Experiment 41

Sunday, February 19, 2023 3:52 PM

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Objectives:

1. Demonstrate the operation of a differential amplifier.
2. Measure the gain and common-mode rejection ratio (CMRR) of a differential amplifier.

Pre-Lab:

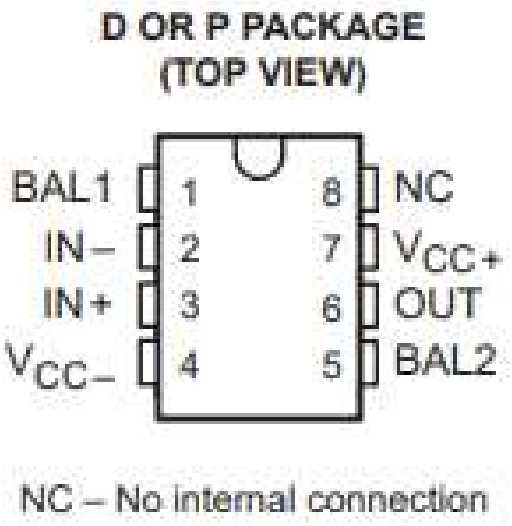

Figure 2 (LF411 Op Amp diagram)

$$V_o = A_v(V_2 - V_1)$$

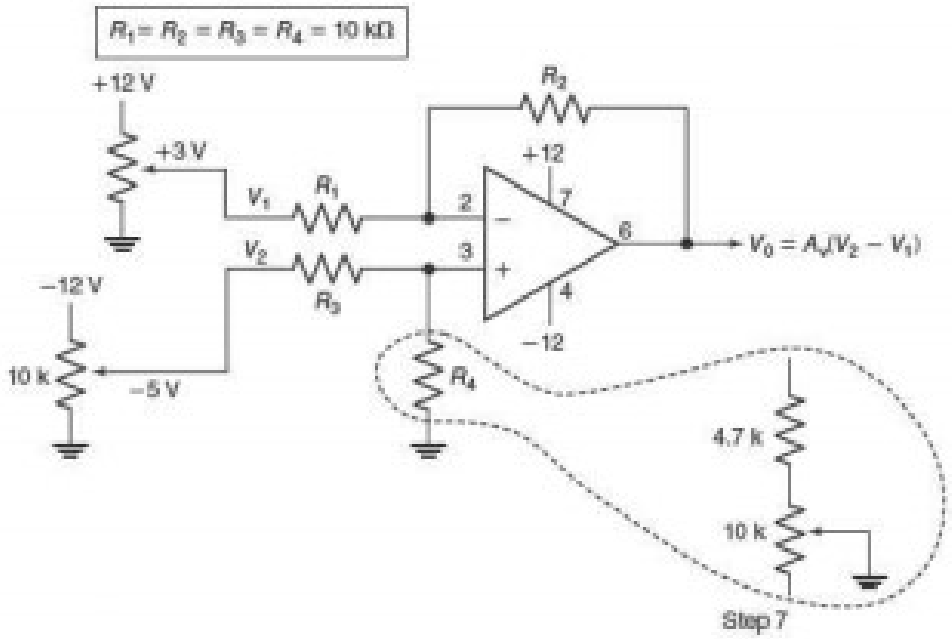

Figure 41-1

Figure 41-1

Figure 2 (General Circuit Layout from Lab Manual)

$$Av = \frac{R2}{R1}$$

$$Av(cm) = \frac{Vo}{V2 - V1}$$

$$CMRR = \frac{Av}{Av(cm)}$$

$$CMRR = 20\log(\frac{Av}{Av(cm)})$$

NOTE: Potentiometers were difficult to calibrate so instead of using potentiometer to control voltage input, the oscilloscope function generator(2.5 V limit) and CH3 of the DC supply(5 V limit) were used.

