GEBZE TECHNICAL UNIVERSITY

ELECTRONICS ENGINEERING

SPRING 2022

ELM237

ELECTRONICS LABORATORY I

LAB 2 Experiment Report

OPERATIONAL AMPLIFIER IMPERFECTIONS AND APPLICATIONS

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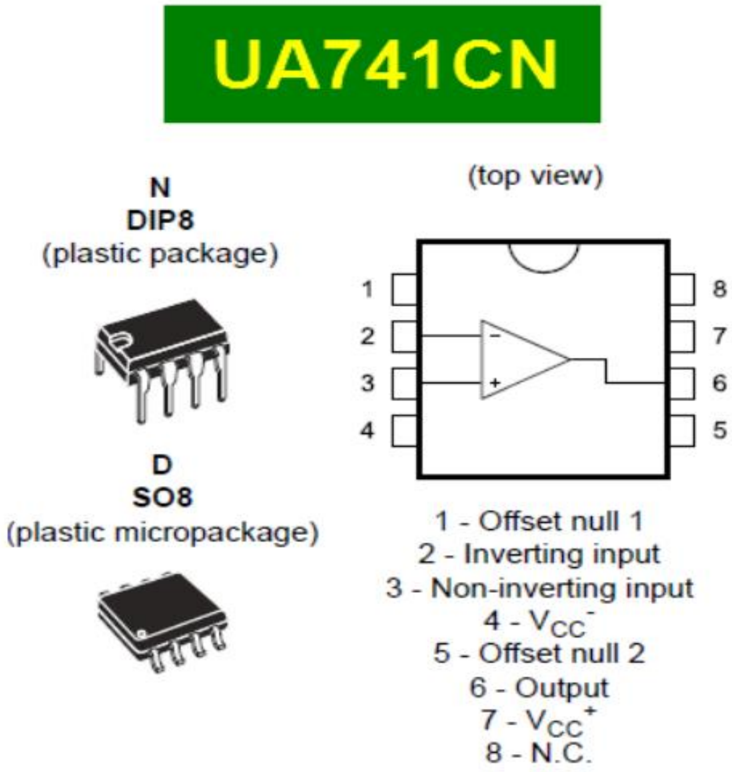


Figure 1. UA741CN Opamp with pin connections.

- An **operational amplifier** (often **op amp** or **opamp**) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op amp produces an output potential (relative to circuit ground) that is typically 100,000 times larger than the potential difference between its input terminals. Operational amplifiers had their origins in analog computers, where they were used to perform mathematical operations in linear, non-linear, and frequency-dependent circuits.

- The popularity of the op amp as a building block in analog circuits is due to its versatility. By using negative feedback, the characteristics of an op-amp circuit, its gain, input and output impedance, bandwidth etc. are determined by external components and have little dependence on temperature coefficients or engineering tolerance in the op amp itself.

- Op amps are used widely in electronic devices today, including a vast array of consumer, industrial, and scientific devices. Many standard IC op amps cost only a few cents; however, some integrated or hybrid operational amplifiers with special performance specifications may cost over US$100 in small quantities. Op amps may be packaged as components or used as elements of more complex integrated circuits.

1.Voltage and Current Offsets

1.1 Offset Measurement:

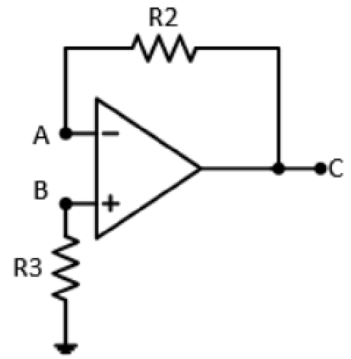


Figure 2. A circuit for the measurement of offsets.

Assemble the circuit as shown in Figure 2. Adjust the power supplies to ±10V. Measure V_C for R_2=R_3=1MΩ (Resistors should be matched within 2% tolerance). Then, short circuit R_3 and measure V_C and as R_3 is shorted, add R_1=1kΩ to ground from the negative input and measure V_C. Put your measurement results to Table 1.

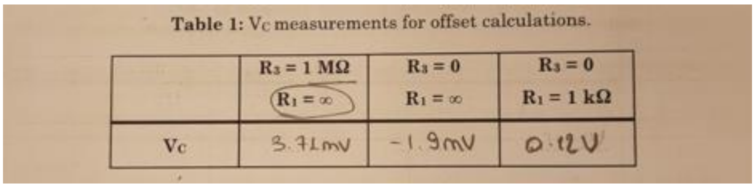


Table 1: V_C measurements for offset calculations.

	R_3 = 1 MΩ R_1 = ∞	R_3 = 0 R_1 = ∞	R_3 = 0 R_1 = 1 kΩ
V_C	3.71mV	-1.9mV	0.12V

Figure 1 experiment output for table 1

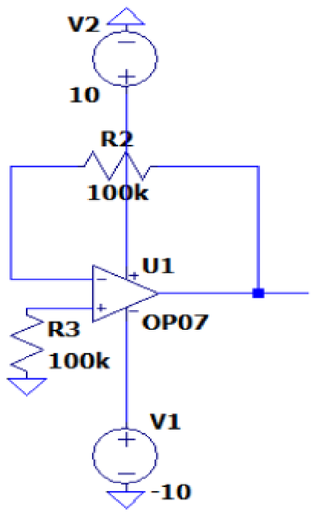


Figure 2 LtSpice

- ✓ We assembled the circuit as shown in Figure 2. We set the power supplies to ±10V. We measured VC for R2=R3=1MΩ (Resistances must be matched within 2% tolerance). Next, we shorted R3 and measure VC and since R3 is short add R1=1kΩ from negative input to ground and we measured VC. We put your measurement results in Table 1.

	R3 = 1 MΩ && R1 = ∞	R3 = 0 && R1 = ∞	R3 = 0 && R1 = 1 kΩ
VC	0 volt	0 volt	0 volt

Table 1

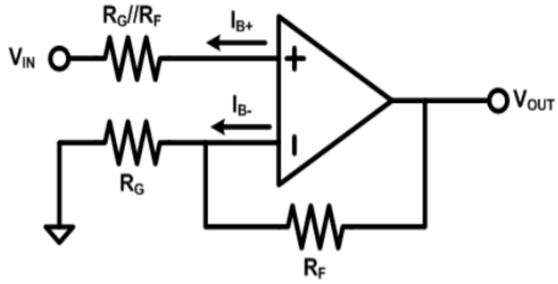


Figure 3

- ✓ **What is input bias current?**
- ✓ This is the current that flows in or out of the input pins. The input pins are the base pins of the transistor (or gate pins in the case of FET inputs). In order for the input transistor to operate, the base current (I_B) must flow. This base current is the input bias current. In actual use, when a resistor with a high resistance (R_{IN}) is inserted at the input, the input bias current is used to express the input signal error.

- ✓ **What is input offset current (I_{IO}) of an operational amplifier?**
- ✓ There is a difference in the input current that flows in or out of each of the input pins, even if the output voltage of the operational amplifier is 0 V, due to the fact the pair characteristics (h_{FE},V_{BE}) of the differential transistor do not match. This difference is known as the input offset current (I_{IO}).

