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PHYX 315
26 April 2019

Lab 10: Thermocouples

Introduction

The purpose of this lab was to analyze and understand the concept of thermocouples. The thermocouple used in this lab was a type J, which consists of a iron and constantan wire. A type J thermocouple has a temperature coefficient of 51.45 μV/°C Figure 1 displays the circuit that was constructed using the specified thermocouple in addition to a INA126 op amp.

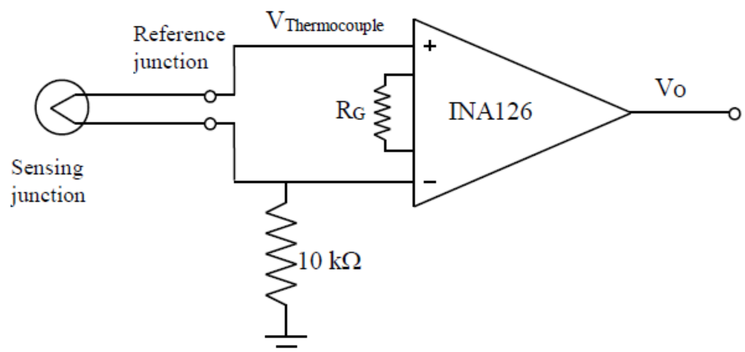

Figure 1. Circuit schematic for the type J thermocouple (Gannett, Lab handout, 2019).

Methodology

A thermocouple has two wires that are dissimilar and is used to obtain an accurate relationship between voltage and temperature (EETech Media n.d.). The Seebeck effect can be observed through use of a thermocouple. The Seebeck effect in relation to thermocouples is when there is production of a small voltage due to the temperature at the junction from the two dissimilar metals (Gannett, Lab handout, 2019). This voltage is produced due to the temperature differences along each wire, which is where the relationship between temperature and voltage is explained. As the temperature of the water increases, the voltage produced increases (EETech Media n.d.). Therefore, the relationship between the two can be described as linear.

Table 1. Theoretical and measured resistor values used in the analysis.

$R_{theoretical}$ [Ω]	$R_{measured}$ [Ω]
100	99.8
10	9.92
680	674
10	9.86

For the INA126 op amp there is a specific equation for the gain (Gannett, lab handout, 2019):

$$g = 5 + \frac{80\ k\Omega}{RG}$$

Where:

g	=	amplifier gain
R_G	=	gain resistor [Ω]

The gain equation was used to determine the gain resistor value needed for a desired voltage gain of 1000. The resistance value needed to obtain the gain target of 1000 resulted as 80 **Ω**. Since this resistor value is not that common, a 100 **Ω** resistor was used instead, which results in a theoretical gain of 805.

Table 1 contains the resistor values with their theoretical and measured value. The first resistor is the chosen gain resistor, the second is the 10 kΩ shown in the schematic, and the last two were chosen to create a voltage divider. The input voltage provided was 100 mV peak to peak, with the addition of the two resistors to create a voltage divider, the voltage resulted as 6.4 mV. The measured output voltage was 3.68 V. This input and output voltage resulted in a gain of 556. We noticed that the gain changed as we changed the frequency. Therefore, for the rest of the analysis the theoretical gain was used.

To measure and compare temperature and output voltage, the junction of the thermocouple was placed in ice water (~ 0 °C). The second point was measured at room temperature, which was 21.5 °C (Gannett, lab, 2019).

Results and Discussion

The data points to develop the linear equation between temperature and output voltage is shown in Table 2. Figure 2 displays the scatter plot and equation between the two points.

Experimentally, the rate of change of Vo per °C is 33.34 mV/°C. This value was determined by looking at the slope of the linear equation generated. The theoretical temperature coefficient of 51.45 μV/°C multiplied with the calculated gain of 575 resulted as 29.58 mV/°C. This value is very close to the actual slope obtained from the graph.

Table 2. Voltage output at a given temperature at the junction of the thermocouple.

T [°C]	Vo [V]
0	1.03346
21.5	0.316

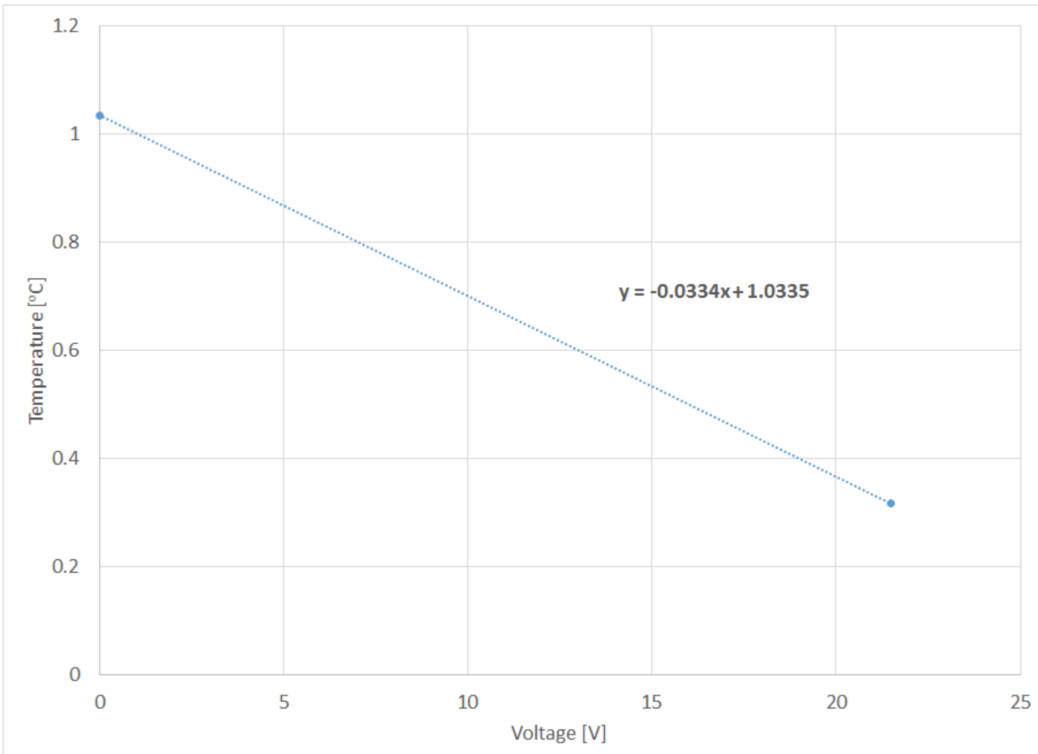

Figure 2. Relationship between temperature and voltage output.

Conclusion

This lab demonstrated that a thermocouple is a very precise tool to create a relationship between temperature and voltage. Error from the change in gain with frequency is unsure, but from the results showed to agree with the theoretical values and expectations.

References

"Thermocouples." (n.d.). *All About Circuits*, EETech Media, LLC., <https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/thermocouples/> (Apr. 26, 2019).