Op-Amp Characteristics

(a) Voltage Follower

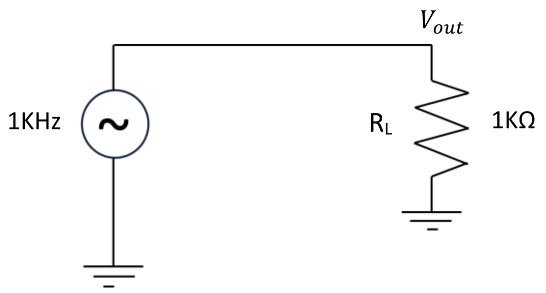

Figure 1(a)

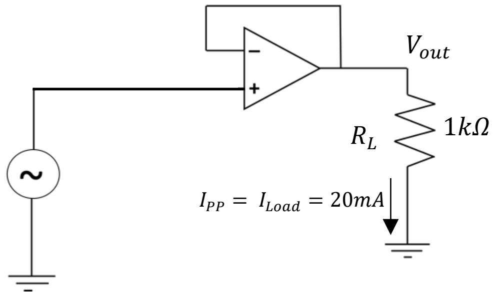

Figure 1(b)

1. Apply a 1 kHz sinusoidal signal to the 1k load shown in Figure 1(a)
   Note: Make sure the signal generator output amplitude is at its minimum.
2. Now increase the signal generator output amplitude until you get **20 mA** peak-to-peak current through the load resistor **R_L**.
   Hint: Measure the ac-voltage across R_L, instead of measuring the current through it. This will allow you to find the peak-to-peak current through the load resistor without the aid of an ammeter. You can use multi-meter for this purpose, remember that it shows you the RMS value of the voltage when put into the ac mode. 10.37 V
3. From the data you obtained from step 2, find the peak value of the current drawn from the signal source ~~for step 2~~.
4. Now connect the circuit shown in Figure 1(b).
   Note: Make sure you that you have adjusted the signal generator amplitude to its minimum before you connect the circuit.
5. Using a 1 kHz sinusoidal signal, repeat step2.

b)

2)

$V = I R$

$V = 20 mA \times 1k\Omega$

$V_{pp} = 20$ V

$V_p = 10$ V

$V_{rms} = \frac{10}{\sqrt{2}}$ V

$= 7.07$

freq. generator

$V_p = 10.19$ V

$V_{rms} = \frac{V_p}{\sqrt{2}}$ $V_p = 14.665$

$I_p = 14.665$ mA

$\boxed{7.07 \text{ V}}$

$\frac{V_p}{\sqrt{2}} = V_{rms}$

$V_p = V_{rms} \times \sqrt{2}$

$\frac{V_p}{\sqrt{2}} = V_{rms}$

7.07 mA

(b) Input offset Voltage

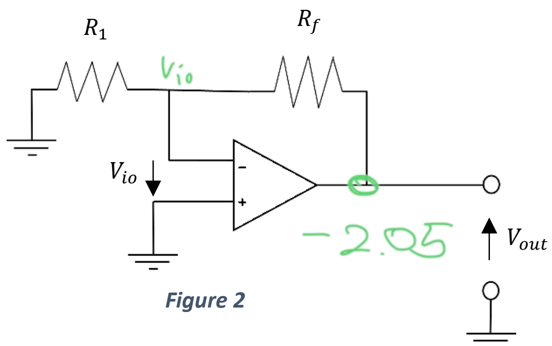

Figure 2

1. Derive an expression for V_{out} in terms of V_{io}, R_f and R_1.
2. Connect the circuit by taking R_f = 100kΩ and R_1 = 100Ω. (In case of unavailability use suitable replacements).
3. Measure the output voltage with respect to the ground. Hence calculate the input Offset Voltage of the Op-Amp.

1) $V_{io} = V_{out} \times \frac{R_1}{(R_1 + R_f)}$

3) -2.05 V

(c) Frequency/Phase Response

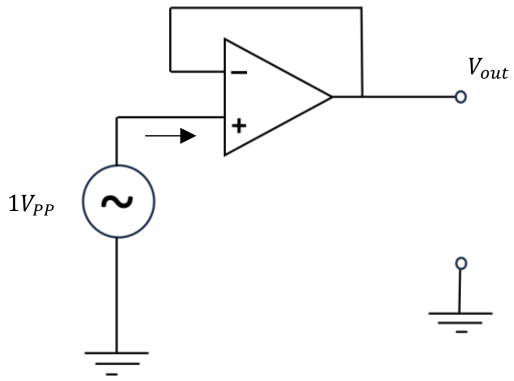

Figure 3

1. Connect the unity gain buffer circuit as shown in Figure 3.
2. Apply a 1V peak to peak sinusoidal signal to the non-inverting terminal.
3. Measure the input signal amplitude and the output signal amplitude for the following frequencies. Also measure the phase difference between Input and output signals. (20Hz 50Hz 100Hz 200Hz 500Hz 1kHz 5kHz 10KHz 50KHz 100kHz 200kHz 500kHz)
   Note: You have to check and make sure that the amplitude of the signal generator output is at 1V peak to peak for each and every frequency mentioned above.
4. Then obtain the frequency response of the Op-Amp by plotting the **Gain Response** and the **Phase Response** on log-scaled plots.

