An oscilloscope is an electronic measuring device which provides a two-dimensional time-domain visual representation of electrical signals. In this experiment, you learn how to use a digital oscilloscope.

MANDATORY EXPERIMENTS

Experiment 1

Download the catalog of the lab oscilloscope. Review the catalog and describe the functionality of the major control groups on the oscilloscope including display group, vertical group, horizontal group, and trigger group.

Figure 1: Oscilloscope's front view.

Experiment 1 continued on next page...

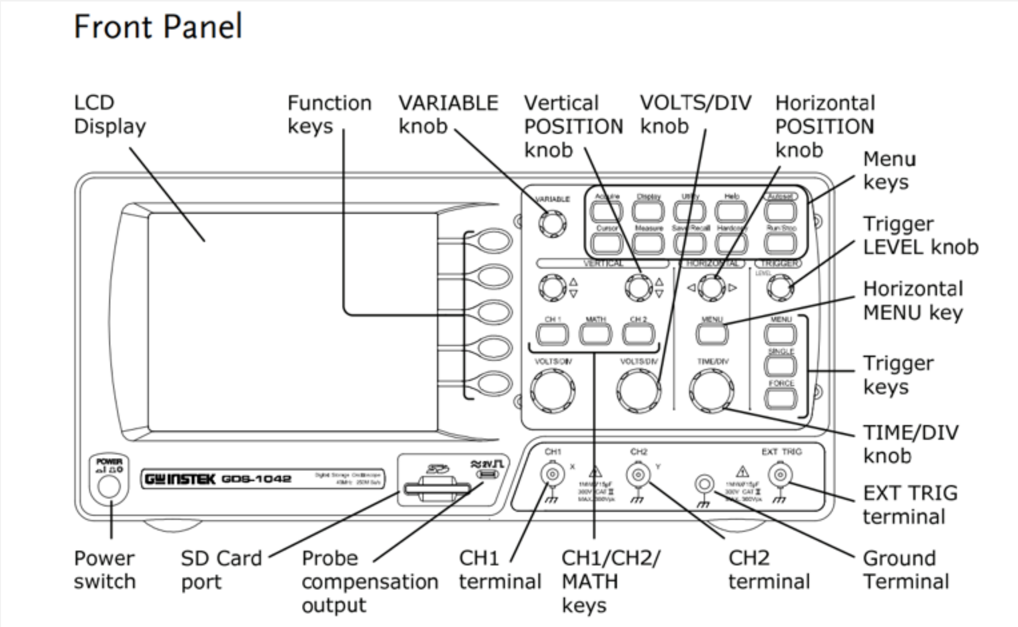

Figure 2: Oscilloscope's front panel buttons .

Display group: Display group includes lcd display and function buttons:
1- LCD display which is TFT color, 320 x 234 resolution, wide angle view LCD display.
2- Function keys(F1 (top) to F5 (bottom)): Are used to Activate the functions which appear in the left side of the LCD display.

Vertical group: Vertical group Includes following buttons and controllers:
1- Vertical position knob: Is used to move the waveform vertically.
2- VOLTS/DIV knob: Is used to select the vertical scale for the signal.
3- CH1/CH2 key: Are used to configure the vertical scale and coupling mode for each channel.
4- MATH key: Is used to perform math operations.

Horizontal group: Horizontal group Includes following buttons and controllers:
1- Horizontal position knob: Is used to moves the waveform horizontally.
2- Horizontal menu key: Is used to configures the horizontal view.
3- TIME/DIV knob: Is used to select the horizontal scale.

Trigger group: Trigger group Includes following buttons and controllers:
1- Trigger level knob: Is used to set the trigger level.Using the trigger level knob moves the trigger point up or down.
2- Single trigger key: Is used to select the single trigger mode
3- Trigger force key: Is used to acquire the input signal once regardless of the trigger condition at the time.

Experiment 2

Turn on the oscilloscope and set its channels to GND input mode. Use vertical position knobs to move and adjust the ground levels.

Figure 3: Channel 2 adjusted.

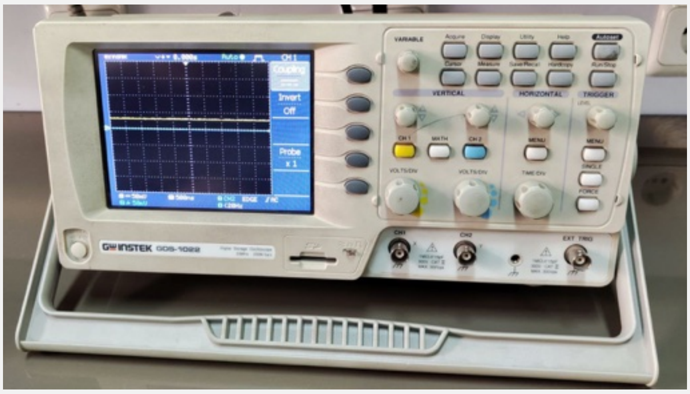

Figure 4: Both channels adjusted.

Experiment 3

Set the first channel to DC input mode while no signal is fed to its probe. Watch how the horizontal axis is swept. Change the time/div knob and see its impact on the sweep speed.

Experiment 3 continued on next page...

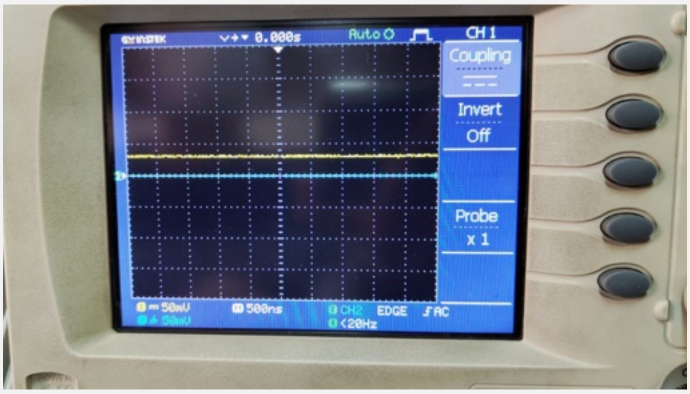

Figure 5: first channel DC mode.

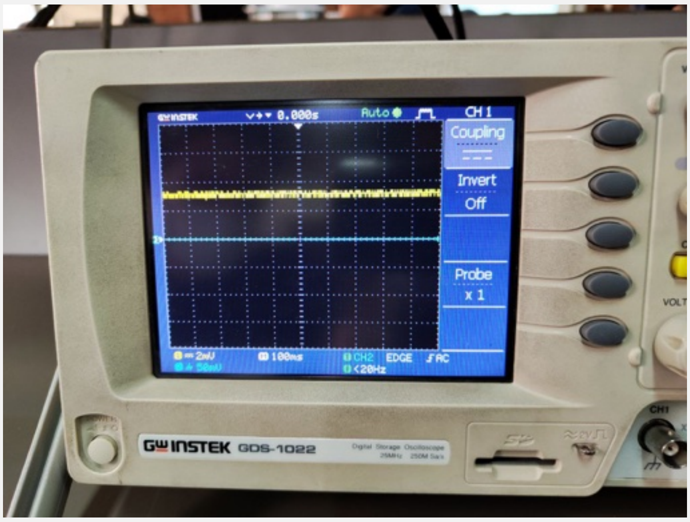

Figure 6: time/div set to 100ms.

