PHY405 Lab 5

Friday, February 28, 2025
Jace Alloway - 1006940802 - alloway1

Collaborators for all questions: none. Partner (for Lab 1-10): Jacob Villasana.

R-1

Using the multimeter in series with the 10k thermistor, the resistance at room temperature R_t was recorded to be $10.3 \pm 0.1\text{k}\Omega$. Based on the resistance / temperature relation

$$\frac{1}{T(R_t)} = A_1 + B_1 \log \frac{R_t}{R_{25}} + C_1 \left(\log \frac{R_t}{R_{25}}\right)^2 + D_1 \left(\log \frac{R_t}{R_{25}}\right)^3 \tag{1}$$
$$A_1 = 3.354016 \times 10^{-3}$$
$$B_1 = 2.884193 \times 10^{-4}$$
$$C_1 = 4.118032 \times 10^{-6}$$
$$D_1 = 1.786790 \times 10^{-7}$$

with the measured room temperature to be $23.1 \pm 0.1^\circ$ C, $T(R_t) \approx 24.3 \pm 0.3^\circ$C from (1) using fractional uncertainty propagation.

R-2

Using the resistive divider (thermistor and 10k resistor in series), measuring the output voltage across the thermistor into a DC power supply, the voltage of the room temperature thermistor was measured. Then, pinching the thermistor with thumb and index finger, the voltage was also recorded. Using a 5V V_{in}, and

$$\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R_{th}}{R_{ref} + R_{th}} \tag{2}$$

the room temperature voltage was recorded to be $V_r = 2.511 \pm 0.001$ V, while the recorded voltage of my finger and thumb pinching the thermistor was approximately $V_f = 2.16 \pm 0.01$ V, as expected, since the voltage should drop (decreases resistance) when the thermistor is heated.

R-3

```
void setup() {
    pinMode (LED_BUILTIN, OUTPUT);
}

void loop() {
    digitalWrite(LED_BUILTIN, HIGH);
    delay(100);
    digitalWrite(LED_BUILTIN, LOW);
    delay(100);
    digitalWrite(LED_BUILTIN, HIGH);
    delay(100);
```

```
    digitalWrite(LED_BUILTIN, LOW);
    delay(1000)
}
```

This program mades the output LED on the arduino blink in the pattern of a heartbeat. R-4 video in included.

R-5

Using the 7805 voltage regulator circuit (with a '105' (1μF) capacitor and a 1k resistor), and the DC power supply input of 5V, 7V, and 25V, the multimeter measured the voltage output with respect to the ground to be 3.592 ± 0.001 V, 5.034 ± 0.001 V, and 5.033 ± 0.001 V, respectively. This implies that the percentage error between the 7V and 25V measurements will be less than 1% (0.02%, exactly).

R-6 / R-7

To compute the volts/bit of an analog input with voltage V and n bits, the volts/bit ratio is given (via binary) by $\frac{V}{2^n}$. For a $5V$, 10-bit input, we have $\frac{5}{2^{10}} \approx 4.88 \to$ 5mV/bit (precision). (R-7) As mentioned in the lab manual, the minimum input voltage to the arduino is 0V, while the maximum cannot exceed 5V else the pins become damaged.

R-8

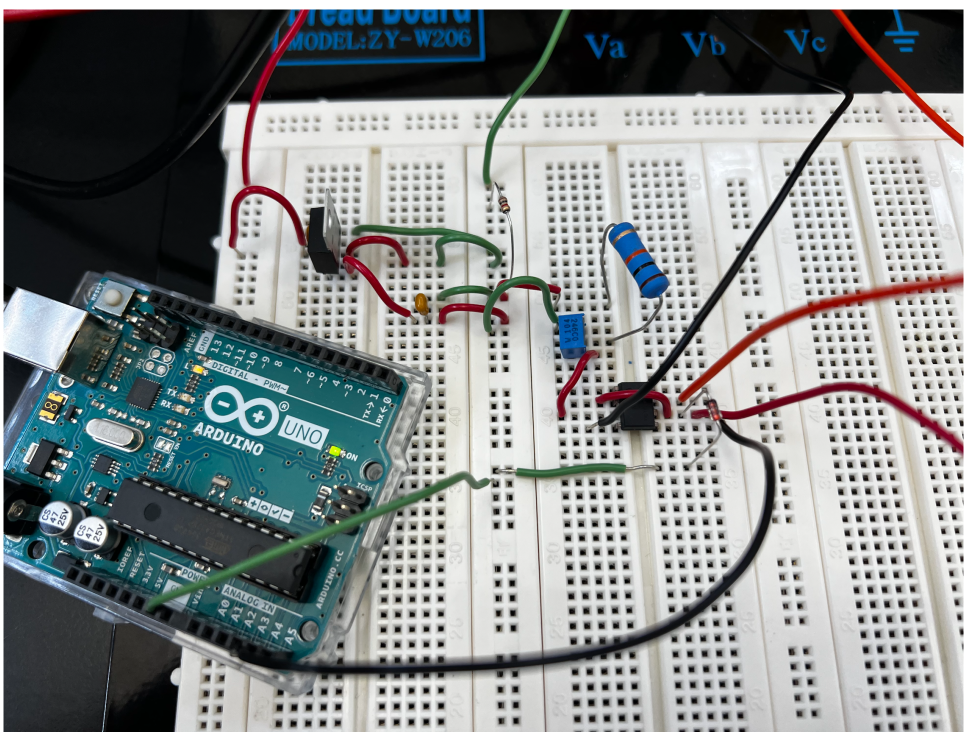

Figure 1: Circuit capture the arduino volts/bit measurement setup. Includes the 5V voltage regulator, a resistive divider using a 10k potentiometer, and an op-amp follower circuit going into the PIN 3 of the arduino analog in input.

