I.D. No.	
Student Name	
Batch No.	
Day & Date	

Signature of the Instructor with Date	

Experiment 1

Characterization of Op-amp

Objective:

To study

1. The input offset voltage
2. The input bias and offset current
3. Open loop gain
4. Slew rate

Components required:

IC 741, 10 kΩ Potentiometer, Resistors - 10,100,1k,1.5K,5.6k,10k,100k,and 1M Ω.

Experiment:

1. Input offset voltage

1.1 Assemble the circuit as shown in Figure 1, with R_1= 100 Ω and R_2= 1kΩ. Observe the dc output voltage. Calculate the input offset voltage which is given by $V_{os}=V_o \times R_1/(R_1+R_2)$

Draw the circuit of Fig6.3 of TB2 Page No. 43

R_2 in Ω	V_o in V	$V_{os}=V_o \times R_1/(R_1+R_2)$ in V
1k		
10k		
100k		

1.2 From the data sheet of 741 op-amp, find the maximum value of input bias current, I_{Bmax}. Calculate the input offset voltage, which is given by $I_{Bmax} \times R_1$.

I_{Bmax}=…………….. Input offset voltage

1.3 Compare the results of step (i) and (ii).

Parameter	From step 1.1	From step 1.2
V_{os}		

1.4 Connect the fixed terminals of a 10 kΩ potentiometer (nulling potentiometer) between pins 1 and 5 of the op-amp and the variable terminal to the negative power supply voltage, -15 V. Change the knob of the potentiometer to make the output zero. This nulls the effect of input offset voltage.

2. Input Bias current and input offset currents:

2.1 Assemble the voltage follower circuit as shown in Figure 2. Connect the non- inverting input to ground. Using a nulling potentiometer, make the output zero for zero input as per procedure 1.4.

Draw the circuit of Fig6.4 of TB2 Page No. 44

2.2 Connect a resistor R1 of value 1 MΩ between the non-inverting input and ground. Measure the output voltage V_{o2}. Calculate the current I_{B2}, given by $I_{B2}=V_{o2}/R_1$.

V_{o2} =………………..

$I_{B2}=V_{o2}/R_1$=……………..

2.3 Remove the resistor R1 and ground the non-inverting input. Now connect resistor R1 of value 1MΩ between the inverting input and output. Measure the output voltage V_{o1}. Calculate the current I_{B1}, given by $I_{B1}=V_{o1}/R_1$.

V_{o1} =………………..

$I_{B1}=V_{o1}/R_1$=……………..

2.4 Calculate the input bias current and the input offset current from these two values.

2.5 Compare the results with the data sheet values.

Parameter	From step 2.4	From Data Sheet
Input bias current		
Input offset current		

3. Open-loop gain

3.1 Assemble the circuit as shown in Figure 3. Given R_1=1.5 kΩ, R_2= 5.6 kΩ, R_3= 10 kΩ and R_4= 10Ω.

Draw the circuit of Fig6.6 of TB2 Page No. 45

3.2 Connect a dc source at the input V_s, and adjust its value so that the output is equal to -10V. Measure V_1.

V_1 =...............V

3.3 Calculate the differential input voltage $V_{diff}=V_{II} - V_{NII}= V_1/1000$

3.4 Calculate the open-loop gain, $A=V_0/V_{diff}$.

4. Slew Rate

4.1 Assemble the voltage follower circuit.

4.2 Apply 10Vp-p, 10 kHz square wave input, V_s.

4.3 Measure the rise time of the output waveform and calculate the slew rate.

4.4 Assemble a inverting amplifier circuit with a gain of 1, by selecting $R_1=R_F=10\ k\Omega$. Repeat steps 4.2 and 4.3.

4.5 Compare the two values.

Draw the circuit of voltage follower and inverting amplifier

Circuit	Rise time	V_{0p-p} in Volts	Slew Rate=V_{0p-p}/rise time
Voltage follower			
Inverting Amplifier			

5 PSPICE Simulations:

Use the macro model μA 741 and connect a load resistor of 10 kΩ and power supply voltages of $\pm$15 V.

