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Subtractor Operational Amplifier

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1. Objectives

The objective of this experiment is to study and simulating subtractor configuration of 741 operational-amplifier using multisim simulating kit.

2. Equipment

a. Oscilloscope
b. Multimeter
c. Power Source
d. Switches
e. Vcc (+15v)
f. Vdd (-15v)
g. IC-741
h. Resistors(1kΩ, 2kΩ, 3kΩ, 4kΩ)

3. Circuit Diagram

Figure 1 shows the circuit diagram for two input subtractor configuration.

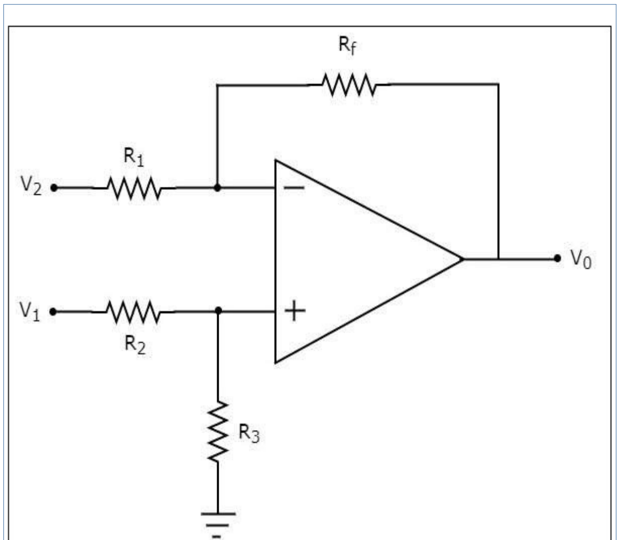

Figure 1

Figure 2 shows the circuit connection for two subtractor configuration on multisim simulating application for DC input.

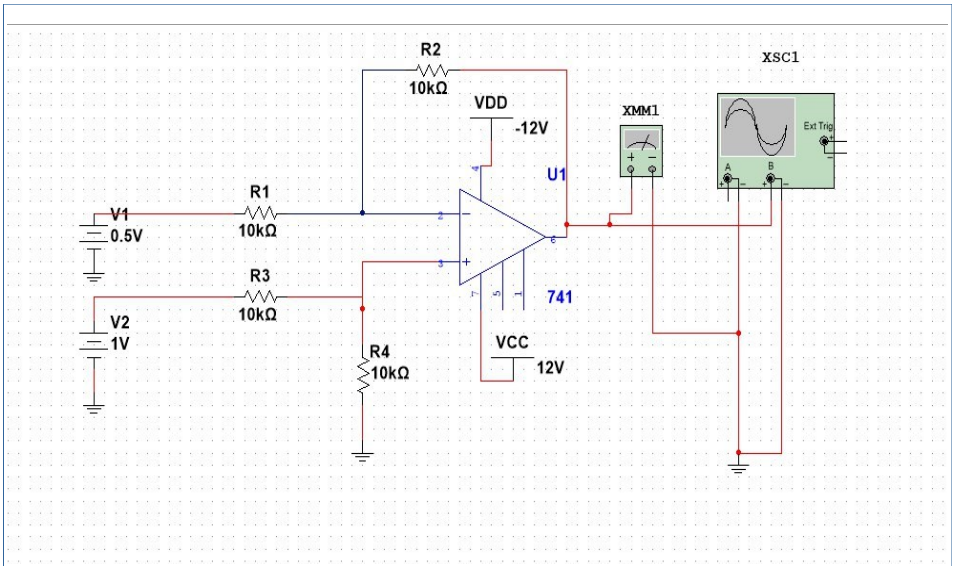

Figure 2

Figure 3 shows the circuit connection for two subtractor configuration on multisim simulating application for AC input.

