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UM-SJTU JI VE215 Lab #3

<u>We will learn to build an Op-amp circuit based on LM-741chips.</u>

<u>We will explore some non-ideal properties of Op-amps in reality.</u>

- Please hand in your post-lab assignment before the due date. Please do your post-lab assignment following the requirements in each problem. Both hand-written and printed are accepted.

- You are encouraged to print this lab manual and then finish the post-lab questions on it. For pictures or diagrams, you may print it in a paper, cut it down and paste on this worksheet.

- Always attach the pictures or screenshots of your waveforms if using the oscilloscope.

Instruments

DC power supply (**Agilent E3631A or MOTECH LPS 305**)

Function Generator with coaxial cables

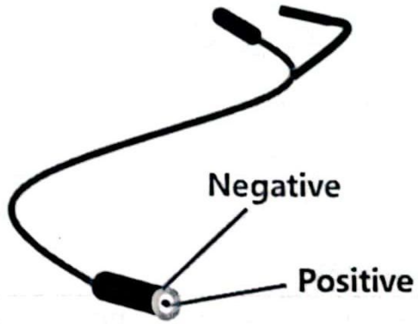
Oscilloscope with coaxial cables **<u>(The TAs will guide you before the lab)</u>**

Breadboard and Wires

LM-741 Op-amp Chips

Resistors of 50Ω and 100Ω

<u>Introduction to coaxial cables</u>: When connecting the oscilloscope and function generator into a circuit, we need to use coaxial cables (The structure of it is in next page). At the instrument (Function generator or Oscilloscope) side, the outer port of its interface is the negative pole and the inner port is the positive pole. At the circuit side, there wire separates into two branch wires, corresponding to the positive and negative ports of the circuit.

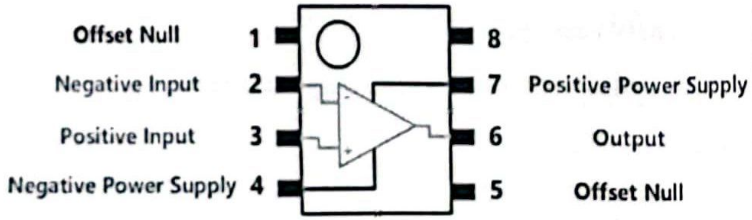


Coaxial Cables (For Function Generator)

<u>CAUTION: Oscilloscope has its special fitting coaxial cables (please ask the TAs or staff) and please do not mix it with the other cables (such as the one used for function generator). Otherwise, it will cause huge noise in circuit.</u>

<u>Problem #1 LM-741 Structure</u> (self learning)

The picture shows the structure of LM-741.



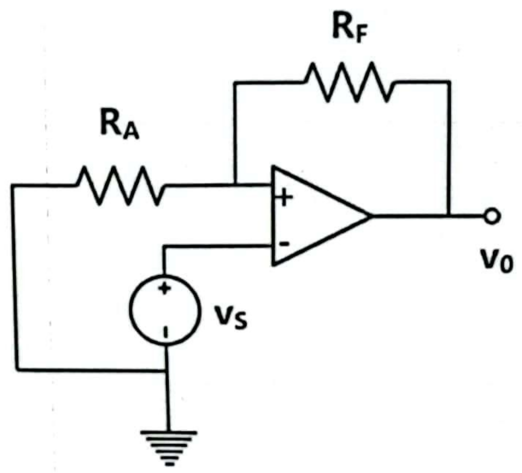
The function of each pins:

- **Pin 1 and Pin 5:** Offset Null for zero setting of LM-741. In this lab, we will not use these two pins and please leave them open.
- **Pin 2 and Pin 3:** Negative and Positive Input ports for signals. These two corresponding to "−" and "+" ports of ideal Op-amp models which we have encountered many times in lecture slides.
- **Pin 6:** Output ports for signals. This corresponds to the output port or "top end" of ideal Op-amp models which we have encountered many times in lecture slides.
- **Pin 4 and Pin 7:** Negative and Positive DC power supply ports. In fact, Op-amp is an active circuit element and it can supply or absorb power to the signal loops. Recall that sometimes, the output currents of Op-amps are not equal to zero. In fact, those currents are provided by the DC power supply. We will mark the two pins as **−Vcc** (Pin 4) and **+Vcc** (Pin 7)

  In order to make the schematics looks neat and clean, these two ports are always hidden in the ideal Op-amp model. However, in reality, the power supply must be connected to let the Op-amp work. Otherwise, it can not do any operation.
- **Pin 8:** It has no effect to the circuit and please leave it open in this experiment.

