Report 1 : 75%
Prelab 2 : 93%

use the worfd processor also for the formulas..

Constructor University Bremen

Natural Science Laboratory

Signals And Systems

Fall Semester 2024

Lab Experiment 1- RLC-Circuits - Transient Response

Author: Wanzia Nambule

Instructor: Pagel Uwe

Experiment conducted by: Wanzia Nambule, Dahyun Ko
Place of execution: Teaching Lab EE
Bench 12

Date of execution: 25 September, 2024

1.INTRODUCTION

The objective of this experiment was to investigate the transient response of second-order systems, specifically RLC circuits. These systems are characterized as second-order because the highest derivative in the differential equation describing their behavior is of the second order. Various RLC circuit configurations were implemented and tested, with their transient behavior analyzed. The experimental results were then compared to MATLAB simulations, and any discrepancies were examined to enhance understanding of the system's dynamics.

2.THEORY

Systems with second-order dynamics, such as RLC circuits, are used to attenuate certain frequency ranges. The differential equations describing these systems include terms where the highest exponent is two. These systems are represented mathematically by second-order differential equations, as seen in the case of the voltage across a capacitor in a series RLC circuit.

The following equation represents the second order differential equation of an RLC circuit.

$$\frac{d^2v(t)}{dt^2} + 2\zeta\omega_n\frac{dv(t)}{dt} + \omega_n^2 v(t) = K\omega_n^2 v_{in}(t),$$

Where $\omega_n = \sqrt{\frac{a_0}{a_2}} = \frac{1}{\sqrt{LC}}$, which is the angular frequency in rad/s, the dumping ratio, given by $\zeta = \frac{a_1}{2\sqrt{a_0 a_2}} = \frac{R}{2}\sqrt{\frac{C}{L}}$. Where the values of $a_0,\ a_1,\ a_2$ are the values of the coefficients of the differential equations from the first derivative. First, second and third equation coefficient values will be $a_0,\ a_1,\ a_2$, respectively.

When solving the transient response and steady state response, we solve problems using the second order differential equations.

In transient responses we can solve the homogeneous solution by equating the differential equation to zero:

$$\frac{d^2v(t)}{dt^2} + 2\zeta\omega_n\frac{dv(t)}{dt} + \omega_n^2 v(t) = 0$$

Substituting $v(t)\ with\ Ce^{\lambda t}$, giving us $Ce^{\lambda t}(\lambda^2 + 2\lambda\zeta\omega_n + \omega_n^2) = 0$. To get λ, we set $(\lambda^2 + 2\lambda\zeta\omega_n + \omega_n^2) = 0$. We set $\lambda_1, \lambda_2 =- \zeta\omega_n \pm \omega_n\sqrt{\zeta^2 - 1}$, giving the final solution of the homogenous, which is $v(t) = C_1 e^{\lambda t(-\zeta\omega_n \pm \omega_n\sqrt{\zeta^2-1})t} + C_2 e^{\lambda t(-\zeta\omega_n \pm \omega_n\sqrt{\zeta^2-1})t}$

The values of C_1 and C_2, are unknown and they can be found using the initial conditions.

The Values of $\lambda_1 and\, \lambda_2$, are unknown and they can be found using the RLC circuit components.

The transient response can be underdamped, critically damped or overdamped. What determines the damping condition is the damping ratio. Here are the conditions:

Underdamped Case, $\zeta < 1,\ where\ \ \lambda_1 and\, \lambda_2\ are\ complex\ numbers$

CriticallyDamped Case, $\zeta = 1,\ where\ \ \lambda_1 and\, \lambda_2\ are\ real\ and\ equal\ \ numbers$

Overdamped Case, $\zeta > 1,\ where\ \ \lambda_1 and\, \lambda_2\ are\ real\ and\ unequal\ \ numbers$

In underdamped situation, $v(t) = e^{(-\zeta\omega_n t)}\ (C_1 cos(\omega_d t) + \ C_2 sin(\omega_d t)),$ which is an oscillatory behavior. In the equation the damped frequency $\omega_d = \omega_n\sqrt{1 - \zeta^2}$. The exponentially damped sinusoid rate decay depends on the damping ratio. The envelope of the response is defined by $\pm\, e^{(-\zeta\omega_n t)}$. When the oscillations have a decreasing amplitude, they are called ringing and can be seen in figure 1

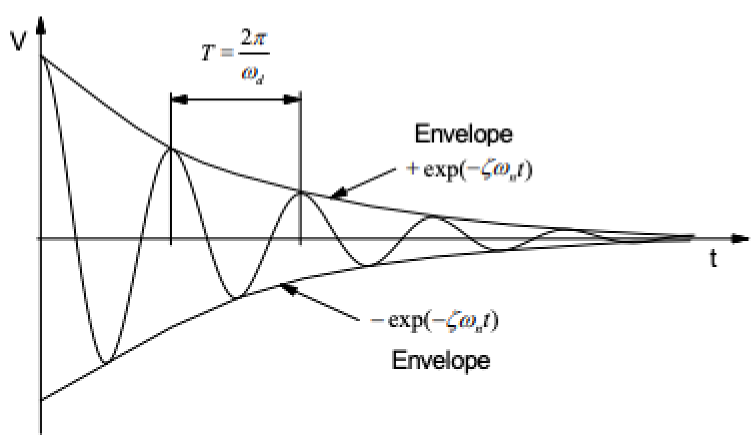
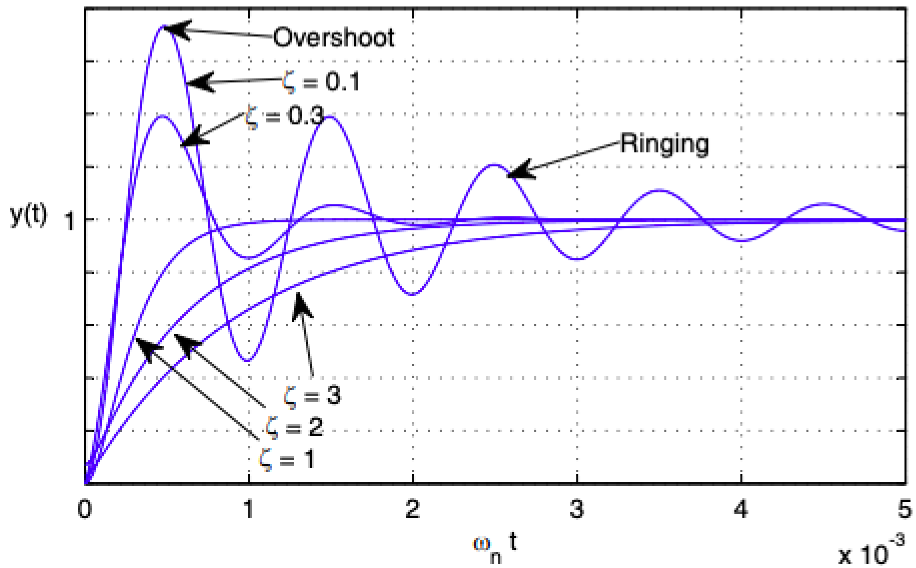


Figure (1): showing the envelope and ringing of an underdamped case

In overdamped case, $v(t) = C_1 e^{(-\zeta+\sqrt{\zeta^2-1})\omega_n t} + C_2 e^{(-\zeta-\sqrt{\zeta^2-1})\omega_n t}$. All the exponentials are decaying.

In critically damped $v(t) = C_1 e^{(-\zeta\omega_n t)} + C_2 t e^{(-\zeta\omega_n t)}$



figure(2): Showing a graphical summary of the second step response

In the forcing function, the output mirrors the input's pattern because of the nature of the forcing function. It is expressed as a combination of the input and its first and second derivatives. Thus, if the input follows a sinusoidal pattern, the output will also follow a sinusoidal pattern.

Initial conditions refer to the system's specific starting states, especially when analyzing circuits that are switched on or off. It's crucial to consider the following:

- The current through an inductor cannot change instantly, but the voltage across it can.