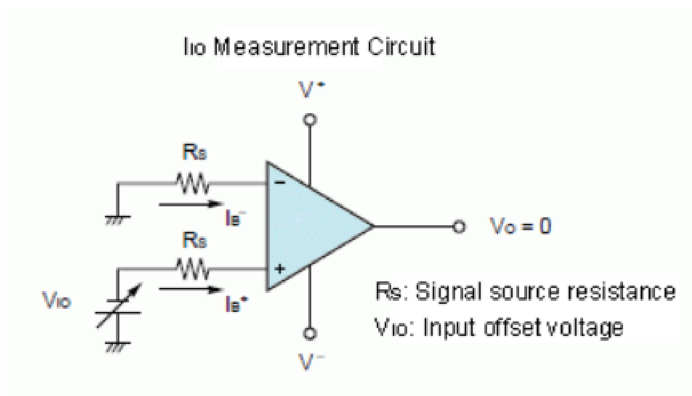


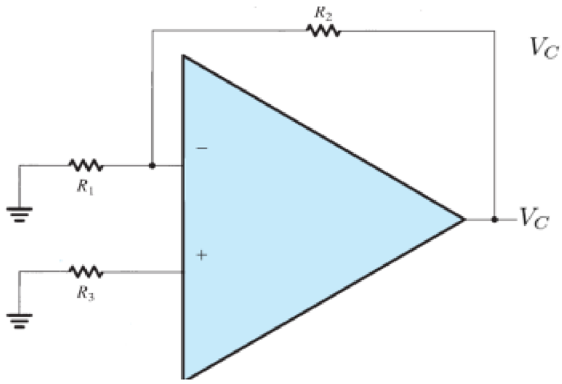
Figure 4

$I_{IO}=|I_B^+-I_B^-|$

✓ The drop in voltage that occurs due to this different current flowing through the signal source resistors (R_S) connected to the operational amplifier inputs causes the offset voltage to rise.

Note that the input offset current causes an error in the output value in the same way as the input offset voltage.

1. Calculations



$$V_C = -I_{B2}R_3 + R_2(I_{B1} - I_{B2}R_3/R_1)$$

Figure 5 formula (Sedra)

1. **When R3 = 1 MΩ, R1 = ∞**

   IOS = 20nA

   From the equation 2 VC is = 20mA.

2. **When R3 = 0, R1 = ∞**

   IIB = 80nA

   VC =80mV.

3. **When R3 = 0, R1 = 1 kΩ**

   VC = 80mV

- ✓ The first part of the experiment was tested both in the electronic environment and in the experimental environment. It has been observed that the obtained results are in agreement with each other. The results in the electronic environment were made for re-examination of the values. Input offset current and input bias current concepts are reinforced. Necessary research has been done and added to the report.

2.Compensated Miller Integrator

2.1 Integrator Offset Control:

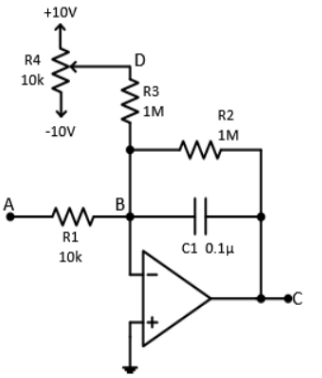


Figure 3: A compansated integrator.

- An **integrator** in measurement and control applications is an element whose output signal is the time integral of its input signal. It accumulates the input quantity over a defined time to produce a representative output.
- Integration is an important part of many engineering and scientific applications. Mechanical integrators are the oldest application, and are still used in such as metering of water flow or electric power. Electronic analogue integrators are the basis of analog computers and charge amplifiers. Integration is also performed by digital computing algorithms.

- ✓ We assembled the circuit as shown in Figure 3. We set the power supplies to ±10V.
- ✓ With node A open and measuring VC, we adjusted R4 to make VC = 0 V.
- ✓ Ground node A. We measured node C and node D.
- ✓ We measured node C. We adjusted R4 to make VC = 0 V. We measured the D node.

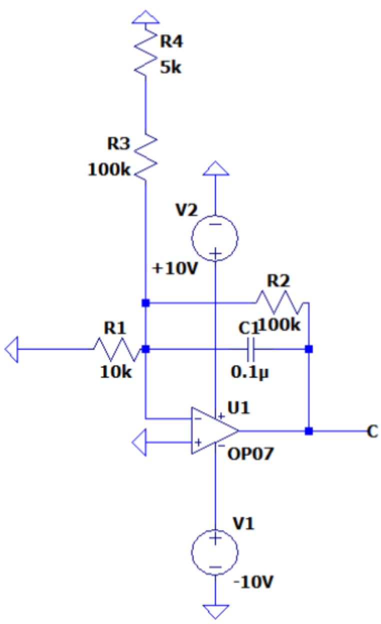


Figure 6 Ltspice for 2.1

Figure 7 2.a

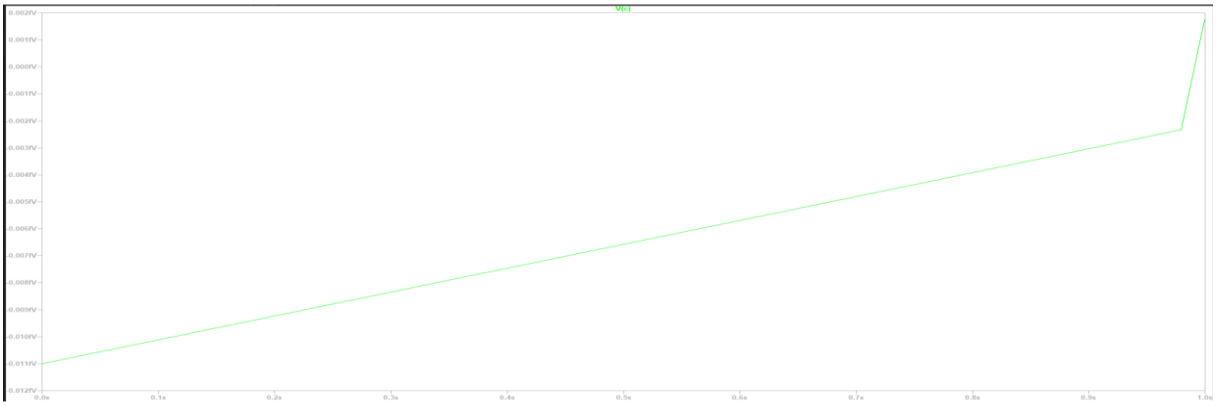


Figure 8 2.b

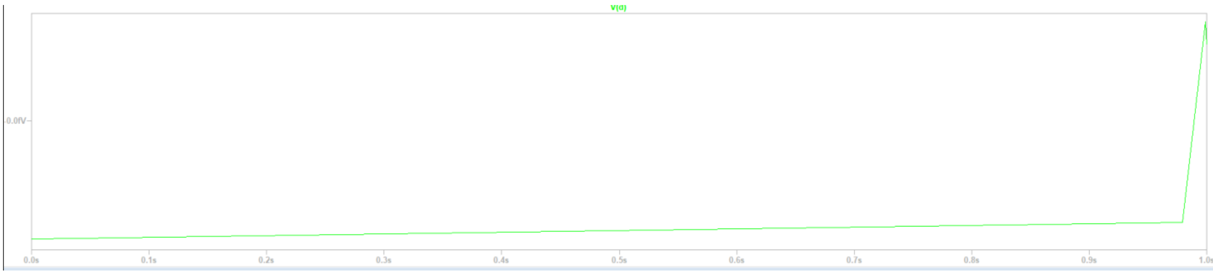


Figure 9 2.c

Table 3. Compensation measurements.

	a)	b)	c)
V_C	60 mV	−96.3mV	−100 mV
V_D	181 mV	1.08 mV	−2.37 V

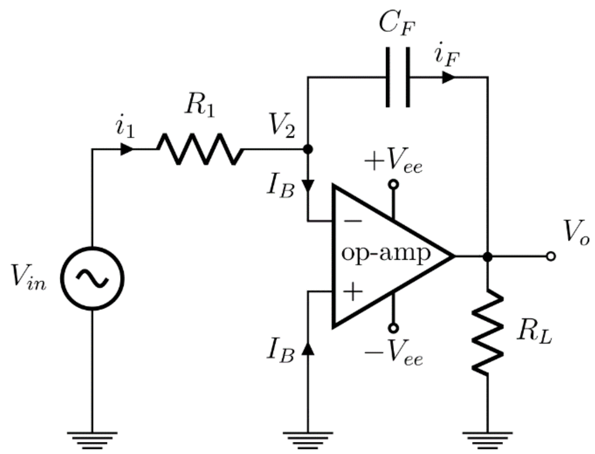
Figure 10 Experiment Results

2.1.1. Experiment Comment

A similarity was observed between the results of the experiment and the results of the circuit established in the electronic environment.

