Name:	Lab Section:	Total score for lab: ________________/10

Lab 5: Operational Amplifiers

INTRODUCTION:

The purpose of this lab is to familiarize you with the properties and operations of the operational amplifier. You will use the LM358 dual op amp to first implement an inverting amplifier. Based on a summing amplifier (which has a very similar working principle as the inverting amplifier), you will build a 4-bit digital-to-analogue converter (DAC) using one of the op amps. The DAC converts a binary input into an analogue output. In the final, stage will add a comparator using the remaining op amp to drive an LED at the output when the DAC input exceeds a minimum value.

Learning Outcomes:

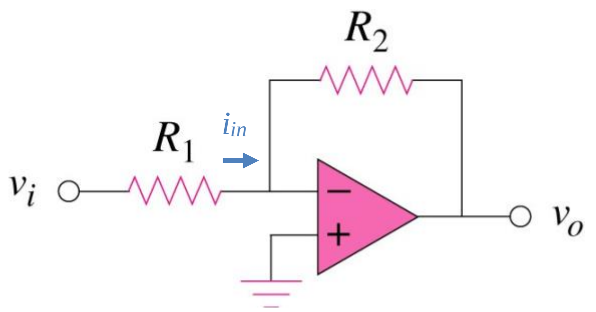
- ☐ Implement an inverting op amp circuit on a breadboard
- ☐ Relate the theory of an ideal op amp to real op amp circuits
- ☐ Implement a DAC using op amps on a breadboard
- ☐ Implement a comparator using op amps to drive an LED at the output

REQUIRED MATERIALS:

Hardware:
1) Digital multimeter
2) Power supply

Components:
1) LM358 dual operational amplifier
2) Resistors
3) LED
4) 4-channel SPST switch
5) Breadboard

LAB TASK 1: INVERTING AMPLIFIER



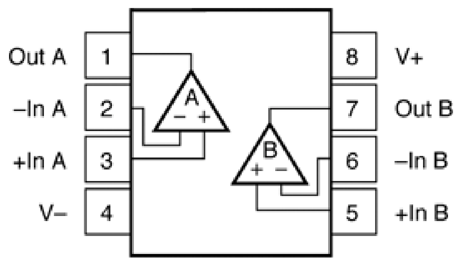


Fig 1: Schematic of an inverter amplifier (Left); Pin connection diagram of LM358 (Right)

1.1 Choose suitable values of resistors to achieve a gain of around 4 for an inverting amplifier (refer to Fig 1).

R_1 =______(measured), R_2 =______ (measured), Expected gain =______

1.2 Build the inverting amplifier circuit shown in Fig 1 on your breadboard. Use ±5V as the supply voltages.

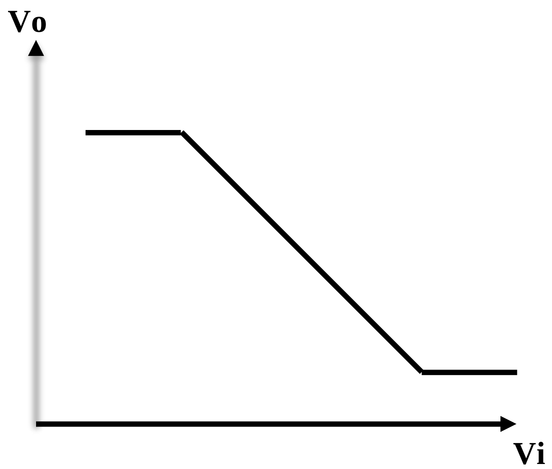
1.3 Starting from $v_i = 0$, increase v_i in steps of roughly 0.3V until you reach roughly 1.8V. Use the DMM to measure v_o **AND** v_i at each data point and record your data in Table 1.

1.4 Then from $v_i = 0$, decrease v_i in steps of roughly 0.3V until you reach roughly –1.8V. Use the DMM to measure v_o **AND** v_i at each data point and record your data in Table 1.

Clarification: In total, you should have 13 data points in the range of v_i from –1.8V to 1.8V

Table 1: Record of Measurements for Inverting Amplifier _______/ **1**

v_i	v_o	Gain (v_o/v_i)	
		Measured	Theory



1.5 Measure the current from the input source using the DMM when $v_i = 0.3$V, and hence determine the input resistance of the circuit.

Input current when $v_i = 0.3$V: $i_{in} =$

Input resistance (of circuit): $v_i/i_{in} =$

_______ / **1**

1.6 Plot your recorded data in Table 1 on Excel.

Determine the measured gain from the slope of the linear best fit line for *vo* vs. *vi*.

