EELE 250 Circuits, Devices, and Motors

Lab #7: Op Amps, Part 2

Scope:

Study more basic Op-Amp circuits: non-inverting configuration and inverting summer

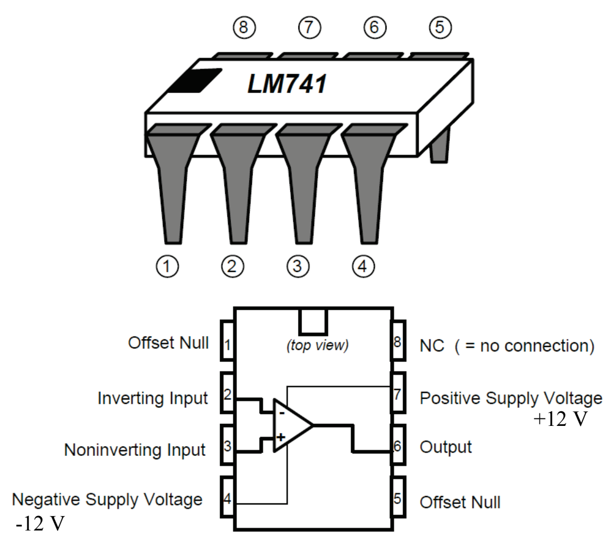
Home preparation:

- Review Hambley chapter 14.
- Read through the experiment and plan out each step.
- Create tables in your notebook with the calculated values and space to enter the measured results for the experiment.
- Prepare the calculated results for the circuits you will be measuring in the lab, fill out the **prelab sheets, AND write the results in your lab notebook** so you can refer to them during the lab while your prelab is being graded.

Laboratory experiment:

In this experiment you will again be using the 8-pin DIP (Dual Inline Package) version of a type 741 operational amplifier (op-amp). Review the diagram of the pin assignments and connections, and also review the setup for the dual output power supplies in the lab when set for *series* mode (+12V, ground, and -12V).

The *Offset Null* (pins 1 and 5) will not be used in this experiment. Those pins must be left unconnected.



Experiment

1. Using the DMM, carefully adjust the dual output bench DC power supply to produce +12V and -12V with respect to a common ground as was done in Lab #6 → *ask your lab TA to check your configuration*.

2. Adjust the signal generator to produce a 1 kHz sine wave with amplitude 1 volt peak to peak.
3. Next, build the circuit shown in Figure 1 on your breadboard. This is a *non-inverting amplifier configuration*. Assemble the circuit with the DC power supply and signal generator OFF, then carefully check your connections before turning the supply and the signal generator on.

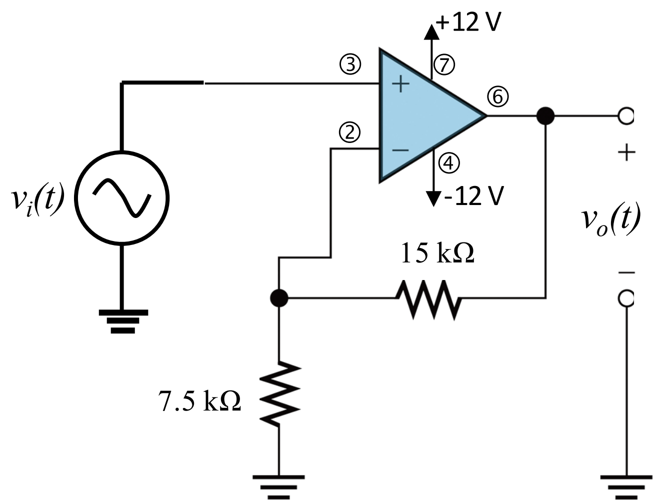


Fig. 1

4. Using the oscilloscope to view $v_i(t)$ on Ch 1 and $v_o(t)$ on Ch 2, record the output voltage amplitude for each of the input sinusoid amplitudes in Table 1. Also calculate the voltage gain ($|v_o|/|v_i|$) and list it in column 3 of the table.

