CSE 251 : Eleketronic Devices & Circuits

Lab-2

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Group : 03

Semester : Summer 2024

Date of Performance : 13.6.24

Date of submission : 26.6.24

Group No: 3

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# Experiment-02

Study of Op-Amp: Introduction to Op-Amp and Comparator Circuits

CSE251 - Electronic Devices and Circuits Lab

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## Objective

1. To understand the basic principles and characteristics of an Operational Amplifier (Op-Amp)
2. To understand Operational Amplifier (Op-Amp) as a Comparator and investigate its use

## Equipment

1. Op-Amp (uA741)
2. Resistance ($1k\Omega, 2.7k\Omega, 10k\Omega$)
3. DC Power Supply
4. Function Generator
5. Trainer Board
6. Digital Multimeter
7. Breadboard, Chords and Wires

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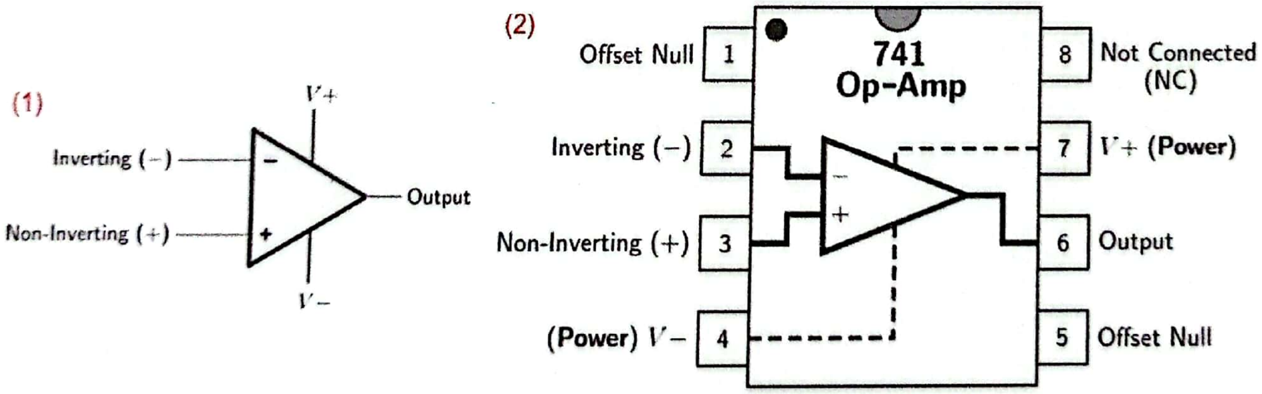
## Background Theory

### Introduction

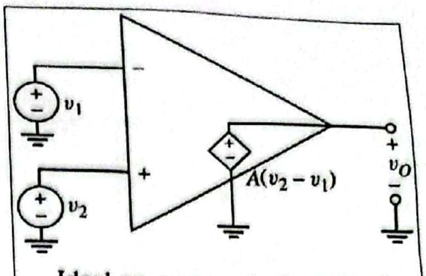



*(1) Op-Amp Simplified Circuit Symbol (2) Op-Amp IC Pin Diagram*

One of the most widely used electronic devices in linear applications is the Operational Amplifier, commonly known as the Op-Amp. An Op-Amp is an integrated circuit that amplifies the difference between two input voltages and produces a single output. We can also do various mathematical operations like addition, subtraction, multiplication, integration, differentiation etc. with the help of Op-Amp. With the addition of suitable external components, Op-Amp can be used for a variety of applications. The figure above shows the simplified circuit symbol of an Op-Amp. There are 2 terminals for input, 1 terminal for output and 2 terminals for powering up the Op-Amp. Inverting, Non-Inverting are the input terminals and $V_S^+$, $V_S^-$ are the terminals used for powering up the Op-Amp. $V_S^+$ is referred to as 'Positive Supply Voltage' and $V_S^-$ is referred to as 'Negative Supply Voltage'. The IC pin diagram of an Op-Amp is also shown where all of the terminals are labeled. Op-Amp is biased with dc supply voltages, although those connections are seldom explicitly shown.