(d) Input Bias Current and Input Offset Current

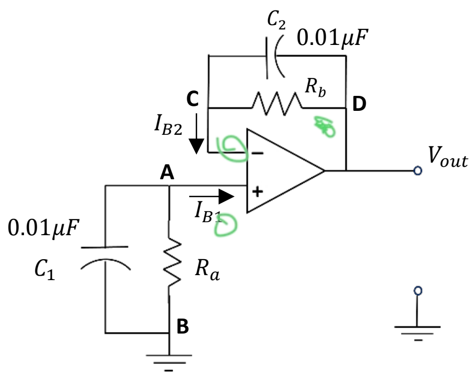

Figure 4

1. Connect the circuit as shown in Figure 4.
   Note: Choose $R_a = R_b > 10M\Omega$. Normally the input bias current I_B, is in the range 100nA. So higher values of R_a and R_b will ensure that $I_B R_b > V_{io}$ so that the voltages created by bias currents are much greater than V_{io}.
2. What is the value of V_{out} when the terminals A and B are short circuited? Measure the value of V_{out} for this condition and calculate the value of I_{B2}.
3. What is the value of V_{out} when the terminals C and D are short circuited? Measure the value of V_{out} for this condikon and calculate the value of I_{B1}.
4. From the values of I_{B1} and I_{B2}, calculate the value of input bias current I_B.
5. Find an expression for the input offset current in terms of I_{B1} and I_{B2} and find the input offset current of the Op-Amp used.

c)

	V_{in} (p-p)	V_{out} (p-p)	phase diff
20	1.03 V	1.07 V	50.04 ms
50	1.03 V	1.07 V	20 ms
100	1.05 V	1.03 V	10 ms
200	1.05 V	1.03 V	5 ms
500	1.05 V	1.03 V	2 ms
1k	1.05 V	1.03 V	1 ms
5k	1.05 V	1.03 V	200 μs
10 k	1.05 V	1.03 V	100 μs
50 k	990 mV	990 mV	19.60 μs
100 k	990 mV	990 mV	9.8 μs
200 k	990 mV	881 mV	4.48 μs
500 k	990 mV	364.32 mV	1.52 μs

d)

2) 0.109 V

3) 0.031 V

(e) Slew Rate

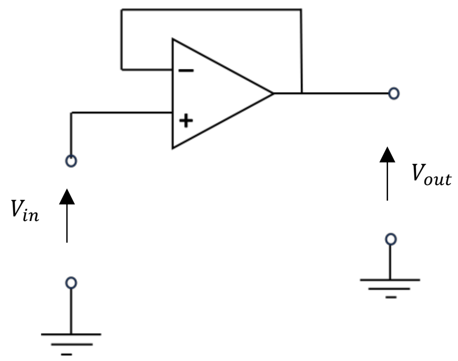

Figure 5

1. Connect the unity gain buffer circuit as shown in Figure 5.
2. Apply a 3V peak to peak sinusoidal signal to the non-inverting terminal.
3. Observe the output waveforms for the following frequencies.
   20Hz 50Hz 100Hz 200Hz 500Hz 1kHz 5kHz 10kHz 50kHz 100kHz 200kHz 500kHz.
   Explain in your own words what you have observed.
   Hint: Consider changes of waveform shape, amplitude etc.
4. Now apply 6V peak to peak square wave signal to the non-inverting terminal.
5. Observe the output waveforms for the following frequencies.
   20Hz 50Hz 100Hz 200Hz 500Hz 1kHz 5kHz 10kHz 50kHz 100kHz 200kHz 500kHz
   Note: You have to check and make sure that the amplitude of the signal generator output is at 6V peak-to-peak for each and every frequency mentioned above.
   (a) At the rising edge of the input waveform, find the time it takes for the output signal to reach its peak value.
   (b) At the falling edge of the input waveform, find the time it takes for the output signal to reach its lowest value.
   (c) Then calculate the temporal rate of change of the closed loop amplifier output voltage for each of above frequencies for both rising edge and falling edge cases.
   (d) Then find the maximum rate of change of the output voltage, hence find the slew rate of the device.
   Hint: It is the usual practice to specify the slower of the two rates (rising edge case or falling edge case) as the slewing rate of the device.
6. Comment on the waveform shapes you observed at the output for higher frequencies.

Discussion

1. Refer to the UA741 Op-Amp and find typical parameter values and responses and compare them with the values and responses you obtained in the practical.
2. Consider the sections (a) to (e) in the practical. List down practical situations where you need to consider the characteristics discussed in those sections.
3. What is frequency response of an amplifier? Explain briefly. Is there a difference between the terms 'frequency response' and the 'frequency spectrum? If so, explain briefly.
4. What is the difference between the high frequency response and low frequency response of an amplifier?
5. What is meant by CMRR and PSRR values of an Op-Amp?

3V

f (Hz)	Amp (V)pp	Shape	observation
20	3.21	sinusoidal	
50	3.21	sinusoidal	shape shrinked
100	3.11	sinusoidal	
200	3.13		
500	3.13		
1	3.13		
5	3.09		
10	3.11		
50	3.01		
100	1.96	saw teeth	
200	1.0		amplitude decreased.
500	380 mV		

6V

observation

	(a) µs	(b) µs	Input Vpp	Output Vpp
20	12	12	6	6
50	12	12	6	6
100	14	12	6	6.1
200	14	10	6	6
500	11.2	11	6	6
1	11.2	10.6	6	6
5	10.92	10.32	6	6
10	10.86	10.26	6.0	6.0
50	7.99	7.81	6.0	4.3
100	3.934	3.882	6.0	2.13
200	2.10	1.991	6	1.13
500	744 ns	745 ns	6.0V	460 mV

output wave form