# Laboratory Experiement#2

## Characterization of Some Basic Op-Amp Circuits


Mohammad Edris Jebran

Student Id:

McGill University

ECSE 331: Electronics



*Abstract*— The purpose of laboratory experiment number two, was to explore the 741 Op-amp, its different configurations and more importantly to analyze 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. The results of this laboratory experiment showed that the behavior of the different Op-Amp circuits were very close to their ideal behavior.


## I. Introduction

The goal of this laboratory was to test, and explore the behavior of the different Op-Amp circuits with the NI Elvis-II test instrument. The laboratory consisted in the first part of building the Comparator circuit, and using the op-amp to observe its output with different conditions. Then the Voltage Follower, Inverting and Non-Inverting op=amp circuits were built and their behavior analyzed under different conditions. Then the Differentiator and the Integrator op-amp circuits were built and their behavior analyzed and finally the D/A converter circuit was built and analyzed in depth. In the main body of this lab report the results for each of the circuits analyzed will be presented in clear and concise manner.

## II. Main Body

We conducted several experiments with the 741 Op-Amp to test, explore the behavior of the different op=amp circuits.

**A.** Comparator Ap-amp circuit

**B.**Voltage Follower Op-amp circuit

**C.**Non-Inverting Op-amp circuit

**D.**Inverting Op-amp circuit

**E.**Differentiator op-amp circuit

**F.**Integrator op-amp circuit

**G.**D/A converter op circuit

### *A. Comparator Op-Amp Circuit*

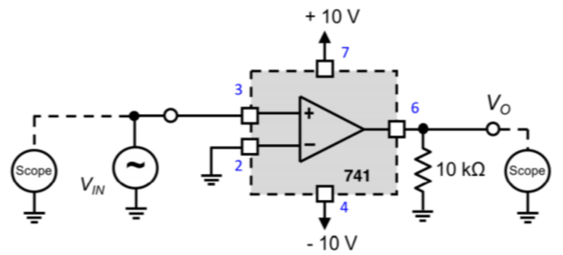


**Fig.1 Comparator op-amp circuit schematics**

1. The output of the circuit when input is $1V_{p\text{-}p}$ sin with 1KHz frequency is 17.39V. Changing the input signal from 1 Volt p-p to o.1-volt peak-peak doesn't change anything for the output because in the comparator, the size of the input doesn't matter, the input is amplified to $V_{cc}$ and $V_{ee}$ alternatively because it has a sinusoidal input.