## Ideal Op-Amp

The ideal Op-Amp senses the difference between two input voltages and amplifies the difference to produce an output voltage. The figure shown on the right side represents the equivalent circuit of an ideal Op-Amp and the circuit configuration is known as the open-loop configuration of Op-Amp. The parameter '$A$' shown in the equivalent circuit is the open-loop differential voltage gain of the Op-Amp. In an ideal Op-Amp, the open-loop gain '$A$' is very large value approaching infinity and there is no current flowing into the the input terminals. But in a real Op-Amp, a small amount of current flows into the input terminals and the open-loop gain ranges from $10^4$ to $10^5$ or higher. We will analyze the circuits using the ideal Op-Amp throughout this experiment.



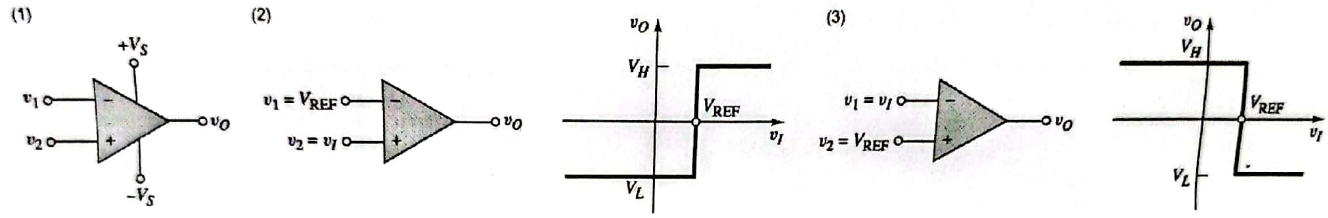
Ideal op-amp equivalent circuit

## Practical Considerations

Looking into the equation of the output, $v_O = A(v_2 - v_1)$, one may think that, we can get any voltage at the output of the Op-Amp. But the output voltage is limited since the Op-Amp is composed of transistors biased in the active region by the dc supply voltages $V_S^+$ and $V_S^-$. When $v_O$ approaches $V_S^+$, it will saturate, or be limited to a value almost equal to $V_S^+$, since it cannot go beyond the positive bias voltage. Similarly, when the output voltage approaches $V_S^-$, it will saturate at a value almost equal to $V_S^-$.

## Op-Amp Comparator

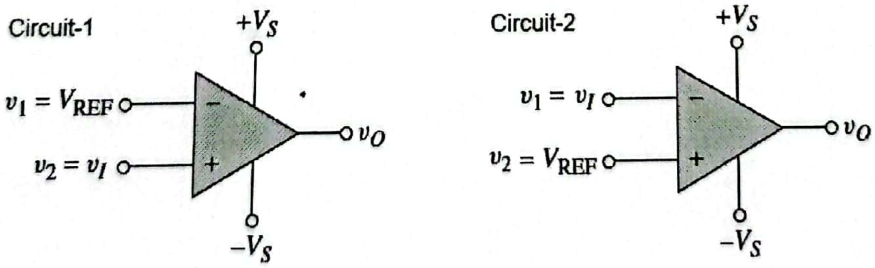
The comparator is essentially an op-amp operated in an open-loop configuration, as shown below:




*(1) Op-Amp Comparator (2) Non-inverting Circuit (3) Inverting Circuit*

A comparator compares two voltages to determine which one is larger. Comparator is usually biased at voltages $V_S^+$ and $V_S^-$, although other biases are also possible. When, non-inverting input > inverting input then, $v_O = V_S^+$. When, inverting input > non-inverting input, i.e. $v_1 > v_2$ then, $v_O = V_S^-$. The figures above show two comparator configurations along with their voltage transfer characteristics to illustrate the behaviour of a comparator with $V_{REF}$ as reference voltage which can be controlled to get the desired output.

# Task-01: Input, Output Waveform of Op-Amp Comparator

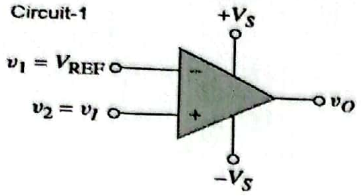



## Procedure

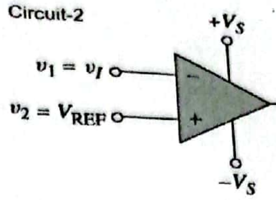
1. Construct *Circuit-1* with $v_I = 2$ V (p-p), 1 kHz sine wave and $V_{REF} = 0.5$ V. Use the trainer board for the supply voltages, $V_S^+ = +8V$ and $V_S^- = -8V$ and use these supply voltages for the next tasks.
2. **The ground of the oscilloscope, trainer board and function generator should be connected.**
3. Connect CH1 and CH2 of the oscilloscope to $v_I$ and $v_O$ respectively. Observe the input and output waveform and capture them using a camera.
4. Now, construct Circuit-2 and repeat the experiment with same values given above. Observe the input and output waveform and capture them using a camera.