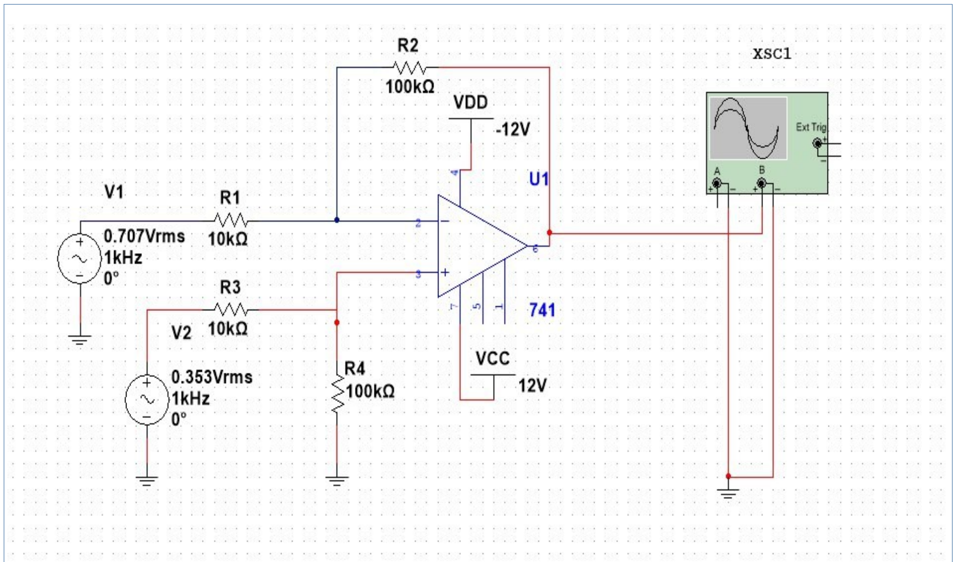

Figure 3

4. Theory

A modern op-amp has hundreds of transistors integrated on a single chip, It is not necessary to understand how the internal circuitry works in order to use the op-amp; it can be treated as a “black-box” device.

The symbol for an 741 op-amp is shown in figure 1, This is the most basic op-amp symbol with five terminals comprised of positive (non-inverting) and negative (inverting) inputs; V+ and V- supply terminals; and one output.

All equations that describe the behavior of op-amp circuits rely on certain assumptions about the op-amp. These assumptions about an ideal op-amp are summarized in table 1 and compared to the real op-amp used in this lab, the 741.

A modern op-amp approaches an ideal op-amp when used within its bandwidth and output limitations. For non-critical applications the ideal op-amp assumptions are valid.

In the case of the 741 as long as the device is operated at low frequencies and does not exceed its rated output voltage and current limits the ideal assumptions are valid.

Parameter	Ideal Op-Amp	741
R_{in}	Infinite	2MΩ
Open loop Gain	Infinite	200,000
Bandwidth	Infinite	1MHz
Voltage Output	Infinite	+/- 15.0V
Current Output	Infinite	25mA
R_O	Zero	75Ω
Input Offset Voltage	Zero	1mV
Input Bias Current	Zero	0.2nA

Table 1

The behavior of an op-amp can be described by two rules:

1. An op-amp will attempt to make the voltage at both its inputs equal through the use of a feedback path.
2. No current can flow through inputs terminals.

Now by connected the 741 as shown in figure 1, we will get the subtractor operation amplifier configuration and this configuration has a negative gain and negative feedback loop and this configuration can subtract two input voltage together and for this configuration the input/output relationship is
given by:

$$Vo = V1\left(\frac{R3}{(R2+R3)}\right)\left(1+\frac{RF}{R1}\right)-\left(\frac{Rf}{R1}\right)V2$$

Formula 1

in case of $R_f = R_1 = R_2 = R_3$ the output will given by the Formula 2:

$$Vo = -(V2 - V1)$$

Formula 2

5. Observation Data

- **Simulation Readings**

Table 2 shows all the readings that we got from the simulation using different values of R and different input voltages and different frequencies.

V_1(v)	V_2(v)	R_1(kΩ)	R_2(kΩ)	R_3(kΩ)	R_4(kΩ)	$V_{o\text{-}real}$(v)	$V_{o\text{-}sim}$(v)	F(Hz)	Error(%)
0.5	0.5	10	10	10	10	0	0.002	0	Nan
0.5	1	10	10	10	10	0.5	0.502	0	0.40
1	3	10	10	10	10	2	-2.002	0	0.09
5	4	10	10	10	10	-1	-0.997	0	0.30
2	6	10	10	10	10	4	4.002	0	0.005
0.5	0.5	10	10	10	100	0	0.001	1000	Nan
0.5	1	10	100	10	100	-5	-4.999	1000	0.049
1	3	10	100	10	100	20(cut)	10.138	1000	49.30
5	4	10	100	10	100	-10	-8.898	1000	11.02
2	6	10	100	10	100	40(cut)	10.138	1000	74.65

Table 2

Table 3 shows the Frequency Response for the 741 operational amplifier.