The circuit was constructed as in the figure below, with the voltage regulator going into the potentiometer resistance divider, into the op-amp follower circuit, into the arduino (pin 3; the other pins

seemed fried).
Taking the voltage output between the resistance divider and the op-amp follower circuit (to measure the input voltage using the multimeter), the input/output was compared by measuring the bit output in the arduino IDE. A conversion formula was applied in the code to convert from bits to voltage in the reading:

```
float bit_pin = analogRead(A3);
float V_out = 5 / 1023 * bit_pin;

Serial.println(V_out);
```

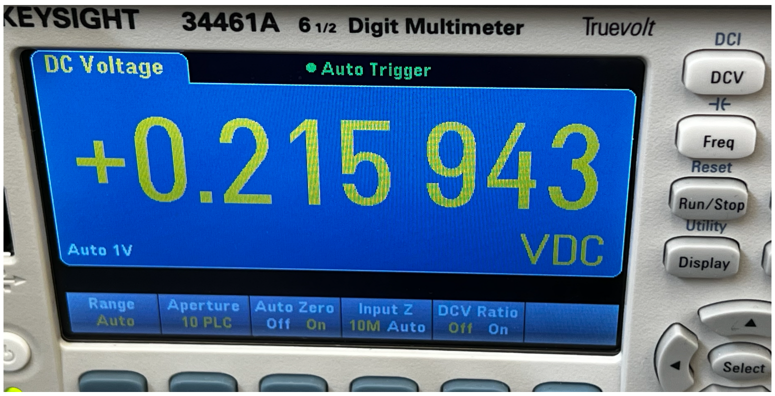

Figure 2: Measured voltage input of the arduino prior to the op-amp follower (the op-amp follower induced periodic fluctuations) just after the resistive divider component.

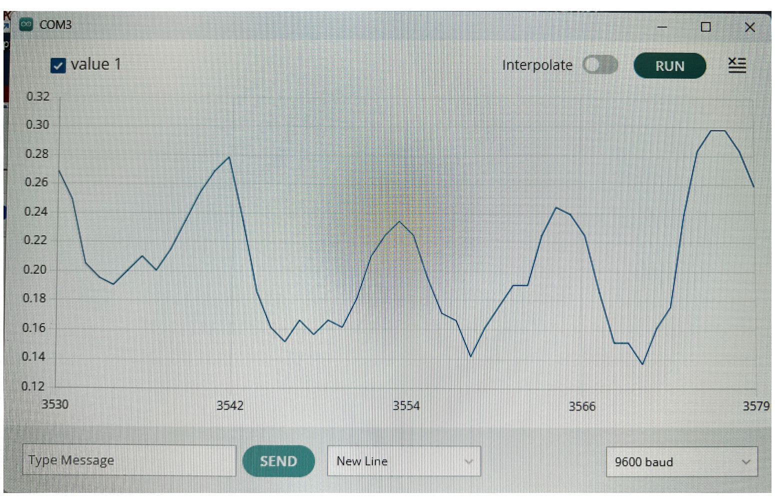

Figure 3: Observed arduino voltage output using the C++ arduino IDE code to measure the PIN 3 input. A conversion formula was implemented in the code to verify the volts/bit measurement (5/1023).

Though the output is oscillating (this is caused by the op-amp follower circuit feedback), it is averaged around the $\sim 0.215 \pm 0.005$ V. Including uncertainty, one may conclude that the measured volts/bit is consistent with that of the expected value (the inputs and measured readings are consistent).

R-9

After replacing the potentiometer with the thermistor, the arduino code was loaded and changed to include all of the thermistor output constants (formula from lab manual) and was ran again and plotted. When touching the thermistor, the voltage reading would increase, and this is observed in the figure below.

Figure 4: Arduino IDE screen capture of the temperature output reading when pinching the thermistor. The lower red line annotation indicates the approximate time of when the thermistor was pinched, decreasing the resistance in the circuit.

R-10

Using the python script taking the input from the appropriate arduino uno port, a plot of thermistor temperature (holding and releasing) was generated over a ~ 2 minute interval.

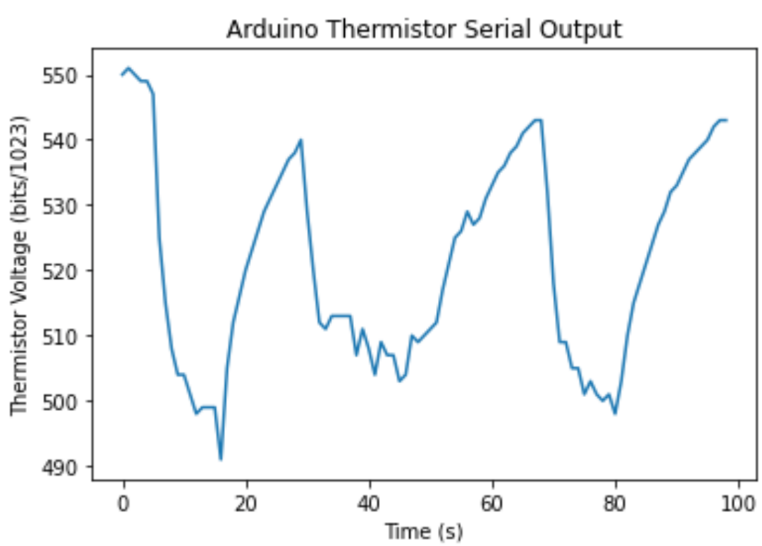

Figure 5: Python-Arduino plot of the thermistor voltage over a ~ 2 minute period, where the thermistor was pinched then released periodically.