PROJECT – SMART MULTIMETER USING MICROCONTROLLER SYSTEMS

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ASSIGNMENT – 01

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Task A — Voltage Divider Analysis and Measurement Module:- (Using V_{in} = 1.5V)

1. Theoretical Calculations -

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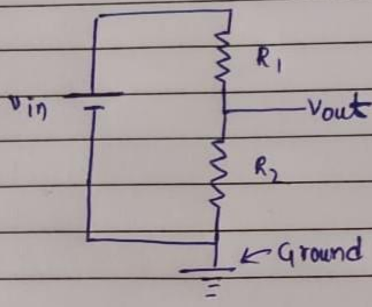
Assignment - 01

Theoretical Calculations :-

Task-A :- Voltage Divider Analysis and Measurement module

· Circuit :-



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

(i) For $V_{in} = 1.5V$

(a) Choose $R_1 = 10k\Omega$ & $R_2 = 10k\Omega$

$$V_{out} = \frac{10k\Omega}{(10k\Omega + 10k\Omega)} \times 1.5V = 0.75V$$

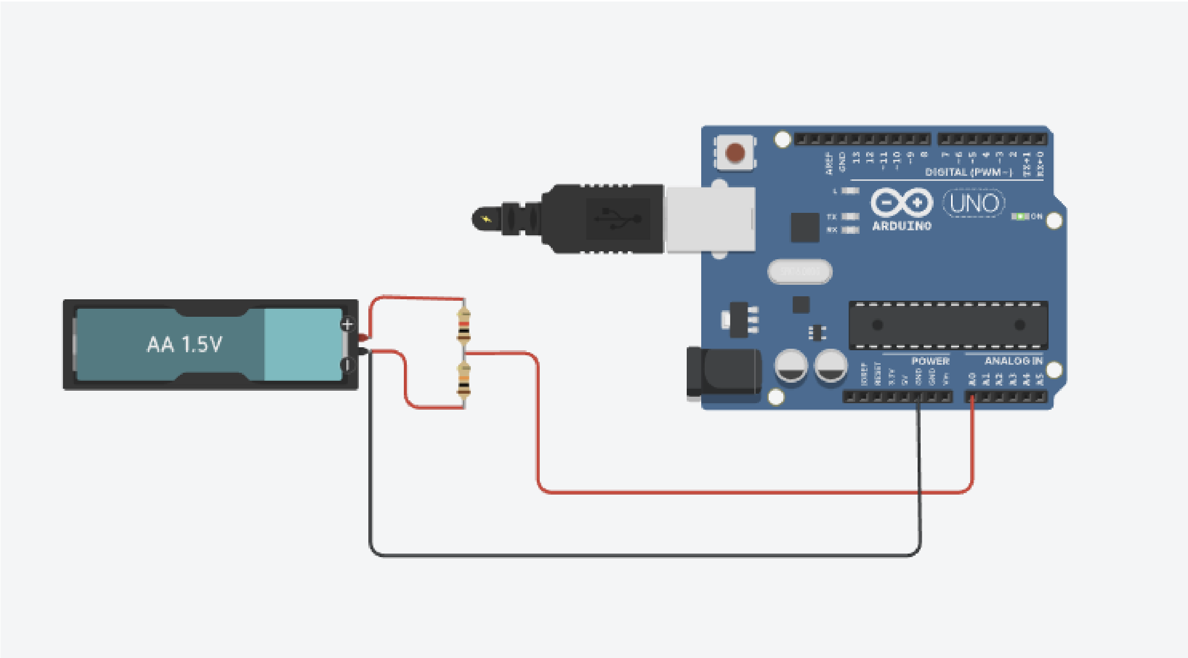
(b) Choose $R_1 = 4.7k\Omega$ & $R_2 = 10k\Omega$

$$V_{out} = \frac{10k\Omega}{(4.7k\Omega + 10k\Omega)} \times 1.5 = \frac{10k\Omega}{14.7k\Omega} \times 1.5 = 1.0204V$$

(c) Choose $R_1 = 1k\Omega$ & $R_2 = 10k\Omega$

$$V_{out} = \frac{10k\Omega}{10k\Omega + 1k\Omega} \times 1.5V = 1.3636V$$

2. Tinkercad Circuit :-



3. Arduino Code:-

1 (Arduino Uno R3)