5.1 Simulate the circuit as used in experiment 1.1 using PSPICE. Do the dc analysis to print the values of the output voltage. Calculate the input offset voltage. Compare the results with the experimental results.

5.2 Simulate the circuit, as used in experiment steps 2.1 through 2.3, using PSPICE. Do the dc analysis to print the values of the output voltage. Calculate the input bias and offset currents. Compare the results with the experimental results.

5.3 Simulate the circuit, as used in experiment steps 3.1 through 3.2, using PSPICE. Compare the results with the experimental results.

6. Viva Questions- Answer the following:

(a) The open loop gain of opamp 741 is ______________.

(b) The unity gain bandwidth of opamp 741 is ___________.

(c) For a good amplifier, slew rate should be very high. State true or false. ___

(d) The differential input impedance of opamp 741 is ___________

(e) The CMRR of a good opamp should be as low as possible. State true or false. ______

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Experiment 2

Inverting Amplifier, Integrator, Non-inverting Amplifier, Adder and Subtractor

Objective:

To design and study:

1. Inverting amplifier,
2. Integrator
3. Non-inverting amplifier
4. Adder
5. Subtractor

Components required:

Dual tracking power supply or ±15 V split power supply, function generator, resistors and capacitors.

Experiment:

1. **Inverting amplifier:**

1.1 Design an inverting amplifier for the gain of 15. Let R_1= 1kΩ. Assemble the circuit on breadboard and feed sinusoidal input signal of amplitude 100 mV and frequency 1 kHz. Observe the input and output voltages on a CRO. Determine the gain of the amplifier and phase difference between the input and output voltages.

1.2 Now vary the input signal frequency keeping the amplitude fixed and find the bandwidth. The bandwidth is equal to the higher cutoff frequency which is the frequency at which the gain reduces to 0.707 of the mid-band frequency gain.

1.3 Calculate the gain-bandwidth product.

1.4 Compare the results with the theoretical values.

R_1 = ………… and R_F = ……….

Draw the circuit of inverting amplifier

Input voltage, v_s= ……

Output voltage, v_0= ….

Voltage gain $A_v = \frac{v_O}{v_s} = \frac{.......}{........} = ...$

Phase difference between input and output voltages=................

Frequency (Hz)	Input voltage v_s (V)	Output voltage v_o(V)	Voltage gain, $A_v = \frac{v_O}{v_s}$	Voltage gain (dB)
500				
1k				
10k				
50k				
60k				
70k				
100k				

Higher cutoff frequency f_H = 0.707 $A_{v(max)}$=.......

Gain bandwidth product GBW= $A_{v(max)} \times f_H$ =.................

Parameter	Experimental	Theoretical
Gain		
Cut-off frequency		
Gain-bandwidth		
Phase difference		

2. Integrator:

Draw the circuit of integrator

2.1 Assemble an integrator with R= 1kΩ and C = 0.1 μF. Connect a resistor R_F of value 1 MΩ across the capacitor. Feed 1V(peak-peak), 500 Hz square wave input and observe input and output voltages on a CRO. Determine the gain of the amplifier. Plot the input and output voltages on the same scale.

2.2 Now change the value of RF to 1 kΩ and repeat the observations. Explain the changes in the output.

2.3 Now change the input signal to sinusoidal input of amplitude 1V and frequency 500 Hz and observe the output.

Gain of the amplifier = ...

3. Non-Inverting amplifier:

Draw the circuit of op-amp non-inverting amplifier

1.1 Design a non-inverting amplifier for the gain of 16. Let R_1= 1kΩ. Assemble the circuit on breadboard and feed sinusoidal input signal of amplitude 100 mV and frequency 1 kHz. Observe the input and output voltages on a CRO. Determine the gain of the amplifier and phase difference between the input and output voltages.

1.2 Now vary the input signal frequency keeping the amplitude fixed and find the bandwidth.

1.3 Calculate the gain-bandwidth product.

1.4 Compare the results with the theoretical values.

R_1 = ………… and RF = ………. .

Input voltage, Vi = ……

Output voltage, V_o = ….

