# Electric Circuits & Electronics Design Lab

# EE 316-01

# Lab 2: Inverting and Noninverting OP-Amp Circuits

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Lab Section 316-01

Lab Date: 6/8/22

Lab Due: 6/15/22

## Introduction:

The purpose of this lab to examine inverting and noninverting OP circuits for AC and DC inputs. We will be looking at closed and open loop gain and general characteristics of the op amps themselves. We will also review the characteristics of an ideal op amp. This report will have 5 main sections. First is the theoretical analysis which is done as the pre-lab and includes Multisim simulations and handwritten solutions to the circuit. Then we have the physical circuits which are constructed on breadboards in lab. Afterwards, we compare the results from those 3 sections and conclude with an analysis of the results.

## Theoretical Analysis:

To begin, we considered an operational amplifier itself given in Figure 1, the characteristics and equations associated with it, and what conditions make it ideal. As a summary, an ideal op amp has: no current at the inverting and noninverting input terminal, the differential input is governed by the $V_2$-$V_1 \approx 0$, input impedance is infinite, and output impedance is zero.

For analysis of an inverting and noninverting op amp, shown in Figures 2 and 3 respectively, we used the supplementary equations given for op amps specifically to fill in Tables 1 and 2. However, you could have solved the amplifiers using the methods learned from the first lab. As a note, since we are doing this by hand the $V_{OUT}$ calculated should be what an oscilloscope sees and $V_{OUTrms}$ is that value divided by $2\sqrt{2}$ . The equations and work used for this analysis can be seen in Appendix 1.

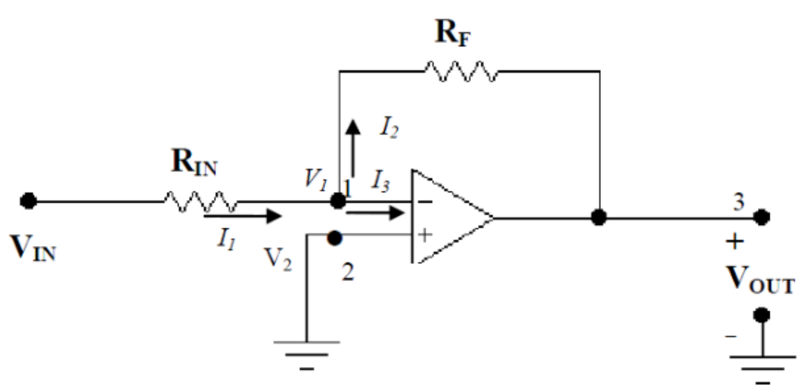



**Figure 1**. Inverting Amplifier

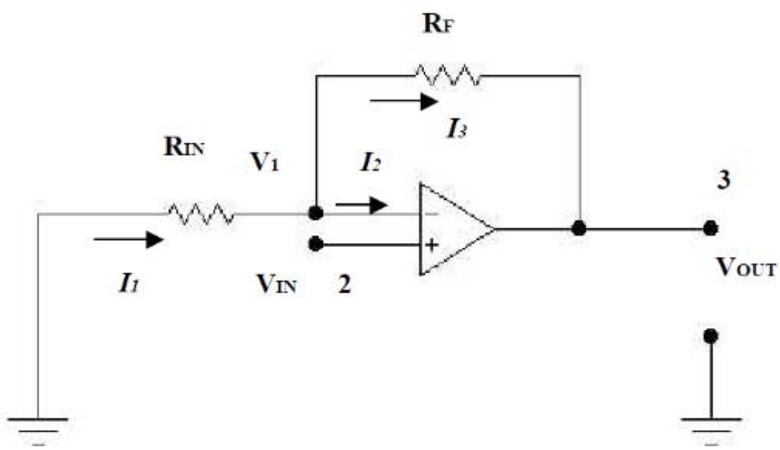



**Figure 2.** Noninverting amplifier

**Table 1.** Voltage and Gain for inverting amplifier

| $V_{INpp}$(V) | $R_{IN}$ (kΩ) | $R_F$ (kΩ) | $V_{OUTpp}$ (V) O-Scope | Gain (v/V) | $V_{OUTrms}$ (V) DMM |
|---|---|---|---|---|---|
| 2 | 1 | 0.5 | -1 | -0.5 | -0.354 |
| | | 1 | -2 | -1 | -0.707 |
| | | 2 | -4 | -2 | -1.414 |
| | | 3 | -6 | -3 | -2.121 |
| | | 4 | -8 | -4 | -2.828 |

**Table 2.** Voltage and Gain for noninverting amplifier

| $V_{INpp}$(V) | $R_{IN}$ (kΩ) | $R_F$ (kΩ) | $V_{OUTpp}$ (V) O-Scope | Gain (v/V) | $V_{OUTrms}$ (V) DMM |
|---|---|---|---|---|---|
| 2 | 1 | 0.5 | 3 | 1.5 | 1.061 |
| | | 1 | 4 | 2 | 1.414 |
| | | 2 | 6 | 3 | 2.121 |
| | | 3 | 8 | 4 | 2.828 |
| | | 4 | 10 | 5 | 3.536 |

## Simulations:

For the next phase of the lab, we built and analyzed the amplifiers in Multisim. We started with the inverting amplifier as showing with Figure 1. We used the same tables as we did before. The circuits created in Multisim can be seen in Figure 3 and 4. As a note, for the simulation though it is not shown in the figures you have to provide ±12 volts to power the amplifier and more on this will be discussed in the results and discussion section. The values measured here differ only in rounding from the theoretical analysis. The results are given in Tables 3 and 4.

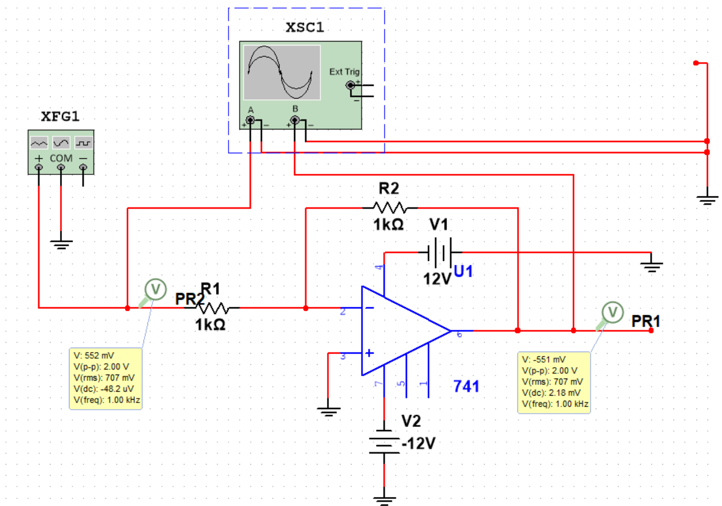



**Figure 3**: Inverting Amplifier

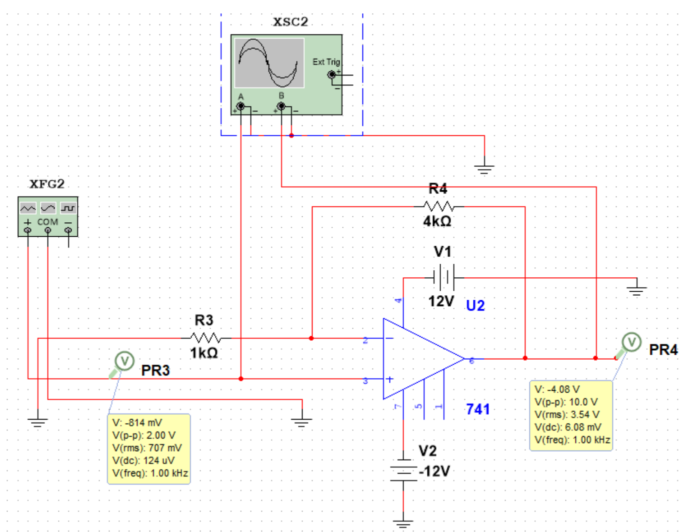



**Figure 4.** Noninverting Amplifier

**Table 3.** Voltage and Gain for Inverting Amplifier Simulation

| $V_{INpp}$(V) | $R_{IN}$ (kΩ) | $R_F$ (kΩ) | $V_{OUTpp}$ (V) O-Scope | Gain (v/V) | $V_{OUTrms}$ (V) DMM |
|---|---|---|---|---|---|
| 2 | 1 | 0.5 | -0.996 | -0.498 | 0.354 |
| | | 1 | -1.994 | -0.997 | 0.707 |
| | | 2 | -3.984 | -1.992 | 1.41 |
| | | 3 | -5.972 | -2.986 | 2.12 |
| | | 4 | -7.962 | -3.981 | 2.83 |

**Table 4.** Voltage and Gain for Noninverting Amplifier Simulation

| $V_{INpp}$(V) | $R_{IN}$ (kΩ) | $R_F$ (kΩ) | $V_{OUTpp}$ (V) O-Scope | Gain (v/V) | $V_{OUTrms}$ (V) DMM |
|---|---|---|---|---|---|
| 2 | 1 | 0.5 | 2.987 | 1.494 | 1.06 |
| | | 1 | 3.982 | 1.991 | 1.41 |
| | | 2 | 5.974 | 2.987 | 2.12 |
| | | 3 | 7.982 | 3.991 | 2.83 |
| | | 4 | 9.987 | 4.994 | 3.54 |

## Experimental:

For the last portion of the lab, we did the same things as prior but on a physical board to validate the conceptual results we obtained. We started with the inverting amplifier from Figure 1 using a 741op-amp and referring to its pinout sheet. The oscilloscope probes were placed on the same wire or clip as the function generator which was used to generate our AC signal for one channel and the other channel was used to measure the output with that probe placed on a wire coming from pin 6 on the board. The multimeter was also placed on a wire coming from pin 6 to get the $V_{RMS}$ value.

The same thing was done for the noninverting amplifier from Figure 2, switching which pins were grounded and given power to make the chip inverting or noninverting. The probes stayed where they were as we simply switched the wires to the pins that determined which type of amplifier you were doing. The results can be seen in Tables 5 and 6 in the results section of this lab and the constructed circuits can be seen in Appendix 2.

## Results and Discussion:

The first two tables have the data previously discussed in the last portion of this lab. The values found here match closely with both the theoretical values and the simulated values in some cases. The smaller discrepancies can be explained by tolerances in the parts used experimentally and on the multi-meter. Several things to note that occurred while doing the simulation and experimental part of the lab are: for the simulation initially when constructing the circuit, the chip itself was not given power, also when comparing the pinout to the simulation circuit you will notice that pins 4 and 7 are swapped this is because the simulation was not giving correct values until that swap was made, and then in the experimental part the $V_{OUT}$ obtained by the oscilloscope is actually the $V_{RMS}$ from the multimeter multiplied by $2\sqrt{2}$ because the oscilloscope itself was giving much larger values and the reason why could not be figured out.

**Table 5.** Voltage and Gain for Inverting Amplifier Breadboard

| $V_{INpp}$(V) | $R_{IN}$ (kΩ) | $R_F$ (kΩ) | $V_{OUTpp}$ (V) O-Scope | Gain (v/V) | $V_{OUTrms}$ (V) DMM |
|---|---|---|---|---|---|
| 2 | 1 | 0.5 | 0.989 | 0.4945 | 0.35 |
| | | 1 | 1.97 | 0.985 | 0.69 |
| | | 2 | 3.93 | 2.83 | 1.39 |
| | | 3 | 5.9 | 2.95 | 2.09 |
| | | 4 | 7.86 | 3.93 | 2.78 |

**Table 6.** Voltage and Gain for Noninverting Amplifier Breadboard

| $V_{INpp}$(V) | $R_{IN}$ (kΩ) | $R_F$ (kΩ) | $V_{OUTpp}$ (V) O-Scope | Gain (v/V) | $V_{OUTrms}$ (V) DMM |
|---|---|---|---|---|---|
| 2 | 1 | 0.5 | 2.91 | 1.46 | 1.03 |
| | | 1 | 3.87 | 1.93 | 1.37 |
| | | 2 | 5.83 | 2.91 | 2.06 |

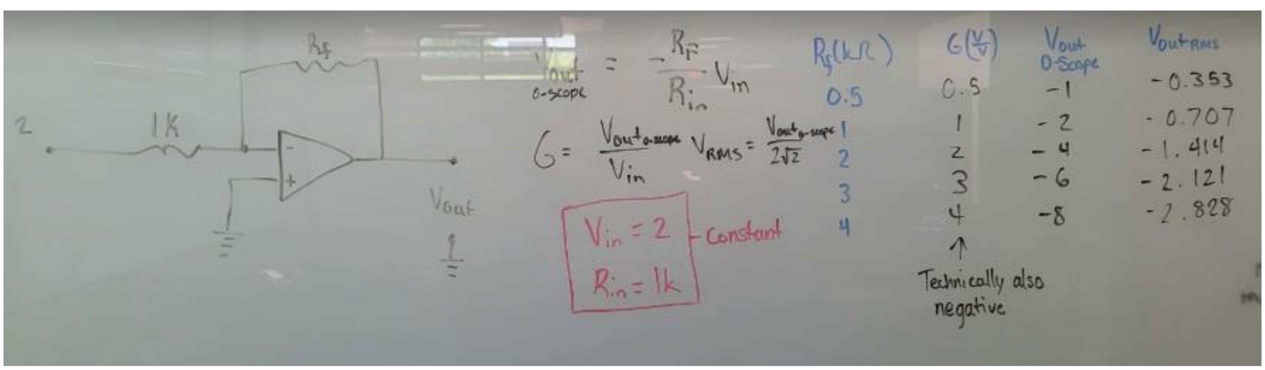
| | | | | | |
|---|---|---|---|---|---|
| | | 3 | 7.75 | 3.87 | 2.74 |
| | | 4 | 9.7 | 4.85 | 3.43 |

The results of this lab confirm that for inverting amplifiers since they have a closed loop gain a minus sign is associated with the gain and $V_{OUT}$. This means that AC input and output have 180 degree phase shift between them and this could be seen on the oscilloscope for the simulation and experimental parts of this lab. However, for the noninverting amplifier we see a positive gain because the output and input are in phase, which could also be seen on the oscilloscope if you moved the two waves to overlap each other.

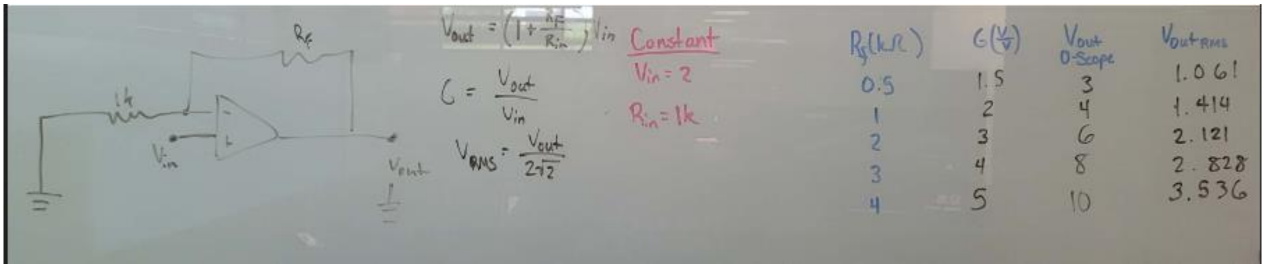
## Conclusion

Overall, the results of the lab were closely in line with our expectations that we got from the theoretical portion. There were only small discrepancies between the theoretical, simulation, and experimental results due to rounding and the tools used to calculate the results. The results of this lab helped our understanding of inverting and noninverting op amps. This lab overall helped review and refresh previous knowledge on solving operation amplifiers and what characteristics an ideal op amp had along with introducing us to a function generator and oscilloscope.

## Appendix 1:



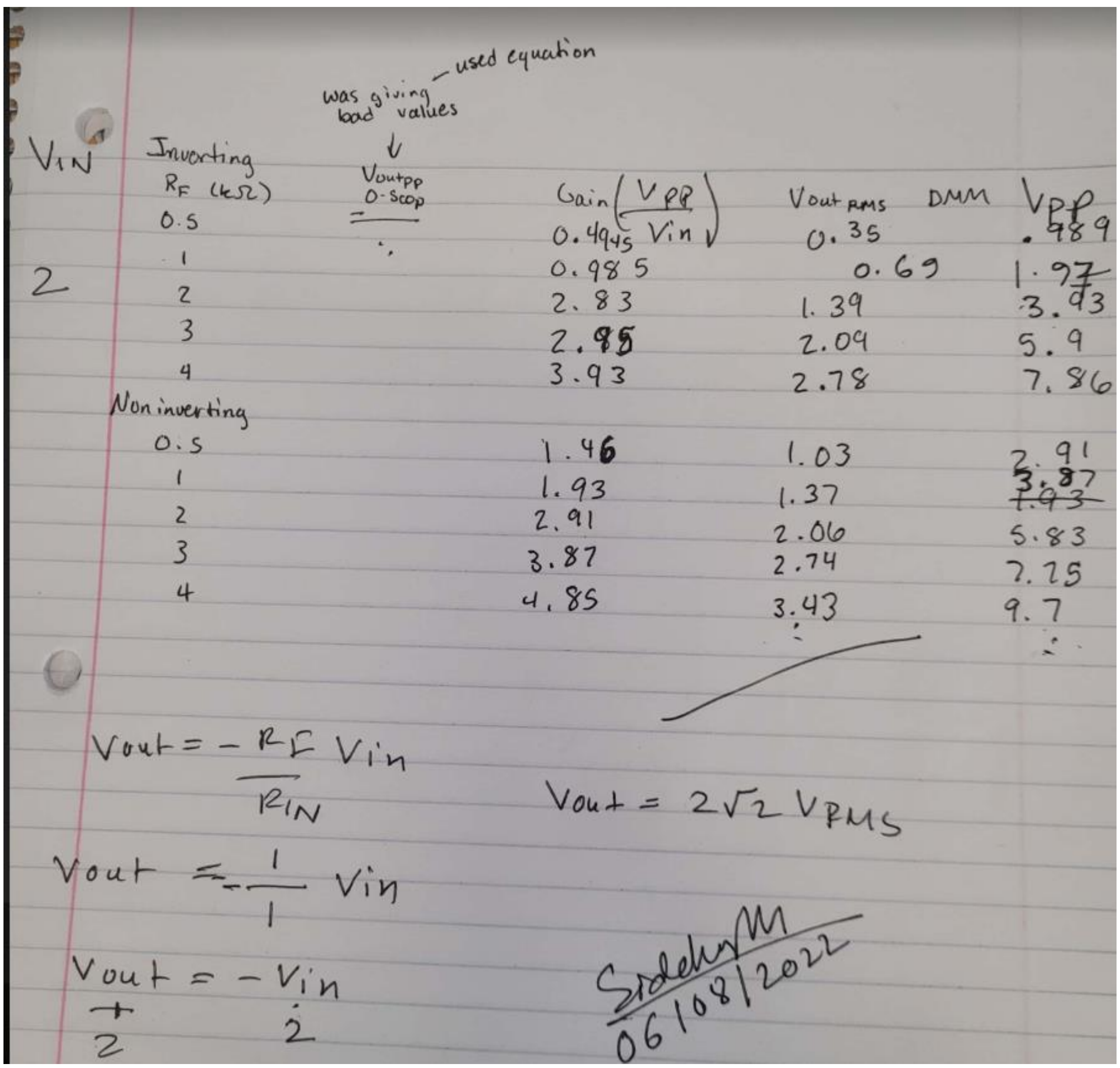

Inverting Amplifier




Noninverting Amplifier

## Appendix 2:

Signed lab results