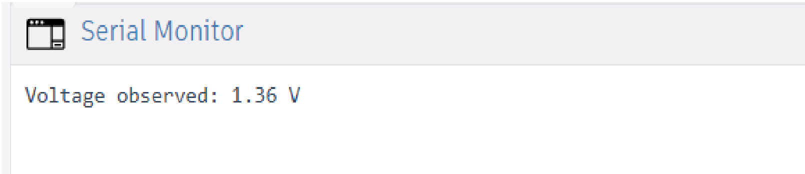
```
// C++ code
//
void setup(){
Serial.begin(9600);
}
void loop(){
  int val = analogRead(A0);
  float voltage = val*(5.0/1023.0);
  Serial.print("Voltage observed: ");
  Serial.print(voltage);
  Serial.print(" V");
  delay(50000);


}
```

4. Tinkercad readings for Different combinations of resistors:-
   a) R1 = 10kΩ & R2 = 10kΩ

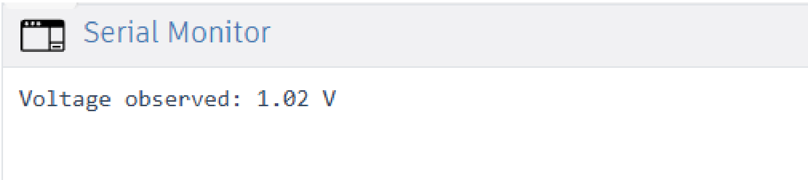
Serial Monitor

```
Voltage observed: 0.75 V
```

b) R1 = 1kΩ & R2 = 10kΩ



c) R1 = 4.7kΩ & R2 = 10kΩ



5. Comparing Theoretical & Experimental Values of observed voltage values :-

R1 & R2	Theoretical(V_{out})	Tinkercad (V_{out})	Error(%)
10kΩ & 10kΩ	0.7500 V	0.75 V	0%
1kΩ & 10kΩ	1.3636 V	1.36 V	0.26%
4.7kΩ & 10kΩ	1.0204 V	1.02 V	0.04%

Important Points :-

1. Purpose of voltage divider in measurement systems :-
   The main purpose is scaling of voltage measured, an arduino can usually handle voltage upto 5V, a voltage divider circuit takes the higher voltage and splits it into two parts, so the smaller part voltage can be safely used by arduino, this allow arduino to measure bigger voltages easily
2. ADC reading-to-voltage conversion formula :-

An ADC converts voltage into a number between 0 to 1023. Where 0 represents 0V and 1023 represents 5V, so conversion formula we use is :-

$$V_{observed} = SensorValue \times \frac{5.0}{1023.0}$$

3. Observations: error, noise, or unexpected results :-

The theoretical values are calculated upto 4 decimal places while the arduino values are shown only upto 2 decimal places, so there are some precesion errors, this is the display limitation of arduino, which truncates the precise values for readability.

Task B — Capacitance Measurement Using RC Time Constant :-

1. Theoretical Calculations :-

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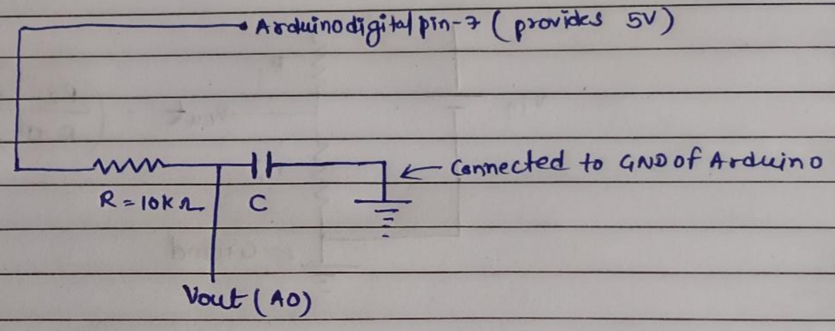
Task-B :- Capacitance Measurement using RC time constant