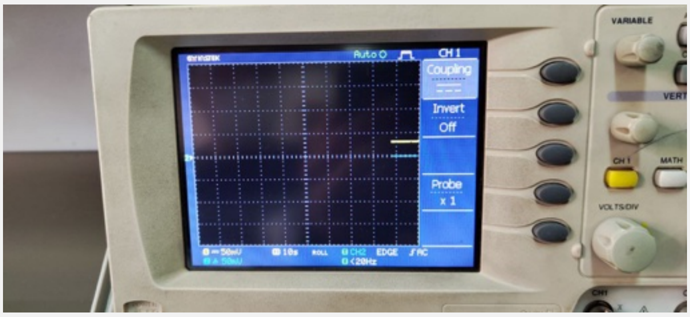

Figure 7: time/div set to 10s.

Experiment 4 continued on next page...

Experiment 4

Connect a probe to the oscilloscope and set the volt/div knob to its minimum. Touch the probe tip by your finger. What do see on the oscilloscope screen? Change in input mode to AC, DC, and GND and check the results.

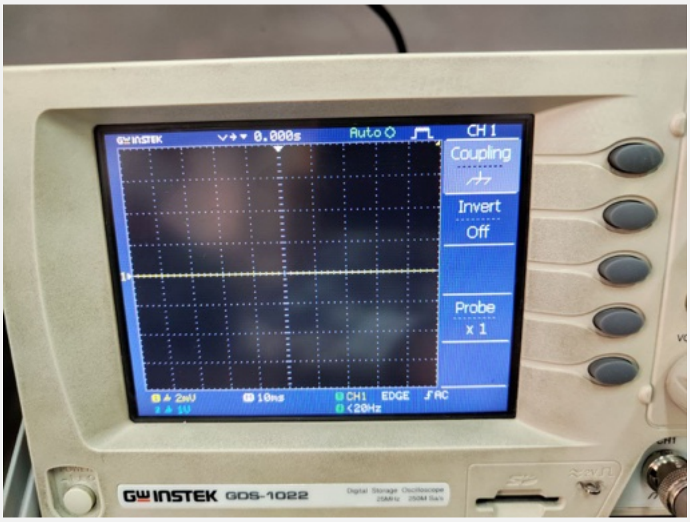

Figure 8: input mode set to GND.

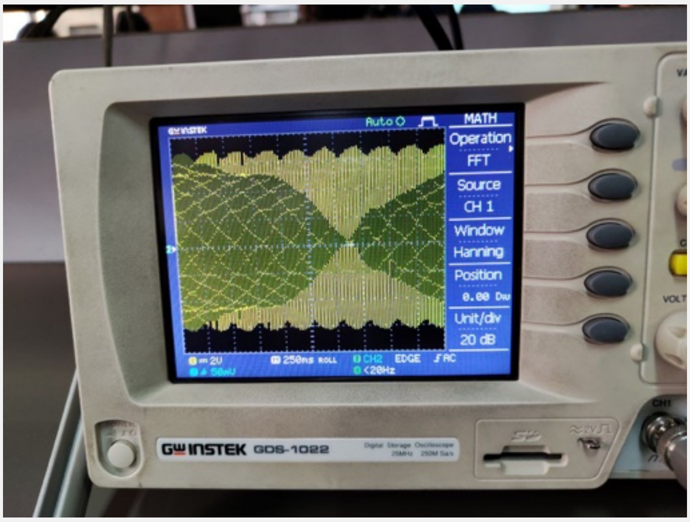

Figure 9: input mode set to AC.

Experiment 4 continued on next page. . .

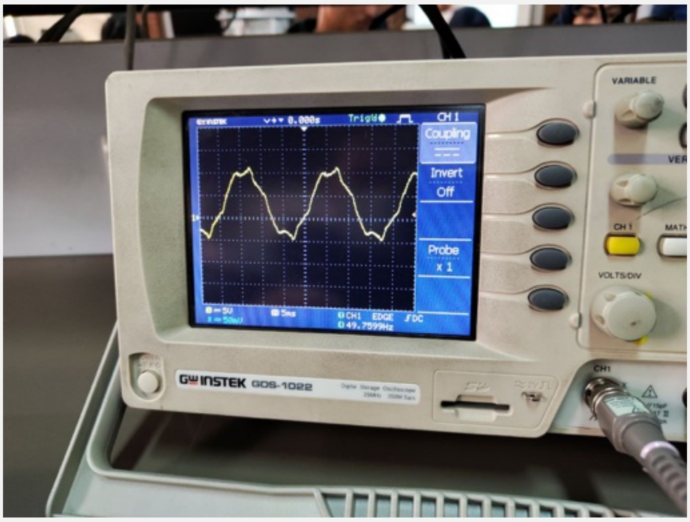

Figure 10: input mode set to DC.

Experiment 5

Connect a proper probe to the first channel of the oscilloscope and watch the calibrated signal of the built-in frequency generator. Read the frequency and amplitude of the calibrated signal. How can this signal be used for calibration check? What happens when the probe is set to 10X?

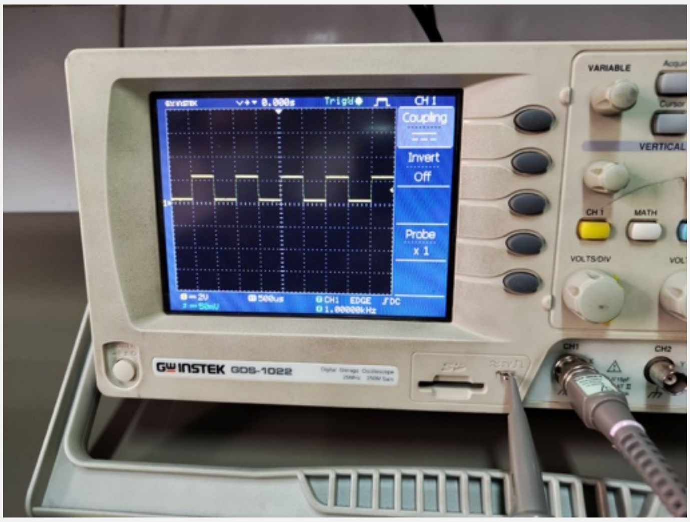

Figure 11: first channel connected to the oscilloscope calibrated signal generator.Pay attention to the channel error.

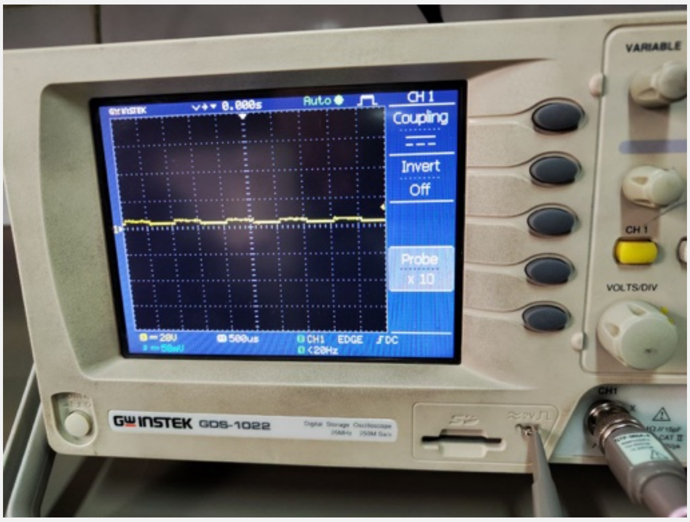

Figure 12: Probe set to 10X.

