PROBLEMS ENCOUNTERED

I did not encounter many issues throughout this lab. The primary issues I had were in the beginning when I had to implement the TLV272 SPICE model and actually have LTspice pull the correct file location along with also struggling to properly wire the circuit in section 5.5.2. The only other issue I had with this lab was properly differentiating which pin was the correct one for the virtual circuit and converting that information into the physical circuit.

INTRODUCTION

The key purpose of this lab is to introduce the idea of operational amplifiers via the use of ideal op amp models, spice models, and practical applications of op amps. This lab will be accomplished using LTspice, TLV272, DAD Board, Breadboard, and a wiring kit. The lab will utilize an introductory section for op amps prior to actually doing work for this lab.

DISCUSSION

5.5 Pre-Lab Requirements

5.5.1 LTspice TLV272 Op Amp Model

This section utilizes the TLV272 SPICE model in LTspice to analyze key operational amplifier characteristics through simulation. DC operating point and transient analyses were used to determine offset voltage, slew rate, maximum output swing, and effective gain using both voltage follower and inverting amplifier configurations.

Vin	Vout
0 V	-0.00280 V

***Table 1**: Measured offset voltage of the TLV272 voltage follower from DC operating point simulation.*

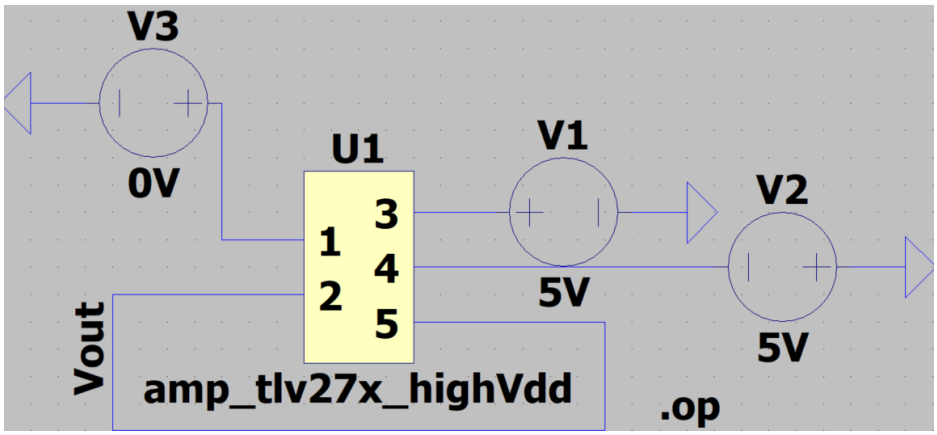


Figure 1: LTspice voltage follower configuration used to determine TLV272 offset voltage through DC .op analysis

V_{in} at 495 µs	**V_{out} at 505 µs**	**Time delay to reach 1 V**	**Slew Rate**
0 V	1 V	3 µs	0.33 V / µs

Table 2: Measured transient response values used to calculate the TLV272 slew rate