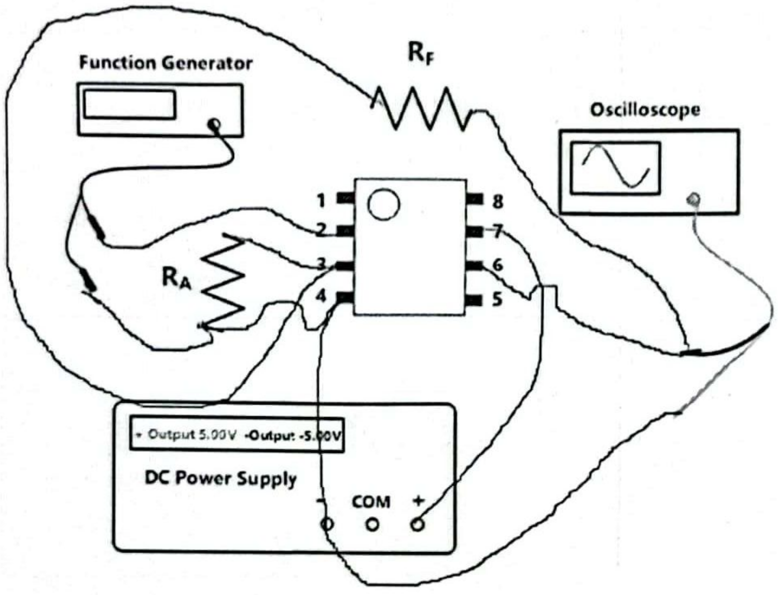
Post-Lab Questions for (P1)

Please connect the real element diagram (next page) based on the schematic.

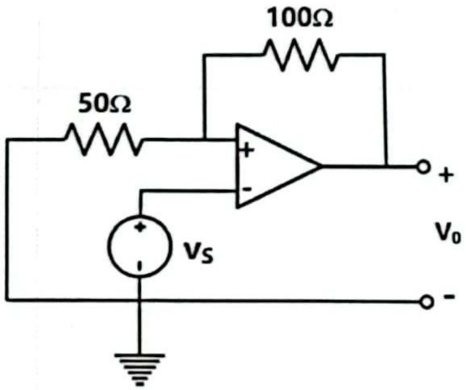


Caution:

- For the DC power supply, **the red ports or lines stand for positive port.**
- For the oscilloscope and the function generator, we need to connect them into circuit using coaxial cables (for more details, please refer to the 1st and 2nd page), which have been plotted in the real element diagram.
- Please **choose the COM port on the power supply as the ground**.



Problem #2 Non Inverting Amplifier



- Please build a non-inverting amplifier circuit according to the circuit diagram above. For the DC power supply of the Op-Amp, we choose **+Vcc = + 5V** and **–Vcc = –5V**. **Please choose the COM port on the power supply as the ground in the schematic.**
- For the input voltage (**V_S** in the figure above), please use the function generator to generate a sine wave. Set the initial amplitude of the sine wave to **$0.2V_{pp}$**. **Caution: Please set the output impedance of function generator to high-Z mode.**
- Please increase the input voltage by **$0.1V_{pp}$** or **$0.2V_{pp}$** each time and use the oscilloscope to measure the peak-to-peak output voltage (**V_o** in the figure above). Please record the data of **V_S** and **V_o** in the table next page. **You need to record the data until V_o saturates, which means V_o do not increase any more as you increasing V_S.**

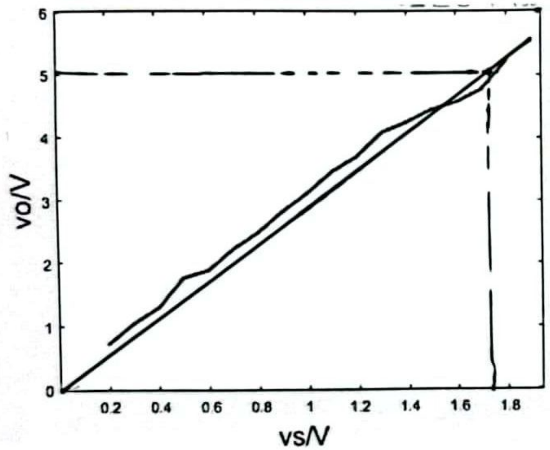
Caution: Please take at least two photos or screenshot the waveforms of your oscilloscope screen while conducting this lab. One should be in non-saturate region and the other should be in saturate region.

