Project Report-Assignment 1

Smart Multimeter

Submitted by

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Task A: Voltage Measurement Using Voltage Divider

Theoretical Voltage at A0:

$$V_{A0} = \frac{6 \times 10}{20} = 3\,\text{V}$$

Experimental Voltage: 3 V

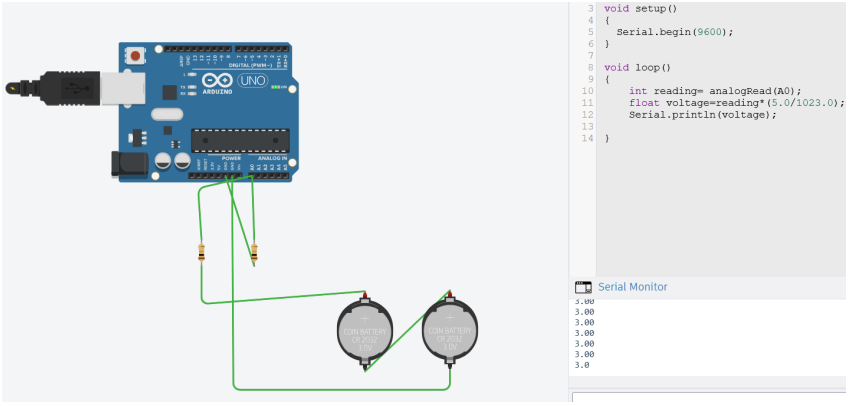


Figure 1: Voltage divider case 1

Theoretical Voltage at A0:

$$V_{A0} = \frac{6 \times 8}{8 + 2} = 4.8\,\text{V}$$

Experimental Voltage: 4.79 V

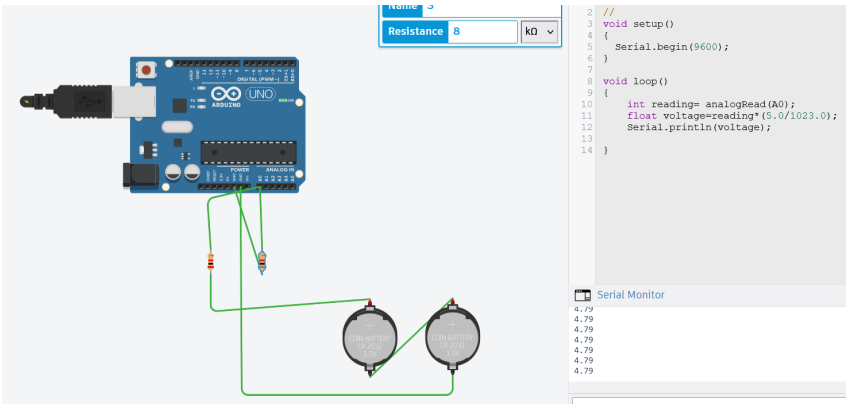


Figure 2: Voltage divider case 2

Theoretical Voltage at A0:

$$V_{A0} = \frac{6 \times 4}{4 + 2} = 4\,\text{V}$$

Experimental Voltage: 3.99 V

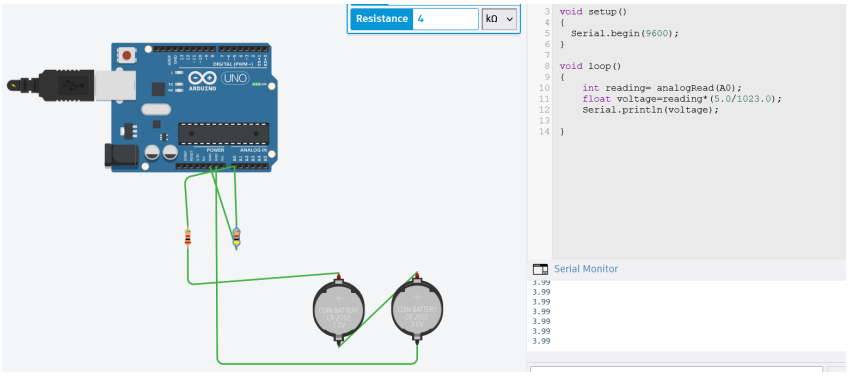


Figure 3: Voltage divider case 3

Arduino Code

```
void setup()
{
  Serial.begin(9600);
}

void loop()
{
    int reading= analogRead(A0);
    float voltage=reading*(5.0/1023.0);
    Serial.println(voltage);

}
```

Voltage divider is necessary in measuring systems such as in this case where the unknown resistance (say R_2) can be estimated based on the formula:

$$V_{in} = V \cdot \frac{R_2}{R_1 + R_2}$$

where V_{in} and V are known and R_1 is chosen. This same concept can be extended to capacitors and inductors as well, although the Kirchhoff equations will be different.

As the Arduino Uno uses a 10-bit ADC, there are 1024 possible values with 1023 being the highest voltage level which corresponds to 5 V. The remaining voltages are scaled accordingly. If the raw ADC value is b, then:

$$V_{in} = \frac{b}{1023} \times 5$$

There was an error of around 0.25% in the last two readings; however, most readings were consistent with theoretical values.

