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EE-202 LAB 2 FINAL REPORT

1-Introduction

It is observed how different signals, square wave step function and sinusoidal wave, affect voltage on the capacitor on RLC circuit. This experiment focuses on analyzing both the transient and steady-state responses of the RLC circuit at the specific resonant frequency for inductor and capacitor.

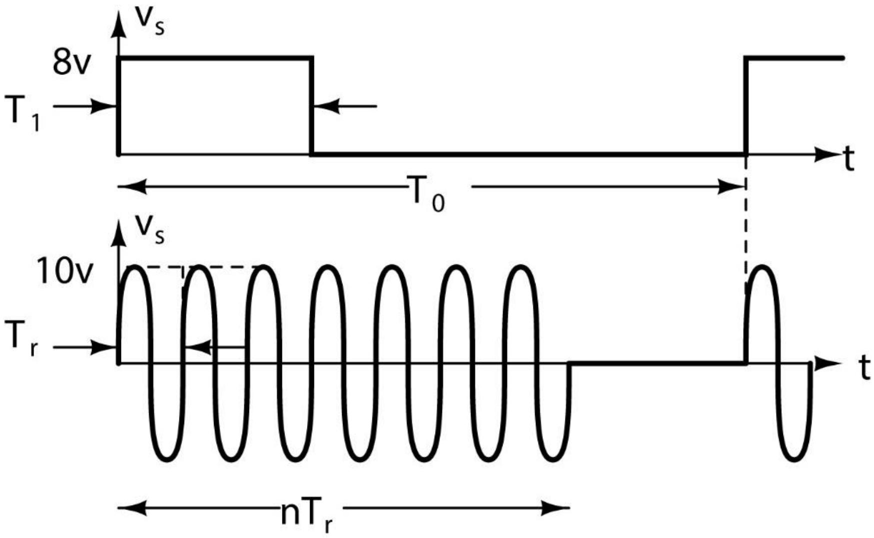

Figure.1: Required Signals

2-Analysis

Resonant Frequency:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

It's derived from the equality of X_L and X_C values.

$$f_r \cong 410936\ Hz$$

Quality Factor:

$$Q = \frac{\omega_r L}{R_{total}}$$

$$Q = \frac{2\pi \times 410936 \times 100\mu H}{1.556} \cong 165.937$$

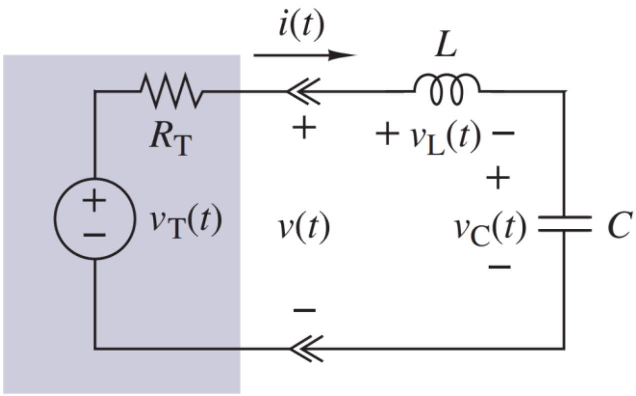

Figure.2: Simplified version of the circuit, from EE-202 Textbook

Applying KVL around the loop,

$$LC\frac{d^2 v_C(t)}{dt^2} + R_T C\frac{dv_C(t)}{dt} + v_C(t) = v_T(t)$$
$$v_L(t) \quad + \quad v_R(t) \quad + v_C(t) = v_T(t)$$

Figure.3: KVL equation of the simplified circuit, from EE-202 Textbook

The methodology for the response will be set up using KVL. The solution will be carried out using MATLAB.

Required values:

$R = 50\ \Omega$

$R_1 = 1.5\ \Omega$

$L = 15\mu H$

$r = 0.1\ \Omega$

$C = 10\ nF$

For the preliminary work, L and C values were a bit different because there was not any desired component. However, in the hardware lab this problem was solved.