V_1(v)	V_2(v)	R_1(kΩ)	R_2(kΩ)	R_3(kΩ)	R_4(kΩ)	F(Hz)	$V_{o\text{-}real}$(v)
0.5	0.5	10	100	10	100	1	5.009
0.5	0.5	10	100	10	100	10	5.003
0.5	0.5	10	100	10	100	100	5.000
0.5	0.5	10	100	10	100	1k	5.000
0.5	0.5	10	100	10	100	100k	0.714
0.5	0.5	10	100	10	100	500k	0.145
0.5	0.5	10	100	10	100	1M	0.075
0.5	0.5	10	100	10	100	10M	0.004

Table 3

- **Oscilloscope output**

  The Figure 3 shows the input signal and the summing output signal on the Oscilloscope.

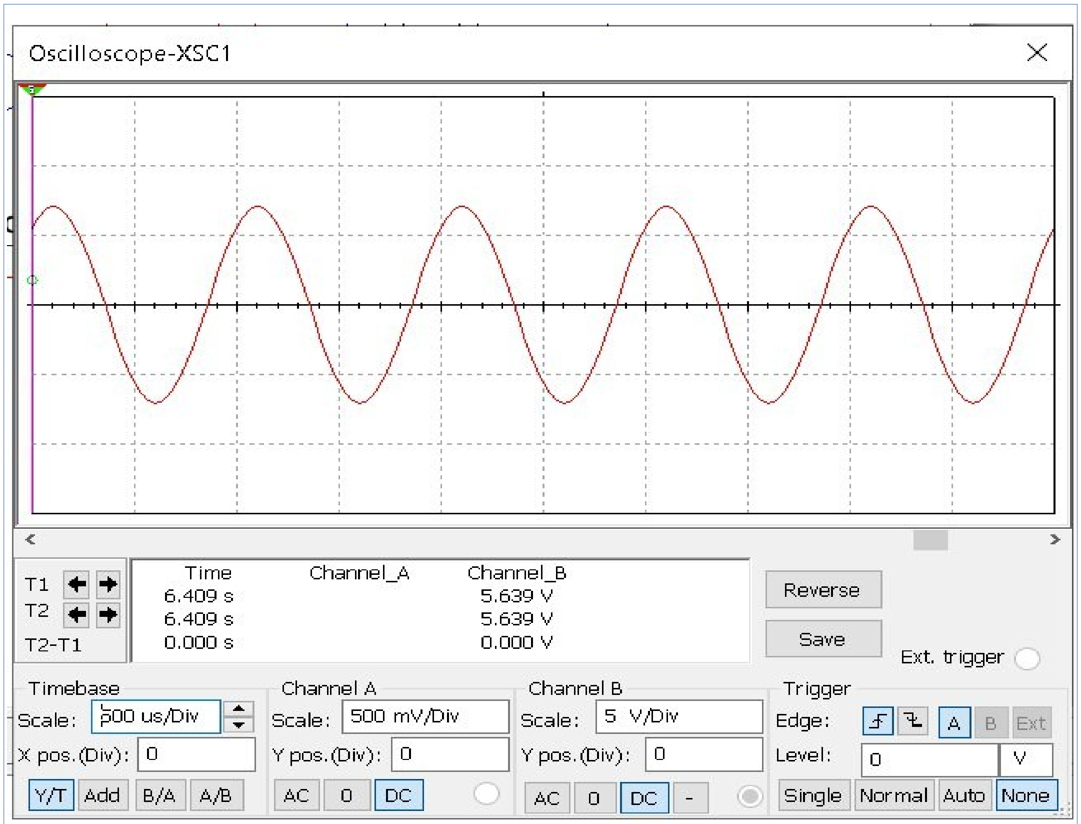

Figure 4: input and output signals

The Figure 4 shows the input signal and Saturated Output signal.

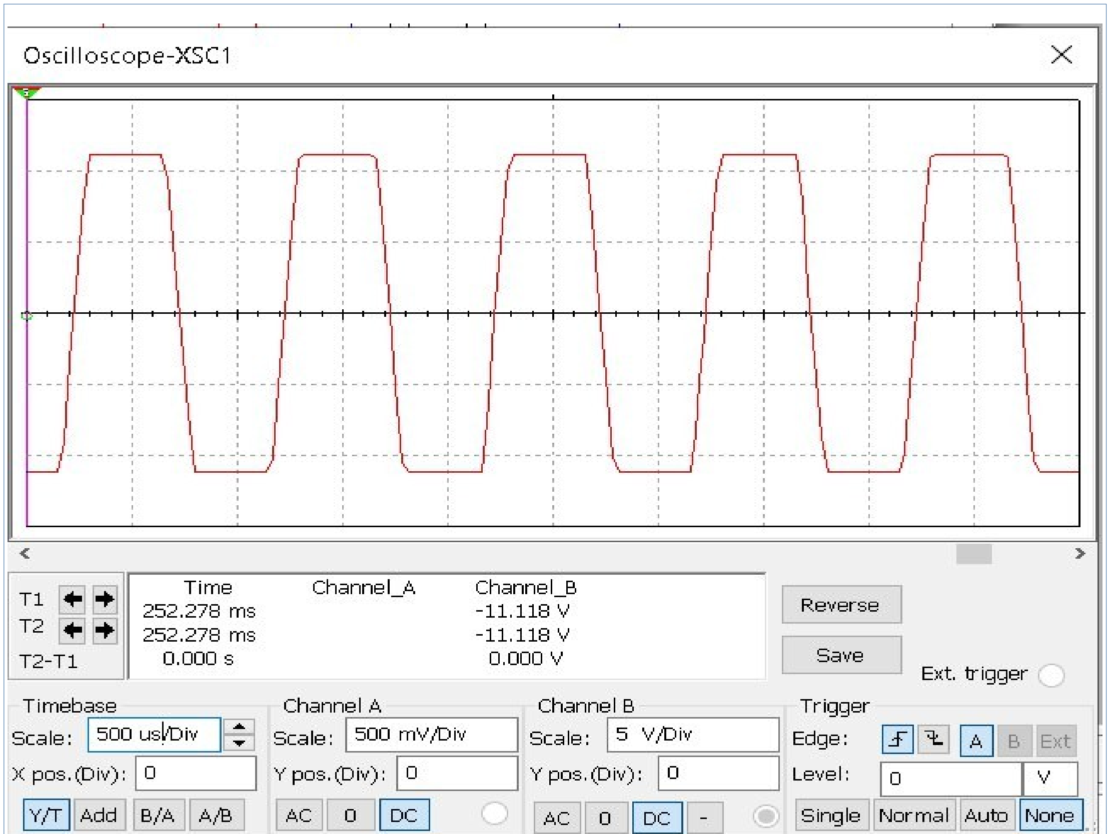

Figure 5: Saturated output Signal

The Figure 5 shows the input signal and zero Output signal when both switches are open

