CALIFORNIA STATE UNIVERSITY SACRAMENTO

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 108L

Electronics I_ Laboratory, 1 unit

Summer_ 2022

Lab - 02_Report_

Submitted to

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By

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INTRODUCTION:

This laboratory introduced the use of operational amplifiers using PSpice and actual circuit. The two amplifiers provided were non-inverting amplifier and inverting amplifier which were shown in figures 1 and 2. Using these circuit, the student must do the hand calculations that were learned from the class and get the resulting data. On the other hand, the student must input the circuit to a PSpice simulation in able to generate graph for the circuit and data. Lastly, the student needs to setup the circuit in breadboard with the given laboratory kit and use the Analog Discovery 2 to measure and analyze the circuit.

Part1 – Preliminary Calculations

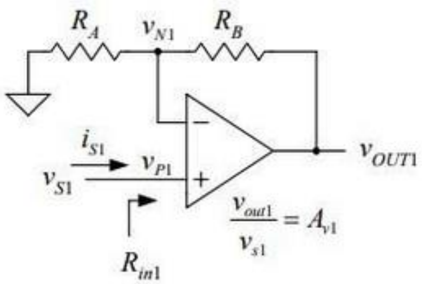

Figure 1. Non-Inverting Amplifier

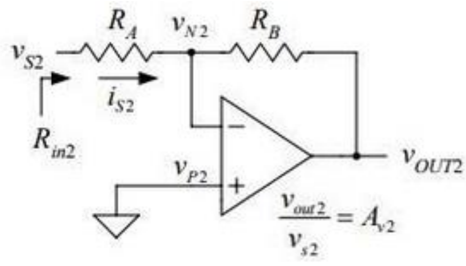

Figure 2. Inverting Amplifier

1. The expression for the voltage gain $A_{v1} = 1 + \frac{R_B}{R_A}$.

2. Using R_A = 5 kΩ and $A_{v1} = 3\ \frac{v}{v}$, we found R_B = 10 kΩ .

3. The input resistance $R_{in1} = \frac{V_{s1}}{i_{s1}} = \infty$.

4. The voltage V_{N1} = 5 V.

5. The expression for the voltage gain $A_{v2} = -\frac{R_B}{R_A}$.

6. Using R_A = 5 kΩ and R_B = 10 kΩ , we found $A_{v2} = -2\ \frac{v}{v}$.

7. The input resistance $R_{in2} = \frac{V_{s2}}{i_{s2}} = 5\ k\Omega$.

8. The voltage V_{N2} = 0 V.

Part2 - Simulations Results

In this part of the laboratory, the student entered the non-inverting amplifier circuit shown in figure 1 to the PSpice simulation shown in figure 3. The student used the 741 model for the operational amplifier with $\pm$ 5V power supplies on it. In addition, the student used input source Vsin as $V_{OFF} = 0\,V$, $V_{AMPL} = 0.5\,V$, $FREQ = 1K$, $AC = 1$.

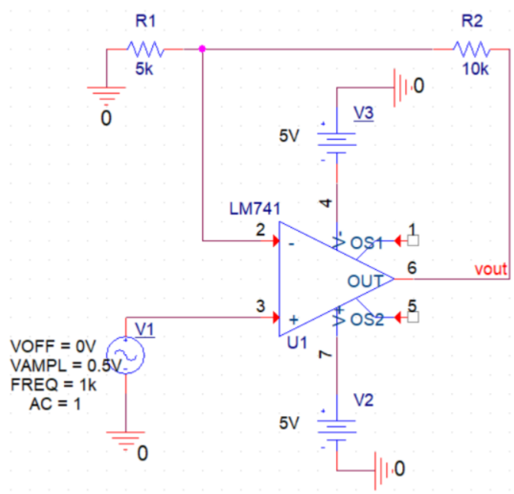

Figure 3. Non-Inverting Amplifier in PSpice.