## Task-02: VTC of Op-Amp Comparator

Circuit-1




Circuit-2




### Procedure

1. Construct ***Circuit-1*** with $v_I = 2$ V (p-p), 1 kHz sine wave and $V_{REF} = 0.5$ V. Use the trainer board for the supply voltages, $V_S^+ = +8V$ and $V_S^- = -8V$.
2. **The ground of the oscilloscope, trainer board and function generator should be connected.**
3. Connect CH1 and CH2 of the oscilloscope to $v_I$ and $v_O$ respectively.
4. For Observing VTC we need to go to the XY mode:
   (a) Press the **Autoset** button → Push the **Position** knobs of both channels (i.e. push to zero).
   (b) Press the **Acquire** button → Press the **XY** button which can be found below the display → Press the **Triggered XY** button which can be found on the right side of the display.
   (c) Change the scaling and position of the plot using the **Scale** knob and **Position** knob of both channels respectively if you need.
   (d) Observe the VTC graph and capture it along with the measurements using a camera.
   (e) Increase the $V_{REF}$ and set it to 1 V, then observe the VTC graph and capture it along with measurements using a camera.
   (f) Next, decrease the $V_{REF}$ and set it to $-1$ V, observe the VTC graph and capture it along with measurements using a camera.
5. Now, construct Circuit-2 and repeat the experiment with same values given above and observe the VTC graph and capture it along with measurements using a camera.

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Signature of the lab faculty

## Task-05: Report

1. Cover page [include course code, course title, name, student ID, group, semester, date of performance, date of submission]
2. Attach the signed Data Sheet.
3. Attach the captured photos of all the waveforms you have observed in the oscilloscope.
4. Answer the questions of the Test Your Understanding section.
5. Add a brief Discussion regarding the experiment. For the Discussion part of the lab report, you should include the answers of the following questions in your own words:
   - What did you learn from this experiment?
   - What challenges did you face and how did you overcome the challenges? (if any)
   - What mistakes did you make and how did you correct the mistakes? (if any)
   - How will this experiment help you in future experiments of this course?


