National Polytechnic Institute
Superior School of Computer Sciences

Analog Electronics.

Practice 5 - Operational Amplifiers.

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Contents

1 Objective:

The student will implement the basic amplifiers configurations:

- **Inverting Amplifier.**
- **Non-inverting Amplifier.**
- **Unity Follower.**
- **Summing Amplifier.**
- **Subtractor Amplifier.**
- **Integrator.**
- **Differentiator.**

And interpret the results obtained for the aforementioned circuits.

2 Introduction:

An operational amplifier, or op-amp, is a very high gain differential amplifier with high input impedance and low output impedance. Typical uses of the operational amplifier are to provide voltage amplitude changes (amplitude and polarity), oscillators, filter circuits, and many types of instrumentation circuits. An op-amp contains a number of differential amplifier stages to achieve a very high voltage gain.

Figure 2.0 shows a basic op-amp with two inputs and one output as would result using a differential amplifier input stage.

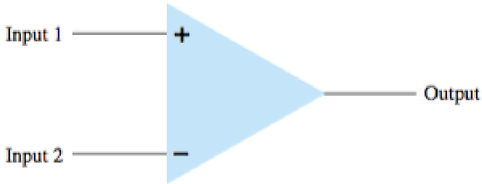

Figure 2.0: Basic op-amp.

2.1 Practical OP-AMP circuits:

The op-amp can be connected in a large number of circuits to provide various operating characteristics. In this section, we cover a few of the most common of these circuit connections.

2.1.1 Inverting Amplifier:

The most widely used constant-gain amplifier circuit is the inverting amplifier, as shown in Figure 2.1.1.0. The output is obtained by multiplying the input by a fixed or constant gain, set by the input resistor R_1 and feedback resistor R_f this output also being inverted from the input. The we can write:

$$V_0 = -\frac{R_f}{R_1} \cdot V_1$$

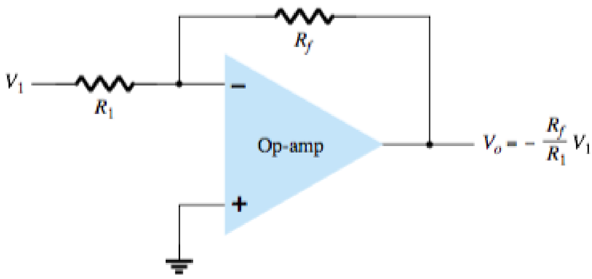

Figure 2.1.1.0: Inverting constant-gain multiplier.

2.1.2 Non-Inverting Amplifier:

The connection of Figure 2.1.2.0 shows an op-amp circuit that works as a non-inverting amplifier or constant-gain multiplier. It should be noted that the inverting amplifier connection is more widely used because it has better frequency stability. To determine the voltage gain of the circuit, we can use the equivalent representation shown in Figure 2.1.2.1.

Note: *The voltage across R_1 is V_1 since $V_i \cong 0\ V$. This must be equal to the output voltage, through a voltage divider of R_1 and R_f, so that:*

$$V_1 = \frac{R_1}{R_1 + R_f} \cdot V_0$$

The we can say that:

$$V_0 \ = \ (\ 1 \ + \ \frac{R_f}{R_1} \ ) \ V_1$$

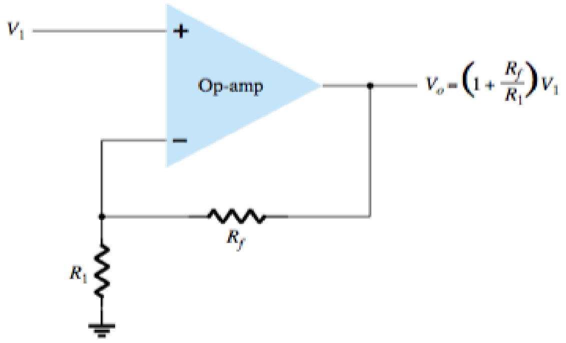

Figure 2.1.2.0: Non-inverting constant-gain multiplier.

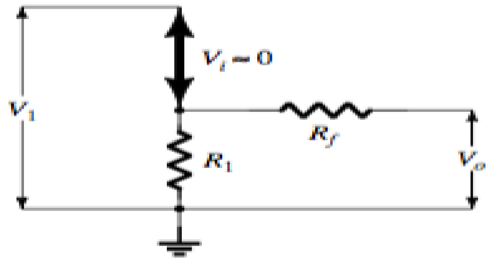

Figure 2.1.2.1: Sub-circuit of Figure 2.1.2.0.

2.1.3 Unity Follower:

The unity-follower circuit, as shown in Figure 2.1.3.0, provides a gain of unity (1) with no polarity or phase reversal. From the equivalent circuit Figure 2.1.3.1 it is clear that:

$$V_0 \ = \ V_1$$

And that the output is the same polarity and magnitude as the input. The circuit operates like an emitter- or source-follower circuit except that the gain is exactly unity.

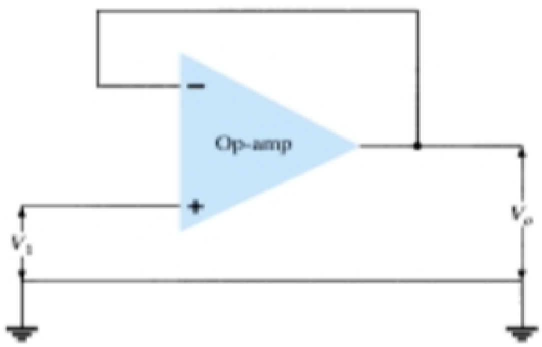

Figure 2.1.3.0: Unity follower.

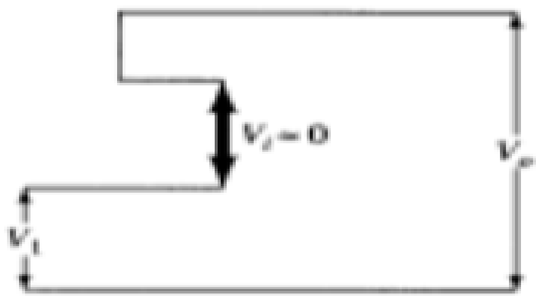

Figure 2.1.3.1: Virtual-ground equivalent circuit.

2.1.4 Summing Amplifier:

Probably the most used of the op-amp circuits is the summing amplifier circuit shown in Figure 2.1.4.0. The circuit shows a three-input summing amplifier circuit, which provides a means of algebraically summing (adding) three voltages, each multiplied by a constant-gain factor. Using the equivalent representation shown in Figure 2.1.4.1, the output voltage can be expressed in terms of the inputs as:

$$V_0 \;=\; -\,(\frac{R_f}{R_1}\cdot V_1 \;+\; \frac{R_f}{R_2}\cdot V_2 \;+\; \frac{R_f}{R_3}\cdot V_3\;)$$

In other words, each input adds a voltage to the output multiplied by its separate constant-gain multiplier. If more inputs are used, they each add an additional component to the output.

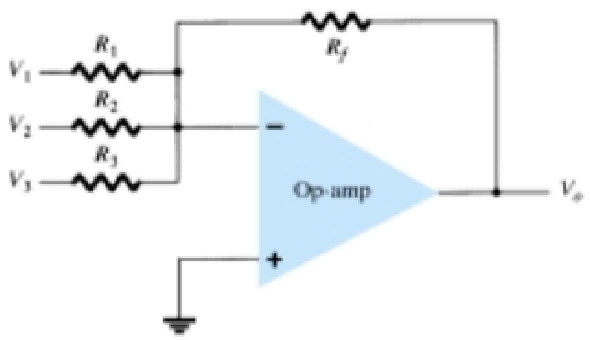

Figure 2.1.4.0: Summing amplifier.

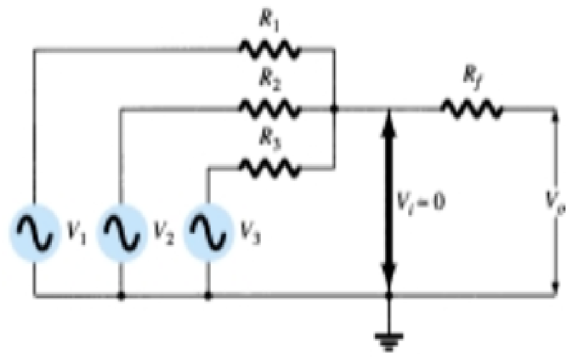

Figure 2.1.4.1: Virtual-ground equivalent circuit.

2.1.5 Differentiator:

A differentiator circuit is shown in Figure 2.1.4.0. While not as useful as the circuit forms covered above, the differentiator does provide a useful operation, the resulting relation for the circuit being:

$$v_0\;(\;t\;)\;=\;-\;R\cdot C\;(\;\frac{dv_1\;(\;t\;)}{dt}\;)$$

where the scale factor is -RC.