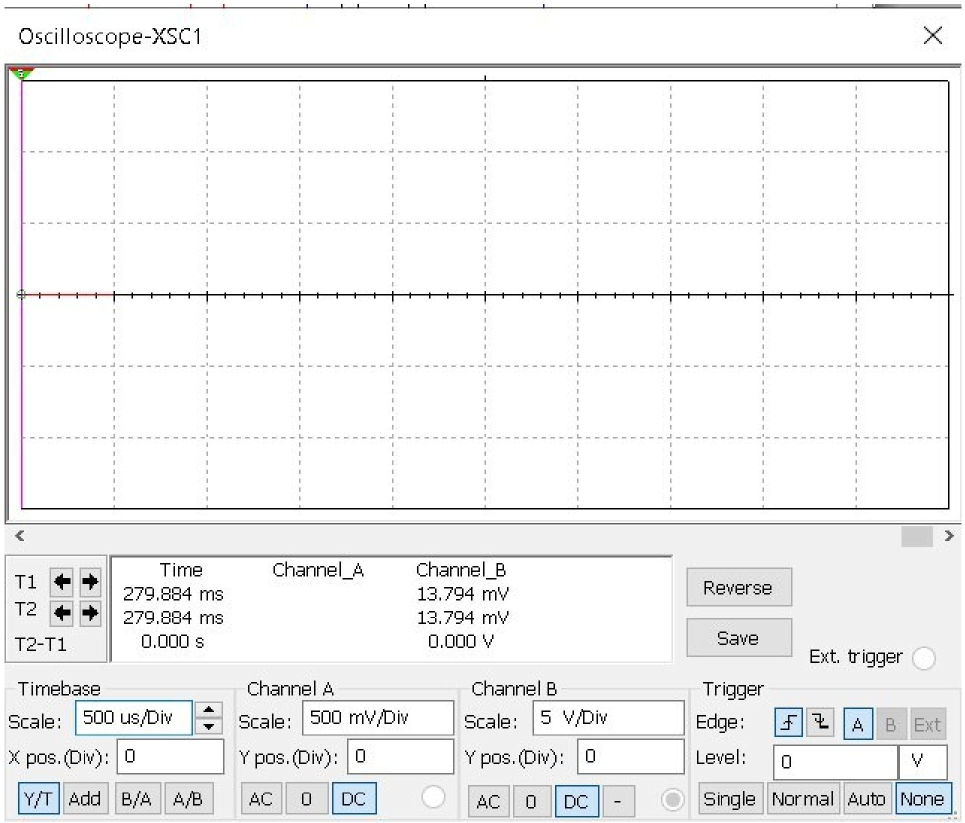

Figure 6: Both Switches are Opened

- **Multimeter output**

The Figure 7 shows the Output signal Voltage value when there is difference between the inputs.

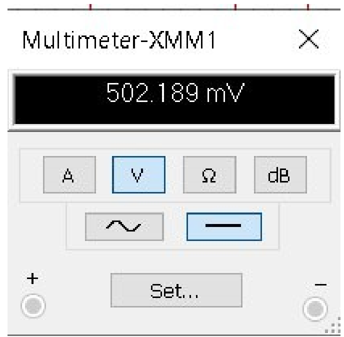

Figure 7

The Figure 8 shows the Output signal Voltage value when where no difference between the inputs.

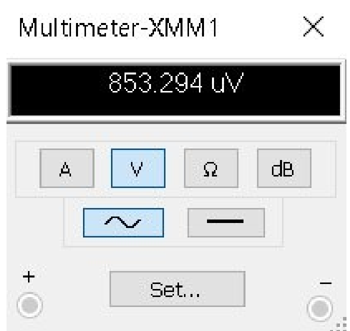

Figure 8

6. Graphs

The Figure 9 shows the graph between Theoretical Output and Actual Output.

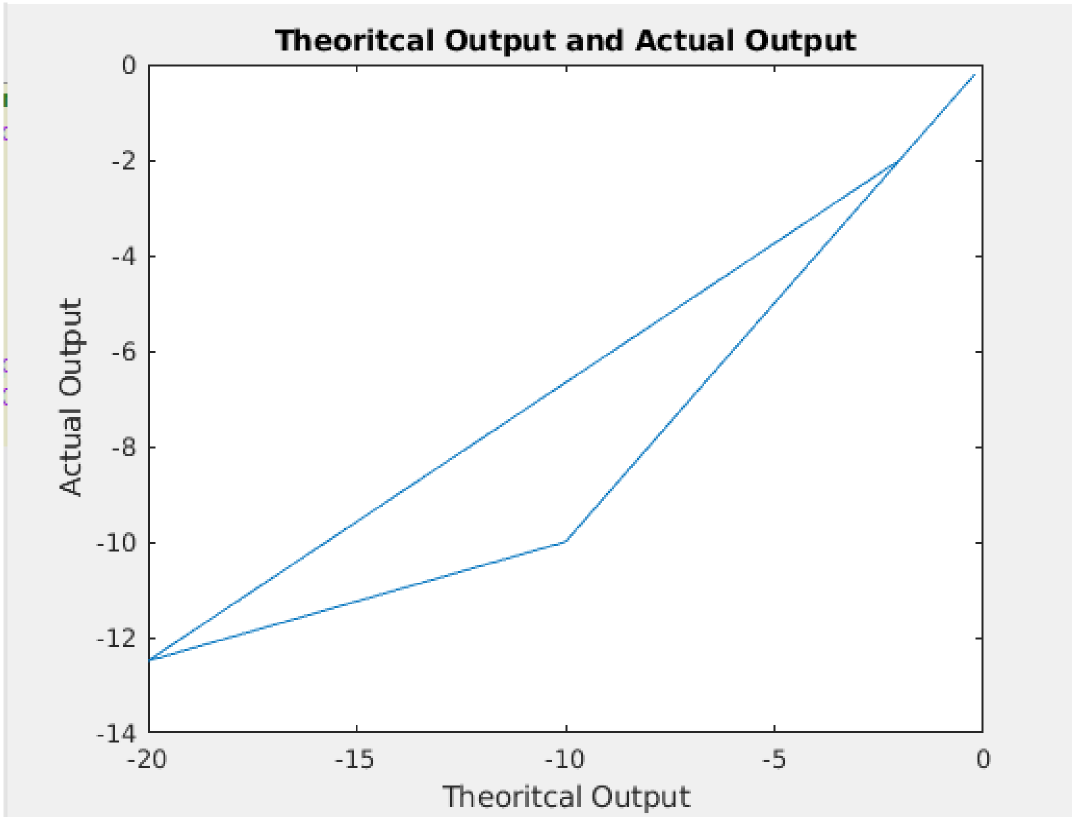

Figure 9: Theoretical Output and Actual Output

The Figure 10 shows the Frequency Response for 741 op-amp in subtractor configuration

