

# Component Level Laboratory

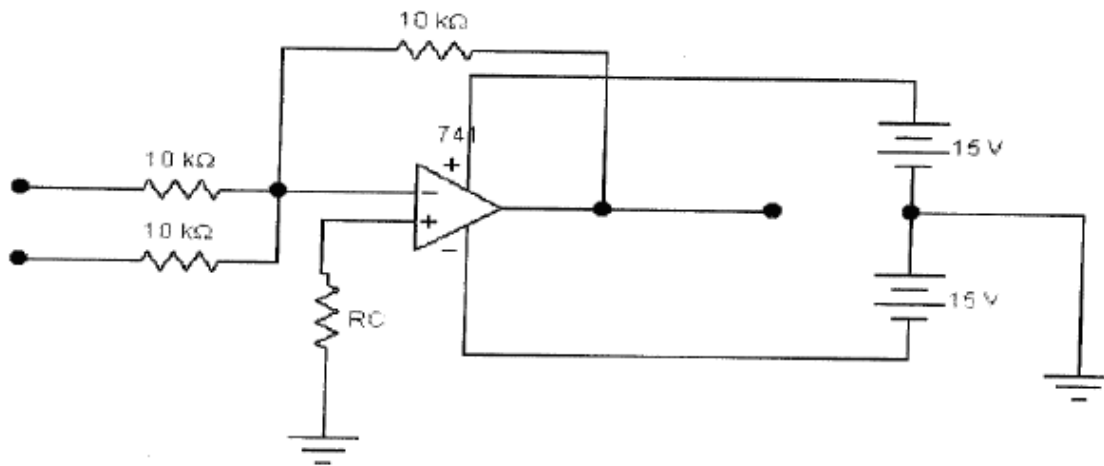
## Analog Signal Conditioning Fundamentals: Op Amp Signal Conditioning and Linearization

### Objective:

The objective of experiment is to learn the functions of Op Amp summing circuit and the nonlinearity of sensor signals. Build Lab view VIs to linearize the sensor signal. Then an Op Amp based signal conditioning circuit will be designed and implemented on breadboard. Finally, learn the Graph VI and Bundle VI in Lab view.

### Exercise 1. Linear Combination (Summing) Op Amp Circuit

A. Using EWB, model the circuit shown below.



(1) Apply two DC input voltages to the circuit (sum of two voltage should be less than 10V). Measure the output voltage and compare with the calculated value.

$V_{out}$  (measured) = \_\_\_\_\_ Difference: \_\_\_\_\_%

(2) Apply a negative DC voltage to one input and a 1 kHz AC sine wave to the other input (sum of DC voltage and the peak value of the AC sine wave should be less than 10V). Using the oscilloscope, measure the output voltage ( $V_{out}$ ). Include a graph of the output voltage  $V_{out}$ . Compare the measured  $V_{out}$  with the calculated one.

Vout peak-to-peak (calculated) = \_\_\_\_\_ Vout peak-to-peak (measured) = \_\_\_\_\_

Difference: \_\_\_\_\_%

B. Construct the same circuit on a breadboard and repeat the steps described above. Record measured values and calculate the differences.

(1) Two DC voltage inputs:

Vout (measured) = \_\_\_\_\_ Difference: \_\_\_\_\_%

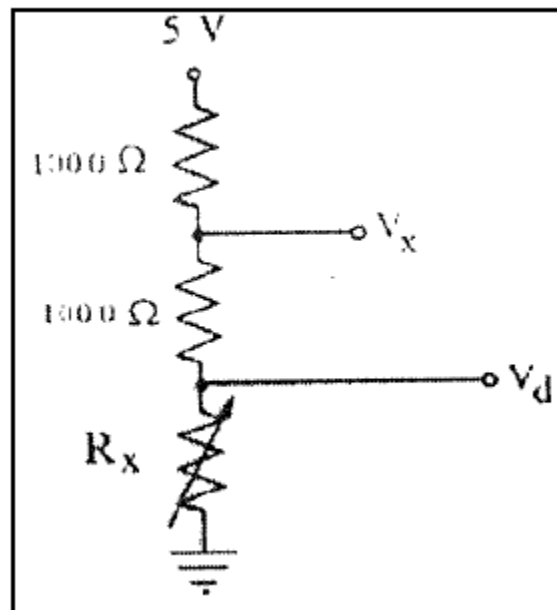
(2) One negative DC voltage input and one 1kHz AC voltage input:

Vout peak-to-peak (measured) = \_\_\_\_\_ Difference: \_\_\_\_\_%

## Exercise 2: Conversion of sensor resistance to voltage variation

Our *simulated* sensor will be a variance resistor with its resistance,  $R_x$ , varies from 0 to 5 k $\Omega$  as the displacement,  $x$ , varies from 0 to 1 cm. Thus, by moving the wiper of the sensor from one extreme to the other we are simulating a displacement of 0 to 1 cm. The equation is:  $R_x = 5000x \Omega$ . We will use a divider circuit to simulate the conversion between the sensor's resistance variations into voltage variations. A plot of the divider's output voltage  $V_d$  versus displacement  $x$  clearly shows the non-linearity between them.

Build the circuit shown below on a breadboard and use a DVM to verify that  $V_d$  and  $V_x$  changes as the sensor resistance is varied. The displacement can be found from  $x = R_x/5000$ . Then we can construct a plot of divider voltage  $V_d$  versus displacement  $x$  by varying the resistance value 20 times from 0 to 5k. You can use following steps to build a VI:





1. Use DAQ assistant to get two channels of signal continuously as you learned in former experiments. Channel 0:  $V_x$ . Channel 1:  $V_d$ . Hint: You can use only one DAQ assistant because once there is a DAQ assistant, the hardware resources will be reserved by it.
2. Split the two signals. You can achieve this by find the “Split signals” in “Express”- “Signal Manipulation”. Then you can adjust the number of splits by changing the vertical length of the block.
3. Connect  $V_x$  to the connector ACH0 and  $V_d$  to the connector ACH1. Remember to connect Ground to AIGND.
4. Use arithmetic calculations to get  $x$  from  $V_x$ .
5. Display the two signals in a XY graph (Graph – Ex XY Graph). Set label of X axes to  $x$ , set label of Y axes to  $V_d$ . Remove the AutoScale function for X and Y, then set the scale for X from 0 to 1.0, set the scale for Y from 0 to 5.0.
6. You may want to use two additional Numeric Indicators to display the value of  $x$  and  $V_d$ .

Set  $R_x$  to one of the extremes and Run the program. Turn  $R_x$  a little bit from one extreme to the other, record value of  $x$  and  $V_d$ . Repeat this until 20 samples have been recorded. Be sure the last sample is taken with  $R_x$  at the other extreme position. Demo this process to the instructor.

You can use excel or other tools to plot a XY Graph that shows  $x$  versus  $V_d$ . Print this out in the lab report.

Now we will design an op-amp circuit that will convert the divider voltage  $V_d$  so that it runs linearly from 0 to 1 volts as the displacement varies from 0 to 1 cm (i.e. the sensor resistance varies from 0 to 5 ohms) to achieve the plot we want that has a slope of one. The new voltage is called  $V_s$ . Using the calculated values and the equations in prelab:

- Design the op-amp circuit that will implement the equation. Show the circuit in the report.
- Assemble this circuit and test to be sure that as  $R_x$  is varied from 0 to 5 Kohm the output voltage indeed varies from 0 to 1 volt.
- Modify the VI you built from Experiment 1. run the program again, taking samples of  $V_x$  and  $V_s$ . The XY Graph will show  $V_s$  versus  $x$ . Note that it is still non-linear. We have simply converted the range from 0 to 1 volt but not changed the non-linearity.
- Measure 20 times and plot the figure in the lab report.
- Show the instructor your results.



## Lab Report Guideline

- Include all derivations of equations
- Include all VIs used
- Include the design of the op-amp circuit, its schematic, and all component values
- Include all XY Graph outputs

### Post lab Exercise:

- (1) The summing circuit is often designed as an inverting circuit. Why?
- (2) Explain what you learned in the lab.