After the setup, the student performed a DC Sweep simulation in which V_{S1} is swept over from – 5V to +5V which is shown in figure 4.

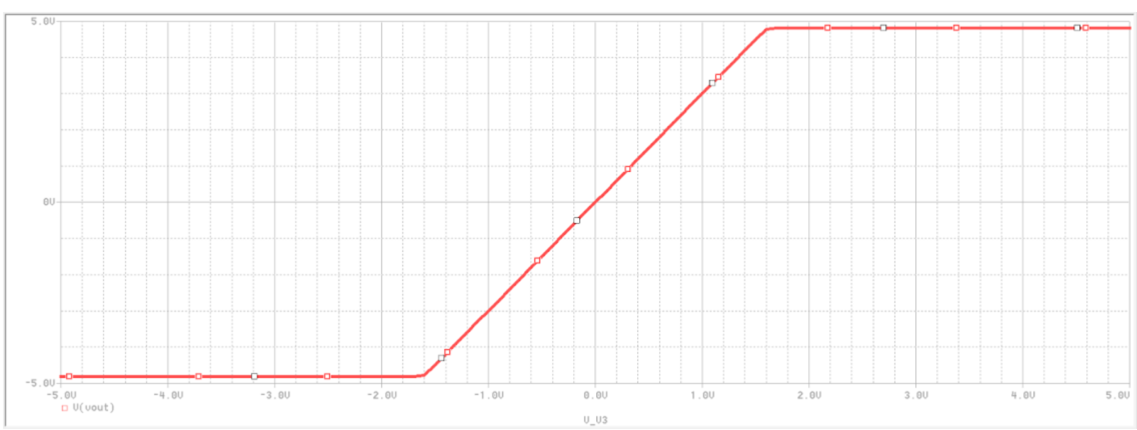

Figure 4. The graph for non-inverting amplifier from from – 5V to +5V.

Upon investigation, the student find out that the V_{outmax} = 5V and V_{outmin} = -5V. and As you look to the part were it is not saturated, the range will be between – 2.5 V and 1.5 V and is functioning as a linear amplifier. With this result, the student found out that the slope of the transfer will be y = x.

For the next circuit, the student setup the inverting amplifier circuit from the figure 2 into PSpice simulation which shown in figure 5. The additional setup for this circuit is the same setup from the figure 3.

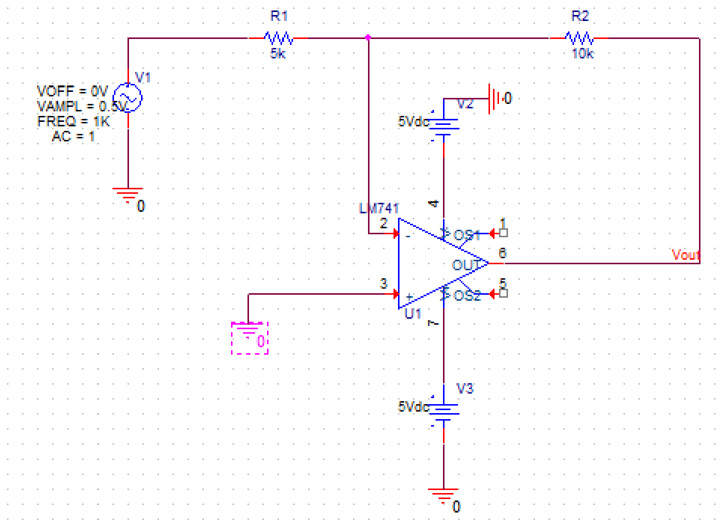

Figure 5. Inverting Amplifier in PSpice.

After that, the student did the same thing to perform a DC sweep simulation V_{S2} is swept over from – 5V to +5V which is shown in figure 6.

