UM–SJTU Joint Institute

Ve215

Laboratory Report

Exercise 2
Op Amp Lab

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1 Introduction

1.1 Objectives

1. Learn how to build and test a variety of circuits based on LM 741 Op Amp chip: non-inverting and inverting amplifiers with fixed gain.

2. Measure the gain of the amplifier and compare it with theoretical calculations.

3. Determine the saturated output voltage of the amplifier.

1.2 Theoretical Background

1.2.1 Op Amp terminals

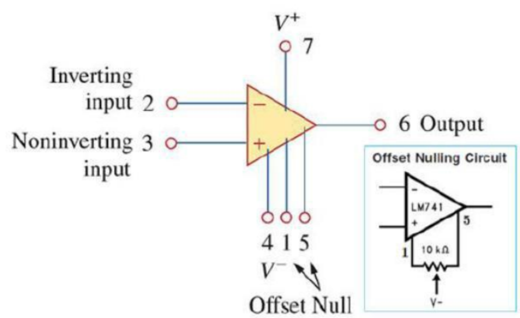


Figure 1: Circuit symbol of a typical op amp.

In Fig 1, there are:

Two terminals for input signals: inverting (labeled -) and non-inverting (labeled +)

A terminal for the output signal.

Two terminals for the power supply voltages: positive +Vcc and negative Vcc. (e.g. In this lab, set +Vcc = 5V; -Vcc = -5V.)

Accordingly, for LM741 op amp chip you see in reality, the pin numbers are shown in Fig2:

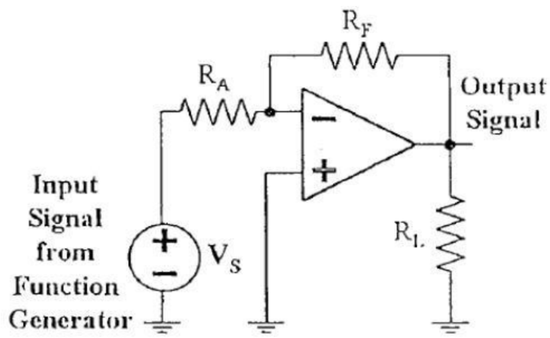


Figure 3: Inverting amplifier.

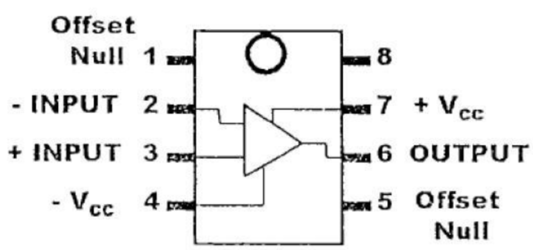


Figure 2: Pin numbers for LM 741 op amp

1.2.2 The gain of amplifier circuits

The amplifier circuits are characterized by their gain values. The voltage gain is the ratio of output voltage to the input voltage in the circuit:

$$VoltageGain = \frac{OutputVoltage}{InputVoltage}$$

In the lab, you can use oscilloscope to measure the input and output peak-to-peak (ppk) amplitudes of the signals through two channels at the same time.

1.2.3 Inverting amplifier

For inverting amplifier, the theoretical gain should be:

$$Gain = \frac{V_{output}}{V_s} = -\frac{R_F}{R_A}$$

1.2.4 Non-inverting amplifier

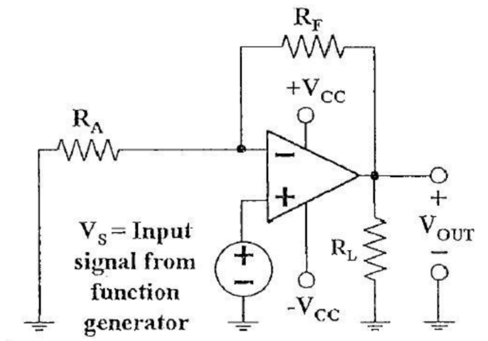


Figure 4. Non-inverting amplifier.

Figure 4: Non-inverting amplifier.