The frequency and amplitude of the calibrated signal are 1 KHz and 1 V respectively. This signal can be used for calibration check by comparing the signal with the calibrated signal. When the probe is set to 10X, the amplitude of the signal is reduced by a factor of 10.

Experiment 6

Set the controls of the function generator to produce a sine wave of 1 kHz frequency and 2 V amplitude. Use the oscilloscope to see the signal. Read the frequency and amplitude of the sine wave. Is there any difference between the read and set frequencies? Why?

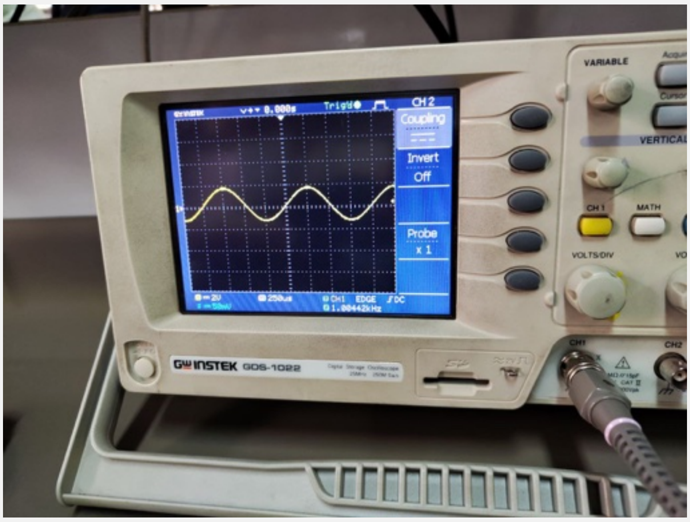

Figure 13: a sine wave of 1 kHz frequency and 2 V amplitude.

Figure 14: A picture of the function generator.

The read frequency is 1.004 KHz and the read amplitude is 2 V. The difference between the read and set frequencies is due to the errors that might occur in the function generator, during the signal transmission or in the oscilloscope. So it's hard to set the frequency and amplitude of the signal exactly the same as wanted.

Experiment 7

Add a DC offset to the sine wave in the previous part and check the corresponding signal on the oscilloscope screen in different input modes of DC, AC, and GND.

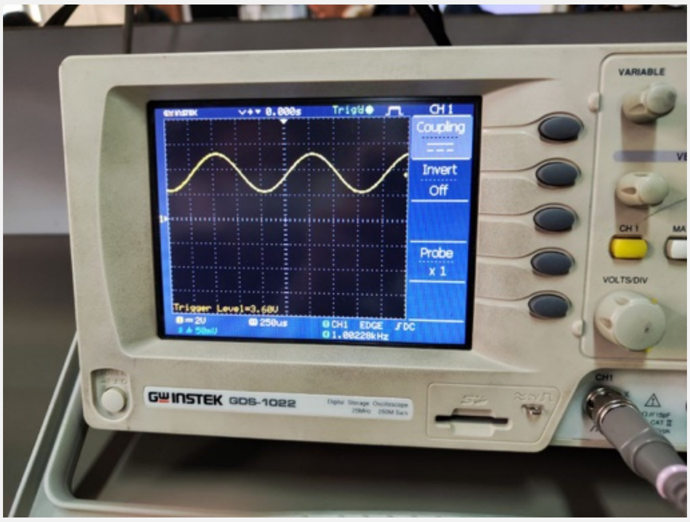

Figure 15: input mode set to DC.

Experiment 7 continued on next page...

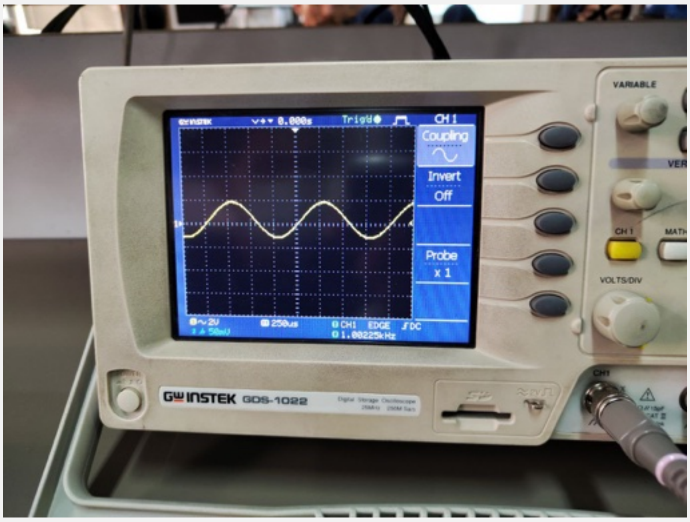

Figure 16: input mode set to AC.

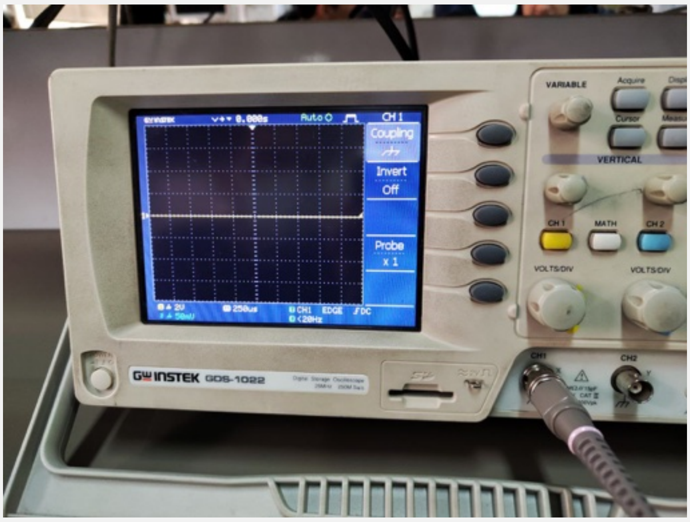

Figure 17: input mode set to GND.

Experiment 7 continued on next page...

Figure 18: Function generator offset changed.

Experiment 8

Feed the two channels of the oscilloscope by a same 1 KHz sine wave and investigate the functionality of the math operations such as Add and Inv.

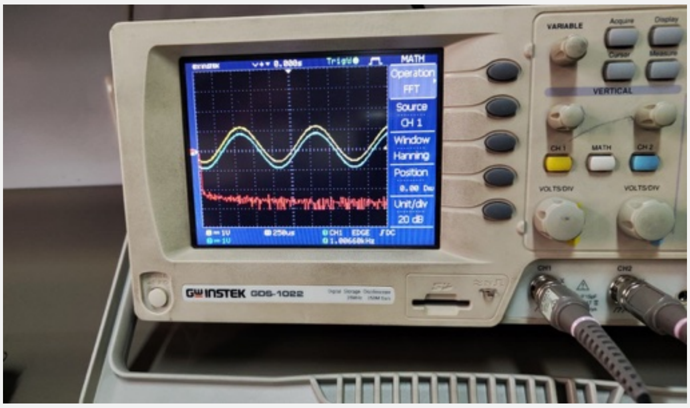

Figure 19: Both channels are fed with a single function generator. Pay attention to the first channel zero error.