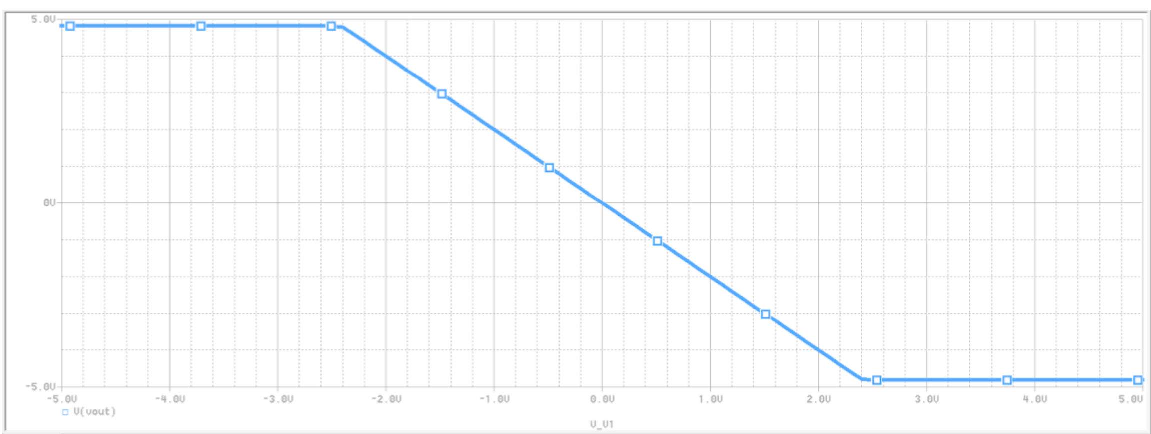

Figure 6. The graph for inverting amplifier from from +5V to -5V.

From the graph, the student identified the V_{outmax} = 5V and V_{outmin} = -5V. The range for the unsaturated part of the graph is between -2.5V to 2.5V which functioning as a linear amplifier and the input resistance is the same as the calculated value 5 kΩ. Additionally, the slope is y = -x for this graph.

Using the same inverting amplitude circuit, the student was able to obtain a plot of i_{S2} as a function of V_{S2} shown in figure 7.

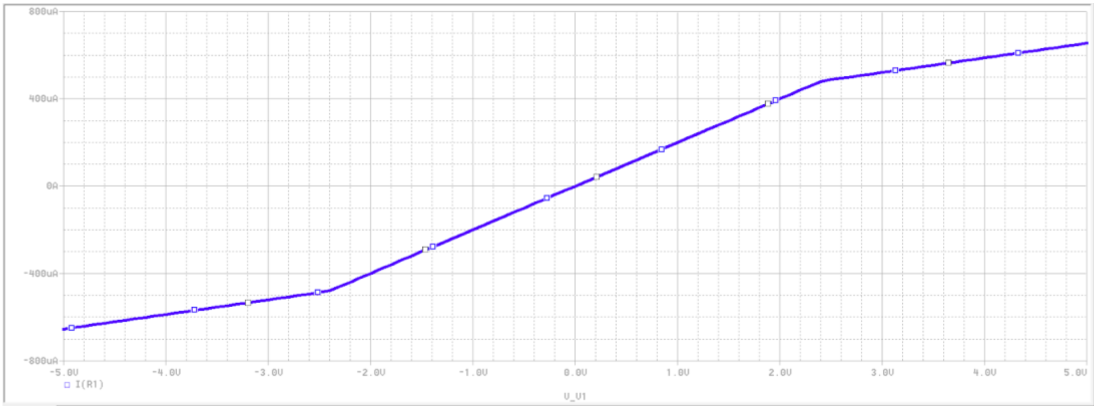

Figure 7. The graph of i_{S2} as a function of V_{S2}.

From the graph, the student calculated the $\frac{\Delta V_{S2}}{\Delta i_{S2}}$ which is equal to 5 kΩ. For the inverting amplifier, the assumption that $V_N = V_P$ does not hold when the output is saturated which it is saturated when it exceeds the op amp's maximum or minimum voltage. After simulating the two circuits, the student changed V_{S2} to a sine wave and observed the waveforms using the three different amplitudes: 0.5V, 1.5V, 3V.