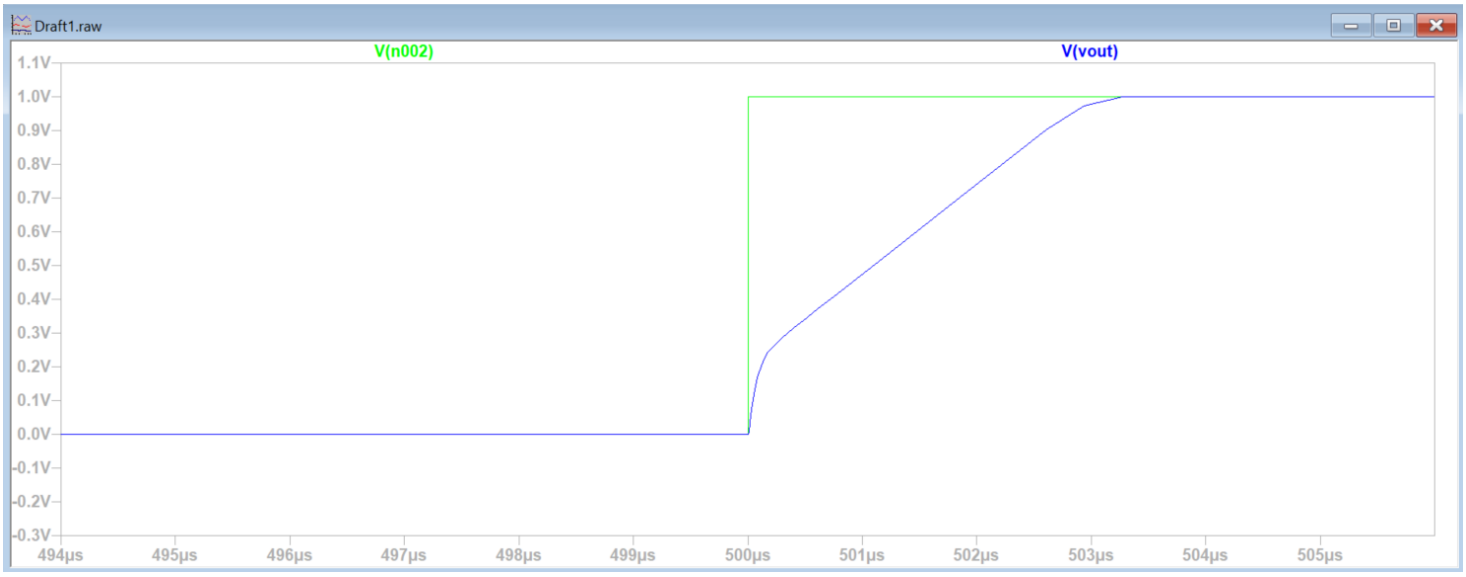


Figure 2: Input and output voltage response of the TLV272 voltage follower used to estimate slew rate from transient response.

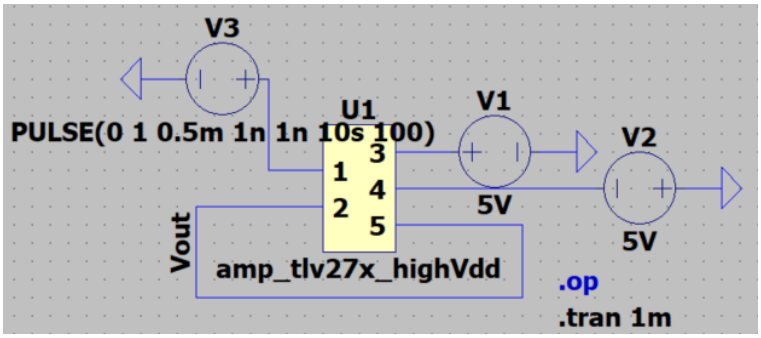


Figure 3: LTspice pulse-input voltage follower circuit used to analyze transient response and slew rate.

V_{max} of V_{out}	5.00 V
V_{min} of V_{out}	-5.00 V

Table 3: Maximum and minimum output voltage swing of the inverting amplifier

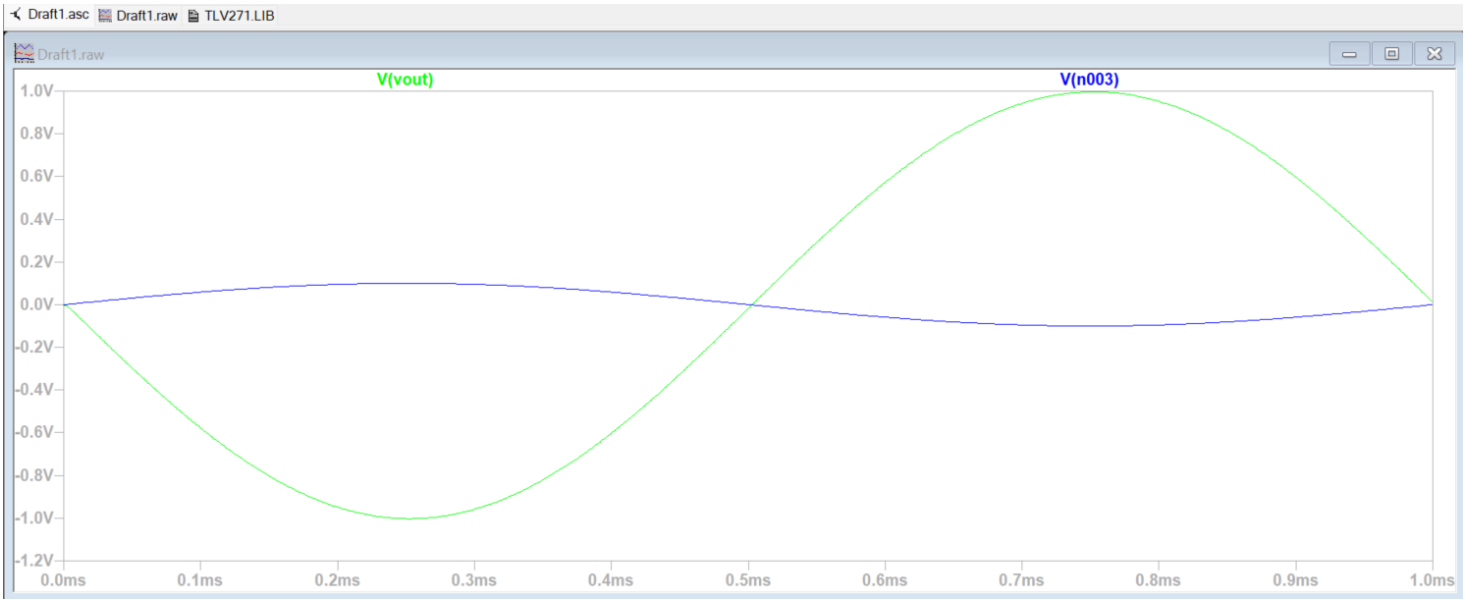


Figure 4: Input and output voltage waveforms of the inverting amplifier showing amplified and inverted sinusoidal behavior.

