Experiment: 7
Operational amplifier as Integrator and Differentiator

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IC161P-Lab Experiment-7 - 6 May 2018 ***Abstract*—This week's experiment we aim at implement Integrator and Differentiator Circuit using Op-Amp LM741. First, we used the Op-Amp with a capacitor for integrating input wave using the infinite open loop gain of Op-Amp. Second, we made Differentiator Amplifier circuit to Differentiate input voltage. In other word, if Input voltage in Differentiator Amplifier circuit is sine wave then the output voltage is cosine wave. We used Square wave as Input in integrator and Triangular Wave as Input Voltage in differentiator.**

Also we were required to analyze and than subsequently remove the various problems encountered in circuits in the laboratory. Going through this experiment we encountered several unexpected results which we solved and analyzed by help of our instructor Hitesh sir and TAs.

I. Introduction

A. *Op-Amp*

Operational amplifiersare linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.

We have to analyze basically two type of amplifier circuit

*1) **Integrating Amplifier**:* By replacing feedback resistance with a capacitor, we now have an RC Network connected across the operational amplifiers feedback path producing another type of operational amplifier circuit commonly called an Op-amp Integrator circuit as shown below.

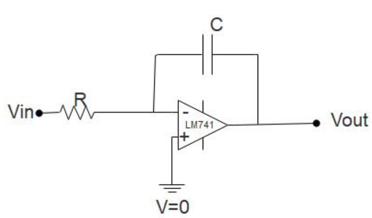

Fig. 1. Integrator Op-Amp

It basically, performs the mathematical operation of Integration, that is we can cause the output to respond to changes in the input voltage over time as the op-amp integrator produces anoutput voltage which is proportional to the integral of the input voltage.

Output Voltage:

$V_{out} = -\frac{1}{R_{in}C}\int_0^t V_{in}dt$

It can also written as
$V_{out} = -\frac{1}{j\omega R_{in}C}\int_0^t V_{in}dt$

Where $\omega = 2\pi f$ and here f is frequency of input signal
The minus sign indicates a $180\,^{\circ}$ phase shift because the input signal is connected directly to the inverting input terminal of the op-amp.

B. *Differential Amplifier*

Here, the position of the capacitor and resistor have been reversed and now the Resistance is connected to the input terminal of the inverting amplifier while the resistor,forms the negative feedback element across the operational amplifier as normal.

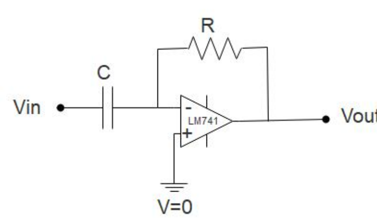

Fig. 2. Differentiator Op-Amp

It basically, performs the mathematical operation ofDifferentiation, that is it produces a voltage output which is directly proportional to the input voltages rate-of-change with respect to time . In other words, the faster or larger the change to the input voltage signal, the greater the input current, the greater will be the output voltage change in response, becoming more of a spike in shape.

Output Voltage:

$V_{out} = -RC\frac{dV_{in}}{dt}$

The minus sign indicates a 180° phase shift because the input signal is connected to the inverting input terminal of the operational amplifier.

II. Apparatus Required

A. Digital Storage Oscilloscope (DSO)-1

Agilent Technologies DSO1052B (50MHz,1GSa/s)

B. Operational Amplifier

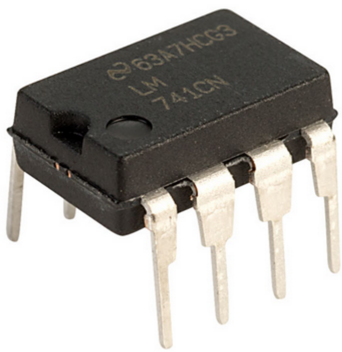

Fig. 3. Operational Amplifier

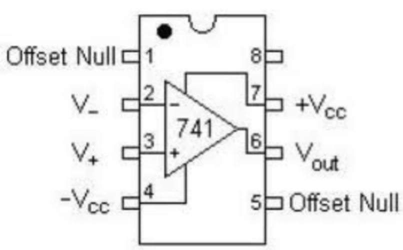

Fig. 4. Pin designation for ic741 op-amp

C. Function generator

Fig. 5. Function generator

D. Multiple Power Supplier-1

Fig. 6. Multiple Power Supply

E. Bread Board

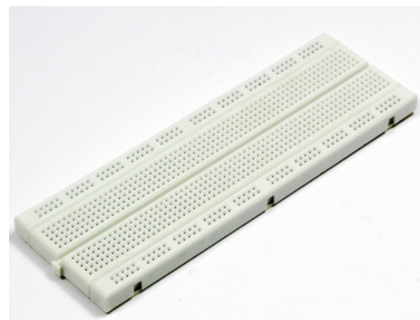

Fig. 7. Breadboard

F. Capacitor-1

$C = 100nf$

G. Resistance-2

$R_1 = 10K\Omega$ $R_2 = 10M\Omega$

H. Some copper wire to have connection between circuit

III. Procedure

A. for Integrator Amplifier

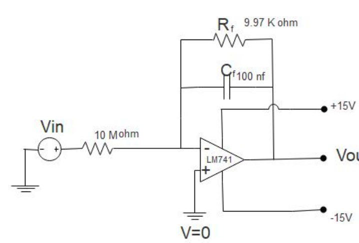

Fig. 8. Circuit of Integrator Op-Amp

1) : We assembled the circuit as shown in figure.

