Ahmet Faruk Çolak
22102104
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EE-202 LAB 1 FINAL REPORT

1-Introduction

It is observed how different inputs, such as square pulse and sinusoidal pulse, affect charging and discharging outcomes of R-C circuit in this laboratory work.

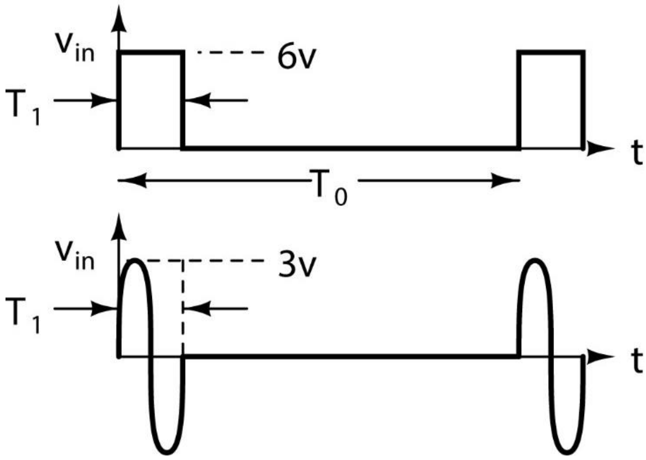

Figure.1: Required Signals

2-Analysis

Capacitor charge formula: $Q = VC$

by taking derivative of both sides,

$$i(t) = \frac{dV(t)}{dt}C$$

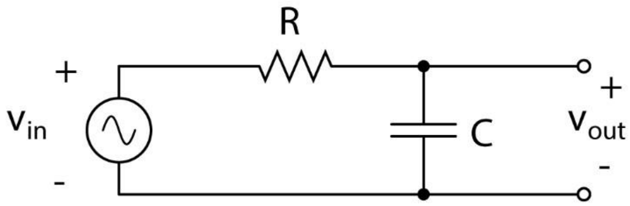

Figure.2: Required Circuit

From KCL equation:

$$\frac{dV(t)}{dt}C + \frac{V(t)}{R} = 0$$

From this equation:

General Formula of Capacitor Charging Equation: $Vout(t) = V_{in} \cdot \left(1 - e^{\frac{-t}{RC}}\right)$

General Formula of Capacitor Discharging Equation: $Vout(t) = V_{initial} \cdot \left(e^{\frac{-t}{RC}}\right)$

Expectations from Mathematical Expressions:

As the value of **t** increases, the charge in the capacitor is expected to approach the input voltage during the charging phase. According to the charging equation, the process occurs exponentially due to the presence of Euler's number. The discharging process is also exponential. As time progresses, the charge in the capacitor rapidly flows into the circuit.

For a sinusoidal pulse input, it is a bit hard to make guesses because of sinusoidal input.

Required values:

$$R = 8.2K\Omega$$

$$C = 820nF$$

$$\tau = 6.472\ ms$$

3-Preliminary Work

A-Square Wave Pulse

From the derived equations in introduction part, MATLAB plot is generated.

```
R = 8.2e3;
C = 820e-9;
tau = R * C;
T1 = (2.9)*tau;
T0 = 46 * tau;

t = linspace(0, T0, 1000);
V_in = 6;
V_out = zeros(size(t));
V_in_pulse = zeros(size(t));

for i = 1:length(t)
    t_mod = mod(t(i), T0);

    if t_mod < T1
        V_out(i) = V_in * (1 - exp(-t_mod / tau));
        V_in_pulse(i) = V_in;
    else
        V_out(i) = V_in * (1 - exp(-T1 / tau)) * exp(-(t_mod - T1) / tau);
        V_in_pulse(i) = 0;
    end
end

figure;
hold on;
plot(t, V_in_pulse, 'r--', 'DisplayName', 'Input Voltage (Pulse)');
plot(t, V_out, 'b-', 'DisplayName', 'Output Voltage (Capacitor)');
title('Capacitor Voltage Response to a Periodic Pulse');
xlabel('Time (s)');
ylabel('Voltage (V)');
legend;
grid on;
hold off;
```

Figure.3: MATLAB code for square pulse (developed from Preliminary Report)