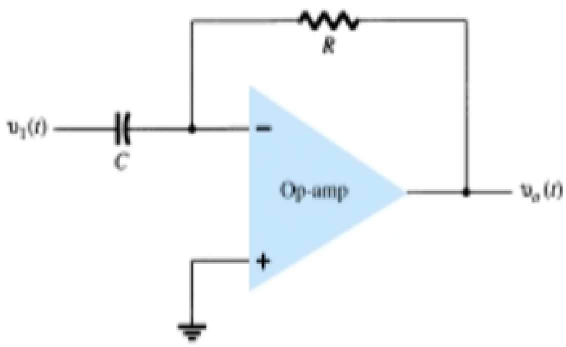

Figure 2.1.5.0: Differenciator circuit.

2.1.6 Integrator:

So far, the input and feedback components have been resistors. If the feedback component used is a capacitor, as shown in Figure 2.1.6.0, the resulting connection is called an integrator. The virtual-ground equivalent circuit Figure 2.1.6.1 shows that an expression for the voltage between input and output can be derived in terms of the current $\boldsymbol{I}$, from input to output. Recall that virtual ground means that we can consider the voltage at the junction of $\boldsymbol{R}$ and X_C to be ground (since $V_i \cong 0\ V$.) but that no current goes into ground at that point. The capacitive impedance can be expressed as:

$$X_C = \frac{1}{j \cdot \omega \cdot C} = \frac{1}{s \cdot C}$$

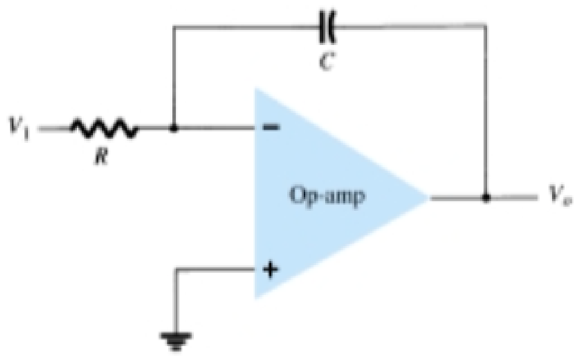

Figure 2.1.6.0: Integrator.

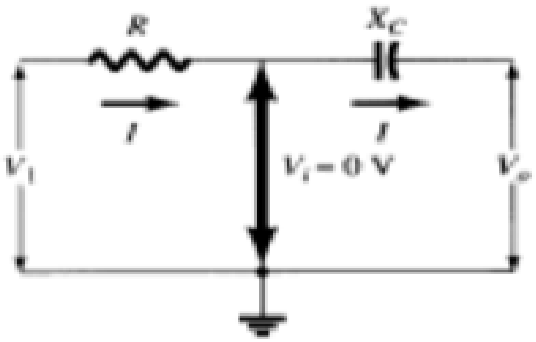

Figure 2.1.6.1: Virtual-ground equivalent circuit.

For $v_0\ (\ t\ )$:

$$v_0\ (\ t\ ) = -\frac{1}{R \cdot C} \int v_1\ (\ t\ )\ dt$$

3 Development:

We are going to analyze the circuits presented in subsection 2.1 implementing an op-amp **TL071** with a 12 V source.

Observation: *For all the circuits we need a positive and negative voltage source in terminals 7 and 4 of the op-amp respectively. In the sources, we choose the option **SERIES** and connect both E_1 and E_2 in series by connecting the negative terminal of E_1 to the positive terminal of E_2, this "new" terminal will be connected to the common ground, thus, the positive terminal of E_1 and the negative terminal of E_2 will be the positive and negative voltages respectively.*

3.1 Inverting Amplifier:

Setting the *waveform generator* in a sinusoidal signal with a frequency of 1 KHz and 1 V_{pp} we connect the positive terminal of the *generator* to the V_i input of the circuit of Figure 3.1.0 (is the one on the left side of the 1 KΩ resistor) and the negative terminal to the common ground. Then, once the respectively sources in the terminals 7 and 4 were connected, we turned on the *generator* and the voltage sources, thus, connecting the channel 1 of the oscilloscope in the input V_i and the channel 2 in the output V_o we registered the waveform in Figure 3.1.1.

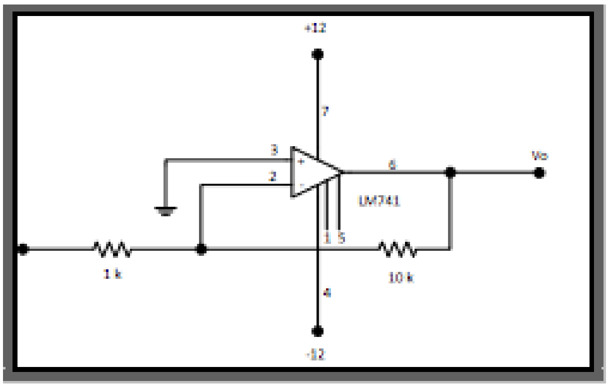

Figure 3.1.0: Inverting amplifier circuit.

The oscilloscope has another way to display the waveform, setting the device in its mode XY we will be able to visualize the **Transfer Function** as in Figure 3.1.2.

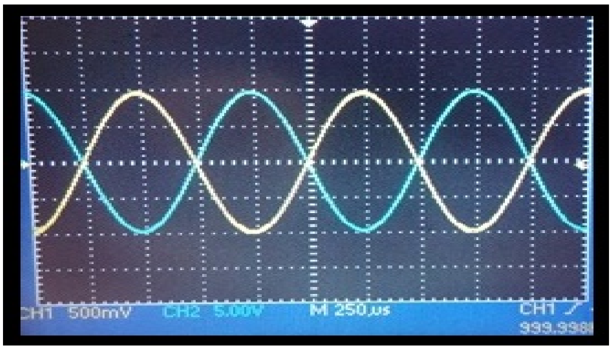

Figure 3.1.1: Input and output waveform.

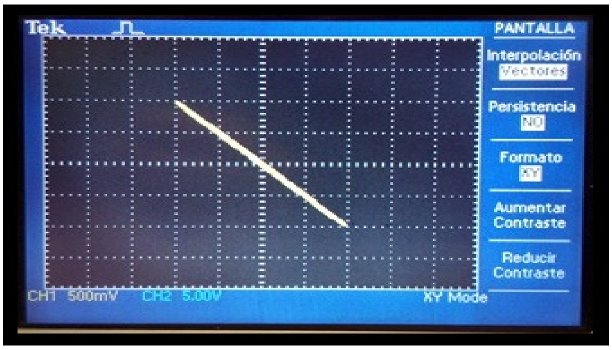

Figure 3.1.2: Transfer Function.

Observation: *The yellow waveform corresponds to the channel 1 and the blue waveform to channel 2 for Figure 3.1.1.*

Finally, we capture the gain and the input and output voltage values in Table 1:

V_i	V_o	**Gain**
1 V_{pp}	10.12 V_{pp}	10

Table 1: Gain of Inverting Amplifier.

3.2 Non-Inverting Amplifier:

Setting the *waveform generator* in a sinusoidal signal with a frequency of 1 KHz and 1 V_{pp} we connect the positive terminal of the *generator* to the V_i input of the circuit of Figure 3.2.0 (is the op-amp terminal 3) and the negative terminal to the common ground. Then, once the respectively sources in the terminals 7 and 4 were connected, we turned on the *generator* and the voltage sources, thus, connecting the channel 1 of the oscilloscope in the input V_i and the channel 2 in the output V_o we registered the waveform in Figure 3.2.1.

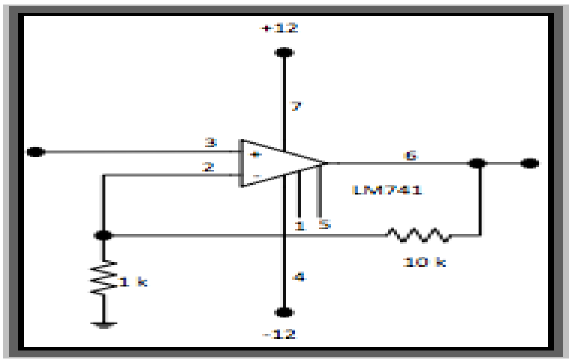

Figure 3.2.0: Non-inverting amplifier circuit.

The oscilloscope has another way to display the waveform, setting the device in its mode XY we will be able to visualize the **Transfer Function** as in Figure 3.2.2.

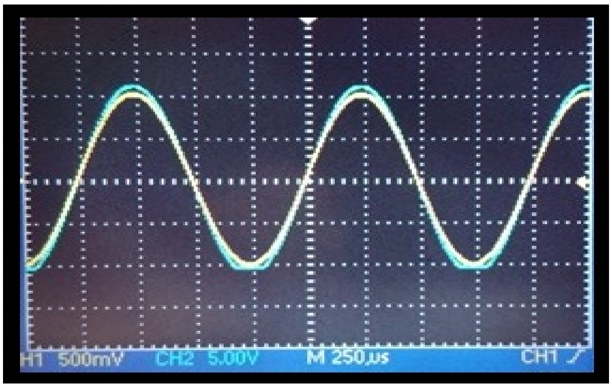

Figure 3.2.1: Input and output waveform.

