Total grade: 94

ECSE 331 Electronics

Laboratory No. 2:

Characterization of Some Basic Op-Amp Circuits

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Characterization of Some Basic Op-Amp Circuits

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[1]

***Abstract*—The purpose of laboratory experiment was to explore the 741 Op-amp about its different configurations. Analyzation of the behavior of some widely used Op-Amp circuits, such as the Comparator, Voltage-Follower, Inverting and Non-Inverting Amplifiers, the Differentiator, Integrator and D/A converter was conducted.**

Result: The results of this laboratory experiment showed that the behavior of the different Op-Amp circuits were very close to their ideal behavior

***Index Terms*—Electronics, NI Elvis-II+, Op-amp**

I. Introduction

THE laboratory consisted of seven parts.

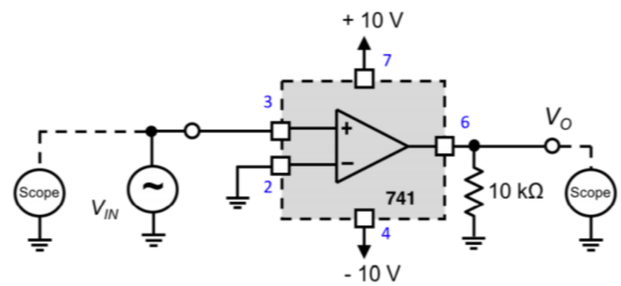
Firstly, the main focus was building a comparator circuit. The 741 Op-amp was used to observe its output with different conditions. Then the Voltage Follower, Inverting and Non-Inverting op-amp circuits were also built, and their behavior were analyzed under different conditions. It was followed by the Differentiator and the Integrator op-amp circuits, and finally the D/A converter circuit was built and analyzed in depth.

II. Experiment Procedures and Analysis

The experiments conducted in the lab are indexed as following:

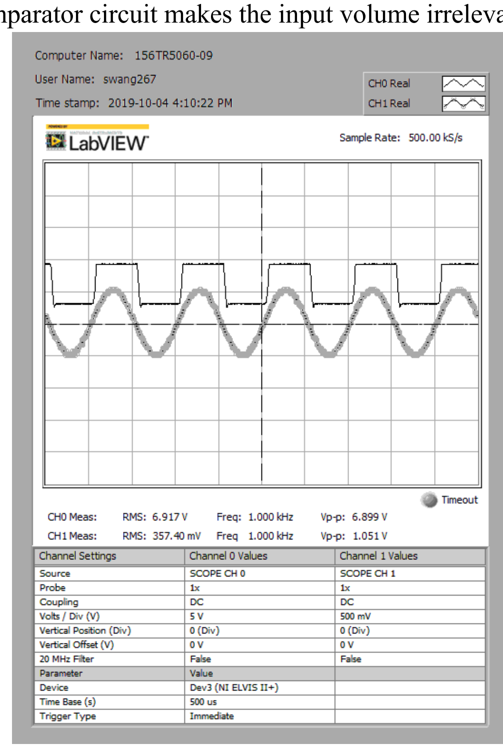
- Comparator op-amp circuit
- Voltage Follower op-amp circuit
- Non-Inverting op-amp circuit
- Inverting op-amp circuit
- Differentiator op-amp circuit
- Integrator op-amp circuit
- D/A converter op-amp circuit

A. Part 1: Comparator Op-Amp Circuit



Result:

As indicated in the figure below. The output of the circuit when input is 1V peak to peak sine wave with 1KHz frequency is 6.90 V. Changing the amplitude of the input signal from 1 Volt to 0.2 Volt does not have significant impact on the output. This is due to the fact that the configuration of the comparator circuit makes the input volume irrelevant.



[1] Experiment was conducted in the laboratory section of course ECSE 331 offered at McGill University.

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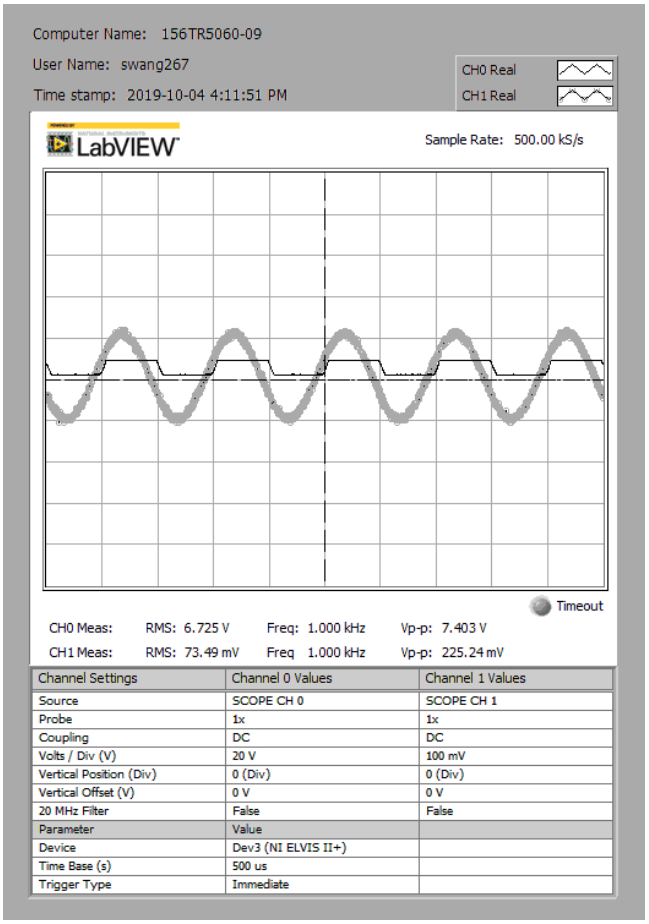
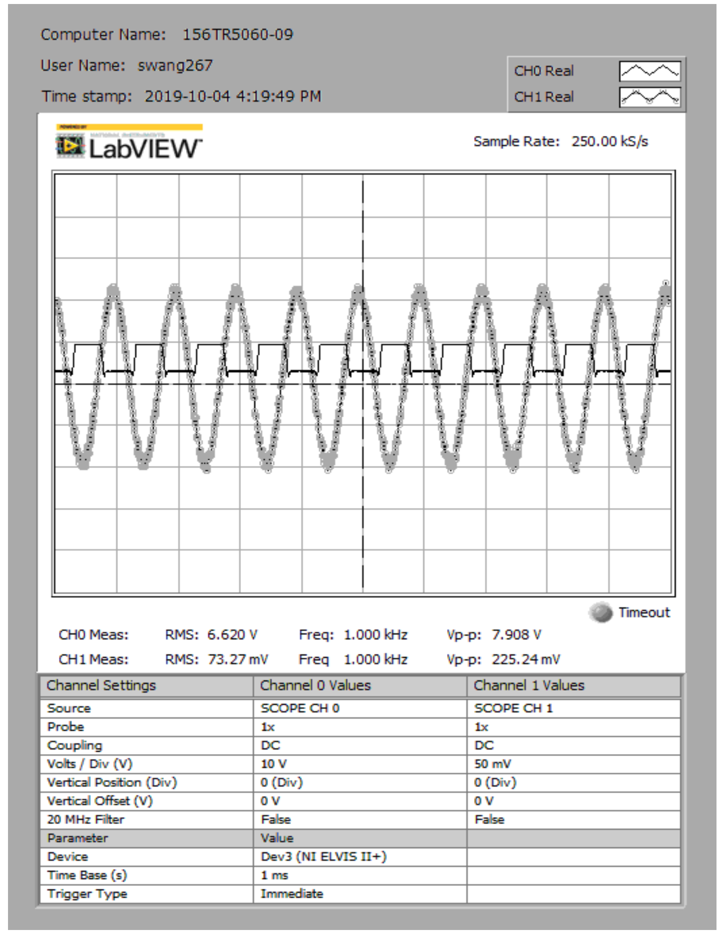
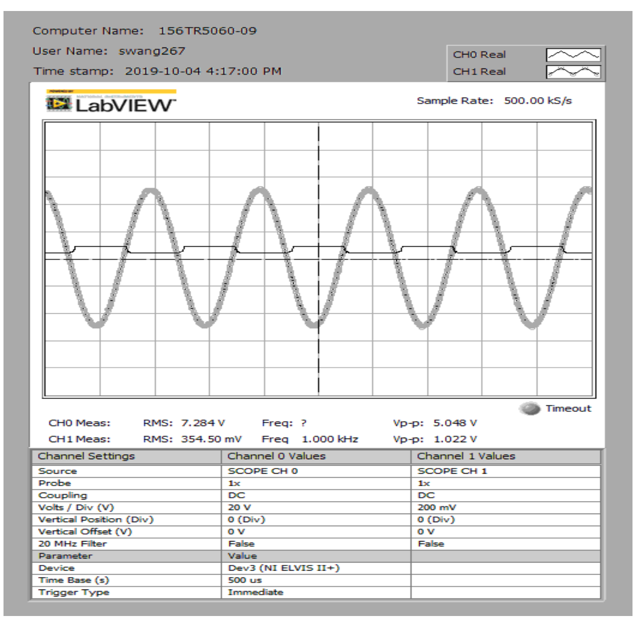