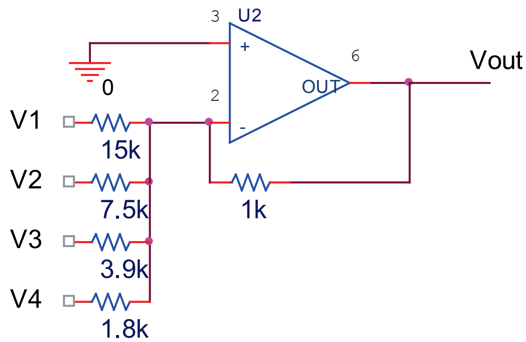
Table 1

1 kHz input signal	**From pre-lab** predicted v_o p-to-p	v_o p-to-p measured in lab (Step 4)	Voltage gain from measurements ($|v_o|/|v_i|$)
1 V p-to-p			
2 V p-to-p			
3 V p-to-p			
4 V p-to-p			

5. If you now gradually increase the input peak-to-peak amplitude, at what input level do you notice clipping distortion in the output waveform?

6. TURN OFF THE BENCH SUPPLY and assemble the circuit of Figure 2 on your breadboard. This configuration is known as an *inverting op-amp summation circuit*. The voltages labeled V1-V4 will be defined in the next step, so for now just leave those resistor ends connected to blank rows in your breadboard. Carefully check all connections to the +12V (pin 7) and -12V (pin 4) power supply and ground BEFORE turning the power supply on.

Fig. 2



This circuit in Fig. 2 is a crude 4-bit “digital to analog converter,” meaning that if we treat V1 - V4 as binary digits (ones and zeros), the output voltage is proportional to the binary interpretation of those bits. Measure and record the output voltage for the following sequence of input voltage combinations shown in Table 2.

Table 2

Digital Input $V_4V_3V_2V_1$	**Meaning:**	**From pre-lab v_{out} calculated [V]**	**Vout Measured [V]**
0 0 0 0	All inputs ground		
0 0 0 1	V1=5V, rest ground		
0 0 1 0	V2=5V, rest ground		
0 0 1 1	V1=V2=5V,rest ground		
0 1 0 0	V3=5V, rest ground		
0 1 0 1	…etc…		
0 1 1 0			
0 1 1 1			
1 0 0 0			
1 0 0 1			
1 0 1 0	V4=V2=5V, rest grnd		

7. Design problem: As described on the <u>prelab sheets</u>, you need to have an op-amp circuit design that will accept an input signal voltage that is in the range -3 volts to +3 volts and creates a replica of this signal that is shifted and scaled so that v_{out} is in the range 0 volts to +5 volts.

   Use your breadboard and components from your lab kit to build the circuit you designed in the prelab.

8. Perform the measurements on your circuit needed to complete Table 3, which will verify how well your design achieves the goal. You will need to figure out a way to create +3V and -3V DC for your inputs: perhaps use the resistor ladder idea from Lab #6?

Table 3		
Vin	Vout Calculated [V]	Vout Measured [V]
-3 V		
0 V		
+3 V		

9. Use the signal generator to create a 6 volt peak to peak (-3V to +3V) sinusoid with frequency 100 Hz and observe the output of your circuit for this input. Comment on the results.

PRELAB SHEETS

Perform the calculations before coming to lab, and show a summary of your work.

Non-inverting op-amp configuration

1. For the circuit of Fig. 1, determine the expected voltage gain and output voltage v_o for the peak to peak amplitude of v_i given in the table. Explain your work.

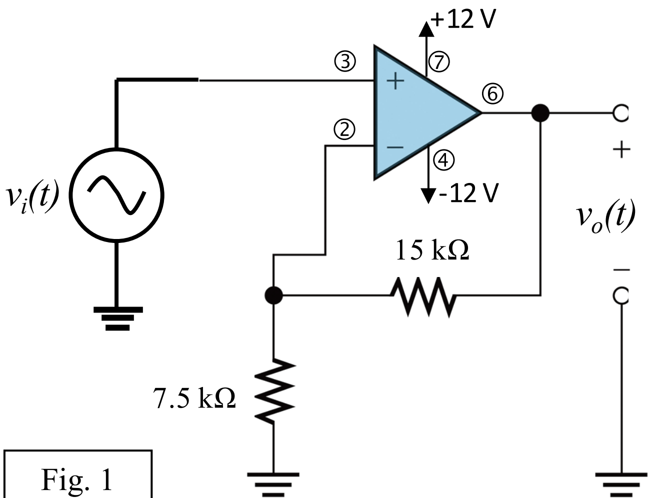


Fig. 1

1 kHz input signal amplitude	Predicted voltage gain ($\|v_o\|/\|v_i\|$)	Predicted v_o p-to-p
1 V p-to-p		
2 V p-to-p		
3 V p-to-p		
4 V p-to-p		