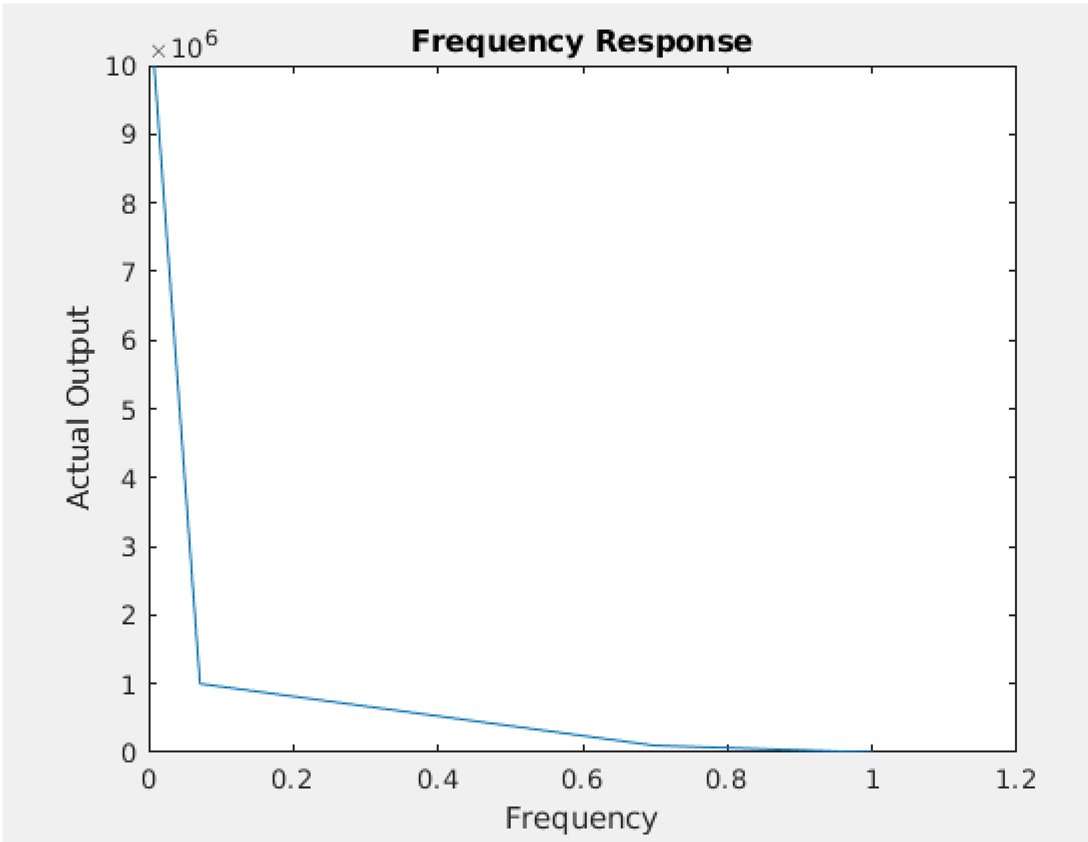

Figure 10: Frequency Response

7. Analysis

From the readings that we got from simulating and showed in Table 2 we can see that the output depend on input and we can change the Gain by changing the Value Resistors and we can see that we can't get the Theoretical output voltage because there is an Output Resistance For operational amplifier and its value shown in Table 1.

If we see the Figure 4 we can notice that we got a cutting on output signal and that happened because the Amplified signal is Limited to the supply inputs voltages (+Vcc / -Vdd) and we can avoid that by increasing the input voltages but notice that we got a maximum value of input voltages for IC-741 as shown in Table 1, and from the Figure 3 we can see that output signal is the two input signals subtracted fro each other and the output is out-phase (negative-gain).

8. Conclusion

From this experiment we can see that the subtractor configuration provides a simple way to add subtract input voltage signals with negative fixed gain that can choose its value by changing Resistors.

And also we see one of the limitation of the subtractor and its Limited input voltage range, and the Frequency limit and slewing-rate limit.