Task B: Capacitance Measurement Using RC Time Constant

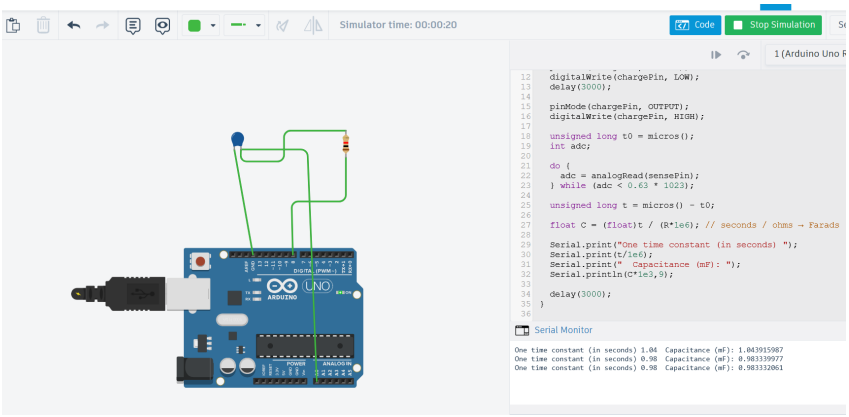


Figure 4: RC charging circuit

The RC time constant is defined as the time taken for the capacitor voltage to reach approximately 63% of the reference voltage. This is governed by:

$$V_C = V_{ref}\left(1 - e^{-t/RC}\right)$$

Substituting $t = RC$ gives:

$$V_C \approx 0.63\, V_{ref}$$

Potential Error Sources

The capacitor and resistor values are subject to tolerance due to unavoidable manufacturing defects, which leads to error in the final calculated value. Additionally, the `analogRead()` function has a sampling time of approximately 110 μs, which introduces uncertainty in detecting the exact threshold voltage.

Comparison Table

Vref	Theoretical Capacitance	Experimental Capacitance	Resistance	Theoretical time constant	Experimental time constant
5V	1mF	0.98mF	1k	1s	0.98s
5V	0.2mF	0.2037mF	2k	0.4s	0.41s
5V	0.5mF	0.4819mF	2k	1s	0.96s

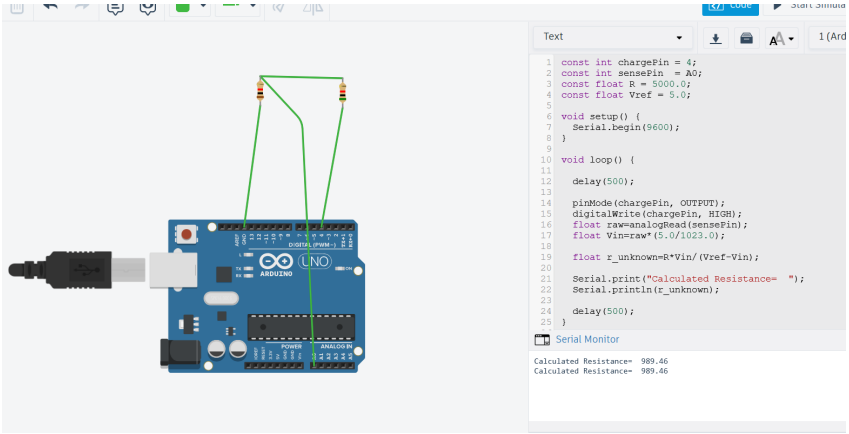
Figure 5: Comparison of theoretical and measured RC time constants

Arduino Code

```arduino
const int chargePin = 8;
const int sensePin  = A0;
const float R = 1000.0;
const float Vref = 5.0;

void setup() {
  Serial.begin(9600);
}

void loop() {
  pinMode(chargePin, OUTPUT);
  digitalWrite(chargePin, LOW);
  delay(3000);

  pinMode(chargePin, OUTPUT);
  digitalWrite(chargePin, HIGH);

  unsigned long t0 = micros();
  int adc;

  do {
    adc = analogRead(sensePin);
  } while (adc < 0.63 * 1023);

  unsigned long t = micros() - t0;

  float C = (float)t / (R*1e6); // seconds / ohms → Farads

  Serial.print("One time constant (in seconds) ");
  Serial.print(t/1e6);
  Serial.print("  Capacitance (mF): ");
  Serial.println(C*1e3,9);

  delay(3000);
}
```

Task C: Resistance Measurement Using Voltage Divider

Arduino Code and Circuit Diagram



Comparison Table

Vref	Theoretical Resistance	Experimental Resistance	Known Resistance
5V	1k	989.46 Ohm	5K
5V	2k	1978.17 Ohm	5K
5V	3k	2967.29 Ohm	5K

Using Kirchhoff's law, we have:

$$V_{in} = V_{ref}\left(\frac{R_2}{R_1 + R_2}\right)$$

Rearranging:

$$R_2 = R_1 \cdot \frac{V_{in}}{V_{ref} - V_{in}}$$

Conclusion

There are many sources of error in the system which can be minimized using the following methods. Using a 16-bit ADC such as the ADS1115 provides improved resolution. Employing metal film resistors with 0.1% tolerance and placing a buffer op-amp between the sampling point and the Arduino analog input reduces loading errors and improves overall accuracy.