Inverting summer configuration

2. For the circuit of Figure 2, calculate the expected output voltage for the input voltage combinations V1 - V4 given in the table.

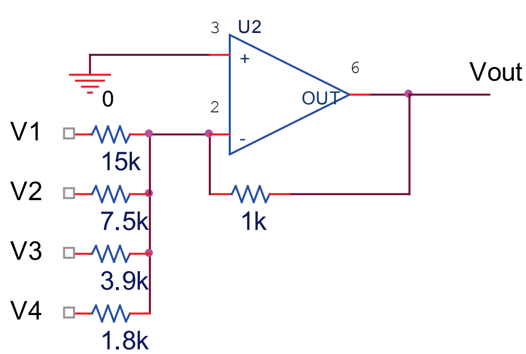


Fig. 2

Digital Input $V_4V_3V_2V_1$	Meaning:	Vout Calculated [V]
0 0 0 0	All inputs ground	
0 0 0 1	V1=5V, rest ground	
0 0 1 0	V2=5V, rest ground	
0 0 1 1	V1=V2=5V,rest ground	
0 1 0 0	V3=5V, rest ground	
0 1 0 1	…etc…	
0 1 1 0		
0 1 1 1		
1 0 0 0		
1 0 0 1		
1 0 1 0	V4=V2=5V, rest grnd	

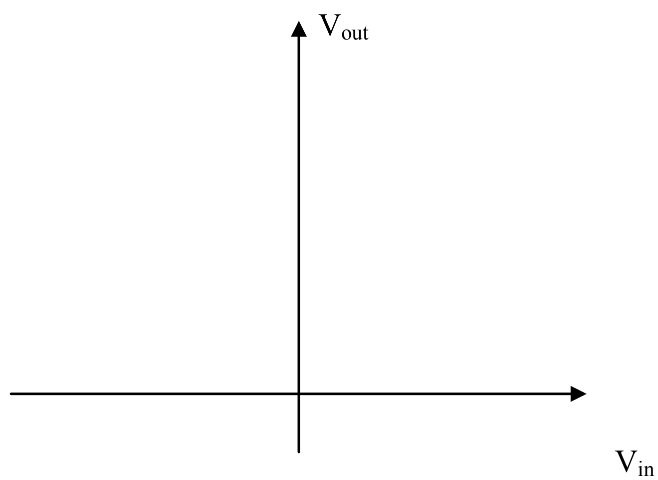
Op-amp design problem

3. It is often necessary in electronic instrumentation to change the voltage range of a signal. For this design, you need to determine a way to take an input voltage with amplitude that is in the range –3V and + 3V and create an output voltage that is a replica of the input, but shifted and scaled so that the output is in the range 0 volts to +5 volts.

   In other words, when the input signal is -3 volts, we want the output signal to be 0 volts, and for input voltages between -3 volts and +3 volts, we want the output voltage to be shifted and scaled proportionally according to the mathematical relationship:

$$v_{out} = (0.833 * v_{in}) + 2.5 \text{ volts} = 0.833 * (v_{in} + 3 \text{ volts})$$

   (a) Sketch the mathematical *transfer function* by graphing the desired v_{out} as a function of v_{in} for -3V < v_{in} < +3V. Label your sketch.



   (b) Now invent some combination of the basic op-amp circuits such as the inverting amplifier, non-inverting amplifier, inverting summer, resistor voltage divider, etc., to make a circuit that will implement the mathematical "operation" required to meet the design specification. You may use two op amps. Sketch your design below or on the back of this sheet.

   See if you can figure out a way to achieve the desired design using just one op amp.