Assignment 1

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1 Task A: Voltage Divider Analysis and Measurement Module

1.1 Purpose and Relevant Formula

The main purpose of using a voltage divider circuit is to keep the input voltage within the safe operating range of the Arduino's ADC, which can only measure voltages between 0 V and 5 V. Since the input voltage may exceed this range, a voltage divider is used to scale the higher voltage down to a measurable level. The output voltage of the divider is given by:

$$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$$

To convert the ADC reading into the corresponding voltage value, note that the Arduino ADC produces digital values from 0 to 1023 for input voltages between 0 V and 5 V. Therefore, the voltage corresponding to a given ADC reading can be calculated as:

$$V = \text{ADC} \times \frac{5.0}{1023.0}$$

1.2 Circuit and Code

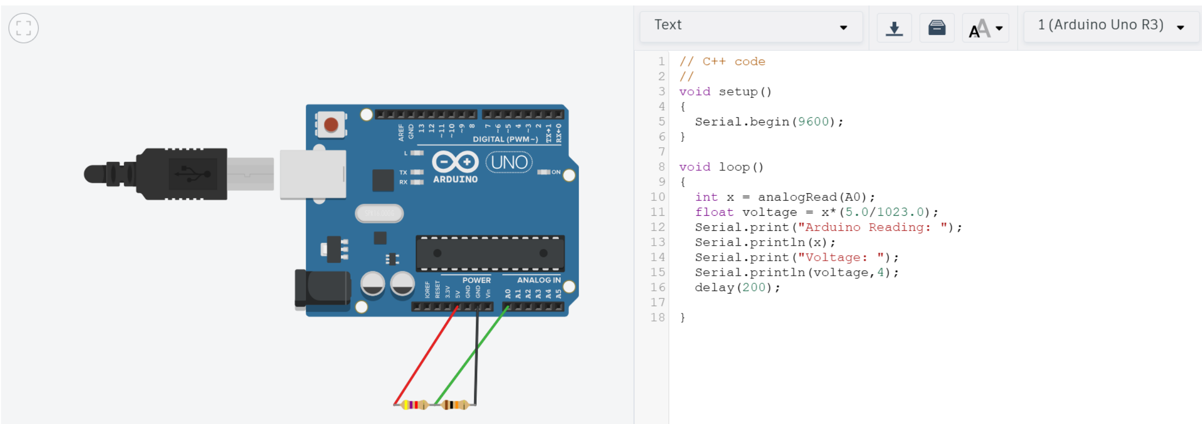

Figure 1: Circuit and Code

1.3 Results

Vin	R1	R2	Vout (Theoretical)	Vout (Experimental)
5.0 V	10 kΩ	10 kΩ	2.500 V	2.4976 V
5.0 V	4.7 kΩ	10 kΩ	3.4013 V	3.4018 V
5.0 V	1 kΩ	15 kΩ	4.6875 V	4.6872 V

1.4 Observations about Error

1. The resistors used in the circuit are non-ideal and typically have a tolerance of about 1–5%, which can introduce measurement inaccuracies.

2. The Arduino employs a 10-bit ADC that divides the 0–5 V range into 1024 discrete levels, resulting in a resolution of approximately 4.88 mV per step. This limited resolution can lead to quantization and rounding errors.

2 Task B: Capacitance Measurement using RC constant

2.1 Purpose and Relevant Formula

The RC time constant, denoted by τ (tau), is defined as

$$\tau = R \times C$$

It represents the characteristic time required for a capacitor to charge or discharge through a resistor. When a capacitor is charged from a voltage source, the voltage across it increases following an exponential relationship given by:

$$V(t) = V_{\text{in}} \left(1 - e^{-t/(RC)}\right)$$

According to this expression, after one time constant τ, the capacitor charges to approximately 63% of the applied input voltage. Substituting $t = RC$ into the equation:

$$V(RC) = V_{\text{in}} \left(1 - e^{-1}\right) \approx 0.632 \times V_{\text{in}}$$

Thus, at $t = \tau$, the capacitor reaches about 63.2% of its final steady-state voltage. This value is important because:

- It serves as a standard reference for describing the speed of response of an RC circuit, as well as a unit of time for how much of the process is completed, as the process is asymptotic and never reaches completion

- It enables the calculation of capacitance by measuring the time taken for the capacitor voltage to reach approximately 63% of its final value, which corresponds to one time constant.

- It is independent of the magnitude of the input voltage and depends solely on the resistance R and capacitance C.