2. Grounding (+) terminal and connecting the signal to the (-) input-terminal changes the phase of the output. As indicated in the diagram below, the signal is shifted by 90 degrees. Since the input is sinusoidal, thus we have an output that varies.



-2. output voltage not in the correct range

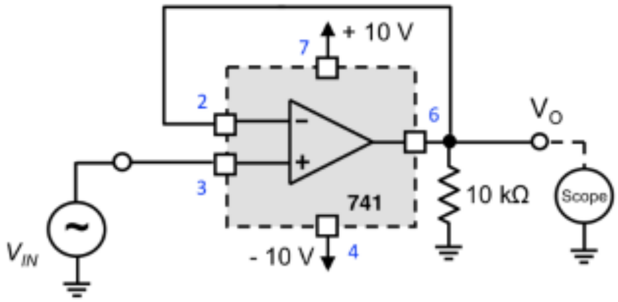


Diagram 2: Voltage Follower circuit

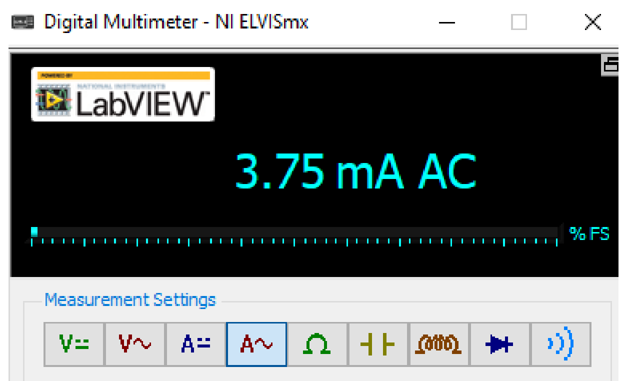


Figure 2.2 measured current based on a 5 volt DC input

B.Part 2: Voltage Follower

We set up the circuit as presented above in *Diagram 2*, the output is measured by the Oscilloscope while the input is set up to be 1 V peak to peak, 1 kHz sinusoidal signal. The measurement result and the sinusoidal output graph is shown below in *figure 2.1*. Note that the output voltage is a sinusoidal wave; it has a frequency of 1.000kHz and a peak to peak voltage of 1.018 V. This Op-Amp adjust its output so that the output has the same frequency and amplitude as the input.

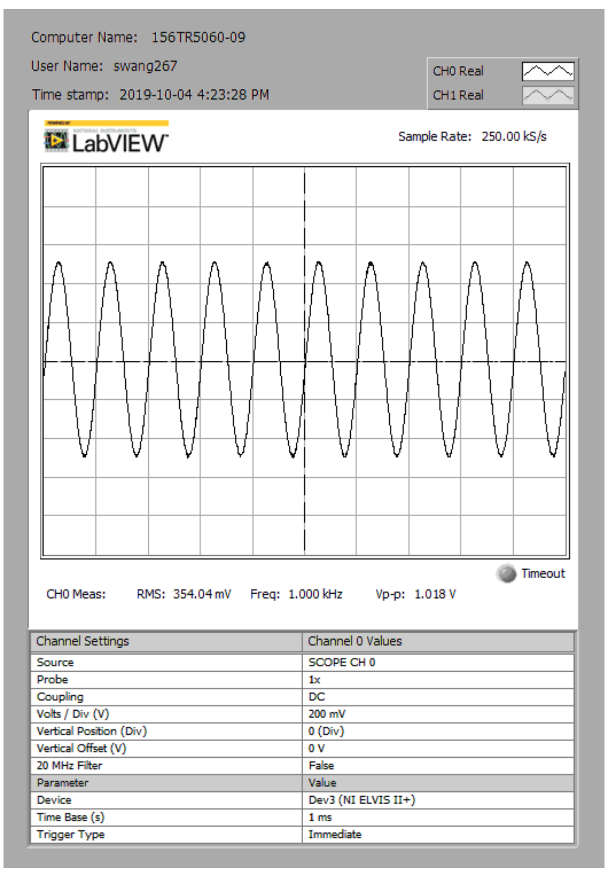


Figure 2.1: Output signal voltage follower circuit with sine-wave input signal

The input impedance is 133.33 ohms (Z = 5V/3.75mA). the measured input current from a 5 volt DC Voltage supply is as shown below in *Figure 2.2*

-2. Should be higher

We then change the input to a 1 V peak to peak, 1kHz square wave. The measurement result and the square-wave output graph is shown below in *Figure 2.3*. Note that the output voltage is a square wave; it has a frequency of 1.000kHz and a peak to peak voltage of 1.044V.