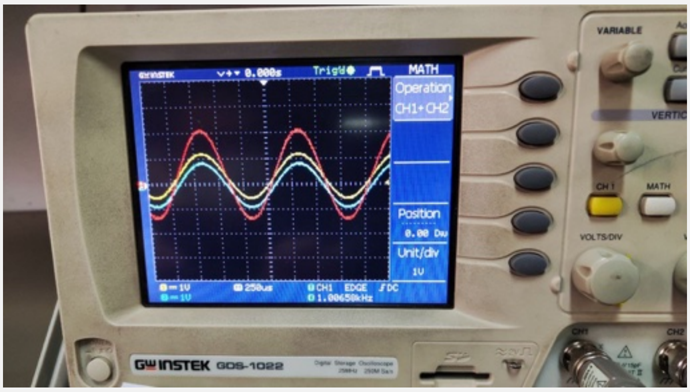

Figure 20: Add math function.

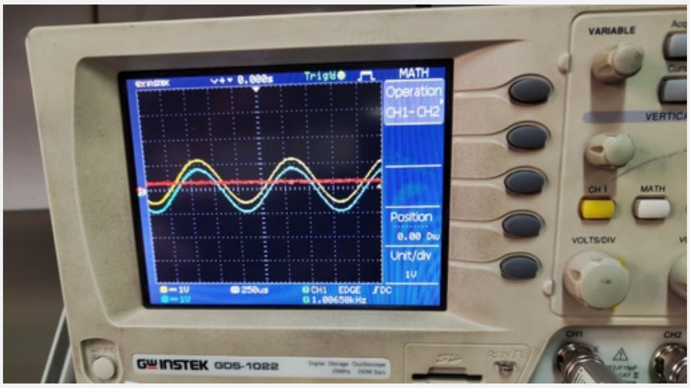

Figure 21: Inv math function.

Experiment 9

Repeat the previous part with two 1 KHz sine waves produced from two different function generators. Explain your observations.

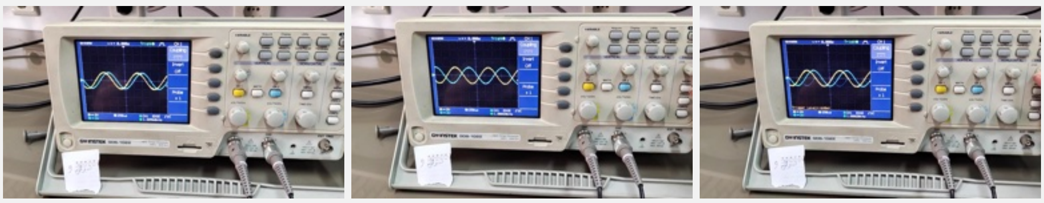

Figure 22: Two 1 KHz sine waves produced from two different function generators.

Experiment 9 continued on next page...

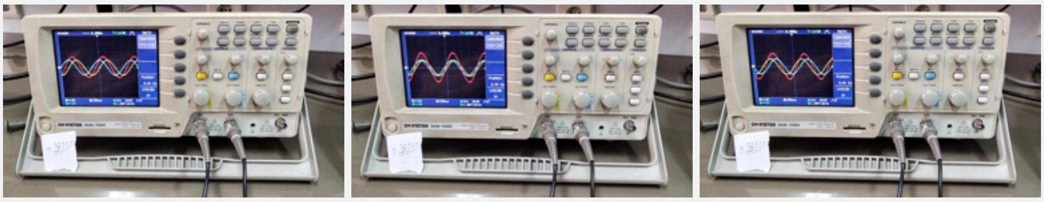

Figure 23: Two sine waves gathered with each other.

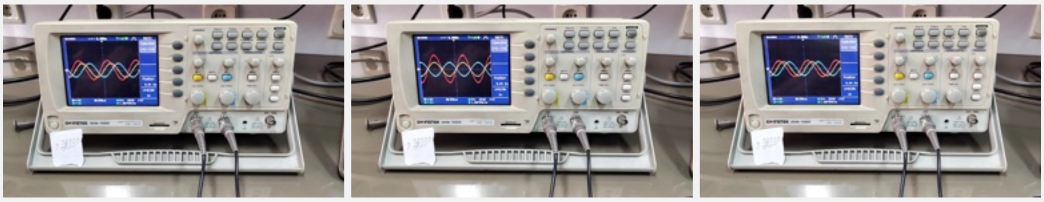

Figure 24: Two sine waves subtracted from each other.

The observed phenomenon in the oscilloscope display can be explained as follows: The first wave appears stationary, while the second wave appears to be moving. This is due to the fact that the oscilloscope determines its time reference based on one of the input waves. In this case, the two input waves are generated by separate function generators, and due to testing errors, their frequencies are slightly different. As a result, the second wave appears to be shifting in time relative to the first wave on the oscilloscope display.

Experiment 10

Use the oscilloscope to watch and measure the potential difference between nodes A and B in the circuit of Fig. 25, where the sinusoidal source has a frequency of 1 kHz and a peak to peak amplitude of 5 V. Can you measure the desired voltage simply using a single probe? If no, describe the problem and propose a solution.

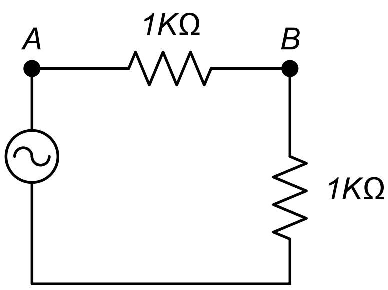

Figure 25: A simple resistive circuit.

Experiment 10 continued on next page...

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We connected the ground base of both input channels of the oscilloscope to the ground base of the function generator. Additionally, we connected the probe of the first channel to point A and the probe of the second channel to point B. By utilizing the subtraction option of the oscilloscope, we subtracted these two waveforms to obtain the potential difference between the two ends of the resistance.

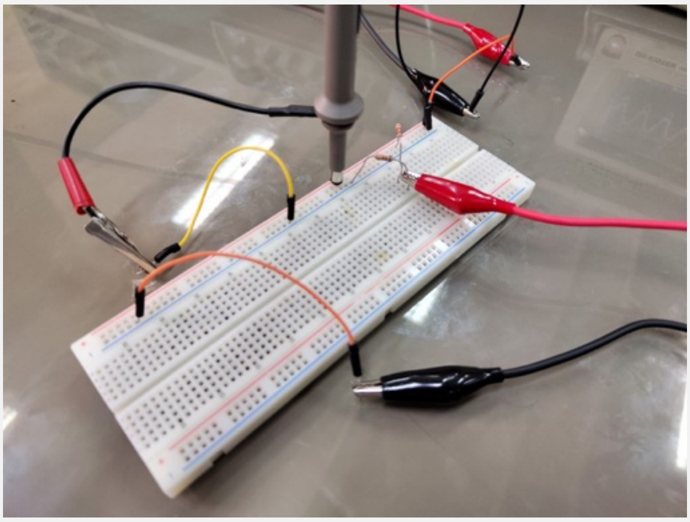


Figure 26: A simple resistive circuit.

