Lab-07:
March 11rd

Objectives: Measure the capacitance of a capacitor without using the digital multimeter

Procedure:

1. Construct the circuit as depicted in Figures 1 and 2 to enable the charging of the capacitor. Ensure that the capacitor, resistor, and voltage source are connected in series.

2. Activate the function generator and adjust its parameters to align with the measurement requirements.

3. To ascertain the ideal frequency for our measurements, observe the oscilloscope's display for a plateau in voltage levels, which indicates a steady state. Refer to Figure 3 for a graphical representation.

4. Proceed to transfer the gathered data into MATLAB for analysis.

5. For the data transfer, initiate the process by pressing the 'trigger' followed by 'save' on the oscilloscope. Save the results as a CSV file onto a USB drive. Then, on a computer, open the CSV file and import the data into MATLAB.

6. Within MATLAB, plot the natural logarithmic relationship of $ln(v(t)) = -\frac{t}{\tau} + ln(V_0)$.

7. Create a linear fit of these points to visually and analytically represent their relationship.

8. From the linear fit, determine the slope and use this value to calculate the capacitance (C).

Figure 1. Set up of RC circuit used

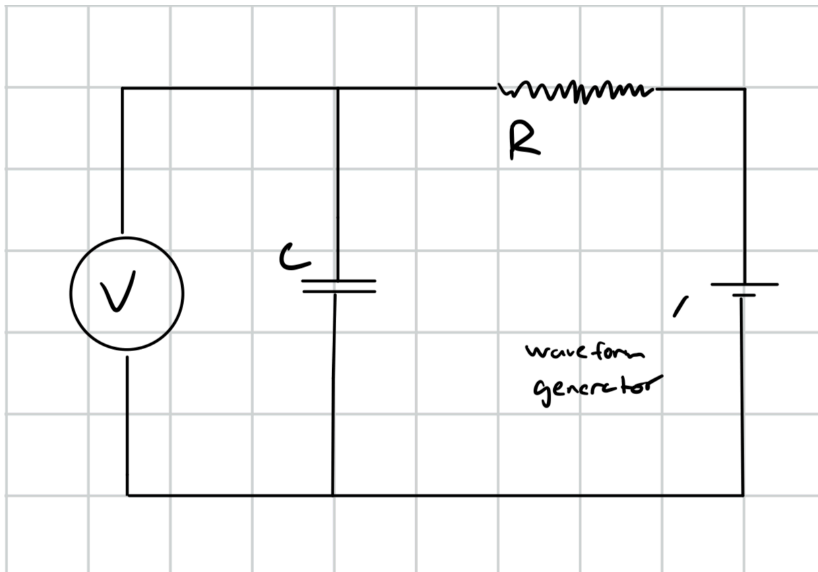


Figure 2. RC circuit created on breadboard

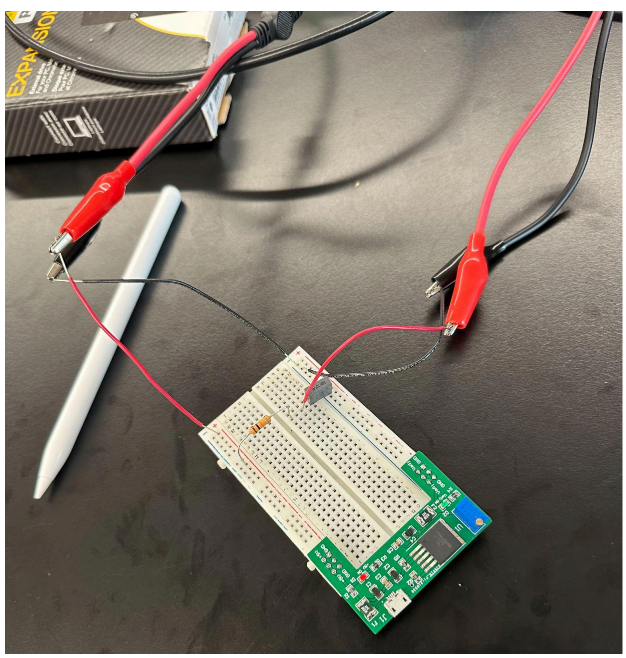


Figure 3. Voltage across capacitor on oscilloscope

Equation:

1. $C = \frac{q}{V}$
   This equation connects capacitance C, to charge q, and voltage V.
2. $v(t) \ = \ V_0 e^{\frac{-t}{\tau}}$
   This second formula connects tau τ, voltage across the capacitor at any given time $v(t)$, initial voltage V_0, and time t

Test and Try

Using the oscilloscopes we can extract the raw data as a file.

Table 1. Voltage across capacitor as a function of time $v(t)$

Time in seconds (t)	Voltage $V(t)$	$ln(V(t)$	Uncertainty of $ln(V(t)$
0	3.81	1.337629189	$1.291 \cdot 10^{-3}$
$1.58 \cdot 10^{-8}$	3.81	1.337629189	$1.291 \cdot 10^{-3}$
$3.41 \cdot 10^{-8}$	3.81	1.337629189	$1.291 \cdot 10^{-3}$
$9.04 \cdot 10^{-8}$	3.57	1.272565596	$1.362 \cdot 10^{-3}$

Figure 1. Voltage across capacitor for discharge function

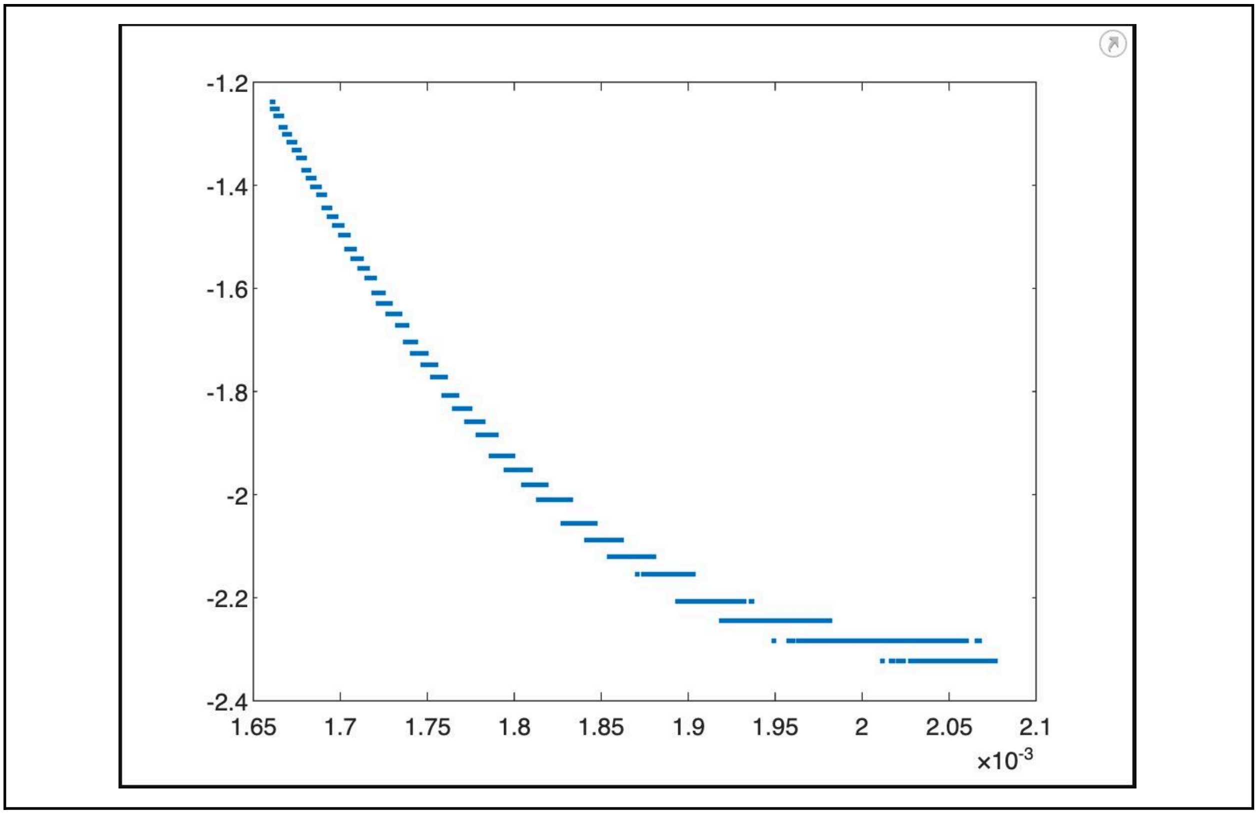
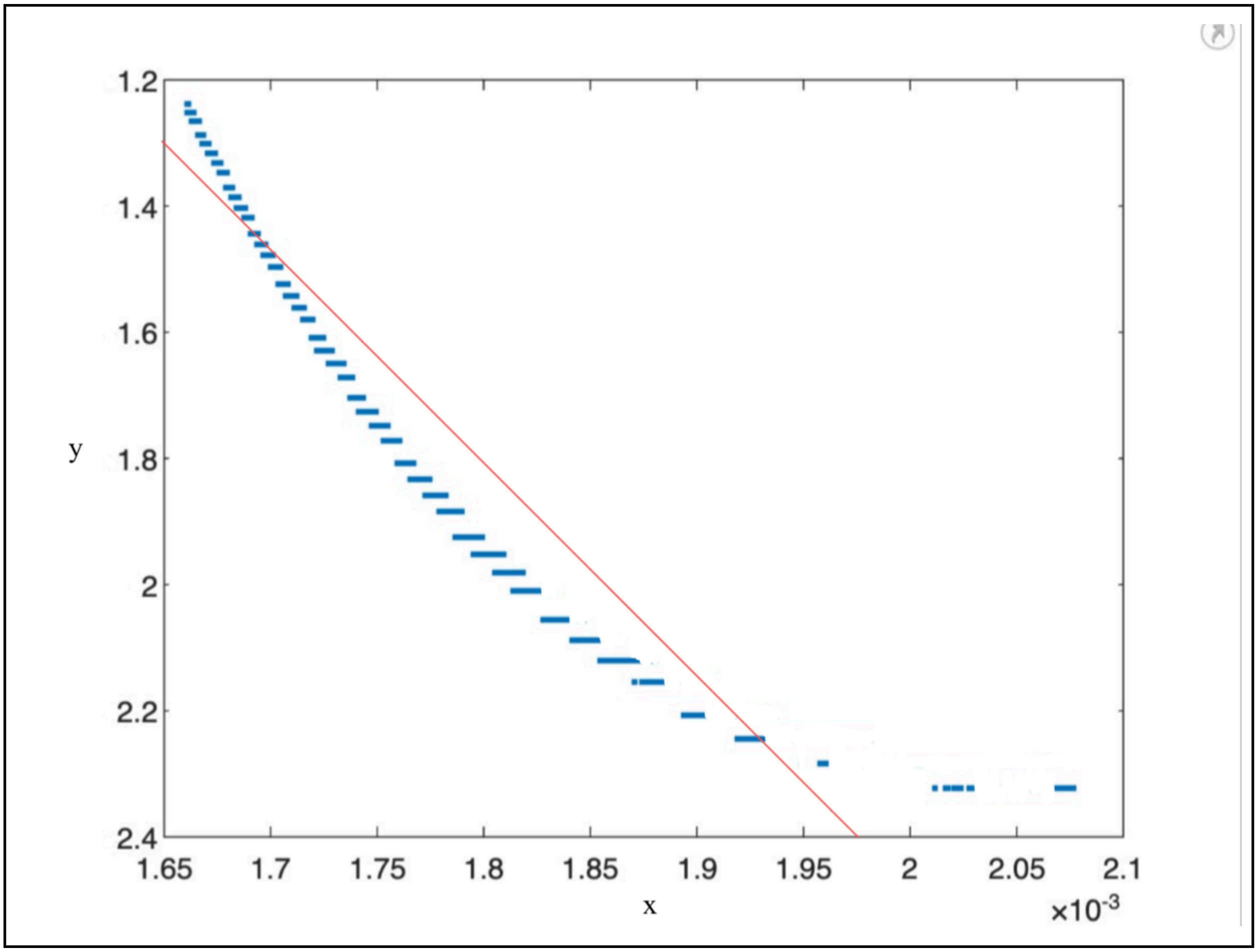