Procedure:

Steps 1-4

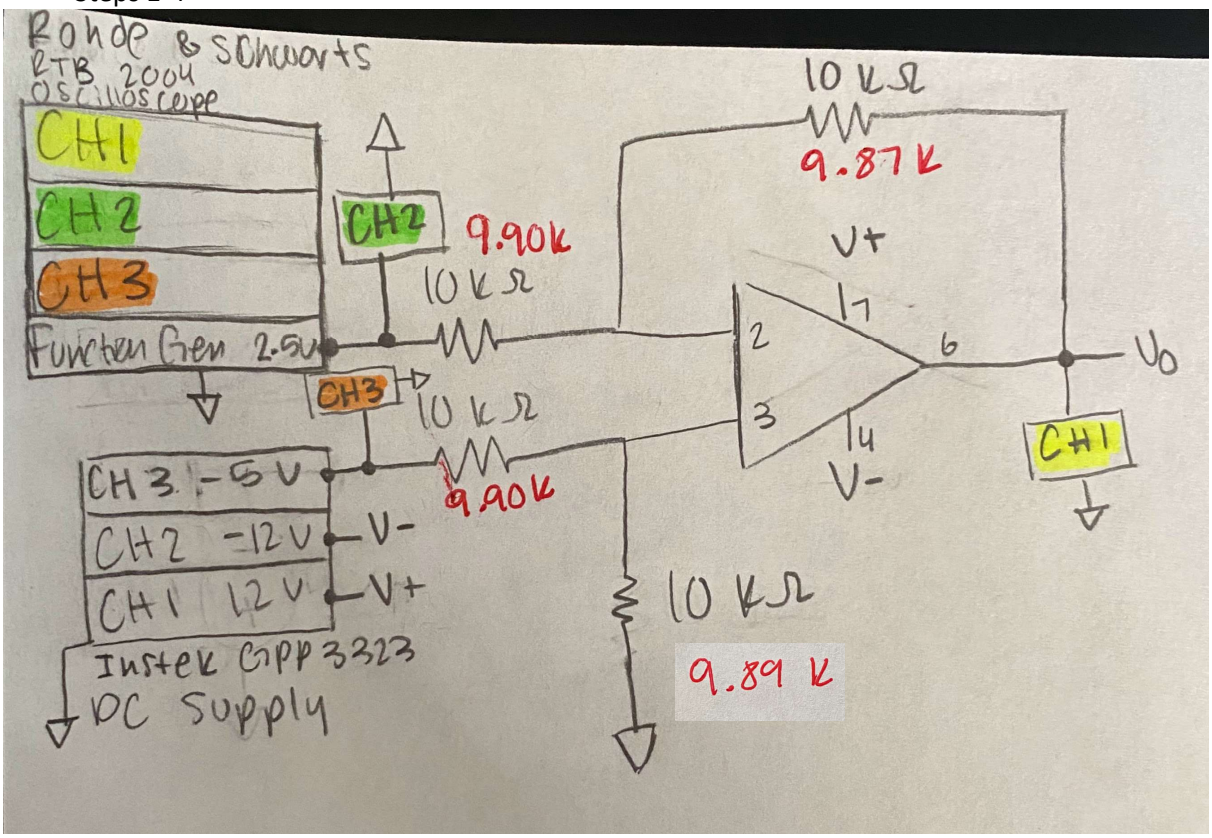

Figure 3 (Circuit Sketch with V1 = 2.5V and V2 = -5V)

As noted above, potentiometers were not used so the function generator on the oscilloscope which has a limit of 2.5V was used for V1. For V2, CH3 of the Instek DC supply was used which has a set value of 5V while CH1 and CH2 were used for the positive and negative source values for the op amp. The positive probe was set to ground and the negative probe was set to the source to create -5V. The colors of the channels on the sketch correspond to the labels and colors of the channels on the oscilloscope figure below.

Figure 4 (Oscilloscope Image of Figure 3 Circuit Sketch, No Offset)

The channels colors and labels correspond to the colors and label of Figure 3. CH1 (yellow) measures the value of Vo which is -8V. CH2 (green) measures the value of V1 which is 2.5V. CH3 (orange) measures the value of V2 which is -5V

Table 1 (Calculated and Measured Values of Figures 3-4)

Av	Av (cm)	CMRR	CMRR [dB]	Vo (calculated) [V]	Vo (real) [V]
0.99697	1	0.99697	-0.026361	-7.98	-8

Steps 5-6

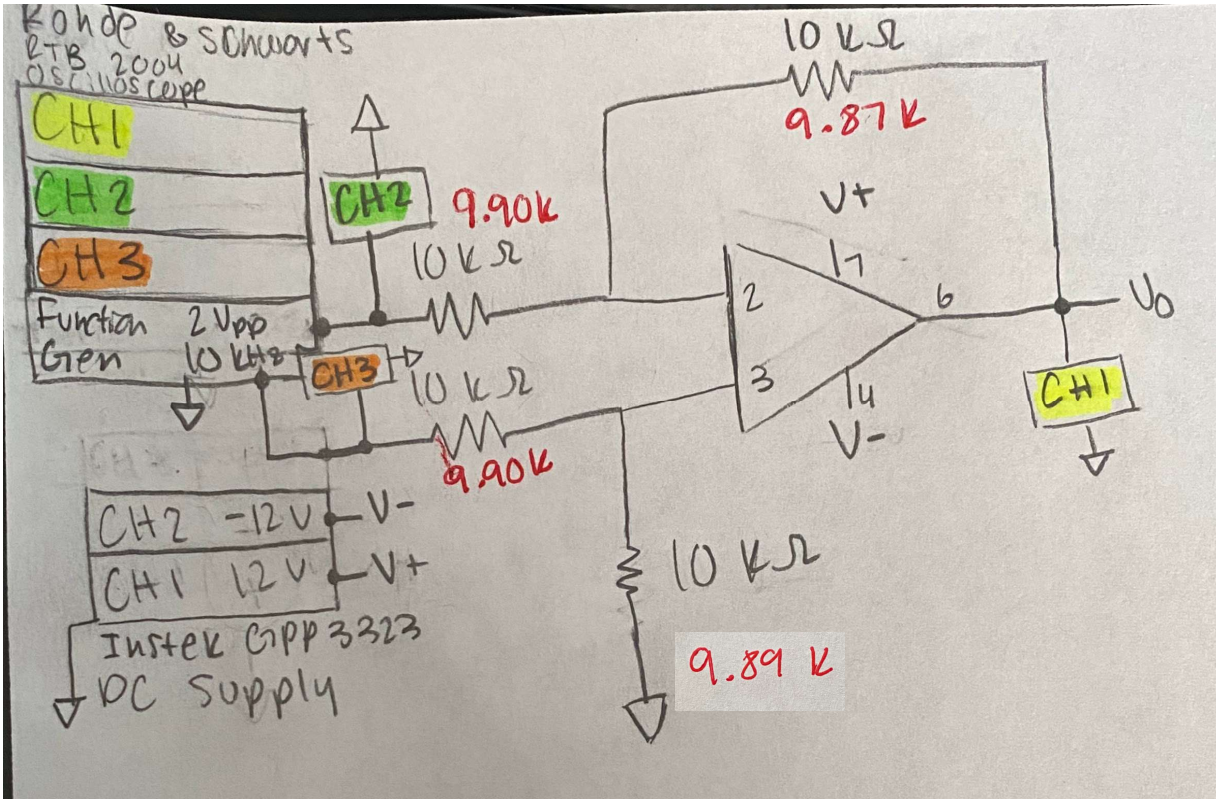

Figure 5 (Circuit Sketch with V1 = V2 = +2Vpp and w = 10kHz)

The function generator on the oscilloscope was used for both V1 and V2 for 2Vpp at 10kHz. No other change to circuit from Figure 3. The colors of the channels on the sketch correspond to the labels and colors of the channels on the oscilloscope figure below.