Circuit :-



(i) For Vin = 5Volt

(a) $C = 100\mu F$

$$V_C(t) = V_0\left(1 - e^{\frac{-t}{RC}}\right) \qquad \{V_0 = 5V\}$$

If we take $t = RC$ then →

$$V_C(t) = V_0\left(1 - e^{-1}\right) = V_0 \times (1 - 0.3678)$$

$$V_C(t) = V_0 \times 0.632$$

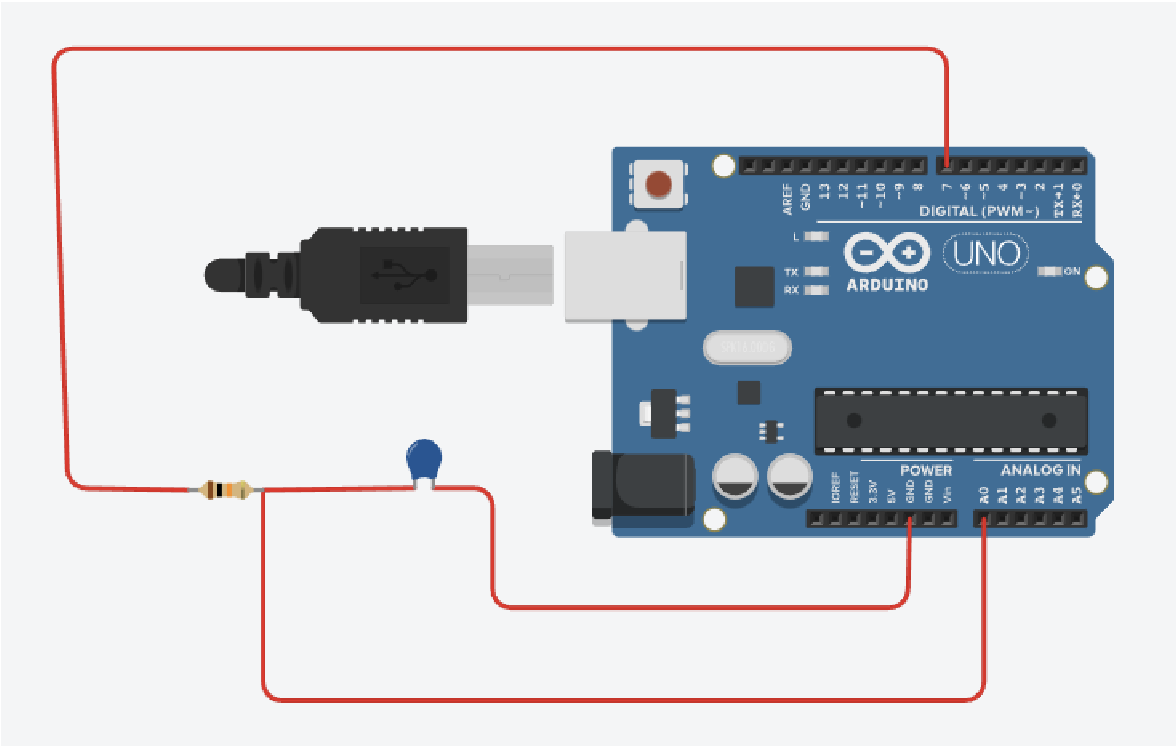
i.e. 63.2% charging of capacitor

(t_1) theoretical $= R_1 \times C_1 = 10K\Omega \times 100\mu F = 1sec$

(b) $C = 1\mu F$

(t_2) theoretical $= R_2 \times C_2 = 10K\Omega \times 1\mu F = 0.01 sec$

2. Tinkercad Circuit :-

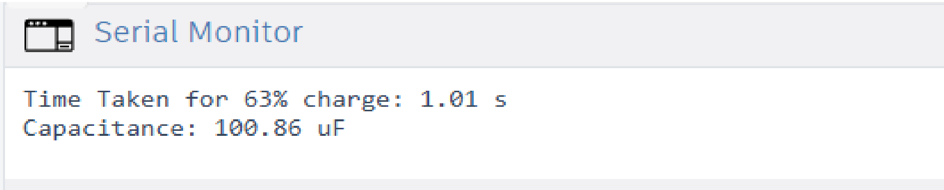


3. Arduino Code :-

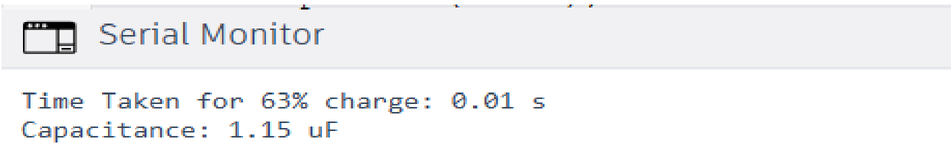
```
const float res = 10000.0; //10k ohm

void setup() {
  Serial.begin(9600);
  pinMode(7, OUTPUT);
}

void loop() {
  digitalWrite(7,LOW);
  while(analogRead(A0)>0);
  //charging and measuring time
  digitalWrite(7, HIGH);
  unsigned long startTime = micros();
  //63.2% voltage achieved
  while(analogRead(A0)<648);
  unsigned long time = micros()-startTime;
  float time_sec = time/1000000.0;
  Serial.print("Time Taken for 63% charge: ");
  Serial.print(time_sec);
  Serial.println(" s");
  float capacitance = (micros()-startTime)/res;
  Serial.print("Capacitance: ");
  Serial.print(capacitance);
  Serial.println(" uF");

  delay(2000);
}
```