Figure 8. sine wave with amplitude = 0.5V.

From the graph above, the blue trace represents the input voltage while the orange trace represents the output voltage. The output voltage has an amplitude of 1.0 V which is bigger than the input voltage which is 0.5V.

Figure 9. sine wave with amplitude = 1.5V.

As the student increased the amplitude, the graph shown an increase with output voltage's amplitude become 3.0 V.

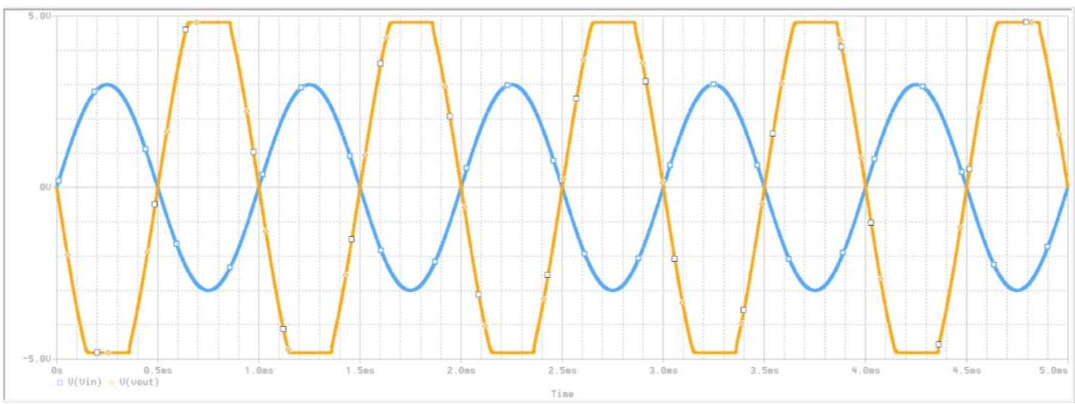

Figure 10. sine wave with amplitude = 3V.

Lastly, the student increased the input voltage's amplitude to 3V which the output voltage's amplitude lead to 5.0 V. This shows that thqe graph is only limited to +5 V and – 5V which seems that there is a cut to the waveform.

Part3 - Laboratory Measurements

For this part of the laboratory, the student constructed the circuit in the breadboard using the same circuit from the figure 11 with the same resistor values and the $\pm$ 5V power supply. The student recorded the V_{OUT1} by grounding the node labeled V_{S1}.

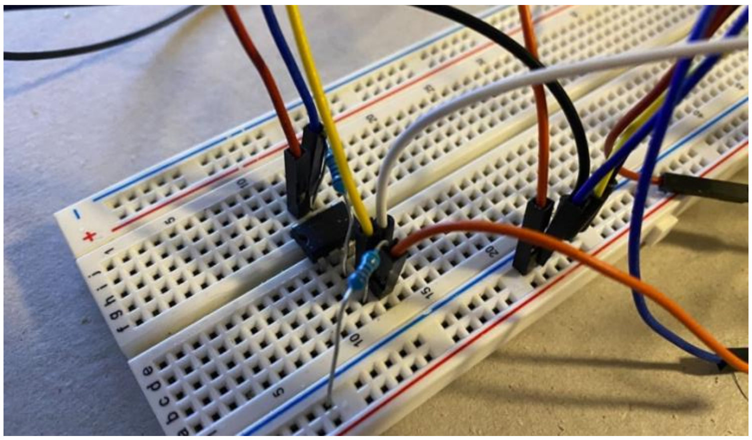

Figure 11. The constructed ciruit of non-invert amplifier in breadboard

After the setup, the student used the AD2 to get the waveforms of V_{S1} and V_{OUT1} shown below.