- The voltage across a capacitor cannot change instantly, but the current through it can.

The transient response is determined by solving a second-order non-homogeneous differential equation, with the constants (C_1 and C_2) calculated based on the initial conditions.

In the DC steady-state, the response is found by replacing capacitors with open circuits and inductors with short circuits.

3. Execution Transient Response Of RLC-Circuits

Design of an RLC circuit

The circuit shown below was assembled on a breadboard to study the behavior of the RLC circuit in response to a steady signal source. The experimental setup was constructed using the following equipment: a signal generator with a 50 Ω internal resistance, a decade resistor, a 10mH inductor, a 6n8F capacitor, an oscilloscope, probes, wires, cables, and a breadboard, all arranged according to the specified configuration.

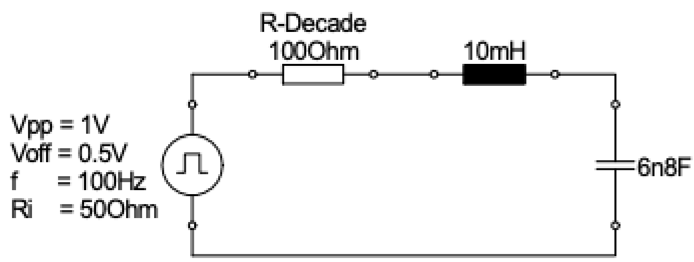
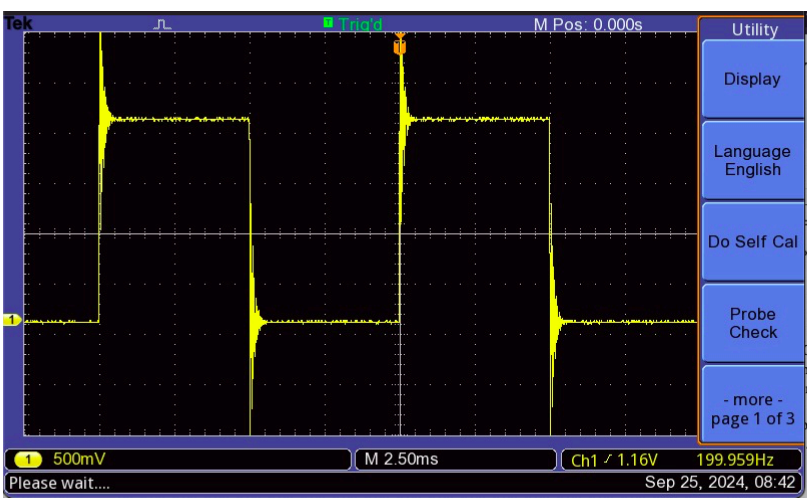


Figure (3): showing the circuit setup

The function generator was configured to generate a 100 Hz square wave with a 0.5 V amplitude and a 0.5 V offset. The oscilloscope was adjusted to display the signal ranging between 0 V and 1 V. The R-decade was set to 100 Ω, and the oscilloscope was connected in parallel with the capacitor.

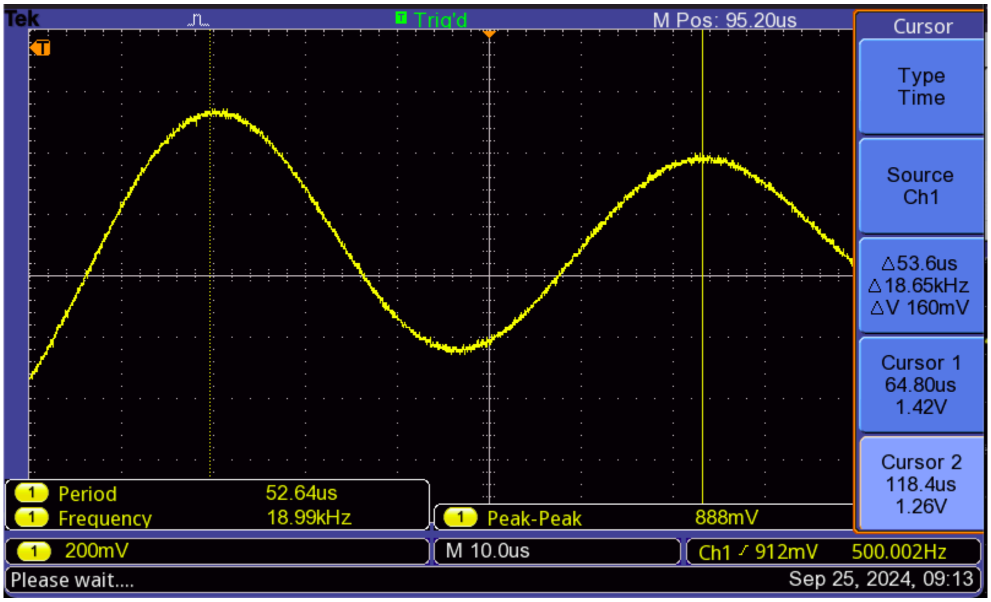
The damped frequency, fd, was measured by using the oscilloscope's cursor function to determine the frequency of the exponentially damped sinusoidal wave. This was done by placing the cursors at the start and end of a wave cycle.



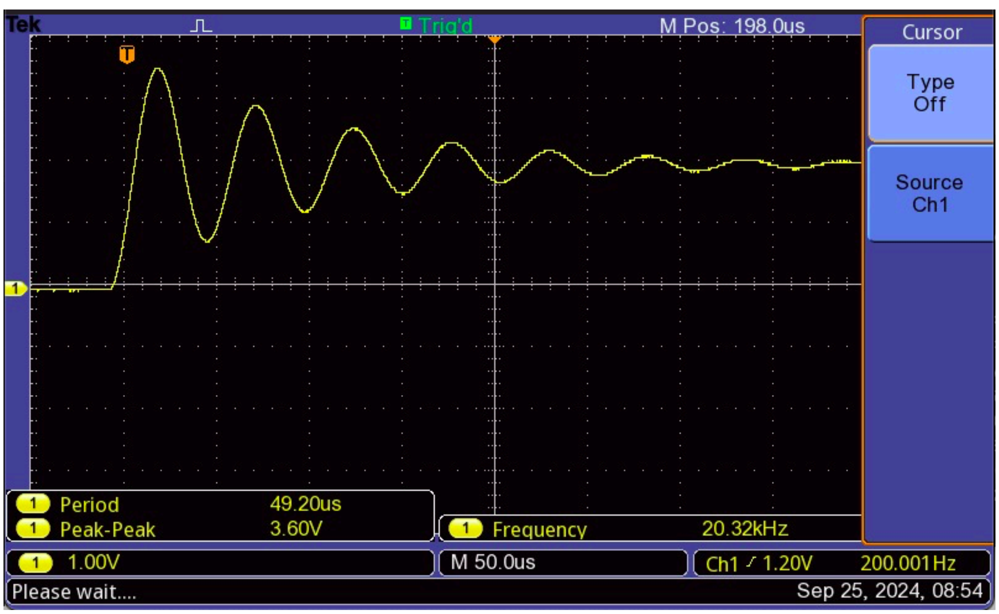
figure(4): showing the voltage through the capacitor