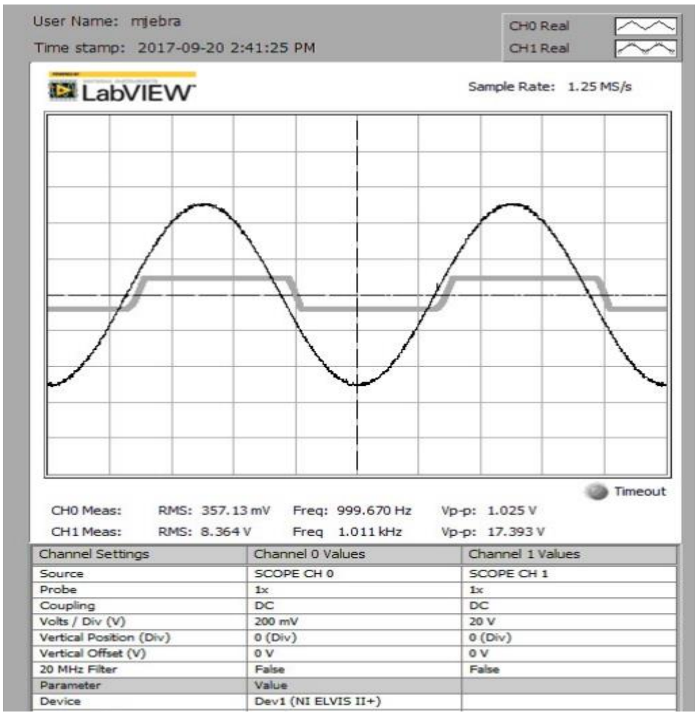


**Fig.2 Outpu and input of comparator circuit with 1KHz sine wave**

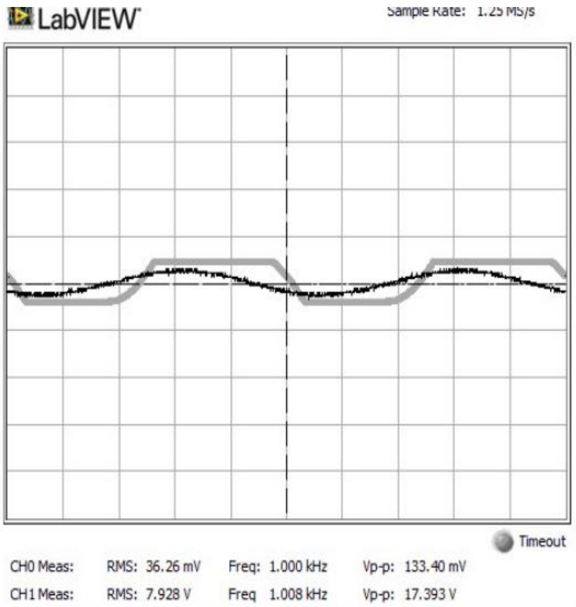


**Fig.3 Output of comparator circuit when input is 0.1$V_{p\text{-}p}$**

2. Grounding (+) terminal and connecting the signal to the (-) input-terminal changes the phase of the output, thus shifting it by 180 degrees, thus inverting the input and amplifying it. But the output is like in part 1, thus the graph is the same as in the first part because the input is sinusoidal, thus we have an output that varies and reaches Vcc+ and Vee-.

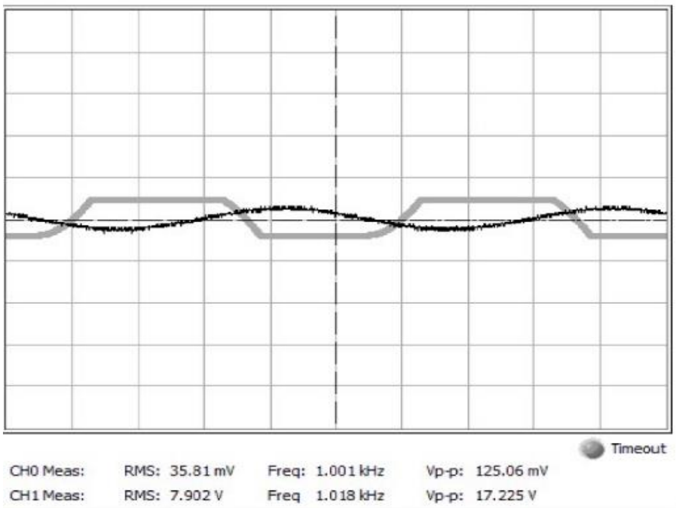


**Fig.4 Output of comparator when + is grounded and – connected to vin**

*B. Voltage Follower Op-Amp Circuit*

**1.** $Vp_{\text{-}p}$ at the output is 1.025volts, which makes sense because voltage follower is supposed to have a unity gain.

**2.** Input impedance = $\mathbf{V_{in}/i_{in}}$ = 1v/0amp =infinity. This is so because no current goes in the non-inverting or inverting terminal, and the voltage at those terminals are 1v.

**3.** For the square wave, the output is also only 1.042volts peak-peak

*C. Non-Inverting Op-Amp circuit*

**1.**The output signal is 2.18Volts peak-peak sinusoidal.

**2.**At the inverting terminal the voltage is 1.017V p-p just like at the non-inverting terminal.

**3.** Gain = Vo/Vin= 2.018/1.017= 1.98 V/V

**4.** If the input signal is increased, the gain wouldn't change, the output would still be twice as big as the input. When Vin= 2.0Volts, the Vo=4.0 Volts, gain =4.0/2.0= 2V/V. Same as in the previous case.