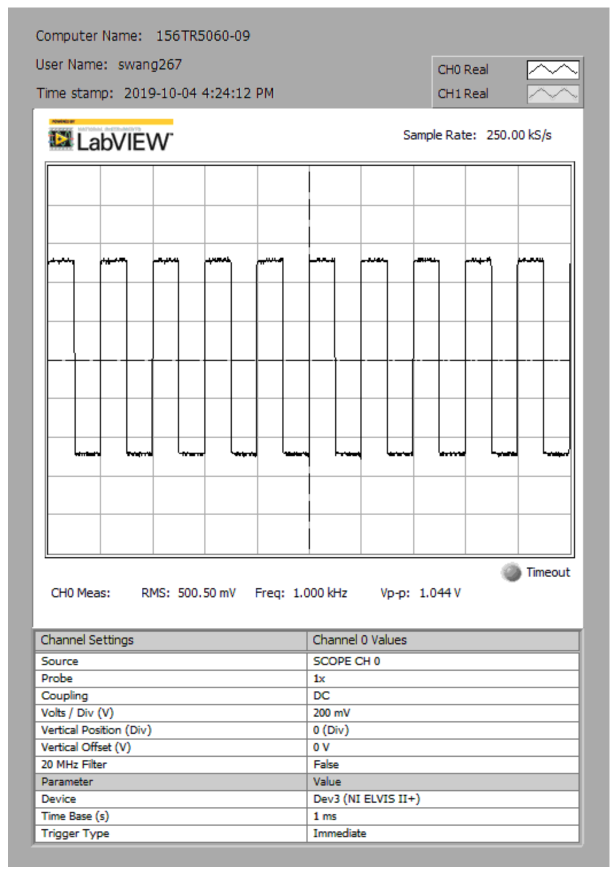
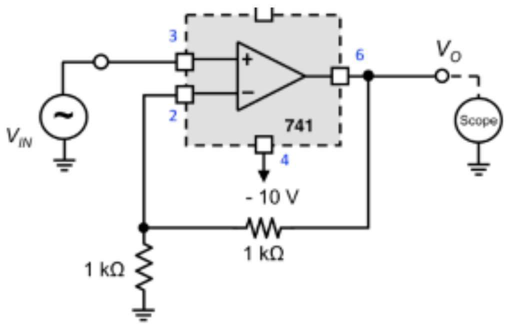


Figure 2.3: Output signal voltage follower circuit with square-wave input signal

Diagram 3 Non-Inverting Amplifier circuit



C.Part 3: Non-Inverting Amplifier

In the circuit presented above in *Diagram 3*, the output is measured by the Oscilloscope while the input is set up to be 1 V peak to peak, 1 kHz sinusoidal signal. The measurement result of the output and the input is shown below (*Figure 3.1*). Note that CH0 measures the output and CH1 measures the inverting input terminal to the op-amp. The output frequency equals to the input frequency; the output peak to peak voltage is 2.101V, which is approximately 2.07 times of the input.

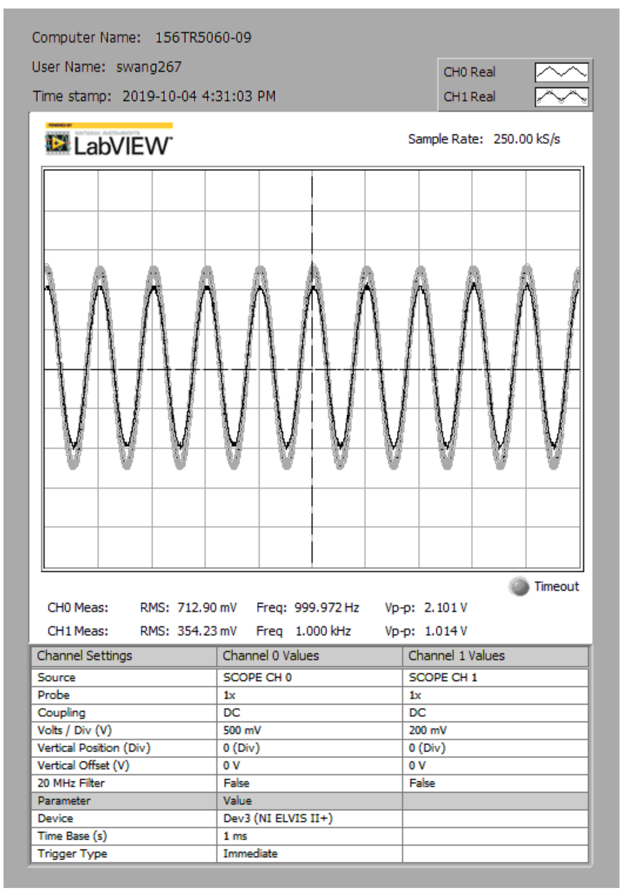


Figure 3.1 output of non-inverting amplifier

We change the input to a 2 V peak to peak, 1 kHz sinusoidal signal. The measurement result of the output and the input is shown below(*Figure 3.2*). Note that CH0 measures the output and CH1 measures the inverting input terminal to the op-amp. The output frequency equals to the input frequency; as the input increases, the output peak to peak voltage increases linearly and reached 4.158V, which is approximately 1.94 times of the input.

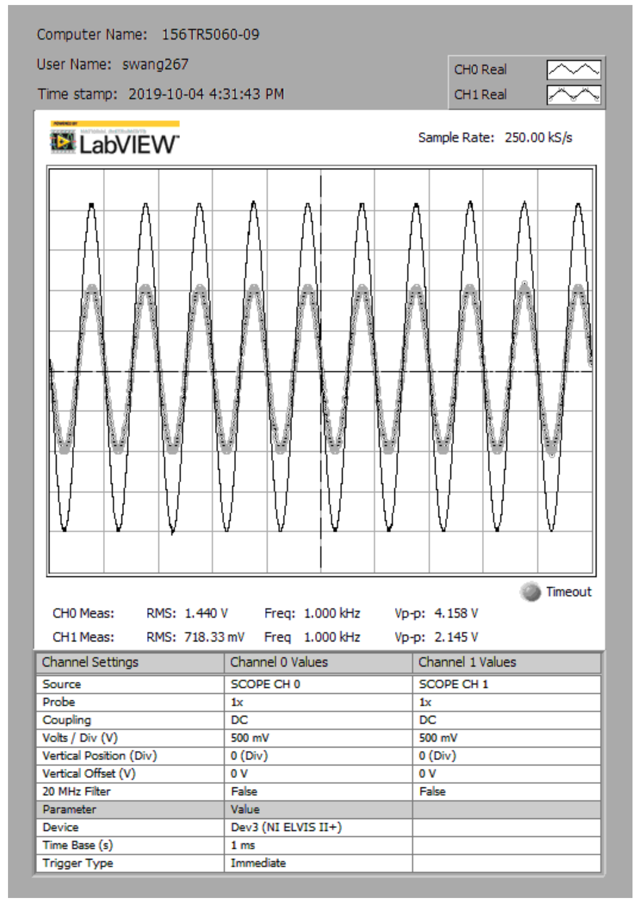


Figure 3.2 output voltage with 2 volt peak to peak input

Then, we change the input to a 1 V peak to peak, 1 kHz square-waved signal. The measurement result of the output and the input is shown below (*Figure 3.3*). Note that CH0 measures the output and CH1 measures the inverting input terminal to the op-amp. The output frequency equals to the input frequency; the output peak to peak voltage is 2.101V, which is approximately 2.00 times of the input.

