OBJECTIVES:

The objectives of this lab are to:

1. Examine the properties of the operational amplifier and learn to design practical op-amp circuits.
2. Verify the concepts and equations of the inverting and non-inverting amplifiers.
3. Investigate the use of the operational amplifier as a comparator.

EQUIPMENTS AND PARTS:

- Breadboard / Digital Trainer Kit
- Three Resistors: R₁=20 kΩ, R₂=100 kΩ, R₃=20 kΩ, 390 Ω, 100 kΩ potentiometer, 8 Ω speaker.
- Operational Amplifier: 741 (UA 741 LC)
- DC Power Supplies with time-constant EMF (0 to 20.0V DC).
- Digital Multimeter (DMM)
- Function Generator
- Oscilloscope

PROCEDURES:

Part A: Inverting Configuration

(i) Inverting Amplifier

1. Measure the resistances R₁, R₂ and R₃ using DMM. Record the values in Table 1. Test the resistance of the potentiometer using DMM. Connect the circuit shown in Figure 1 using a 741 Op Amp. Be sure to connect the ±V_{CC} = ±15V supply voltages.

2. Verify that the gain is -5 (by calculation).

3. Adjust the function generator to 1V(p-p), 10 kHz. sine wave. Verify using oscilloscope.

4. Measure and record the output voltage in Table 1. Calculate the gain and compare with the theoretical gain in procedure 2.
5. Confirm that the op-amp inverts the input by displaying both input and output on the scope (using CH 1 at the input and CH2 at the output). Sketch waveforms.

6. Increase the input amplitude of the function generator until the top of the output sine wave is being cut off. This effect is called clipping. Measure the voltage of the positive and negative halves. How do these values compare to ±Vcc?

Part B: Non-Inverting Configuration

1. Determine the gain of the circuit in Figure 2.

2. Connect the circuit in Figure 2.

3. Adjust the function generator to 1V(p-p), 10 kHz sine wave. Verify using oscilloscope.
4. Measure the output voltage, calculate the gain and compare with the theoretical gain in 1. Record in Table 3.

5. Using the oscilloscope, display both input and output waveforms. (Using CH 1 at the input and CH 2 at the output). Sketch and label the input and output waveforms.

6. Turn off the power supply.

7. Modify the circuit in Figure 2 as in Figure 3. Use 20kΩ as R₁ and 100 kΩ potentiometer as R₂ and a speaker as the output.

8. Turn on the function generator. Adjust the generator to 500mV peak to peak and the frequency to 100Hz.

9. Turn on the power supply(±15V).

10. Increase or decrease the amplification level using the potentiometer (R2).

11. Using the function generator’s frequency control, try different values of frequency. What is the minimum frequency you can hear? What is the maximum? Note down their values in Table 4.

![Figure 3](image-url)
Part C: Comparator

(i) Simple Comparator with dc input

1. Wire up the op-amp and pot as shown in Figure 4.

2. Vary the pot until v+ at pin 3 is 5.5v. Measure and record Vout at pin 6 in Table 6.
3. Vary the pot until v+ at pin 3 is 4.5v. Measure and record Vout at pin 6.
4. The readings you get are the maximum and minimum saturation values of the op-amp for an 8V supply. Saturation values for most op-amps are 1 volt away from the supply volts.
5. Modify the circuit by adding a 390 Ω resistor and an LED at the output as in Figure 5.
6. Monitor the two voltage points v+ and Vout at the same time and observe the LED.

Figure 4

Figure 5
7. First, get an accurate reading of $v$ by using DVM to measure the voltage at pin 2 of the op-amp where the 5 volt supply is connected. For this measurement and the following two measurements, jot down all the digits displayed by the meter.

8. Vary the 100 kΩ pot carefully to get the minimum voltage needed at $v^+$ (pin 3) to keep the voltage output at pin 6 at positive saturation or LED glowing. Record this voltage, $(v^+1)$.