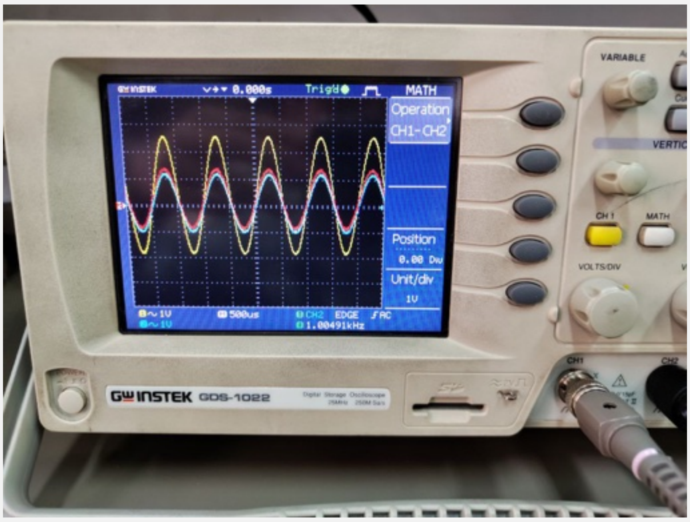


Figure 27: oscilloscope's picture.

Experiment 10 continued on next page. . .

Figure 28: Function generator's setting.

By interchanging the positive and negative terminals of the function generator, and connecting the ground terminal of the oscilloscope probe to the negative terminal of the function generator (which corresponds to one end of the resistor), and connecting the positive terminal of the oscilloscope to the other end of the resistor, we can accurately measure the potential difference across the resistor. This configuration allows us to obtain the desired voltage measurement using a single probe.

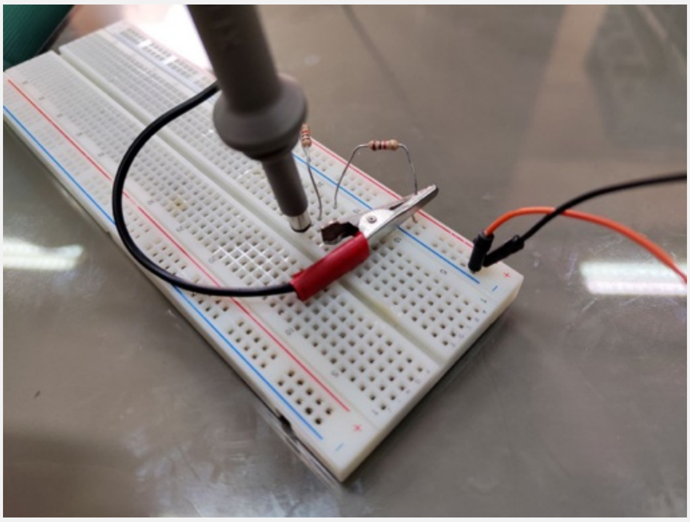


Figure 29: Circuit related to resistance voltage measurement with one probe.

Experiment 10 continued on next page...

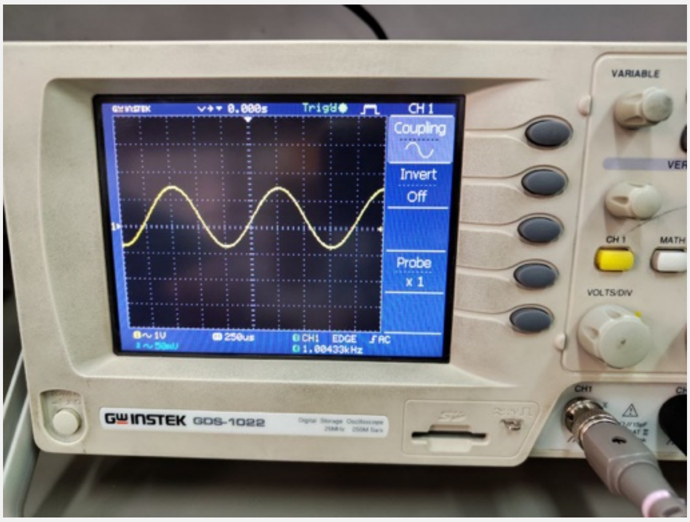


Figure 30: Measuring resistance voltage with one probe.

Experiment 11

Set the controls of the function generator to produce a sine wave of 70 Hz frequency and 1 V amplitude. Connect the sine wave to the first channel of the oscilloscope and see it for various triggering sources. Discuss the observations.

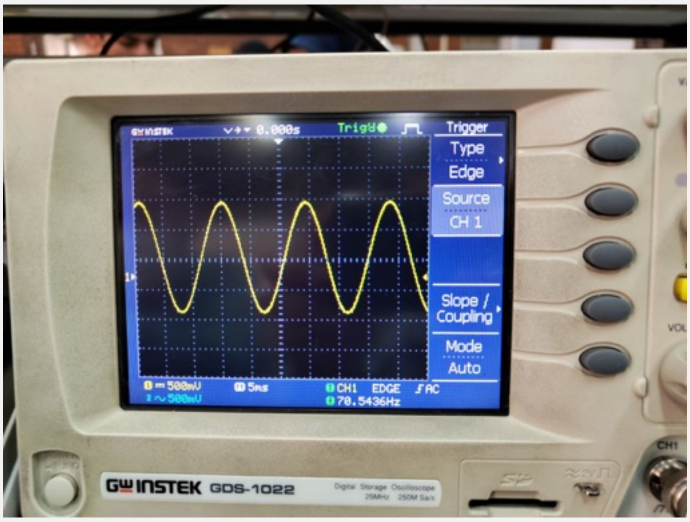


Figure 31: Trigger source set to CH1.

Experiment 11 continued on next page...

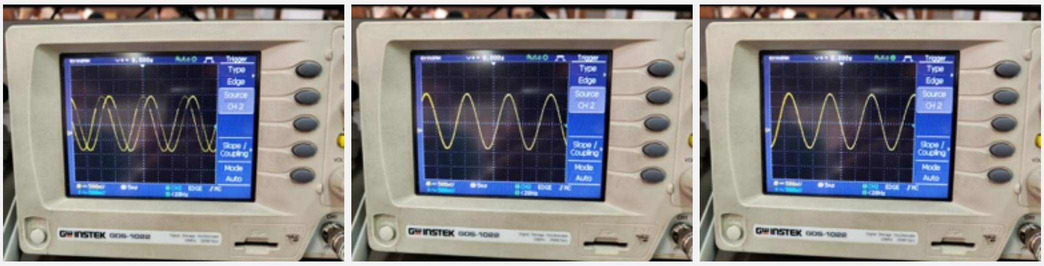


Figure 32: Trigger source set to CH2.