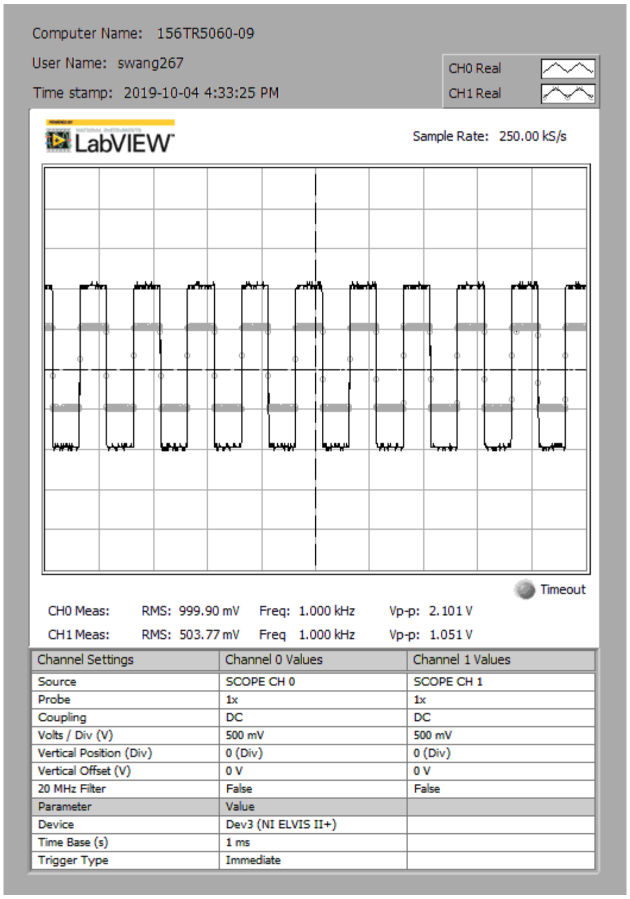


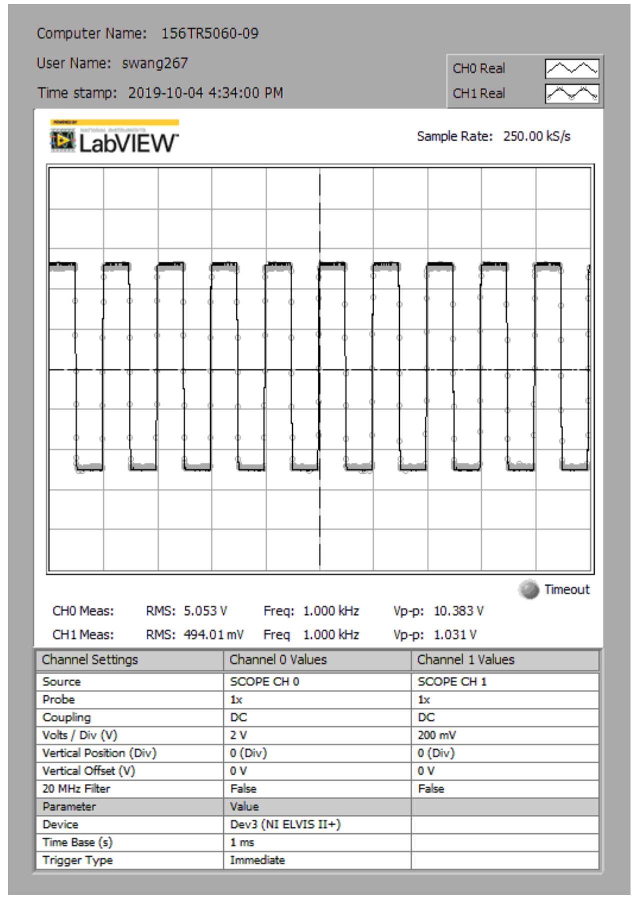
Figure 3.3 output voltage in non-inverting circuit with a square wave input

We collect the amplitude of input and output signal and calculate for the average gain of this non-inverting amplifier as shown in *Table 1*.

Table 1: non-inverting amplifier data collected

Input pk-to-pk (V)	1.014	2.145	1.051
Output pk-to-pk (V)	2.101	4.158	2.101
Gain (V/V)	2.072	1.938	1.999
Average Gain (V/V)	2.003		

We change the circuit's gain to 10 by changing the 1 kOhm resistor between pin 2 and 6 of the op-amp into a 9kOhm



resistor. The new circuit diagram is shown as below in *figure 3.4.*

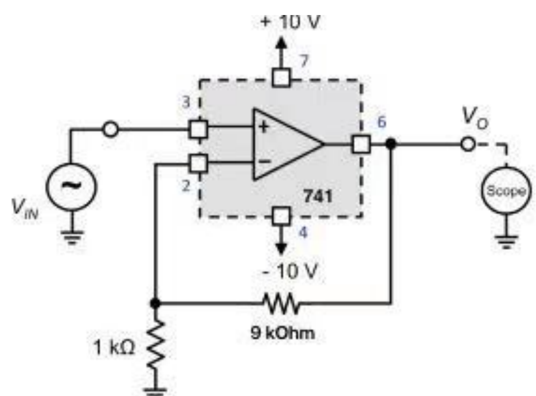


Figure 3.4: non-inverting circuit with gain of 10

We justify our design by experiment. The output is measured by the Oscilloscope while the input is set up to be 1 V peak to peak, 1 kHz square-waved signal. The measurement result of the output and the input is shown below. Note that CH0 measures the output and CH1 measures the inverting input terminal to the op-amp. The output frequency equals to the input frequency; the output peak to peak voltage is 10.383V; the gain is approximately 10.