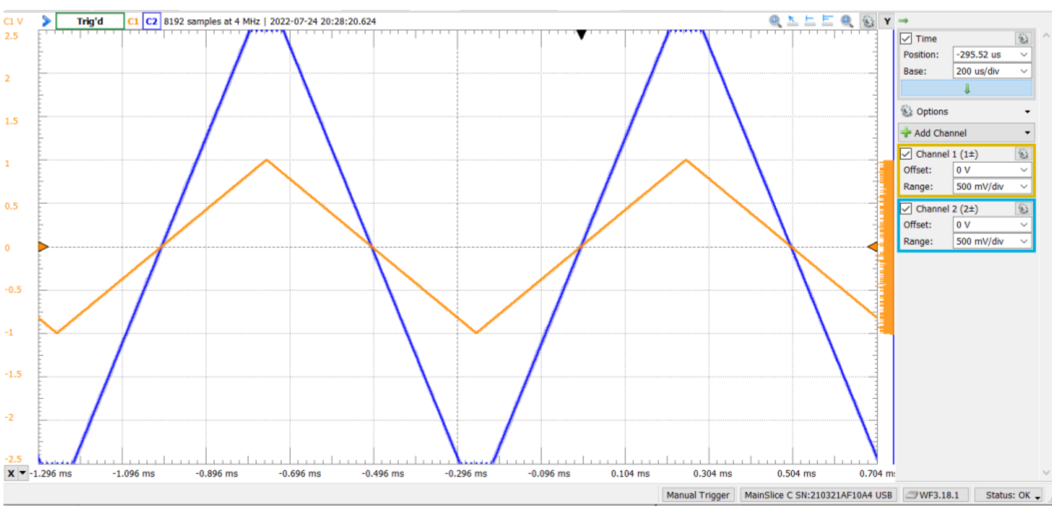

Figure 12. The waveforms of V_{S1} and V_{OUT1} for Non-Inverting Amplifier

From the graph in figure 11, the orange trace is V_{S1} and the blue trace is V_{OUT1}. For the non-inverting amplifier, the student plot the waveforms of V_{S2} and V_{OUT2}. With it, the student was able to calculate the small-signal gain $\frac{V_{out1}}{V_{s1}}$ which is 0. The student also observed that the clipping of the output voltage corresponds to the $\pm$ 2.5 V. shown in figure 12. After that, the student proceed to inverting amplifier and built the circuit which shown in figure 13.

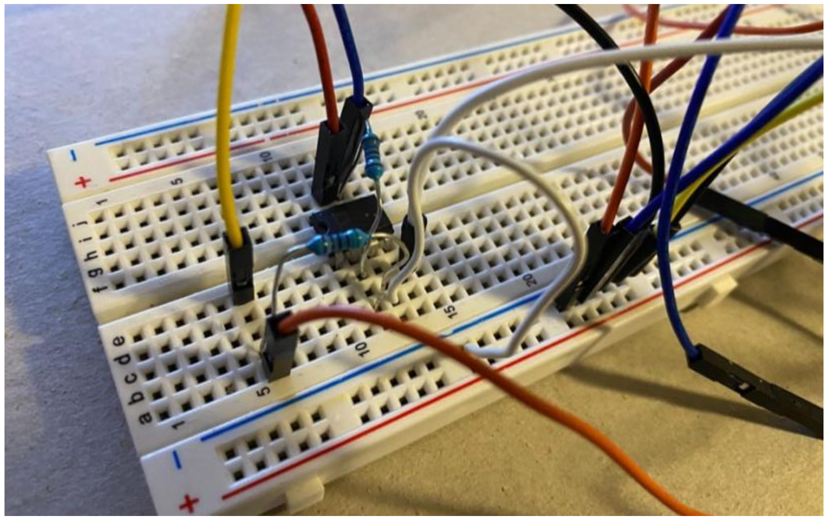

Figure 13. The constructed ciruit of Inverting Amplifier in breadboard

With the same process from the non-interting amplifier circuit, the student generate the waveforms of V_{S2} and V_{OUT2} shown in figure 14. The student adjusted the signal source so the V_{S2} is a 1 V_{pp}, 1kHz triangle wave with zero DC offset.

