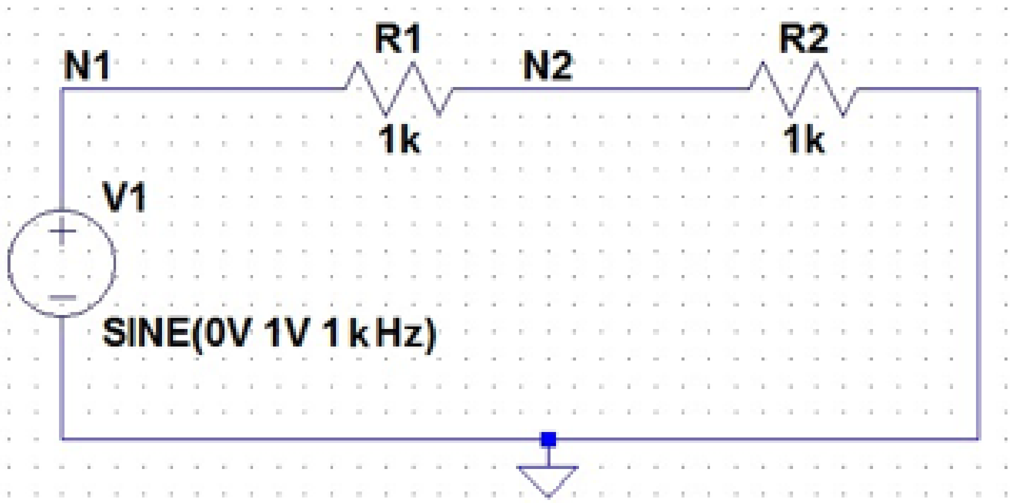
Name: __________Ebagnisev Sahiv LopezBorja_______________

# EEE 202 Lab 6 Data Sheet
# AC Analysis

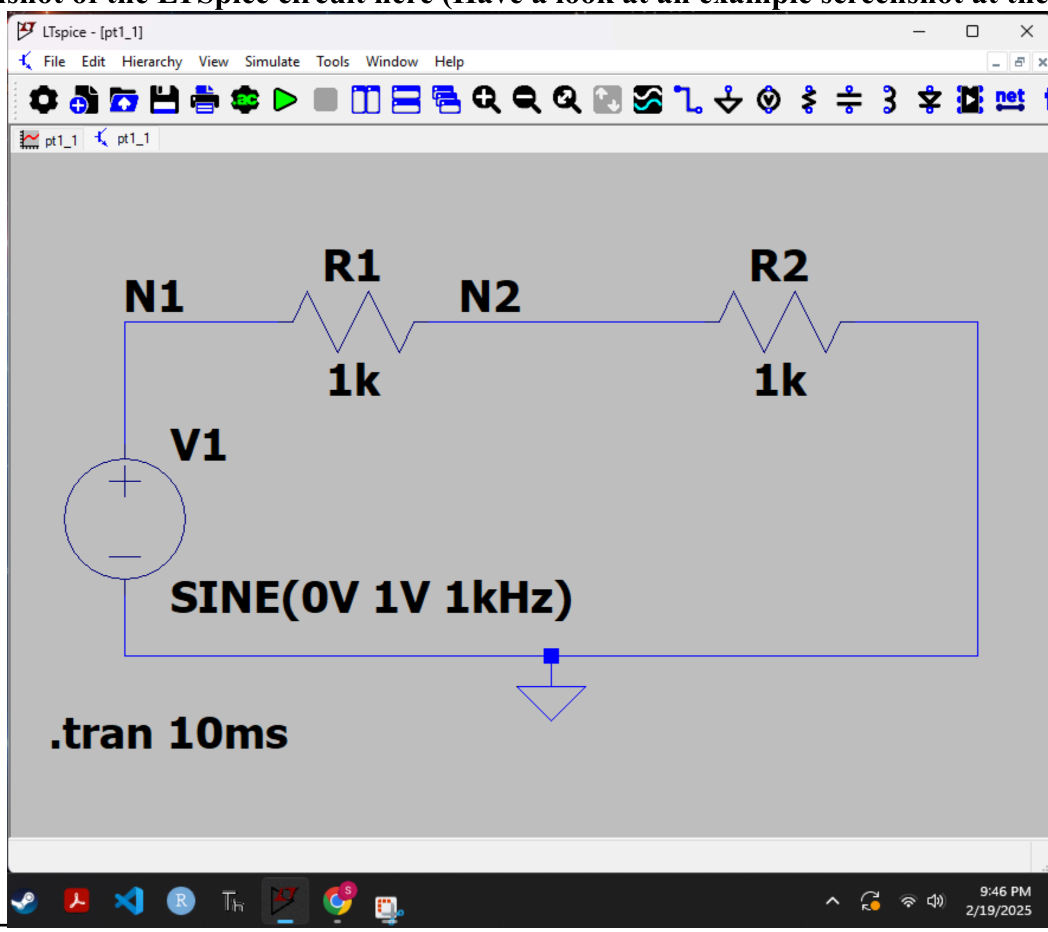
**Part 1 (15 pts): Prelab Calculations and LTSpice Simulation Work**