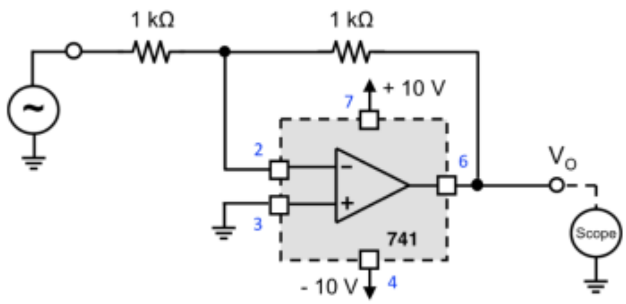


Diagram 4: inverting Amplifier

D.Part 4: Inverting Amplifier

In the circuit presented above, the output is measured by the Oscilloscope while the input is set up to be 1 V peak to peak (not shown on the graph below but is recorded by our group), 1 kHz sinusoidal signal. The measurement result and the sinusoidal output graph is shown below (Figure 4.1). Note that the output voltage measured by CH0 is a sinusoidal wave; it has a frequency of 1.000kHz and a peak to peak voltage of 976.26mV. CH1 measures the voltage at pin 2 (shown on the circuit diagram above). The gain is approximately **0.976**. The voltage at pin 2 (the inverting input terminal) is very small.

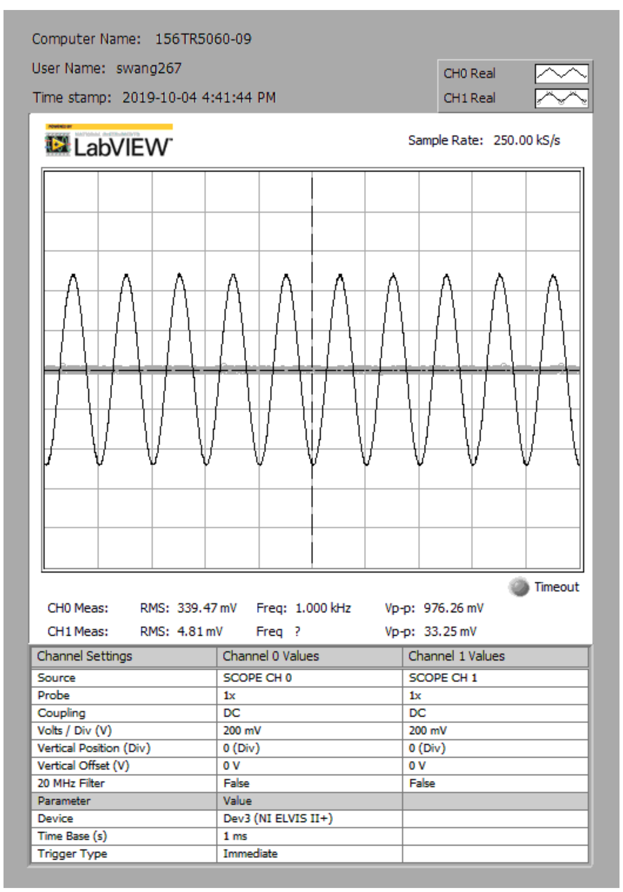


Figure 1Figure 4.1: the input and output signal in inverting circuit

-2.The signal at the output should be very small.

If we ing input terminal) to real ground while keep the input as before, the following result is observed in *figure 4.4*.

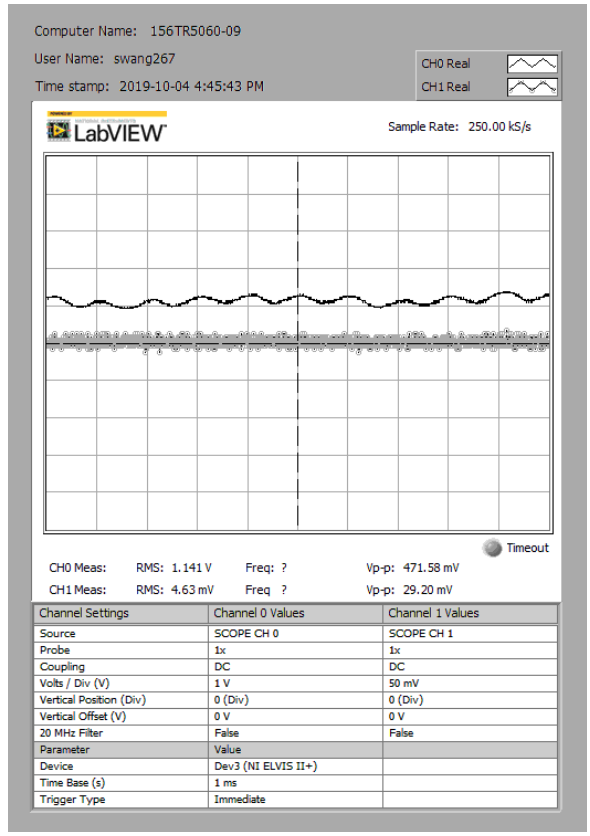


Figure 4.2: connecting pin 2 to the real ground

We change the circuit's gain to 10 by changing the 1 kOhm resistor between pin 2 and 6 of the op-amp into a 10kOhm resistor. The new circuit diagram is shown as below in *figure 4.3.*

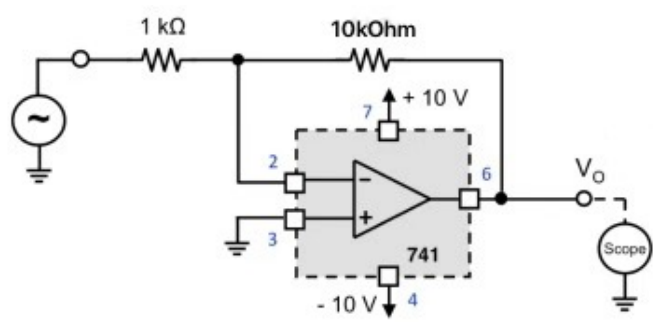


Figure 4.3: Modified inverting circuit with gain of 10

We justify our design by experiment. The output is measured by the Oscilloscope while the input is set up to be 1 V peak to peak, 1 kHz sinusoidal signal. The measurement result of the output and the input is shown below in *figure 4.4*. Note that CH0 measures the output. The output frequency equals to the input frequency; the output peak to peak voltage is 9.646V; the gain is approximately 10.