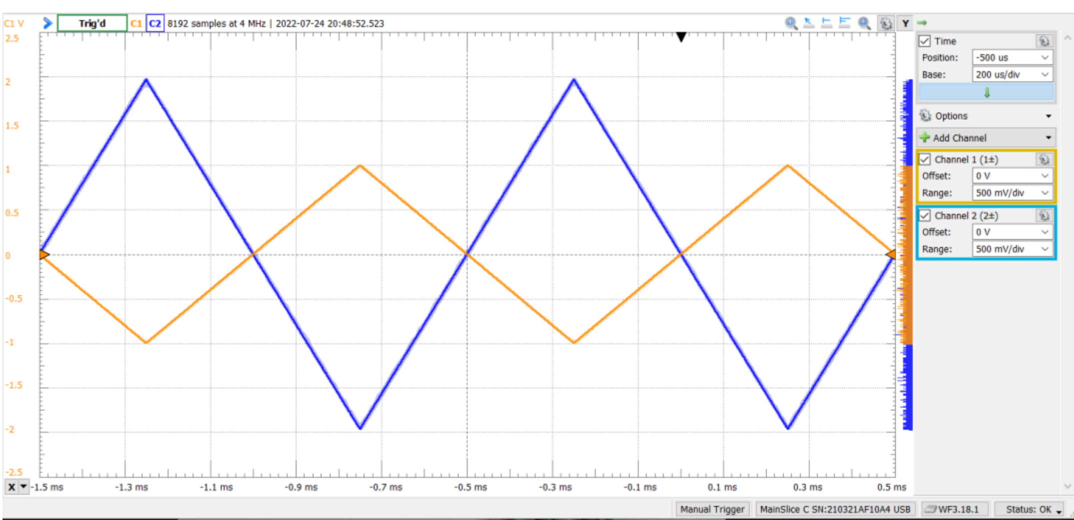

Figure 14. The waveforms of V_{S2} and V_{OUT2} for Inverting Amplifier

From the graph in figure 14, the student calculated the small-signal gain $\frac{V_{out1}}{V_{s1}}$ which is around 1. After, the student changed the V_{S2} to a sine wave shown in figure 15. We observed how the waveform is similar to the PSpice waveform with different amplitudes.