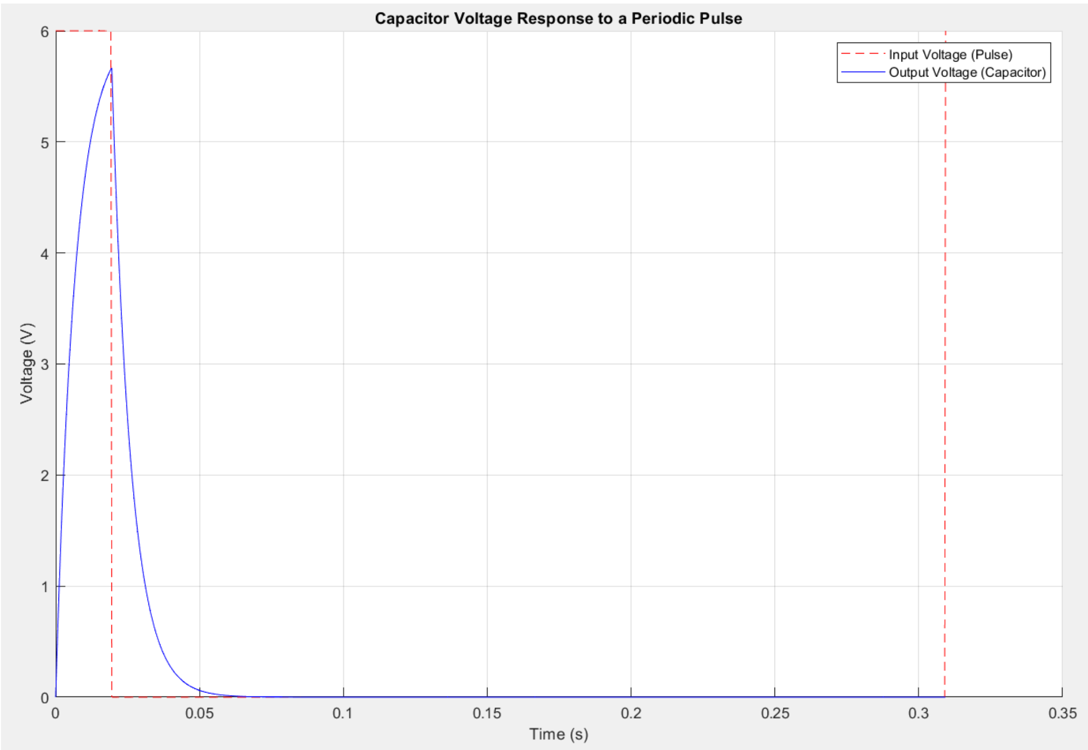

Figure.4: MATLAB generated plot, square wave input to the capacitor

The LTSpice model is not required but to verify the output, simulation was made.

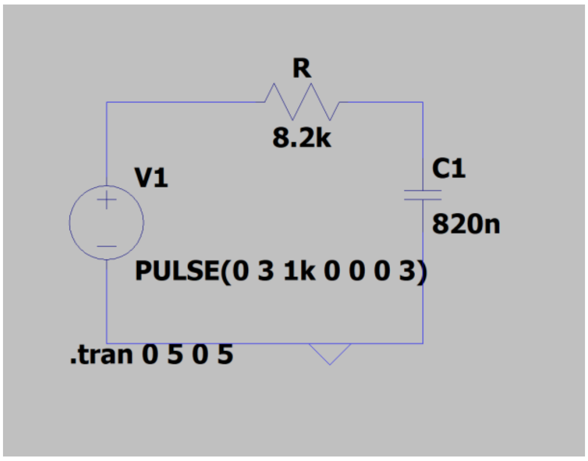

Figure.5: LTspice schematic of the circuit, from Preliminary Report

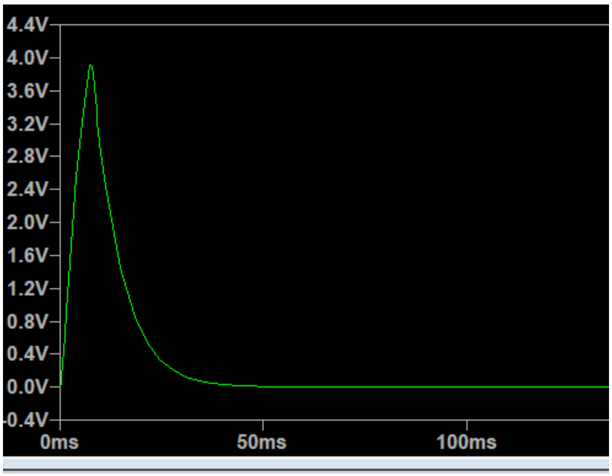

Figure.6: Square Wave Pulse Response of the Capacitor LTspice simulation, from Preliminary Report

This is the output of same values but $T_1 = \tau$. This graph shows less time less charge:

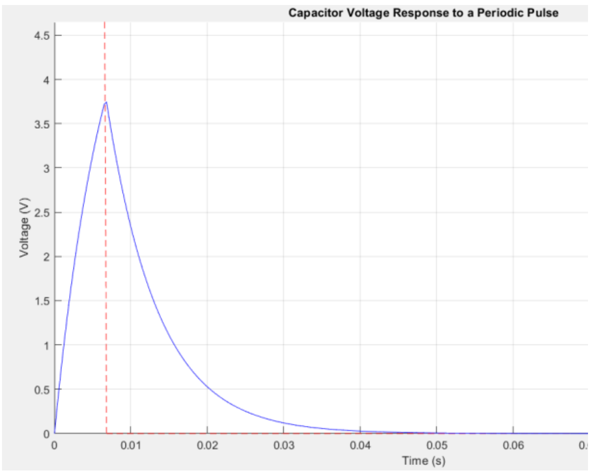

Figure.7: MATLAB simulation for different T_1

B-Sine Wave Pulse

```
R = 8.2e3;
C = 820e-9;
tau = R * C;
T1 = (2.9) * tau;
T0 = 46 * tau;

% Zaman vektörü
t = linspace(0, T0, 1000);

V_in_peak = 3;
V_out = zeros(size(t));
V_in_pulse = zeros(size(t));

for i = 1:length(t)
    t_mod = mod(t(i), T0);

    if t_mod < T1
        V_in_t = V_in_peak * sin(2 * pi * t_mod / T1);
        V_out(i) = V_in_t * (1 - exp(-t_mod / (R * C)));
        V_in_pulse(i) = V_in_t;
    else
        V_out(i) = V_out(i-1) * exp(-(t_mod - T1) / (R * C));
        V_in_pulse(i) = 0;
    end
end

figure;
hold on;
plot(t, V_in_pulse, 'r--', 'DisplayName', 'Input Voltage (Sinusoidal Pulse)');
plot(t, V_out, 'b-', 'DisplayName', 'Output Voltage (Capacitor)');
title('Capacitor Voltage Response to a Sinusoidal Pulse');
xlabel('Time (s)');
ylabel('Voltage (V)');
legend;
grid on;
hold off;
```

Figure.8: MATLAB code for sinusoidal pulse (developed from Preliminary Report)