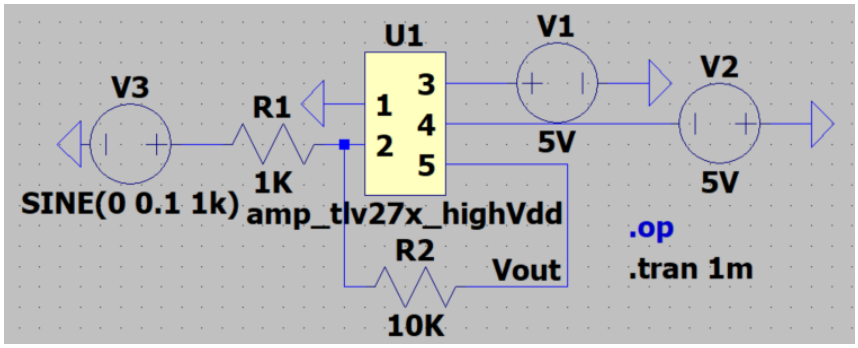


Figure 5: LTspice inverting amplifier configuration using R1 = 1 kΩ and R2 = 10 kΩ to achieve an ideal gain of -10.

Effective Gain	10.03

Table 4: Effective gain measured from the LTspice inverting amplifier simulation.

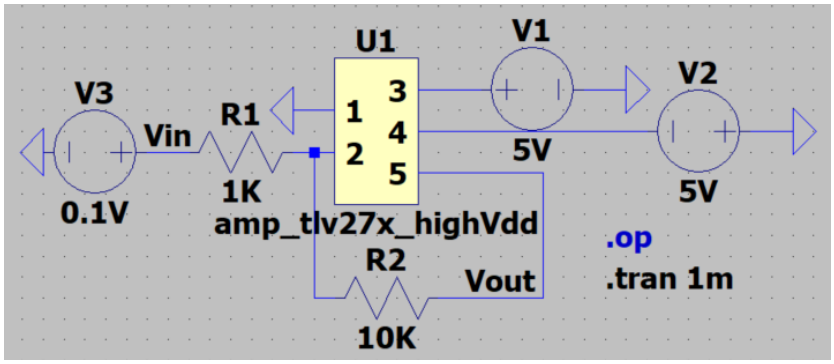


Figure 6: LTspice setup used to calculate effective gain using a 0.1 V DC input source.

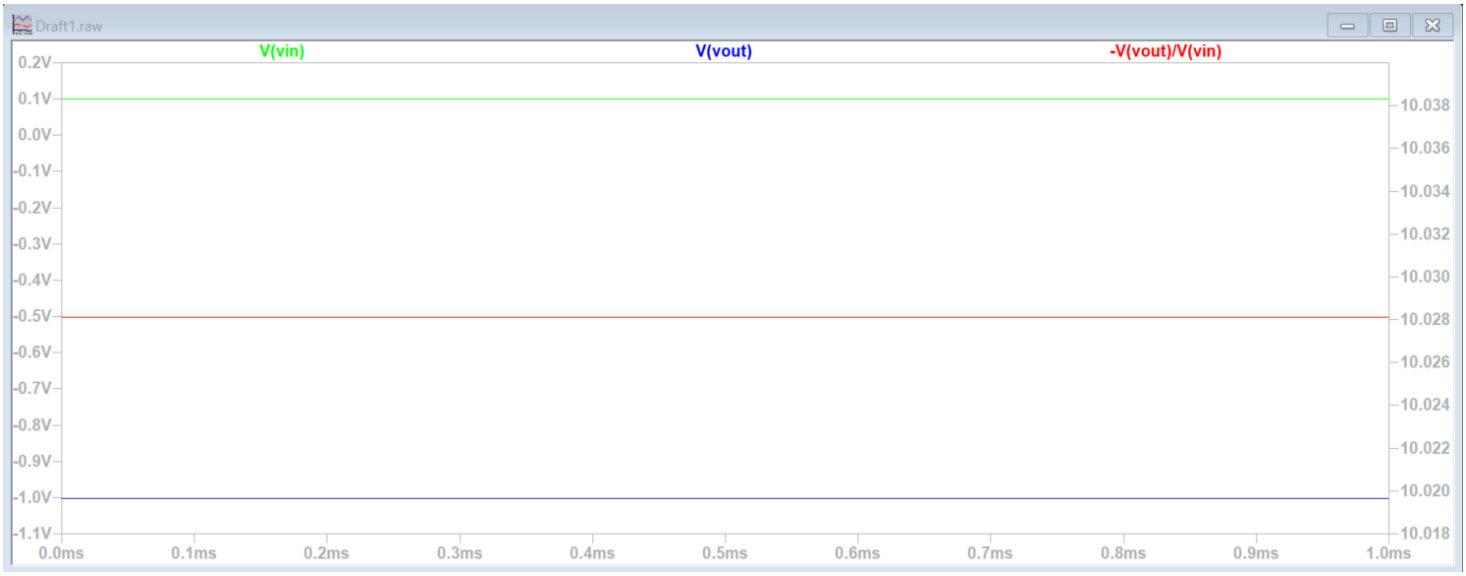


Figure 7: Effective gain plot generated from -V(vout)/V(vin), showing the measured amplifier gain.

