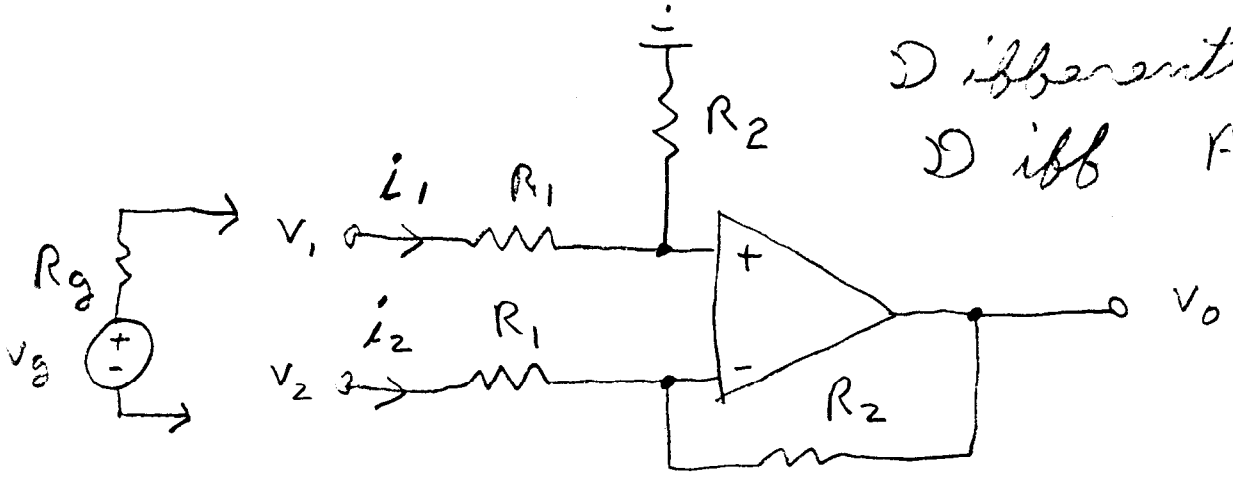
Differential Amplifier

Diff Amp



$$V_o = \underbrace{\frac{R_2}{R_1 + R_2}\left[1 + \frac{R_2}{R_1}\right] V_1}_{\text{Output When } V_2 = 0} + \underbrace{\left(-\frac{R_2}{R_1}\right) V_2}_{\text{Output When } V_1 = 0}$$

Superposition

$$V_o = \frac{R_2}{R_1}(V_1 - V_2), \quad A_d = \frac{V_o}{V_1 - V_2} = \frac{R_2}{R_1}$$