Voltage gain $A_v = \frac{v_O}{v_s} = \frac{\cdots\cdots\cdot}{\cdots\cdots\cdots} = \cdots\cdots\cdots\cdot$

Phase difference between input and output voltages=…………….

Frequency (Hz)	Input voltage v_s (V)	Output voltage v_o(V)	Voltage gain, $A_v = \frac{v_O}{v_s}$	Voltage gain (dB)
500				
1k				
10k				
50k				
60k				
70k				
100k				

Higher cutoff frequency f_H = 0.707 $A_{v(max)}$=.......

Gain bandwidth product GBW= $A_{v(max)} \times f_H$ =..........

Parameter	Experimental	Theoretical
Gain		
Cut-off frequency		
Gain-bandwidth		
Phase difference		

4. Adder:

2.1 Assemble an analog adder circuit with R_F= R_1 = 8.2 kΩ., R_2 = 3.9 kΩ and R_3 = 2 kΩ. Feed sinusoidal input of amplitude 1 V and frequency 1 kHz to each input. Measure the amplitude of the output voltage and compare with the theoretical values.

2.2 Compare the experimental results with the theoretical values.

Draw the circuit of op-amp adder

Output voltage, $v_O = -\left[\left(\frac{R_F}{R_1}\right)v_1 + \left(\frac{R_F}{R_2}\right)v_2 + \left(\frac{R_F}{R_3}\right)v_3\right]$

=..................

R_F=R_1 = 8.2 kΩ, R_2 = 3.9 kΩ and R_3 = 2 kΩ

v_1=v_2=v_3= 1 V and frequency =1 kHz

Thus v_o= ....

Experimental value of v_o= ......

5. Subtractor:

Draw the circuit of op-amp subtractor

3.1 Assemble a subtractor circuit with $R_F = R_1 = 8.2\ k\Omega$. Feed V_1= 2 V and V_2 = 0.5 V sinusoidal signal of frequency 1 kHz. Observe the input and output voltages on a CRO. To get two signals from the same source, use a high resistance potentiometer.

3.2 Plot v_1, v_2 and v_o on the same scale. Compare the amplitudes with the theoretical values.

$R_F = R_1 = 8.2\ k\Omega$.

v_1 = 2 V and v_2 = 0.5 V sinusoidal signal of frequency 1 kHz.

Theoretical value of output voltage = $\frac{R_F}{R1}(v_2 - v_1)$ =................

Measured output voltage v_o= ……..…..V

6.

PSPICE Simulation:

Use the macro model μA 741 and connect a load resistor of 10 kΩ and power supply voltages of ±15 V.

6.1 Simulate the Differentiator circuit with R- 10kΩ and C=0.05 μF as used in experiment 4.1 using PSPICE. Plot the input and output voltages on the same scale. Determine the positive and negative peak voltages of the output. Also determine the rise and fall times of the output voltage. Assume ±0.1V, 5 kHz triangular wave input.

6.2 Simulate the non-inverting amplifier circuit (for the gain of 16), as used in experiment step 5.1 using PSPICE. Assume sinusoidal input of amplitude 100mV and frequency 1 kHz. Find the gain of the circuit and phase difference between the input and output voltages. Plot the frequency response curve of the amplifier and find the bandwidth. Compare the results with the experimental results.

6.3 Simulate the voltage follower circuit, as used in experiment step 6.1 using PSPICE. Assume sinusoidal input of amplitude 100mV and frequency 1 kHz. Find the gain of the circuit and phase difference between the input and output voltages. Plot the frequency response curve of the amplifier and find the bandwidth. Compare the results with the non-inverting amplifier.

6. Quiz Questions:

(a) The minimum voltage gain possible for an non-inverting amplifier is ________

(b) With ±15V supply voltage, the maximum rail to rail voltage swing of an inverting amplifier is ____________.

(c) The opamp in an inverting amplifier operates in ___________ region.

(d) If the gain of an inverting amplifying circuit is 10 and ±15V power supplies are used. What range of input values allows the opamp to be in linear region?

________V.