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EEE102-02

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LAB-1: Introduction To Digital Oscilloscopes

PURPOSE

This laboratory aims to explore digital oscilloscopes and electronic components such as resistors, capacitors, breadboards, and jumper cables. By constructing basic circuits and using a signal generator, it is aimed to observe how electrical signals are graphically represented over time.

PART 1

Methodology: Before doing any measurements, the oscilloscope probe needs to be compensated in order to prevent getting inaccurate results. In this part, to compensate the probe, first, the probe's BNC connector was attached to Channel 1 of the oscilloscope. Its hook was connected to the compensation signal source and the ground clip was connected to any metal in the oscilloscope. Initially, the displayed square waveform did not appear as a perfect square, so the adjustable screw was manually calibrated using a screwdriver until both the top and bottom edges of the wave were sharp and straight. This process ensured that the probe, which has a 10X attenuation factor, matched the input capacitance of the oscilloscope.

Results: Before the probe was compensated, it was either undercompensated when the screw was turned too counterclockwise or overcompensated when it was turned too clockwise, which led the squares in the graph to have curved edges (Figures 1.1-1.2). When the probe was compensated, the squares were straight and had sharp edges (Figure 1.3).

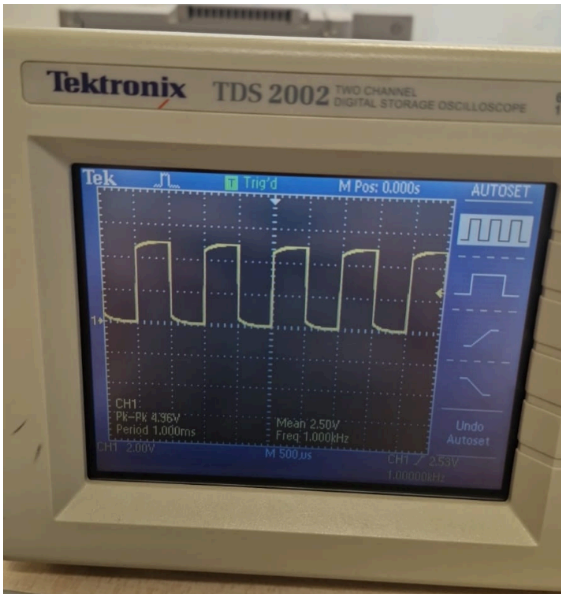

Figure 1.1: Undercompensated oscilloscope

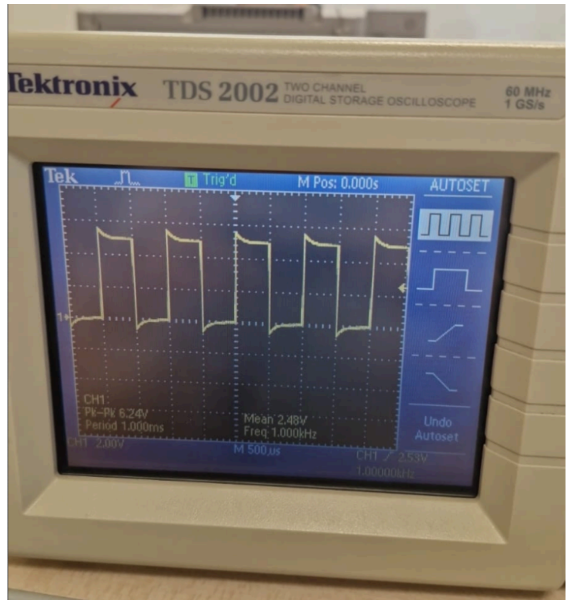

Figure 1.2: Overcompensated oscilloscope

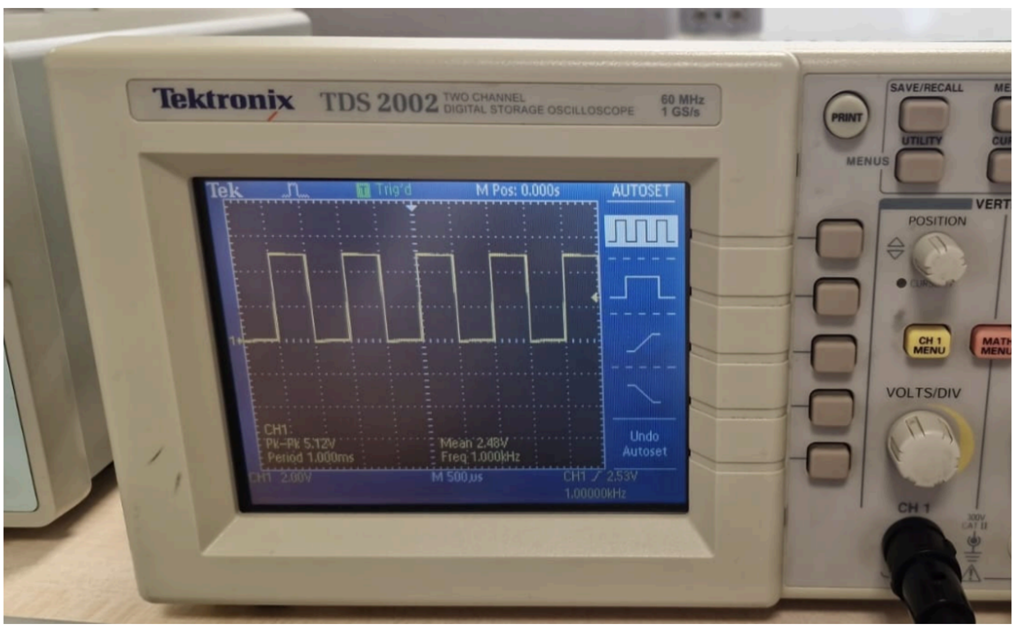

Figure 1.3: Compensated oscilloscope

PART 2

Methodology: Using a signal generator, a 1 kHz sinusoidal signal with a 5 Vpp peak-to-peak voltage and no DC component was produced. This was done by setting the amplitude to 2.5 Vpp, frequency to 1kHz and setting the DC offset to zero. The oscilloscope was then used to monitor the waveform. First, with the trigger set to a rising edge from the oscilloscope's trigger mode function, and then with the trigger set to a falling edge to capture the waveform.

Results: The oscilloscope generated a sinusoidal 2-dimensional waveform depicting the voltage-time graph based on the amplitude and frequency values set (Figure 2.1). When the trigger was set to a rising edge, the graph's slope with respect to origin could be seen as positive (Figure 2.2). When the trigger was set to a falling edge, the graph was the symmetrical of the previous graph with respect to the x-axis (Figure 2.3).

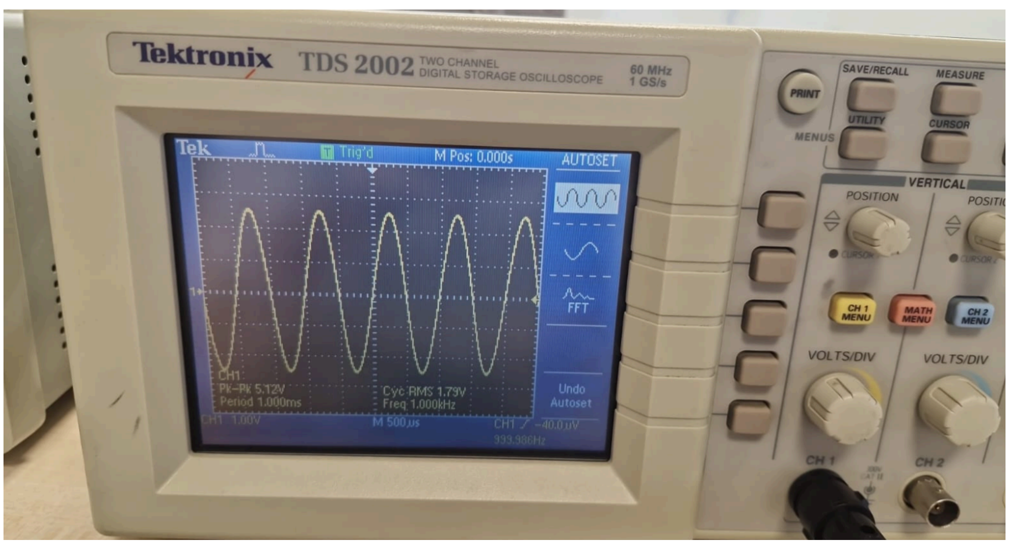

Figure 2.1: Sinusoidal voltage-time graph

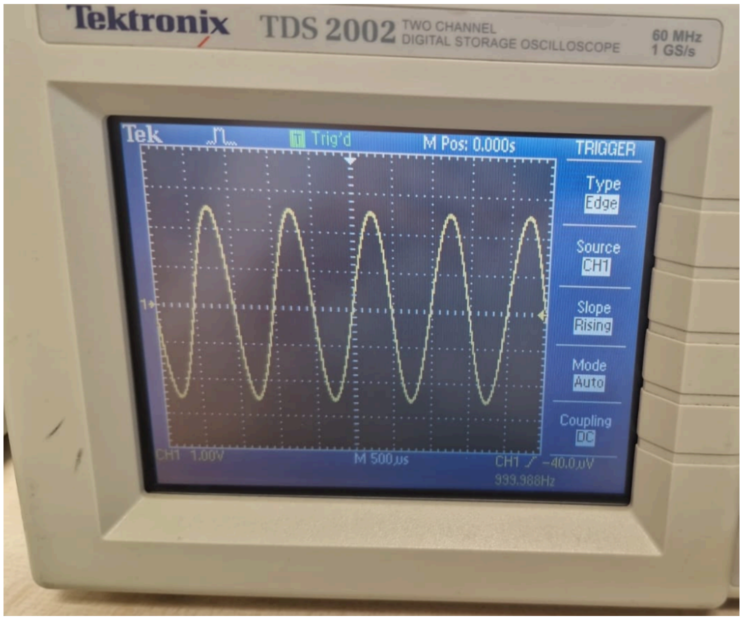

Figure 2.2: Rising edge triggering

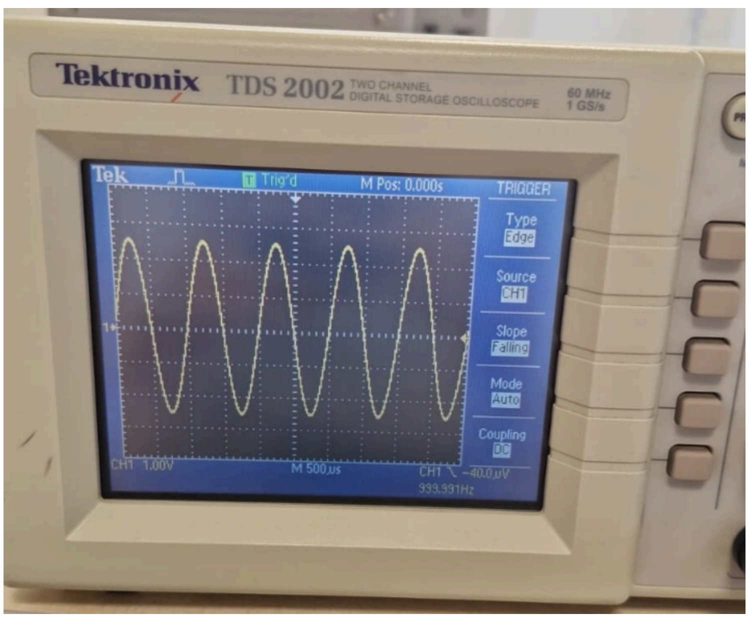

Figure 2.3: Falling edge triggering

PART 3

Methodology: Triggering is essential for displaying a steady waveform by setting a specific voltage level at which the oscilloscope captures the signal. If the trigger level is set too high or too low, the waveform becomes unstable. In this part, a 1 Vpp, 2 kHz triangular wave was generated using the signal generator. In order to generate a 1Vpp signal, the generator's amplitude was set to 0.5V. The trigger knob on the oscilloscope was then adjusted to observe its effect on waveform stability.

Results: When the trigger knob was turned clockwise and counterclockwise within the limits of the amplitude, the graph started to move respectfully towards right and left on the x-axis while the trigger level moved respectfully up and down (Figures 3.1-3.2-3.3). When the trigger level passed the limit of the amplitude, meaning it was above or below the peak points of the graph, the graph was completely unstabilized (Figure 3.4). The trigger of an oscilloscope synchronizes the horizontal movement of the graph at the appropriate signal location.[1] This is crucial for the observation and analysis of clear signals.

[1] Oscilloscope Systems and Controls: Functions & Triggering Explained | Tektronix. (n.d.). Retrieved February 12, 2025, from https://www.tek.com/en/documents/primer/oscilloscope-systems-and-controls

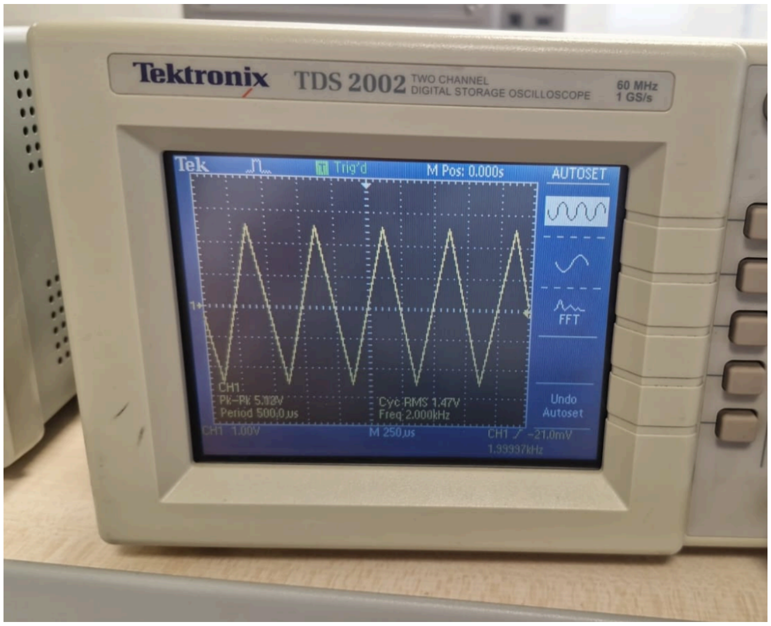

Figure 3.1: Triangular wave on auto-set

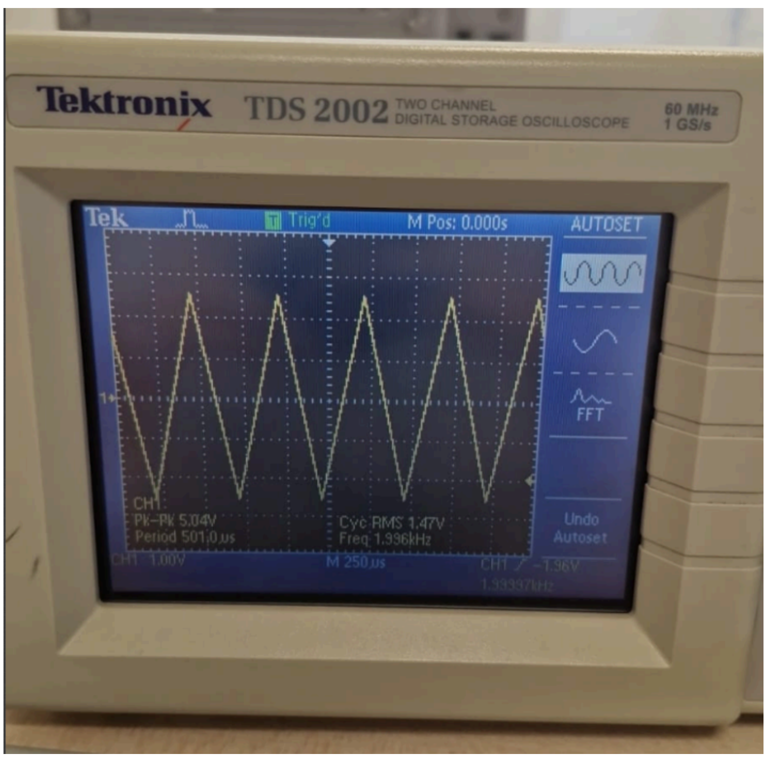

Figure 3.2: Trigger knob turned clockwise

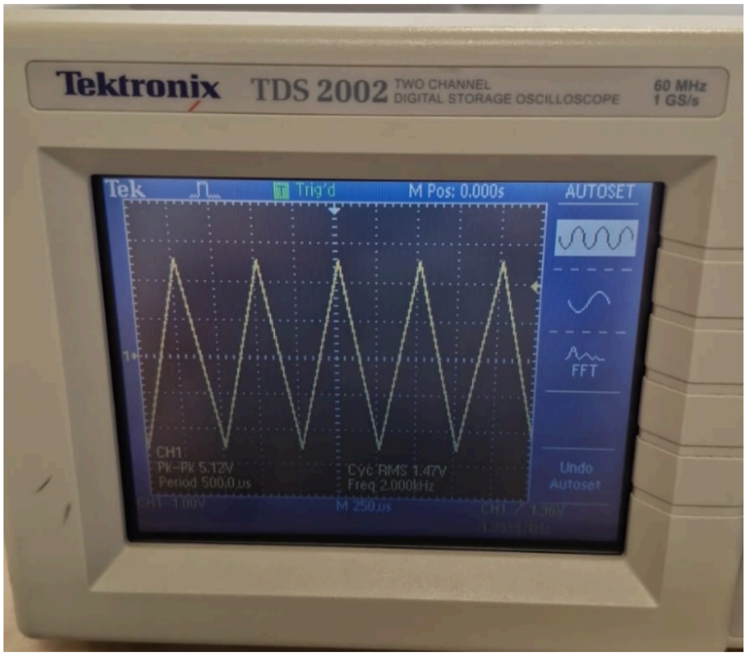

Figure 3.3: Trigger knob turned counter clockwise

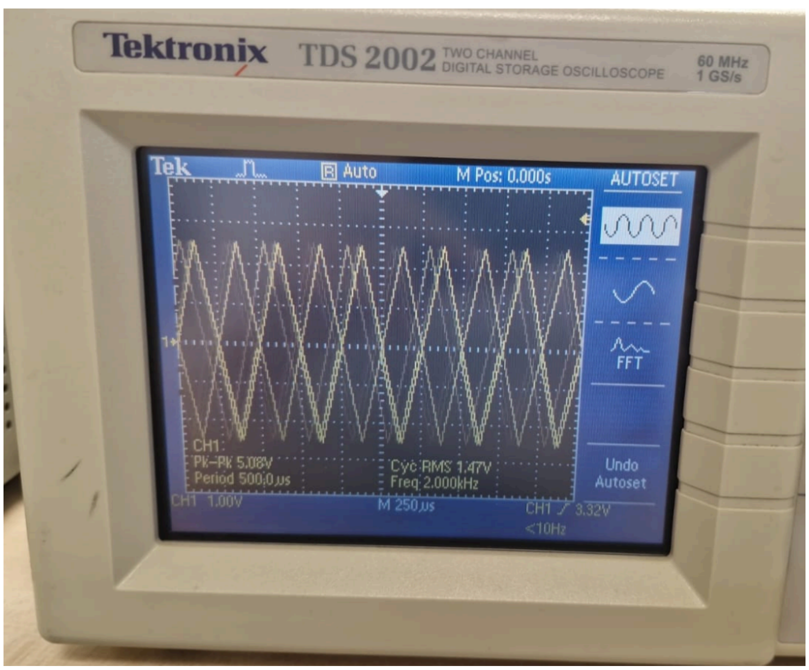

Figure 3.4: Trigger knob outside the limits of amplitude

PART 4

Methodology: A Digital-to-Analog Converter (DAC) converts digital signals into analog signals, while an Analog-to-Digital Converter (ADC) performs the opposite function by transforming analog signals into digital data. Conventional oscilloscopes are usually ADCs to convert incoming analog signals and electromagnetic waveforms into digital signals for display and analysis. Once the signal is sampled, each of those analog voltage values is converted into a digital number and these numbers are used by the oscilloscope's processor to reconstruct and display the waveform on the screen.[2]

To examine the oscilloscope's acquisition modes, a 1 Vpp square wave with a 5 kHz frequency was generated using a signal generator. The sample mode, the peak detect mode and the average mode from the acquire menu of the oscilloscope were tested and observations of the differences in the waveforms' representations were recorded.

Results: When the graph was in sample mode, oscilloscope captured data points from each of the uniform time intervals based on its sample rate and displayed the graph of those data points on the screen (Figure 4.1). In the peak detection mode, the oscilloscope determined the maximum and minimum data points for each interval, and it emphasized these peak points in the graph (Figure 4.2). In the average mode, the oscilloscope used two or more data points from each interval, averaged these values and plotted the graph of the average values (Figure 4.3). The average mode especially prevented the signals from turning into noise and improved the observation of repetitive signals.

[2] *Difference between ADC and DAC » Scienceeureka.com*. (n.d.). Retrieved February 12, 2025, from https://scienceeureka.com/difference-between-adc-and-dac/

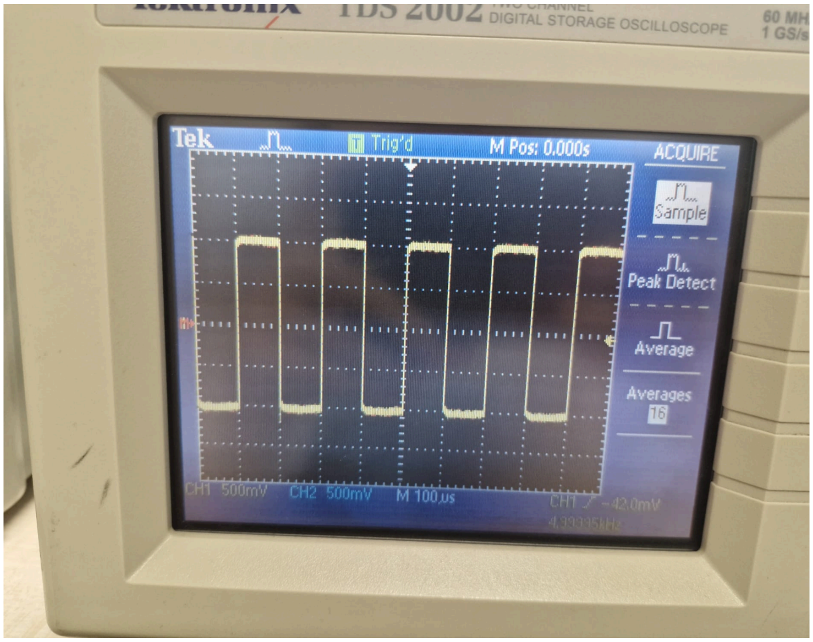

Figure 4.1: Graph in sample mode

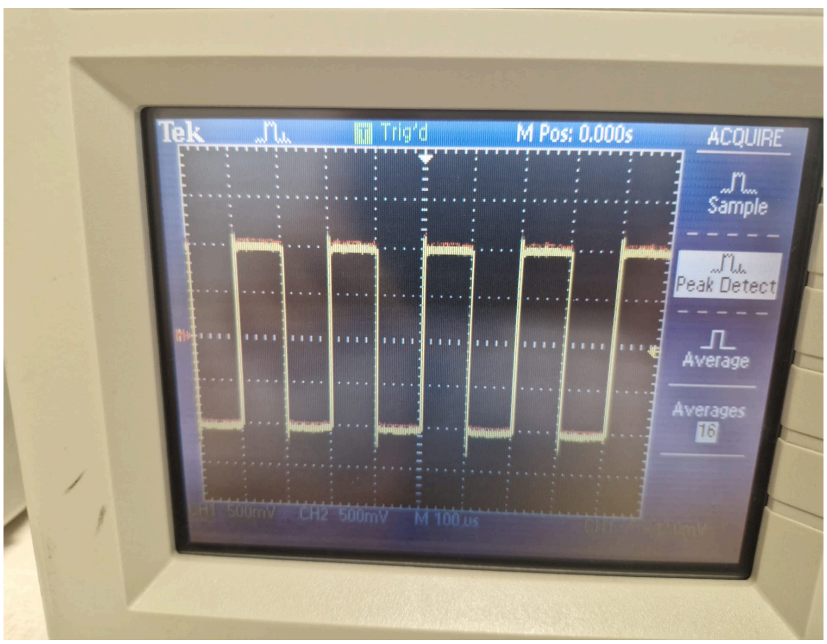

Figure 4.2: Graph in peak detection mode

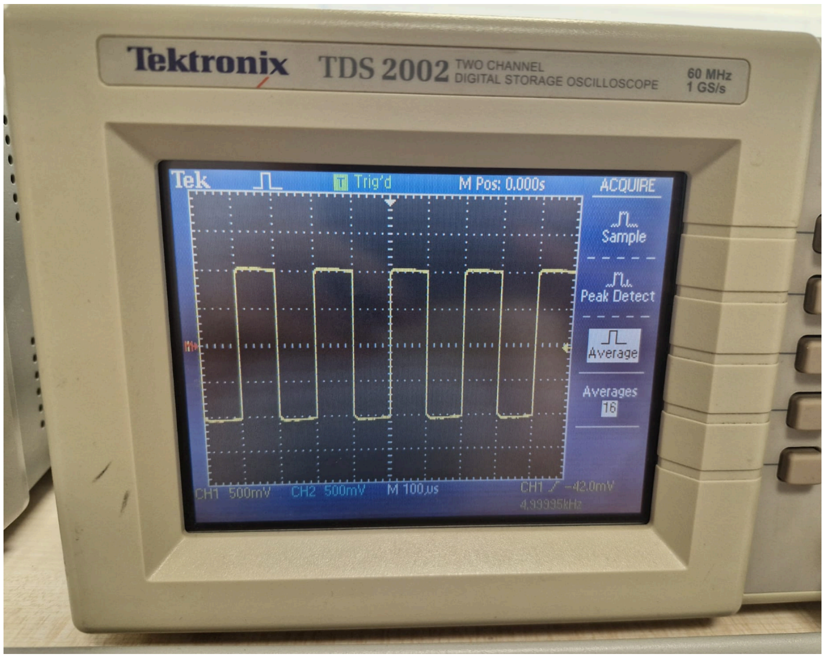

Figure 4.3: Graph in average mode

PART 5

Methodology: A sinusoidal signal with 2 Vpp amplitude and 1 kHz frequency was generated. To obtain 2 Vpp, the signal generator was set to 1 V. However, in this part, 1 V DC offset was generated and observed using both DC and AC coupling on the oscilloscope. DC coupling retains all signal components including both AC and DC components, while AC coupling filters out the DC offset and makes it easy to analyze AC variations independently.

Results: In DC coupling mode, the oscilloscope displayed the full signal, including both the AC component and the DC offset. As the DC offset was 1V, the wave shifted 1V on the y-axis (Figure 5.1). When switched to AC coupling mode, the DC component was removed. Hence, the graph was centered around origin once again (Figure 5.2).

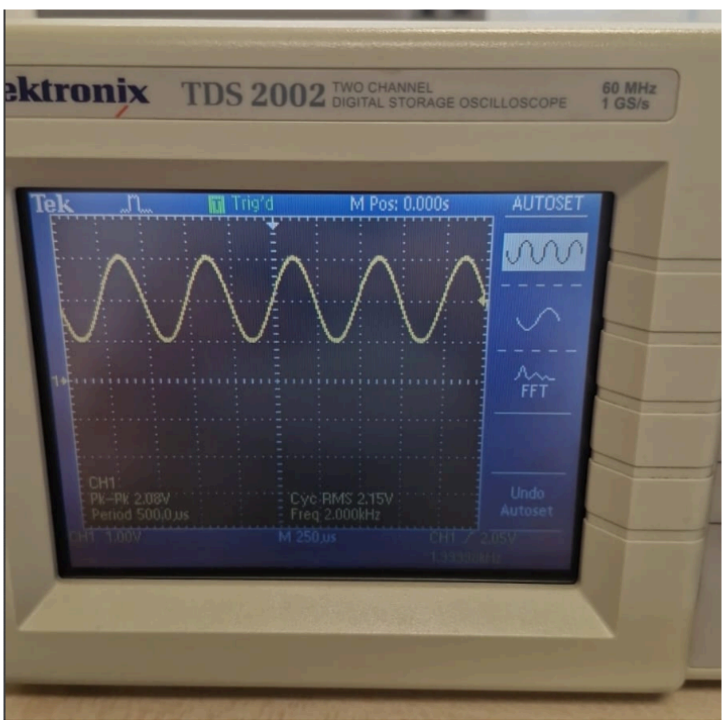

Figure 4.1: Graph on DC coupling

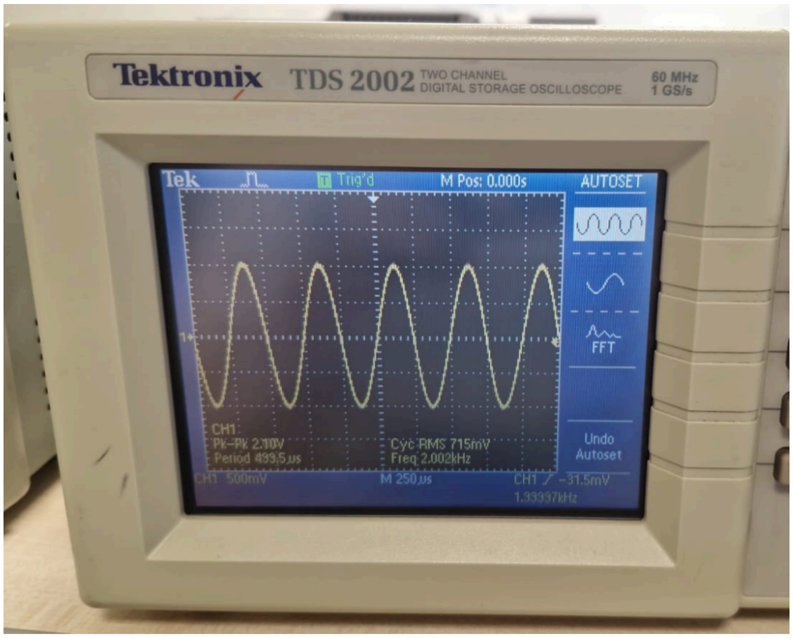

Figure 5.2: Graph on AC coupling

PART 6

Methodology: The circuit diagram in Figure 6.1 was designed using a breadboard, a 1kΩ resistor, a capacitor, male-male jumper wires and two oscilloscope probes (Figure 6.2).

A breadboard, also known as a protoboard, serves as the framework for building temporary electronic circuits or conducting circuit design experiments. The rows and columns of internally connected spring clips beneath the plastic casing of a breadboard allow engineers to quickly connect wires or components. The breadboard's female input pins are constructed from metal plates that are spring-loaded to attach to the male pin. Conventionally, the female pins on the left and right sides of the board are referred to as the voltage and ground lines, and they appear as red and blue lines respectively. Ground and voltage wires are connected in every column. [3]

In the circuit, one of the probes was connected to the X point, and the other probe was connected to the Y point, which is one leg of the capacitor, and their ground tips were connected to the ground. The signal generator's ground was connected to the breadboard's ground, and the signal lead was connected to the breadboard's positive terminal so that it would reach both the X and Y signals' places (Figure 6.3).

X was connected to Channel 1 and Y was connected to Channel 2. A 2 Vpp 1kHz sinusoidal signal with 0 DC offset as the X signal. At the end, frequency was arranged as 100kHz instead of 1kHz and the same procedure was repeated.

[3] Fernandez, A., & Dang, D. (2013). The Fellowship of the LaunchPad. In A. Fernandez & D. Dang (Eds.), Getting Started with the MSP430 Launchpad (pp. 13–20). *Newnes*. https://doi.org/10.1016/B978-0-12-411588-0.00003-0