**Question 1 – Resistive Circuits**

**Build this circuit in LTspice and run a Transient Analysis (.tran) for 10ms:**

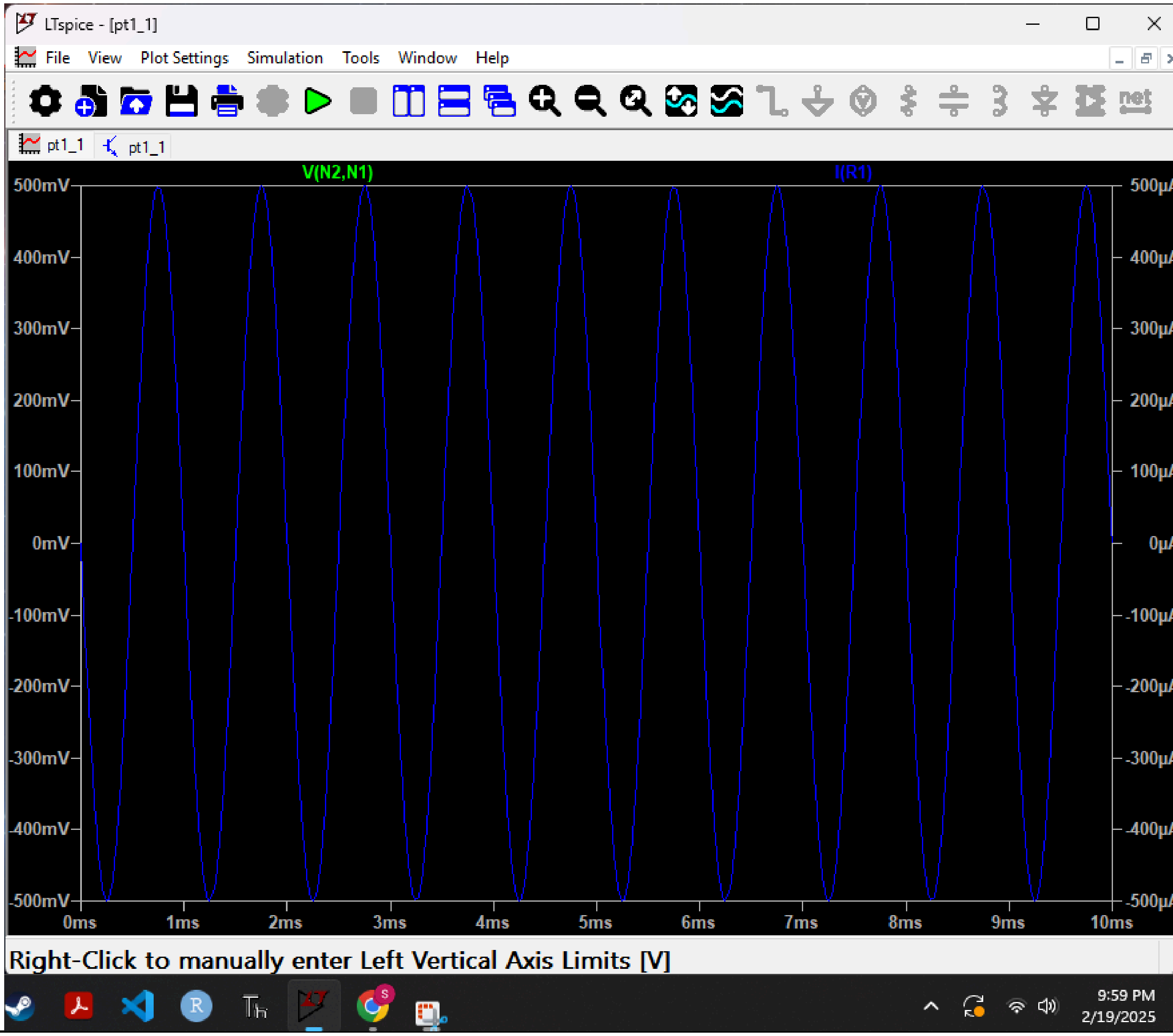



**Include a screenshot of the LTSpice circuit here (Have a look at an example screenshot at the end of this document):**



**Simulate in LTspice. Plot the voltage across R1 (N1-N2) and the current (left to right). Make sure the voltage and current curves are plotted on the same plot.**

**Screenshot of LTSpice Plot - Make sure that your computer's date and time are showing up in your screenshot:**




**Is the current in-phase or out-of-phase with the voltage? Why do you think this is the case?**

**The current and voltage are in phase. This is the case because our circuit only has resistors and this keeps it in phase.**

**Question 2 (RC – Pulse Source):**

**a) What is the expression for the current, *i*(*t*):**

**Show your steps.**

**Steps (handwritten or typed):**

**V_i(0) = 0V**
**V_c(0-) = V_c(0+)**
**i_(0+) = 1V / 100 Ohms = 0.01 A**

**i(t) = K_1 + K_2 e^(-t/tau)**

**0.01A = K_1 + K_2 so we have i(t) = 0.01e^(-t/tau)**

**tau = R_thev * C**

**i(t) =** $0.01e^{-t/0.00001}$

**b) What are the expressions for the voltages across the resistor, $v_R(t)$ and the capacitor, $v_C(t)$:**

**Show your work.**

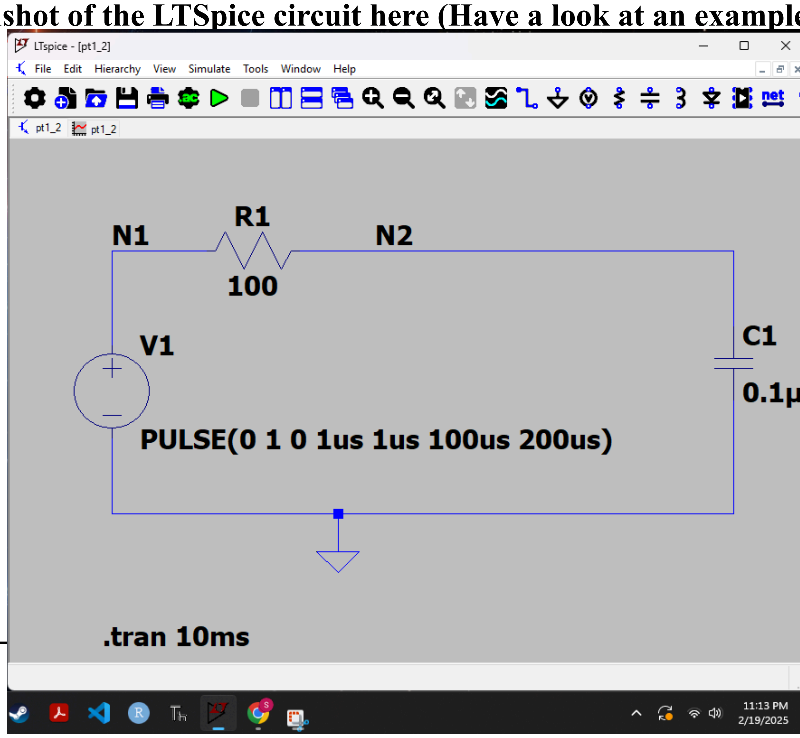
**Steps (handwritten or typed):**

**$v_R$(t) = i(t) * R =** $e^{-t/0.00001}$

**$v_C$(t) = V_in - $v_R$(t) =** $1 - e^{-t/0.00001}$

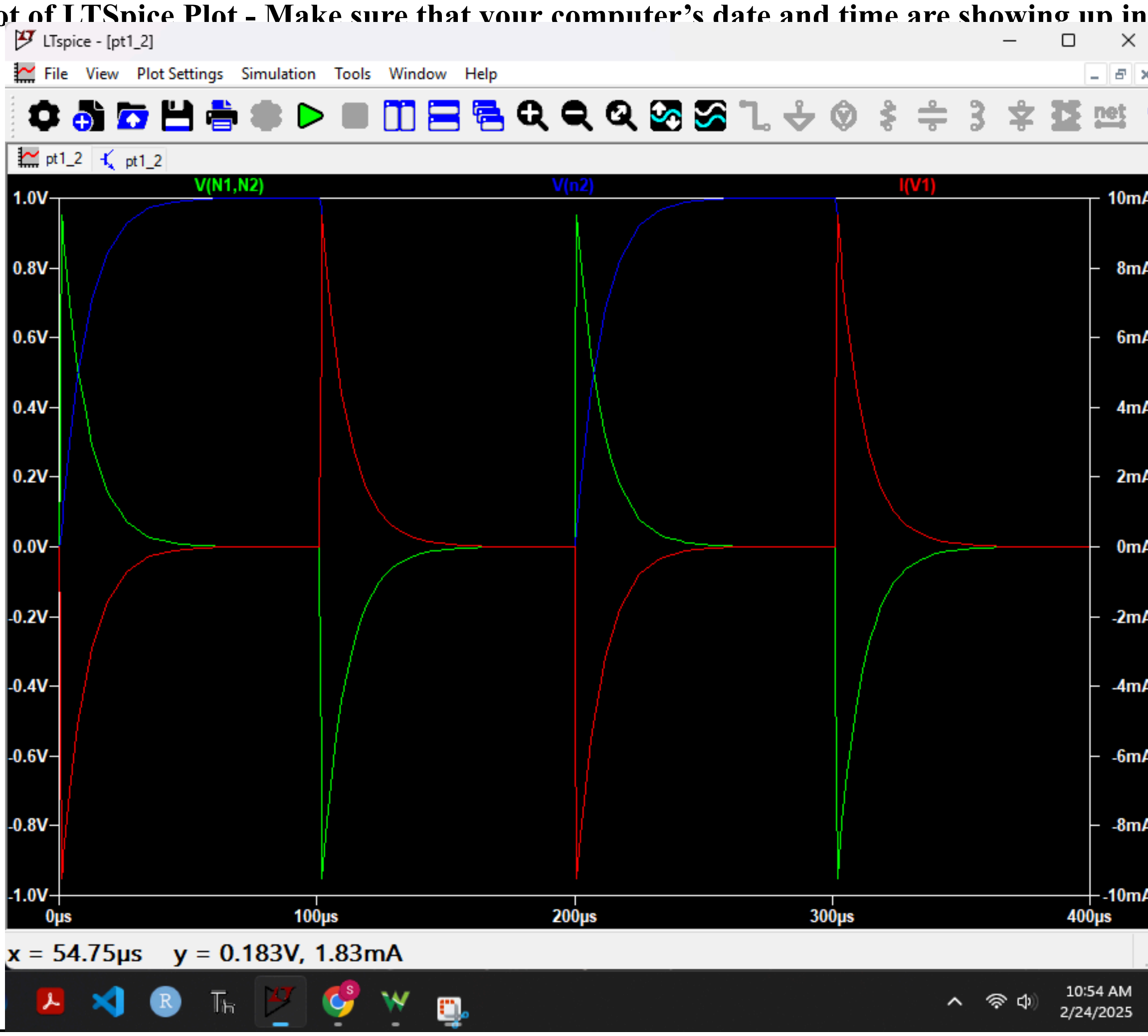
**c) Create a simulation of your RC circuit in LTSPICE.**