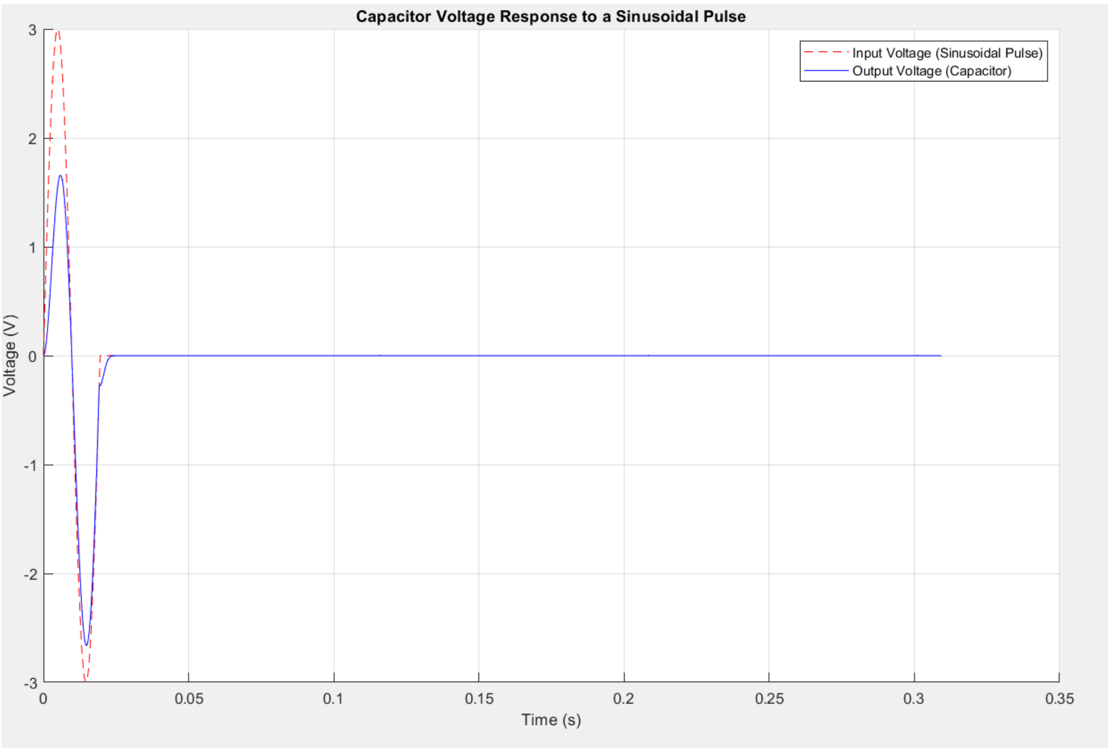

Figure.9: MATLAB generated plot, sinusoidal wave input to the capacitor

	Square Wave Pulse		Sine Wave Pulse
	$T_1 = \tau$	$T_1 = 2.9\tau$	$T_1 = 2.9\tau$
Maximum Voltage	3.72 V	5.64 V	1.64 V
Minimum Voltage	0 V	0 V	-2.65 V

Table.1: Minimum and Maximum Voltage values for different input signals

4-Hardware Implementation

The experiment explored the charging and discharging behavior of an RC circuit when subjected to square wave and sinusoidal pulse inputs. The goal was to observe and analyze the circuit's response, comparing experimental findings with theoretical calculations and simulations.

Experimental results very closely matched preliminary predictions. A 6V square wave pulse resulted in the expected exponential charging and discharging of the capacitor, reaching near 6V during charge and returning to near zero during discharge, mirroring simulation results.

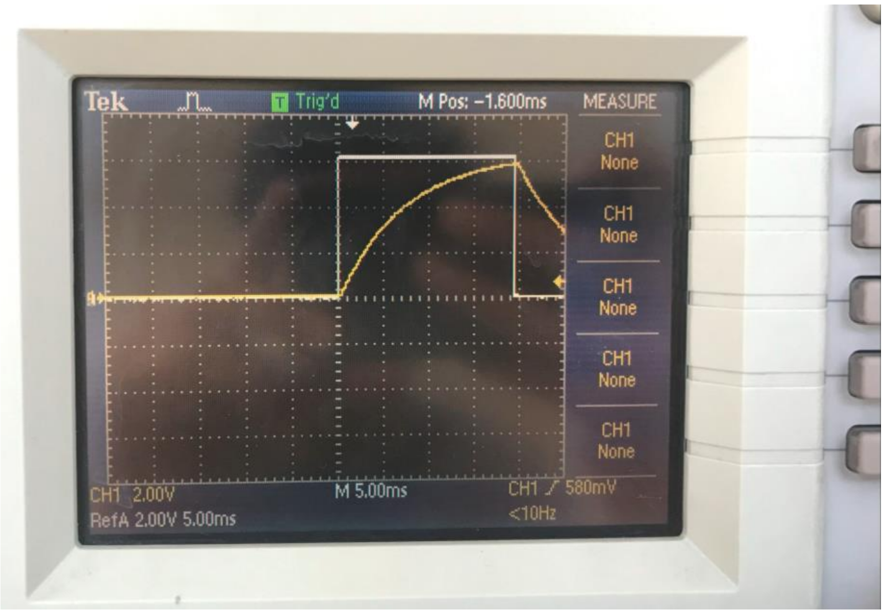

Figure.10: Square Wave Pulse Input and the Voltage of Capacitor

Similarly, a 3V sinusoidal pulse input produced a sinusoidal-like capacitor voltage, consistent with preliminary findings. Minor discrepancies can be attributed to factors like component tolerances and measurement equipment limitations.

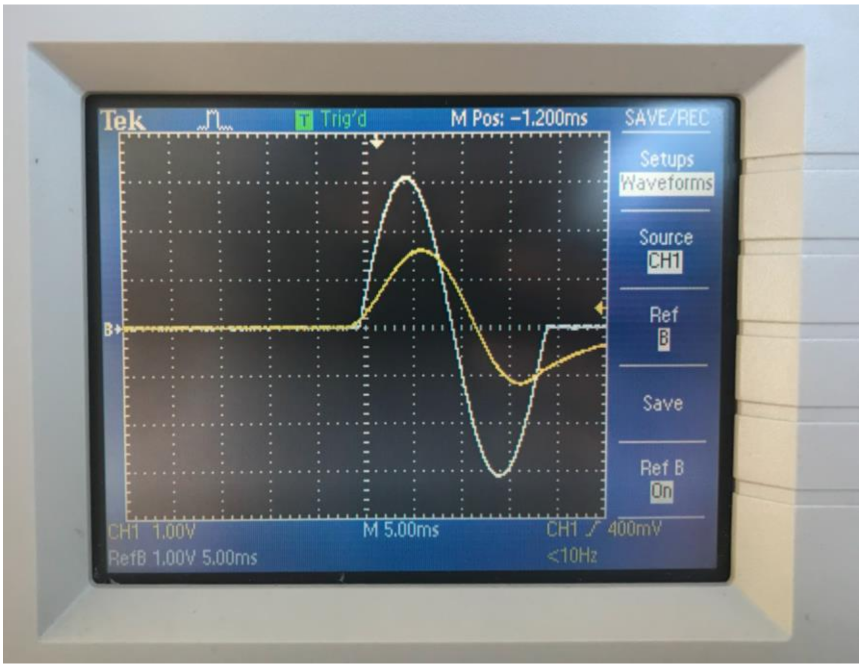

Figure.11: Sinusoidal Wave Pulse Input and the Voltage of Capacitor

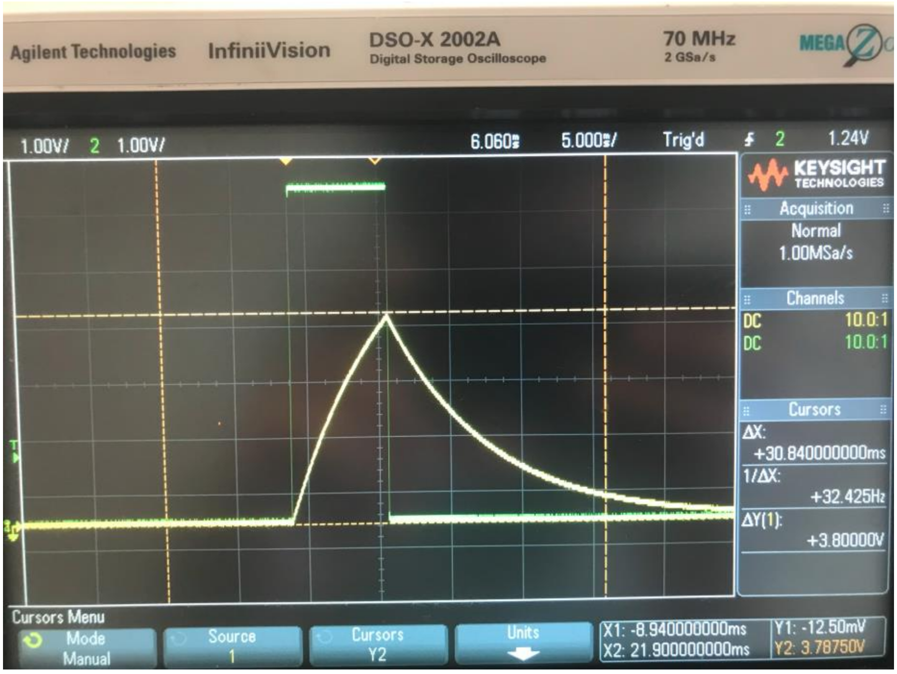

Figure.12: Square Wave Pulse Input for different T_1

Also, when the pulse duration is short, the capacitor may not have sufficient time to fully charge, resulting in a noticeable difference between the applied voltage and the capacitor voltage.

Effectiveness of the Method:

The experimental method effectively achieved the assignment's objectives. Applying square wave and sinusoidal pulses and measuring the capacitor voltage allowed for direct observation and characterization of the RC circuit's charging and discharging dynamics. This validated the theoretical understanding and confirmed the simulation models' accuracy.

5-Conclusion

Key Revelations:

The experiment yielded key insights:

1. **Different signals create different charging patterns.** Applying different signal types to an RC circuit results in unique charging behaviors, potentially valuable for future circuit designs.
    - RC circuits charge and discharge exponentially with a square wave input, with the speed dependent on the resistance and capacitance values (time constant).
    - RC circuits respond to sine wave inputs by producing a similar sine wave voltage across the capacitor, demonstrating their ability to handle AC signals.
2. **Component values and pulse characteristics influence charging and discharging times.** The resistor (R) and capacitor (C) values, along with pulse duration and fall time, directly impact the charging and discharging pattern. Larger R and C values lead to slower processes, while shorter pulse durations may limit capacitor charging.

The experiment successfully demonstrated the fundamental principles of RC circuit behavior and provided valuable practical experience. The strong agreement between experimental results and preliminary predictions reinforces the theoretical understanding of RC circuit dynamics and validates the experimental method's effectiveness.