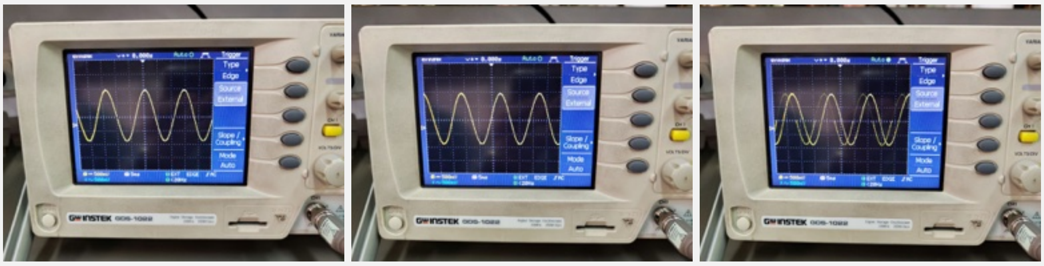


Figure 33: Trigger source set to External.

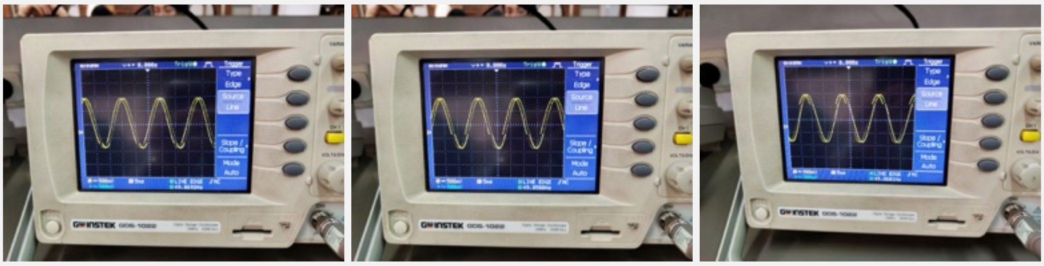


Figure 34: Trigger source set to Line.

Oscilloscope has various triggering sources. CH1, CH2, External and Line.

CH1 and CH2 sources: In these two cases, the oscilloscope sets the time origin based on channel 1 and channel 2, respectively. Therefore, in the first state, the wave is stationary, but in the second state, the wave moves.

External source: In this case, the oscilloscope sets the time origin based on the input given to the third base (external base).

Line source: In this case, the oscilloscope sets the time origin based on the city's electricity frequency.

Experiment 12

Change the trigger level and trigger slope in the previous part and analyze your observations.

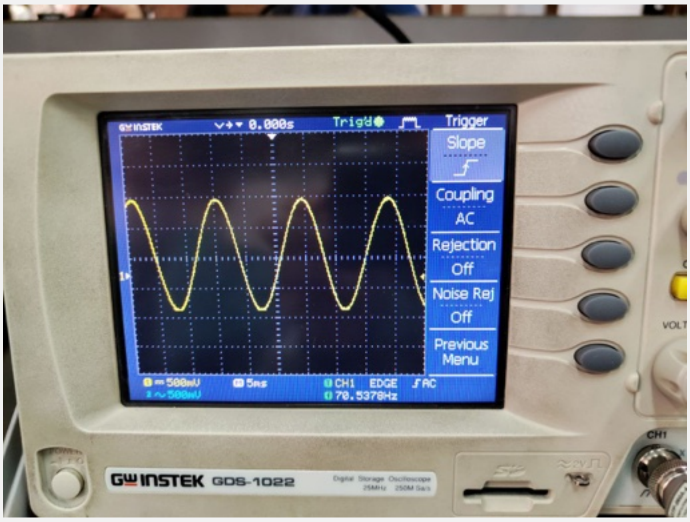


Figure 35: Default mode.

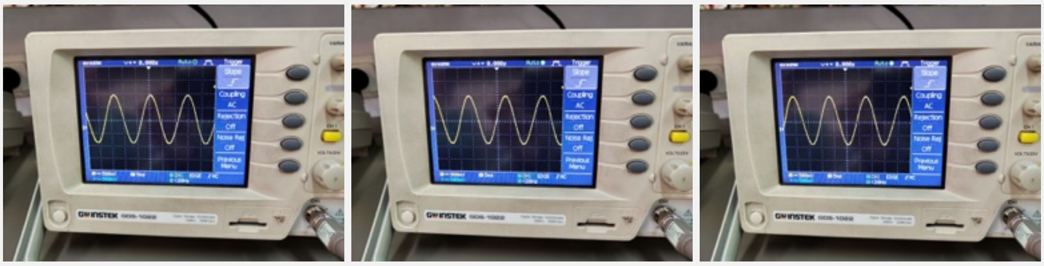


Figure 36: Trigger level changed to +v.

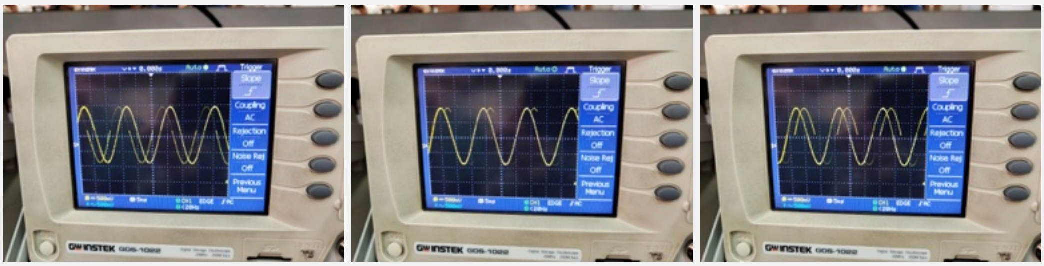


Figure 37: Trigger level changed to -v.

Experiment 12 continued on next page...

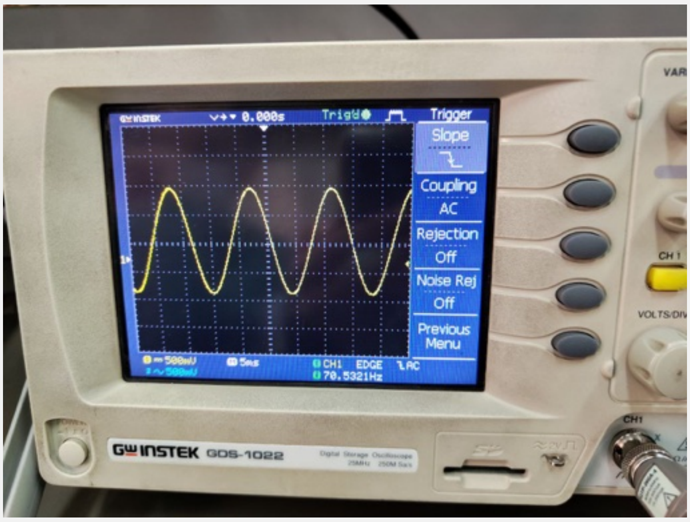


Figure 38: Trigger slope changed.