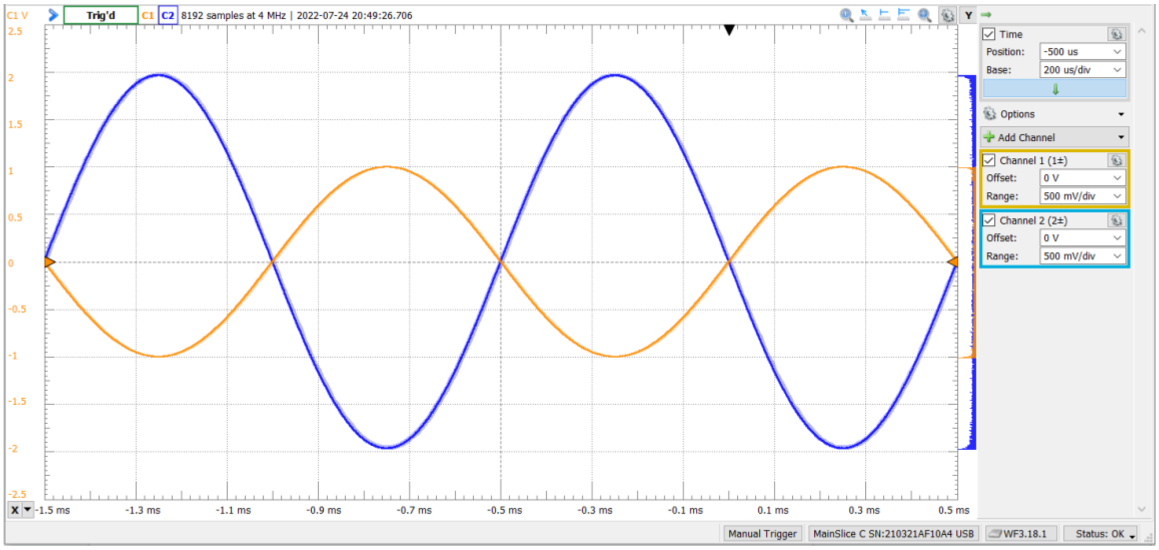

Figure 15. The sine waveform for Inverting Amplifier

CONCLUSION:

The whole laboratory shows the use of amplifiers and introduced to two amplifiers: the non-inverting amplifier and inverting amplifier. In the preliminary calculations, the student mainly calculated for the expression for the voltage gains as well as gathered results for the voltages and input resistances. For the Pspice simulation, the student inputs the two amplifier circuits into the application and investigate the results. Comparing the two circuits, the student found out that the V_{outmax} and V_{outmin} are the same for inverting and non-inverting amplifier circuits. Lastly, the laboratory measurement part is the challenging part as the confusing parts on where to hook the wires in breadboard. On the other hand, the student was able to generate good results and matches to the data from the other parts of the laboratory. With these measurements and simulations, the student learned how the two amplifiers have similarities and differences just as flipping the waveform which gives a mirror effect of the two graphs.

Table 1. Laboratory calculation and simulation comparison

	Non – Inverting	**Inverting**
slope	1	-1
gain	3	-2
$\boldsymbol{V_{outmax}}$	5 V	5 V
$\boldsymbol{V_{outmin}}$	- 5 V	- 5 V

APPENDIX

1. NODE V_{N1} : $\dfrac{V_{N1}}{R_A} + \dfrac{V_{N1} - V_{OUT}}{R_B} = 0$ $\quad V_{N1} = V_{P1} = V_{S1}$

$$\frac{V_{S1}}{R_A} + \frac{V_{S1} - V_{OUT}}{R_B} = 0$$

$$V_{S1}\left[\frac{1}{R_A} + \frac{1}{R_B}\right] = \frac{V_{OUT}}{R_B}$$

$$A_{V1} \quad \frac{V_{OUT}}{V_{S1}} = \frac{R_B(R_A + R_B)}{R_A R_B} = 1 + \frac{R_B}{R_A}$$

2. using $R_A = 5\,k\Omega$:

$$A_{V1} = 3\,\frac{V}{V} = 1 + \frac{R_B}{5}$$

$$R_B = 10\,k\Omega$$

3. Input Resistance $R_{in_1} = \dfrac{V_{S1}}{i_{S1}} = \dfrac{V_{S1}}{0} = \infty$

4. $V_{N1} = V_{P1} = V_{S1} = 5\,V$

5. NODE V_{N2} : $\dfrac{V_{N2} - V_{S2}}{R_A} + \dfrac{V_{N2} - V_{OUT2}}{R_B} = 0$ $\quad V_{N2} = V_{P2} = 0$

$$-\frac{V_{S2}}{R_A} = \frac{V_{OUT2}}{R_B}$$

$$A_{V2} = \frac{V_{OUT2}}{V_{S2}} = -\frac{R_B}{R_A}$$

6. $R_A = 5\,k\Omega$ $\quad A_{V2} = -\dfrac{R_B}{R_A} = -\dfrac{10\,k\Omega}{5\,k\Omega} = -2\,V/V$
   $R_B = 10\,k\Omega$

7. Input Resistance : $R_{in_2} = R_A = 5\,k\Omega$

8. $V_{N2} = V_{P2} = 0\,V$