Figure 2. Graph of $ln(V(t)$ over time



From this and after running the MATLAB script we come upon two values, the slope as well as the uncertainty of slope.

$m = -1.0231 \cdot 10^4$

$uncertainty\ of\ m = 0.3721$

Rearranging our equations from before we can get an equation with a similar form to
$y = mx + b$

$ln(v(t)) = -\frac{t}{\tau} + ln(V_0).$

Using this we can solve for capacitance

$$\ln(v(t)) = \left(-\frac{1}{\tau}\right)t + \ln(v_0)$$

$$\underbrace{\ln(v(t))}_{Y} = \underbrace{\left(-\frac{1}{\tau}\right)}_{m}\underbrace{t}_{x} + \underbrace{\ln(v_0)}_{B}$$

$$m = -\frac{1}{\tau} \quad = \quad \tau = \frac{-1}{m}$$

$$C = \frac{-1}{RM} \qquad R = 10k\Omega$$

$$C = 9.8831 \cdot 10^{-9}\,F$$

Uncertainty Calculation

$$\frac{\partial T}{\partial m} = \frac{1}{m^2}$$

$$\partial T = \sqrt{\left(\frac{\partial T}{\partial m}\right)^2 (\partial m)^2}$$

$$\partial T = 4.871 \cdot 10^{-4}\,S$$

$$\frac{\partial C}{\partial T} = \frac{1}{R} \qquad \frac{\partial C}{\partial R} = -\frac{T}{R^2}$$

$$\partial C = \sqrt{\left(\frac{\partial C}{\partial T}\right)^2 (\partial T)^2 + \left(\frac{\partial C}{\partial R}\right)(\partial R)^2}$$

$$= 2 \cdot 10^{-10}\,F$$

From these calculations we can determine the capacitance to $9.88nF \ \pm \ 2nF$

Reflection:
Upon reflecting on our experiment in the laboratory Lab 07 we were tasked with measuring the capacitance of a capacitor without using a digital multimeter. This led us to adopt a traditional approach that provided valuable insights. The main goal was to understand the principles of capacitance measurement through hands-on practice utilizing both standard equipment and modern tools like MATLAB for data analysis.

The methodology of the experiment demanded attention to detail starting from setting up the RC circuit to making precise adjustments on the function generator and oscilloscope. The step by step process involved building the circuit, fine tuning the equipment for data collection and then analyzing that data using MATLAB to determine the capacitance value.

Our findings revealed a calculated capacitance value of 9.88nF with an uncertainty margin of ±2nF closely resembling the expected value of 10nF. The small margin of error between the calculated and anticipated values confirms the credibility of our approach and the accuracy of our implementation. Moreover the alignment of our results with those from other groups reinforces the trustworthiness of the methods used indicating a successful translation of theoretical ideas into real world experimentation.

While the experiment was largely successful, reflecting on the process reveals room for improvement in runs. Improving data collection precision through more thorough calibration of equipment like oscilloscopes and function generators could further reduce measurement uncertainty. Additionally, considering MATLABs role in data analysis, providing a tailored session on its application specific to the experiment's requirements could ensure a more consistent level of expertise among participants potentially leading to more precise outcomes.

To sum up, Lab 07 successfully accomplished its goal of measuring capacitance without depending on digital multimeters. Our calculated results closely match what we anticipated showcasing the strength of our experiment's design. However the reflections and recommendations for enhancements mentioned here provide insights, for improving the precision of upcoming labs. This ensures that each new version improves upon the one offering a more impactful and enlightening learning experience.