2.2.2. Integrator Operation

The **operational amplifier integrator** is an electronic integration circuit. Based on the operational amplifier (op-amp), it performs the mathematical operation of integration with respect to time; that is, its output voltage is proportional to the input voltage integrated over time. The integrator circuit is mostly used in analog computers, analog-to-digital converters and wave-shaping circuits. A common wave-shaping use is as a charge amplifier and they are usually constructed using an operational amplifier though they can use high gain discrete transistor configurations.



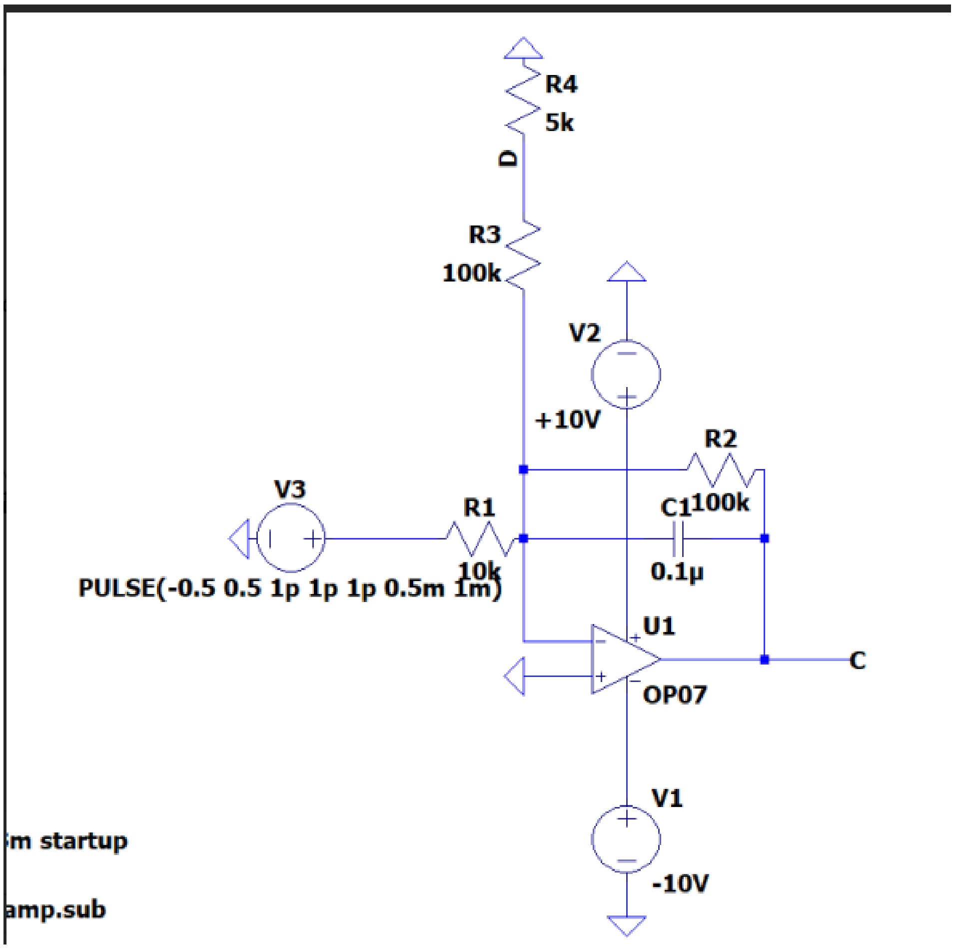


Figure 11 Ltspice

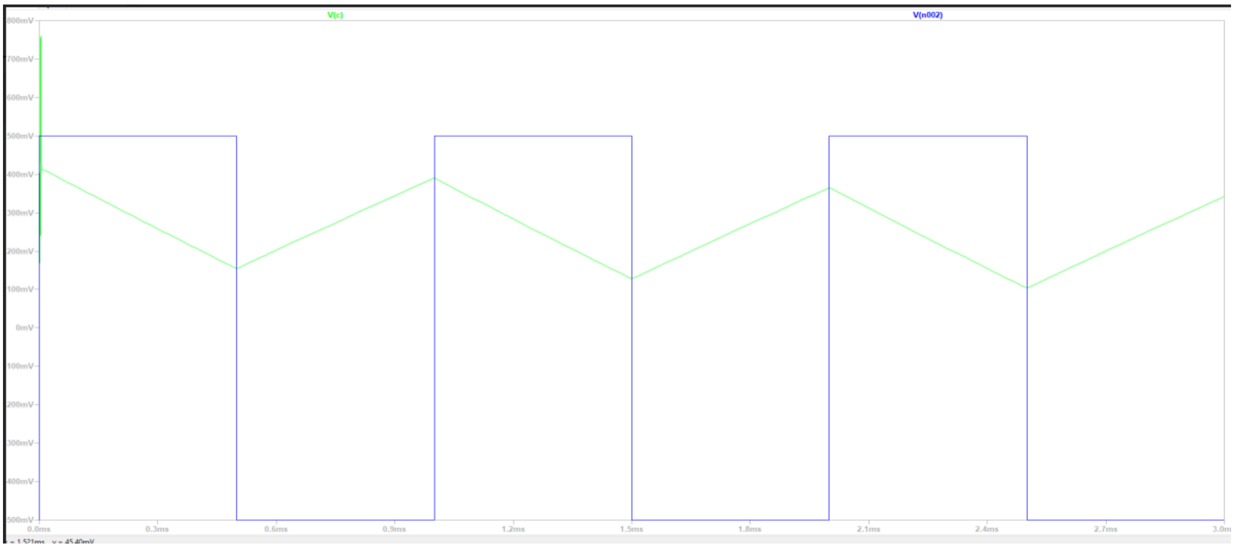


Figure 12 VA – VC

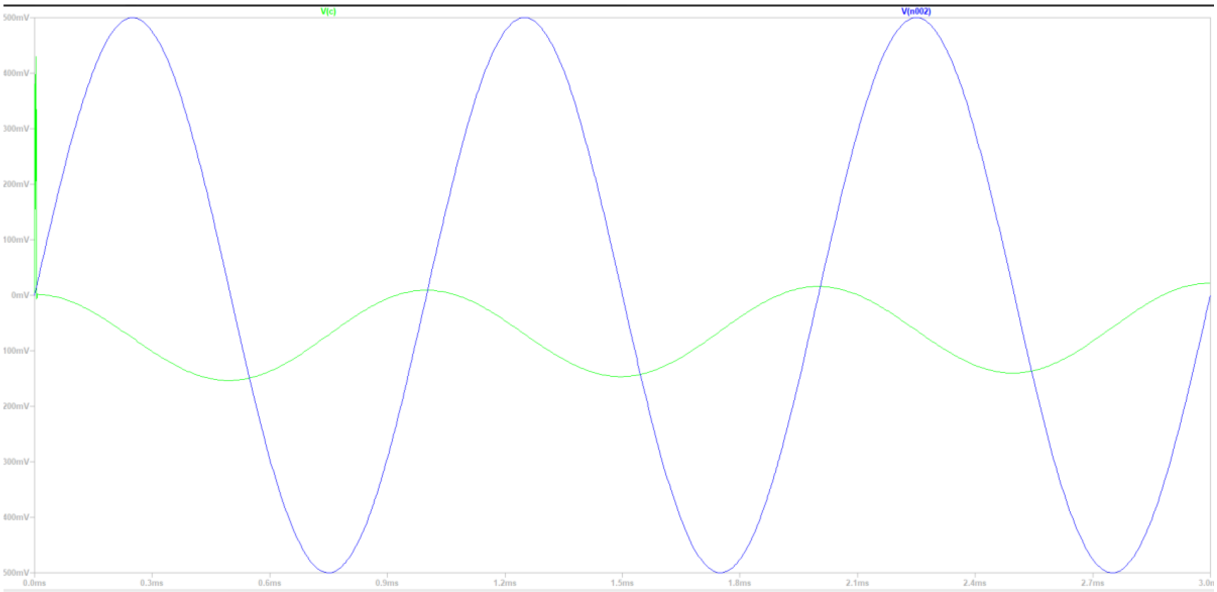
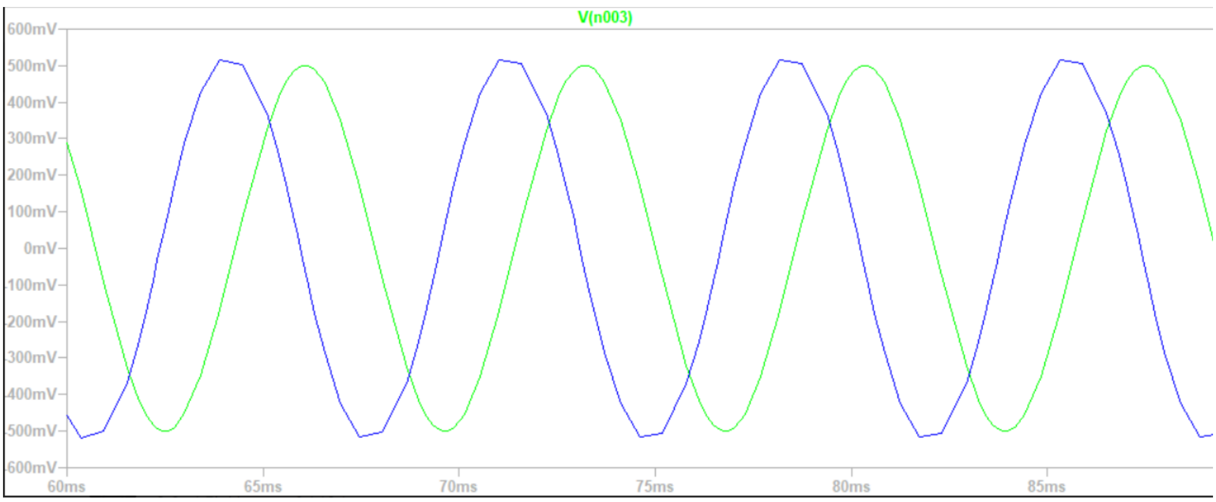
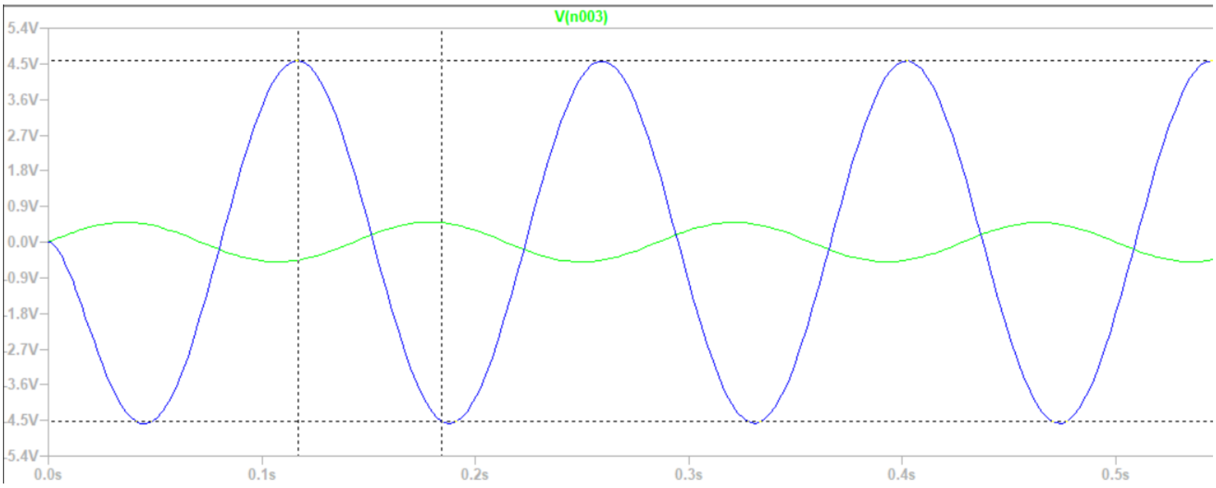


Figure 13 Graphics for experiment





f = 150 Hz φ = 84.24 °

f|Vc/Va| = 0.1 = 1.5kHz φ = 79.14°

f|Vc/Va| = 10 = 7 kHz φ = 38.60°

✓ The experiment could not be completed in the experimental setting. Therefore, the necessary circuit was established in electronic environment and waveforms were taken. Necessary calculations have been made at the report level.

3.Frequency Effects

3.1 Small Signal Frequency Response:

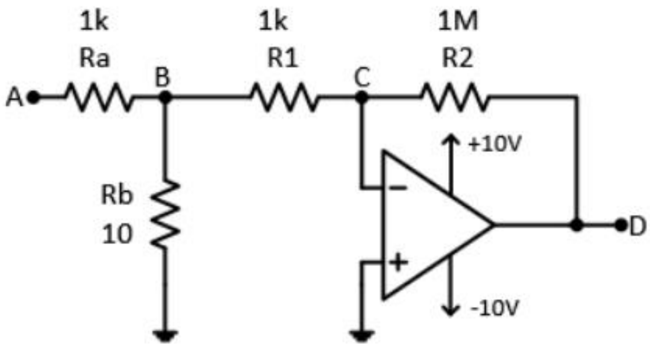
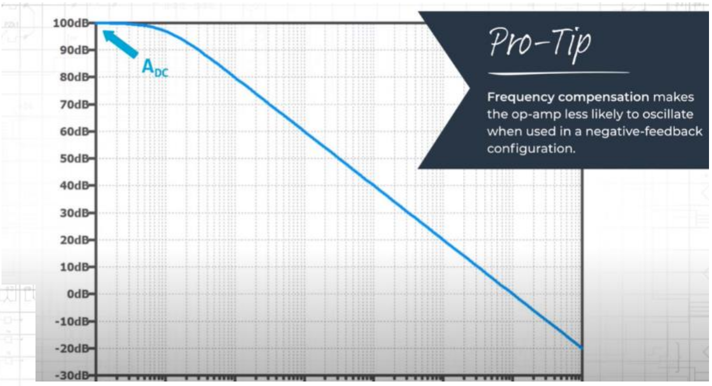
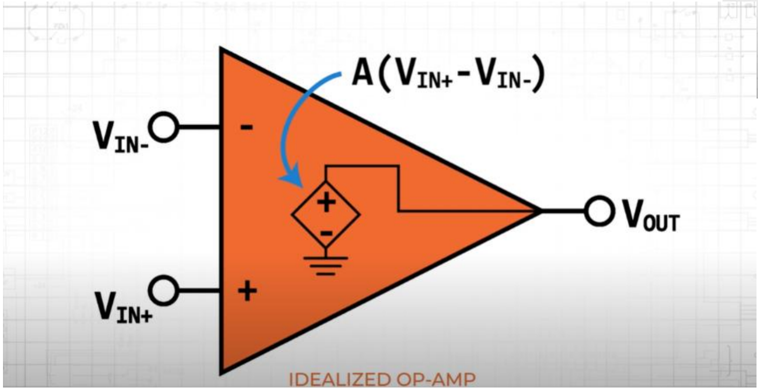


Figure 4. A high-gain inverting amplifier for frequency measurement.

Assemble the circuit as shown in Figure 4. We set the power supplies to ±10V.We connected a function generator to input A at 100 Hz. We measured nodes A and D. We adjusted the generator amplitude to provide a peak output of 2 Vpp at 100 Hz at the D node. We increased the frequency of the generator to the value at which vD was reduced by 3dB. (1/√2 = 0.707 of 100 Hz). We noted the frequency as f4. We increased the frequency to 10 f4. We measured the peak-to-peak output value.Change resistor R2 from 1MΩ to 100kΩ and repeat a), b), c).

- An op-amp starts to lose gain at a low frequency, but because its initial gain is so high, it can still function as an effective amplifier at higher frequencies.





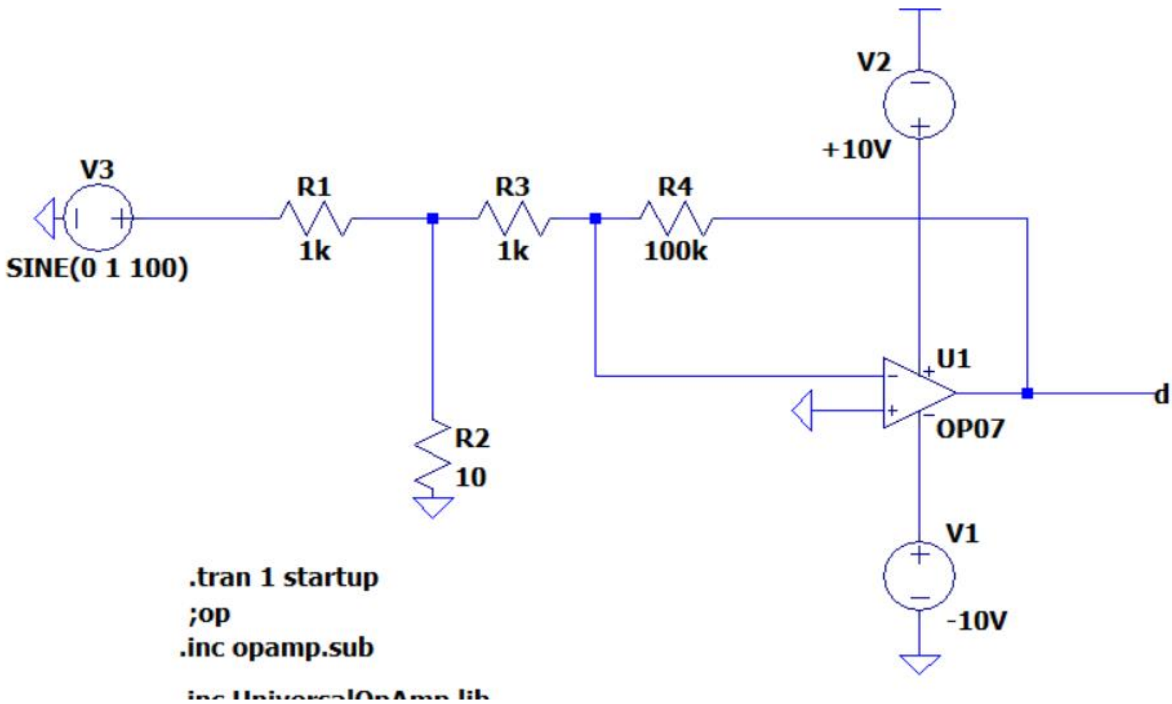


Figure 14 LtSpice

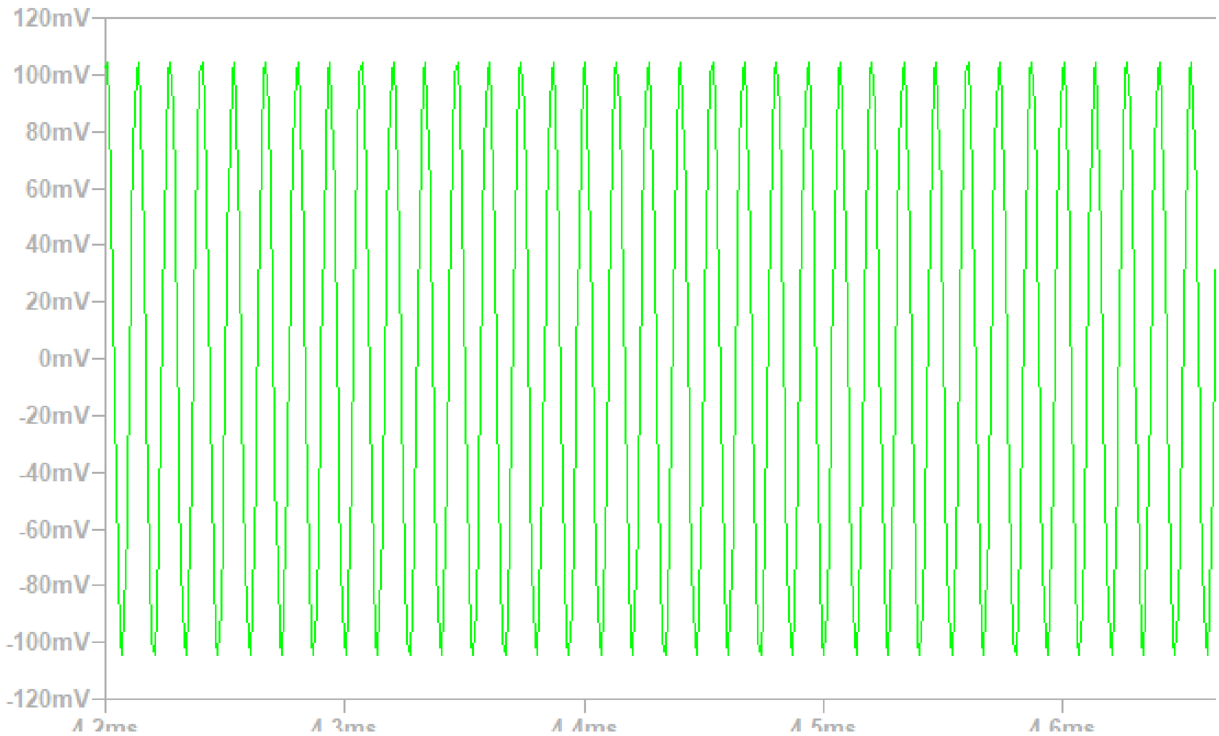


Figure 15 Small-signal frequency measurements for R2 = 1MΩ

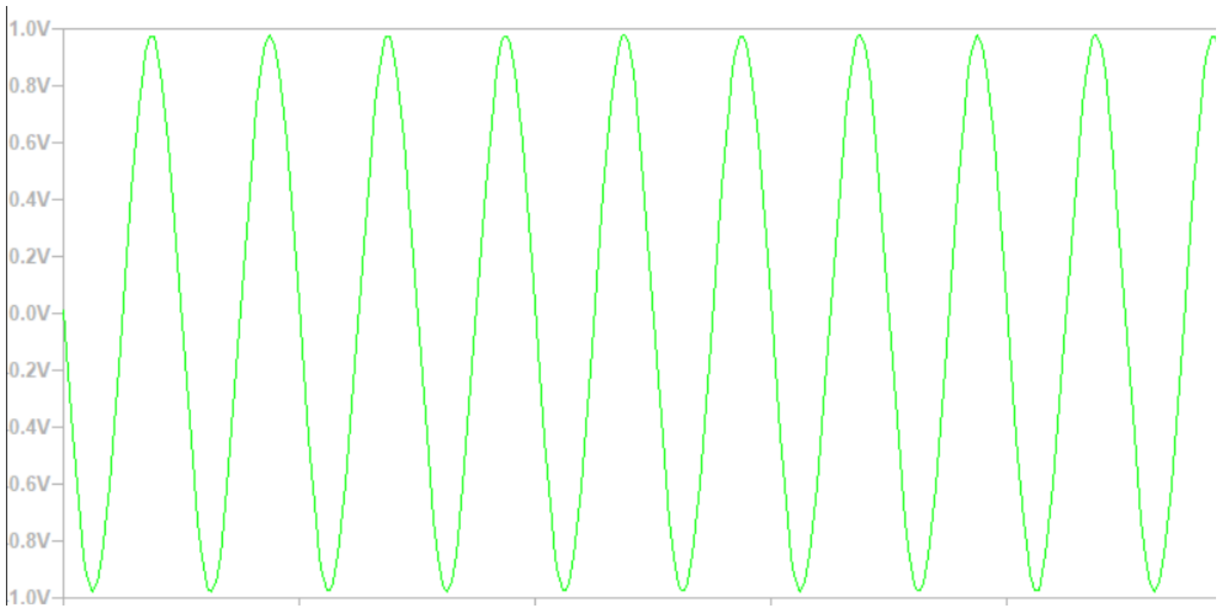


Figure 16 3.1a

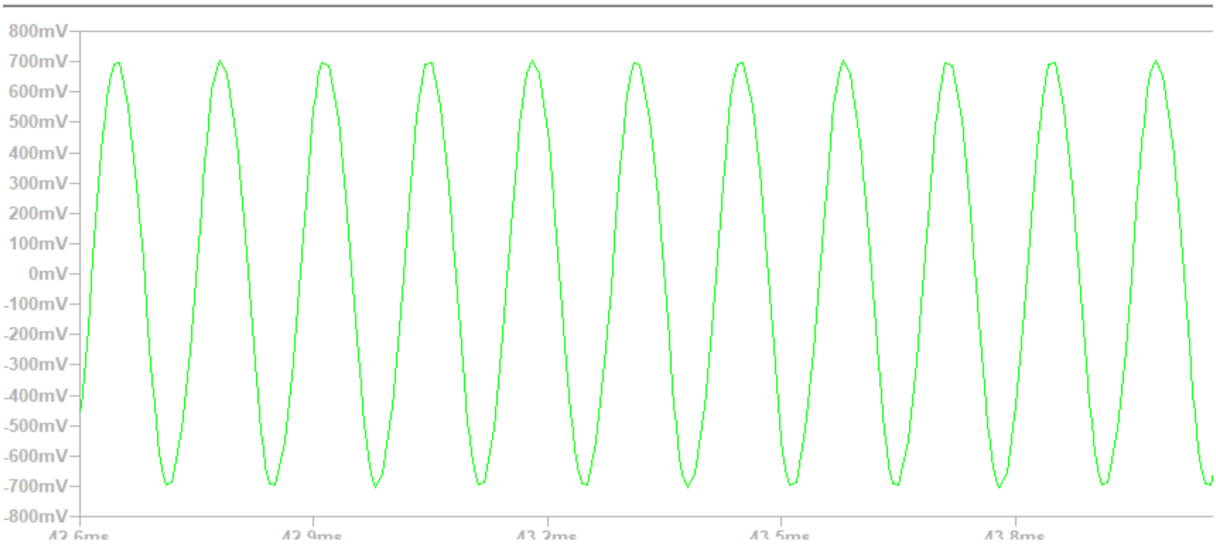


Figure 17 3.1b

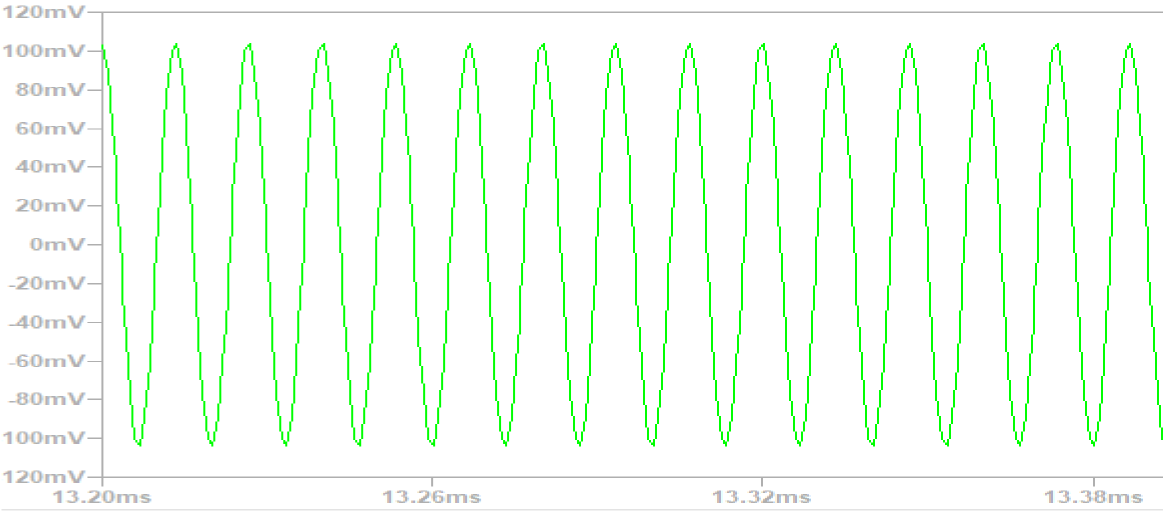


Figure 18 3.1c

R2 = 1 MΩ	a)	b)	c)
Va	2 Vpp	2 Vpp	2 Vpp
Vd	2 Vpp	0.707	4 Vpp4
f4	100 Hz	750 Hz	75 khz

Table 4. Small-signal frequency measurements for R2 = 1MΩ

R2 = 100kΩ	a)	b)	c)
Va	1	2 Vpp	2 Vpp
Vd	2 Vpp	0.707Vp	100 mV
f4	100 Hz	7.5 kHz	75k hz

Table 5. Small-signal frequency measurements for R2 = 100kΩ

Table 4. Small-signal frequency measurements for $R_2 = 1M\Omega$

$R_2 = 1M\Omega$	a)	b)	c)
VA	1.07Vpp	1.07Vpp	1.07Vpp
VD	2 V_{pp}	1.48 Vpp	0.26Vp
f_4	100 Hz	10KHz	10KHz

Experiment Results

3.2 Slew-rate limiting:

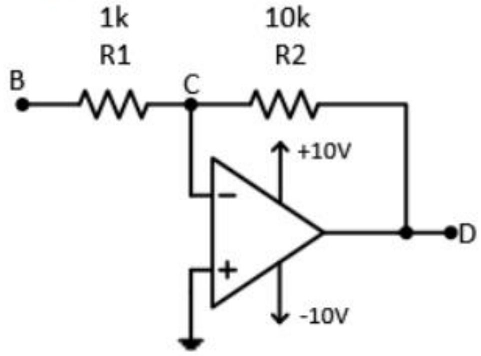
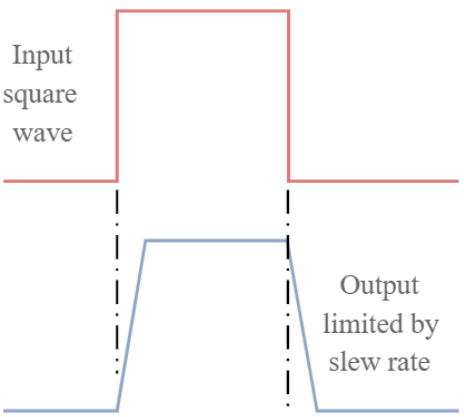


Figure 5. A circuit for evaluatig slew rate.



Effect of op amp slew rate

- **OPAMP SLEW-RATE**

- The output of an operational amplifier can only change by a certain amount in a given time. This limit is called the slew rate of the op-amp, and although slew rate is not always mentioned, it can be a critical factor in ensuring that an amplifier is able to provide an output that is a faithful representation of the input..

- Operational amplifier slew rate can limit the performance of a circuit if the slew rate requirement is exceeded. It can distort the waveform and prevent the input signal being faithfully represented at the output if the slew rate is exceeded.

- One of the figures quoted in the data sheets for operational amplifiers is the slew rate, and this needs to be checked and some calculations made to ensure that the particular op amp device can handle the output change rate demanded of it.

- In certain applications where speed is required and the output needs to change quickly, the slew rate of the operational amplifier can have a significant effect on the overall performance of the electronic circuit, and the design needs to accommodate this.

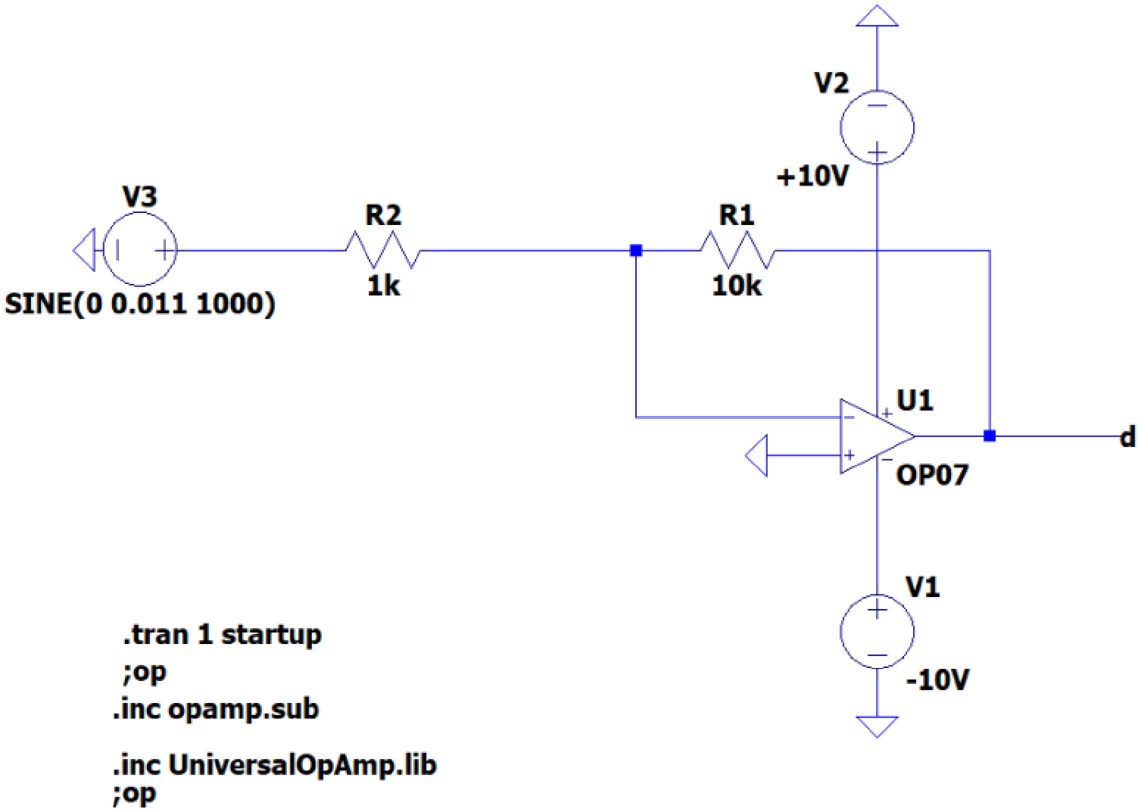


Figure 19 LtSpice

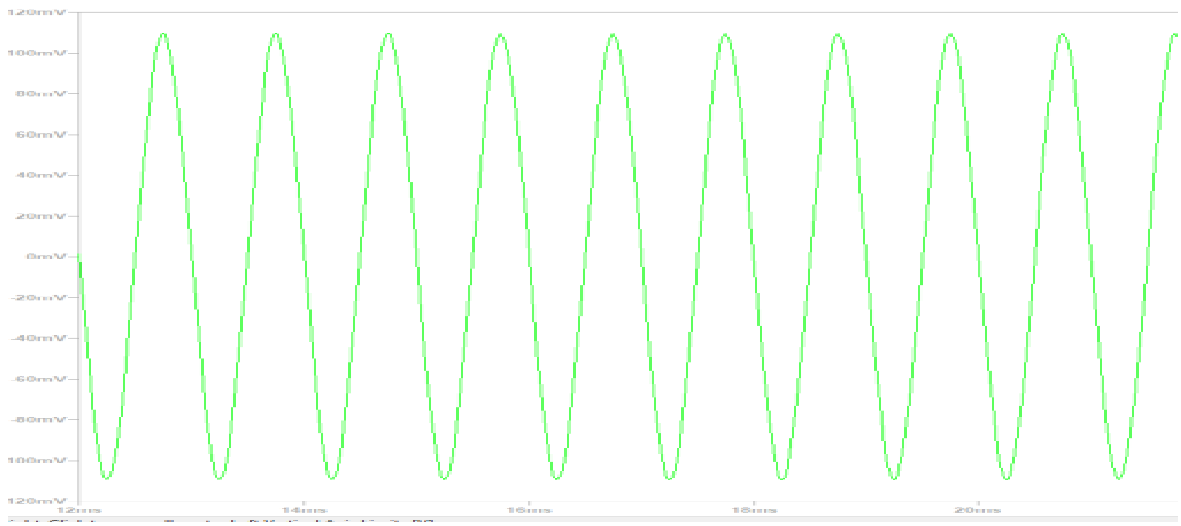


Figure 20 3.2a

Figure 21 3.2b

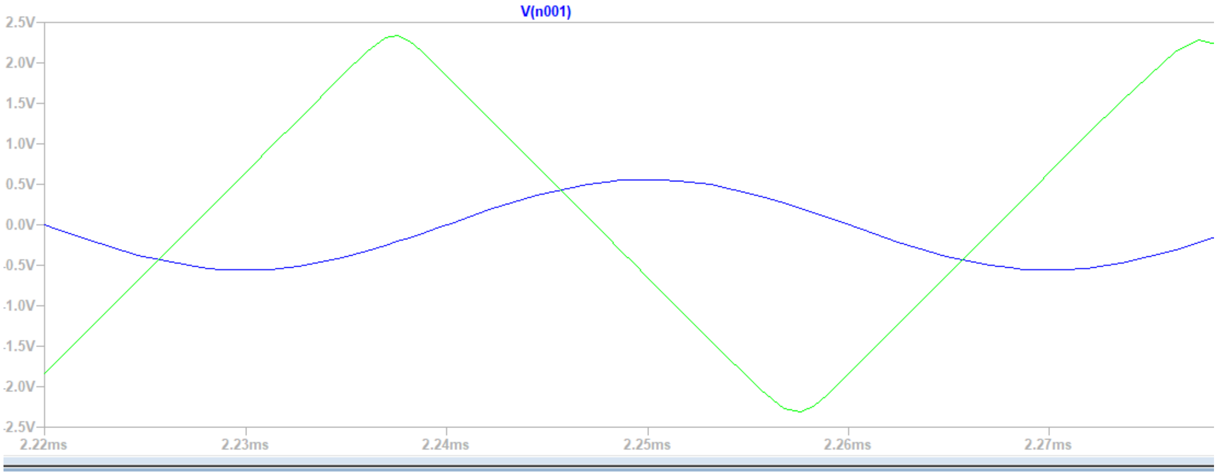
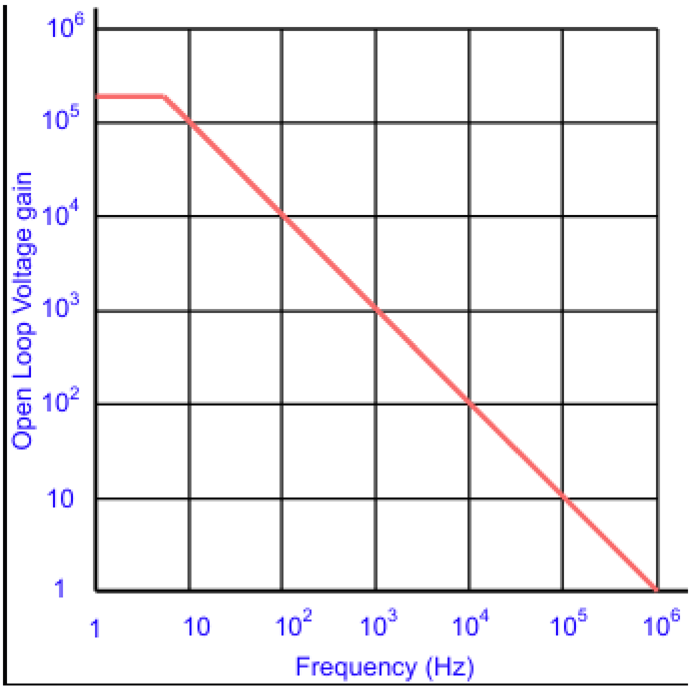
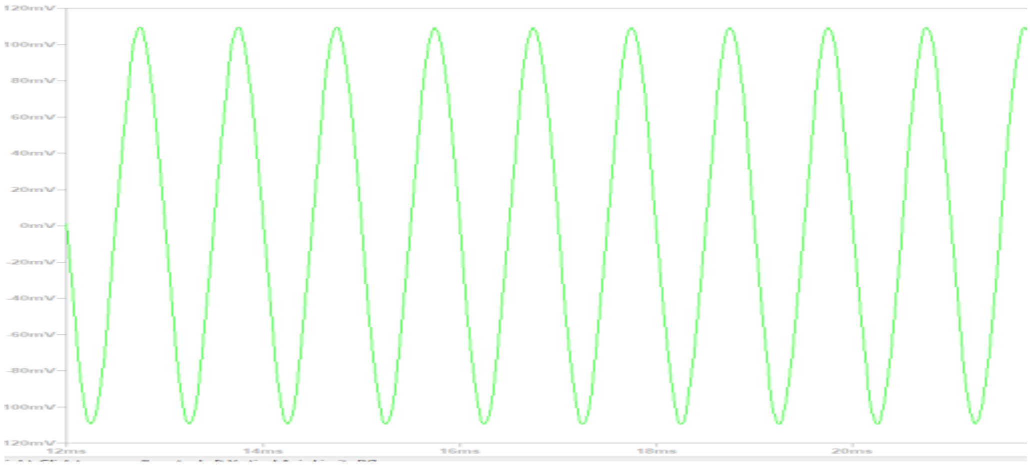


Figure 22 3.2c



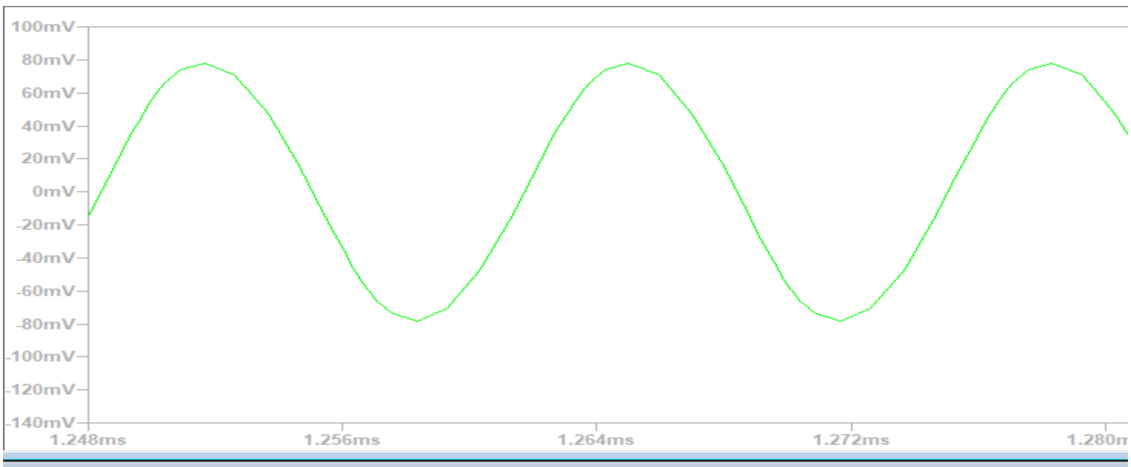
✓ **As seen in the experimental results, the gain decreases as the frequency increases.**

a) Measure nodes B and D. Adjust the generator amplitude to provide a peak output at node D of 0.2 Vpp at 1 kHz.



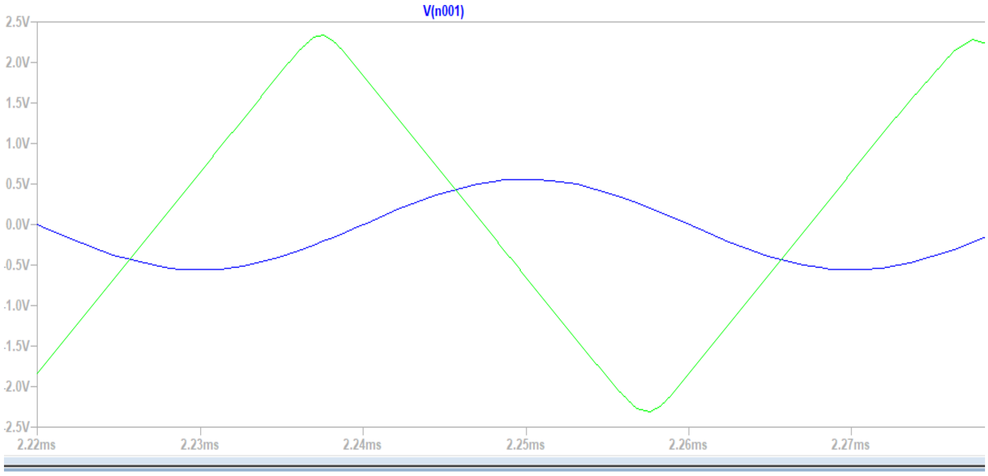
1) 0.2Vpp - Vd|||Vb = 24Vpp

b) Raise the frequency of the generator to the value at which vD is reduced by 3dB (to 1/√2 = 0.707 of its 1 kHz value). Note the frequency as f5. Verify that it's 100 times that in E3.1 b), namely 100 f4.



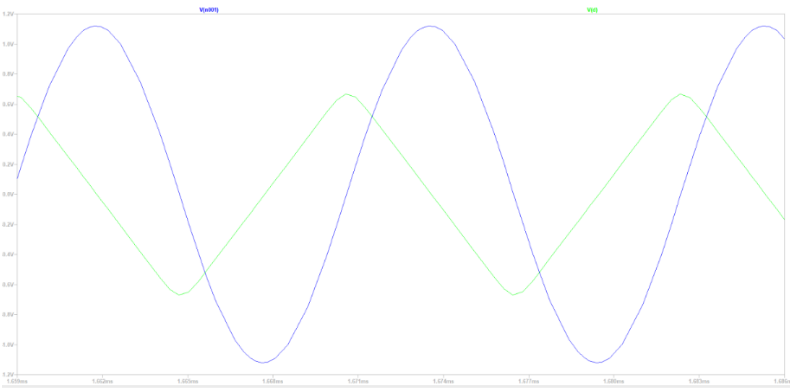
When f5 value is 75k, a decrease of 0.707 can be achieved. It has been confirmed to be as much as 100 f4.

c) Reduce the frequency to 1 kHz. Raise the input signal amplitude until vD reaches 8 Vpp. Note vB.



3)Vb = 1.2Vpp && Vd = 8Vpp

d) Keeping vB fixed and observing vD, raise the frequency until vD falls to 0.707 of its low-frequency value. Note the frequency as f6; Sketch the waveform.



4) f6 = 29 kHz

e) Lower vB to half its former value. What does vD become?

Vd = 5.12 Vpp

f) Raise the frequency to reduce vD to 0.707 of its value in e). Note the frequency as f7.

F7 =2.12 kHz

CONCLUSION

We started this experiment by talking about the opamp and its uses. We got information about the opamp named UA741CN. We tried to integrate the concepts of input bias current, input offset current, integrator, operational amplifier integrator, connection between opamp and frequency and SLEW-RATE into the experiment. We have both investigated and experimentally observed that the op amp has a time delay to respond to changes in its input, called the slew rate. We observed how the gain changes with increasing frequency. In addition to the measurements we made in the experimental environment, we reassembled all the circuits in the electronic environment and compared the measurements we took. We added the tables that we could fill in during the experiment to the report. We consolidated our knowledge by getting the chance to use the LtSpice environment again.

REFERENCES

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