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
VPO
Visual Persistence Oscilloscope
GW INSTEK
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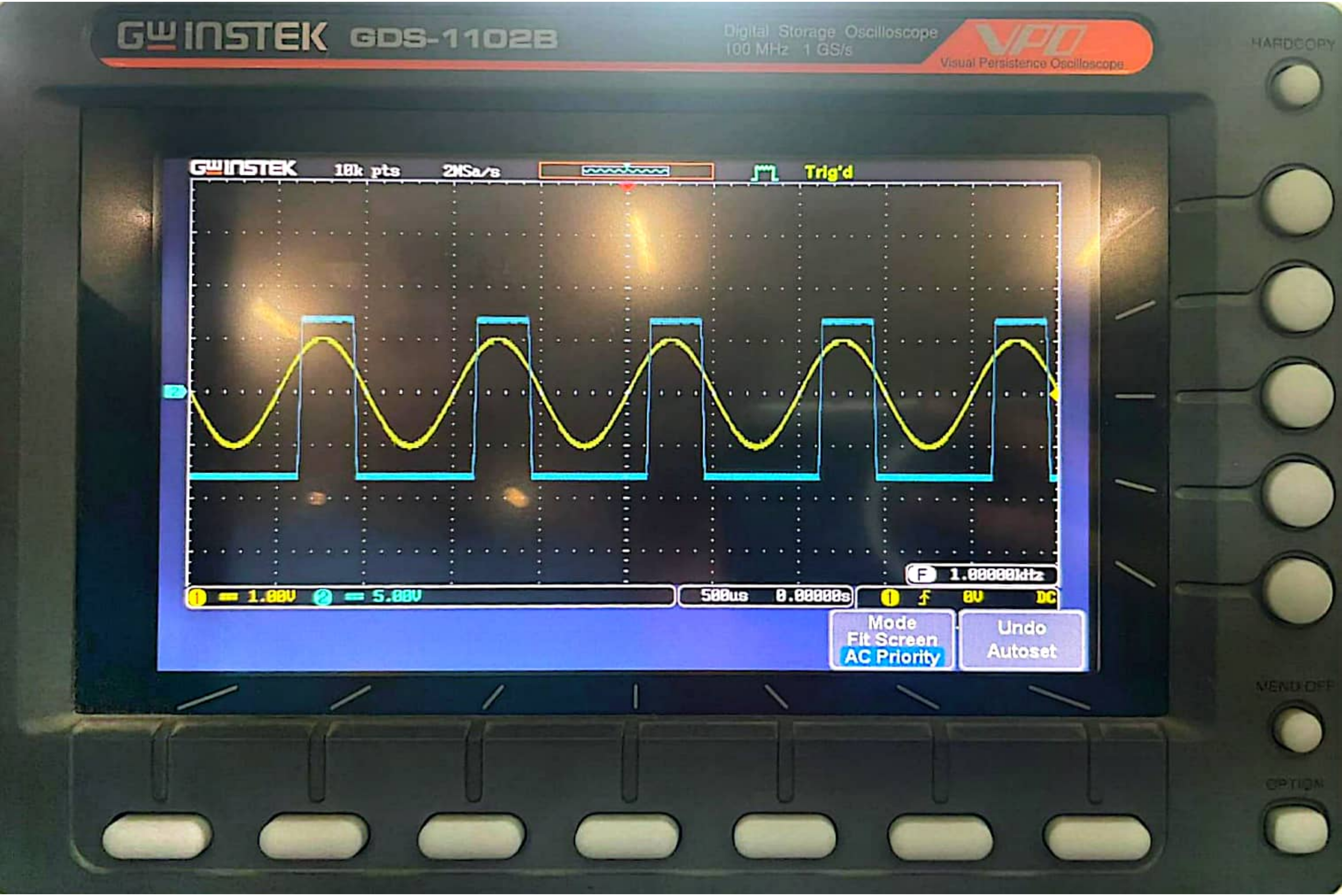
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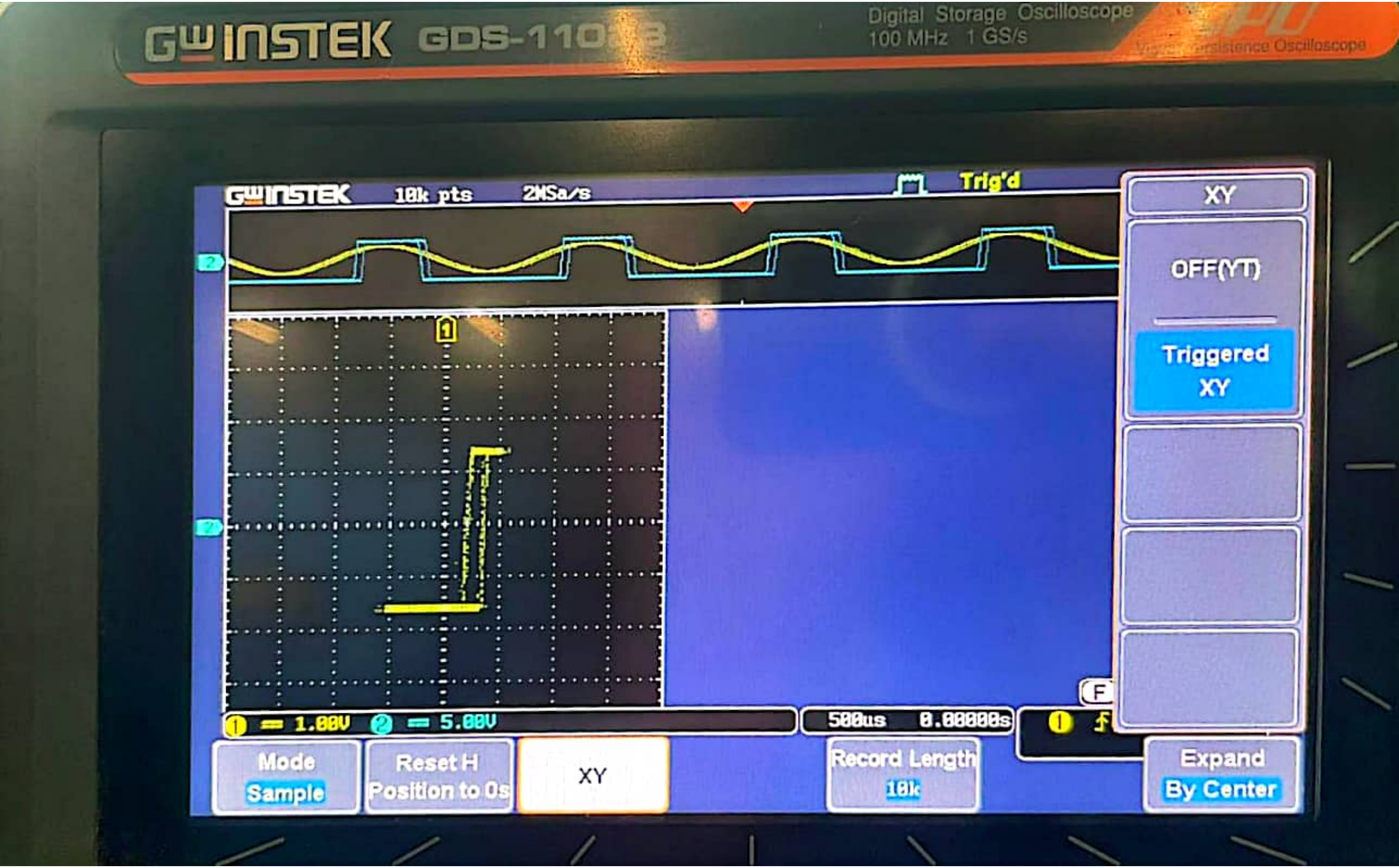

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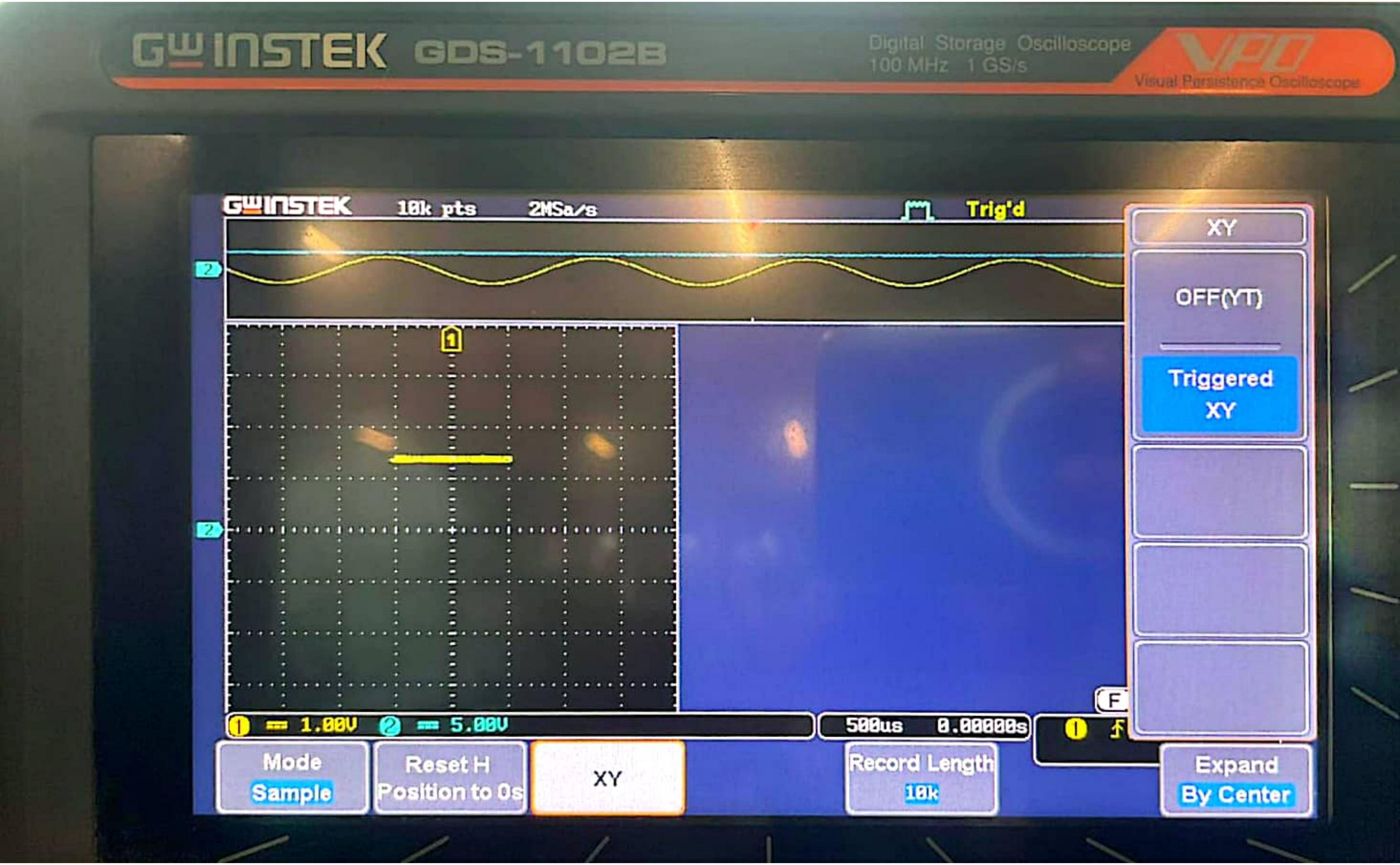
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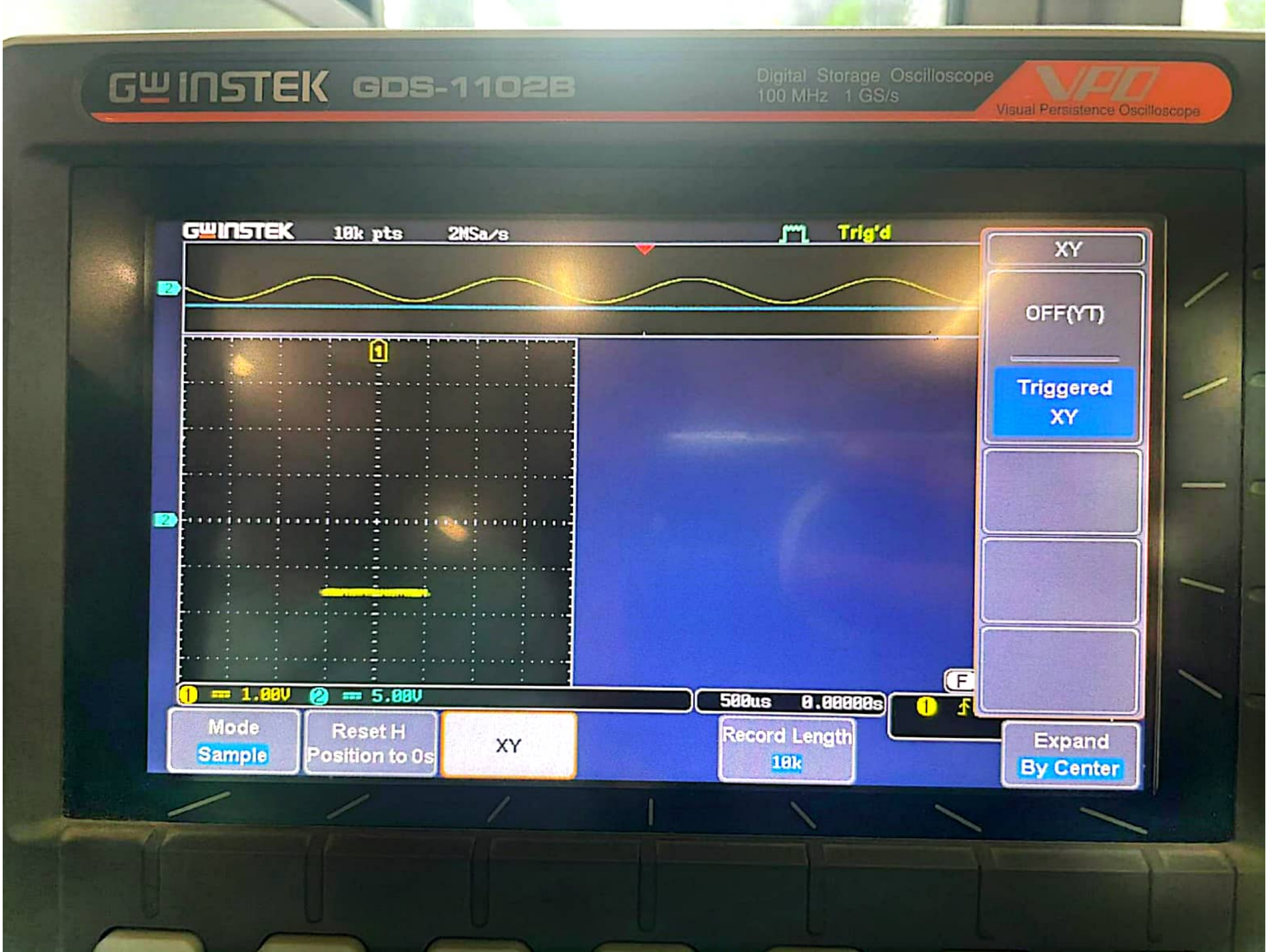
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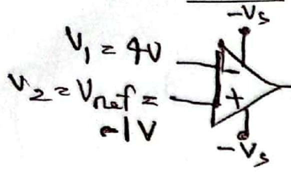
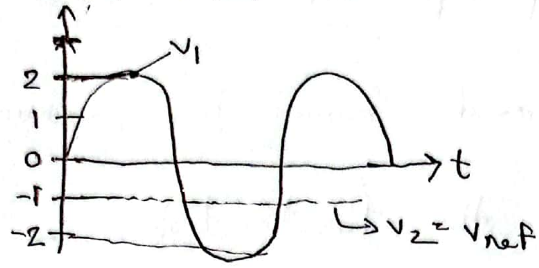
## Test Your Understanding