Input Voltage v_S (V_{pp})	Output Voltage v_o (V_{pp})	Input Voltage v_S (V_{pp})	Output Voltage v_o (V_{pp})
0.2	0.720		
0.4	1.31		
0.6	1.91		
0.8	2.51		
1.0	3.14		
1.2	3.72		
1.4	4.26		
1.6	4.58		
1.8	5.23		
0.3	1.05		
0.5	1.79		
0.7	2.25		
0.9	2.85		
1.1	3.48		
1.3	4.1		
1.5	4.46		
1.7	4.78		

Post-Lab Questions for (P2)

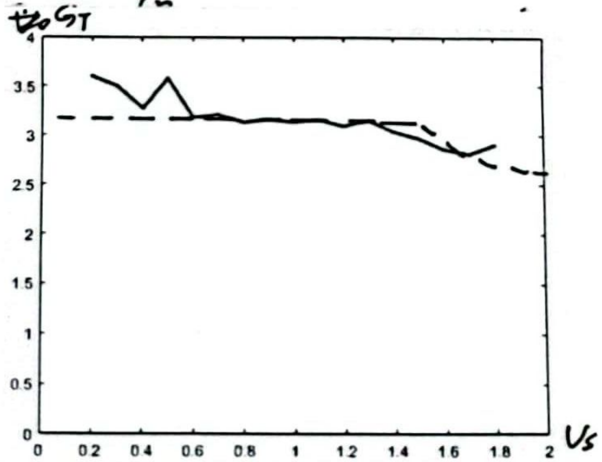
(1) Please attach the two photos of your waveform (one in non-saturated region and the other in saturated region) as well as the data table in the post-lab assignment.

(2) Please plot the curve between $\mathbf{V_o}$ and $\mathbf{V_S}$. According to your result, at which input $\mathbf{V_S}$ will the output voltage $\mathbf{V_o}$ saturate?

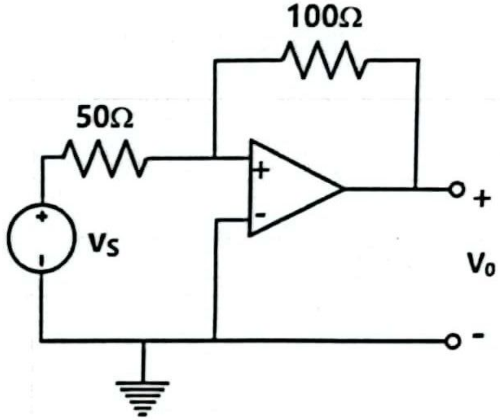


At about 1.7V

(3) What's the expected gain $\mathbf{G_T}$ of the op-amp? How to calculate the real Op-amp gain $\mathbf{G_R}$ based on your experimental data? Please plot the curve between $\mathbf{G_R}$ and $\mathbf{V_S}$.



Problem #3 Inverting Amplifier



- Please build an inverting amplifier circuit according to the circuit diagram above. For the DC power supply of the Op-Amp, we choose $+V_{cc} = +5V$ and $-V_{cc} = -5V$. **Please choose the COM port on the power supply as the ground in the schematic.**
- For the input voltage ($\mathbf{V_S}$ in the figure above), please use the function generator to generate a sine wave. Set the initial amplitude of the sine wave to $\mathbf{0.2V_{pp}}$. **Caution: Please set the output impedance of function generator to high-Z mode.**
- Please increase the input voltage by $\mathbf{0.1V_{pp}}$ or $\mathbf{0.2V_{pp}}$ each time and use the oscilloscope to measure the peak-to-peak output voltage ($\mathbf{V_o}$ in the figure above). Please record the data of $\mathbf{V_S}$ and $\mathbf{V_o}$ in the table next page. You need to record the data until $\mathbf{V_o}$ saturates, which means $\mathbf{V_o}$ do not increase any more as you increasing $\mathbf{V_S}$.

Caution: Please take at least two photos or screenshot the waveforms

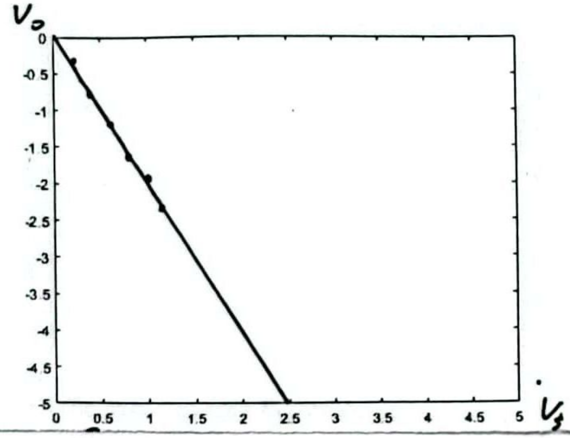
of your oscilloscope screen while conducting this lab. One should be in non-saturate region and the other should be in saturate region.