## Pictures of Circuits

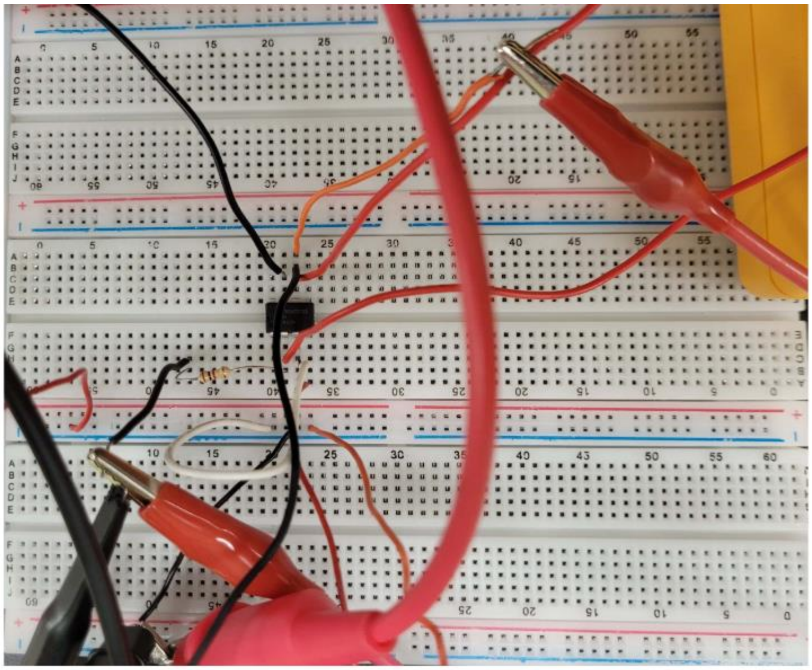


Figure 1 (inverting) physical circuit

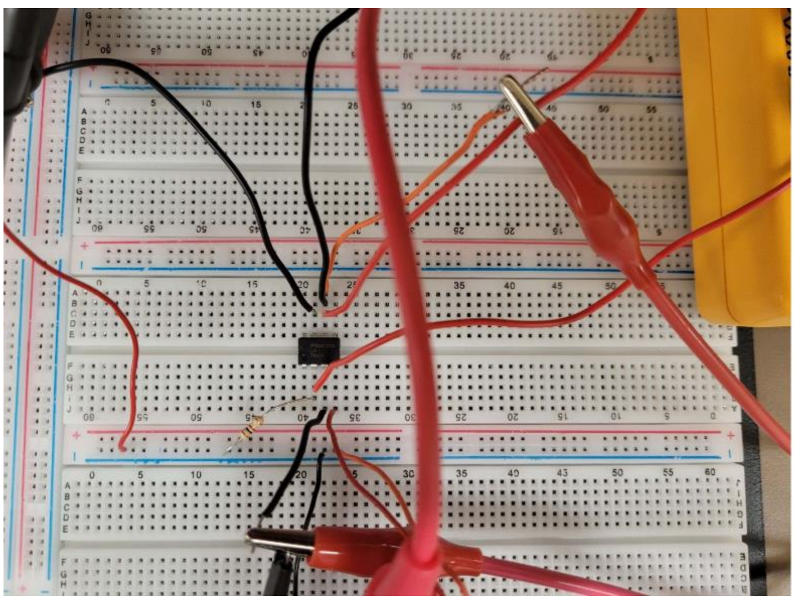
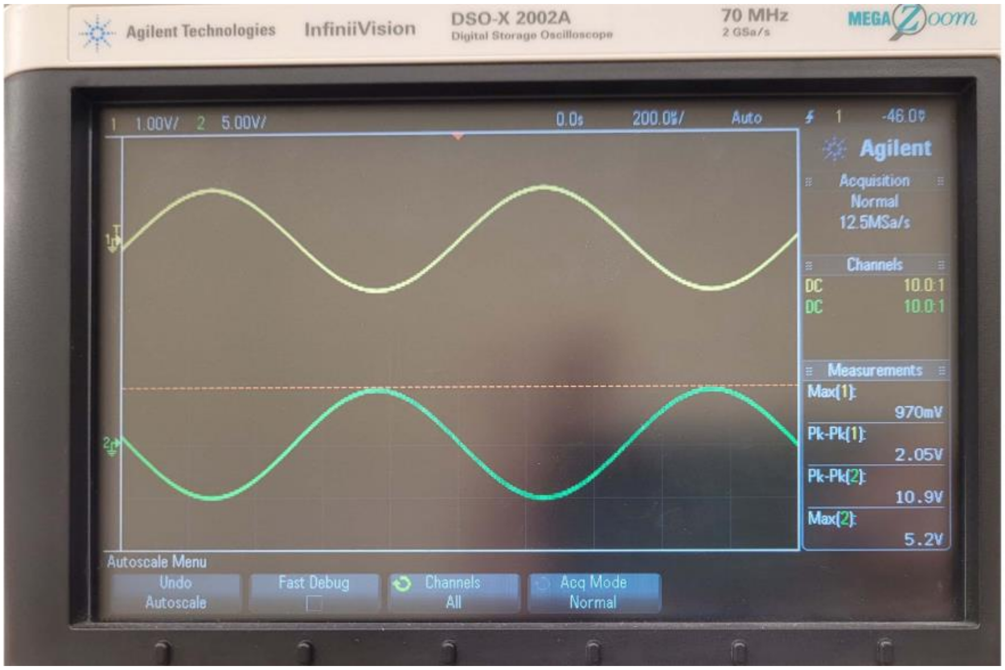