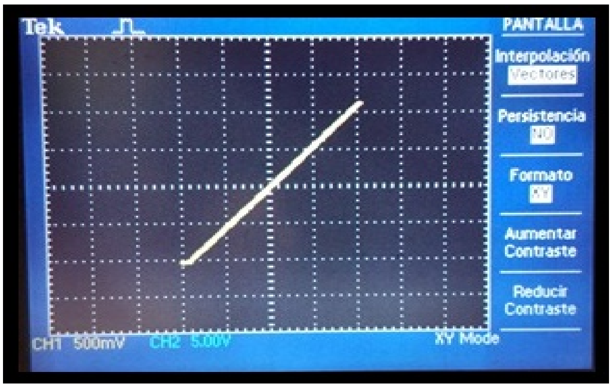

Figure 3.2.2: Transfer Function.

Observation: *The yellow waveform corresponds to the channel 1 and the blue waveform to channel 2 for Figure 3.2.1.*

We capture the gain and the input and output voltage values in Table 2:

V_i	V_o	**Gain**
1 V_p	10.3 V_p	10

Table 2: Gain of Inverting Amplifier.

Finally, increasing the amplitude of the input signal we visualize that the output starts to get saturated from values bigger than 2 V_{pp}:

V_{sat} (+)	V_{sat} (-)
$V_{sat} > 1\ V_p$	$V_{sat} < -1\ V_p$

Table 3: Output saturation.

When the output begins to get saturated, in the oscilloscope we visualize that the output turns from a sinusoidal into a square waveform as in Figure 3.2.4:

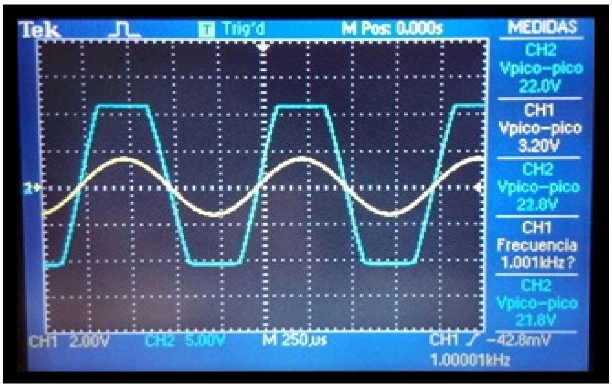

Figure 3.2.4: Saturated output waveform.

3.3 Unity Follower:

Setting the *waveform generator* in a sinusoidal signal with a frequency of 1 KHz and 5 V_{pp} we connect the positive terminal of the *generator* to the V_i input of the circuit of Figure 3.3.0 (is the op-amp terminal 3) and the negative terminal to the common ground. Then, once the respectively sources in the terminals 7 and 4 were connected, we turned on the *generator* and the voltage sources, thus, connecting the channel 1 of the oscilloscope in the input V_i and the channel 2 in the output V_o we registered the waveform in Figure 3.3.1.

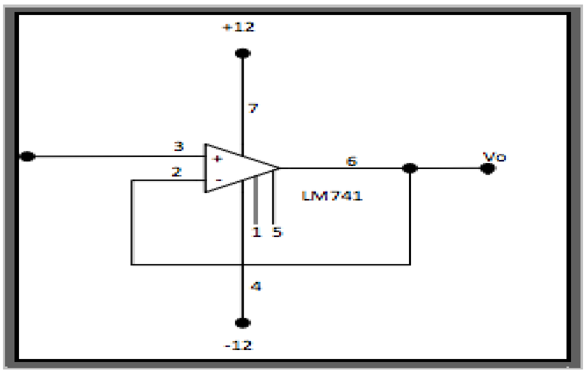

Figure 3.3.0: Unity Follower circuit.

The oscilloscope has another way to display the waveform, setting the device in its mode XY we will be able to visualize the **Transfer Function** as in Figure 3.3.2.

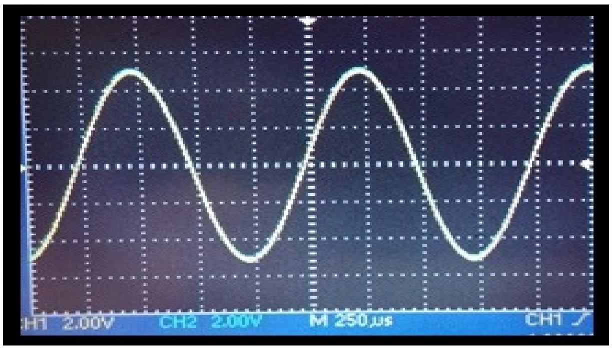

Figure 3.3.1: Input and output waveform.

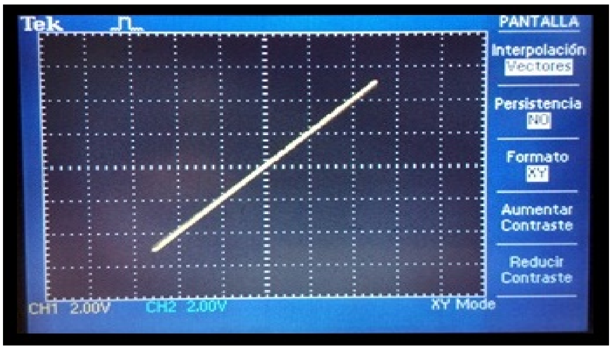

Figure 3.3.2: Transfer Function.

Observation: *The yellow waveform corresponds to the channel 1 and the blue waveform to channel 2, because it's a unity follower the waveform are exactly the same.*

Finally, we capture the gain and the input and output voltage values in Table 4:

V_i	V_o
5 V_{pp}	5.08 V_{pp}

Table 4: Input and output voltage.

3.4 Summing Amplifier:

Once the circuit in Figure 3.4.0 were assembled, we connect the respectively sources in terminals 7 and 4, then with the voltmeter we measure both input voltages V_1 and V_2 and the output voltage V_o.

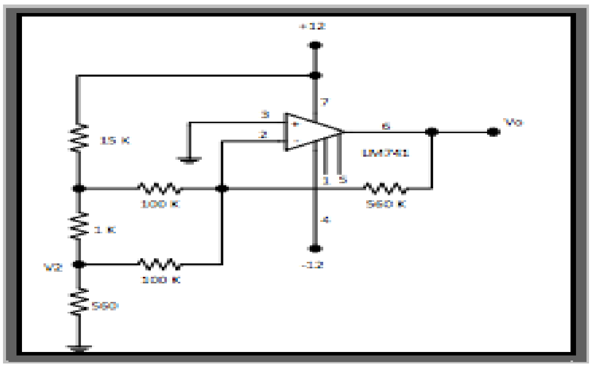

Figure 3.4.0: Summing Amplifier circuit.

Finally the measured voltages were registered in table 5:

V_1	V_2	V_o
1.11 V	398 mV	-8.5 V

Table 5: Voltage measured values.

3.5 Subtracting Amplifier:

Once the circuit in Figure 3.5.0 were assembled, we connect the respectively sources in terminals 7 and 4, then with the voltmeter we measure both input voltages V_1 and V_2 and the output voltage V_o.

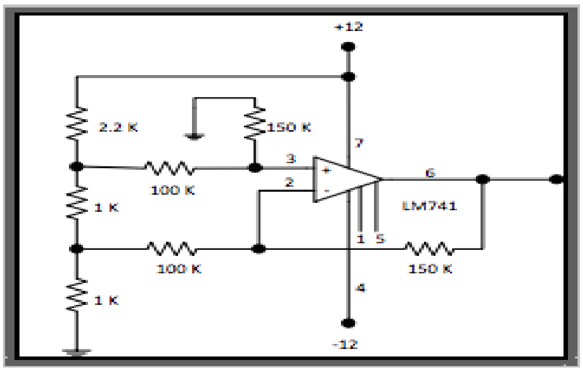

Figure 3.5.0: Subtracting Amplifier circuit.

Finally the measured voltages were registered in table 6:

V_1	V_2	V_o
5.7 V	2.86 V	4.3 V

Table 6: Voltage measured values.

3.6 Integrator:

Setting the *waveform generator* in a square signal with a frequency of 1KHz and 1 V_{pp} we connect the positive terminal of the *generator* to the V_i input of the circuit of Figure 3.6.0 (is the one on the left side of the 10 KΩ resistor) and the negative terminal to the common ground. Then, once the respectively sources in the terminals 7 and 4 were connected, we turned-on the *generator* and the voltage sources, thus, connecting the channel 1 of the oscilloscope in the input V_i and the channel 2 in the output V_o we registered the waveform in Figure 3.6.1.

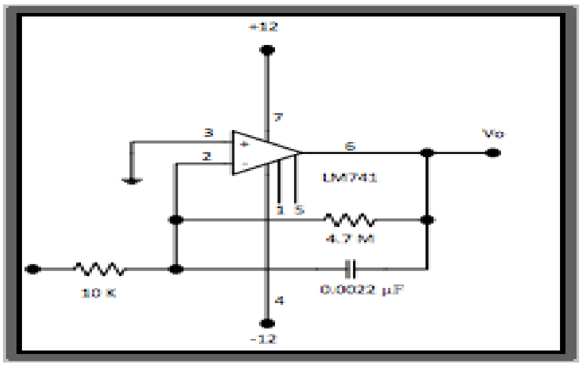

Figure 3.6.0: Integrator circuit.