3-Preliminary Work

A-Square Wave Pulse

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

```
L_val = 10e-6;
R_val = 1.56;
C_val = 1.5e-9;
V_source = 0.212;
part_value = V_source / L_val;

alpha = R_val / L_val; % Coefficient of y'
beta = 1 / (L_val * C_val); % Coefficient of y
y_steady = part_value / beta; % Steady-state solution
real_root = -alpha / 2; % Real part of roots
angular_freq = sqrt(4 * beta - alpha^2) / 2; % Angular frequency
A1 = -y_steady; % From y(0) = 0
A2 = -(real_root * A1) / angular_freq; % From y'(0) = 0

tau = 1 / abs(real_root); % Time constant
t = linspace(0, 5 * tau, 1000);

% Calculate y(t) using the general solution
y_solution = exp(real_root * t) .* (A1 * cos(angular_freq * t) + A2 * sin(angular_freq * t)) + y_steady;

% Calculate the voltage across the capacitor V(t)
V_cap = y_solution / C_val;

% Plot results
figure;
plot(t, V_cap, 'g', 'LineWidth', 1.5); hold on;
plot(t, (y_steady / C_val) * ones(size(t)), '--m', 'LineWidth', 1.5);
title('Voltage Across Capacitor V_c(t)');
xlabel('Time (seconds)');
ylabel('Voltage V_c(t) (Volts)');
grid on;
```

Figure.4: MATLAB code for square wave input, from Preliminary Report

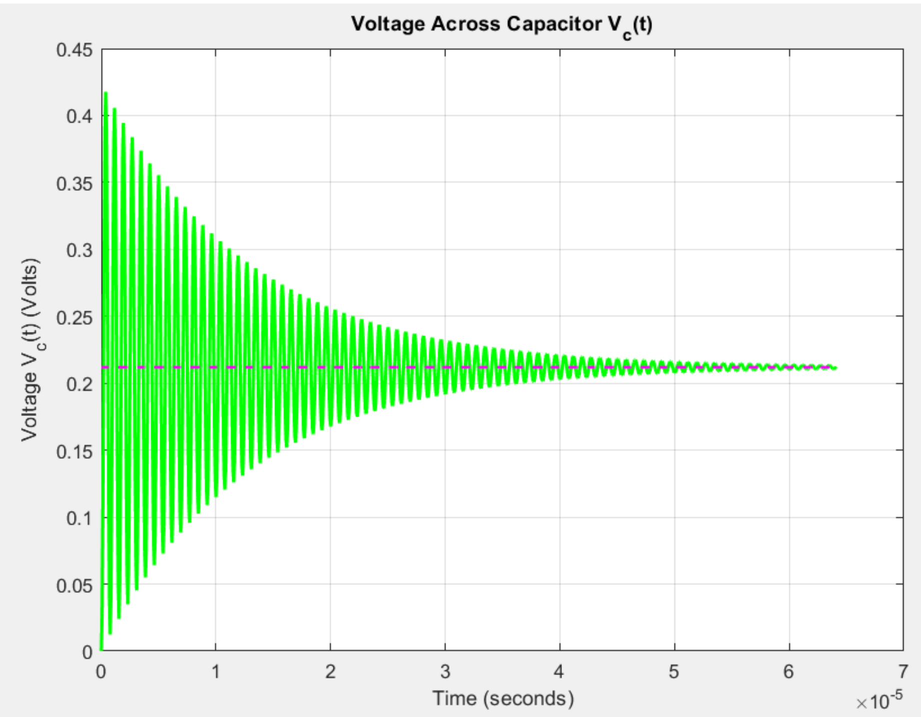

Figure.5: MATLAB generated plot, voltage across capacitor, from Preliminary Report