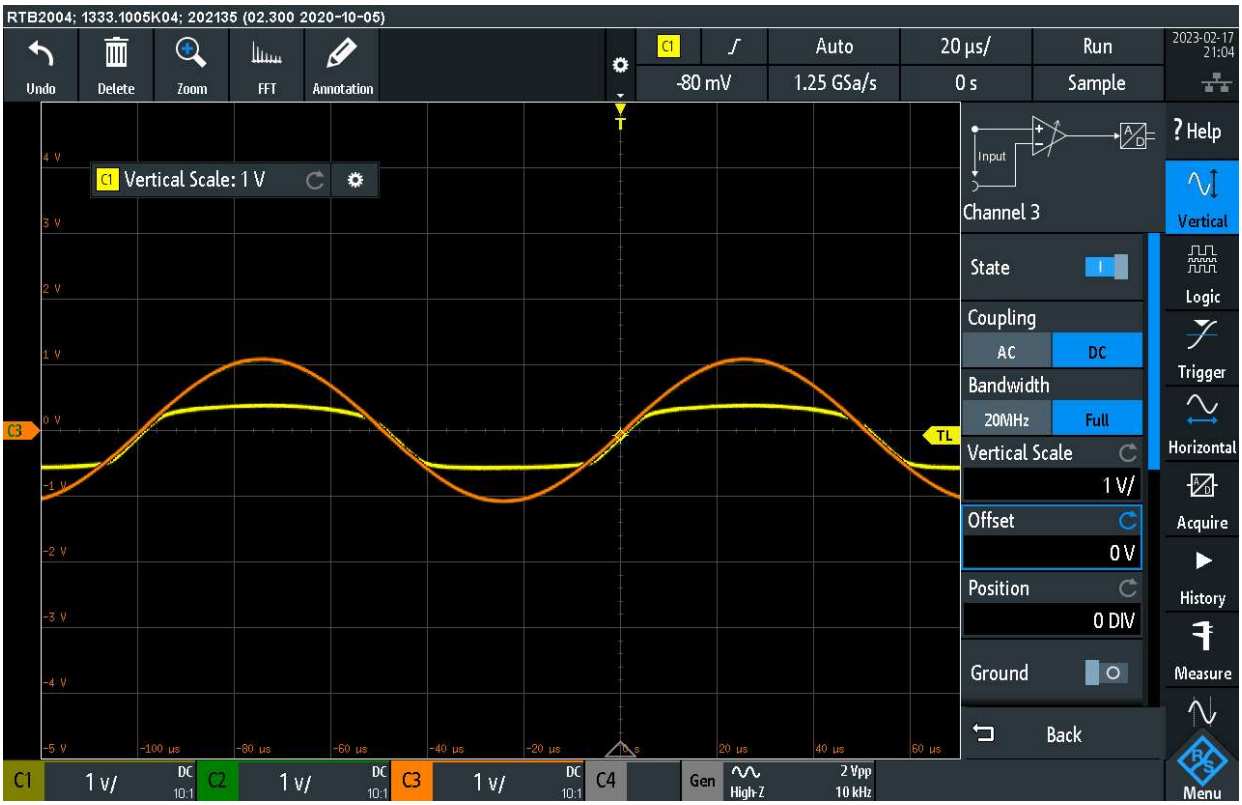

Figure 6 (Oscilloscope Image of Figure 5 Circuit Sketch, No Offset)

The channels colors and labels correspond to the colors and label of Figure 5. CH1 (yellow) measures the value of Vo which is 865 mVpp. CH2 (green) measures the value of V1 which is 2Vpp. CH3 (orange) measures the value of V2 which is 2Vpp. The output of Vo signal is clipping at 450 mVpp which means

the signal/op amp is oversaturated.

Figure 7 (Oscilloscope Image of Figure 5 Circuit Sketch, offset added to make distinct functions visible) The channels colors and labels correspond to the colors and label of Figure 5. CH1 (yellow) measures the value of Vo which is 865 mVpp. CH2 (green) measures the value of V1 which is 2Vpp. CH3 (orange) measures the value of V2 which is 2Vpp. The output of Vo signal is clipping at 450 mVpp which means the signal/op amp is oversaturated.

Table 2 (Calculated and Measured Values of Figures 5-7)

Av	Av (cm)	CMRR	CMRR [dB]	Vo (calculated) [Vpp]	Vo (real) [Vpp]
0.99697	0.4325	2.30513	7.25392	1.994	0.865