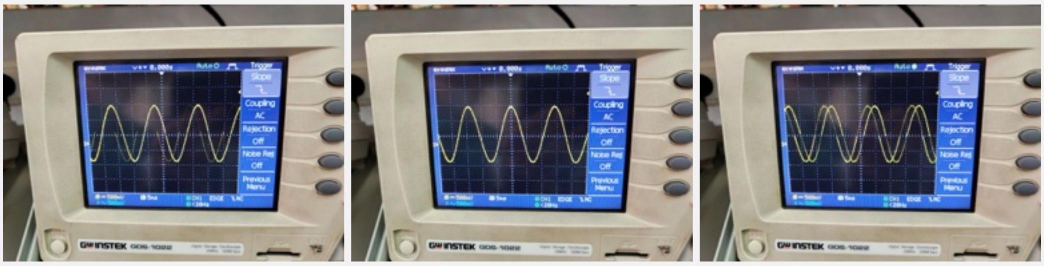


Figure 39: Trigger level changed to +v.

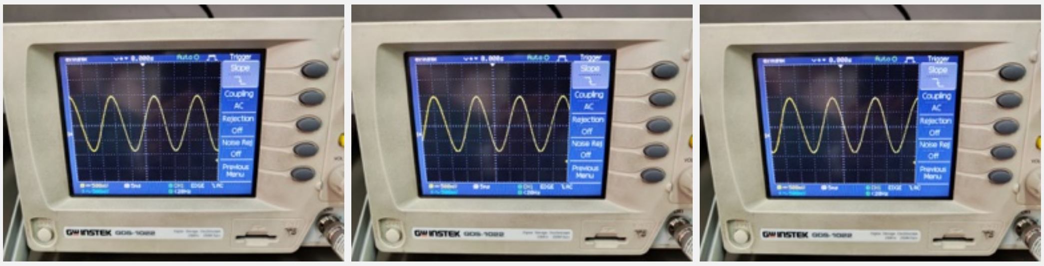


Figure 40: Trigger level changed to -v.

By changing the level trigger, if it goes out of the wave range, it causes the wave to move on the screen.

By changing the trigger slope, the wave is projected according to the horizontal line.

Experiment 13 continued on next page. . .

Experiment 13

Feed two sine waves with differences frequencies to two channels of the scope and see the corresponding Lissajous curve on the XY mode. Characterize the Lissajous curve. Is there any relationship between the Lissajous curve and the frequencies of the sine waves?

Figure 41: First Function generator set to $100Hz$ and Second one set to $100Hz$.

Figure 42: First Function generator set to $200Hz$ and Second one set to $100Hz$.

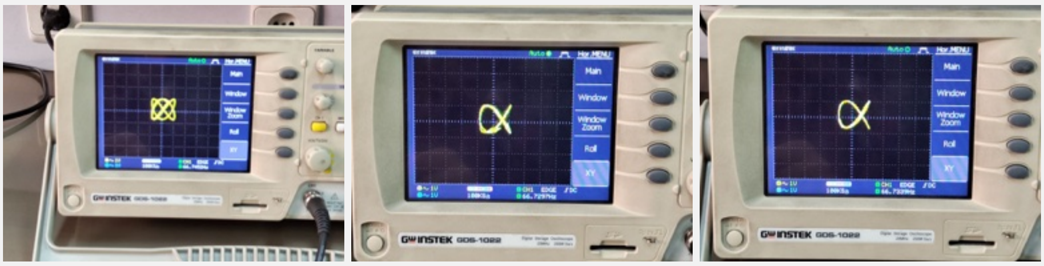


Figure 43: First Function generator set to $70Hz$ and Second one set to $100Hz$.

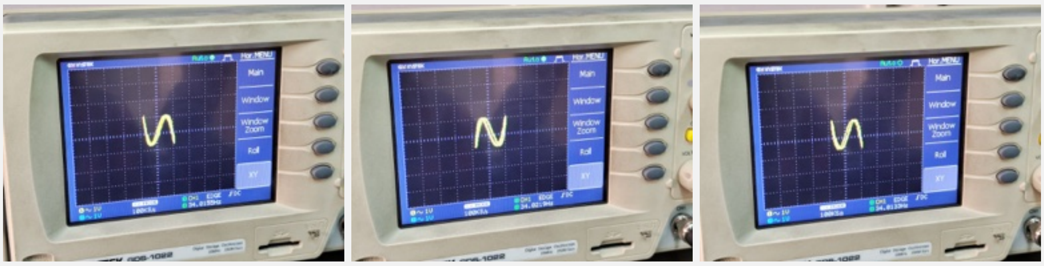


Figure 44: First Function generator set to $34Hz$ and Second one set to $100Hz$.

Figure 45: First Function generator set to $200Hz$ and Second one set to $100Hz$.

$$\frac{\text{Number of horizontal peaks}}{\text{Number of vertical peaks}} = \frac{\text{The frequency of the second generator}}{\text{The frequency of the first generator}}$$

Experiment 14

Build the circuit of Fig. 46 on the breadboard and see the labeled voltages in the XY mode on the oscilloscope screen. Sweep the frequency and amplitudes of the input sine wave and observe the results. Can you interpret the results?

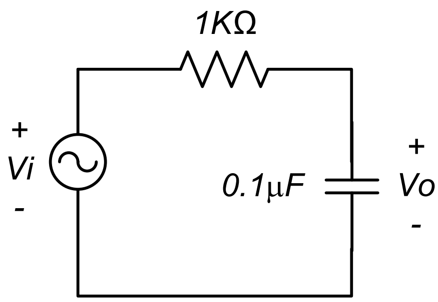
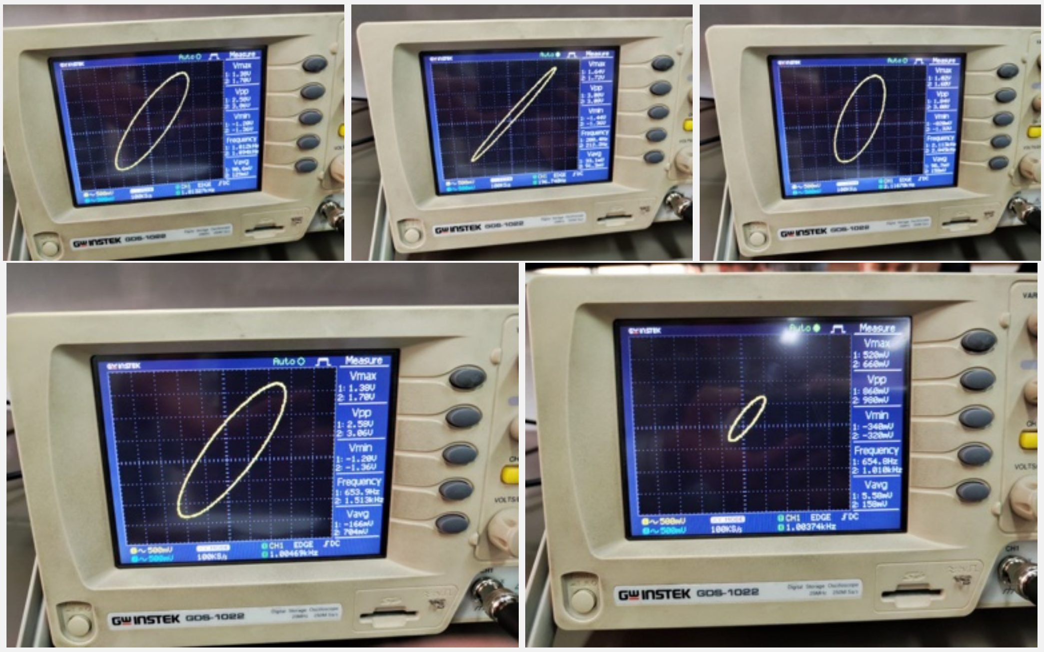


Figure 46: An RC circuit.