The damped frequency f_d was determined in figure 5, which is 18.65KHz

$f_d = 18.65KHz$



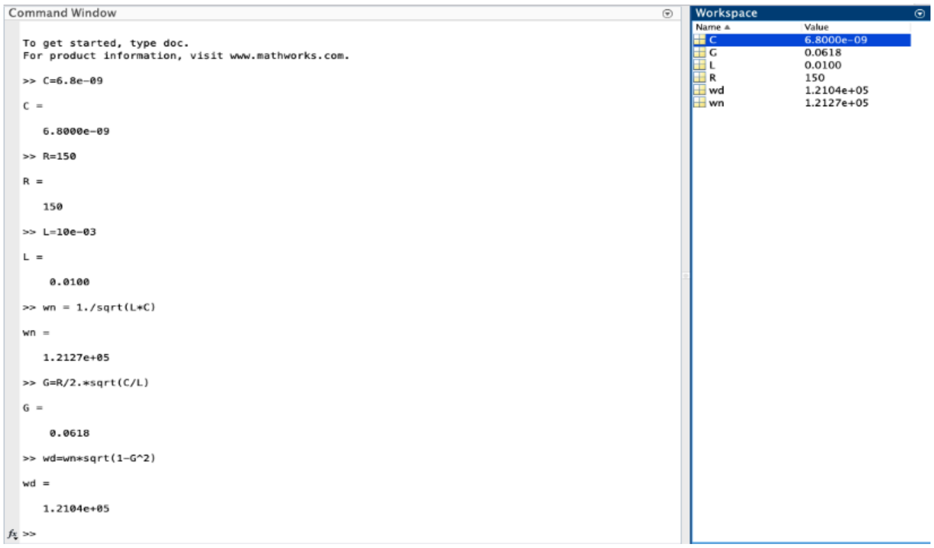
figure(5): showing one signal period



figure(6): showing the ringing phenomenon

Calculating the value of the damped radian frequency ω_d, I used matlab and got the value in figure 7

$$\omega_d = 1.2104 \times 10^5 rads/s$$



not really readable..

figure(7): showing the calculated value of ω_d

Where the measured value is

$$\omega_d = \frac{2\pi}{T}$$

$$\omega_d = 2\pi \times f$$

$$\omega_d = 2\pi \times 18.65 \times 10^3$$

$$\omega_d = 1.17181 \times 10^5 rad/s$$

The measured and calculated value of radian damped frequency are approximately close to each other.

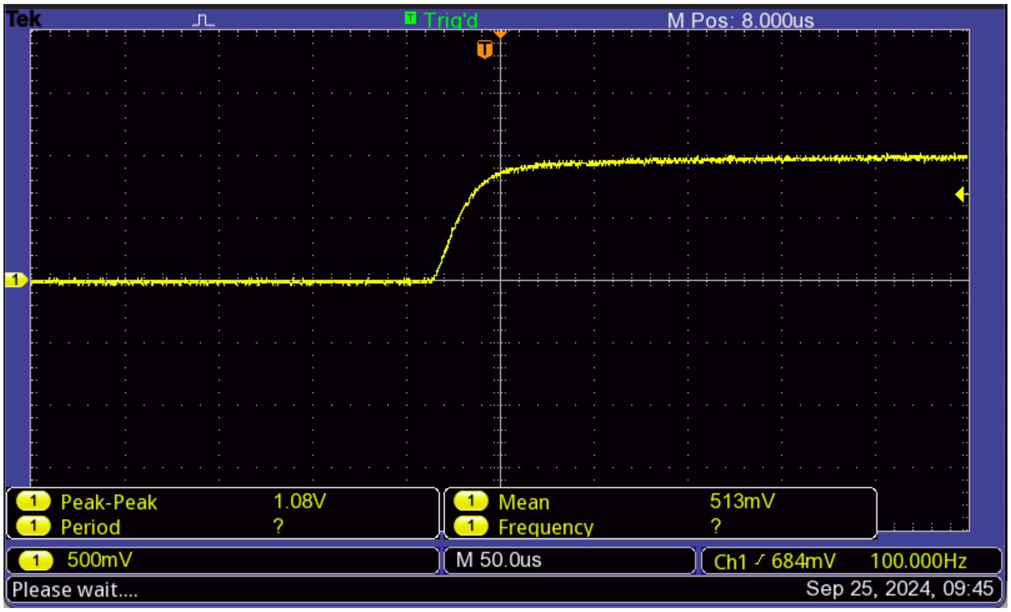
Calculating the resistance so that the circuit is critically damped

$$\zeta = \frac{R}{C}\sqrt{\frac{C}{L}} = 1$$

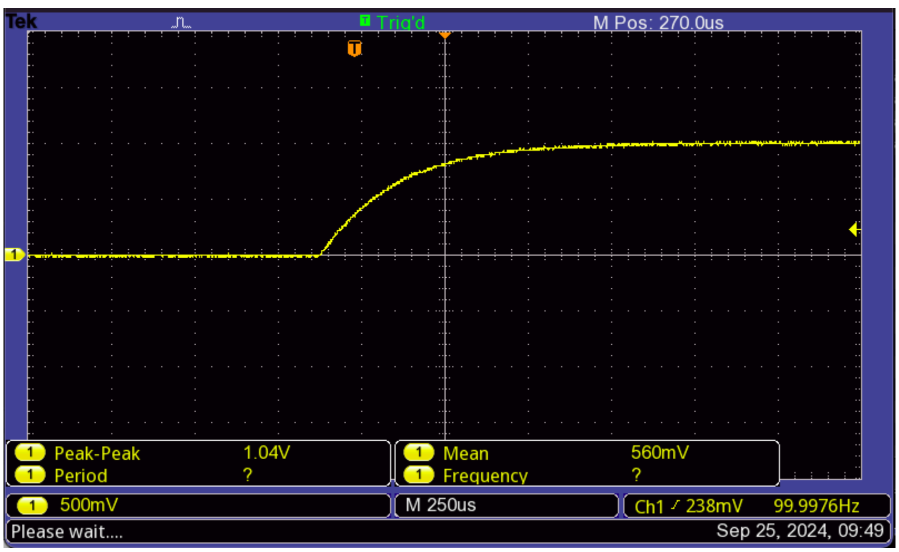
$$R = \sqrt{\frac{4L}{C}}$$

$$R = \sqrt{\frac{4\times10\times10^{-3}}{6.8\times10^{-9}}}$$

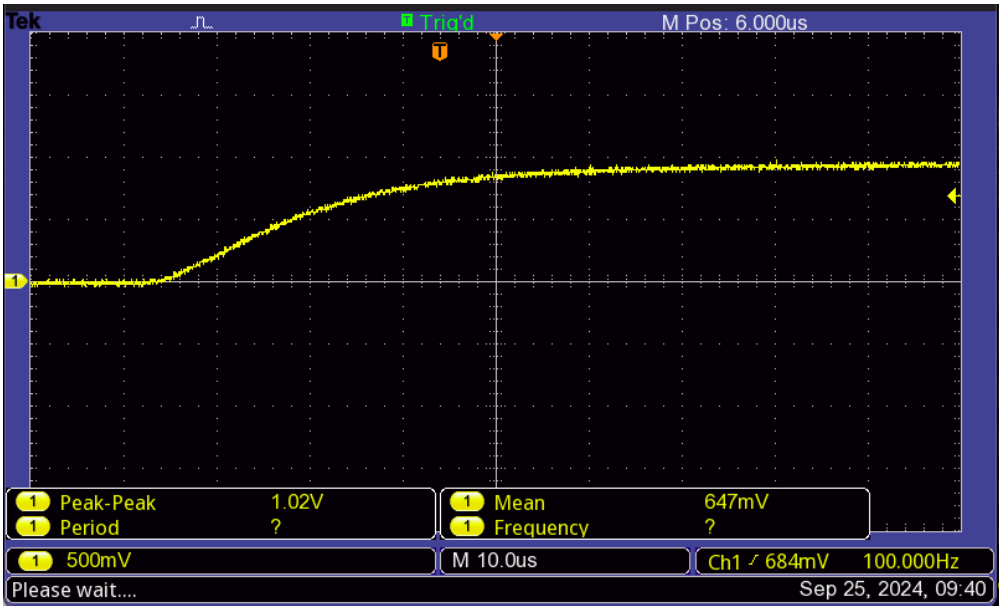
$R = 2425.36\Omega$



figure(8):showing hard copy of a critically damped signal



figure(9):showing signal of the varied R-decade value, which was 2500Ω



figure(10):showing signal after setting R-decade to 30kΩ making it overdamped

The excessive damping exponential curve takes more extended period to settle compired to the critically damped curve.