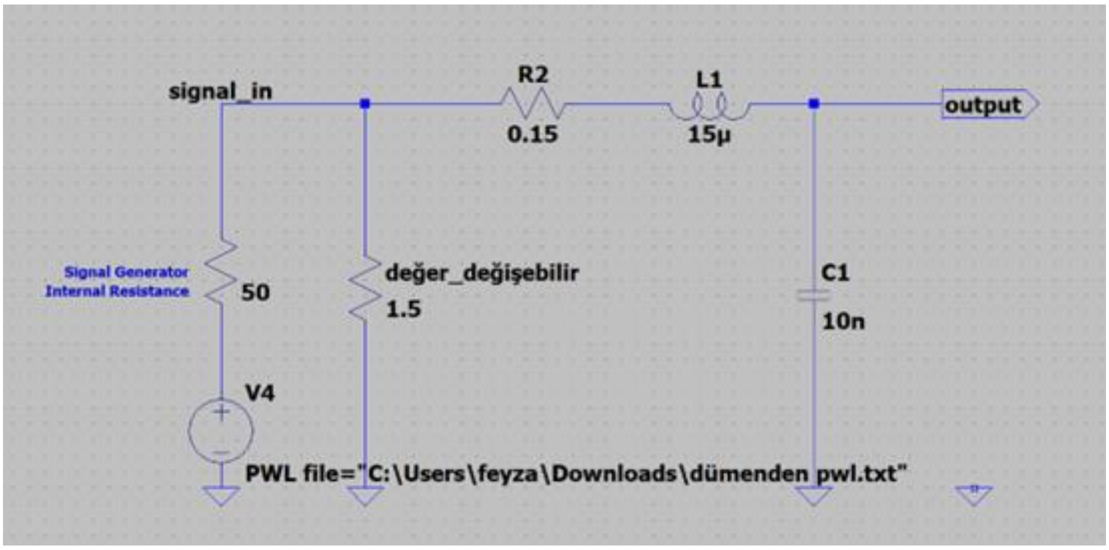

Figure.6: LTspice schematic of the circuit, from Preliminary Report

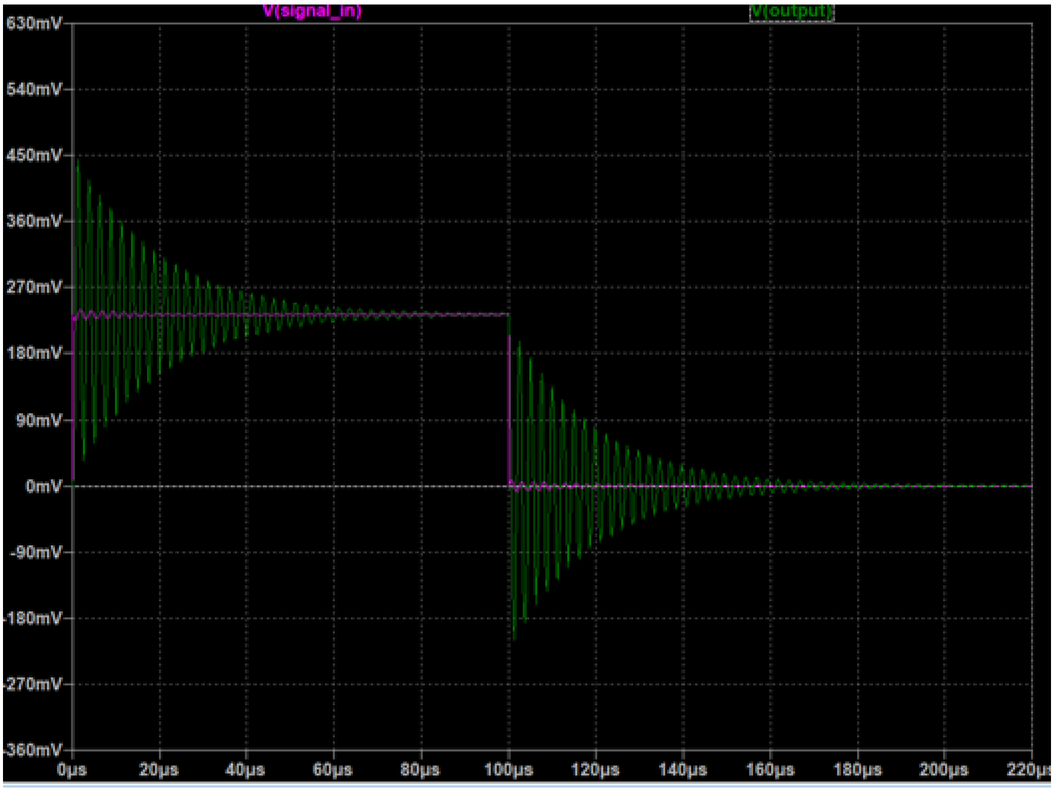

Figure.7: Square Wave Response, LTspice simulation, from Preliminary Report

B-Sine Wave Pulse

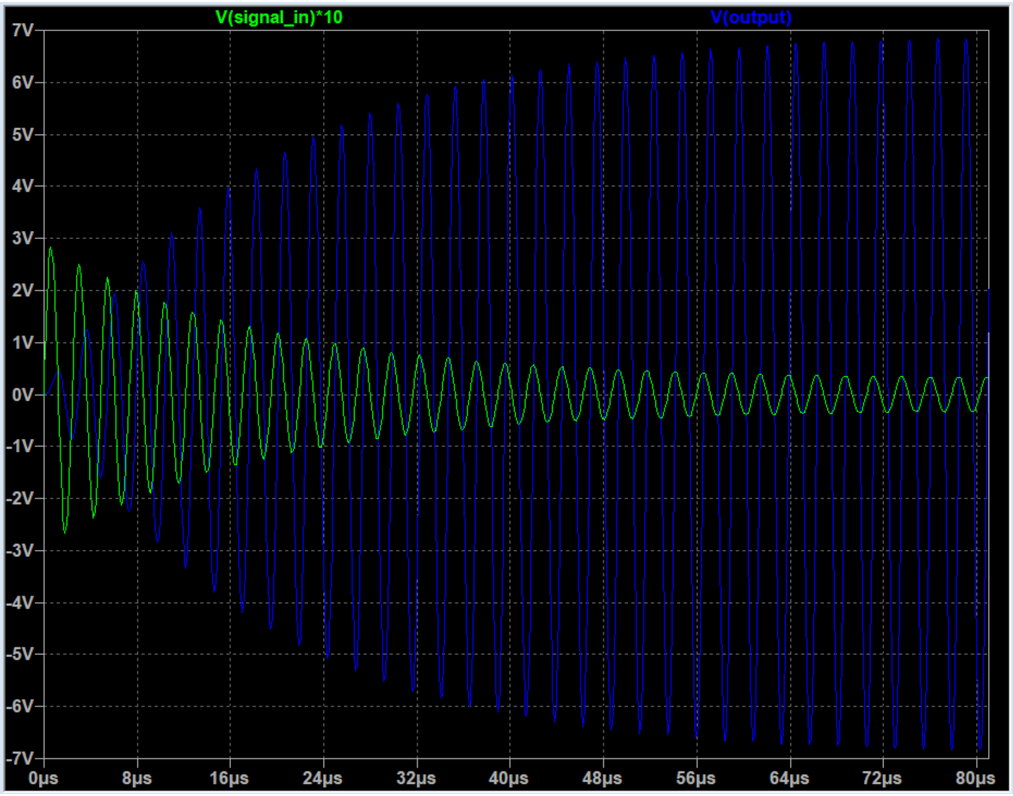

Figure.8: Sinusoidal Wave Response of the Capacitor, LTspice simulation

	Square Wave	Sinusoidal Wave
Time to reach steady state	$\sim 60\mu s$	$\sim 64\mu s$
Maximum Voltage	$\sim 450mV$	$\sim 7V$

Table.1: Time to reach steady state and maximum voltage values for different input signals

4-Hardware Implementation

Following the 8V step function input, the capacitor voltage displayed a damped oscillation waveform. Although the Lab 2 manual contained an error that resulted in slight discrepancies in the output voltage deltas, the overall waveform shape