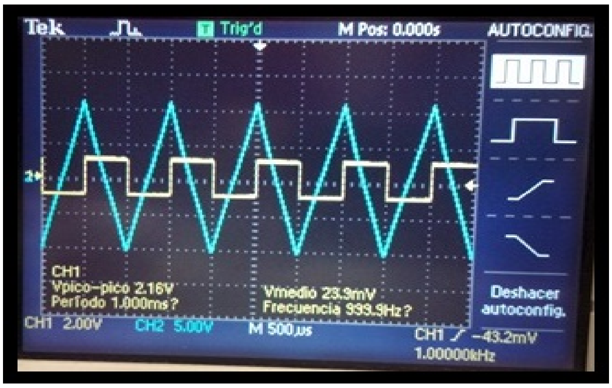

Figure 3.6.1: Input and output waveform.

Observation: *The input waveform is a square wave, as an effect of the integration the output waveform is a triangle wave.*

3.7 Differentiator:

Setting the *waveform generator* in a square signal with a frequency of 1 KHz and 1 V_{pp} we connect the positive terminal of the *generator* to the V_i input of the circuit of Figure 3.7.0 (is the one on the left side of the 0.01 μF capacitor) and the negative terminal to the common ground. Then, once the respectively sources in the terminals 7 and 4 were connected, we turned-on the *generator* and the voltage sources, thus, connecting the channel 1 of the oscilloscope in the input V_i and the channel 2 in the output V_o we registered the waveform in Figure 3.7.1.

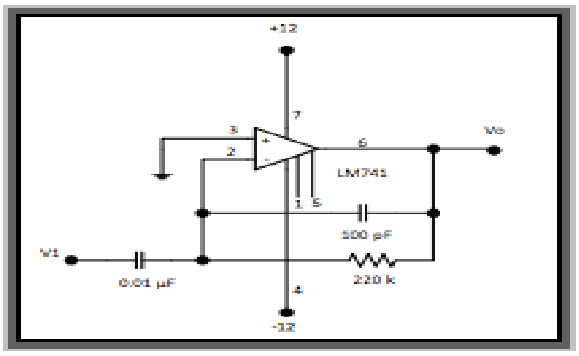

Figure 3.7.0: Differentiator circuit.

Figure 3.7.1: Input and output waveform.

Observation: *The input waveform is a triangle wave, as an effect of the differentiation the output waveform is a square wave.*

4 Simulations:

For each circuit that we have analyze in the section 3, we simulate each one of them, and we proceeded to make a comparative table with all the simulated results and the development ones.

4.1 Inverting Amplifier:

For the circuit in Figure 3.1.0 we simulate it and captured the results in Figures 4.1.0 and 4.1.1:

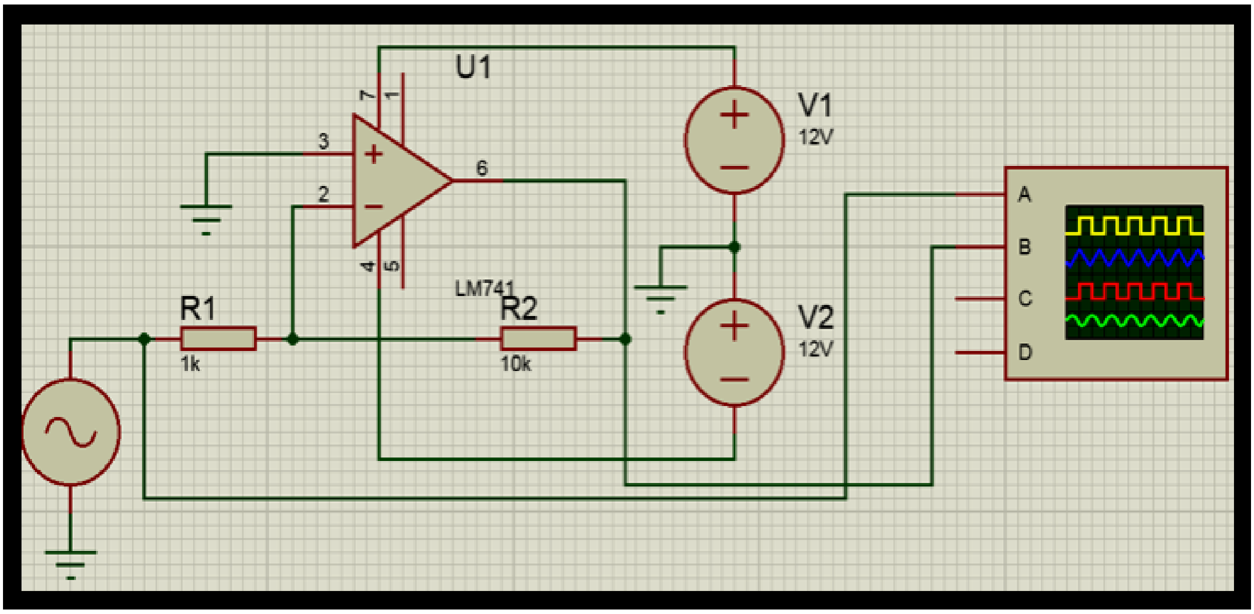

Figure 4.1.0: Simulation of circuit in Figure 3.1.0.

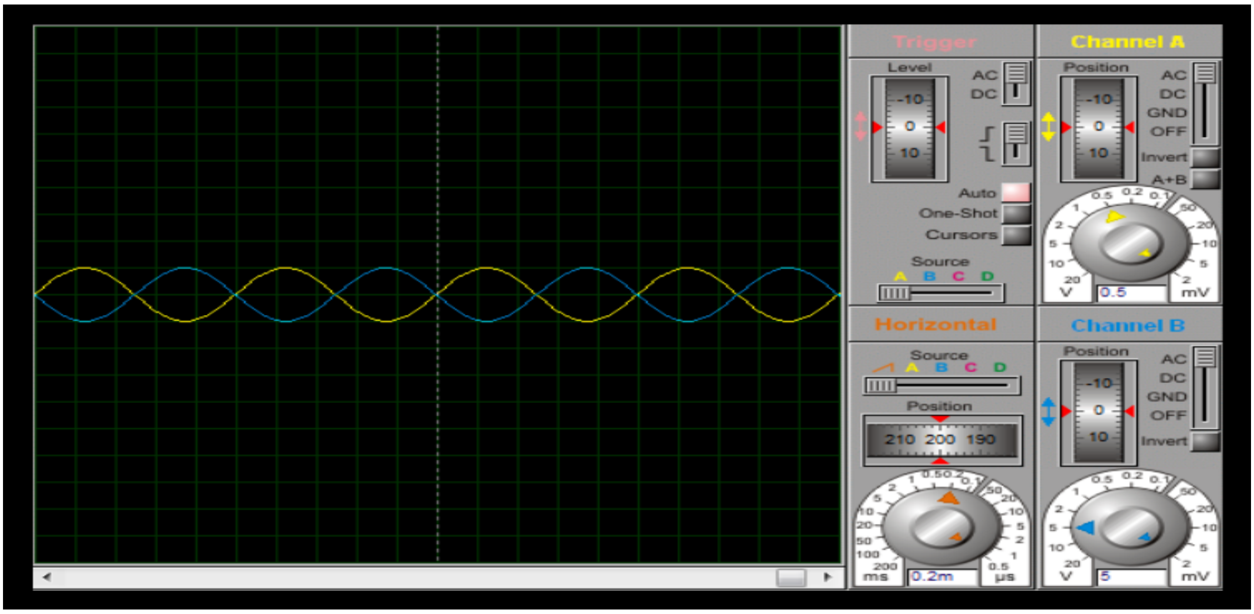

Figure 4.1.1: Simulated waveform of Figure 4.1.0.

4.2 Non-inverting Amplifier:

For the circuit in Figure 3.2.0 we simulate it and captured the results in Figures 4.2.0 and 4.2.1:

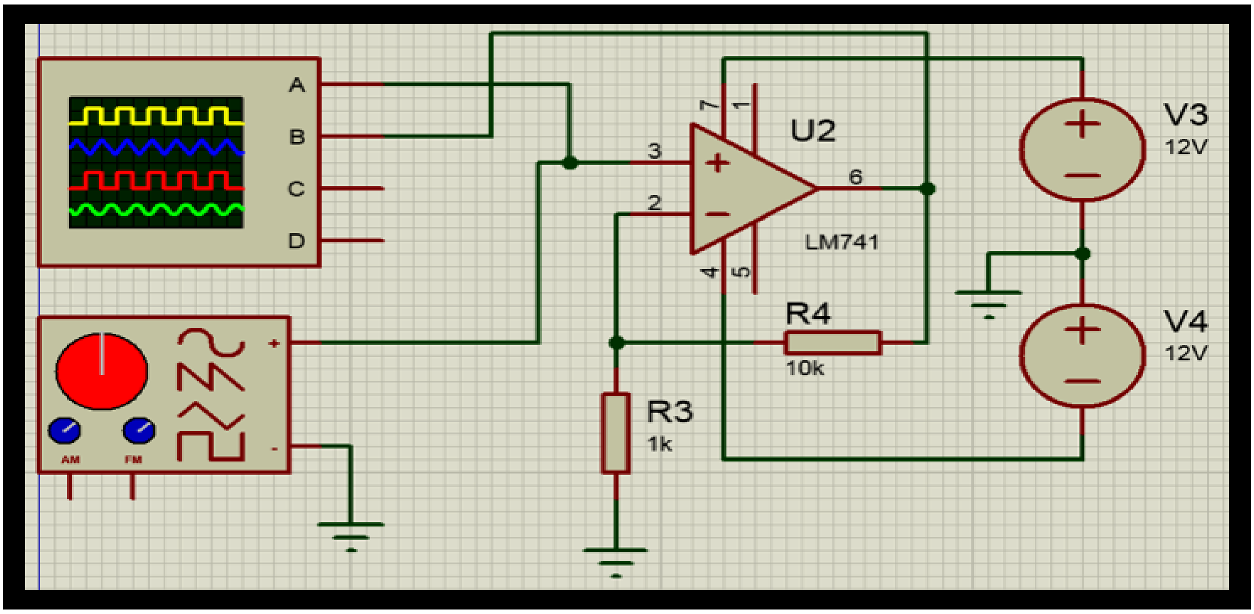

Figure 4.2.0: Simulation of circuit in Figure 3.2.0.

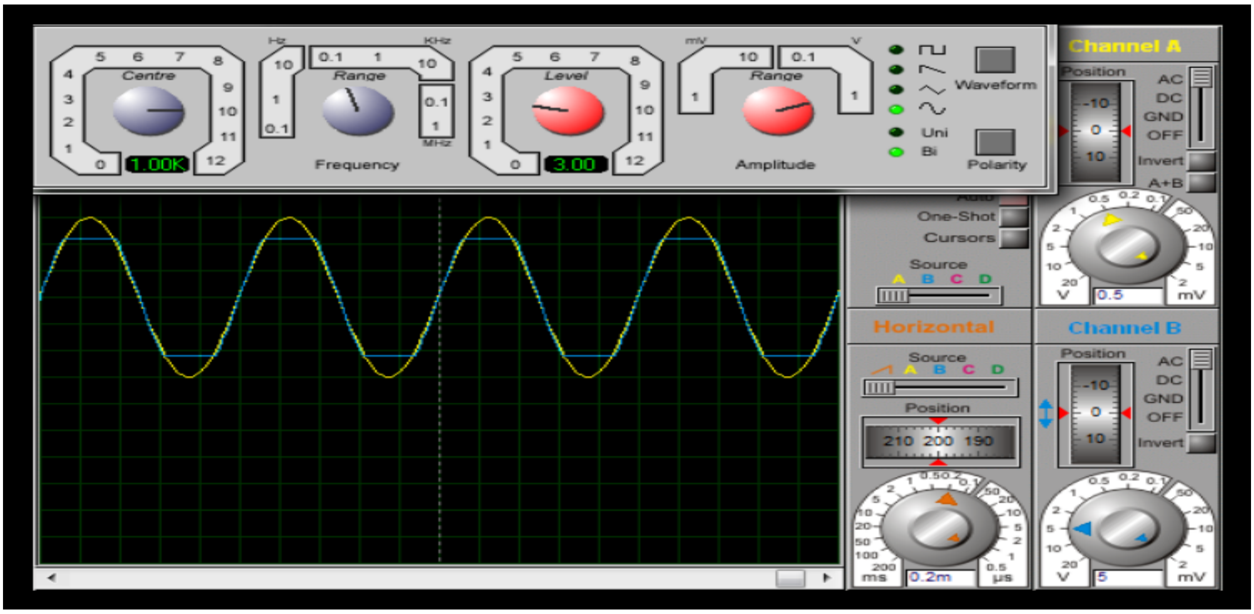

Figure 4.2.1: Simulated waveform of Figure 4.2.0.

4.3 Unity Follower:

For the circuit in Figure 3.3.0 we simulate it and captured the results in Figures 4.3.0 and 4.3.1:

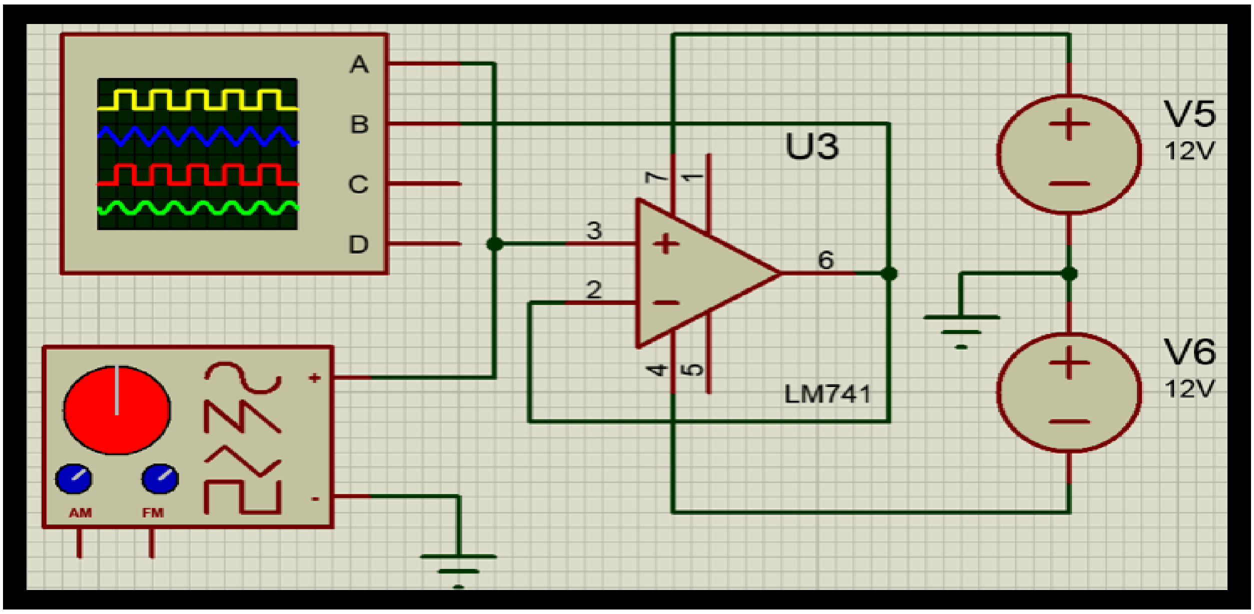

Figure 4.3.0: Simulation of circuit in Figure 3.3.0.

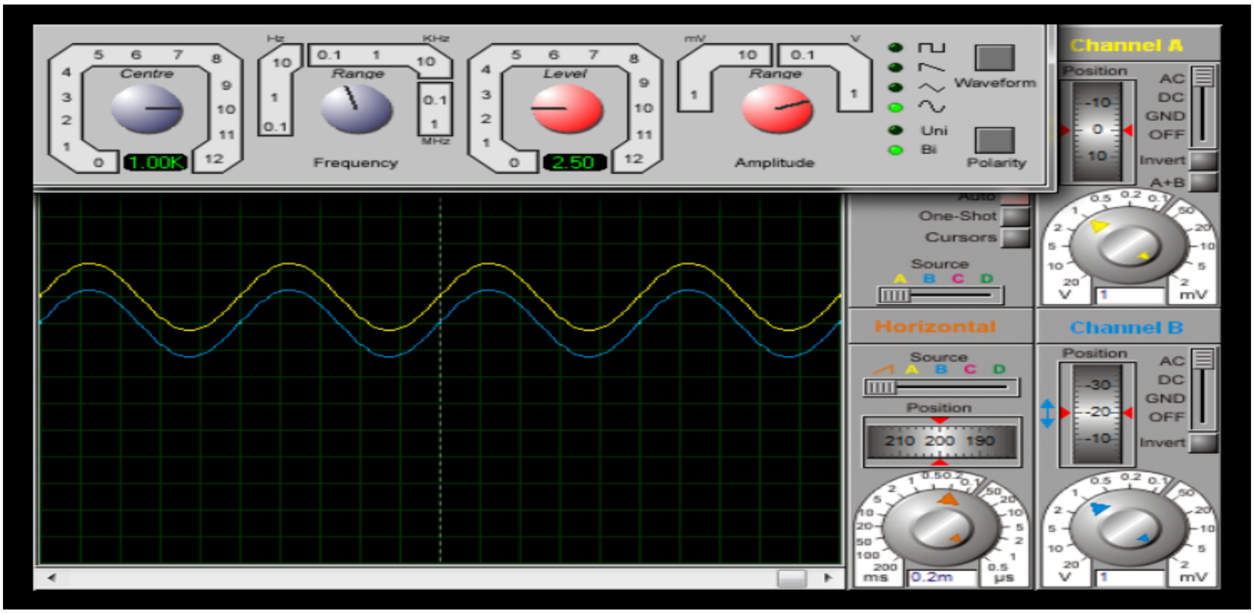

Figure 4.3.1: Simulated waveform of Figure 4.3.0.

4.4 Summing Amplifier:

For the circuit in Figure 3.4.0 we simulate it (Figure 4.4.0) and captured the results in Table 7:

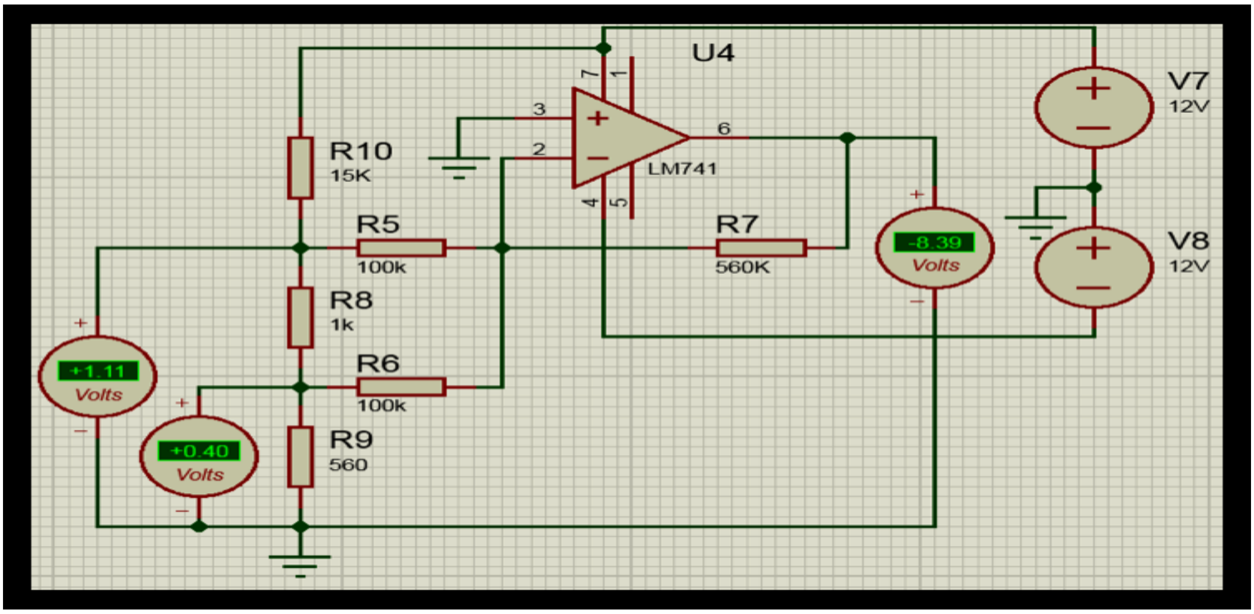

Figure 4.4.0: Simulation of circuit in Figure 3.4.0.

V_1	V_2	V_o
1.11 V	400 mV	-8.39 V

Table 7: Voltage simulated values.

4.5 Subtracting Amplifier:

For the circuit in Figure 3.5.0 we simulate it (Figure 4.5.0) and captured the results in Table 8:

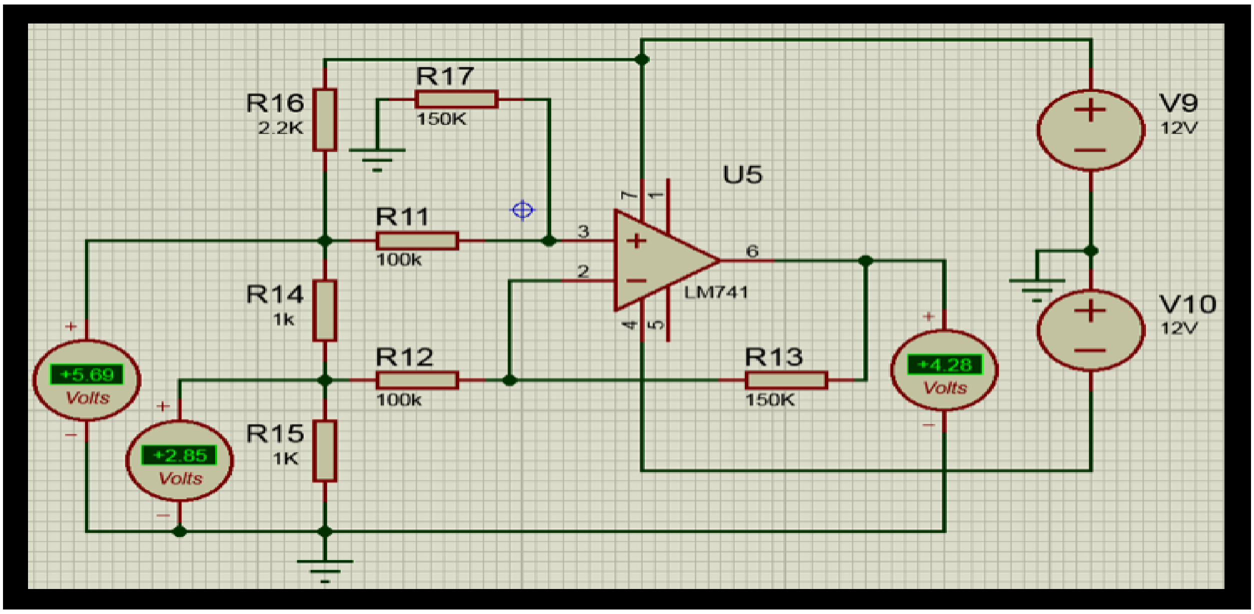

Figure 4.5.0: Simulation of circuit in Figure 3.5.0.

V_1	V_2	V_o
5.69 V	2.85 V	4.28 V

Table 8: Voltage simulated values.

4.6 Integrator:

For the circuit in Figure 3.6.0 we simulate it and captured the results in Figures 4.6.0 and 4.6.1:

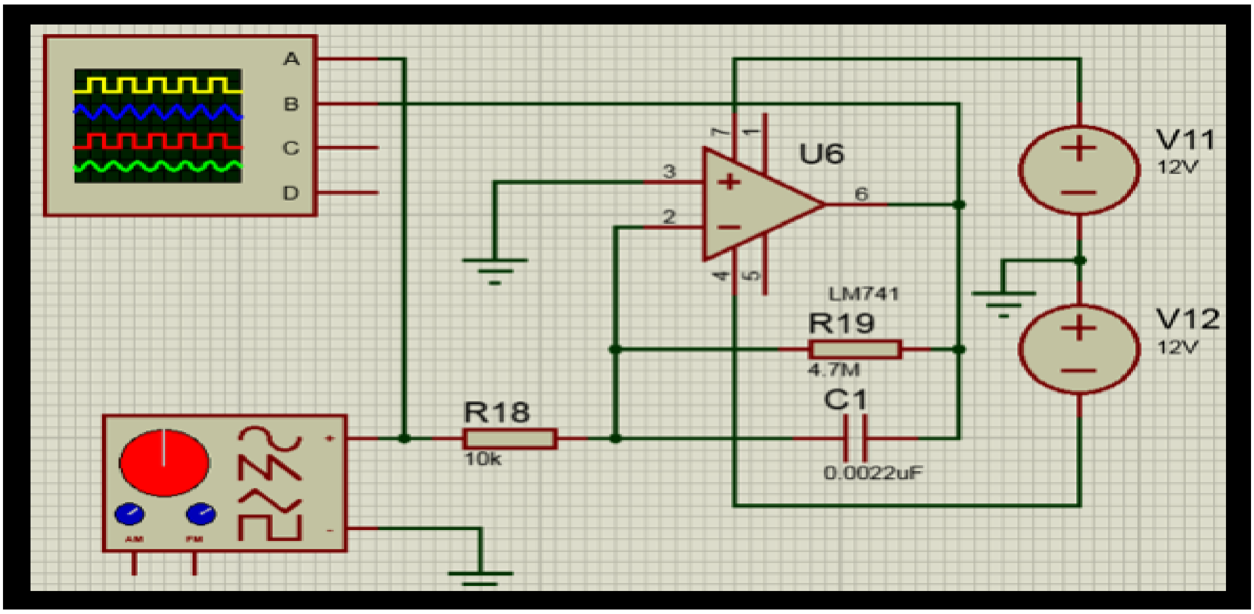

Figure 4.6.0: Simulation of circuit in Figure 3.6.0.

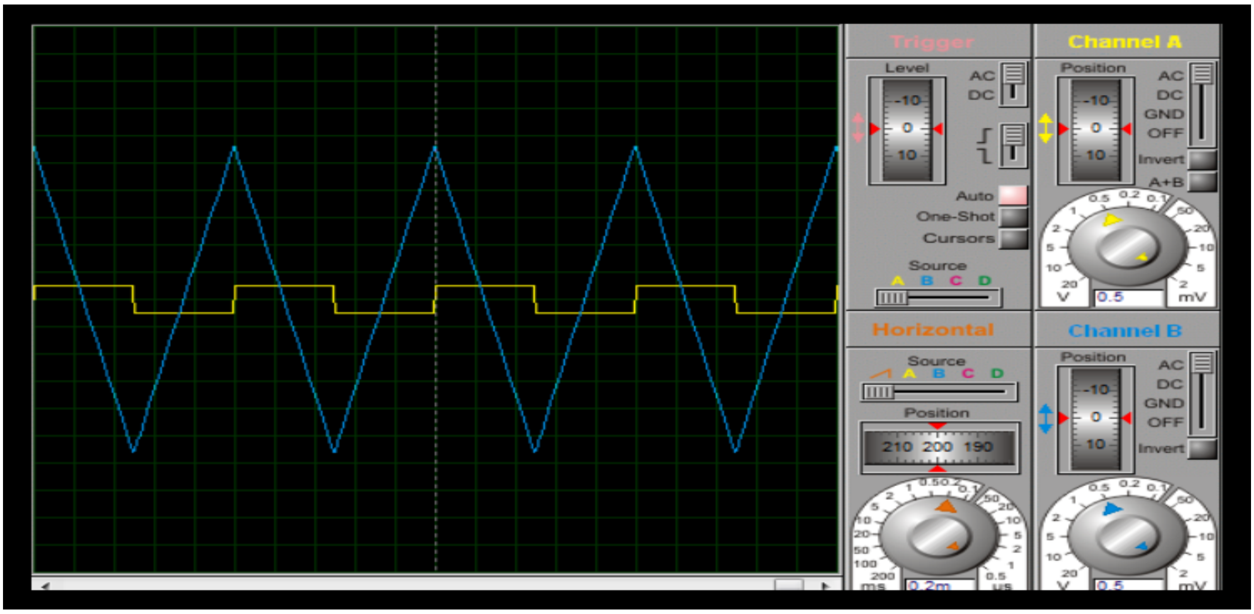

Figure 4.6.1: Simulated waveform of Figure 4.6.0.

4.7 Differentiator:

For the circuit in Figure 3.7.0 we simulate it and captured the results in Figures 4.7.0 and 4.7.1:

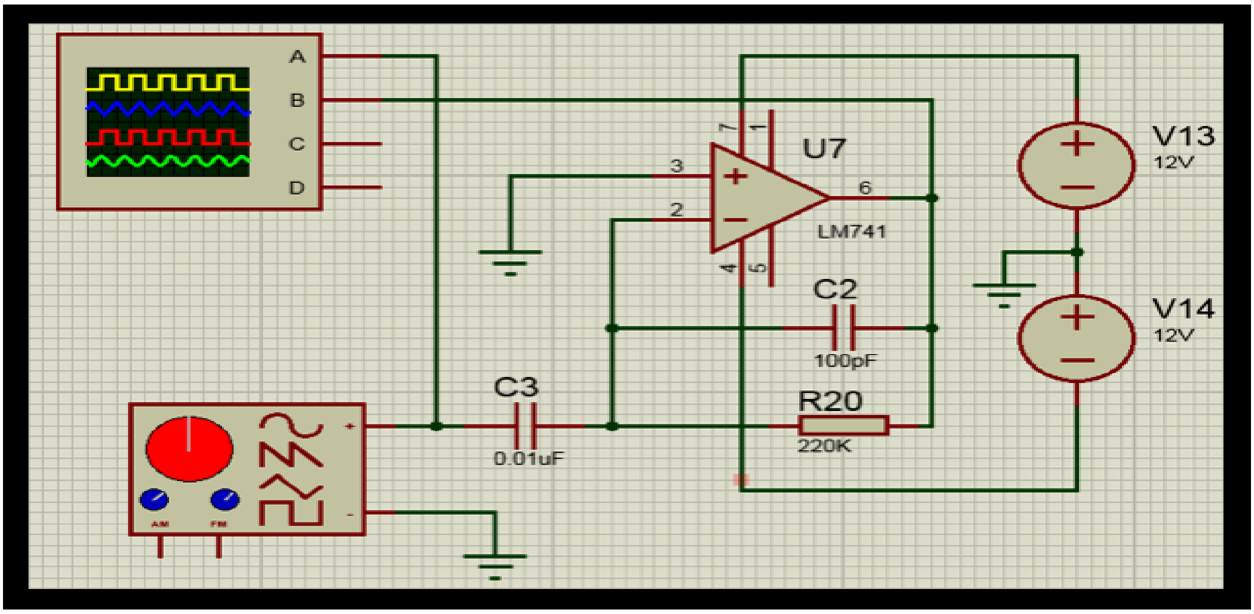

Figure 4.7.0: Simulation of circuit in Figure 3.7.0.

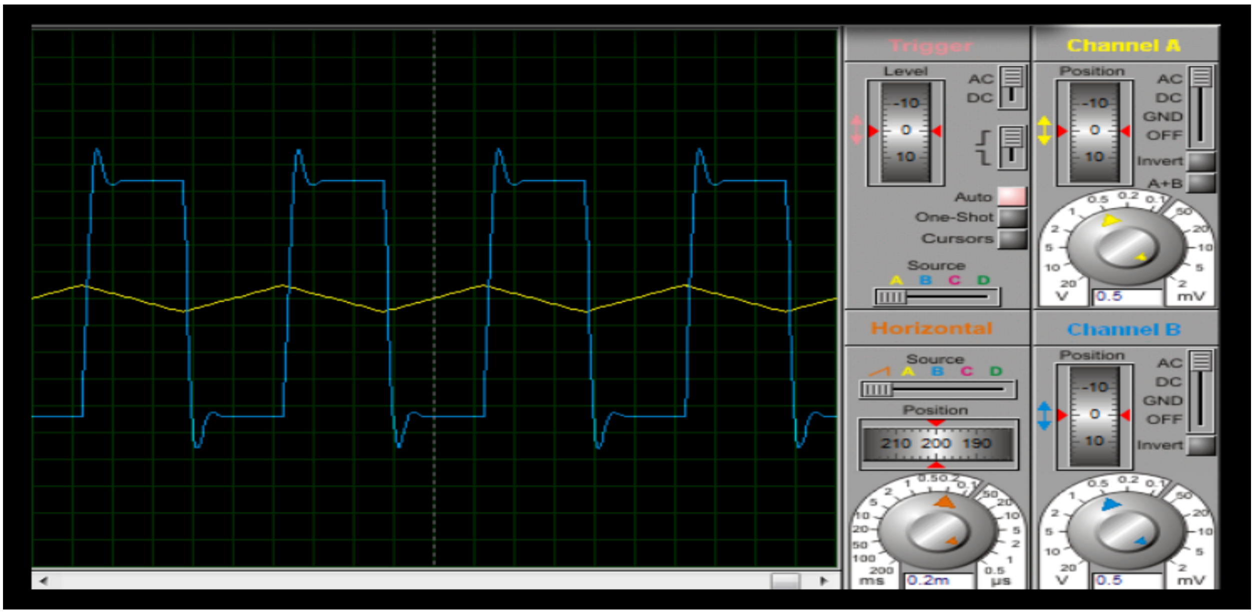

Figure 4.7.1: Simulated waveform of Figure 4.7.0.

5 Theoretical Analysis:

For each circuit that we have analyze in the section 3, we calculate each one of them, and we proceeded to make a comparative table with all the theoretical results and the development ones.

5.1 Inverting Amplifier:

The circuit that we are going to analyze it's the one in Figure 3.1.0 using the following parameters:

- V_{ent} **= 1** V_{pp}
- R_f **= 10 K** Ω
- **R = 1 K** Ω

- ***For V_{sal} in the positive semi-cycle:***

Formula: $V_{sal} = -\left(\frac{R_f}{R}\right)\cdot\left(V_{ent}\right)$***:***

$$V_{sal} = -\left(\frac{10\ K\ \Omega}{1\ K\ \Omega}\right)\cdot\left(0.500\ V_p\right)$$

$$= -5\ V_p$$

- ***For V_{sal} in the negative semi-cycle:***

Formula: $V_{sal} = -\left(\frac{R_f}{R}\right)\cdot\left(V_{ent}\right)$***:***

$$V_{sal} = -\left(\frac{10\ K\ \Omega}{1\ K\ \Omega}\right)\cdot\left(-0.500\ V_p\right)$$

$$= 5\ V_p$$

- ***For the Gain:***

Formula: $A_v = \left(\frac{R_f}{R}\right)$***:***

$$A_v = \left(\frac{10\ K\ \Omega}{1\ K\ \Omega}\right)$$

$$= 10$$

Finally we can assume that V_{sal} = 10 V_{pp}.

5.2 Non-inverting Amplifier:

The circuit that we are going to analyze it's the one in Figure 3.2.0 using the following parameters:

- V_{ent} **= 1** V_{pp}
- R_f **= 10 K** Ω
- **R = 1 K** Ω

- ***For V_{sal} in the positive semi-cycle:***

Formula: $V_{sal} = (\frac{R_f}{R} + 1) \cdot (V_{ent})$**:**

$$V_{sal} = (\frac{10\ K\ \Omega}{1\ K\ \Omega} + 1) \cdot (0.500\ V_p)$$

$$= 5.5\ V_p$$

- ***For V_{sal} in the negative semi-cycle:***

Formula: $V_{sal} = (\frac{R_f}{R} + 1) \cdot (V_{ent})$**:**

$$V_{sal} = (\frac{10\ K\ \Omega}{1\ K\ \Omega} + 1) \cdot (-0.500\ V_p)$$

$$= -5.5\ V_p$$

- ***For the Gain:***

Formula: $A_v = (\frac{R_f}{R} + 1)$**:**

$$A_v = (\frac{10\ K\ \Omega}{1\ K\ \Omega} + 1)$$

$$= 11$$

Finally we can assume that V_{sal} = 11 V_{pp}.