2) : And we given $-V_{CC}$ and V_{CC} $-15V and 15V$ respectively .

3) : A squre wave was applied by the function generator.

4) : The plots of the wave and the output voltage (V_out) were obtained using the DSO.

5) : The peak voltages of both graphs were obtained using Meas button.

6) : The voltage gain was calculated and compared to the theoretically obtained value.

7) : We noted the observations accordingly.

B. For Differentiator Amplifier

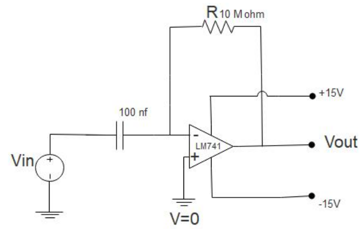

Fig. 9. Circuit of Differentiator Op-Amp

1) : We assembled cicuit as shown in figure.

2) : Triangular wave was applied to V_1 of suitable voltage so that the V_{out} doesnt exceed V_{CC}.

3) : The plots of the wave and the output voltage (V_out) were obtained using the DSO.

4) : The peak voltages of both graphs were obtained using Meas button.

5) : The voltage gain was calculated and compared to the theoretically obtained value.

6) : We noted the observations accordingly.

IV. Experimental Results

$V_{CC} = 15V$
$-V_{CC} = -15V$
PINK- for Input wave.
BLUE- for Output wave.

A. For Integrator circuit

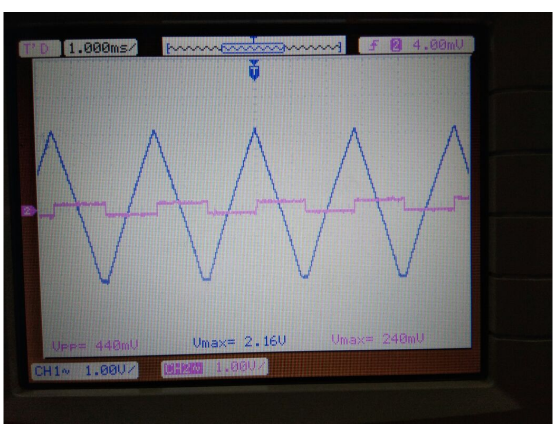

Fig. 10. Output of integrator circuit.

1) : Input Wave is Square Wave of $amplitude = 240mV$.

2) : Output is a triangular wave of $amplitude = 2.16V$.

B. For differenciator circuit

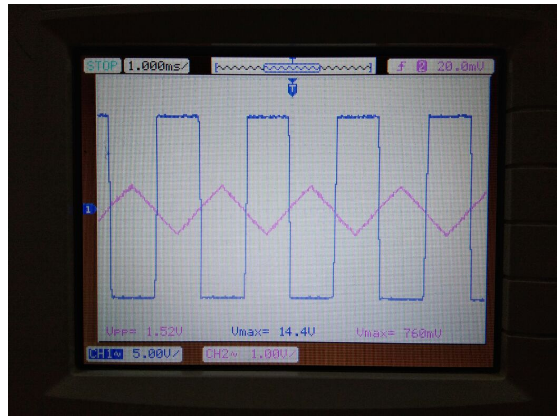

Fig. 11. Output of Differentiator circuit.

1) : Input Wave is triangular Wave of $amplitude = 760mV$.

2) : Output obtained is a square wave of $amplitude = 14.4V$.

V. Calculations

A. For integrator

$$V_{in} = 240mv$$
$$V_{out} = 2.16V$$
$$Gain = \frac{-V_{out}}{V_{in}} = \frac{-2.16}{0.24} = 9$$

B. For differentiator

$$V_{in} = 760m$$
$$V_{out} = 14.4V$$
$$Gain = \frac{-V_{out}}{V_{in}} = \frac{-14.4}{0.76} = 18.9$$

VI. Precaution

A. Don't let touch your hand while measuring the resistor, it will give wrong result or measurement.

B. Before using the prob cross check that probe con-figuration selected in DSO is the same as the probe using in the circuit (usually 1-X probe).

C. Do not allow the crocodile clips to touch each other.

D. Don't let touch your hand while measuring the resistor, it will give wrong result or measurement.

E. Select the DC coupling in DSO.

VII. Conclusion

We concluded that by using the Integrator and differentiator circuit we can change the signal wave from one function to another as our requirements. And we can also increase the amplitude or we can say that we can amplify them.

REFERENCES

[1] Lecture Slides of Dr. Kunal Ghosh (Assistant Professor,IIT Mandi) and Instructions of Dr. Hitesh Shrimali (Assistant Professor,IIT Mandi).

[2] Previous year's report and guidence of Aanand Ramrakhyani. *and various report of various groups*. [*https://insite.iitmandi.ac.in/moodle/*]. IC 161P course, 2017.

[3] *All about circuit*. [*https://www.allaboutcircuits.com/textbook/semiconductors/chpt-8/differentiator-integrator-circuits/*].

[4] xcircuit for making circuits `http://opencircuitdesign.com/xcircuit/`