4. Readings from two different combinations of capacitors(100 uF and 1uF) :-

   a) C = 100 uF



   b) C = 1uF



5. Comparison of theoretical and experimental tinkercad readings :-

Capacitor(uF) actual	Theoretical Time(RC)	Experimental Time	Capacitance experimental	Error(%)
100 uF	1.00 sec	1.01 sec	100.86 uF	0.86%
1 uF	0.01 sec	0.01 sec	1.15 uF	15%

Important Points :-

1. Explain the RC time constant and why 63% is significant :-
   The RC time constant is a considerable measure of how quickly a capacitor charges through a resistor,
   $$\tau = RC$$
   According to charging equation it takes exactly one time constant of the capacitor to reach 63.2% of the input voltage. By measuring the time it takes to reach this specific voltage value, we can easily calculate the capacitance without having complex calculations

2. Discuss potential error sources (tolerance, noise, ADC resolution) :-
    a) Tolerance :-
       Most of the capacitors have tolerance level of about ±20%, which is the main source of error
    b) ADC resolution :-
       The arduino measures voltage using steps (0 to 1023), it may not be able to catch the voltage exactly at 63.2% , this error changes the time measurement slightly

Task C — Beginner Ohmmeter Prototype :-

1. Theoretical Calculations :-

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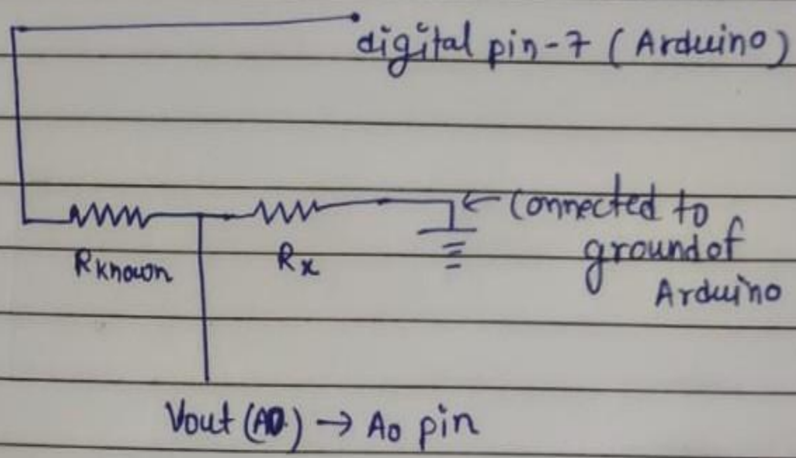
Task C :- Beginner Ohmmeter Prototype