Experiment 14 continued on next page...



The circuit consists of a resistor and a capacitor connected in series. The input signal is applied to the circuit, and the output signal is measured across the capacitor. The output signal is then fed to the oscilloscope, and the XY mode is activated. The input signal is a sine wave with a frequency of 1 KHz and an amplitude of 1 V. The amplitude of the input signal is swept from 0.1 V to 1 V, and the frequency is swept from 1 KHz to 10 KHz. The results are shown in the figures above. The results show that the output signal is an oval which is really close to a circle. The radius of the circle is proportional to the amplitude of the input signal, and the frequency of the input signal determines the speed of the circle.

From the circuit, we can represent the input and output voltages as follows:

$$V_i = A\cos(\omega t)$$

$$V_o = B\cos(\omega t + \theta)$$

where V_i is the input voltage, V_o is the output voltage across the capacitor, A and B are amplitudes, ω is the angular frequency, and θ is the phase difference.

When visualizing the voltages on the oscilloscope in XY mode, the resulting plot represents a Lissajous figure, given by the equation:

$$\left(\frac{V_x}{A}\right)^2 + \left(\frac{V_y}{B}\right)^2 = 1$$

where V_x and V_y are the oscilloscope's X and Y inputs respectively. This equation describes an ellipse, and for certain phase relationships, it can form a circle.

Experiment 14 continued on next page...

If we assume specific conditions, such as $\theta = \frac{\pi}{2}$, the equations transform into:

$$V_i = A\sin(\omega t)$$

$$V_o = A\cos(\omega t)$$

This yields:

$$V_i^2 + V_o^2 = A^2$$

representing a perfect circle with radius A, where A is the amplitude of the input signal.

Therefore, the observed output on the oscilloscope is an elliptical pattern that approaches a circular shape as the phase difference between the input and output signals approaches $\frac{\pi}{2}$. The radius of the observed pattern is directly proportional to the amplitude of the input signal. By sweeping the frequency, the speed at which the pattern moves changes, demonstrating the frequency dependence of the capacitor's impedance.

BONUS EXPERIMENTS

Experiment 15

Consider the block diagram of a typical analog oscilloscope shown in Fig. 47 and explain how an analog oscilloscope works. How does an analog oscilloscope differ from its digital counterpart?

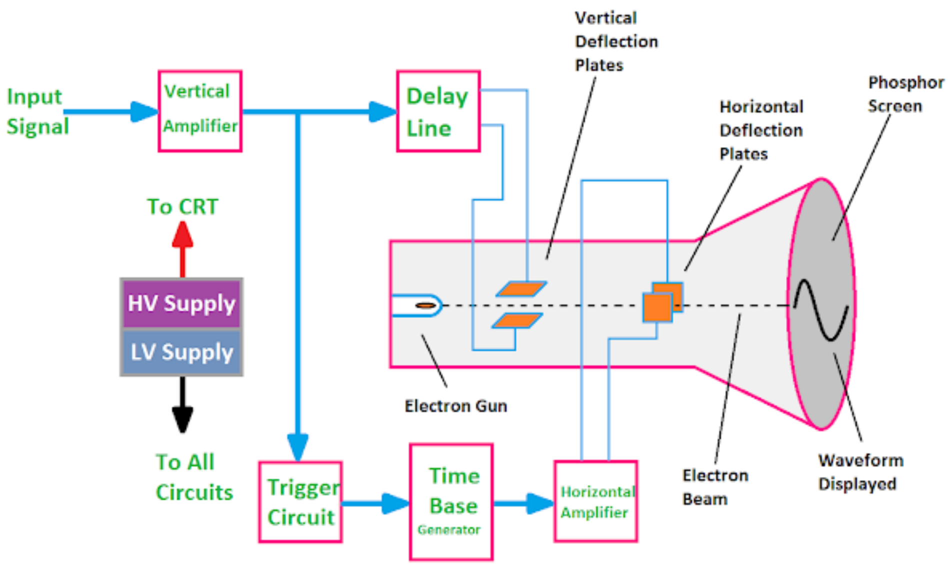


Figure 47: Block diagram of an analog oscilloscope.

Experiment 15 continued on next page...

The block diagram of an analog oscilloscope consists of the following components:

- Vertical amplifier: Amplifies the input signal.
- Time base generator: Generates the sweep signal.
- Trigger circuit: Synchronizes the sweep signal with the input signal.
- Cathode ray tube (CRT): Displays the input signal.

The input signal is amplified by the vertical amplifier and fed to the vertical deflection plates of the CRT. The time base generator generates a sweep signal that is fed to the horizontal deflection plates of the CRT. The trigger circuit synchronizes the sweep signal with the input signal to ensure that the input signal is displayed correctly on the screen.

The main difference between an analog oscilloscope and a digital oscilloscope is the display technology. An analog oscilloscope uses a CRT to display the input signal, while a digital oscilloscope uses an LCD or LED display. Digital oscilloscopes offer more features and better accuracy than analog oscilloscopes, but they are more expensive.

Experiment 16

What might lead to a distorted representation of the oscilloscope calibration signal on the screen? What do you offer to resolve the problem?

There are several factors that can lead to a distorted representation of the oscilloscope calibration signal on the screen. Some of these factors include:

- Incorrect settings of the oscilloscope: Ensure that the oscilloscope settings, such as timebase, voltage scale, and trigger level, are properly configured for the input signal.
- Poor quality of the input signal: Check the input signal source and make sure it is clean and free from noise or interference.
- Incorrect connection of the probe: Ensure that the probe is properly connected to the oscilloscope and the circuit under test. Check for loose connections or damaged cables.
- Interference from other electronic devices: Keep the oscilloscope away from other electronic devices that may introduce electromagnetic interference.
- Incorrect calibration of the oscilloscope: Perform a calibration procedure on the oscilloscope to ensure accurate measurements.
- Incorrect grounding of the oscilloscope: Ensure that the oscilloscope is properly grounded to avoid ground loops and unwanted noise.
- Incorrect triggering settings: Adjust the triggering settings of the oscilloscope to properly capture the desired waveform.

Experiment 16 continued on next page...

To resolve the problem, you can take the following steps:

- Check the settings of the oscilloscope and adjust them as needed to match the input signal.
- Verify the quality of the input signal and eliminate any noise or interference sources.
- Double-check the connection of the probe and ensure it is securely attached to the oscilloscope and the circuit.
- Minimize the proximity of the oscilloscope to other electronic devices to reduce interference.
- Perform a calibration procedure on the oscilloscope to ensure accurate measurements.
- Ensure that the oscilloscope is properly grounded to avoid ground loops and unwanted noise.
- Adjust the triggering settings of the oscilloscope to capture the desired waveform accurately.

By following these steps, you can troubleshoot and resolve any issues that may lead to a distorted representation of the oscilloscope calibration signal on the screen.

Experiment 17

Return your work report by filling the LaTeXtemplate of the manual. Include useful and high-quality images to make the report more readable and understandable.