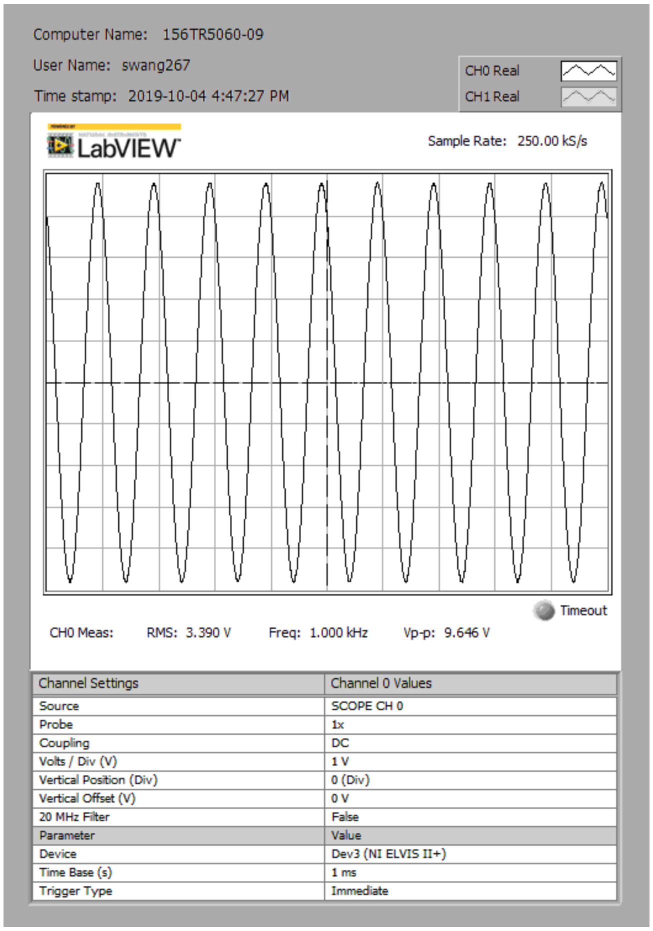


Figure 4.4 inverting circuit with a gain of 10 output measurement

We then apply a 5 V peak to peak input to original circuit, shown in *diagram 4* at the beginning of this section.

Since the input impedance of a circuit is simply the ratio of the input voltage to the input current. By KCL at pin2, we calculate that the input impedance of this circuit should be around 1000. We then apply a constant DC input voltage of 10V to the input and we measures the current. The current is 9.7mA. So we compute and get the input impedance equals to 1030.9 (V/A), which is closed to 1000 (V/A).

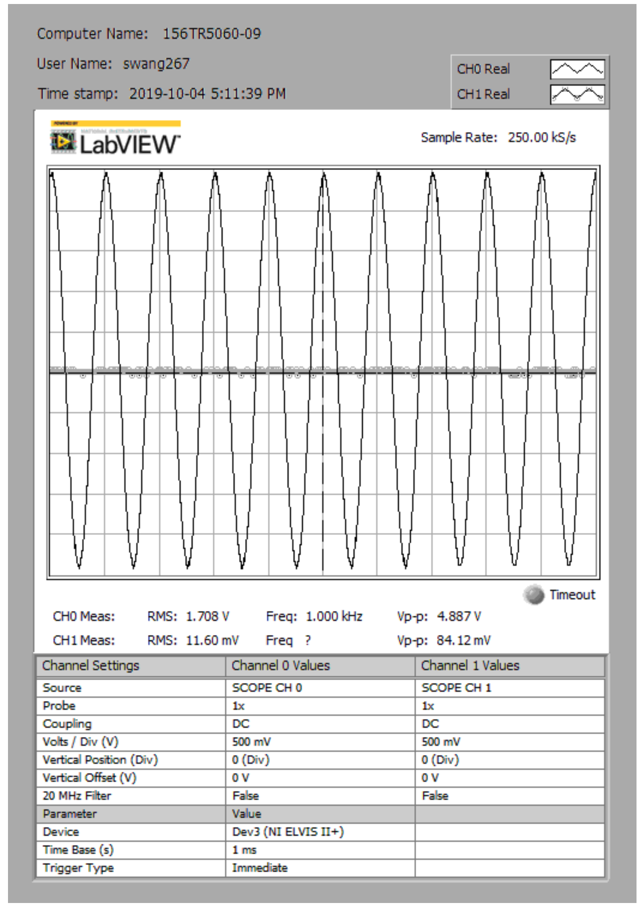


Figure 4.5: inverting circuit

In the above diagram, CH0 in the following diagram is the voltage of the input; CH1 measures the voltage at pin 2 (the inverting input terminal). The current flowing through the 1kOhm resistor should be a sinusoidal wave with an amplitude of 4.887V/(1030.9(V/A)), which equals to 4.7405mA, since the input impedance is 1030.9 (V/A).

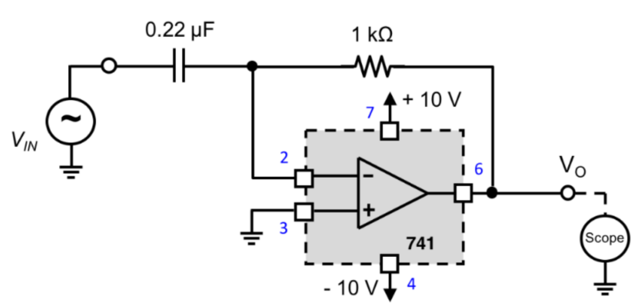


Diagram 5: Differentiator circuit

E.Part 5: Differentiator

In the circuit presented above (in *Diagram 5*), the output is measured by the Oscilloscope at pin 6 (as indicated in the circuit diagram) while the input is set up to 1 volt peak to peak 1kHz Sine-wave. The measurement is as shown below in *Figure 5.1*. Note that the output voltage is measured by CH0, it is a 999.996Hz sine-wave with 1.330 volt peak to peak. The input is measured by CH1 between the function generator and the capacitor, it is a 1.00kHz sine-wave with 1.022 volt peak to peak.

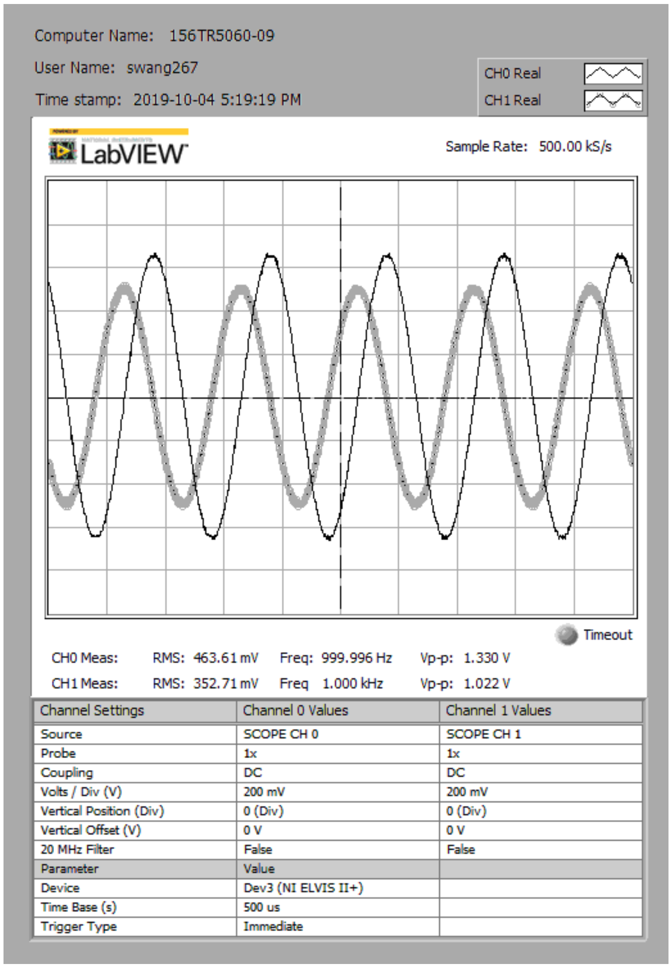


Figure 5.1: Differentiator with sine-wave signal input

We then changed the wave form to triangular wave input on the function generator while keep the frequency of the wave at 1kHz and 1 volt peak to peak. The measurement is as shown in *Figure 5.2* below, where the triangle-wave is the input of the signal which is measured by Ch1, this wave has a frequency of 1.000khz and 972.57 mV peak to peak. the output is a squral-wave with the same frequency but a 875.27 mV peak to peak voltage.

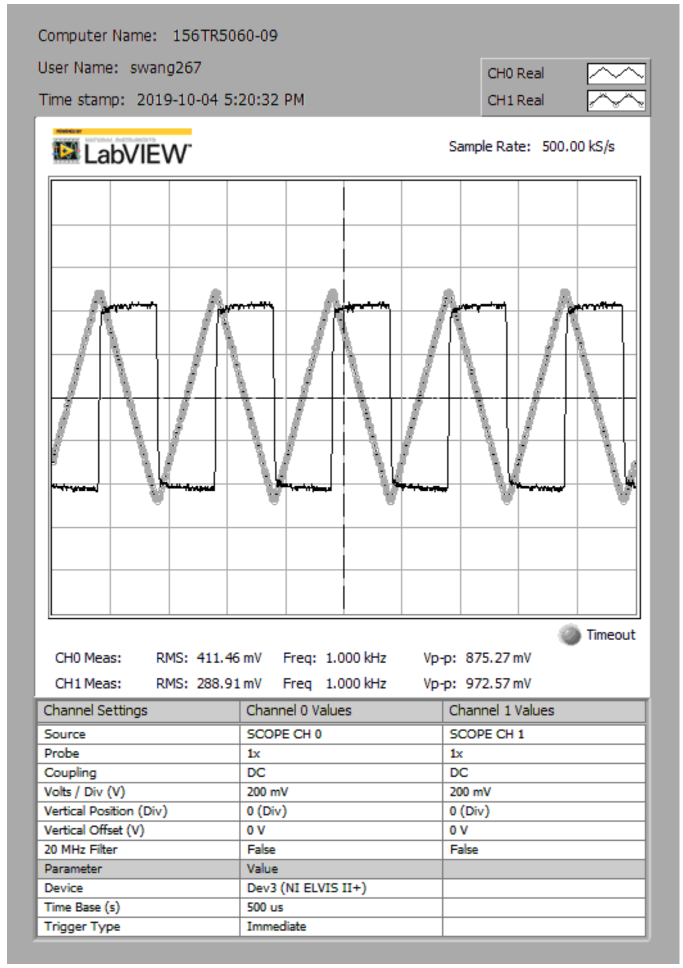


Figure 5.2: Differentiator with square-wave signal input

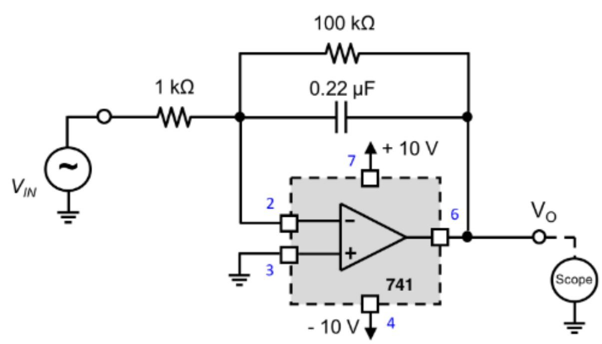


Diagram 6: integrator circuit

F,Part 6:Integrator

In the circuit presented above, the output is measured by the Oscilloscope at pin 6 (as indicated in *Diagram 6*) while the input is set up to 1 volt peak to peak 1kHz Sine-wave. The measurement is as shown below in *Figure 6.1*. Note that the input voltage is measured by CH1, it is a 1KHz sine-wave with 973.87 mV peak to peak. The output is measured by CH1 between the function generator and the capacitor, it is a 999.855Hz sine-wave with 784.26mV peak to peak.