remained consistent as predicted, with the highest delta in the damped oscillation reaching approximately 450mV. The observed circuit response in the hardware lab also closely matched the LTSpice simulation results, indicating the validity of the simulation model.

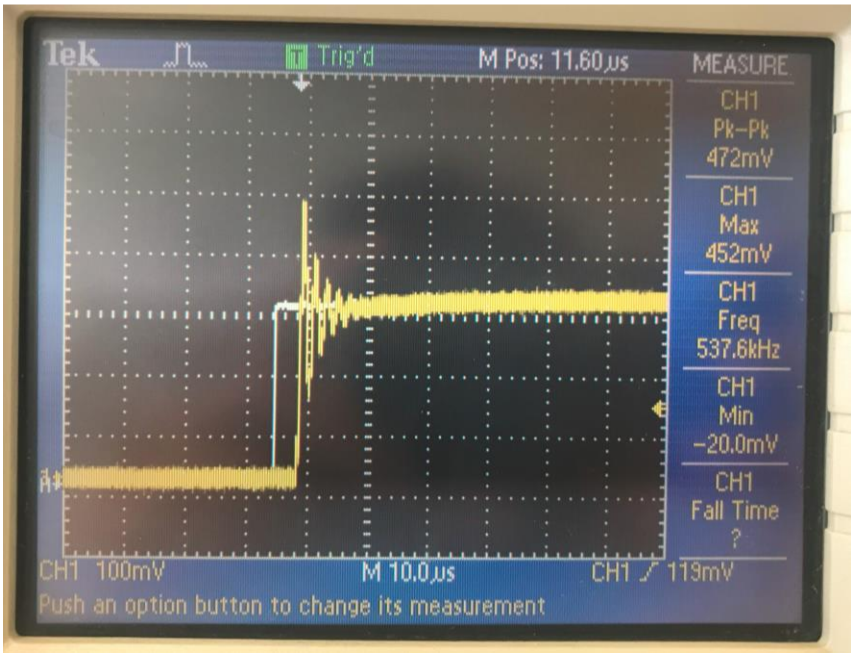

Figure.9: Square Wave Step Function Input and the Voltage of Capacitor

The sinusoidal signal response of the circuit generally matched the LTSpice simulation in terms of waveform shape. However, some inconsistencies were observed in the peak voltage levels compared to the simulation, which could be attributed to the characteristics of the physical components used. For instance, using a different capacitor with the same nominal value sometimes resulted in a closer match to the simulation, while at other times, the response deviated.