Step 7

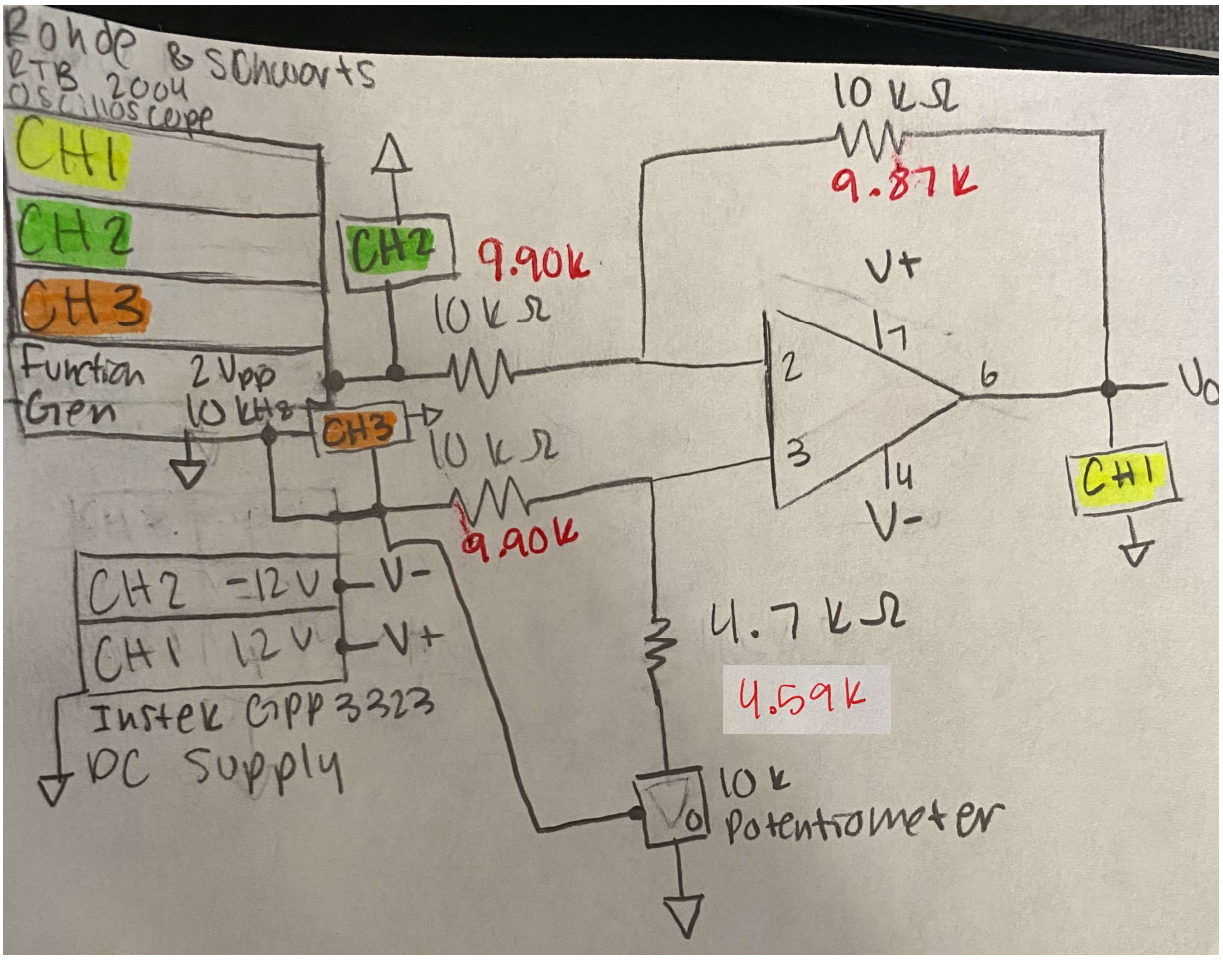

Figure 8 (Circuit Sketch with V1 = V2 = +2Vpp and w = 10kHz)

The function generator on the oscilloscope was used for both V1 and V2 for 2Vpp at 10kHz. R4 was removed and replaced by a 4.7k ohm resistor and a 10k potentiometer.No other change to circuit from Figure 5. The colors of the channels on the sketch correspond to the labels and colors of the channels on the oscilloscope figure below.