**Include a screenshot of the LTSpice circuit here (Have a look at an example screenshot at the end of this document):**



**d) Create plots of your RC circuit in LTSPICE (*i(t), $v_R(t)$, and $v_C(t)$ all on the same plot*)**

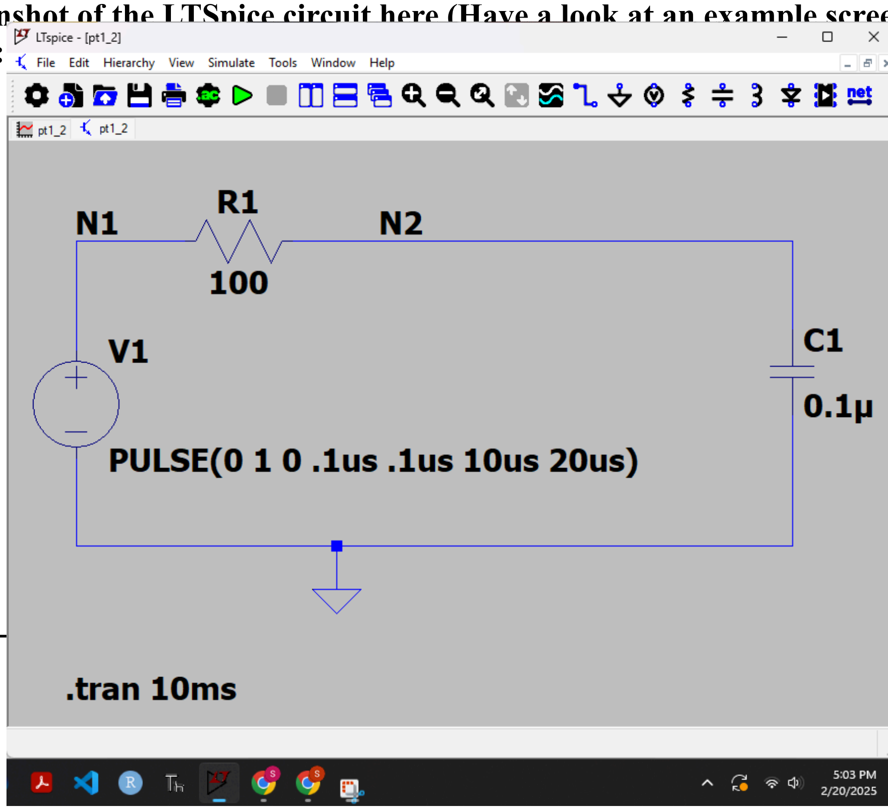
**Screenshot of LTSpice Plot - Make sure that your computer's date and time are showing up in your:**




**e) Repeat the LTSpice simulations you carried out in question 1 but with tON, rise time, fall time, and the period all <u>reduced by a factor of 10.</u>**

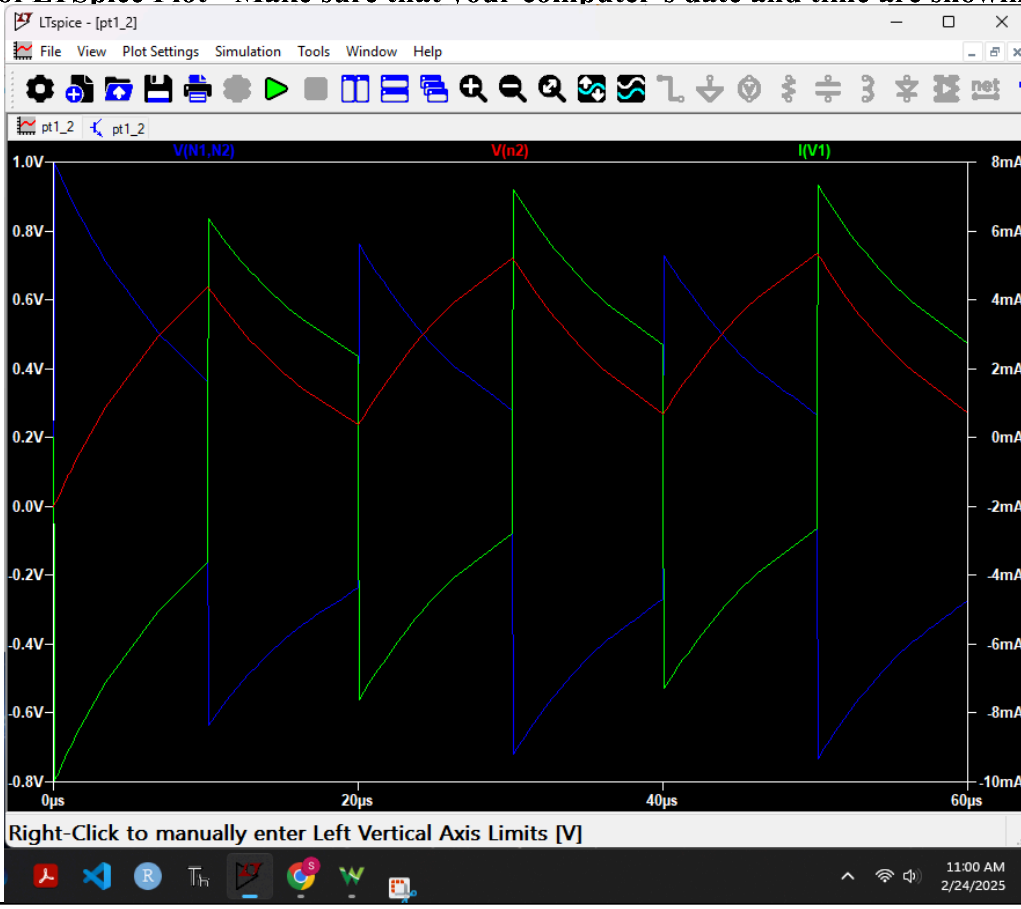
a) LTSpice circuit schematic screenshot

**Include a screenshot of the LTSpice circuit here (Have a look at an example screenshot at the end of this document):**



b) Include the plot of i(t), $v_R(t)$, and $v_C(t)$ (all on the same plot).

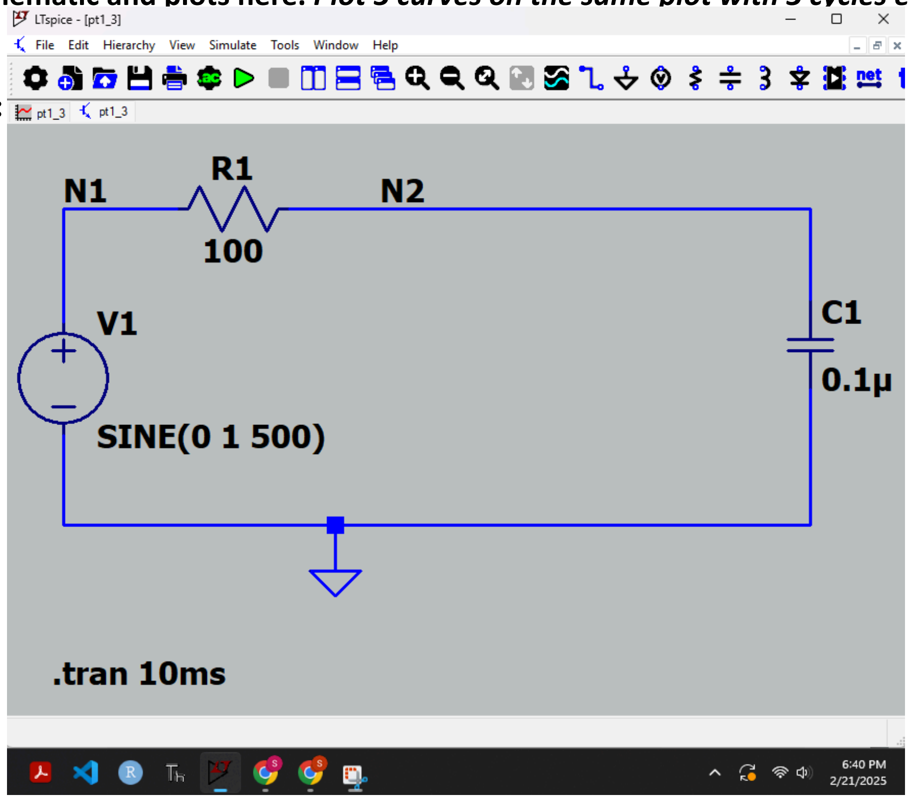
**Screenshot of LTSpice Plot - Make sure that your computer's date and time are showing up in your screenshot:**



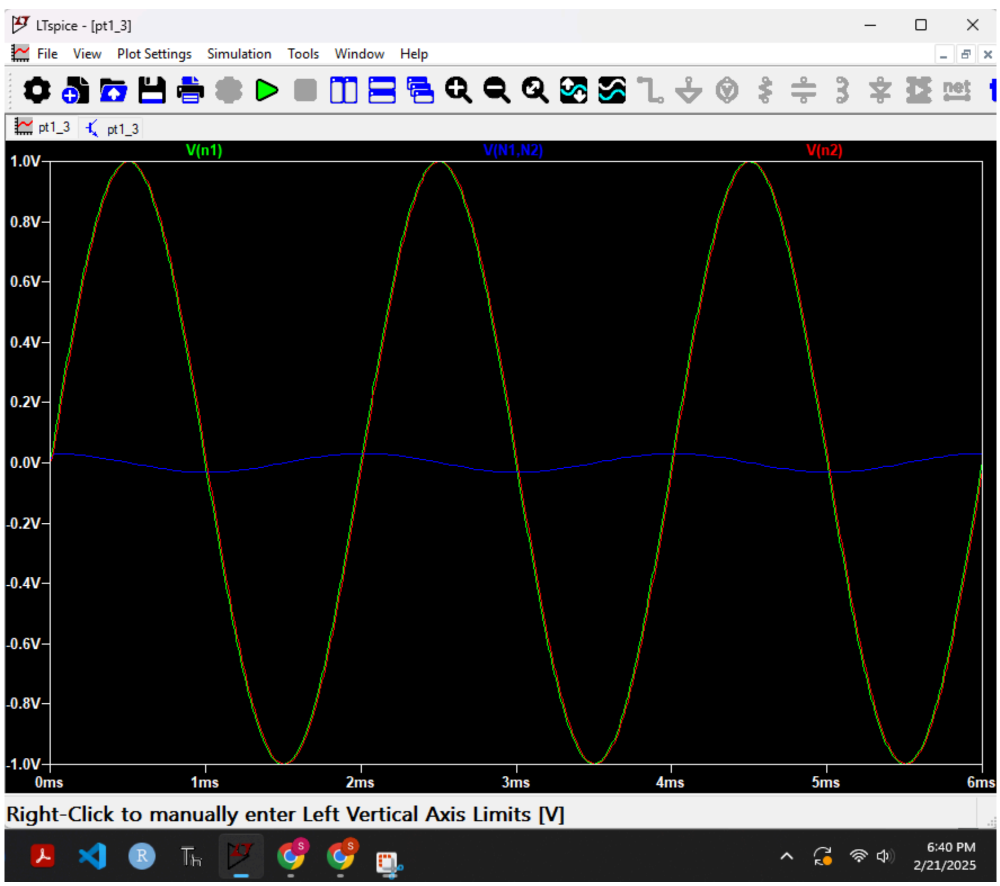
**Question 3 – RC – Sinusoids):**

a) **Create a simulation of your RC circuit and plots of ($v_S(t)$, $v_R(t)$, and $v_C(t)$) in LTSPICE and attach the images of your schematic and plots here.** ***Plot 3 curves on the same plot with 3 cycles each.***

**Screenshot of schematic:**




**Screenshot of plot:**



***b)*** **Magnitude difference between** $v_S(t)$ ***and*** $v_C(t)$ **=** ______________***0.5***______________ ***mV***

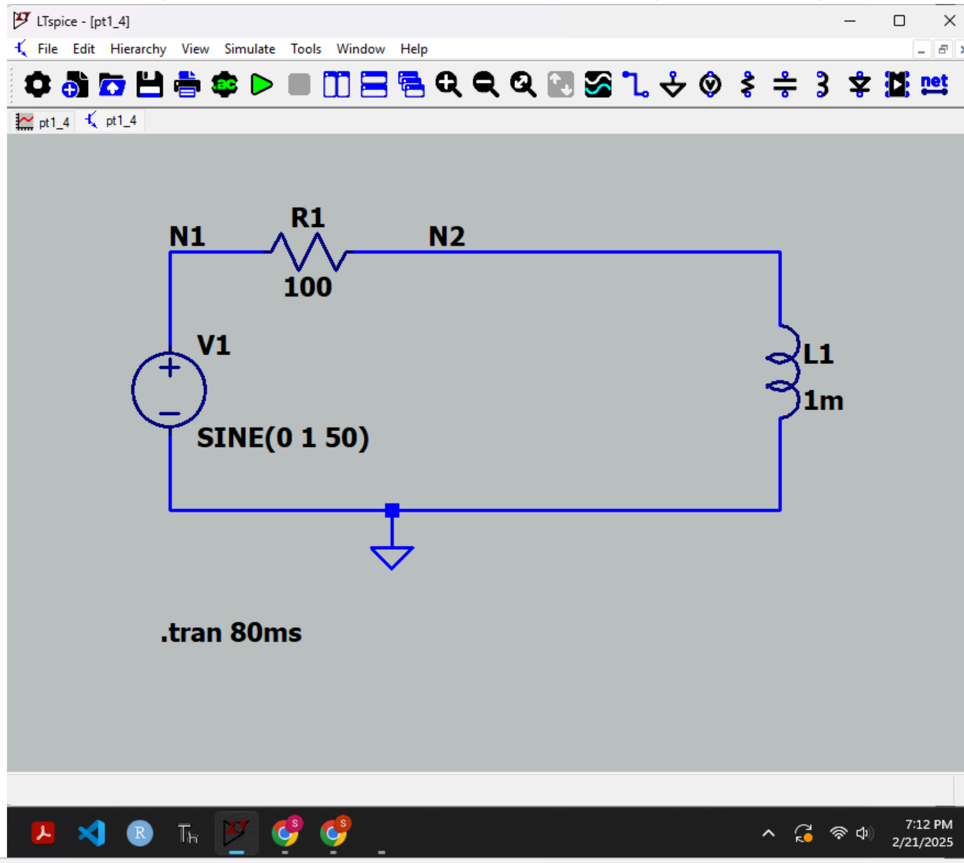
**Phase difference between** $v_S(t)$ ***and*** $v_C(t)$ **=** ______________***1.98***_______________ ***Degrees***

***(Δ t = 511.05-500.05)***

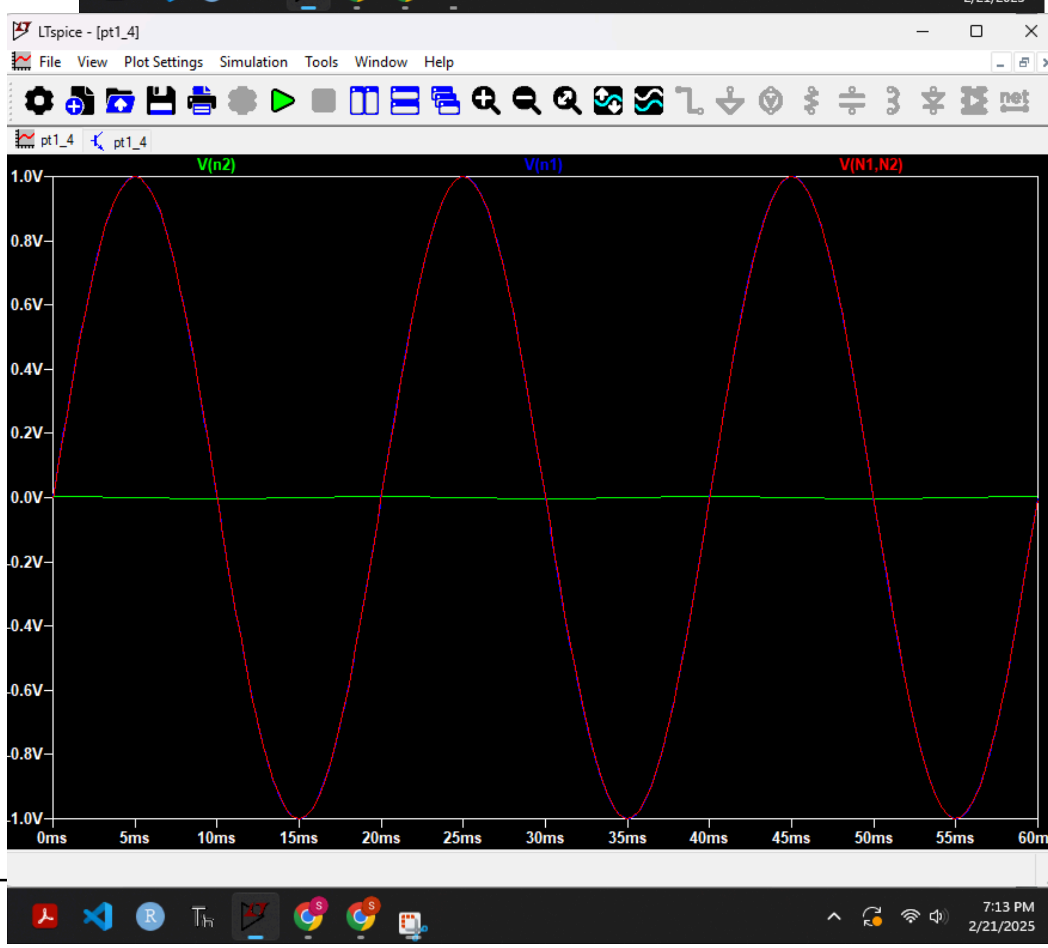
**Question 4 – RL Circuits – Sinusoidal Source:**

a) **Create a simulation of your RL circuit and plots of ($v_S(t)$, $v_R(t)$, and $v_L(t)$) in LTSPICE and attach the images of your schematic and plots here. *Plot 3 curves on the same plot with 3 cycles each*.**

**Screenshot of schematic:**




**Screenshot of plot:**



***b)*** **Magnitude difference between $v_S(t)$ *and* $v_L(t)$ =** ___________***0.9968***_______________ ***Volts***

**Phase difference between $v_S(t)$ *and* $v_L(t)$ =** ______________***90***_____________ ***Degrees***

**Question 5 – RMS Calculations:**
**Show your work!**

**a) RMS value of a 2Vpp sine wave:**

For a sine wave with peak-to-peak voltage $V_{pp} = 2V$, the amplitude is:

$$V_m = \frac{V_{pp}}{2} = \frac{2V}{2} = 1V$$

The voltage function is:

$$v(t) = V_m \sin(\omega t) = 1 \sin(\omega t)$$

Computing RMS:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\int_0^T \sin^2(\omega t)dt}$$

Using the identity:

$$\int_0^T \sin^2(\omega t)dt = \frac{T}{2}$$

we get:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T} \times \frac{T}{2} \times V_m^2}$$

$$V_{\text{RMS}} = \frac{V_m}{\sqrt{2}} = \frac{1V}{\sqrt{2}} \approx 0.707V$$

**b) RMS value of a 2Vpp square wave:**

For a square wave with constant amplitude $V_m = 1V$, the voltage function is:

$$v(t) = \pm V_m$$

Since the square of a constant is just itself:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\int_0^T V_m^2 dt}$$

$$V_{\text{RMS}} = \sqrt{\frac{1}{T} \times (T \times V_m^2)}$$

$$V_{\text{RMS}} = V_m = 1V$$

c) **RMS value of a 2Vpp sawtooth wave:**

For a sawtooth wave that linearly ramps from $-1V$ to $+1V$, we define:

$$v(t) = \frac{2V_m}{T}t - V_m$$

Since $V_m = 1V$, the function simplifies to:

$$v(t) = \frac{2}{T}t - 1$$

Computing RMS:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\int_0^T \left(\frac{2}{T}t - 1\right)^2 dt}$$

Expanding:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\int_0^T \left(\frac{4}{T^2}t^2 - \frac{4}{T}t + 1\right) dt}$$

Solving each integral using the reverse power rule and solving:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\left[\frac{4}{T^2} \times \frac{T^3}{3} - \frac{4}{T} \times \frac{T^2}{2} + T\right]} = \sqrt{\frac{1}{T}\left[\frac{4T}{3} - 2T + T\right]}$$

$$V_{\text{RMS}} = \sqrt{\frac{4}{3} - 2 + 1}$$

$$V_{\text{RMS}} = \sqrt{\frac{1}{3}}$$

**Question 6 – Power Calculations:**
**Show your work!**

a) **Power of sine wave ($V^2$/1K) averaged over time:**
b) **Power of square wave ($V^2$/1K) averaged over time:**
c) **Power of sawtooth wave ($V^2$/1K) averaged over time:**

$$P_{\text{Sine Wave}} = \frac{(0.707V)^2}{1000} = 0.5 \text{ mW}$$

$$P_{\text{Square Wave}} = \frac{(1V)^2}{1000} = 1 \text{ mW}$$

$$P_{\text{Sawtooth Wave}} = \frac{(0.577V)^2}{1000} = 0.333 \text{ mW}$$

**Comment on the relationship between the average power and the RMS value of the voltage (Provide a formula):**

$$P = \frac{V_{\text{RMS}}^2}{R}$$

**Part 2 (10 pts): Hardware Lab Work**

1) a) Multimeter reading of a 2Vpp sine wave: ________0.5_________V

b) Multimeter reading of a 2Vpp square wave: ________0.8_________V

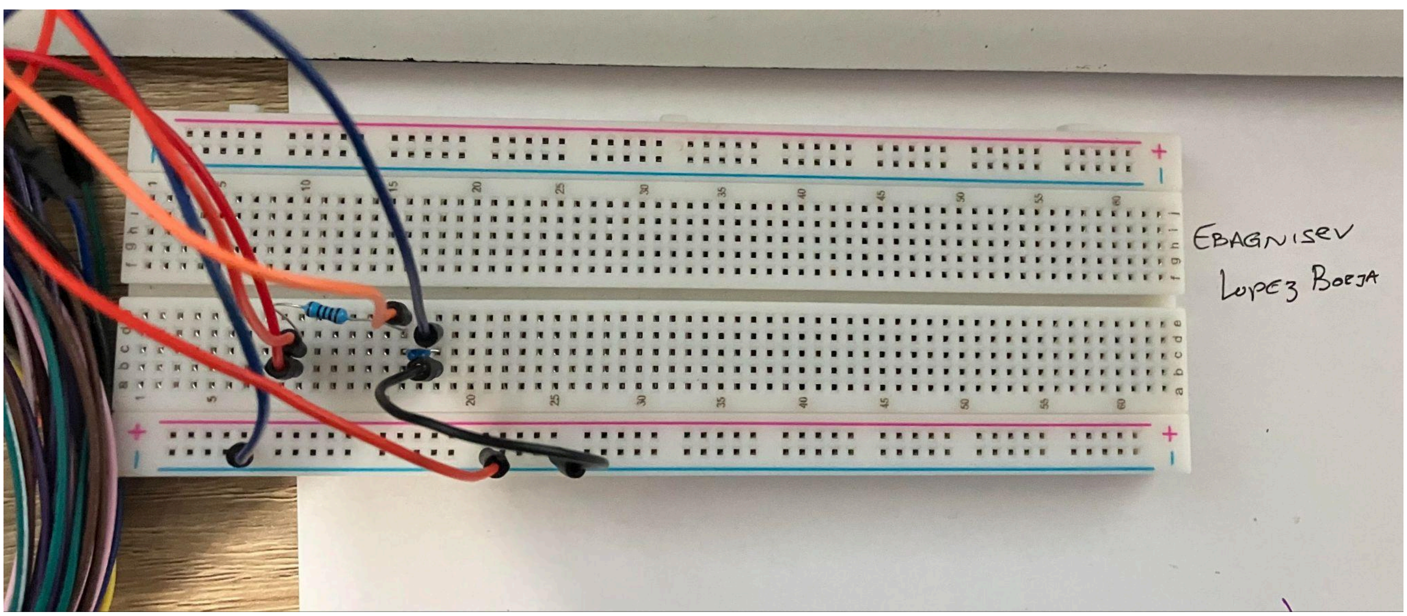
c) Multimeter reading of a 2Vpp sawtooth wave: ________0.3_________V

d) Based on your measurements, does the multimeter provide peak-to-peak voltages or RMS voltages?

RMS voltages

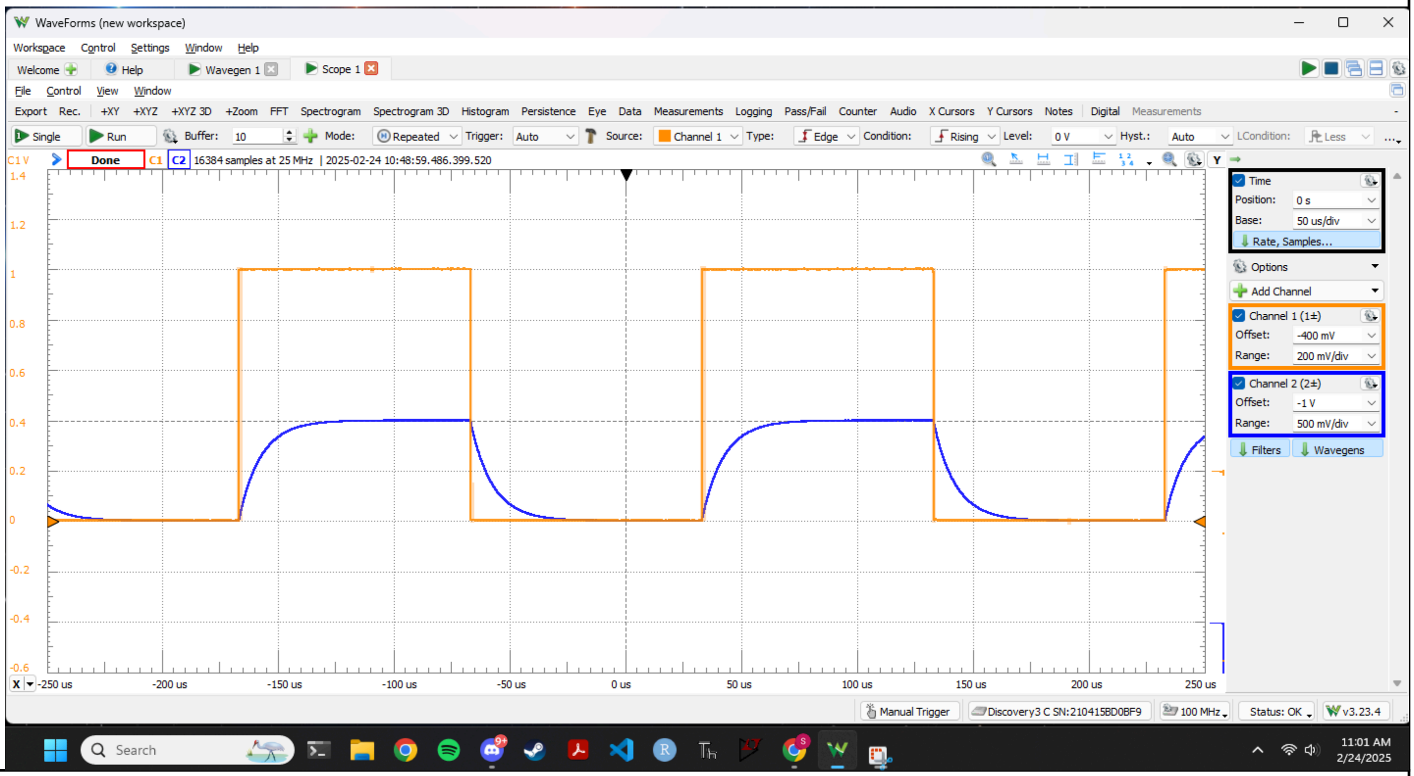
**2) Hardware RC circuit – Pulse Source**

**Build RC circuit on hardware and connect both channels of oscilloscope**
**Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):**



**Using your oscilloscope, plot $v_S(t)$ *and* $v_C(t)$. *Make sure both waves are displayed on the same figure and the numbers are readable in the screenshot:***

**Screenshot of Oscilloscope Plot - Make sure that your computer's date and time are showing up in your screenshot:**

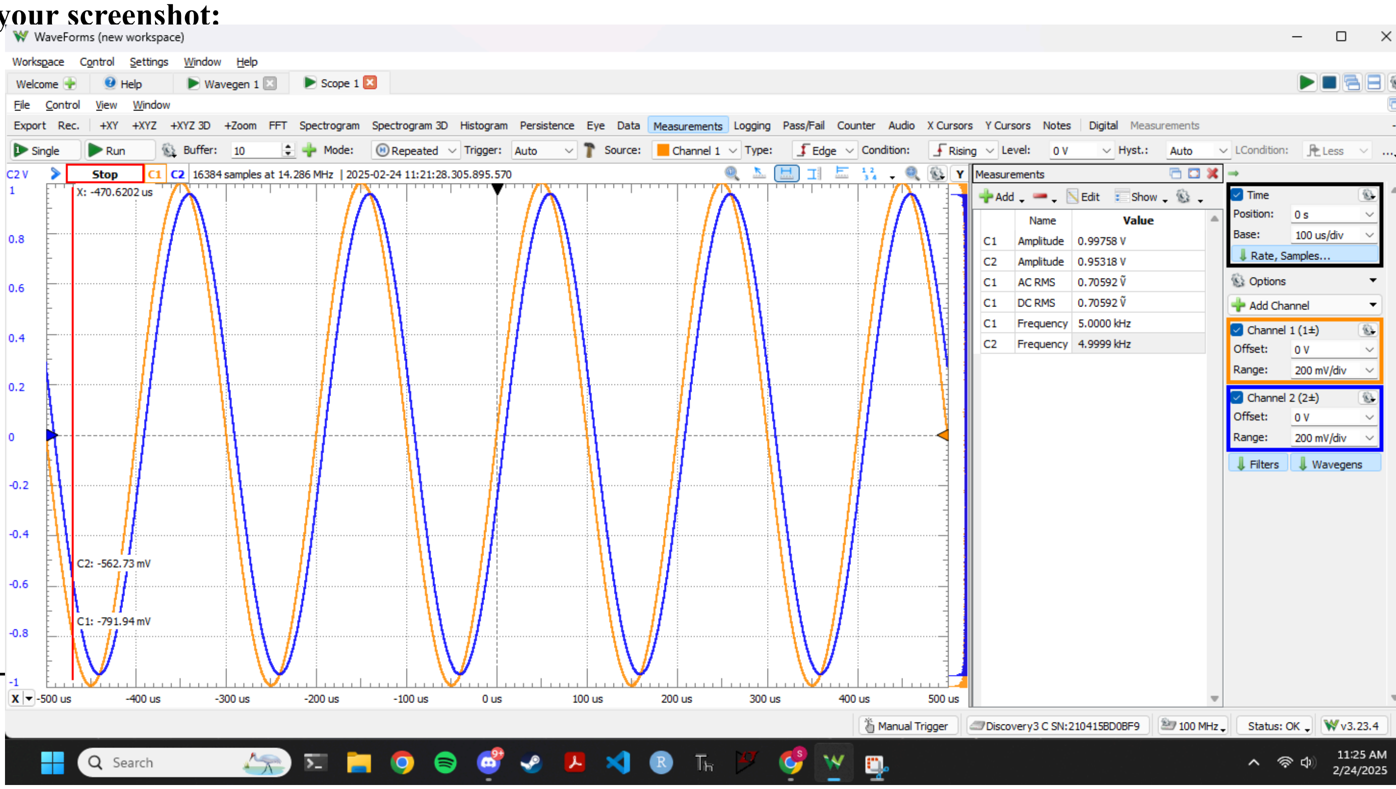



**3) Hardware – RC Circuit – Sine Wave:**

**Change the voltage source (waveform W1 on your Analog Discovery kit) to a sine wave with the parameters as indicated in the manual.**

**Using your oscilloscope, plot $v_S(t)$ *and* $v_C(t)$. *Make sure both waves are displayed on the same figure and the numbers are readable in the screenshot:***

**Screenshot of Oscilloscope Plot - Make sure that your computer's date and time are showing up in your screenshot:**



**Provide the following from the oscilloscope plot of your RC circuit:**

**a) The magnitude of the voltage across the capacitor:** ____**0.95318**_______**V**

**b) The RMS of the voltage from the source:** ____**0.70592**_______**V**

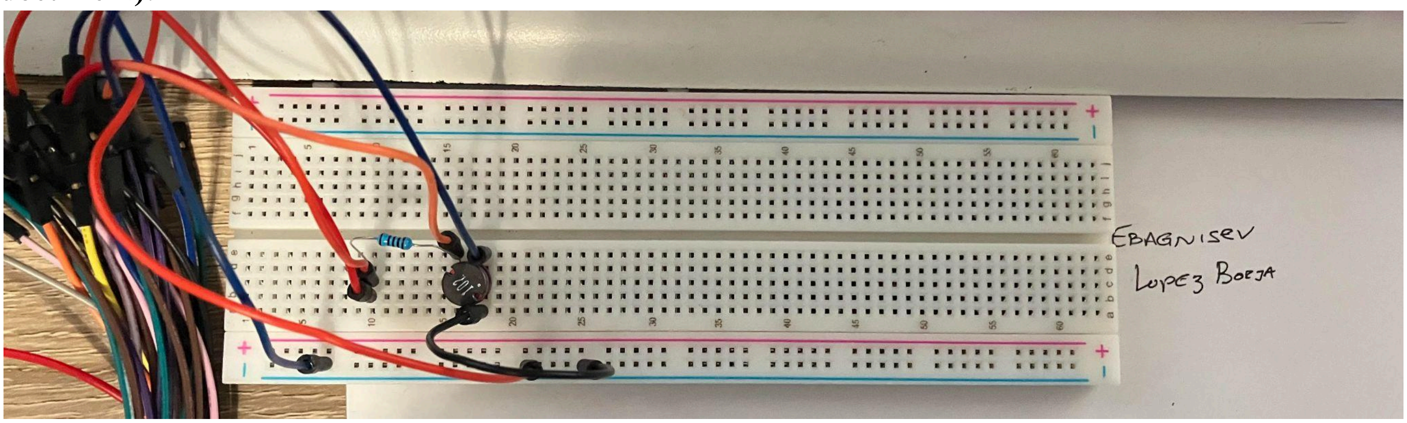
**c) The phase difference, in degrees, between the source and cap voltage:** _____**17.64**______**Degrees**

**d) The capacitor voltage is** ______**lagging**_______________ **the source voltage**

leading or lagging

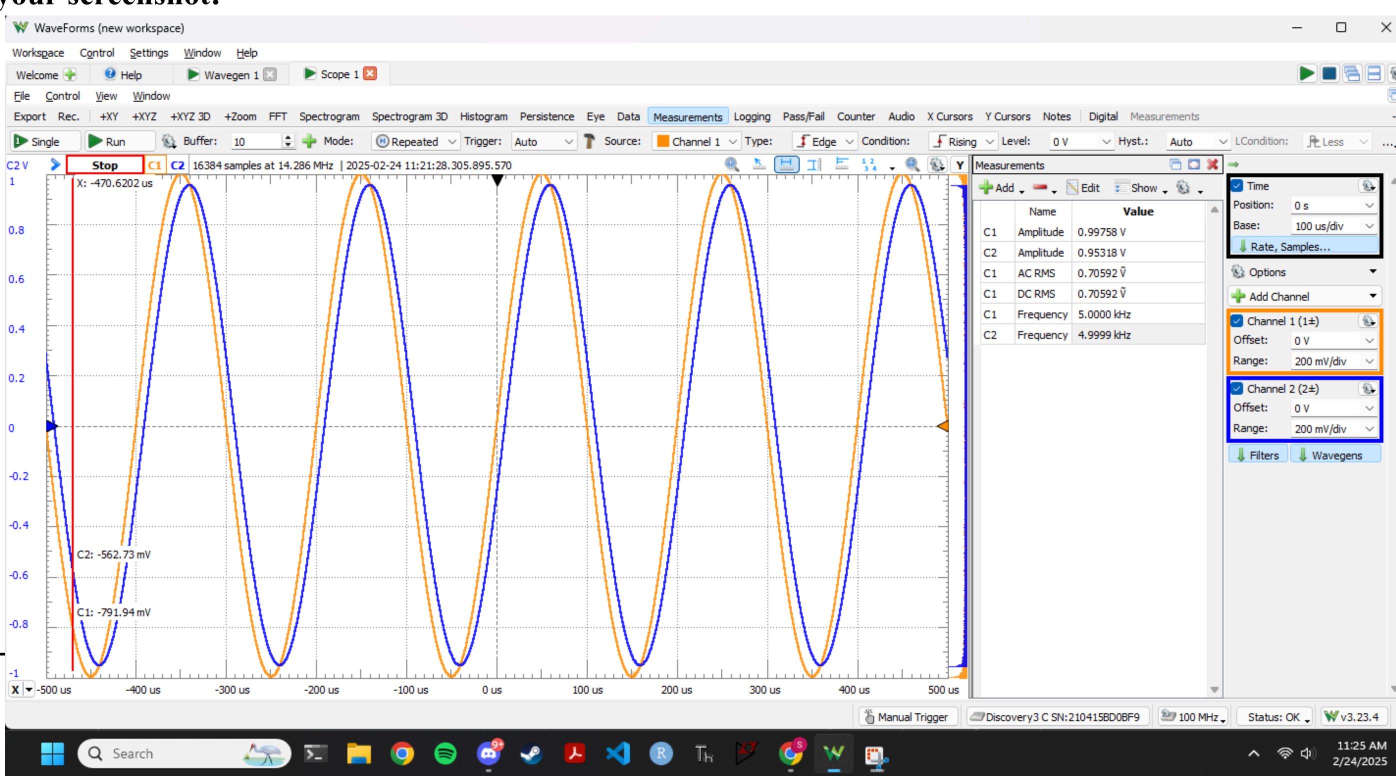
**4) Hardware - RL Circuit – Sine Wave:**

**Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):**




**Using your oscilloscope, plot** ***$v_S(t)$ and $v_L(t)$). Make sure both waves are displayed on the same figure and the numbers are readable in the screenshot:***

**Screenshot of Oscilloscope Plot - Make sure that your computer's date and time are showing up in your screenshot:**



**Provide the following from the oscilloscope plot of your RL circuit:**

**a) The magnitude of the voltage across the inductor:** **_____24.991______mV**

**b) The RMS of the voltage from the source:** **____0.70312_______V**

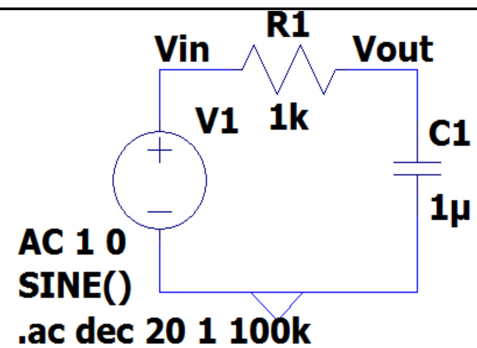
**c) The phase difference, in degrees, between the source and inductor voltage:** **__3.906__Degrees**

**d) The inductor voltage is ________leading______________ the source voltage**

leading or lagging

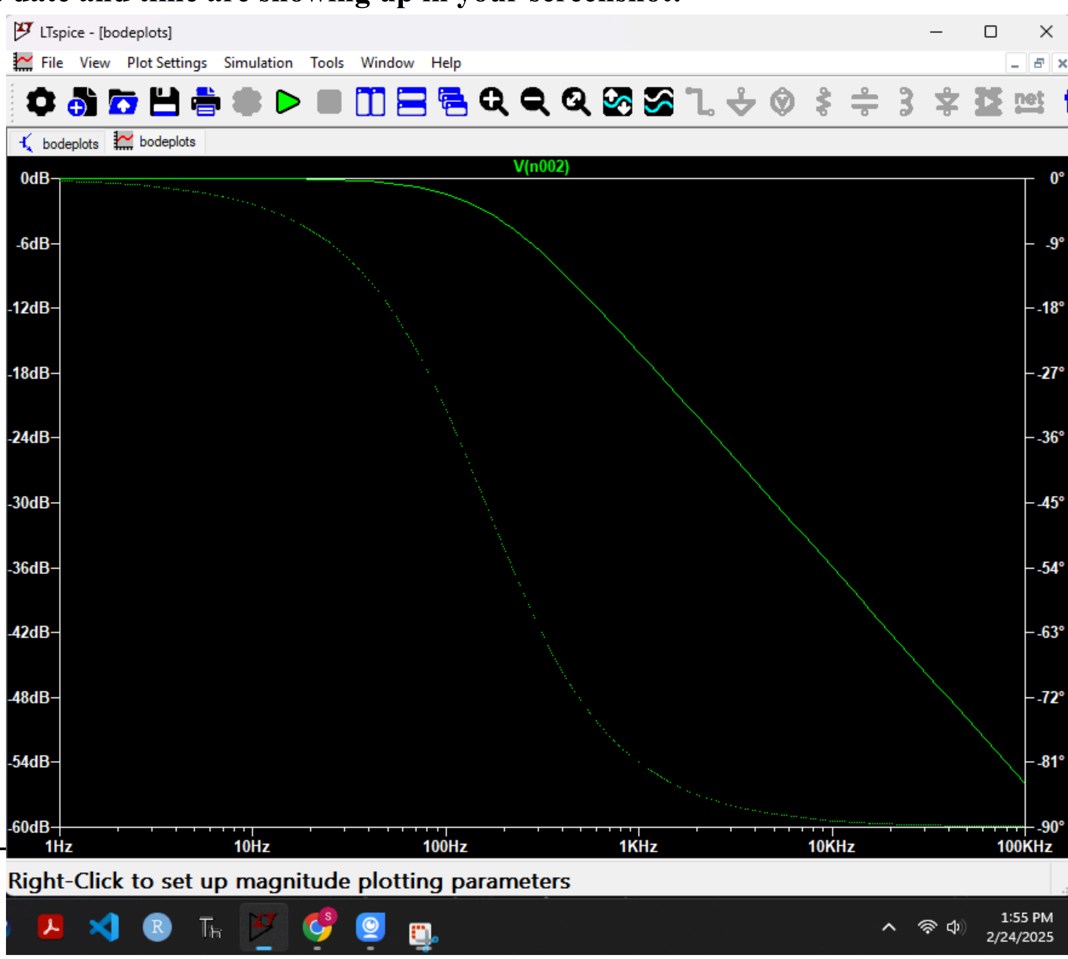
**Part 3: Extra Credit (10 pts) - Bode Plots**

**Create bode plots of the shown RC circuit (*magnitude in dB, phase in degrees)* and attach an image of your plot here. *Make sure the numbers are readable in the photo.* You can depend on LTSpice as explained in the manual above or use the Analog Discovery 2 kit as explained in the following video** [https://youtu.be/31tq_A_2TcY](https://youtu.be/31tq_A_2TcY). Circuit connections are explained at min 4:16)

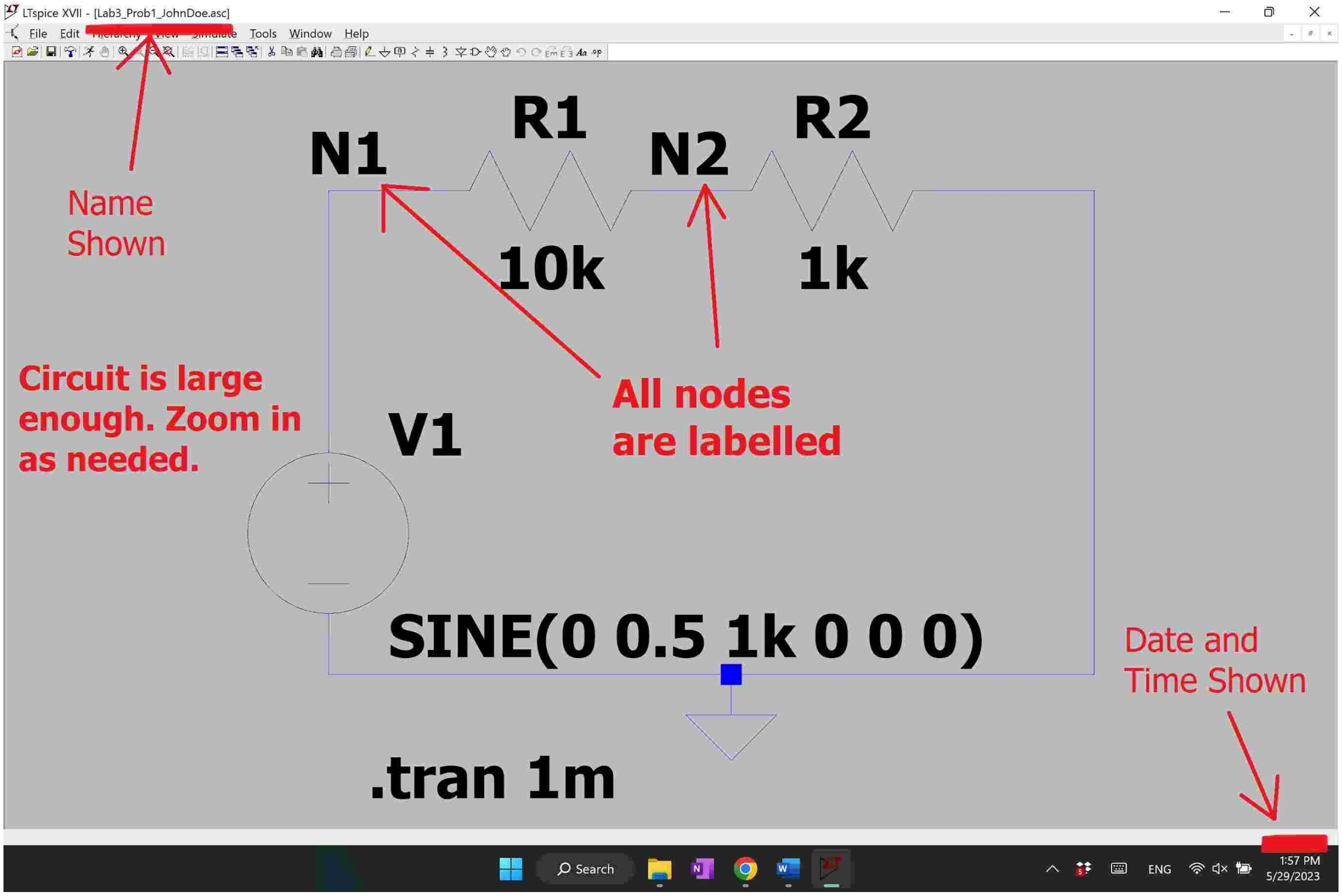



Bode plot (including magnitude and phase plots):

**Screenshot of Oscilloscope Plot - Make sure that your computer's date and time are showing up in your screenshot:**



**LTSpice Screenshot Example (Note your name, date and time, readable circuit, and labelled nodes – screenshots might vary based on the operating system you are using) – This applies to screenshots of circuits only. Screenshots of graphs/plots/anything else can include only the date and time.**




**Hardware Image Example. Note your name:**

1- **on a piece of paper; OR**
2- **typed electronically (must be typed on the breadboard WITHOUT any "text background". Breadboard must show up in the background of your name.)**


John
Doe
John Doe
ANALOG DISCOVERY
DIGILENT
AstroAI
AM33D
nex