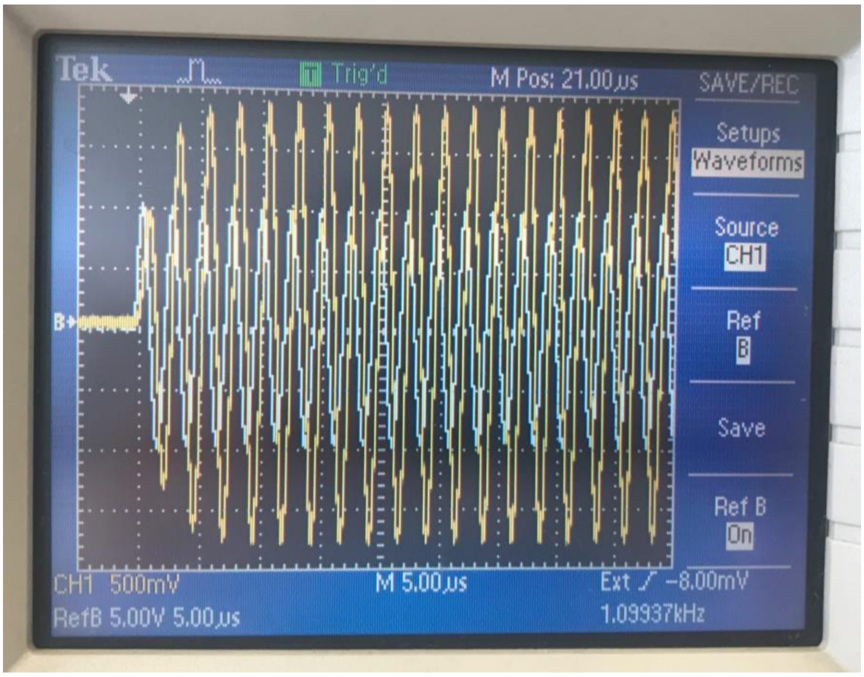

Figure.10: Sinusoidal Wave Pulse Input and the Voltage of Capacitor

Effectiveness of the Method:

The experimental method generally achieved the assignment's objectives, allowing for the observation and analysis of an RLC circuit's response. While the overall trends and waveform shapes aligned with theoretical predictions and LTSpice simulations, some inconsistencies in voltage levels were encountered.

These discrepancies could be attributed to several factors. The chosen capacitor and resistor values were at the extreme ends of the allowed range, potentially making the circuit more sensitive to component tolerances and parasitic effects. Additionally, the use of a breadboard, as opposed to a soldered circuit, may have introduced unwanted resistance and capacitance, further contributing to the inconsistencies. For future experiments, selecting component values closer to the mid-range and employing a soldered circuit could potentially yield more consistent and reliable results. This experiment highlighted the importance of careful component selection and construction techniques in achieving accurate and repeatable measurements in sensitive circuits.

5-Conclusion

This experiment provided valuable insights into the behavior of RLC circuits under different input signals, particularly at the resonant frequency.

Key Revelations:

1. **Distinct responses to different signal types:** Applying step function and sinusoidal inputs to an RLC circuit resulted in unique output waveforms. This highlights the importance of understanding how RLC circuits react to different excitation sources in various applications.
    - The step function input produced a damped oscillatory response in the capacitor voltage, demonstrating the energy storage and dissipation characteristics of the circuit.
    - The sinusoidal input at the resonant frequency resulted in a sinusoidal output with a specific amplitude and phase shift, showcasing the circuit's frequency-selective properties.

2. **Influence of component values and construction techniques:** The experiment revealed the significance of careful component selection and circuit construction in achieving accurate and consistent results.
    - Choosing extreme component values potentially increased the circuit's sensitivity to tolerances and parasitic effects, contributing to observed discrepancies between experimental and simulated results.
    - Utilizing a breadboard instead of a soldered circuit may have introduced unwanted resistance and capacitance, further affecting the measurements.

The experiment successfully demonstrated the fundamental principles of RLC circuit behavior and provided practical experience in analyzing their transient and steady-state responses. While minor inconsistencies were encountered, the overall agreement between experimental observations and LTSpice simulations validated the theoretical understanding of RLC circuit dynamics. Moreover, the experiment highlighted the importance of careful component selection and construction techniques for achieving accurate and reliable measurements in sensitive circuits, providing valuable lessons for future experiments.