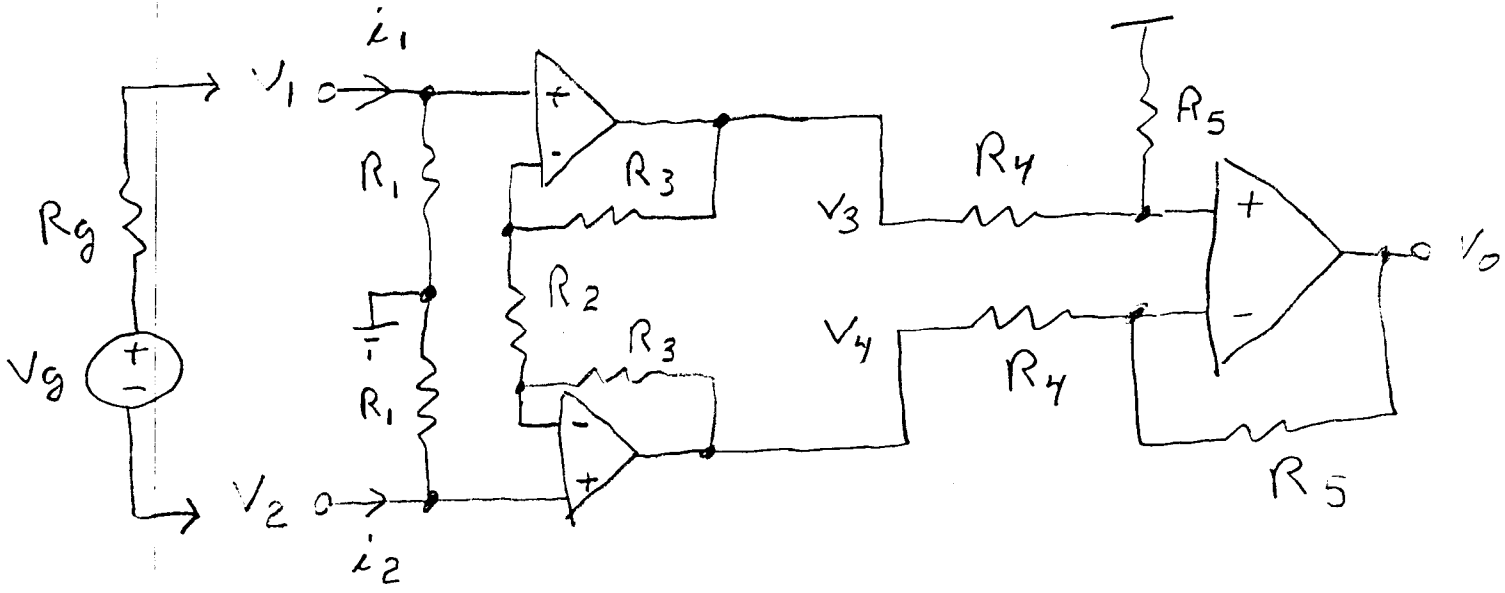
$\bar{Z}_{id} \equiv$ differential input impedance

$$\bar{Z}_{id} \equiv \frac{V_1 - V_2}{i_1}$$

$$\bar{Z}_{id} = 2R_1$$

$$V_1 - V_2 = V_g \frac{2R_1}{2R_1 + R_g}$$