Slope of the linear best fit line: ______________________

Is it similar to the gain estimated in task 1.1? ☐ Similar ☐ Different _______/ **1**

1.7 Explain why the graph is flat close to +5V and 5V is due to :

_______ / **1**

1.8 Explain by using a sketch how the v_o vs. v_i graph will change if the value of R_1 is halved while R_2 is kept the same. Use the blank space beside Table 1 to sketch your curve.

Slope will be ☐same ☐ double ☐ half

_______ / **1**

Note: Do not dismantle your circuit on the breadboard as you will reuse it in Task 3. Get yourself marked by the lab supervisor, demonstrator, or technical staff.

LAB TASK 2: Digital-to-Analogue Converter (DAC) based on Op Amp

2.1 **Switch off** the voltage supply to the op amp first. Then begin to build the circuit in Fig 3 (modified from Fig 2). We will use a 4-channel SPST switch to provide us with the $2^4 = 16$ different input binary combinations.

In this lab task, you have full freedom in the choice of resistor values (based on your solution in Pre-lab). The only recommendation is to choose $R_f = R_1$ which might help to simplify your solution for Lab Task 3.

MEASURE all resistor values and enter them into Table 2.

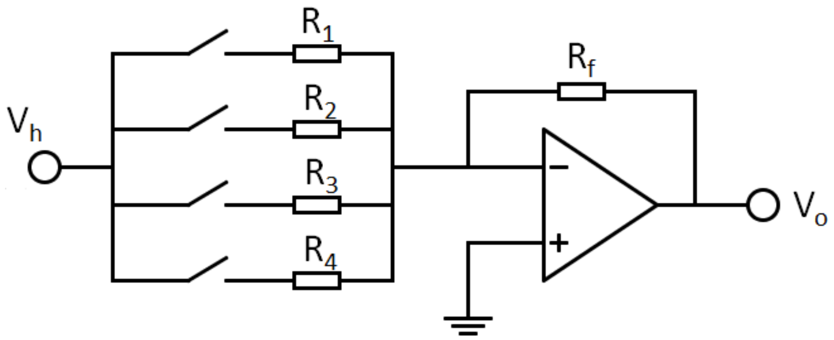


Fig 3: Schematic of DAC for Lab Task 2

Table 2: MEASURED values of resistors for proposed DAC

R_f	R_1	R_2	R_3	R_4

2.2 Set V_h to -1V. This value represents logic high in the input combination. Use $\pm V_s$ values similar to Lab Task 1.
2.3 Measure V_o for all 16 input combinations allowed by the switch. Record your readings in Table 3.

Table 3: Digital-to-analogue conversion measurement results

Binary combo	Value in decimal	Measured V_o
0000		
0001		
0010		
0011		
0100		
0101		
0110		
0111		
1000		
1001		
1010		
1011		
1100		
1101		
1110		
1111		

Demonstrate to a grader that your DAC works before moving onto the next task

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WARNING: DO NOT DISMANTLE THE CIRCUIT. YOU WILL EXPAND IT IN LAB TASK 3!

LAB TASK 3: DAC with Comparator Output

In this final part of the lab, you will extend the circuit from Lab Task 2 to have an LED alarm that lights up when the input combination exceeds a minimum set value. This can be achieved using a comparator which compares the output of the DAC in Fig 3 to a reference voltage (V_{ref}). The output of the comparator saturates either towards the negative or positive supply depending on the relative voltage difference between the inverting and non-inverting terminals.

Your task here is to add an additional stage to your DAC circuit from Lab Task 2 with the function of driving an LED when the input combination of the DAC ***reaches/exceeds*** a binary value of 1-0-0-0.

A suggested solution is shown in Fig 4. You will need to decide on the required value of V_{ref} and how to apply it. Use the other op amp that is unused to implement the comparator. This is an extension of the Lab Task 2 and should not need to dismantle the DAC you have built in Lab Task 2.

V_{ref} = ____________________

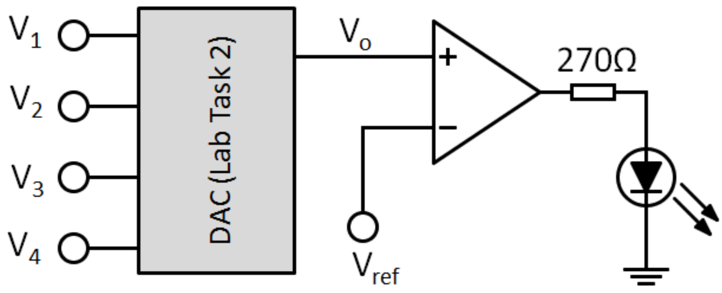

Fig 4: Suggested comparator circuit and LED connection with respect to DAC output (V_o)

Demonstrate to a grader that your circuit works to claim your final marks.

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