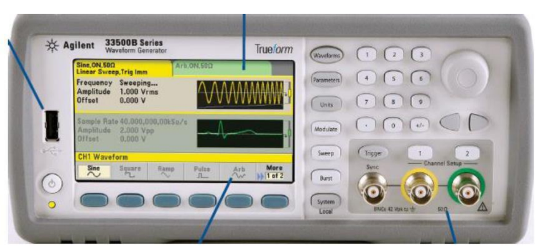
For non-inverting amplifier, the theoretical gain should be:

$$Gain = \frac{V_{output}}{V_S} = 1 + \frac{R_F}{R_A}$$

1.3 Appratus

1.3.1 Function generator

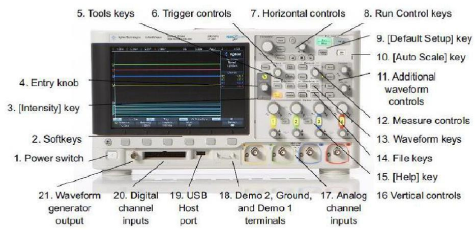
Check the next page about the main buttons we would use



- "Parameter": to change the amplitude, frequency of wave to generate. **Note:** The amplitude here equals to half of the pp value (i.e. If you set a wave whose amplitude is 100mV, the measured pp value would be 200 V_{pp} where the subscript pp means peak to peak value).

  "1"/ "2": to switch on the channel.

1.3.2 Oscilloscope



"Auto scale": to automatically achieve an output on the screen with proper scale
"Meas": to turn on the measurement of the wave
"1"/"2": to show or hide the wave you detecting through channel 1 or 2

2 Non-inverting Amplifier

$R_1[\Omega]$	50.9
$R_f[\Omega]$	99.6

Table 1: Resistances

$+Vcc[V]$	5
$-Vcc[V]$	-5

Table 2: Voltage Supply to the Op Amp

$V_{pp(in)}[V]$	$V_{pp(out)}[V]$
0.1	0.34
0.2	0.62
0.3	0.91
0.4	1.26
0.5	1.50
0.6	1.84
0.7	2.11
0.8	2.43
0.9	2.71
1.0	3.0
1.1	3.37
1.2	3.62
1.3	3.75
1.4	3.81
1.5	3.83

Table 3: The Input-Output Relationship

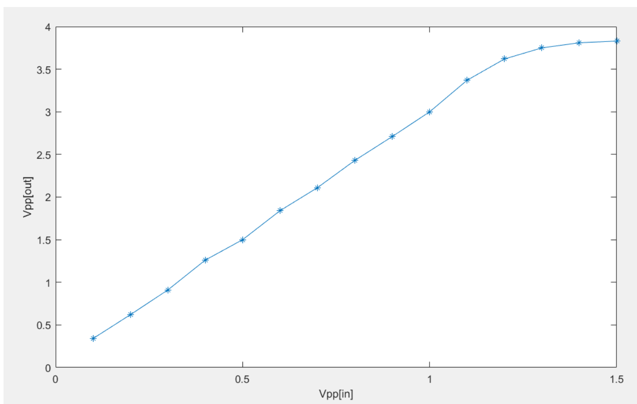
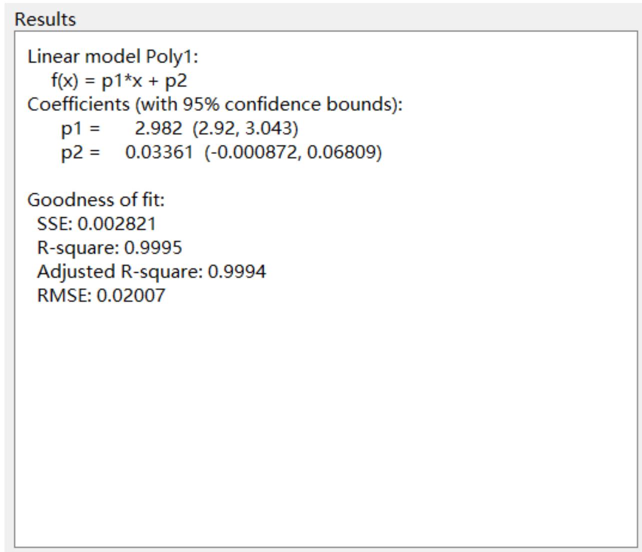


Figure 5: The relationship between Vout and Vin

Just take the V from 0.1 to 0.9 we can get that


Results

Linear model Poly1:
f(x) = p1*x + p2
Coefficients (with 95% confidence bounds):
p1 = 2.982 (2.92, 3.043)
p2 = 0.03361 (-0.000872, 0.06809)

Goodness of fit:
SSE: 0.002821
R-square: 0.9995
Adjusted R-square: 0.9994
RMSE: 0.02007

Figure 6: the output of non-inverting amplifier

The figure below is about the relationship between the Gain and the Vin.

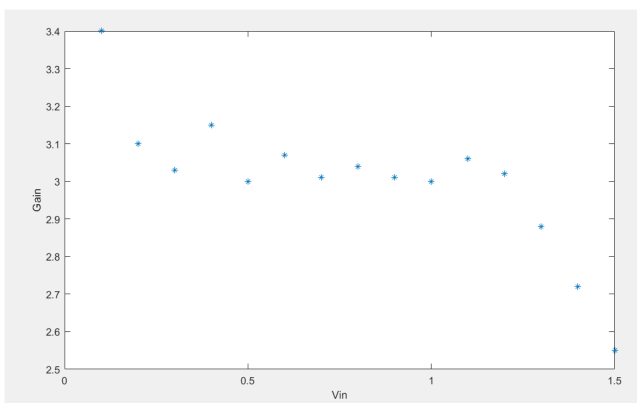


Figure 7: The relationship between the gain and Vin

3 Inverting Amplifier

$R_1[\Omega]$	50.9
$R_f[\Omega]$	99.6

Table 4: Resistances

$+Vcc[V]$	5
$-Vcc[V]$	-5

Table 5: Voltage Supply to the Op Amp

$V_{pp(in)}[V]$	$V_{pp(out)}[V]$
0.1	0.221
0.2	0.418
0.3	0.615
0.4	0.830
0.5	1.02
0.6	1.22
0.7	1.42
0.8	1.61
0.9	1.80
1.0	2.05
1.1	2.25
1.2	2.47
1.3	2.65
1.4	2.85
1.5	3.06
1.6	3.26
1.7	3.440
1.8	3.660
1.9	3.840
2.0	4.020
2.1	4.30
2.2	4.460
2.3	4.60
2.4	4.820
2.5	4.94
2.6	5.07
2.7	5.15
2.8	5.31
2.9	5.39
3.0	5.43

Table 6: The Input-Output Relationship

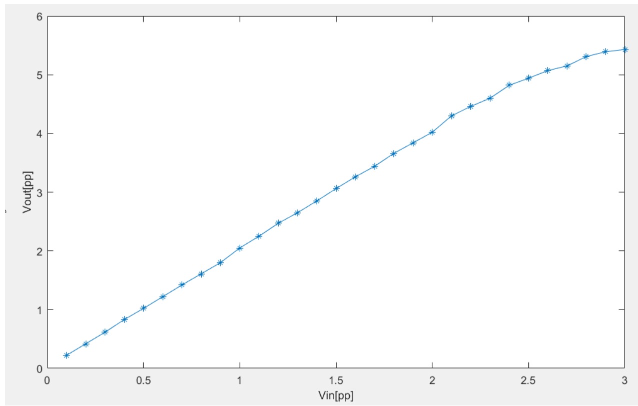


Figure 8: The Input-Output Relationship

Just take the V from 0.1 to 0.9 we can get that

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Results
Linear model Poly1:
    f(x) = p1*x + p2
Coefficients (with 95% confidence bounds):
      p1 =       1.982  (1.96, 2.004)
      p2 =    0.02611  (0.01378, 0.03844)

Goodness of fit:
  SSE: 0.0003605
  R-square: 0.9998
  Adjusted R-square: 0.9998
  RMSE: 0.007176
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Figure 9: the output of inverting amplifier

The figure below is about the relationship between the Gain and the Vin.

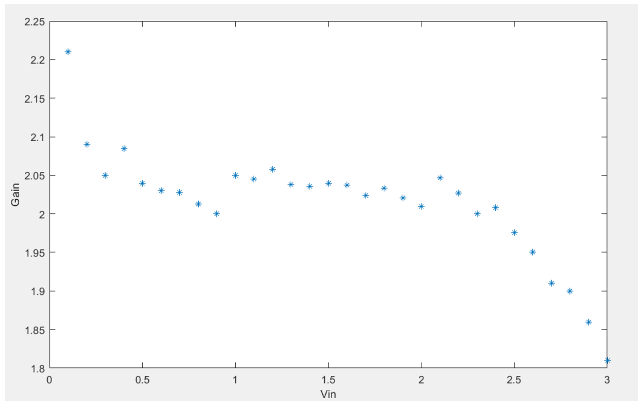

Figure 10: The relationship between Gain and Vin

4 Result

From this experiment, we have learned to build and test a variety of circuits based on LM741 Op Amp chip: non-inverting and inverting amplifiers with fixed gain. We also measure the gain of the amplifier and compare it with theoretical calculations.

1. From this part of the experiment, we can know that the result is relatively correct. When comparing the data from $Vin = 0.1V$ to $Vin = 0.9V$, we can know that the average of gain is 3.09. Compared with the expected data, we can know that th error is about 3%. And actually it is not very big. Actually, this kind of result doesn't have a very big error. The reason why I don't take the value when $Vin > 0.9V$ is that the outcome is about the saturated voltage. In this experiment, because that there are some errors about the equipments we are using, therefore, it seems to be very difficult to measure the absolutely correct saturated output voltage. And in our experiment, it is about $Vout = 3.83V$ when $Vin = 1.5V$. It is not absolutely correct because that when we were doing the experiment, we find that the what the equipment shows about the $Vout$ is about 13times of the expected value. And it is always shifting in two numbers when $Vin = 1.5V$. Therefore, it seems that we can't get a very nice data and result in this experiment.

2. From this part of the experiment, we can know that the result is relatively correct. When comparing the data from $Vin = 0.1V$ to $Vin = 0.9V$, we can know that the average of gain is 2.06. Compared with the expected data, we can know that th error is about 3%. And actually it is not very big. Actually, this kind of result doesn't have a very big error. The reason why I don't take the value when $Vin > 0.9V$ is that the outcome is about the saturated voltage. In this part, out team changes to another desk to

test the second part and I think the equipments are much more accurate. In our experiment, we found that when the $Vin = 2.9V$ and $Vin = 2.0V$, the rise of the $Vout$ is nt very big. And because of the limitation of time, we don't have more time to test more data. But this is enough to illustrate that this is the saturated voltage.

This experiment is a little bit tough to do because that some of the equipments are not absolutely correct. However, I think that the outcome is still relatively correct. I think the lab should use some good equipments instead of some equipments that have problems. And during the lab, TA provides two kinds of Op Amp. And it seems that we use another one and use the LM741 method to connect the circuit at the first time. Therefore, it seems that I still need to be more careful when doing the experiment.

In general, the experiment is very meaningful. It makes us have a better understanding about the inverting and non-inverting amplifiers. And we know more about its gain. But we still have some difficulties when doing the lab.

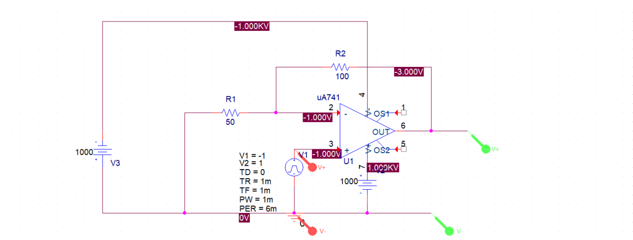

Figure 11: Non-inverting Amplifier 1

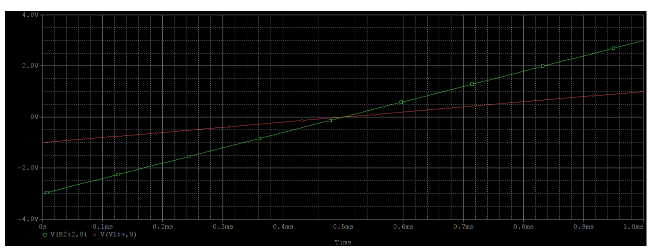

Figure 12: Non-inverting Amplifier 2

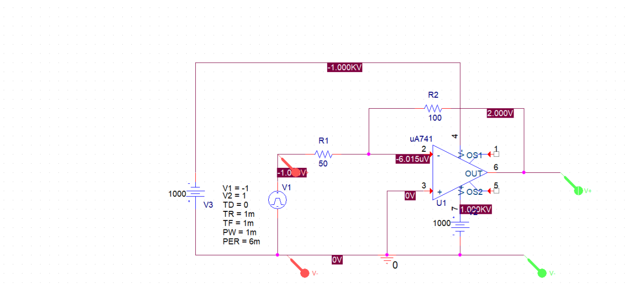

Figure 13: Inverting Amplifier 1

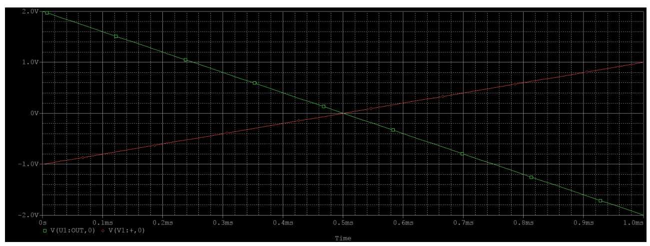

Figure 14: Inverting Amplifier 2