Instrumentation Amplifier



$$V_1 - V_2 = (V_3 - V_4)\,\frac{R_2}{R_2 + 2R_3}$$

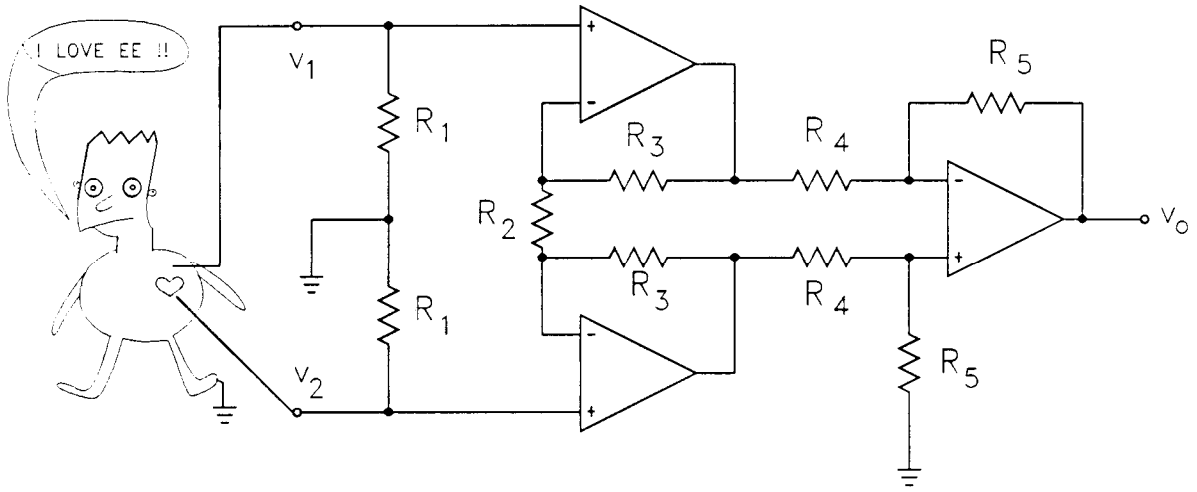
$$V_3 - V_4 = (V_1 - V_2)\left[1 + \frac{2R_3}{R_2}\right]$$

$$V_o = \frac{R_5}{R_4}(V_3 - V_4)$$

$$V_o = \frac{R_5}{R_4}\left[1 + \frac{2R_3}{R_2}\right](V_1 - V_2)$$

$$A_d \equiv \text{differential gain} = \frac{V_o}{V_1 - V_2} = \frac{R_5}{R_4}\left(1 + \frac{2R_3}{R_2}\right)$$

$$\bar{Z}_{id} = \frac{V_1 - V_2}{i_1} = 2R_1$$



Common mode gain

$V_1 = V_2 \Rightarrow V_o = 0$

$A_{cm} = \frac{V_o}{V_1} \equiv$ common mode gain

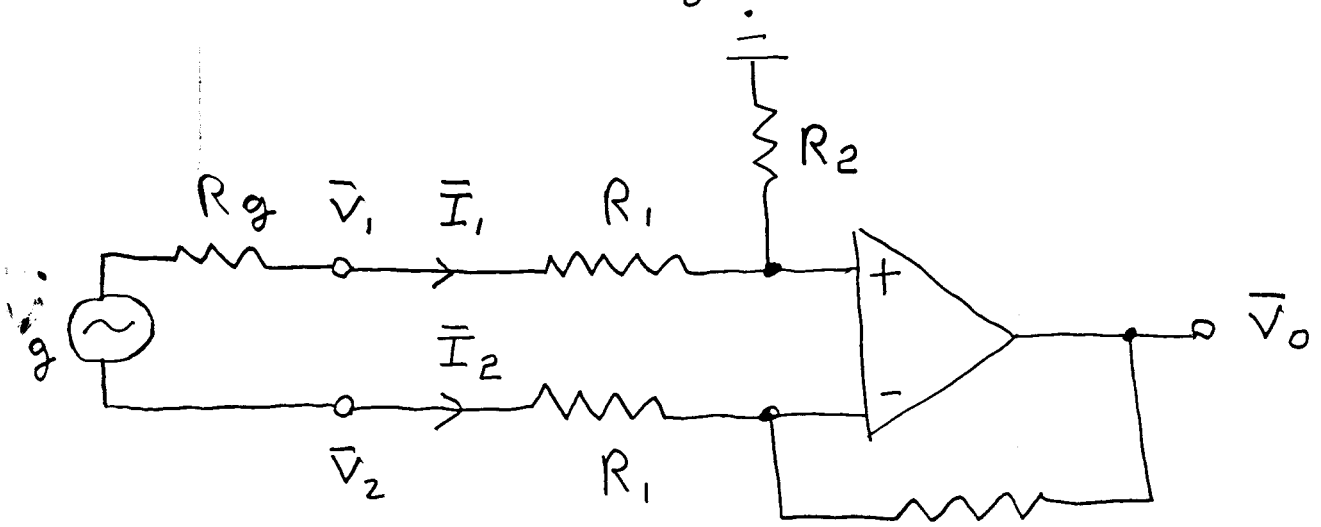
should be small

CMRR $\equiv$ common mode rejection ratio

CMRR $= \frac{A_d}{A_{cm}}$ huge

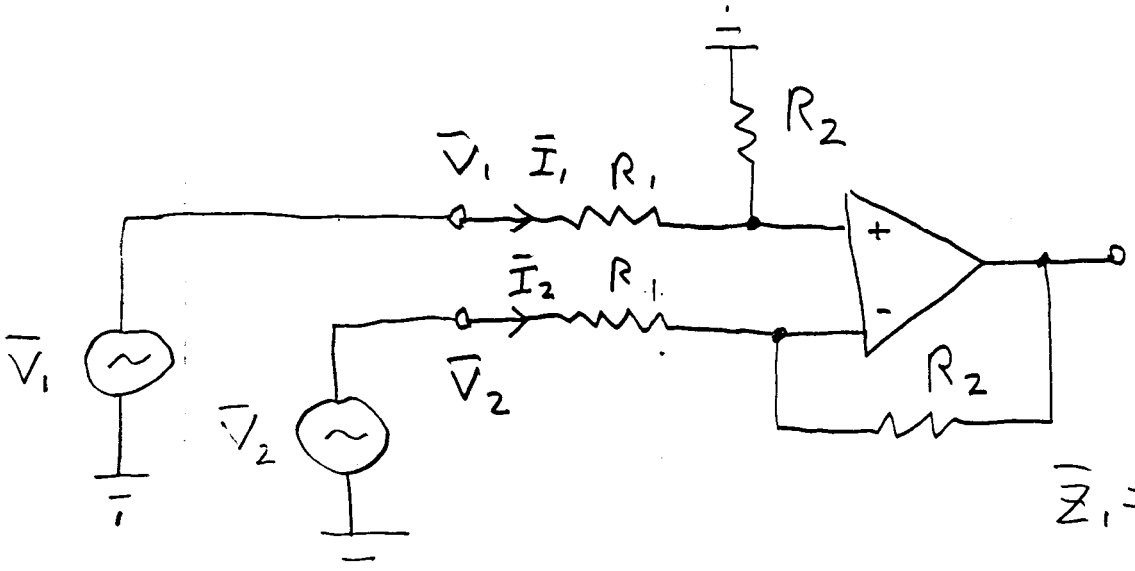
$CMRR_{dB} = 20 \log_{10} CMRR$

Floating Source or Input



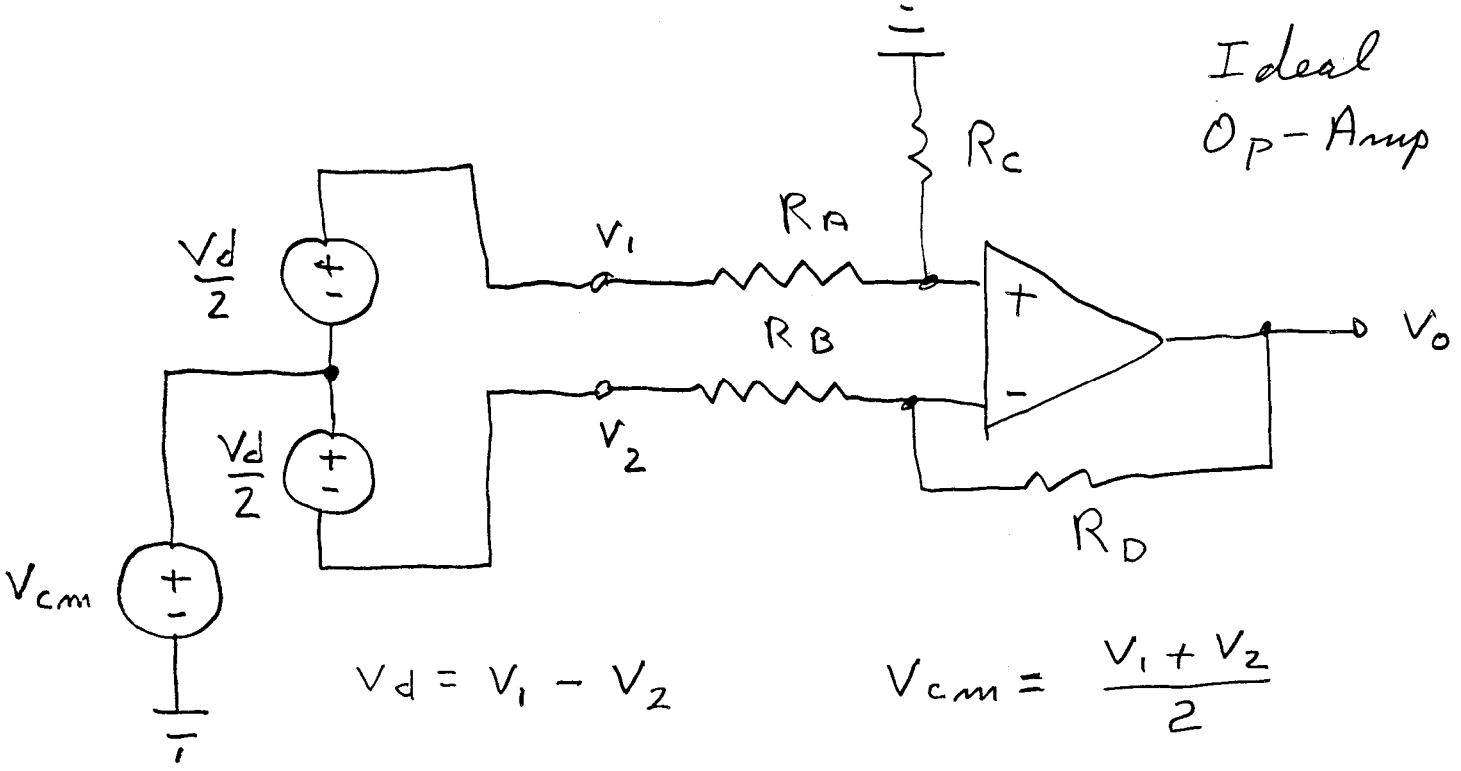
$$\bar{T}_d = \frac{\bar{V}_o}{\bar{V}_1 - \bar{V}_2} = \frac{R_2}{R_1} \qquad \bar{Z}_{id} = \frac{\bar{V}_1 - \bar{V}_2}{\bar{I}_1} = 2R_1$$

Single Ended Source or Input



$$\bar{Z}_1 = \frac{\bar{V}_1}{\bar{I}_1} = R_1 + R_2$$

$$\bar{T}_d = \frac{\bar{V}_o}{\bar{V}_1 - \bar{V}_2} = \frac{R_2}{R_1} \qquad \bar{Z}_2 = \frac{\bar{V}_2}{\bar{I}_2} = ?$$



$$V_d = V_1 - V_2 \qquad V_{cm} = \frac{V_1 + V_2}{2}$$

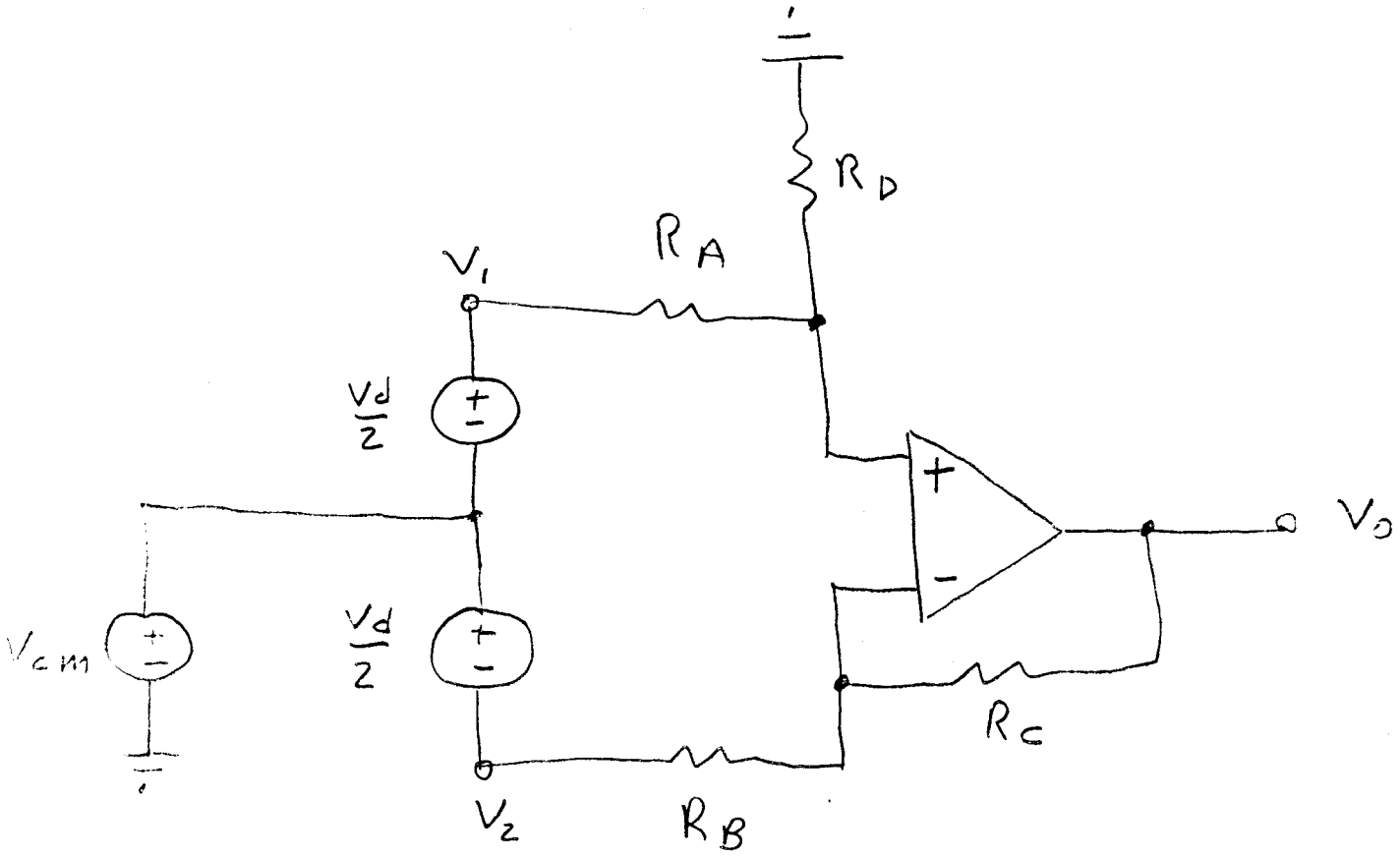
$$V_o = \frac{R_C}{R_A + R_C}\left[1 + \frac{R_D}{R_B}\right]\left[\frac{V_d}{2} + V_{cm}\right] - \frac{R_D}{R_B}\left[-\frac{V_d}{2} + V_{cm}\right]$$

$$A_d = \frac{V_o}{V_d} = \left[\frac{R_C}{R_B}\,\frac{R_B + R_D}{R_A + R_C} + \frac{R_D}{R_B}\right]\frac{1}{2}$$

$$A_{cm} = \frac{R_C}{R_B}\,\frac{R_B + R_D}{R_A + R_C} - \frac{R_D}{R_B}$$

$$V_o = A_d V_d + A_{cm} V_{cm}$$

CMRR = common mode rejection ratio $= \dfrac{A_d}{A_{cm}}$



Differential Input $V_d = V_1 - V_2$

Common Mode Input $V_{cm} = \frac{V_1 + V_2}{2}$

If $R_A = R_B = R_1$

$R_C = R_D = R_2$

$$V_o = \frac{R_2}{R_1}(V_1 - V_2)$$

Georgia Institute of Technology

School of Electrical and Computer Engineering

ECE 3042 Microelectronic Circuits Laboratory Verification Sheet

NAME:_____ SECTION:_____

GT NUMBER:_____ GTID:_____

Experiment 4: Differential and Instrumentation Amplifiers

Procedure	Time Completed	Date Completed	Verification (Must demonstrate circuit)	Points Possible	Points Received
2. Diff Amp Inv Input Grounded				8	
2. Diff Amp Non-Inv Input Grounded				8	
2. Diff Amp Floating Source Input				8	
2. Diff Amp Common Mode Gain				8	
2. Diff amp Common Mode Gain Minimization				8	
3. Inst Amp Inv Input Grounded				8	
3. Inst Amp Non-Inv Input Grounded				8	
3. Inst Amp Floating Source Input				8	
3. Inst Amp Common Mode Gain				8	
3. Inst Amp Common Mode Gain Minimization				8	
4. Curve Tracer				20	

To be permitted to complete the experiment during the open lab hours, you must complete at least **five** procedures during your scheduled lab period or spend your entire scheduled lab session attempting to do so. A signature below by your lab instructor, Dr. Brewer, or Dr. Robinson permits you to attend the open lab hours to complete the experiment and receive full credit on the report. Without this signature, you may use the open lab to perform the experiment at a 50% penalty.

SIGNATURE:_____ DATE:_____

ECE 3042 Check-off Requirements for Experiment 4

Make sure you have made all required measurements before requesting a check-off. For all check-offs, you must demonstrate the circuit or measurement to a lab instructor. All screen captures must have a time/date stamp.

1. Diff Amp Inverting Input Grounded
   - ✓ Screen capture displaying 1 kHz input and output of 2 Vpp. Show measured Vpp for each channel.
   - ✓ Calculation of the gain.
   - ✓ Screen capture displaying input and output signals for an input frequency equal to the upper -3 dB frequency. Display the Vpp for each channel and the frequency.
   - ✓ Screen capture showing voltages on either side of added 10k resistor. Have Ch1 display the voltage at the generator and Ch2 the voltage on the circuit side of the 10k resistor. Show Vpp measurements.
   - ✓ Calculation of input resistance. (Rin = v2*Rtest/(v1-v2), where v1 is the voltage on Ch1 and v2 is the voltage on Ch2. Rtest = 10k).
2. Diff Amp Non-Inverting Input Grounded
   - ✓ Repeat first two requirements for 1.
3. Diff Amp Floating Source
   - It may be easier to set the differential voltage by adjusting the input level until the Vpp difference between Ch1 and Ch2 is around 0.2 instead of using the math function on the scope. The difference does not have to be exactly 0.2.
   - ✓ Screen capture displaying the voltages on either side of RB. Show Vpp measurements.
   - ✓ Screen capture displaying the output voltage for the input differential voltage.
   - ✓ Calculation of the gain.
4. Diff Amp Common Mode Gain
   - ✓ Screen capture displaying 1 kHz input and output. Show measured Vpp for each channel. Because the output voltage is small, it may be necessary to increase the input and use the average function on the scope to get good measurements. The average function is located under the acquire menu. Make sure the scope is triggered on the input signal.
   - ✓ Calculation of common mode gain.
   - ✓ Calculation of CMRR in dB.
5. Diff amp Common Mode Gain Minimization
   - ✓ Measurement of fixed resistor in series with pot.
   - ✓ Screen capture displaying 1 kHz input sine wave and output after pot is adjusted to minimize the common mode gain. Show measured Vpp for each channel. You may have to use the average function.
   - ✓ Measurement of pot plus series resistance that minimizes the gain.
   - ✓ Screen capture displaying 1 kHz input SQUARE wave and output after pot is adjusted to minimize the common mode gain. Show measured Vpp for each channel. You may have to use the average function.
   - ✓ Measurement of pot plus series resistance that minimizes the gain.
6. Instrumentation Amplifier
   - ✓ Same as for Diff Amp but Rtest = 100k.
7. Curve Tracer
   - ✓ Screen capture showing XY plot of diode current versus voltage. Adjust the gain (volts/div) and time base (time/div) of the scope to give a good plot.