Circuit :-

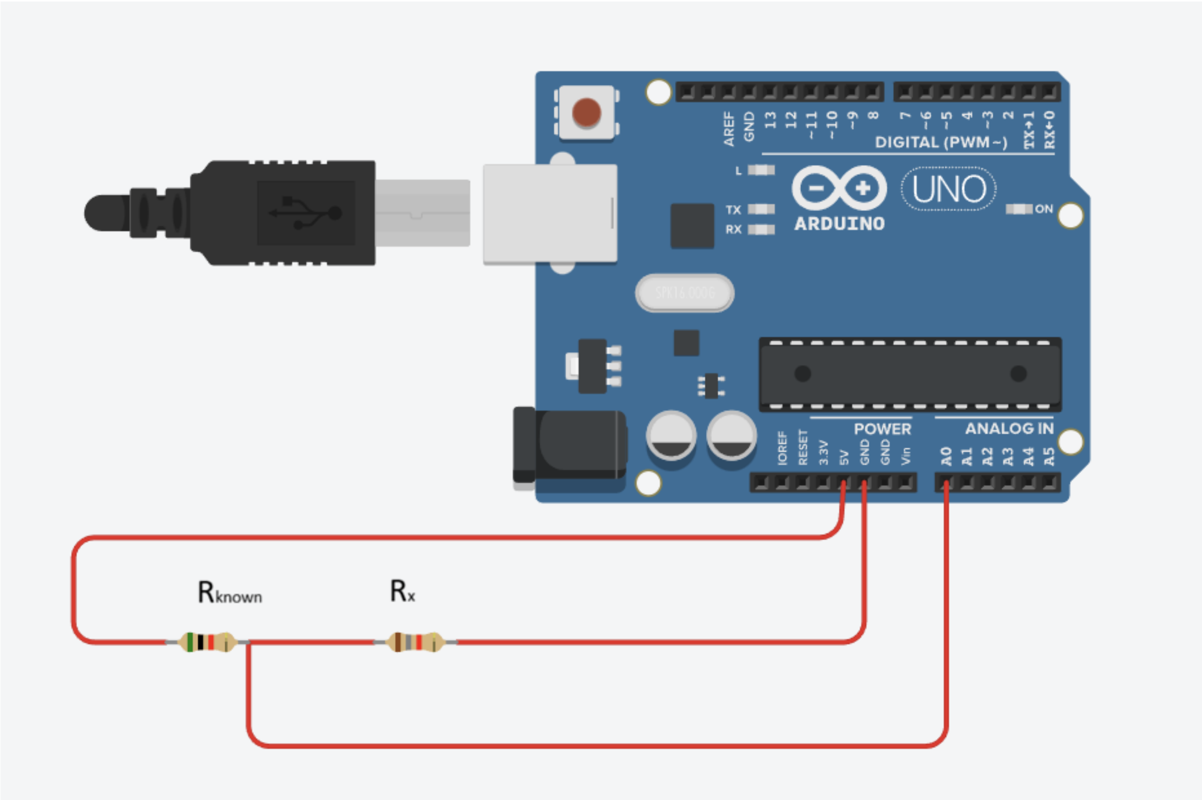


$$V_{out} = \left(\frac{R_x}{R_x + R_{known}} \right) \times V_{in} \qquad V_{in} = 5\text{ volt.}$$

$$V_{out} \cdot R_x + V_{out} \cdot R_{known} = R_x \cdot V_{in}$$

$$\boxed{R_x = \frac{V_{out} \cdot R_{known}}{V_{in} - V_{out}}}$$

2. Tinkercad circuit



3. Arduino Code :-

Using R_{known} = 5 kΩ & V_{in} = 5V

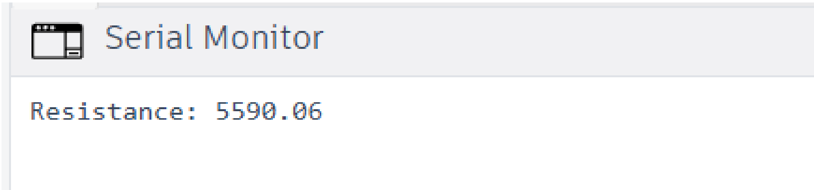
Text | 1 (Arduino Uno R3)

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

void loop() {
  int raw = analogRead(A0);
  //using known resistor or resistance 5k ohm
  float Rx = 5000.0*raw/(1023.0-raw);
  Serial.print("Resistance: ");
  Serial.println(Rx);
  delay(5000);
}
```

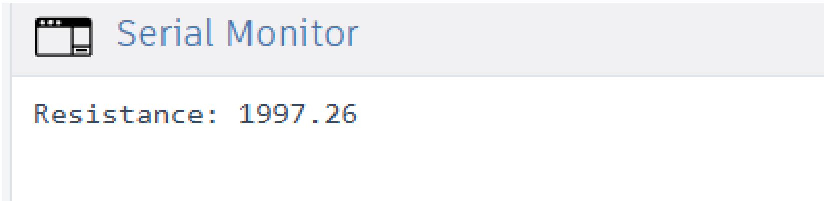
4. Readings from different unknown resistors :-

a) $R_x = 5.6k\Omega$



b) $R_x = 9.3k\Omega$

c) $R_x = 2k\Omega$



5. Comparing theoretical and experimental values of unknown resistors :-

R_{actual}	$R_{experimental}$	Error(%)
5600 Ω	5590.06 Ω	-0.18%
9300 Ω	9287.71 Ω	-0.13%
2000 Ω	1997.26 Ω	-0.14%

Important Points :-

1. Measurement Uncertanity :-
   a) ADC Resolution :-
      This is the primary source of the error because ADC cannot measure voltage continuously, it must round off the voltage to the nearest integer step.
   b) Calculation precision :-
      The arduino performs the resistance calculation using floating point maths having limited precision thus giving some error in calculations.