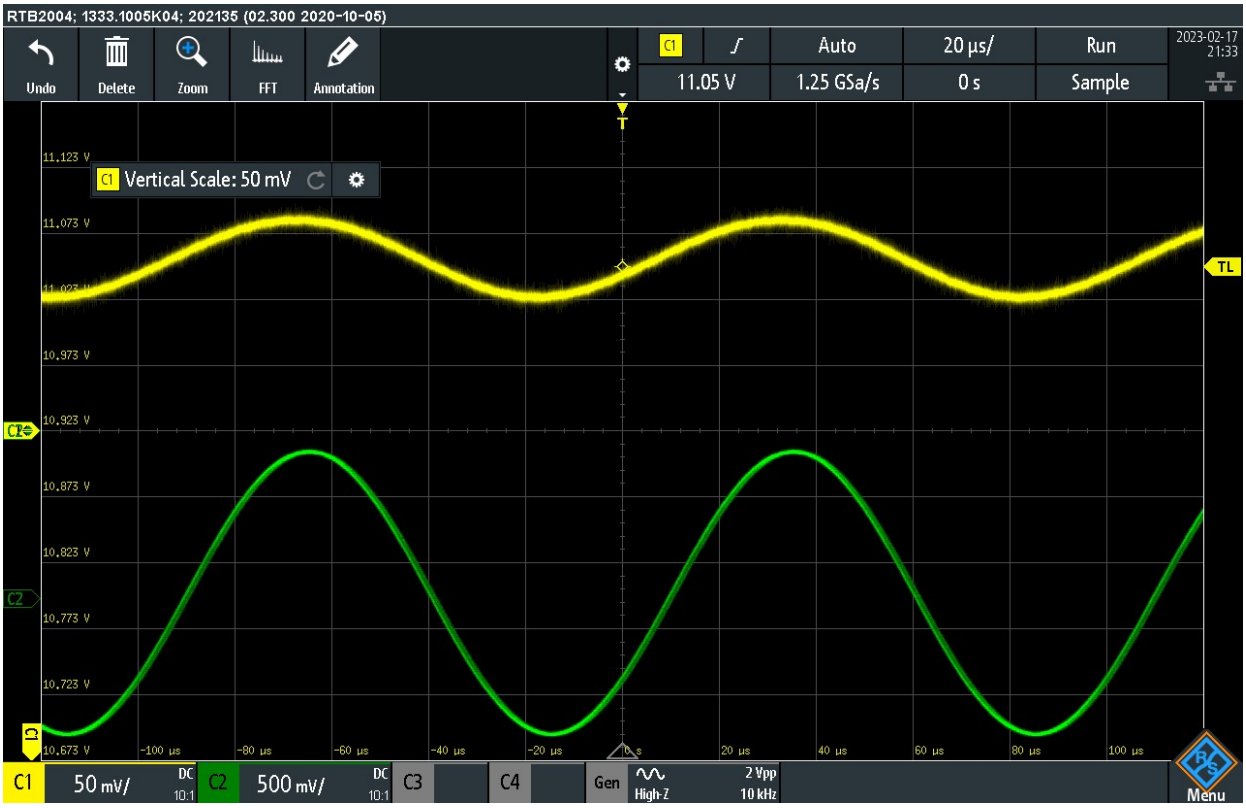

Figure 9 (Oscilloscope Image of Figure 8 Circuit Sketch, Offset and Scale Difference Applied, Max Vo)
The channels colors and labels correspond to the colors and label of Figure 8. CH1 (yellow) measures the value of Vo which is 60 mVpp. CH2 (green) measures the value of V1 and V2 which is 2Vpp. The output voltage measured by CH1 is with the potentiometer set clockwise which gives the highest voltage output