5.3 Unity Follower:

The circuit that we are going to analyze it's the one in Figure 3.3.0 using the following parameters:

- V_{ent} = **5** V_{pp}

Formula: $V_{sal} \;=\; V_{ent}$***:***

- ***For*** V_{sal} ***in the positive semi-cycle:***

$$V_{sal} \;=\; 2.5\ V_p$$

- ***For*** V_{sal} ***in the negative semi-cycle:***

$$V_{sal} \;=\; -2.5\ V_p$$

Finally we can assume that $V_{sal} \;=$ ***5*** V_{pp}***.***

5.4 Summing Amplifier:

The circuit that we are going to analyze it's the one in Figure 3.4.0 using the following parameters:

- R_f = **560 K** Ω
- R_1 = **100 K** Ω
- R_2 = **100 K** Ω
- $R_{div\ 1}$ = **560** Ω
- $R_{div\ 2}$ = **1 K** Ω
- $R_{div\ 3}$ = **15 K** Ω

- ***For E_2 using a voltage divider:***

Formula: $E_n = (\frac{(R_n)(E)}{R_1 + R_2 + ... + R_n})$***:***

$$E_2 = \frac{(R_{div\ 1}) \cdot (12\ V)}{R_{div\ 1} + R_{div\ 2} + R_{div\ 3}}$$

$$= \frac{(560\ \Omega) \cdot (12\ V)}{560\Omega + 1\ K\ \Omega + 15\ K\ \Omega}$$

$$= 405.79\ mV$$

- ***For E_1 using a voltage divider:***

$$E_1 = E_2 + \frac{(R_{div\ 2}) \cdot (12\ V)}{R_{div\ 1} + R_{div\ 2} + R_{div\ 3}}$$

$$= 405.79\ mV + \frac{(1\ K\ \Omega) \cdot (12\ V)}{560\Omega + 1\ K\ \Omega + 15\ K\ \Omega}$$

$$= 405.79\ mV + \frac{(1\ K\ \Omega) \cdot (12\ V)}{560\Omega + 1\ K\ \Omega + 15\ K\ \Omega}$$

$$= 1.13\ V$$

- ***Then, for V_{sal}:***

Formula: $V_{sal} = -R_f (\frac{E_1}{R_1} + \frac{E_2}{R_2} + ... + \frac{E_n}{R_n})$***:***

$$V_{sal} = -560\ K\ \Omega (\frac{1.13\ V}{100\ K\ \Omega} + \frac{405.79\ mV}{100\ K\ \Omega})$$

$$= -8.6V$$

5.5 Subtracting Amplifier:

The circuit that we are going to analyze it's the one in Figure 3.5.0 using the following parameters:

- R_f = **150 K** Ω
- R_1 = **100 K** Ω
- R_2 = **100 K** Ω
- $R_{div\ 1}$ = **1 K** Ω
- $R_{div\ 2}$ = **1 K** Ω
- $R_{div\ 3}$ = **2.2 K** Ω

- ***For E_2 using a voltage divider:***

Formula: $E_n = (\frac{(R_n)(E)}{R_1 + R_2 + ... + R_n})$:

$$E_2 = \frac{(R_{div\ 1}) \cdot (12\ V)}{R_{div\ 1} + R_{div\ 2} + R_{div\ 3}}$$

$$= \frac{(1\ K\ \Omega) \cdot (12\ V)}{1\ K\ \Omega + 1\ K\ \Omega + 2.2\ K\ \Omega}$$

$$= 2.8\ V$$

- ***For E_1 using a voltage divider:***

$$E_1 = E_2 + \frac{(R_{div\ 2}) \cdot (12\ V)}{R_{div\ 1} + R_{div\ 2} + R_{div\ 3}}$$

$$= 2.8\ V + \frac{(1\ K\ \Omega) \cdot (12\ V)}{560\Omega + 1\ K\ \Omega + 2.2\ K\ \Omega}$$

$$= 2.8\ V + \frac{(1\ K\ \Omega) \cdot (12\ V)}{1\ K\Omega + 1\ K\ \Omega + 2.2\ K\ \Omega}$$

$$= 5.65\ V$$

- ***Then, for V_{sal}:***

Formula: $V_{sal} = R_f\ (\frac{E_1}{R_1} - \frac{E_2}{R_2} - ... - \frac{E_n}{R_n})$:

$$V_{sal} = 150\ K\ \Omega\ (\frac{5.65\ V}{100\ K\ \Omega} - \frac{2.8\ V}{100\ K\ \Omega})$$

$$= 4.27\ V$$

6 Comparisons:

In this sections we will compare the development, simulated and theoretical results for each circuit in each configurations.

6.1 Inverting Amplifier:

Comparison of subsection's 3.1, 4.1 and 5.1 results:

	V_i	V_o	**Gain**
Practical	1 V_{pp}	10.12 V_{pp}	10
Simulation	1 V_{pp}	10 V_{pp}	10
Theoretical	1 V_{pp}	10 V_{pp}	10

Table 9: Inverting amplifier comparison table.

6.2 Noninverting Amplifier:

Comparison of subsection's 3.2, 4.2 and 5.2 results:

	V_i	V_o	**Gain**
Practical	1 V_{pp}	10.3 V_{pp}	10
Simulation	1 V_{pp}	11 V_{pp}	10
Theoretical	1 V_{pp}	11 V_{pp}	10

Table 10: Non-inverting amplifier comparison table.

6.3 Unity Follower:

Comparison of subsection's 3.3, 4.3 and 5.3 results:

	V_i	V_o
Practical	5 V_{pp}	5.08 V_{pp}
Simulation	5 V_{pp}	5 V_{pp}
Theoretical	5 V_{pp}	5 V_{pp}

Table 11: Unity follower comparison table.

6.4 Summing Amplifier:

Comparison of subsection's 3.4, 4.4 and 5.4 results:

	V_1	V_2	V_o
Practical	1.11 V	398 mV	-8.5 V
Simulation	1.11 V	400 mV	-8.39 V
Theoretical	1.13 V	405.79 mV	-8.6 V

Table 12: Summing amplifier comparison table.

6.5 Subtracting Amplifier:

Comparison of subsection's 3.5, 4.5 and 5.5 results:

	V_1	V_2	V_o
Practical	5.7 V	2.86 V	4.3 V
Simulation	5.69 V	2.85 V	4.28 V
Theoretical	5.65 V	2.8 V	4.27 V

Table 13: Subtracting amplifier comparison table.

7 Questionnaire:

- **What represents the negative sign in the circuits: Inverter, adder, derivator and integrator?**

  The negative sign of the expression indicates the phase inversion between the input and the output.

- **Explain because it exists a difference between the voltage of theoretical and practical exit of the circuits, adder and subtract:**

  The difference between the values occurs when considering that the operational amplifier is ideal because of the virtual ground that we generate in the moment of realizing the calculations.

- **Which function has the circuit follower of voltage?**

  At first glance it seems that the voltage follower, having a unitary closed loop gain, would have no interest from the electronic point of view. However, having a zero-input current (Is = 0) allows us to couple a voltage source with relatively high input resistance to a load with relatively low resistance, without the charging effect occurring. It is said that the voltage follower produces an electrical insulation between the source and the load. For this reason, the voltage follower is also called a separator or buffer.

- **Which is the purpose to add him a resistance in parallel to the capacitor in the integrador and a capacitor in parallel to the resistance of the derivator?**

  (i) To prevent the occurrence of any continuous voltage (eg imperfections of the AO) at the input of the Integrator to bring its output to saturation, an RC resistance is placed in parallel with the capacitor to limit the gain in DC to -RC / R.

  (ii) If there was noise at the input, this would normally be of a higher frequency compared to the signal to be derived, this would cause smaller noise values to appear at the output much larger. To avoid this, a resistor R1 (in series with the capacitor C) is placed in the input and a capacitor C1 is added in parallel with the feedback resistor (R) to reduce the tendency to oscillate of the circuit.

8 Conclusion:

The amplifiers, as far, are the most complicated and important device that we think, we analyze in this course, this because, they have a lot of applications and different configuration for a so tiny and simple device. Its functionality it's based on the transistor principle and we have seen and demonstrated that depending of the devices that we connect around of the amplifier it will do a specified operation as a addition, product, subtraction, integration, derivation, inclusive the Fourier Transform. This device has a lot of applications in the industry and in out daily life.

9 Bibliographic References:

[1] BOYLESTAD, Robert L. ”Electronic Devices and Circuit Theory”. Edit. Prentice Hall. 2009.