**5.** For a square wave input, 1.025V p-p, the corresponding output is 2.127Volts, which gives a gain =2.127/1.025= 2.07V/V, which is almost the same gain as before, so a gain of 2V/V.

**6.** Since gain for the non-inverting circuit is given by Vo/Vin= 1+ Rf/R1, in our current circuit, Rf=R1 =1K Ohm which gives Gain =1+(1/1) =2, if we want to increase the gain to 10V/V, we have to replace Rf by a 9KOhm resistor, then Gain= 1+(9/1)=10V/V.

*D. Inverting Op-Amp Circuit*

**1**.The voltage at the inverting input terminal is close to 0, 3.90mV rms.

**2**. The gain of the circuit is close to unity, it is = Vo/Vin= 0.966/0.980= 0.99V/V, which is close to unity.

**3**. If we connect the inverting-terminal to the real ground, the output will be around 84mV, which is due to noise and some other factors, basically, the op-amp wouldn't function correctly if we use the real ground!

**4**.To make the amplifier's gain 10V/V, the Rf which is one would have to be replaced by a 10kOhm resistor, because Gain= -Rf/R1 for this inverting amplifier, where R1=1KOhm.

**5**. Current flowing through the 1KOhm resistor is 0.00276 amperes when the peak-peak voltage is 10v.

**6**.The input impedance is $V_{in(rms)}/i_{rms}$ =3.35/0.00276= 1.21KOhms.

*E. Differentiator Op-Amp Circuit*

**1.** There are big differences between the output and the input, the differentiator is supposed to give at the output the derivative of the input function with a gain. Vo(t)= (-0.2*10^-3)* $\int_0^t Vin(t)dt$. When a 1Volt peak-peak sine function with f=1kHz is set as an input, the output is shifted by around 180° and it amplifies it by 1.3. So, there is a gain of 1.3V/V and the output is also shifted 180°.

**2.** If we apply a triangular wave instead of a sinusoidal, we observe that the output is a rectangular wave which makes sense, and is in correspondence with the theory. The output was rectangular and it also had gain of 0.897, which means the signal was attenuated.

### *F. Integrator Op-Amp Circuit*

**1.** When a 1Volt peak-peak sinusoidal voltage is applied at a frequency of 1KOhms, the output is another sinusoidal function shifted by around 90° and it is also attenuated by a gain factor of **0.763V/V.** (Vo/Vin= 0.7379/0.96=0.763V/V)

**2.** When a triangular wave with a V peak of 1 volt is applied, the output is a square wave with a peak of 1.289V, which makes sense because the integrator integrates the input, and in this case, amplifies it by a gain factor of around **1.3V/V** (Vo/Vin = 1.289/0.99213 = 1.2992V/V).

### *G. D/A Converter*

The points deviate from the line by an insignificant amount sense the R^2 is 0.9984, which means that the points are very close to the line. Thus, the conversion was successful.

## CONCLUSION

To conclude, this lab was very helpful and eye opening because various Op-Amp circuits were built and their behavior observed, and this created a contrast with everything learnt in the classroom. We saw in this lab that an op-amp behaves very closely to its idealized model and that it can build a very large number of different circuits.

In this lab, the experiments showed that the Inverting amplifiers, amplifies and inverts the input, it showed that the non-inverting op-amp doesn't invert an input, it only amplifies it. It was also observed that a capacitor connected to the Vin and the inverting input terminal creates a differentiator circuit, where the input will be differentiated when it comes out at the output terminal. It was shown that an integrator circuit can be built by placing a capacitor in the negative feedback loop. The output in this case was the integrated version of the input. And finally, in this lab experiment, we successfully converted digital to analog with the D/A converter.