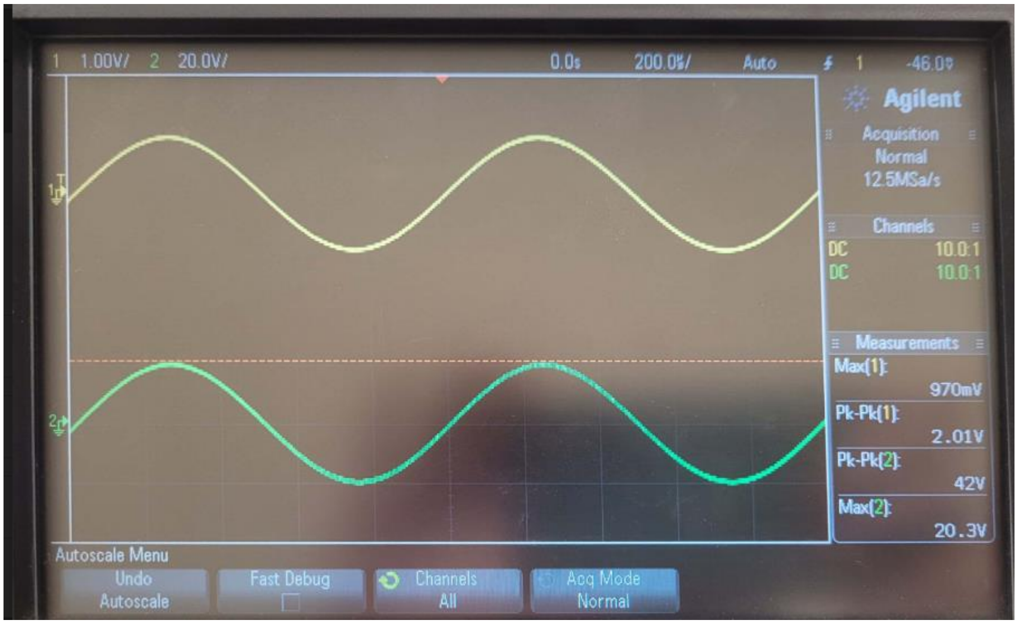


Figure 2 (noninverting) physical circuit

Oscilloscope Waves




Inverting Amplifier




Noninverting amplifier