9. The maximum voltage needed at $v^+$ (pin 3) to keep the voltage output at pin 6 negative or LED dark. Record this voltage, $(v^+2)$. What is the difference $(v^+1 – v^+2)$?

10. Switch off the power supply.

(ii) Comparator with triangular input waveform

1. Disconnect the the resistance and LED at the output as in Figure 6. Replace the supply voltage at pin 2 with a signal generator.

2. Set the voltage supply at $v^-$ (pin 2) to a triangular wave with a 8 V$_{p-p}$ and frequency of 500 Hz.

3. Vary 100 kΩ pot to set voltage at $V^+$ (pin 3) to 2 volts.

4. Use the oscilloscope to view the input and output voltages (CH 1 - Vin and CH 2 - $V_o$).

5. Sketch the input and output voltages shown on the oscilloscope on the same axis. Make sure the oscilloscope is at DC coupling.

![Figure 6](image-url)
EXPERIMENT 2 REPORT SHEET

OPERATIONAL AMPLIFIER (OP-AMP)

Semester : ___________  Course : __________
Session : ___________  Section : __________
Date : ___________  Group : __________

Group Members : ____________________________________________
______________________________

Lecturer : __________________________________________________

Pre-Lab : / 20
Lab Performance : / 10
Ethics : / 5
Results : /30
Discussion : /35

Total Marks : /100
Lab 2- Operational Amplifier

RESULTS:

A. Inverting Configuration

i) Inverting Amplifier $V_s = 1V_{pp}$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measured</th>
<th>Calculated/Nominal</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_1$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_o$ (V)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain ($A_V$)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1

Waveforms: $v_s$ and $v_o$

![Waveform Diagram]

At Clipping:

| $V_s$ (V)   |          |
| $V_{omax}$ (V) |          |
| $V_{omin}$ (V) |          |

Table 2

(5 Marks)

(4 Marks)

(3 Marks)
Part B: Non Inverting Configuration

\[ V_S = 1 \text{V p-p} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measured</th>
<th>Calculated/Nominal</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_O (\text{V}) )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain (( A_V ))</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3

Waveforms: \( v_s \) and \( v_o \)

Maximum frequency (Hz) 
Minimum frequency (Hz)

Table 4
Part C: Comparator

(i) Simple Comparator with dc input

<table>
<thead>
<tr>
<th>$V^+$ (V)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 6

(ii) Comparator with triangular input

Waveforms: $v_s$ and $v_o$

\[
\begin{array}{cccc}
V^- (V) & V^+1 (V) & V^+2 (V) & (V^+1 - V^+2) V \\
(Pin 2) & (Pin 3) & (Pin 3) & \\
V_o (V) & & & \\
\end{array}
\]

(6 Marks)

(30 Marks)
DISCUSSION

Answer the following questions in your lab report.

1. Referring to Table 1 and Table 2, do the measured gains and the calculated gains agree with the expectations? Compare and discuss.  
   (6 Marks)

2. a) How do you vary the gains of the non-inverting and inverting amplifier?  
   b) What is the value of the potentiometer resistance in Figure 3 to set the gain of the amplifier to 3?  
   (4 Marks)

3. We have seen example of clipping in an operational amplifier circuit. Explain how and why clipping should be accounted for in designing an amplifier circuit.  
   (4 Marks)

4. Why does the output signal in part A (ii) distorted?  
   (2 Marks)

5. From your knowledge and the experiment, what is the range of frequencies that human can hear  
   (2 marks)

6. From the experiment and the results in Table 6, explain how a comparator works.  
   (3 marks)

7. For an ideal op-amp the difference between the two readings \( v^+1 - v^+2 \) in Table 6 should be zero. What is the difference that you get.?  
   (3 marks)

8. Why the observations for 7, 8 and 9 in part C (i) would be similar if the diode were connected in reverse?  
   (3 marks)

9. Explain how the comparator circuit in part C (ii) produce the output waveform \( v_o \). Does the waveform agree with the predicted waveform?  
   (3 marks)

10. Write the conclusion for Experiment 2.  
   (5 marks)

(35 Marks)