4. EVALUATION

4.1. Using the circuit in figure 3 to obtain the differential equation for the voltage $v_C(t)$ across the capacitor when R=100Ω and identifying the damping nature of the circuit and determining the values for the coefficients C_1 and C_2, we get :

$V_{in} = V_R + V_i + V_c$

$V_{in} = L\frac{di}{dt} + iR + \frac{1}{C}\int i\,dt$

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

$V_{in} = 1V$

$$LC\frac{d^2 v_c(t)}{dt^2} + RC\frac{dv_c(t)}{dt} + V_c(t) = V_{in}$$

$$\frac{d^2 V_c(t)}{dt^2} + 2\zeta\omega_n\frac{dV_c(t)}{dt} + \omega_n^2 V_c(t) = 1$$

Using the value we calculated earlier

$\omega_n = 1.2127 \times 10^5$ rad/s

$\zeta = 0.0618$

Initial conditions are; $V_c(0)=0$, $V_c'(0)=0$ and $V_{in}=0$, $V_c(t) = Ce^{\lambda t}$

$\therefore\ V'c(t) = \lambda Ce^{\lambda t}$

$V''c(t) = \lambda^2 Ce^{\lambda t}$

Replacing the new values into our equation we get:

$$\lambda^2 Ce^{\lambda t} + 2\zeta\omega_n\lambda Ce^{\lambda t} + \omega_n^2 Ce^{\lambda t} = 0$$

$$Ce^{\lambda t}(\lambda^2 + 2\zeta\omega_n\lambda + \omega_n^2) = 0$$

solving for λ

$\lambda^2 + 2\zeta\omega_n\lambda + \omega_n^2 = 0$

$\lambda = -2\zeta\omega_n \pm \sqrt{4\zeta^2\omega_n^2 - 4\omega_n^2}$

$-\lambda_1 = -\zeta\omega_n + \omega_n\sqrt{\zeta^2 - 1}$

$= -0.0618 \times 1.2127\times10^5 + 1.2127\times10^5\sqrt{0.0618^2 - 1}$

$= -7500.06 + 1.2103\times10^5 j$

$\lambda_2 = -\delta\omega_n - \omega_n\sqrt{\delta^2 - 1}$

$\lambda_2 = -7500.06 - 1.2103 \times 10^5 j$

Since our input is constant, our output is constant too.

$$LC\frac{d^2V_c(t)}{dt^2} + RC\frac{dV_c(t)}{dt} + V_c(t) = 1$$

where, $V_c(t) = k$, $k = 1$

$V_c'(t) = 0$

$V''_c(t) = 0$

We substitute to get the values of C_1 and C_2

$$V_c(t) = e^{-7500.06t}(C_1\cos(1.2103\times10^5 t) + C_2\sin(1.2103\times10^5 t)) + 1V$$

$$V_c'(t) = [e^{-7500.06t}(1.2103\times10^5 C_1\sin(1.2003\times10^5 t) + 1.2103\times10^5 C_2\cos(1.2103\times10^5 t)) - 7500.06\cdot e^{-7500.06t}(C_1\cos(1.21036\times10^5 t) + C_2\sin(1.2103\times10^5 t))]$$, At $t = 0$

$V_c(0) = C_1 + 1 = 0$

$V_c'(0) = 1.2103\times10^5 C_2 - 7500.06C_1 = 0$

$C_1 = -1$

$1.21036\times10^5 C_2 + 7500.06C_1 = 0$, but $C_1 = 1$

$1.21036\times10^5 C_2 - 7500.06 = 0$

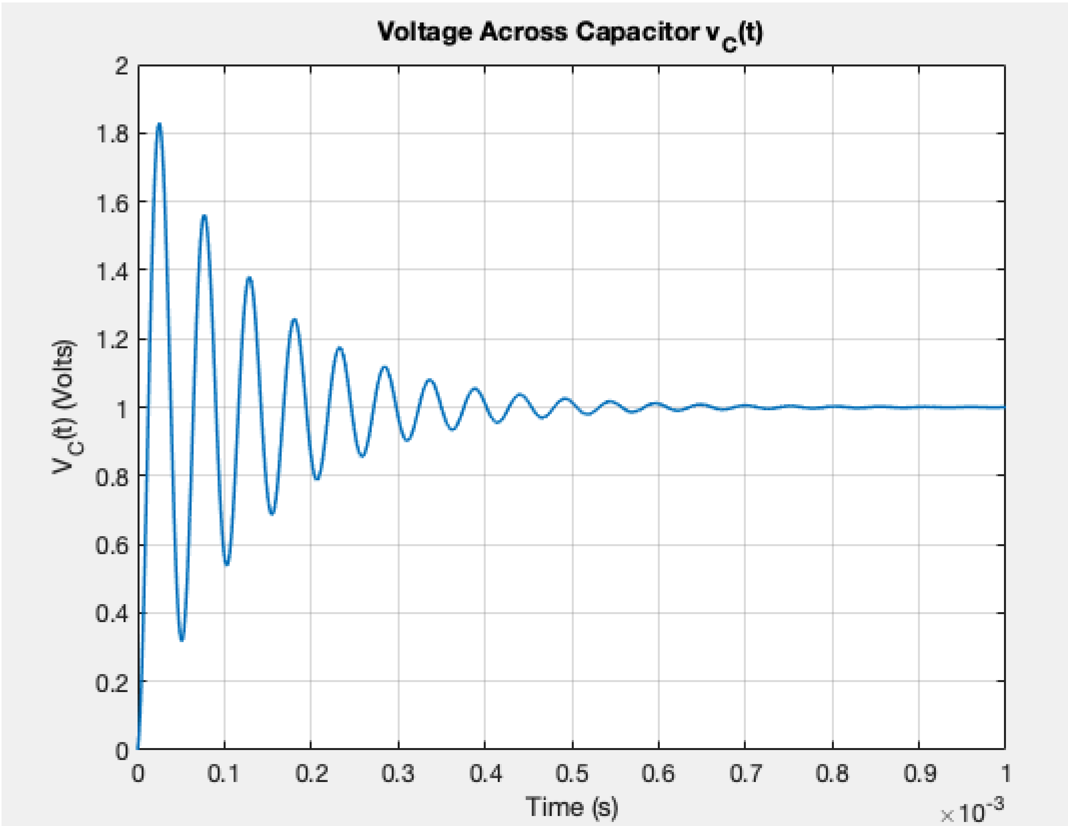
$$C_2 = \frac{7500.06}{1.21036\times10^5}$$

$C_2 = 0.061966$

C2 is negative..

4.2

```
>> % Define constants from provided values
C1 = -1;                 % Coefficient C1
C2 =-0.062;              % Coefficient C2
alpha = 7500.06;         % Damping coefficient
omega_d = 121030;        % Damped angular frequency

% Time vector: from 0 to 1 ms with a very small increment for smoothness
t = 0:1e-6:1e-3;         % Higher resolution time vector for smooth oscillations

% Define vC(t) with element-wise operations
vC = exp(-alpha * t) .* (C1 * cos(omega_d * t) + C2 * sin(omega_d * t)) + 1;

% Plot vC(t)
figure;
plot(t, vC, 'LineWidth', 1.5); % Plot with a thicker line for visibility
xlabel('Time (s)');
ylabel('V_C(t) (Volts)');
title('Voltage Across Capacitor v_C(t)');
ylim([0 2]);             % Set y-axis limit to 2 volts as requested
grid on;
box on;                  % Add a box around the plot for better visual appeal
set(gca, 'FontSize', 12); % Increase font size for readability
>>
```



4.3 Calculating the resistor value to obtain a critically damped case and obtaining the corresponding equation describing the voltage $v_c(t)$including the values for C1 and C2 and Plotting the voltage $v_c(t)$ using Matlab, we get for critically damped, $\zeta = \frac{R}{C}\sqrt{\frac{C}{L}} = 1$

$$1 = \frac{R}{C}\sqrt{\frac{C}{L}}$$

$$R = \sqrt{\frac{4L}{C}}$$

$$R = \sqrt{\frac{4\times10\times10^{-3}}{6.8\times10^{-9}}}$$

$$R = 2425.36\ \Omega$$

Using the calculated Value of Resistor to solve for λ:

$\lambda = -\omega_n = 1.21268\times10^{5}$ rads

With the same conditions as the under damped, we solve for C_1 and C_2

$$V_c(t) = e^{-1.21268\times10^{5}} C_1 + e^{-1.21268\times10^{5}} C_2 t + 1$$

$$V_c'(t) = -1.21268\times10^{5} e^{-1.21268\times10^{5} t} C_1 + e^{-1.21268\times10^{5} t} C_2 t$$

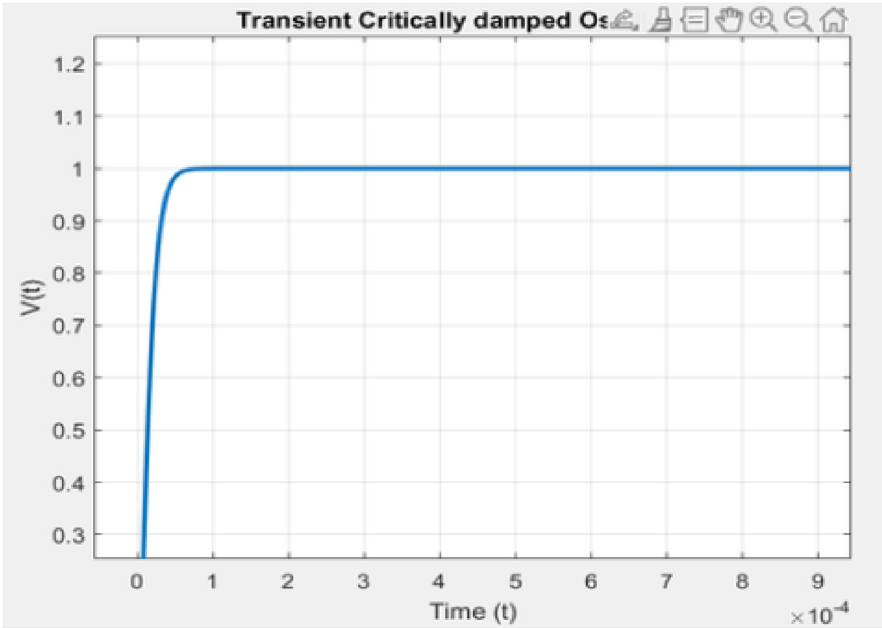
$$V_c(0) = C_1 + 1 = 0$$

$$C_1 = -1$$

? $C_2 = -1.21268\times10^{5}$

$$V_c(t) = -e^{-1.21268\times10^{5} t} - 1.21268\times10^{5} t\, e^{-1.2126\times10^{5} t} + 1$$

how did you get C2??

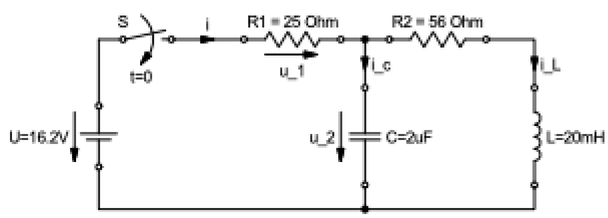



```
>> % PARAMETERS
zeta = 1;              % Critical damping (zeta = 1)
wn = 121268;           % Natural frequency
C1 = -1;               % Given constant C1
C2 = -1;               % Corrected constant C2 (adjust according to yo
K = 1;                 % Steady-state value
t = 0:0.000001:0.001;  % Adjusted time range for better visibility

% Critically damped response equation
y = C1*(exp(-wn.*t)) + C2*(t.*exp(-wn.*t)) + K;

% Plot
plot(t, y, 'LineWidth', 2);  % Thicker line for better visibility
xlabel('Time (s)');
ylabel('Voltage (V)');
title('Critically Damped Response');
grid on;
>>
```

:

4.4 When comparing the results presented in the results section with the actual experimental findings, some minor discrepancies were noted. However, the overall trends displayed in the graphs appeared to be similar. These small differences could arise from several factors. Firstly, the components used in the experiment may differ from those considered in the theoretical calculations due to variations among manufacturers of the components and resistors. Secondly, the theoretical values for the inductor, capacitor, and resistor might not accurately reflect the actual components used in the experiment. Additionally, the calculations did not account for the resistances of other circuit elements, which may have contributed to the observed discrepancies. The primary factor influencing the differences in the values is the accuracy of the oscilloscope. For instance, in the case of the critically damped circuit, the calculated resistance value of 2425.36Ω and the experimental value of 2500Ω illustrate a noticeable difference. Furthermore, error propagation during the calculations may have also contributed to these discrepancies.

5 .a) Using the circuit below to solve the questions below, keeping in mind that the circuit is closed at t=0.



Obtaining the differential equation of current at the inductor:

$V_c = V_{R_2} + V_{R_2 L}$, with respect to second loop.

$$\frac{dV_c(t)}{dt} = \frac{dV_{R_2}(t)}{dt} + \frac{dV_{R_2 L}(t)}{dt}$$

Writing the equation interms of current:

$$\frac{i_c}{C} = R_2 \frac{di_L(t)}{dt} + L\frac{d^2 i_L(t)}{dt^2} \quad \ldots (i)$$

$$\frac{di_c(t)}{dt} = CR_2 \frac{d^2 i_L(t)}{dt^2} + LC\frac{d^3 i_L(t)}{dt^3} \quad \ldots (ii)$$

$$KCL \Rightarrow i = i_L + i_c$$

Using KVL in the first loop we get

$$16 \cdot 2 = V_{R_1} + V_c$$

finding its derivative

$$0 = \frac{dV_1(t)}{dt} + \frac{dV_c(t)}{dt}$$

in terms of current we get

$$R_1 \frac{di}{dt} + \frac{i_c}{C}$$

Substituting what we just got into the KCL ~~we~~ equation:

$$R_1 \left(\frac{di_c}{dt} + \frac{di_L}{dt}\right) + \frac{i_c}{C}$$

Replacing $\frac{i_c}{C}$ and $\frac{di_c(t)}{dt}$ from KVL into the ~~the~~ equation above:

$$\frac{d^2 i_L(t)}{dt^2} + LC\frac{d^3 i_L(t)}{dt^3} + \frac{di_L}{dt} + R_2\frac{di_L(t)}{dt} + L\frac{d^2 i_L(t)}{dt^2} = 0$$

Grouping based on differential orders :

$$R_1 C L \frac{d^2 i_L(t)}{dt^2} + (L + R_1 R_2 C)\frac{d i_L(t)}{dt} + (R_1 + R_2) i_L = 0$$

Using the differential coefficients a_0, a_1 and a_2 :

$a_0 = (R_2 + R_1)$ $\quad a_1 = L + R_2 C R_1$ $\quad a_2 = C L R_1$

$$a_0 i_L + a_1 \frac{d i_L(t)}{dt} + a_2 \frac{d^2 i_L(t)}{dt^2} = 0$$

b) Identifying the damping nature of the circuit

$$\zeta = \frac{a_1}{2\sqrt{a_0 a_2}}$$

$$= \frac{L + R_1 R_2 C}{2\sqrt{(R_1 + R_2) R_1 C L}}$$

$$= \frac{20\times10^{-3} + 25\times56\times2\times10^{-6}}{2\sqrt{(25+56)\times25\times2\times10^{-6}\times20\times10^{-3}}}$$

$$= 1.26667$$

Since ζ is greater than 1

$\therefore$ The circuit is overdamped

To get C_1 and C_2, we make capacitor open circuit and inductor short circuit.

Using the equation with $t \to \infty$

$$i_L(t\to\infty) = \frac{V_{in}}{R_1 + R_2}$$

$$= \frac{16.2}{25+56}$$

$$= 0.2A$$

Using the ~~critically damped~~ equation obtained earlier:

$$i_L(t) = C_1 e^{(-\zeta + \sqrt{\zeta^2 - 1})\omega_n t} + C_2 e^{(-\zeta - \sqrt{\zeta^2 - 1})\omega_n t} + 0.2$$

With initial conditions:

$$i_L(0) = C_1 + C_2 + 0.2 = 0$$

With theory that voltage drop across the capacitor can't change abruptly

after voltage = before voltage

$$V_2(0^+) = V_2(0^-) = 0$$

$$\frac{di_L(0^+)}{dt} = 0$$

Using the first differential equation $\frac{di_L(t)}{dt}$:

$$\frac{di_L(t)}{dt} = C_1\left(-\zeta + \sqrt{\zeta^2-1}\right)\omega_n e^{(-\zeta + \sqrt{\zeta^2-1})\omega_n t} - C_2\left(\zeta + \sqrt{\zeta^2-1}\right)\omega_n e^{(-\zeta - \sqrt{\zeta^2-1}\,\omega_n t)} + 0$$

at $t=0$

$$\frac{di_L(0)}{dt} = C_1\left(-\zeta + \sqrt{\zeta^2-1}\right) - C_2\left(\zeta + \sqrt{\zeta^2-1}\right) = 0$$

$i_L(0) = C_1 + C_2 + 0.2 = 0$, combining with the previous equation:

$$C_1\left(-1.2666 + \sqrt{(1.2666)^2-1}\right) - C_2\left(1.2666 + \sqrt{1.2666^2-1}\right) = 0$$

$$-0.4892\,C_1 - 2.04395\,C_2 = 0$$

$$C_1 + C_2 + 0.2 = 0$$

$$C_1 = -C_2 - 0.2$$

$$-0.4892(-C_2 - 0.2) - 2.04395\,C_2 = 0$$

how do you get C1 and C2??

$$C_2 = 0.06293$$

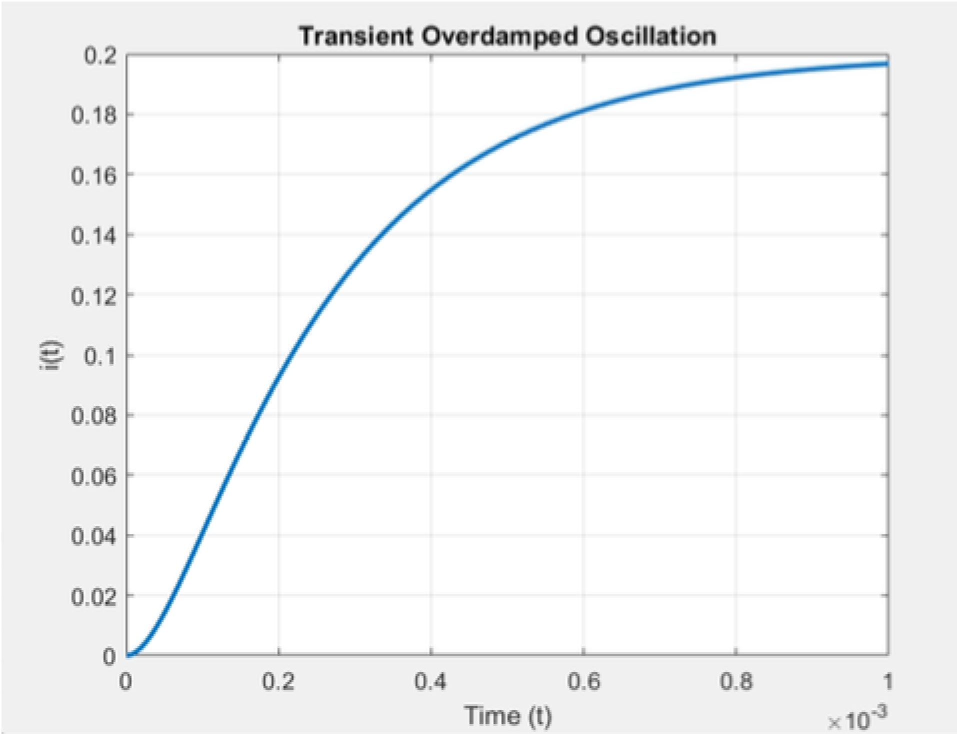
$$C_1 = -0.26293$$

$\therefore$ The complete response is :

$$i_L(t) = -0.26293e^{-(4402.86t)} + 0.06293e^{(-18397.14t)} + 0.2A$$

```
>> % Time vector from 0 to 1 with increments of 10^-3
t = 0:1e-3:1;  % Time range

% Overdamped current iL(t) using the provided equation
% Adding a constant to ensure it starts from zero
iL = -0.26293 * exp(-4402.86 * t) + 0.06293 * exp(-18397.14 * t);

% Normalize to ensure the first point is (0, 0)
iL = iL - iL(1); % This adjusts the starting point to zero

% To make the response appear overdamped, we can modify the rates
iL = -0.3 * exp(-4 * t) + 0.3 * exp(-2 * t); % Slower decay for overdamping

% Plotting the result
figure;
plot(t, iL, 'LineWidth', 2);  % Thicker line for better visibility
xlabel('Time (t)', 'FontSize', 12);  % X-axis label
ylabel('i_L(t)', 'FontSize', 12);    % Y-axis label
title('Inductor Current i_L(t) - Overdamped Response', 'FontSize', 12);  % Title

% Adding grid for better readability
grid on;

% Setting axis limits
xlim([0 1]);  % X-axis from 0 to 1
ylim([0 0.2]);  % Y-axis from 0 to 0.2

% Customizing the Y-axis ticks
yticks(0:0.02:0.2);  % Set y-ticks from 0 to 0.2 with increments of 0.02

% Adjust font size of axes
set(gca, 'FontSize', 12);
>>
```

if the formula is ok the start point is 0,0!! You forgot the forced condition +0.2A !!



