Design of Basic Measurement Modules Using Arduino

Assignment 1

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Introduction

This assignment's objective is to design and simulate basic measurement modules using Arduino Uno in Tinkercad, focusing on voltage, resistance and capacitance measurement techniques used in digital multimeters.

The project emphasizes voltage divider principles, ADC operation, RC time constants and basic error analysis.

1 Task A: Voltage Divider Analysis and Measurement Module

1.1 Objective

To simulate voltage measurement using a voltage divider and Arduino ADC, demonstrating how digital multimeters measure voltage.

1.2 Concept

A voltage divider divides an input voltage into a smaller output voltage using two resistors:

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

Arduino Uno uses a 10-bit ADC, producing values from 0 to 1023. The ADC-to-voltage conversion formula is:

$$V = \frac{\text{ADC Reading} \times 5.0}{1023}$$

1.3 Circuit Diagram

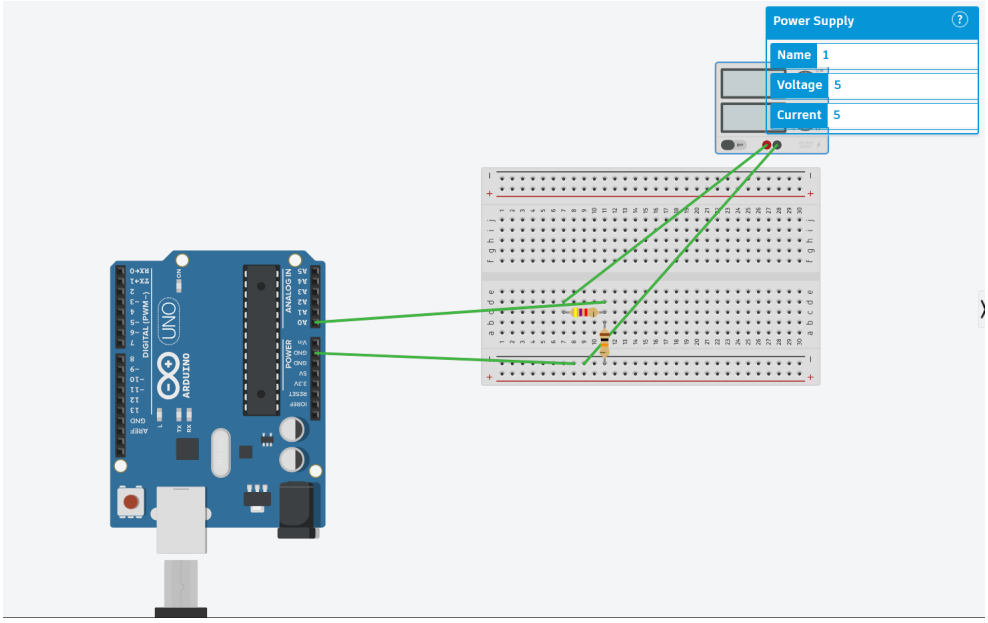

Figure 1: Voltage Divider Based Ohmmeter Circuit (Task C)

1.4 Arduino Code

```
float V;

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

void loop() {
  int adcValue = analogRead(A0);
  V = adcValue * (5.0 / 1023.0);
  Serial.print("Measured Voltage: ");
  Serial.println(V);
  delay(1000);
}
```

1.5 Results

Table 1: Voltage Divider Results

R_1 (Ω)	R_2 (Ω)	Theoretical V_{out} (V)	Measured V_{out} (V)
10k	10k	2.500	2.500
4.7k	10k	3.401	3.401
1k	15k	4.686	4.686

1.6 Observation

- The Arduino-measured voltages almost match the theoretical voltage divider values.

2 Task B: Capacitance Measurement Using RC Time Constant

2.1 Objective

To measure capacitance by observing the charging time of a capacitor in an RC circuit.

2.2 Concept

The RC time constant is defined as:

$$\tau = RC$$

At time $t = \tau$, the capacitor voltage reaches approximately 63% of the supply voltage. Capacitance is calculated as:

$$C = \frac{t}{R}$$

2.3 Circuit Diagram

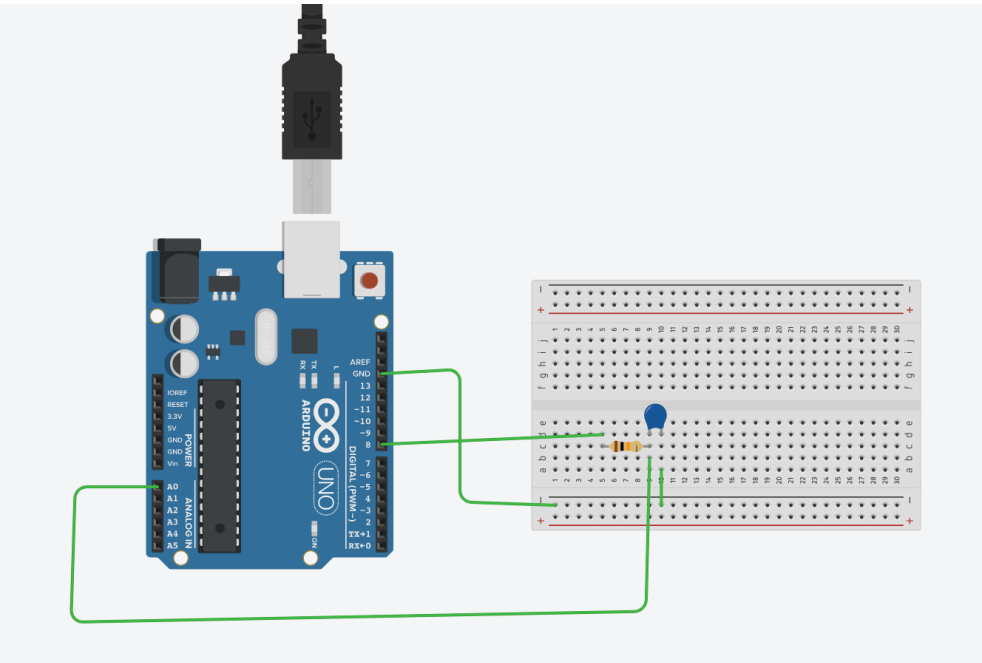

Figure 2: Voltage Divider Based Ohmmeter Circuit (Task C)

2.4 Arduino Code

```
int chargePin = 8;
unsigned long startTime;
unsigned long chargeTime;

void setup() {
  Serial.begin(9600);
  pinMode(chargePin, OUTPUT);
}

void loop() {
  digitalWrite(chargePin, LOW);
  delay(100);

  startTime = micros();
```

```
  digitalWrite(chargePin, HIGH);

  while (analogRead(A0) < 648); // 63% of 1023

  chargeTime = micros() - startTime;
  Serial.print("Charge Time (us): ");
  Serial.println(chargeTime);
  delay(2000);
}
```

2.5 Results

Table 2: Capacitance Measurement Results

Capacitor Value	Expected Time (ms)	Measured Time (ms)
10 uF	100	100.776
100 uF	1000	1007.184

2.6 Possible reasons for varying value in serial monitor (Error)

- Capacitor tolerance
- ADC sampling delay
- Threshold approximation for 63%
- **Note:** Delay should be enough for the capacitor to recharge

3 Task C: Beginner Ohmmeter Prototype

3.1 Objective

To measure an unknown resistance using a voltage-divider-based ohmmeter.

3.2 Concept

Unknown resistance is calculated using:

$$R_x = R_{ref} \times \frac{V_{out}}{V_{in} - V_{out}}$$

3.3 Circuit Diagram

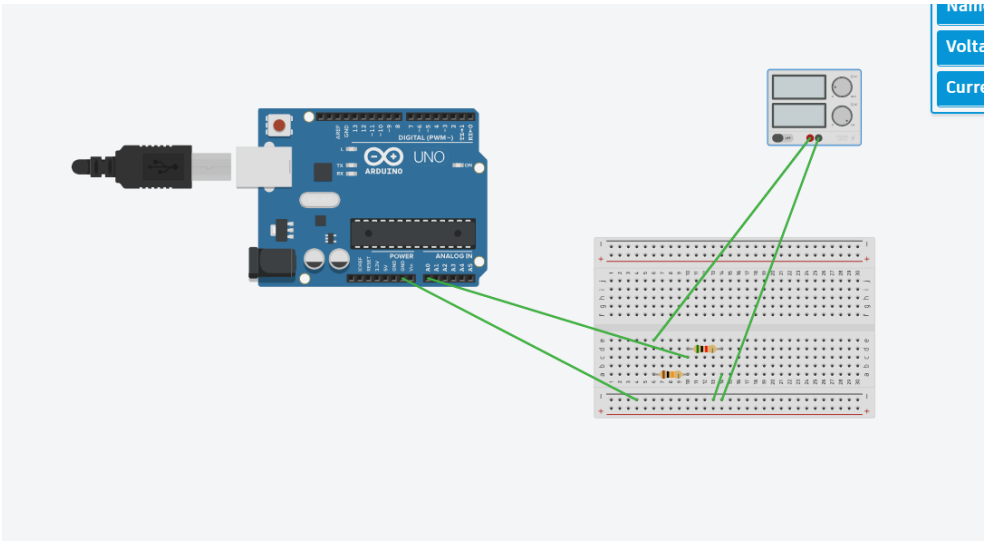

Figure 3: Voltage Divider Based Ohmmeter Circuit (Task C)

3.4 Arduino Code

```
const float Vin = 5.0;
const float Rref = 10000.0;  //Known resistor

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

void loop() {
  int adcValue = analogRead(A0);
  float Vout = adcValue * (Vin / 1023.0);

  float Rx = (Rref * Vout) / (Vin - Vout);

  Serial.print("Unknown Resistance: ");
  Serial.print(Rx, 2);
  Serial.println(" ohms");

  delay(1000);
}
```

3.5 Results

Table 3: Ohmmeter Results

Actual Resistance (Ω)	Measured Resistance (Ω)
1k	1k
5k	5k
10k	9.981k
15k	15.012k

3.6 Accuracy & Errors

- The Arduino measures voltage using a 10-bit ADC, which introduces quantization due to finite resolution.
- The calculated resistance depends on the digitized voltage value, causing small numerical deviations.
- The voltage-divider equation amplifies minor voltage rounding errors into resistance error.
- Some resistor values align exactly with ADC step boundaries, resulting in exact measurements.
- This behavior reflects real-world digital measurement systems.

4 Conclusion

This project demonstrated how basic electrical principles are applied in real-world measurement systems. Voltage dividers, RC time constants and resistance measurement techniques form the foundation of digital multimeters. The assignment strengthened understanding of ADC behavior, error sources and engineering documentation.