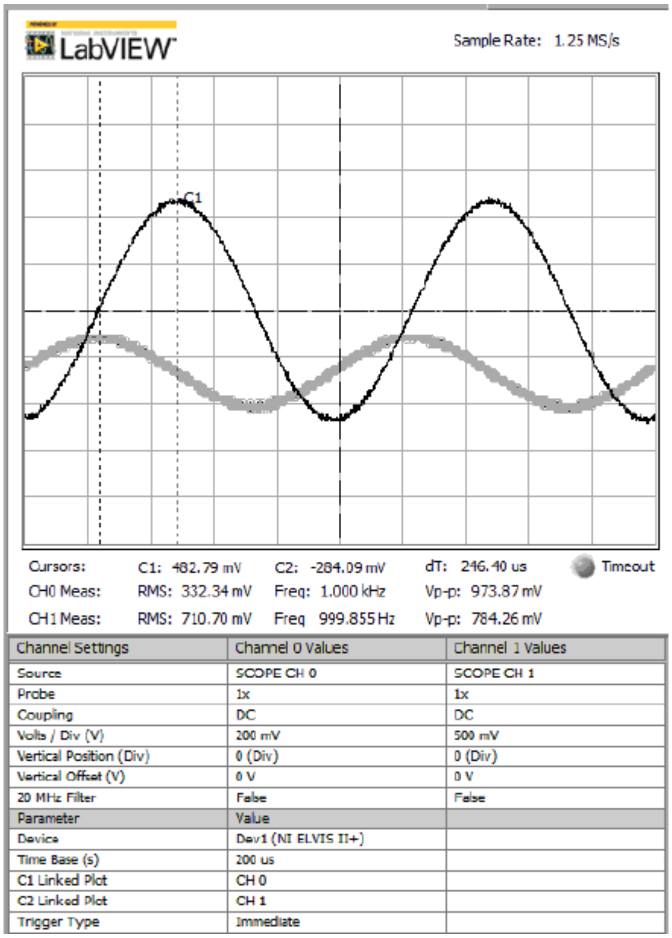


Figure 6.1: Integrator input and output signal

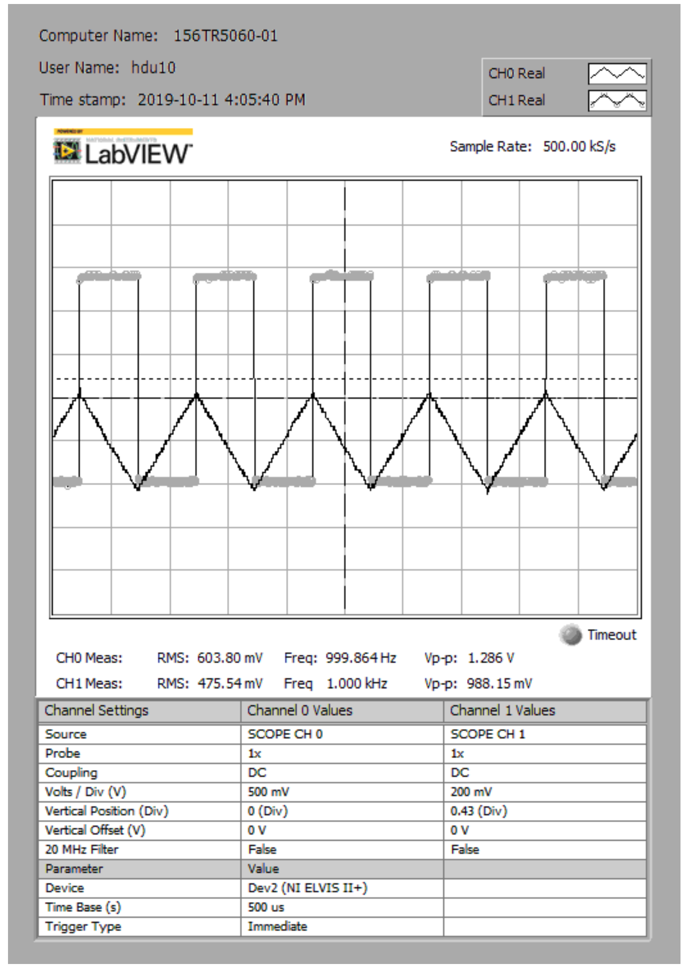


Figure 6.2: input and output voltage signal with square wave voltage signal as input

We then changed the wave form to square-wave input on the function generator while keep the frequency of the wave at 1kHz and 1 volt peak to peak. The measurement is as shown in the diagram below (*Figure 6.2*), where the square -wave is the input of the signal which is measured by Ch1, this wave has a frequency of 1.000khz and 972.57 mV peak to peak. the output is a triangle-wave with a frequency of 999.864Hz and a 1.286V peak to peak voltage.
The output should be a sine-like-wave but here it shows as dc signal in the first part, the second part the magnitude of the output should be big since the capacitor's capacity is relatively small

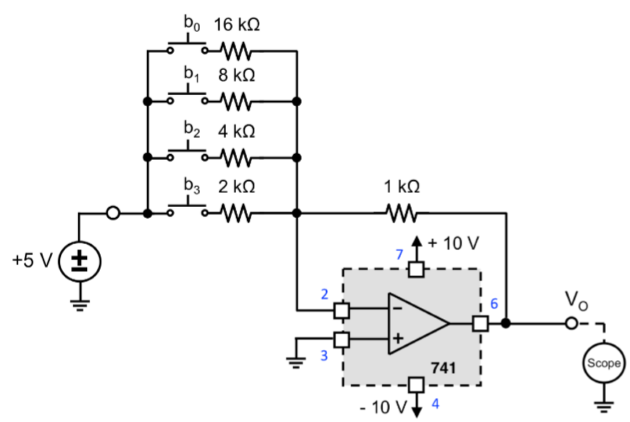


Diagram 7: D/A Converter

F.Part 7: D/A Converter

In the circuit presented above, the output is measured by the multimeter at pin 6(as shown in the diagram. Since each sub-branch which is connected directly with the 5 volt DC voltage source and pin 2(as shown in the diagram) has a switch, we coded such that when the switch is opened indicates 0 and closed indicates 1, and switch b0 correspond to the 0 index on the code and b1 correspond to the 1 index in the code and so on. We performed all experiment with all possible combinations, the result is as shown in the *table 2* below.

Table 2: Coded digital representation implemented by using switches data collected

Code	Integer value	Out put voltage
"0000"	0	0
"0001	1	-0.3
"0010"	2	-0.6
"0011"	3	-0.9
"0100"	4	-1.27
"0101"	5	-1.57
"0110"	6	-1.88
"0111"	7	-2.18
"1000"	8	-2.49
"1001"	9	-2.79
"1010"	10	-3.09
"1011"	11	-3.39
"1100"	12	-3.76
"1101"	13	-4.06
"1110"	14	-4.38
"1111"	15	-4.66

The graph of the output voltage vs the integer value of the digital control signal is generated as below in Figure 7.1.

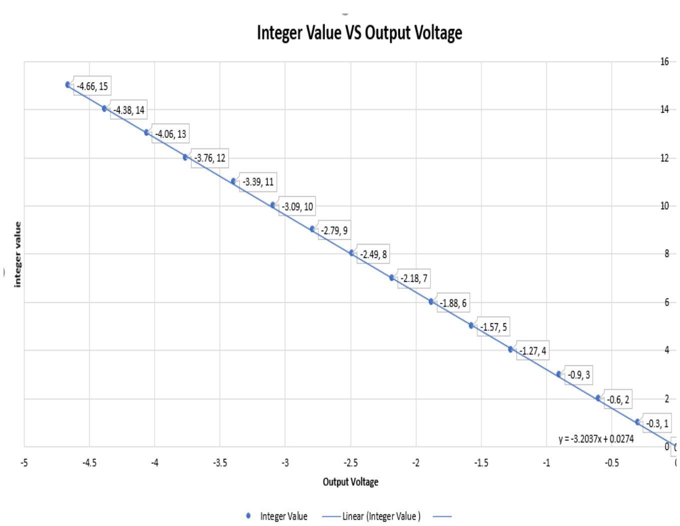


Figure 7.1: Graphed data

As we can see the basic trend is linear after connecting the two end points the maximum distance our measured points deviate from the straight line is o.o1 in output voltage and 0.03 in integer value.

III, Conclusion

During this lab we have Constructed 7 different circuit (Comparator, Voltage follower, Non-inverting Amplifier, Inverting Amplifier, Differentiator, integrator and D/A Converter) and performed the corresponding experiments. By building the circuit based on instructions we had a better understanding on the mechanisms of the circuit with op-amps presented (i.e. How does the position of the capacitor differ the circuit at different location? How does the loaded resistance would effect the overall gain of the circuit?) and the construction of D/A convertor (How to implement binary representation by using switches?). With these hands on experience with the actual circuit truly helped us to have a deeper understanding of the basic op-amps circuit theory.