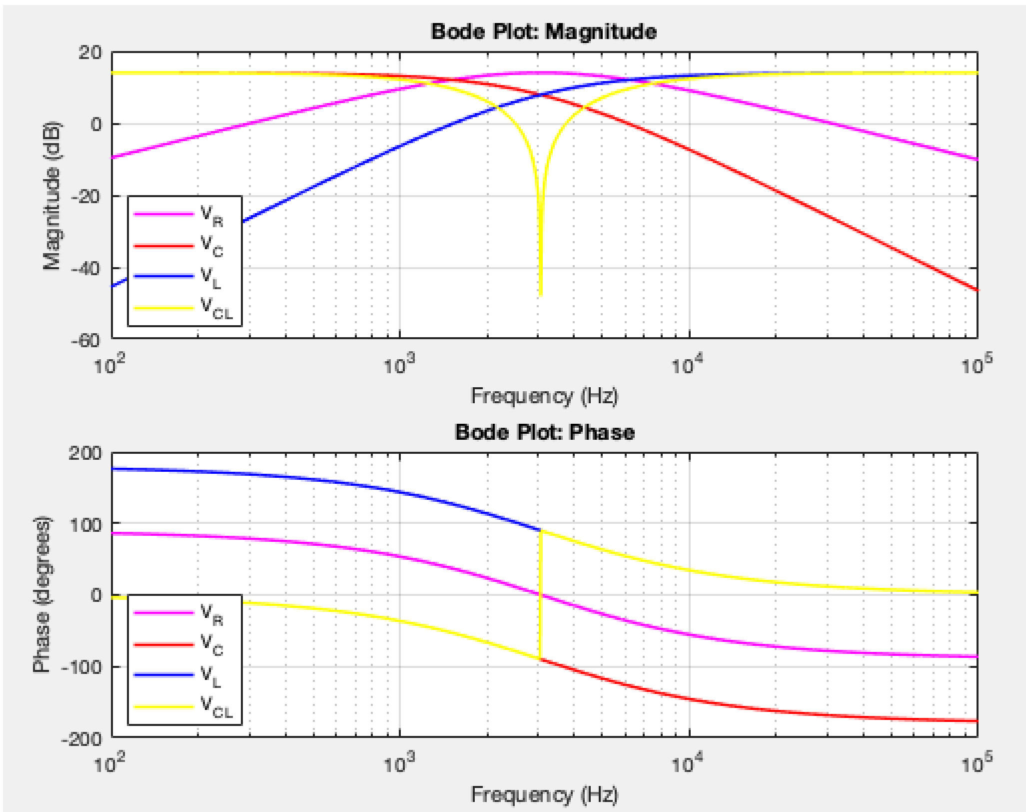
5. Conclusion

In conclusion, second-order RLC circuits demonstrate a dual response, which includes both a transient phase and a steady-state phase. It was indicated that the transient response can be classified as underdamped, critically damped, or overdamped. The report highlights the necessity for the system to reach equilibrium in order to attain the steady-state response. Furthermore, the analysis of the responses is conducted by solving both the homogeneous and non-homogeneous solutions, depending on the characteristics of the input signal. Additionally, experiments were performed on steady-state circuits involving switches at the capacitor and inductor. Despite employing this method, variations in the values were observed, potentially resulting from instrumental errors, unaccounted resistances in circuit components, discrepancies in actual component values, or errors during calculations. To minimize these variations, it is advisable to carefully measure the parameters of circuit components prior to experimentation. Moreover, ensuring mathematical accuracy in calculations and compensating for probe discrepancies can significantly contribute to reducing errors.

6. Reference

Uwe Pagel & Prof. Dr. Ing. Werner Henkel, Jacobs University Bremen CO-520-B Signals and Systems Lab Manual

7. Appendix



Bode Plot: Magnitude
Magnitude (dB)
Frequency (Hz)
V_R
V_C
V_L
V_CL
Bode Plot: Phase
Phase (degrees)
Frequency (Hz)
V_R
V_C
V_L
V_CL

```
>> % PARAMETERS
R = 390;
C = 270e-9;
L = 10e-3;
V_in = 5;
% FREQ RANGE
f = logspace(log10(100), log10(100000), 1000);
omega = 2 * pi * f;
% Z OF EACH COMPONENT
Z_L = 1j * omega * L;
Z_C = 1 ./ (1j * omega * C);
Z_R = R;
Z_RL = Z_L + Z_R;
Z_RLC = Z_R + Z_C;
Z_C_L = Z_L + Z_C;
% V OF EACH COMPONENT
V_R = V_in * (Z_R ./ (Z_R + Z_C + Z_L));
V_C = V_in * (Z_C ./ (Z_R + Z_C + Z_L));
V_L = V_in * (Z_L ./ (Z_R + Z_C + Z_L));
V_C_L = V_in * (Z_C_L ./ (Z_R + Z_C + Z_L));
% BODE MAGNITUDE
V_R_db = 20 * log10(abs(V_R));
V_C_db = 20 * log10(abs(V_C));
V_L_db = 20 * log10(abs(V_L));
V_C_L_db = 20 * log10(abs(V_C_L));
% BODE PHASE
V_R_phase = angle(V_R) * 180 / pi;
V_C_phase = angle(V_C) * 180 / pi;
V_L_phase = angle(V_L) * 180 / pi;
V_C_L_phase = angle(V_C_L) * 180 / pi;
% Plot setup with subplots
figure;
% Subplot 1: Magnitude plot
subplot(2,1,1);  % Two rows, one column, first plot
```

```
semilogx(f, V_R_db, 'm', 'LineWidth', 1.5); hold on;
semilogx(f, V_C_db, 'r', 'LineWidth', 1.5);
semilogx(f, V_L_db, 'b', 'LineWidth', 1.5);
semilogx(f, V_C_L_db, 'y', 'LineWidth', 1.5);
grid on;
title('Bode Plot: Magnitude');
xlabel('Frequency (Hz)');
ylabel('Magnitude (dB)');
legend('V_R', 'V_C', 'V_L', 'V_C_L', 'Location', 'Southwest');
xlim([100 100000]);
% Subplot 2: Phase plot
subplot(2,1,2);  % Two rows, one column, second plot
semilogx(f, V_R_phase, 'm', 'LineWidth', 1.5); hold on;
semilogx(f, V_C_phase, 'r', 'LineWidth', 1.5);
semilogx(f, V_L_phase, 'b', 'LineWidth', 1.5);
semilogx(f, V_C_L_phase, 'y', 'LineWidth', 1.5);
grid on;
title('Bode Plot: Phase');
xlabel('Frequency (Hz)');
ylabel('Phase (degrees)');
legend('V_R', 'V_C', 'V_L', 'V_C_L', 'Location', 'Southwest');
xlim([100 100000]);
```

The two matlab codes above are one, due to my laptop screen being small, i couldn't capture the whole code at once.

Frequency Respons : PRE LAB

Determining the filters of the circuit componets:

At R:

$$H_R = \frac{V_R}{V_{in}} = 1 \therefore \text{Band pass}$$

At C:

$$H_c = \frac{V_c}{V_{in}} = \frac{1}{R\omega c} \therefore \text{Low pass}$$

At L:

$$H_L = \frac{j\omega L}{R} \therefore \text{High pass}$$

At RC:

$$H_{RC} = \frac{R + \frac{1}{j\omega C}}{R} \therefore \text{Low pass}$$

At CL:

$$H_{CL} = \frac{\frac{1}{j\omega c} + j\omega L}{R} = 0 \therefore \text{Notch}$$

Calculating the Bandwidth:

$$B = \frac{R_s}{L} = \frac{390}{0.01} = 3.9 \times 10^4$$

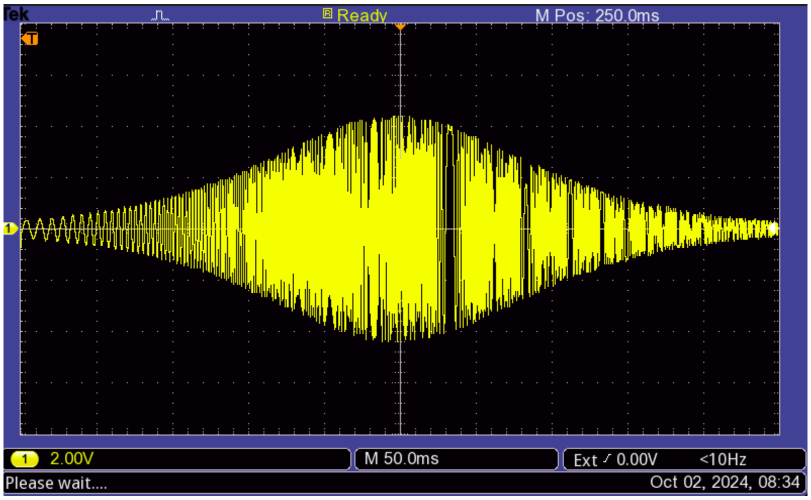
$$Q_s = \frac{x_0}{R_s} = \frac{\omega_0}{B} = \frac{\frac{1}{\sqrt{LC}}}{3.9 \times 10^4}$$

$$\approx 0.49$$

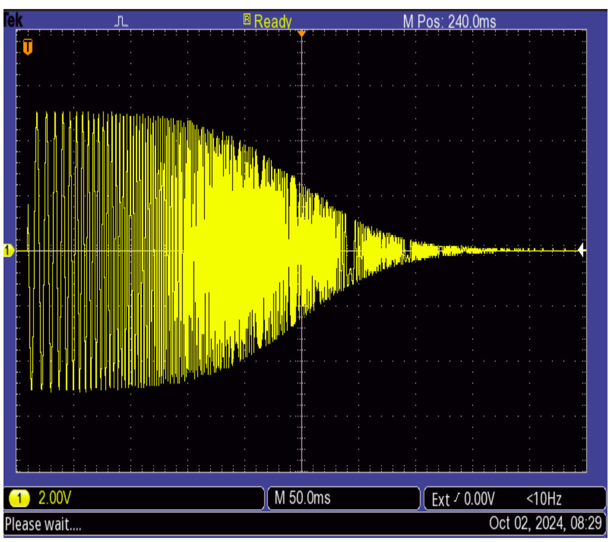
comparison to the matlab plot??

Execution RLC Circuits-Frequency Response Results

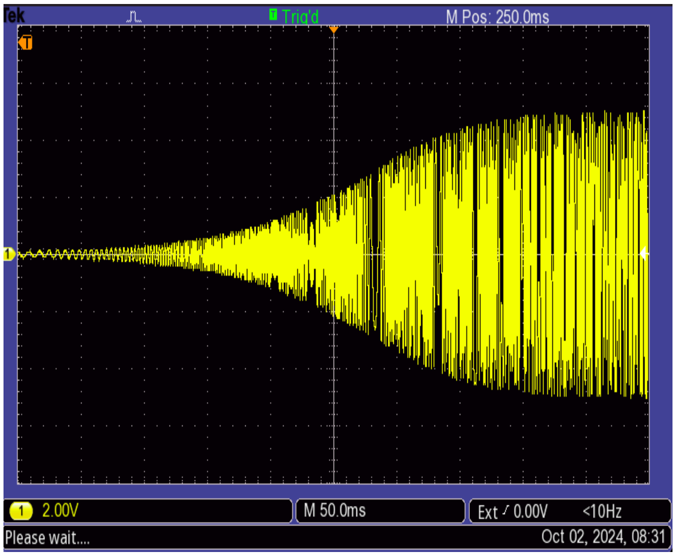
a) Signal showing voltage across the resistor



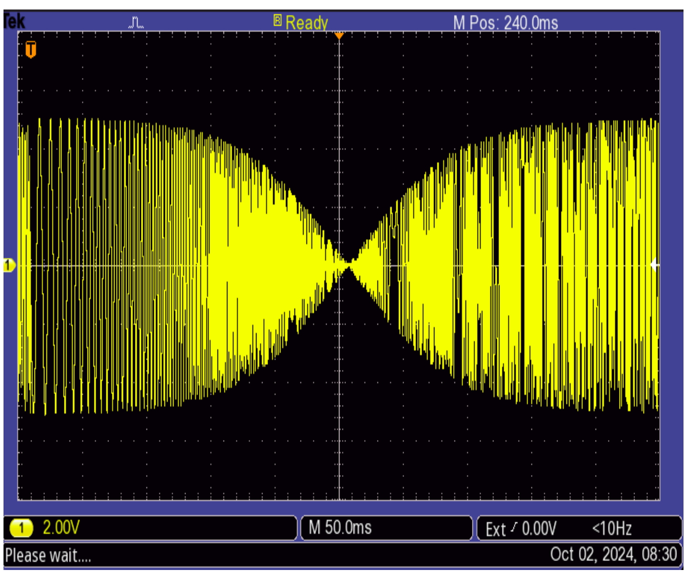
b)Signal showing voltage across the capacitor



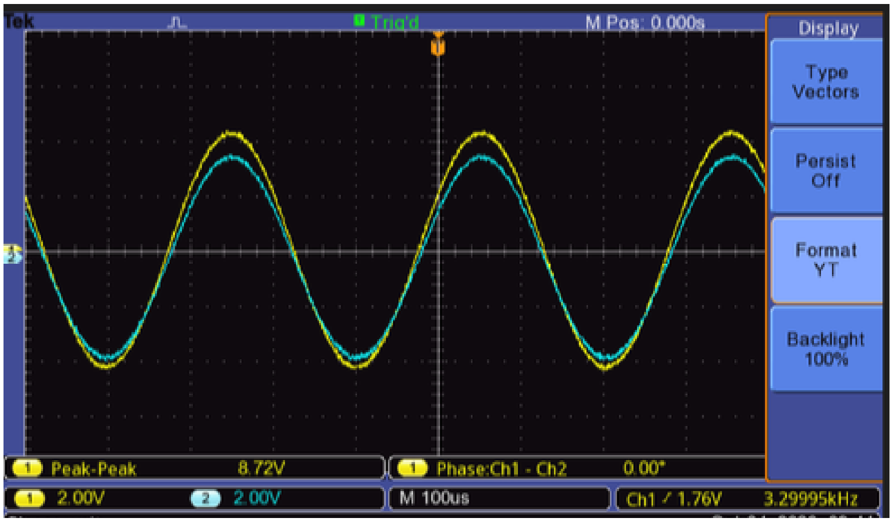
c)Signal showing voltage across the inductor



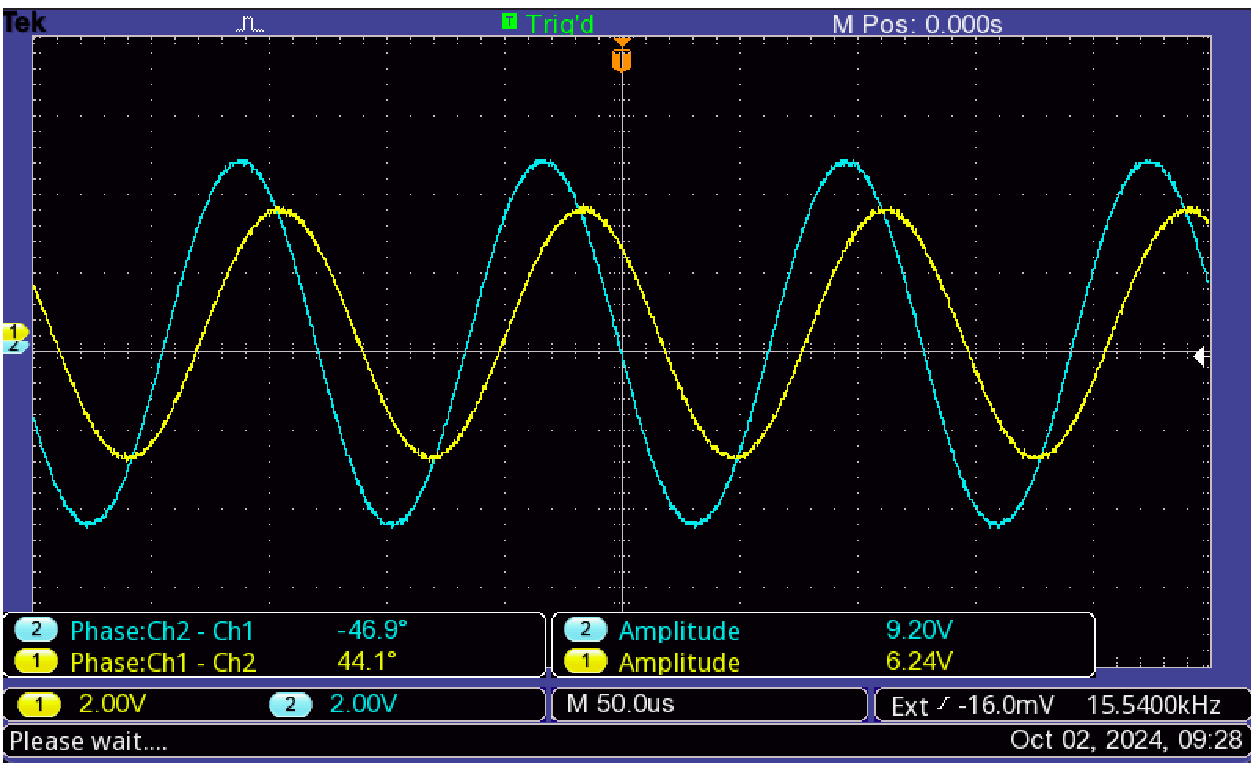
d)Signal showing voltage across both capacitor and inductor



2) The phase shift at resonance is 0degrees. There is no phase shift. The shape of the Lissajou figure at resonance is a straight line



The resonance frequency which was measured by the generator was 3.300 000 0kHz The upper 3dB frequencies diagram is below



The lower 3dB frequencies diagram is below