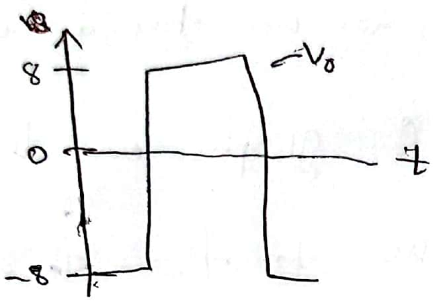
Answer the following questions:

1. You are given an Op-Amp comparator with $v_1$ = 4 V (p-p) sine wave and $v_2 = V_{REF}$ = -1 V. Draw the waveform of $v_1$, $v_2$ and $v_O$ in the same graph with proper labels.

**Answer:**

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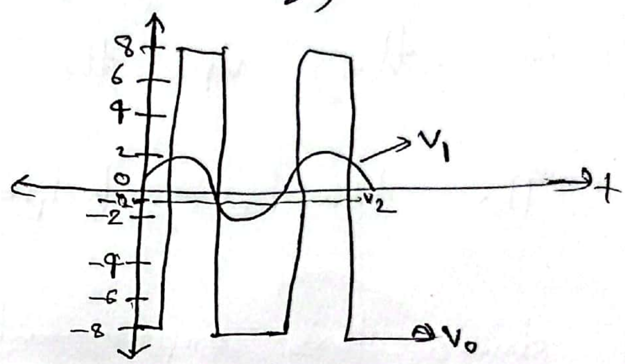
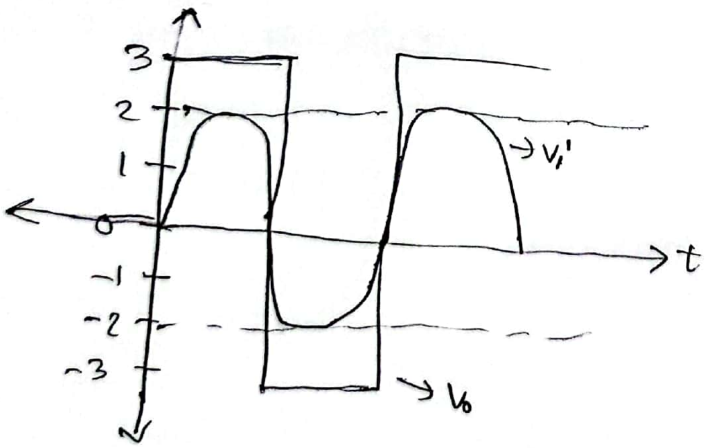



2. You are given an Op-Amp comparator with $v_i = 2\sin(t)$, where the two ends of the input voltage, $v_i$ (sinusoidal source) is connected to $v_1$ and $v_2$ of Op-Amp. Draw the waveform of $v_{AC}$ and $v_O$ in the same graph with proper labels.

**Answer:**



Discussion ! From this experiment, I learned about inverting, non-inverting Op-Amp and the way to detect it using a oscilloscope and how the waveforms differ from each other. In the first task, we did not face any problem. In the 2nd task, we faced some problem in setting up the VTC graph on the oscilloscope. The teachers helped us to fix the graph. By doing this experiment, we will be able to build advanced circuits for further more experiments in the future.