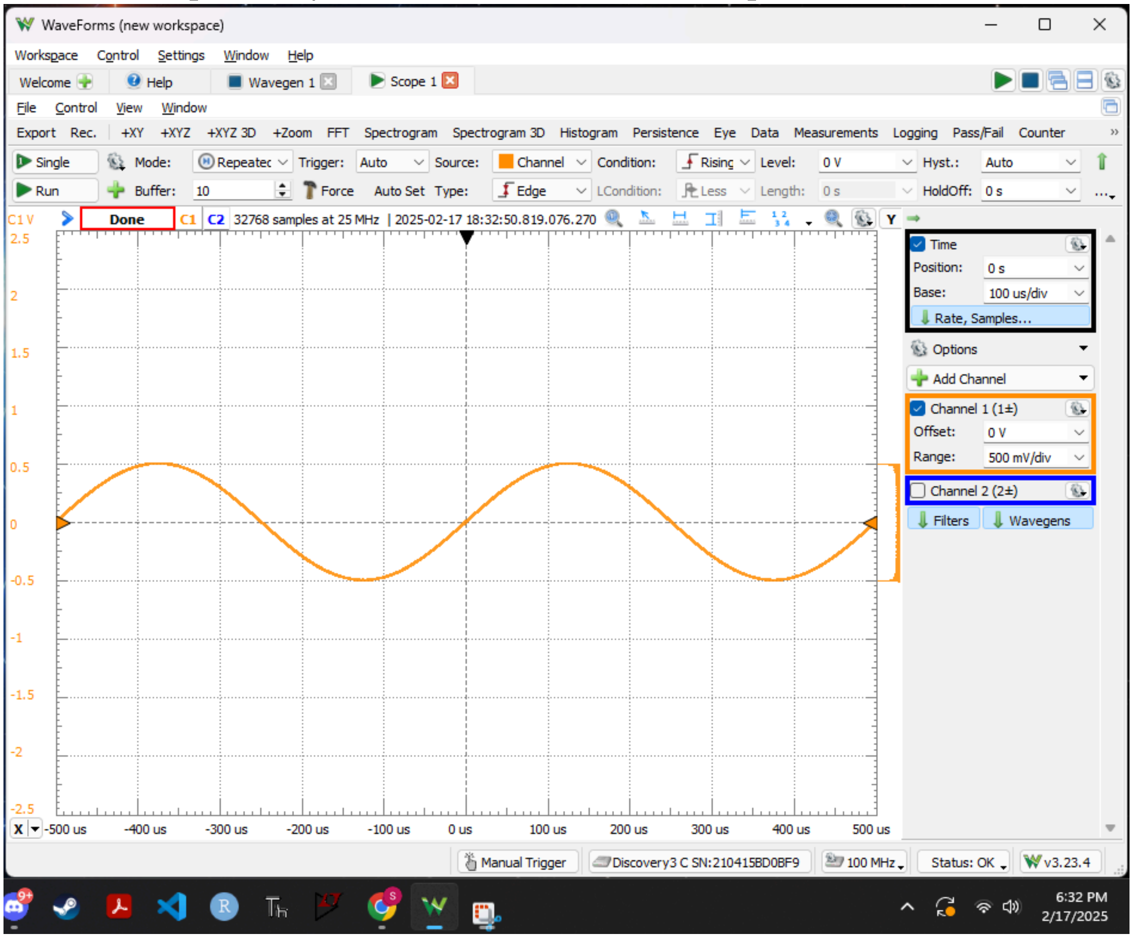
Name: _____Ebagnisev Sahiv LopezBorja________

EEE 202 Lab 5 Data Sheet
Operational Amplifiers

Part 0: Waveform Generators and Oscilloscopes

1) What is the maximum voltage rating on your Waveform Generator?	$10\ V$

2) Adjust the WFG to output a 1V (peak to peak) sine wave with a frequency of 2 kHz. Take a screenshot or photo of your waveform on the oscilloscope and include it here:

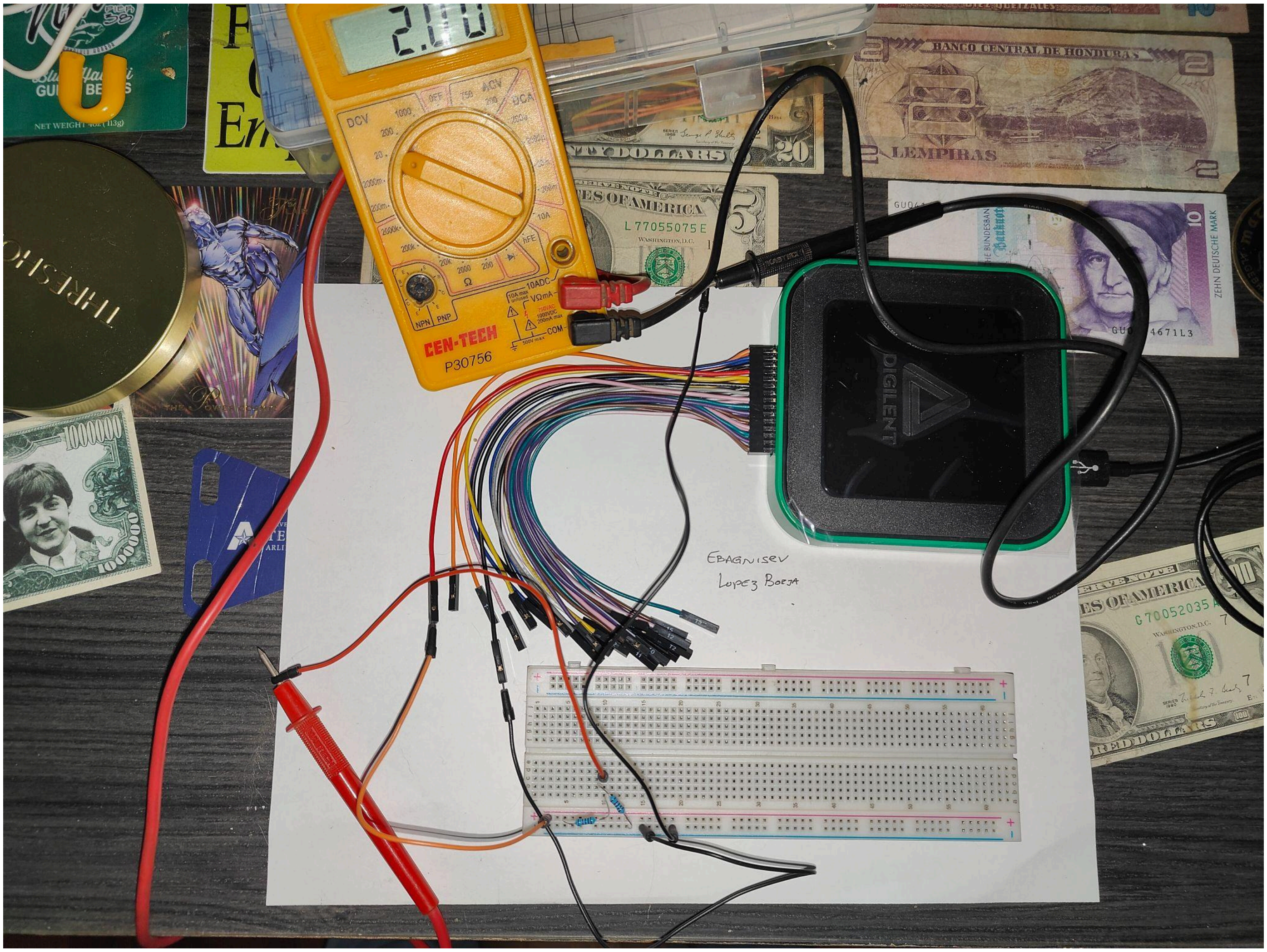


3) What is the input impedance of the oscilloscope?	**1 MΩ in parallel with 24 pF**
4) What is the maximum acceptable input voltage for the oscilloscope? (Hint: read the manual or watch the supplier's video here: https://youtu.be/HUAy0J3XqaU)	$\pm\ 25\ V$
5) What is the voltage resolution of the oscilloscope? Hint: resolution= $\frac{V_{max} - V_{min}}{2^{\#\ bits\ resolution}}$ [Do not forget the units]	$\frac{25\ V-(-25\ V)}{2^{14}}$ **= 3.05 mV**

Part 1: Voltage Reference

Connect the circuit in Part 1 of the manual. In each case below, record the relationship between R_A and R_B, their actual values, and V_{Ref} measured at the junction between them based on a multimeter measurement.

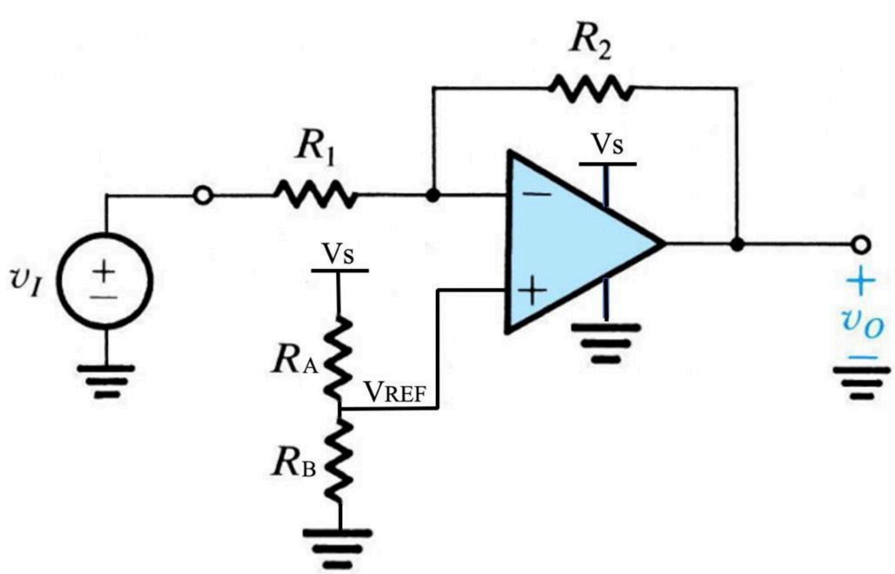
Include a photo of your hardware circuit here - only include that of one of the five following cases (Have a look at an example photo at the end of this document):



Resistor Values (kOhms)	Multimeter measurement
1) R_A = _$10\ k\Omega$_ R_B = _$10\ k\Omega$_	V_{Ref} ____$2.00\ V$_____ reason for discrepancy with 2 V expectation: N/A
2) R_A = _____90.9kΩ________	I_A = _$22.0011\ \mu A$_ I_B = _$20.001\ \mu A$_ I_C = _$2.0001\ \mu A$_
3) R_A = _____909Ω________	I_A = _2.20011 mA_ I_B = _2.0001 mA_ I_C = _200.01 μA_
4) R_A = _$50\ k\Omega$_ R_B = _$50\ k\Omega$_	V_{Ref} = ____$1.95\ V$_____ reason for discrepancy with 2 V expectation: Due to R_A being in series with the two in parallel, we have that due to the voltage divider its behavior is quite sensitive to the resistor values chosen.
5) R_A = _$50\ \Omega$_ R_B = _$50\ \Omega$_	VRef = ____1.99 V_____ reason for discrepancy with 2 V expectation: The higher value between the chosen resistors gives a closer value to 2 V.

Part 2: Simulation of Inverting Op-Amp in LTSpice

Assume a gain of 2 V/V and the input voltage v_I being a sine wave with $2V_{pp}$



1) **Determine RA & R_B. Show your steps. Does R1 impact this?**
The output is within a positive range (since op-amps cannot output negative voltages with a single supply), we shift the reference voltage to +2V.

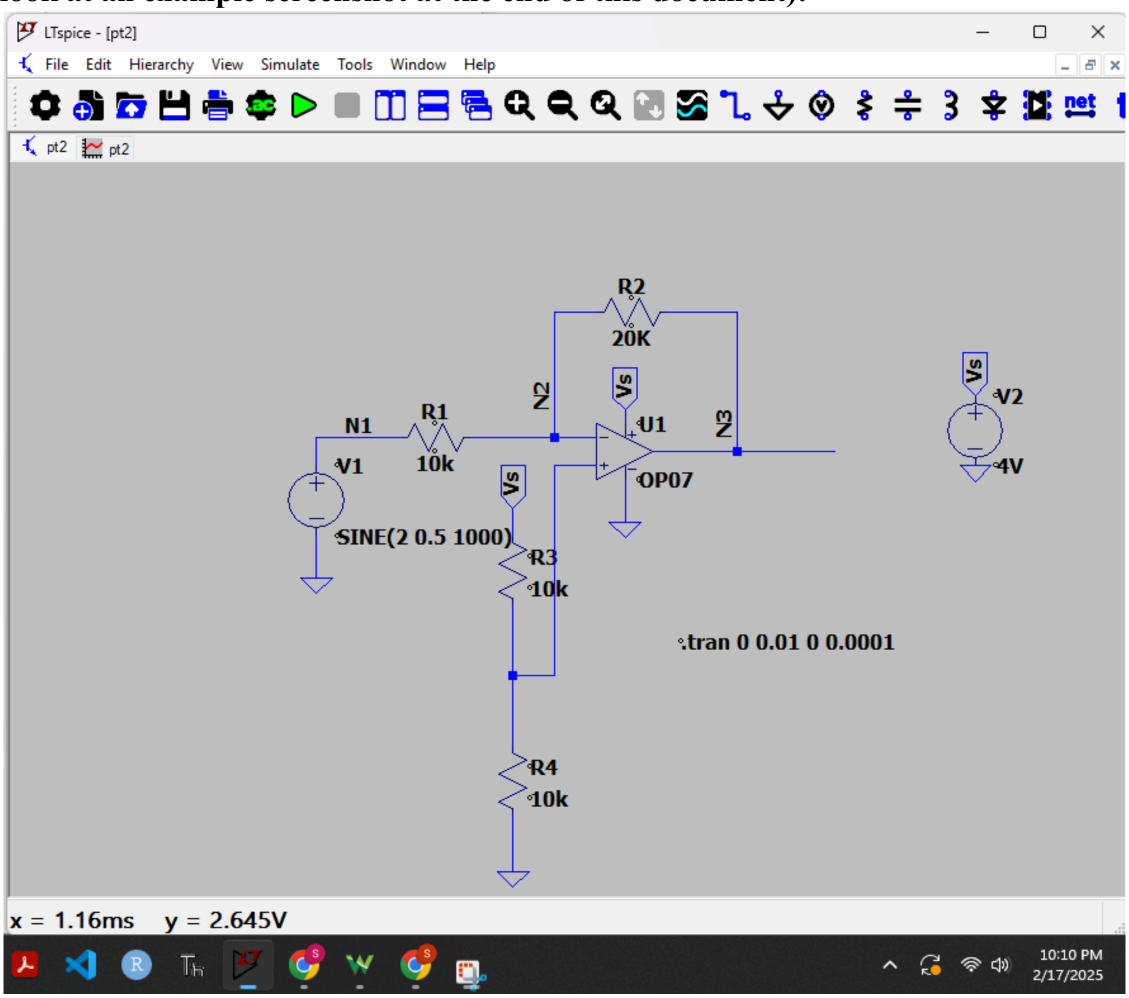
With this we see that the value of the voltage divider amongst the resistors R_A & R_B is equal to ½. With this we have that $R_A = R_B$.

R_1 does not impact R_A & R_B as these two resistors control the reference voltage at the non-inverting terminal of the op-amp. In this case, R1 helps with the gain.

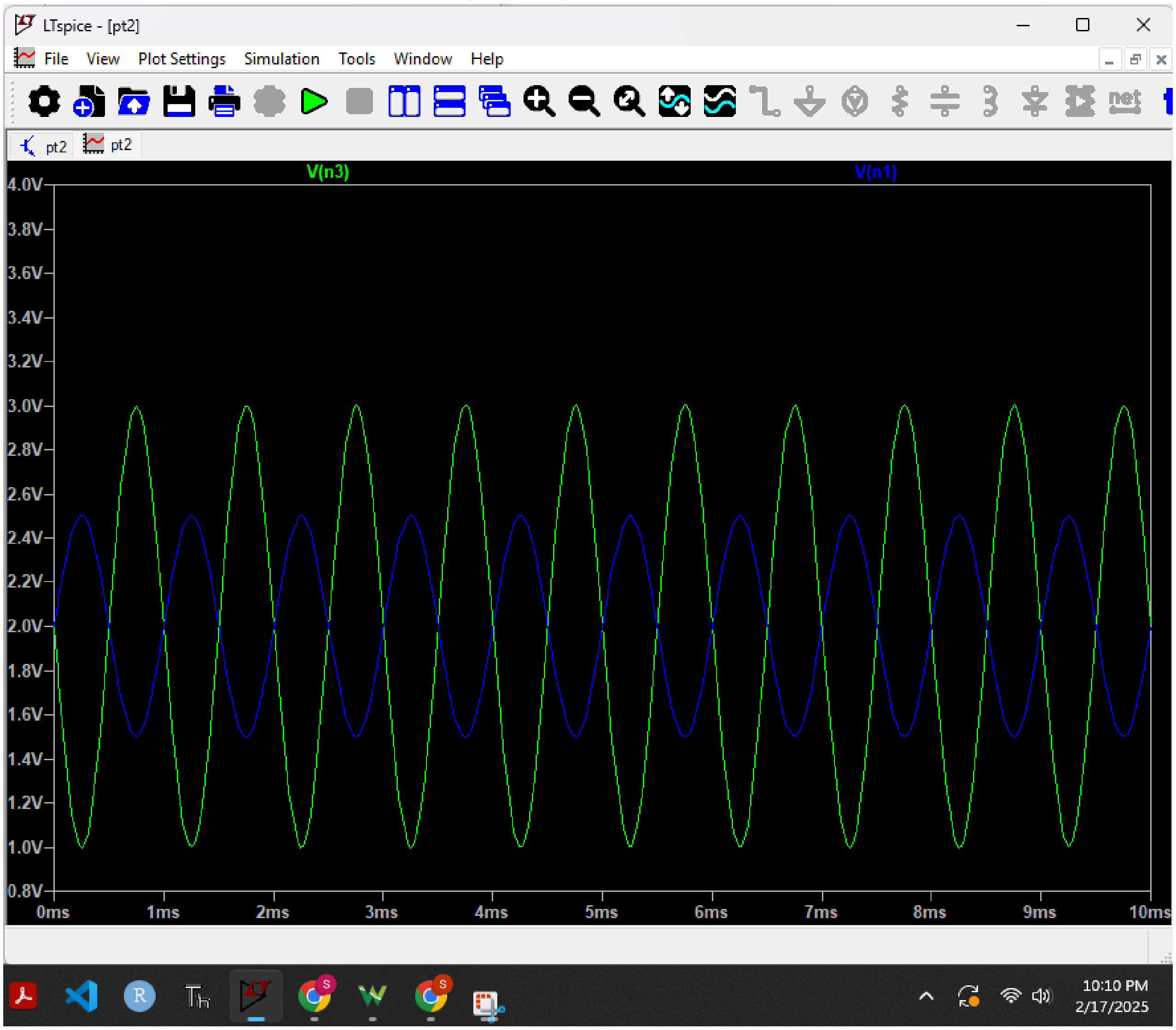
2) **Determine R_1 and R_2. Show your steps.**
$2 = -\frac{R_2}{R_1}$ **, so we have that $2R_1 = R_2$.**

Resistor values R_A = _10k_, R_B = _10k_, R_1 = _10k_, R_2 = _20k_

With the same gain and input voltage, build your circuit in LTSpice and run a Transient Simulation (use OP07 as your Op Amp). Plot the output and input waveforms of your op-amp circuit. You should show at least one period and the voltage scale of your graph (i.e. the range of the y-axis) should be 0 to 4 V. Screenshot of LTSpice schematic circuit. Make sure your circuit nodes are labeled (Have a look at an example screenshot at the end of this document):



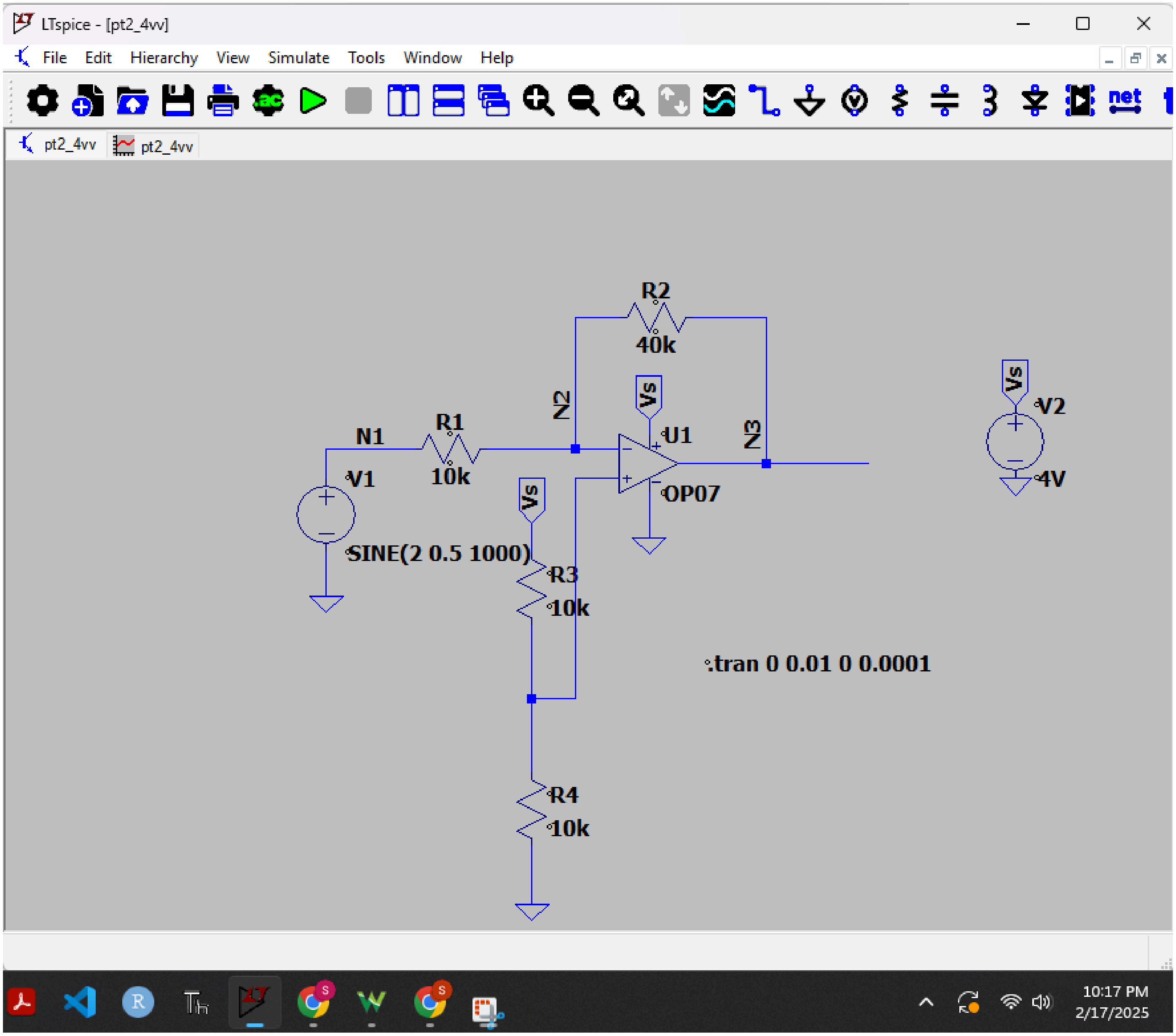
Screenshot of LTSpice Plot - output and input voltage on the same plot (Make sure that your computer's date and time are showing up in your screenshot):



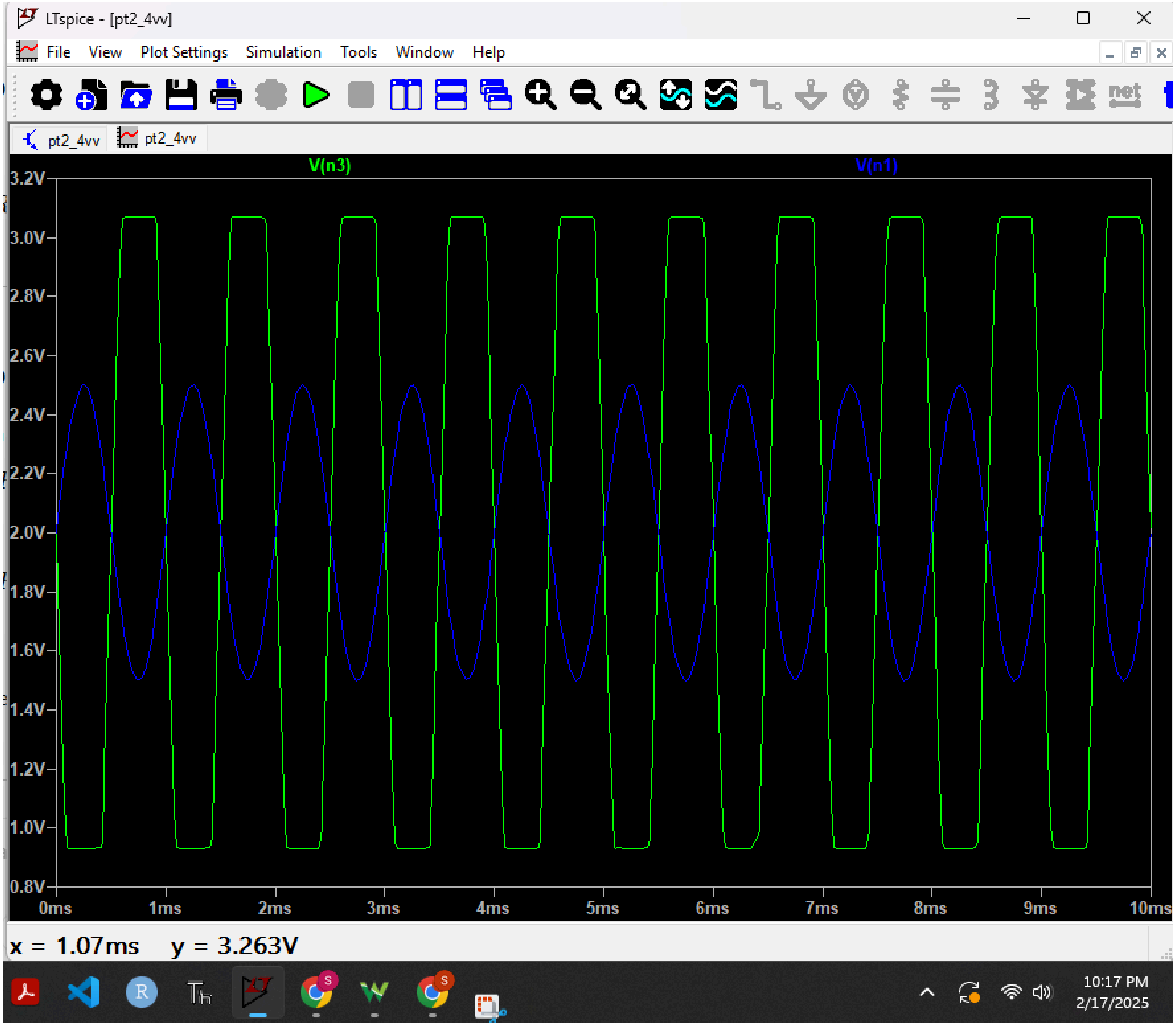
Repeat for a 4V/V gain:

Resistor values R_A = _10k_, R_B = _10k_, R_1 = _10k_, R_2 = _40k_

Screenshot of LTSpice schematic circuit. Make sure your circuit nodes are labeled (Have a look at an example screenshot at the end of this document):



Screenshot of LTSpice Plot - output and input voltage on the same plot (Make sure that your computer's date and time are showing up in your screenshot):



Part 3: Physical Validation Inverting Configuration of the Op-Amp
Build the Physical Prototype of the circuit and include an image (use OP484 or MCP6022). Your Inverting Configuration design on the prototype board, should contain resistors, connection wires, and the Op-Amp. (Attach the image of your physical circuit to the lab data sheet.) **Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):**
Capture the screenshot of your oscilloscope waveforms showing the channel 1 input from the waveform generator and the channel 2 output of the Op-Amp. You should display a stable image triggered on channel 1 with at least one period of the sinusoid and a voltage range of 0 – 4V. **Include a screenshot of your waveforms here (Have a look at an example photo at the end of this document):**
Is your Op-Amp a "rail-to-rail" Op-Amp? If not, what are the upper and lower clipping voltages?

Discussion (don't disassemble your circuit yet, as you may need it to answer the questions):

1) **Is your op-amp a "rail-to-rail" op-amp? If so, are you still seeing some "clipping" of the output for a 2 V/V gain and why? When you increase the gain of your configuration to 4 v/v, what are the upper and lower clipping voltages?**

   Since our supply voltage is 0V to 4V, the output voltage is fine in this range, and clipping should not occur in an ideal case. A rail-to-rail op-amp is capable of outputting voltages close to the supply rails, but if we notice clipping we can see that it is not truly rail-to-rail. Reasons for this might be due to the op-amp limitations/factors.

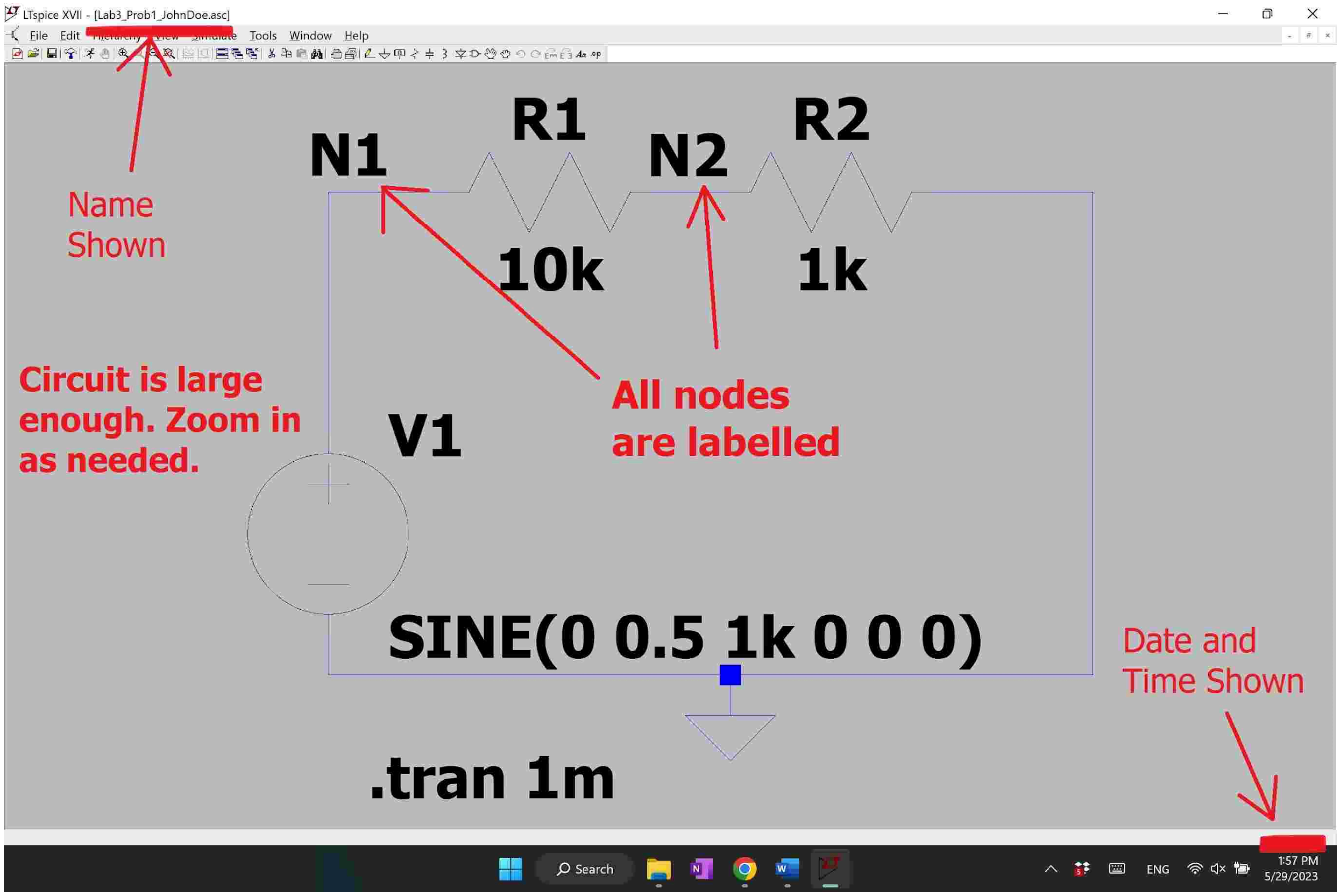
2) **How do your calculation, simulation, and measurement results compare? Did the "ideal op-amp" calculations closely match what was seen in the physical circuit?**

3) **What advantages/disadvantages do you see in using op-amps?**
   As there exists various types of op-amps we see that they are easy to design circuits with and they assist with higher gain and accuracy on output voltages. They also have a low power consumption with a high impedance. In terms of the disadvantages, we see that they can clip input and output ranges when the voltage they handle is exceeded. As noted above, some op-amps are not rail-to-rail and this will limit the output range.

4) **Which did you like better, simulation of the circuit, or physically building it? Which one would you prefer to do in your career design, simulation verification, or physical implementation?**

I preferred the simulation verification process. It is faster and allows for correction and modifications without having to deal with cross-wiring or other dangers. The simulation was a more natural debugging process than having to manually build the circuit.

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
ANALOG DISCOVERY
DIGILENT
AstroAI
AM33D
John Doe