MULTIMEDIA UNIVERSITY OF KENYA
FACULTY OF ENGINEERING AND TECHNOLOGY DEPARTMENT OF COMPUTER AND ELECTRICAL ENGINEERING
LAB REPORT: CIT 2118
UNIT NAME: FUNDAMENTALS OF COMPUTERS
UNIT CODE: CIT 2118
TITLE: COMPUTATIONAL MODELING OF CAPACITOR DYNAMICS IN RC CIRCUITS
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1. INTRODUCTION

In computer systems, signals are rarely instantaneous. Every physical connection has inherent resistance and capacitance that affects how data is transmitted. This lab explores the RC Circuit, a fundamental building block of hardware timing and signal integrity.

The core of this experiment is the Time Constant (\tau). It represents the time required to charge the capacitor to approximately 63.2\% of its full charge or discharge it to 36.8\% of its initial voltage. Understanding this is crucial for students of CIT 2118, as it explains why computer processors have maximum clock speed limits—electronic components need time to "switch" states.

2. THEORETICAL BACKGROUND

2.1 Charging Phase

When a DC voltage V is applied to an RC circuit, the capacitor does not reach the source voltage immediately. The current is initially high and gradually decreases as the capacitor stores energy. The mathematical expression is:

2.2 Discharging Phase

When the source is removed and the circuit is closed, the stored energy flows back through the resistor. The voltage decay follows an exponential path:

2.3 Component Definitions

* Resistor (R): Limits the flow of current. Measured in Ohms (\Omega).
* Capacitor (C): Stores energy in an electric field. Measured in Farads (F).

3. METHODOLOGY & SIMULATION

This lab utilized the Python programming language to simulate these physical laws. By using the NumPy library, we handled large arrays of time data, while Matplotlib allowed for the visualization of the voltage curves.

3.1 Step-by-Step Procedure

* Initialization: Define the physical parameters (R = 1000\ \Omega, C = 1\ \mu F, V = 5V).
* Time Domain Setup: Create a linear space of time points from 0 to 10ms using np.linspace.
* Equation Implementation: Translate the exponential growth and decay formulas into Python code.
* Observation: Plot the results and observe how the curve flattens or steepens based on \tau.

3.2 The Simulation Script

```
import numpy as np
import matplotlib.pyplot as plt

# Parameter Setup
R = 1000      # 1k Ohm
C = 1e-6      # 1 microFarad
V = 5         # Supply Voltage
tau = R * C   # Time Constant (0.001s)

# Time range for 10ms
t = np.linspace(0, 0.01, 1000)

# Calculating Curves
V_charge = V * (1 - np.exp(-t / tau))
V_discharge = V * np.exp(-t / tau)

# Visualization Logic
plt.figure(figsize=(10, 5))
plt.plot(t, V_charge, label="Charging Path", linewidth=2)
plt.plot(t, V_discharge, label="Discharging Path", linestyle="--")
plt.axvline(x=tau, color='gray', alpha=0.5, label="1 Tau (Time Constant)")
plt.xlabel("Time (seconds)")
plt.ylabel("Capacitor Voltage (V)")
plt.title("CIT 2118: RC Circuit Transient Response")
plt.legend()
plt.grid(True)
plt.show()
```

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4. DATA ANALYSIS & DISCUSSION

4.1 Impact of \tau on Performance

During the lab, we modified the values of R and C. It was observed that:

* High Resistance/Capacitance: The curve becomes very flat. In a computer, this would represent a "slow" signal, potentially leading to data errors if the clock cycles are too fast.
* Low Resistance/Capacitance: The curve is nearly vertical. This allows for high-frequency operations, such as those found in modern CPUs.

4.2 Connection to Computing Fundamentals

This experiment relates to several key areas of the CIT 2118 syllabus:

* DRAM Refresh: Computer memory (RAM) uses capacitors. Since they discharge over time (as seen in our simulation), the CPU must "refresh" them constantly to prevent data loss.
* Signal Integrity: In high-speed buses (like USB or PCIe), the "rise time" of a signal is limited by RC effects.

* Noise Reduction: Capacitors act as "decoupling" components, absorbing voltage spikes to protect sensitive logic gates.

5. CONCLUSION

The simulation successfully demonstrated the exponential behavior of capacitors in an RC circuit. By utilizing Python, we were able to visualize how physical components dictate the timing and reliability of electronic systems. We conclude that the time constant \tau is a critical parameter in both circuit design and the fundamental limits of computing speed.

6. REFERENCES

* Multimedia University Lab Manual for CIT 2118.
* Fundamentals of Computer Hardware Design, 2025 Edition.
* Numpy and Matplotlib Documentation for Scientific Computing.