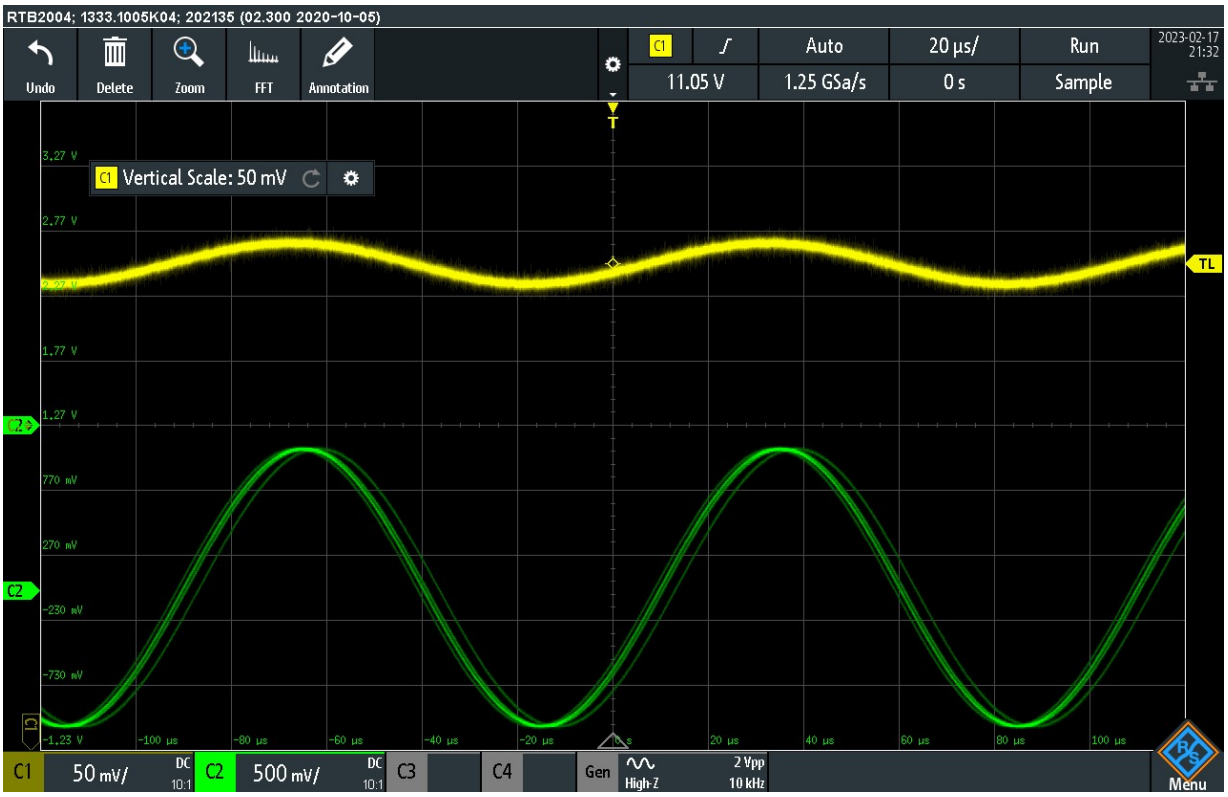

Figure 10 (Oscilloscope Image of Figure 8 Circuit Sketch, Offset and Scale Difference Applied, Min Vo)
The channels colors and labels correspond to the colors and label of Figure 8. CH1 (yellow) measures the value of Vo which is 50 mVpp. CH2 (green) measures the value of V1 and V2 which is 2Vpp. The output voltage measured by CH1 is with the potentiometer set counter-clockwise which gives the lowest

voltage output

Table 3 (Calculated and Measured Values of Figure 9)

Av	Av (cm)	CMRR	CMRR [dB]	Vo (calculated) [Vpp]	Vo (real) [Vpp]
0.99697	0.03	33.2323	30.4312	1.994	0.06

Table 4 (Calculated and Measured Values of Figure 10)

Av	Av (cm)	CMRR	CMRR [dB]	Vo (calculated) [Vpp]	Vo (real) [Vpp]
0.99697	0.025	39.8788	32.0148	1.994	0.05

With the 10k potentiometer set to minimize output voltage, the value of CMRR increased from 30.4312 dB to 32.0148 dB which is an improved CMRR value.

Questions:

1. A differential op amp has a gain of 150. The common-mode gain is 0.03. What is the CMMR in decibels?

$$CMRR = \frac{Av}{Av(cm)} = \frac{150}{0.03} = 5000$$

$$CMRR = 20\log\left(\frac{Av}{Av(cm)}\right) = 20\log(5000) = 73.9794\ dB$$

2. How can the resistors in the circuit be more closely matched?

By measuring multiple resistors and picking 4 with the closest real values would improve the real gain values as well as CMRR

3. In step 7, is there any improvement in CMRR? Explain.

With the 10k potentiometer set to minimize output voltage, the value of CMRR increased from 30.4312 dB to 32.0148 dB which is an improved CMRR value.