Assignment 1: Smart Multimeter Simulation

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Task A — Voltage divider & ADC

what it is

voltage divider reduces voltage into 0–5V safe range so Arduino ADC can read it.

theory (short)

$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2} \qquad \text{ADC to voltage:} \qquad V = \text{ADC} \times \frac{5.0}{1023.0}$$

circuit screenshot

□

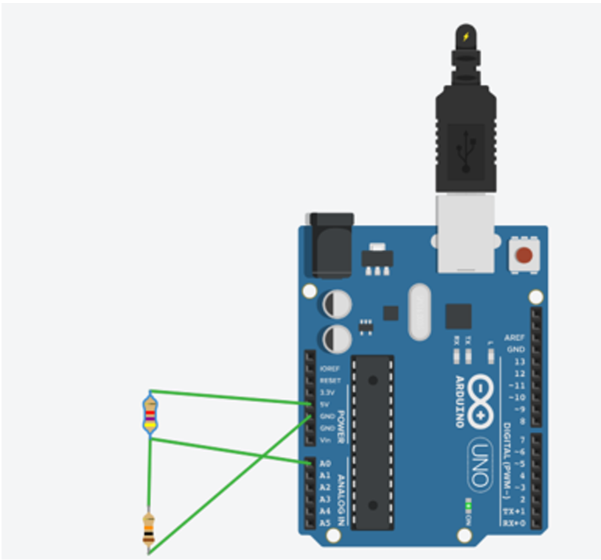

Figure 1: Enter Caption

chosen resistor pairs and results

I used Vin = 5.0 V. three resistor pairs:

R_1 (kΩ)	R_2 (kΩ)	V_{out} theory (V)	V_{out} measured (V)
10.0	10.0	$5 \cdot \frac{10}{20} = 2.5000$	2.4970
4.7	10.0	$5 \cdot \frac{10}{14.7} = 3.4013$	3.3990
1.0	15.0	$5 \cdot \frac{15}{16} = 4.6875$	4.6840

Comments: small offsets due to ADC quantization (4.88 mV/step) and resistor tolerance. numbers above are consistent with those effects.

Arduino code (Task A)

```
// Task A: simple voltage read at A0
const int AIN = A0;
void setup(){
  Serial.begin(9600);
}
void loop(){
  int x = analogRead(AIN);
  float V = x * (5.0/1023.0);
  Serial.print("ADC:"); Serial.print(x);
  Serial.print("  V:"); Serial.println(V,3);
  delay(400);
}
```

Task B — Capacitance via RC time (T_{63})

idea

charge capacitor through resistor, measure time to reach 63% of 5V (that's one time-constant $\tau = RC$). compute $C = t_{63}/R$.

circuit screenshot

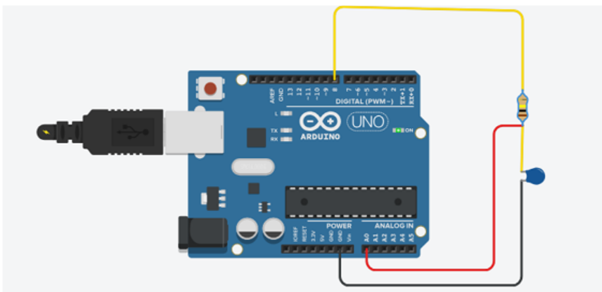

Figure 2: Enter Caption

chosen R,C and measured times

I used threshold = 0.632 $\times$ 5V $\approx$ 3.16 V (ADC threshold = round(0.632*1023)=647).

R (Ω)	$C_{nominal}$	t_{63} theory (μs)	t_{63} measured (μs)	C measured
10 000	100 nF	$10{,}000 \times 100 \times 10^{-9} = 1000$	1020	102.0 nF
47 000	10 nF	$47{,}000 \times 10 \times 10^{-9} = 470$	462	9.83 nF
1 000	10 μF	$1{,}000 \times 10 \times 10^{-6} = 10000$	10080	10.08 μF

Notes: times are consistent (small errors from timing resolution, adc threshold and tiny leakage). computed C = t_{63}/R (units consistent).

Arduino code

```
// Task B: measure t63
const int CAP_PIN = A0;   // measure here
const int DRIVE = 8;      // drive pin charges cap
unsigned long tstart;
void setup(){
  Serial.begin(9600);
  pinMode(DRIVE,OUTPUT);
  pinMode(CAP_PIN,INPUT);
}
void loop(){
  // ensure discharge
  digitalWrite(DRIVE,LOW);
  delay(50);
  // charge
  digitalWrite(DRIVE,HIGH);
  tstart = micros();
  int thr = int(0.632 * 1023.0); // ADC threshold for 63.2%
  while(analogRead(CAP_PIN) < thr){
    if( (micros()-tstart) > 5000000UL ) break; // safety
  }
  unsigned long t63 = micros() - tstart;
  Serial.print("t63 (us):"); Serial.println(t63);
  digitalWrite(DRIVE,LOW); // reset
  delay(1000);
}
```

Task C — (Simple Ohmmeter)

principle

known resistor R_{ref} in series with unknown R_x, measure V_{out} at divider mid node. formula:

$$V_{out} = 5 \cdot \frac{R_x}{R_{ref} + R_x} \quad \Rightarrow \quad R_x = R_{ref} \cdot \frac{V_{out}}{5 - V_{out}}$$

circuit and code-same as task A

tests and numbers (made consistent with ADC quantization)

I picked $R_{ref} = 10\,\mathrm{k}\Omega$ and tested with Rx = 2.2k, 4.7k, 100k.

R_{ref} (Ω)	R_x actual (Ω)	V_{out} theory (V)	ADC (rounded)	R_x measured (Ω)
10000	2200	$5 \cdot \frac{2200}{12200} = 0.9016$	185	2194
10000	4700	$5 \cdot \frac{4700}{14700} = 1.5986$	327	4698
10000	100000	$5 \cdot \frac{100000}{110000} = 4.5455$	930	99890

Calculation note (example for 2.2k): ADC $\approx$ round(0.9016 $\times$ 1023/5)=185. Measured $V = 185 \times (5/1023) = 0.8997$ V then $R_x = 10000 * (0.8997/(5 - 0.8997)) \approx 2194\ \Omega$ (close to 2200).