5.5.2 Op Amp Construction

This section involves the physical construction of the TLV272 operational amplifier circuit on a breadboard using the DAD board, ±5 V power supplies, and external resistors. Experimental oscilloscope measurements were used to observe the relationship between the input and output waveforms and verify amplifier performance through measured gain.

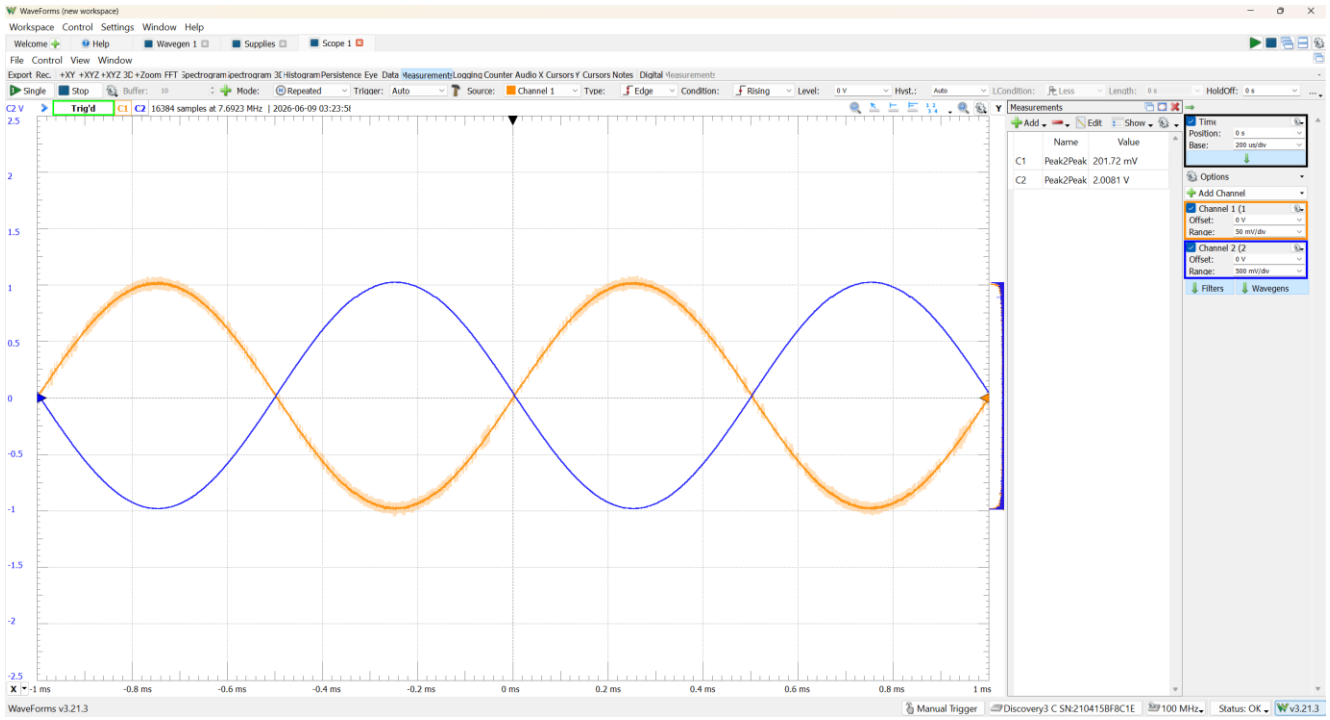


Figure 8: Oscilloscope measurement of experimental input and output waveforms showing amplified and inverted output behavior. The range of Channel 2 is 10x that of Channel 1, causing them to appear equal in amplitude.

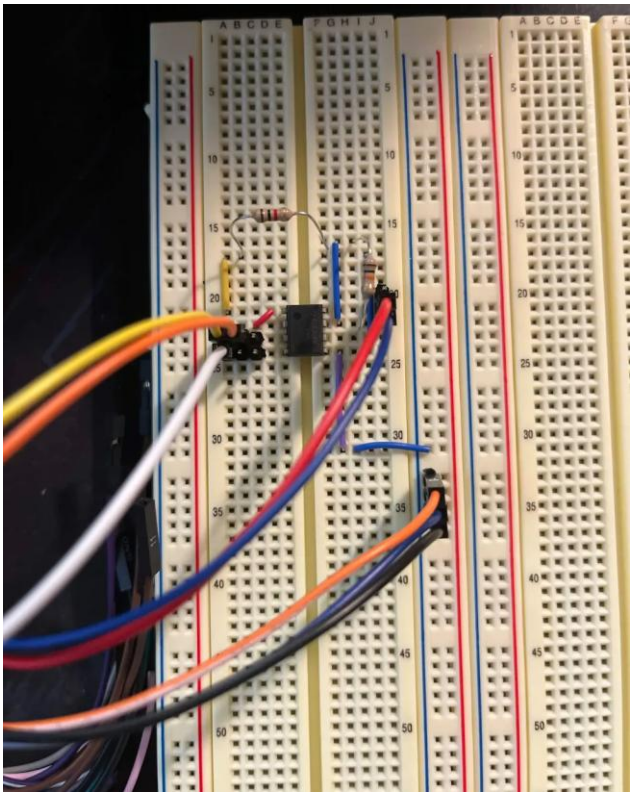


Figure 9: Breadboard implementation of the TLV272 voltage follower and inverting amplifier powered with ±5 V supplies.

Vin	Vout	Gain
0.201 VPP	2.01 VPP	-10.0

Table 5: Experimental oscilloscope measurements of input voltages, output voltage, and measured gain.

5.6 In-Lab Requirements

5.6.1 Experimental Op Amp Measurements

This section focuses on experimentally evaluating the performance of the TLV272 operational amplifier using pre-built voltage follower and inverting amplifier configurations on a breadboard. Measurements obtained using the DAD board and oscilloscope were used to determine offset voltage, slew rate, maximum output voltage swing, and effective gain, which were then compared to LTspice simulation results to evaluate agreement between theoretical and experimental behavior.

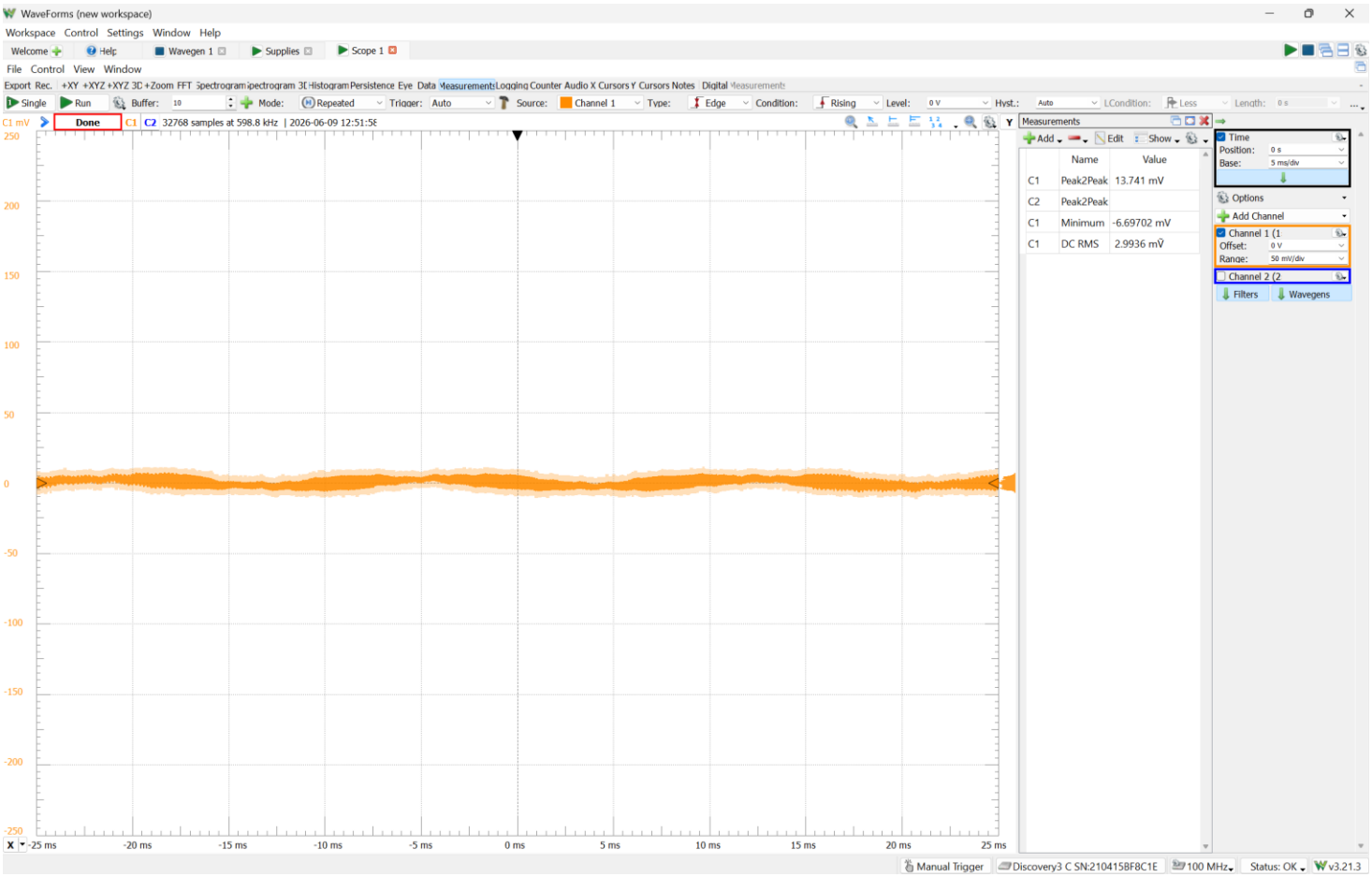


Figure 10: Experimental oscilloscope measurement of the TLV272 voltage follower output used to determine offset voltage under a 0 V DC input condition.

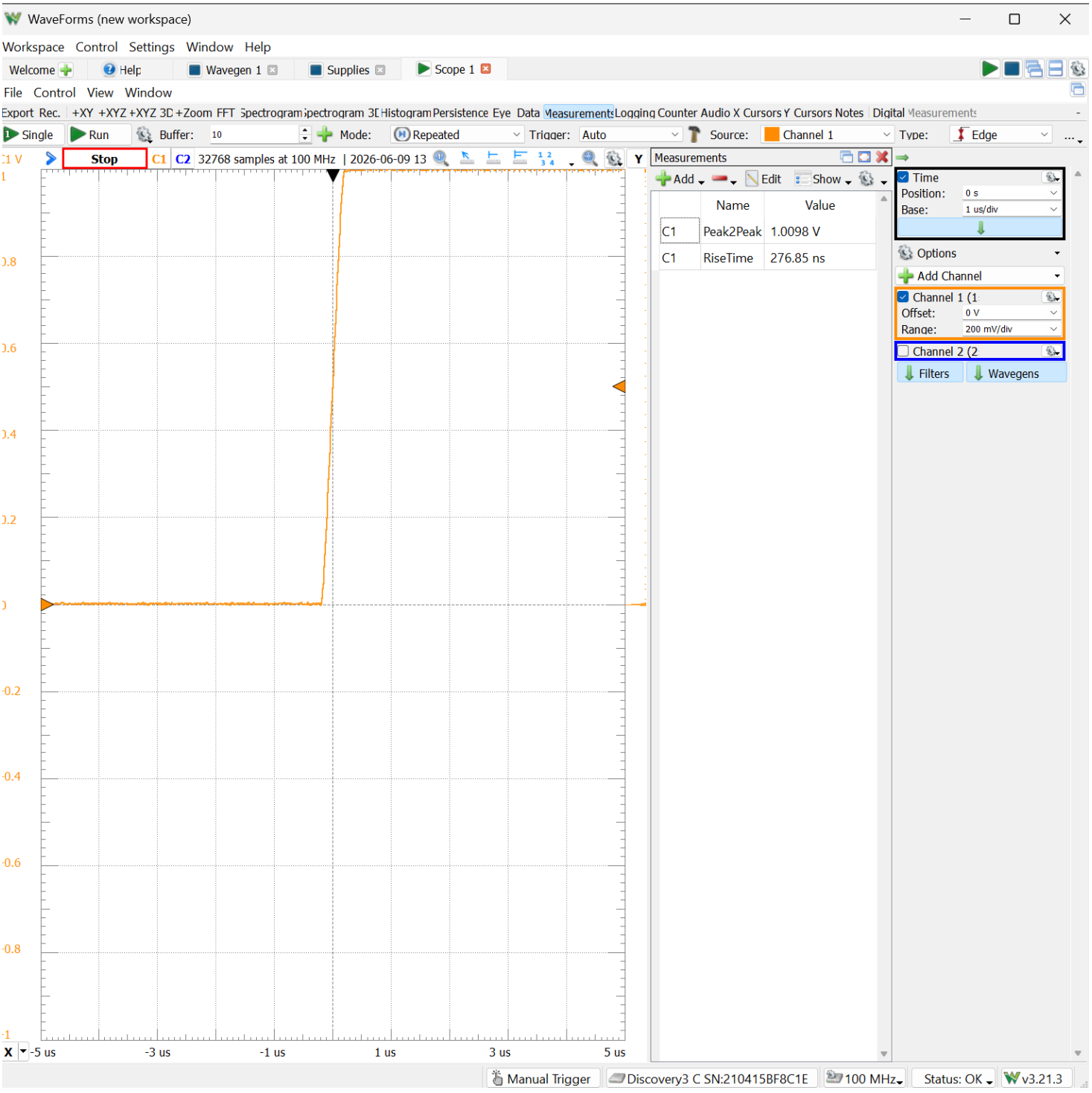


Figure 11: Experimental oscilloscope measurement of the TLV272 voltage follower transient response used to calculate slew rate from the measured rise time.

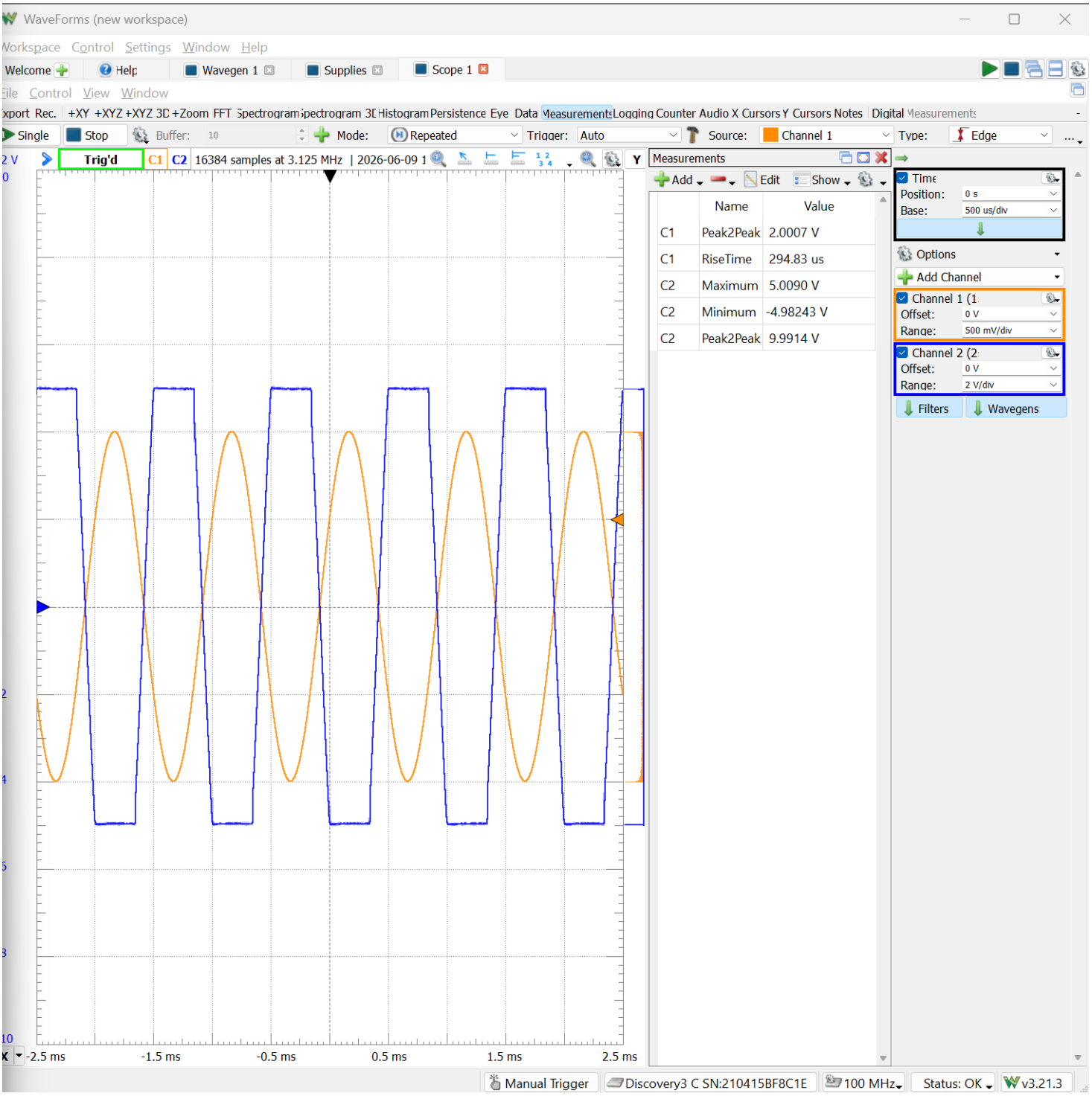


Figure 12: Experimental oscilloscope measurement of the inverting amplifier output used to determine maximum output voltage swing, including V_{max} and V_{min}.

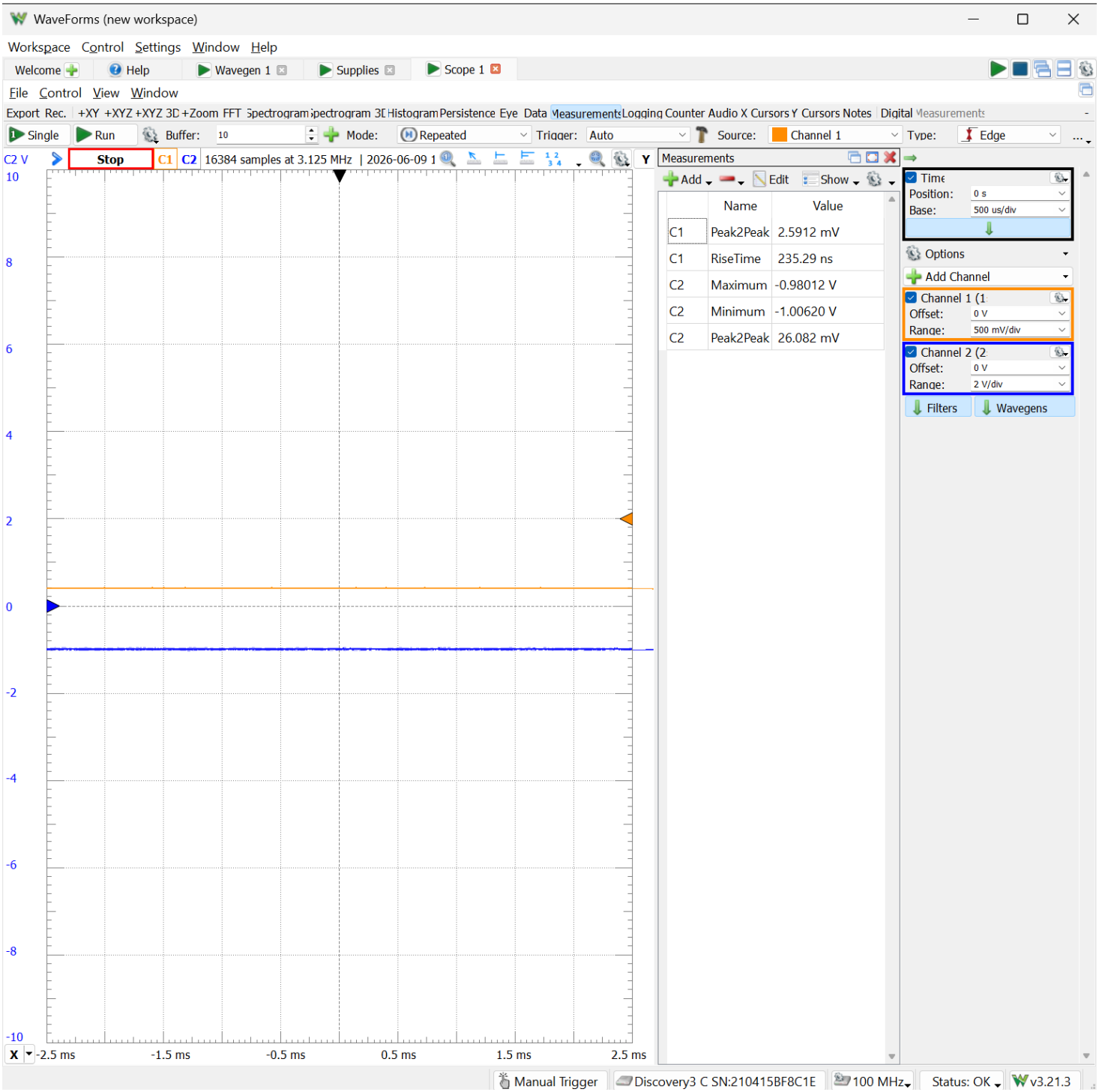


Figure 13: Experimental oscilloscope measurement of the inverting amplifier response used to determine effective gain with a 0.1 V DC input signal.

	LTspice Circuit	**Experimental Circuit**	**Error**
Offset Voltage	2.8 mV	2.99 mV	6.79%

	LTspice Circuit	**Experimental Circuit**	**Error**
Slew Rate	0.33 V / µs	3.61 V / µs	993.94%
V_{min}	-5 V	-4.98 V	-0.40%
V_{max}	5 V	5.01 V	0.20%
V_{swing}	10 V	9.99 V	-0.10%
Effective Gain	-10.0	-10.06	0.60%

Table 6: Comparison of LTspice and experimental results for TLV272 operational amplifier performance, including offset voltage, slew rate, output voltage swing, and effective gain with associated percent error.

Discussion Question:

The ideal op amp model assumes that there is infinite gain, infinite input impedance, zero output impedance, zero offset voltage, and no limitations on the output which makes it extremely useful for circuit analysis. The LTspice TLV272 model is much more appropriate when realistic behavior is needed because it includes non-ideal characteristics such as slew rate and offset voltage. The physical op amp differs slightly from this but in general, the ideal model is best for conceptual understanding while the spice model is more suitable for actual physical implementations.

The SPICE model for the op amp should be fairly accurate in predicting circuit behaviors like gain and have small discrepancies compared to physical measurements. Since the simulations do not completely accurately predict the experimental values they will not likely match, however, spice models are great at using physical behavior to guide decision making.

CONCLUSION

In this lab, the TLV272 op amp was analyzed utilizing both LTspice simulations and experimental measurements utilizing a breadboard and a Digilent Discovery Board. Voltage followers and inverting amplifier configurations were used to help determine the offset voltage, slew rate, output swing for the voltage, and effective gain. These values were utilize to compare simulated results via percent error analysis. Overall, the experimental results showed good agreement within the simulated models yet had a larger discrepancy with the slew rate highlighting the influence that real-world devices have on circuit effects.