2.2 Circuit and Code

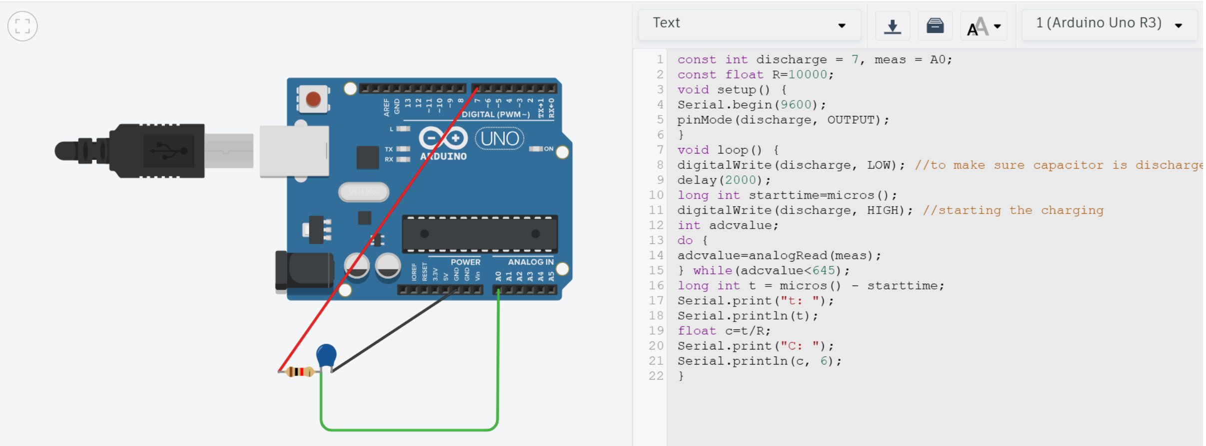

Figure 2: Circuit and Code

2.3 Results

T 63% (Experimental)	T 63% (Theoretical)	C (Experimental)	C (Actual)	R
10.024 ms	10 ms	1.0024 uF	1 uF	10 kΩ
169.920 ms	170 ms	16.9920 uF	17 uF	10 kΩ

2.4 Observations about Error

1. The resistor and capacitor used in the circuit are non-ideal and typically have a tolerance of about 1–5%, which can introduce measurement inaccuracies.
2. The Arduino employs a 10-bit ADC that divides the 0–5 V range into 1024 discrete levels, resulting in a resolution of approximately 4.88 mV per step. This limited resolution can lead to quantization and rounding errors.
3. The micros() function has a resolution of its own, and may introduce some errors in each trial.
4. Capacitor needs to be fully discharged before being used in other trials or else the initial voltage is not zero and results in a shorter 63% charging time.

3 Task C: Beginner Ohmmeter Prototype

3.1 Purpose and Relevant Formula

We will be using the same circuitry and formulas as Task A.

$$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$$

$$V = \text{ADC} \times \frac{5.0}{1023.0}$$

However, contrary to Task A, where we needed to find V_{out}, given R_1 and R_2, here we are given R_1 (reference resistance), read V_{out} using Serial monitor and need to find R_2 (unknown resistance). The rearranged formula is:

$$R_2 = R_1 \times \frac{V_{out}}{V_{in} - V_{out}}$$

3.2 Circuit and Code

The circuit is the same as Task A, while the code is the same with slight modifications to print resistance instead of voltage.

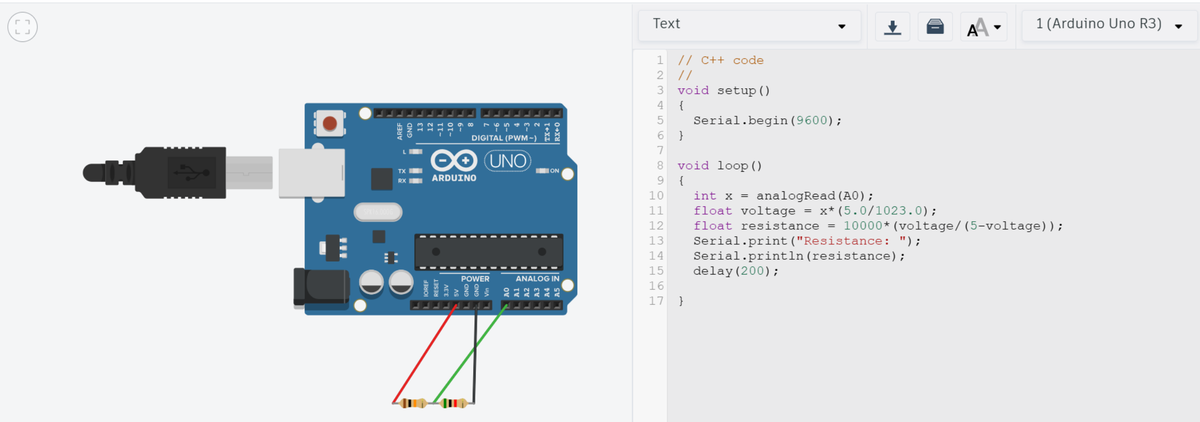

Figure 3: Circuit and Code

3.3 Results

Vin	R1 (reference)	R2 (actual)	R2 (experimental)
5.0 V	10 kΩ	5 kΩ	5000.00 Ω
5.0 V	10 kΩ	50 kΩ	49824.55 Ω
5.0 V	10 kΩ	15 kΩ	15012.22 V

3.4 Observations about Error

1. The resistors used in the circuit are non-ideal and typically have a tolerance of about 1–5%, which can introduce measurement inaccuracies.

2. The Arduino employs a 10-bit ADC that divides the 0–5 V range into 1024 discrete levels, resulting in a resolution of approximately 4.88 mV per step. This limited resolution can lead to quantization and rounding errors.