Input Voltage V_S (V_{pp})	Output Voltage V_o (V_{pp})	Input Voltage V_S (V_{pp})	Output Voltage V_o (V_{pp})
0.2	0.32		
0.253	0.470		
0.293	0.579		
0.358	0.675		
0.406	0.772		
0.450	0.872		
0.498	0.957		
0.611	1.18		
0.651	1.29		
0.708	1.40		
0.756	1.50		
0.788	1.61		
0.896	1.78		
0.997	1.97		
1.06	2.13		
1.12	2.23		
1.17	2.33		

Post-Lab Questions for (P3)

(1) Please attach the two photos of your waveform (one in non-saturated region and the other in saturated region) as well as the data table in the post-lab assignment.

(2) Please plot the curve between $\mathbf{V_o}$ and $\mathbf{V_S}$. According to your result, at which input $\mathbf{V_S}$ will the output voltage $\mathbf{V_o}$ saturate?

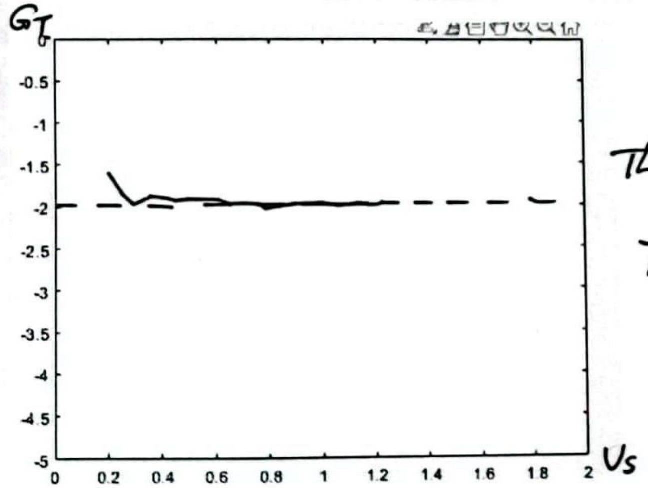


At about 2.5V.

real Op-amp gain $\mathbf{G_R}$ based on your experimental data? Please plot the curve between $\mathbf{G_R}$ and $\mathbf{V_S}$.

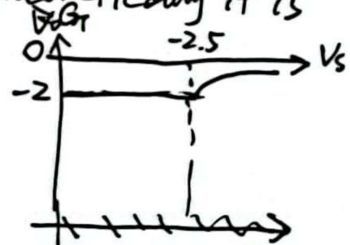
The expected gain $G_T = \frac{100}{50} = -2$

The Op-amp gain $G_R = -\frac{V_o}{V_s}$.

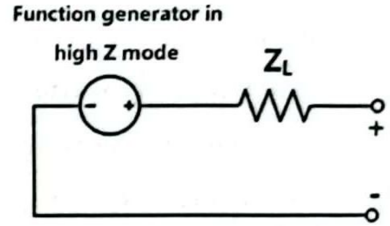


The saturated part is not tested

Theoretically it is



(4) In reality, the function generator could be simplified to the following model, where $\mathbf{Z_L}$ stands for its inner impedance:



Now, please think about the previous caution **"Caution: Please set the output impedance of function generator to high-Z mode"** At "high-Z mode", the output impedance of the function generator is **0Ω** at low frequency. Suppose we set the output impedance to be **50Ω** instead of high-Z mode, what will happen to the experimental value of the Op-amp gain of Non-inverting Amplifier experiment? What will happen to that of Inverting Amplifier experiment?

The impedance may increase the resistance of 50Ω

In Non-inverting experiment, the 50Ω is equivalent to 100Ω, the $G_T = \frac{100}{100}+1 = 2$, if not saturated. ~~Thus the g~~

in inverting experiment, the 50Ω is also equivalent to 100Ω, the $G_T = -\frac{100}{100} = -1$, if not saturated

Post-Lab Reflection Questions

(1) Is your experimental result the same as your analysis (Need data as proof)? If not, how do you interpret this difference? What do you think is the source of the experimental error?

(2) What do you learn from this experiment? (e.g. what experimental procedures, how to debug, etc.)

(1) Partially it is.

The line of V_o and V_s, as well as G_T and V_s ~~it~~ is close to the dots and goes through the original point. However, in phase 3, the test did not reach the saturated part, so it is not the same

(2) · Read the post-lab and the requirements of the experiment beforehand

· To use the multimeter to test crucial parts and find the bug.

References

[1] *Circuits Make Sense,* Alexander Ganago, Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor.