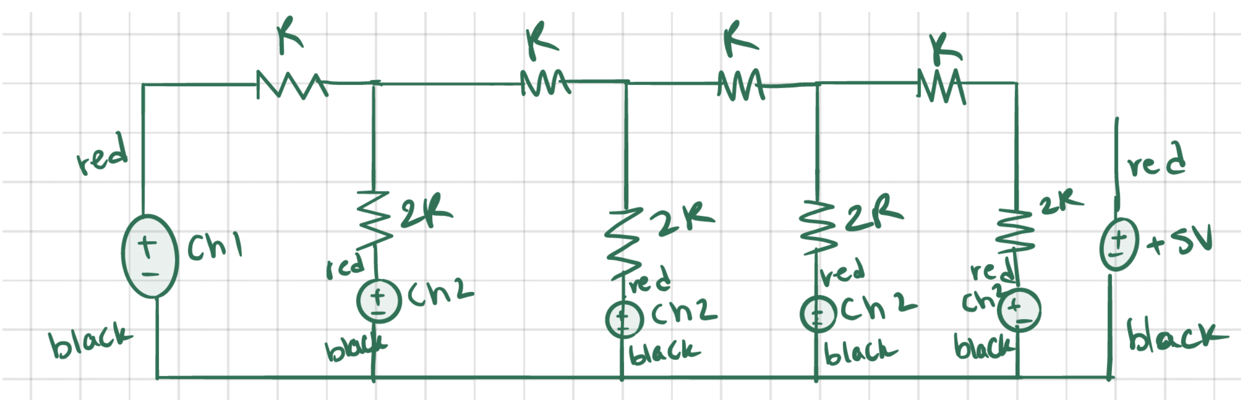

Figure 7: Schematic of the experiment set up for experiment 4

We constructed a 4-legged R-2R ladder network using the same Bourns resistor chips. We used a single resistor for the R branch and 2 resistors in series for the 2R branch to ground. We changed which leg channel 2 was in series with in order to measure the current going through each leg at variable voltage inputs by the positive lead of channel 1. The negative lead of the 5 volt supply was the ground.

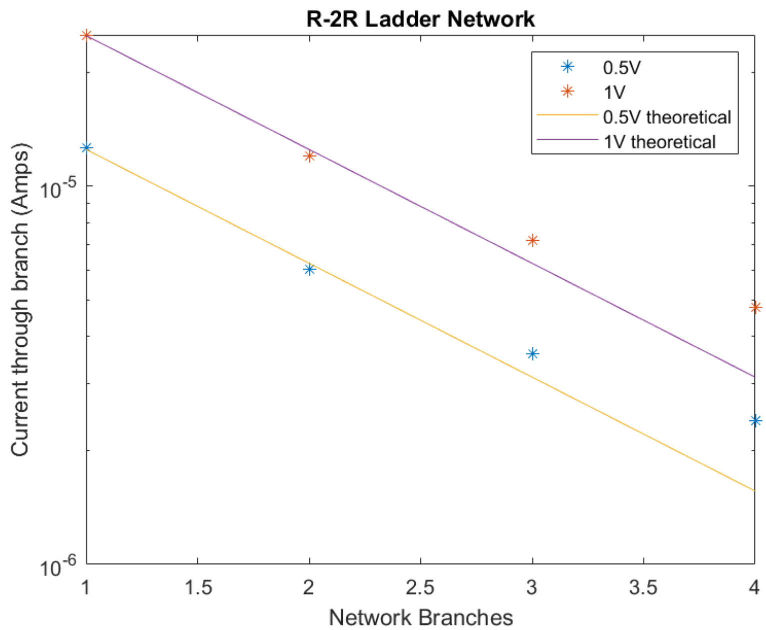

Figure 8: Current through the different branches at 2 different voltages: 0.5V and 1V.

These current vary with position as expected since the currents through the branches decrease the farther in the branch is from applied voltage. Since the log of 0.5 is -0.3, and every next branch is a half the current of the last branch, the slope should be -0.3. We see the same slope in figure 8.