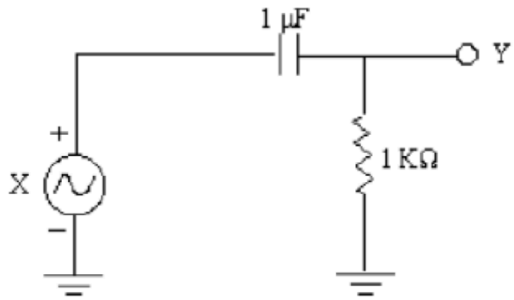

Figure 6.1: Circuit diagram

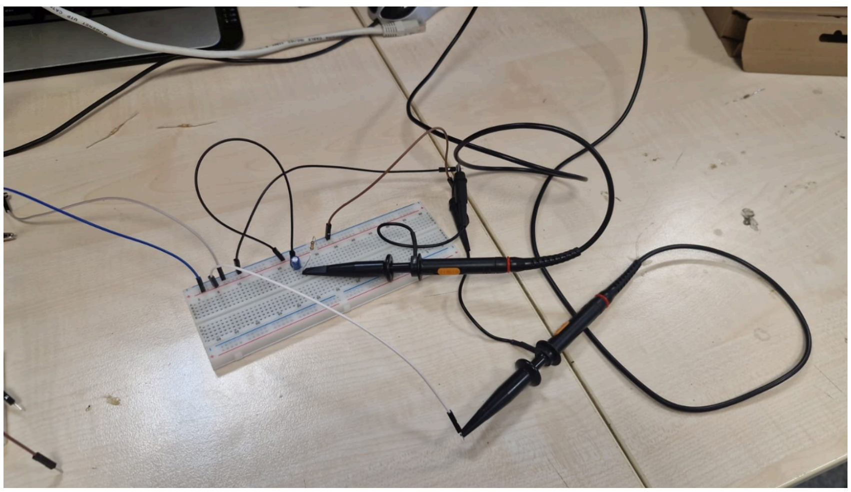

Figure 6.2: Designed circuit

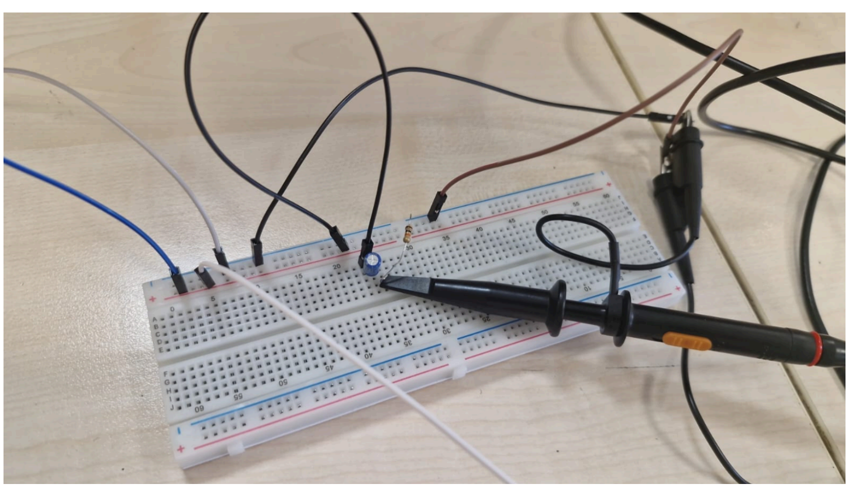

Figure 6.3: Close-up view of the circuit

Results: When the signal was generated, two separate waves were displayed on the oscilloscope's screen. Due to the capacitor and the resistor on the breadboard, there was a phase difference between the graphs of Channel 1 and Channel 2 (Figure 6.4). For the 1kHz input signal, the observed time delay was approximately 23.2μs (Figure 6.5). For the 100kHz input signal, the time delay was approximately 290ns (Figure 6.6). The signals' periods can be calculated from the formula $T = \frac{1}{f}$. For the former signal, the period is $1 \div 1000Hz = 1000\mu s$. For the latter signal, the period is $1 \div 100000Hz = 10\mu s$. With these values, the phase shift can be calculated from the formula $\phi = \frac{\Delta t}{T} \times 360°$, Δt being time delay and T being the signal period.

The phase shift for the 1kHz signal:

$$\phi = \frac{23.2}{1000} \times 360° = 8.35° = 0.15rad.$$

The phase shift for the 100kHz signal:

$$\phi = \frac{0.29}{10} \times 360° = 10.44° = 0.18rad.$$

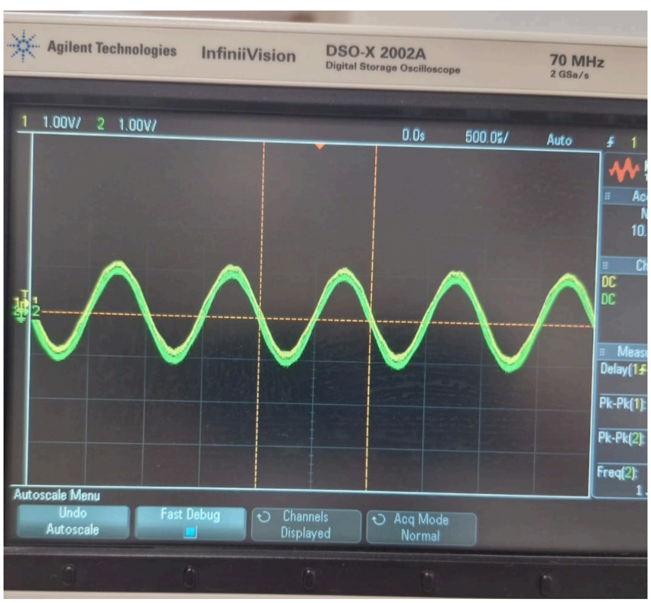

Figure 6.4: Observed phase difference when graphs are on top of each other

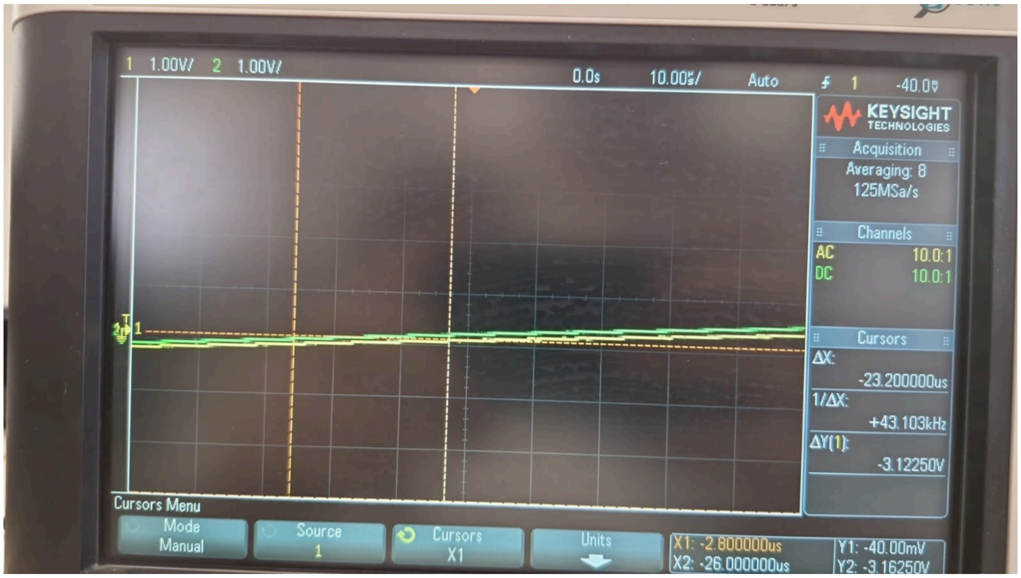

Figure 6.5: Phase difference of the 1kHz signal

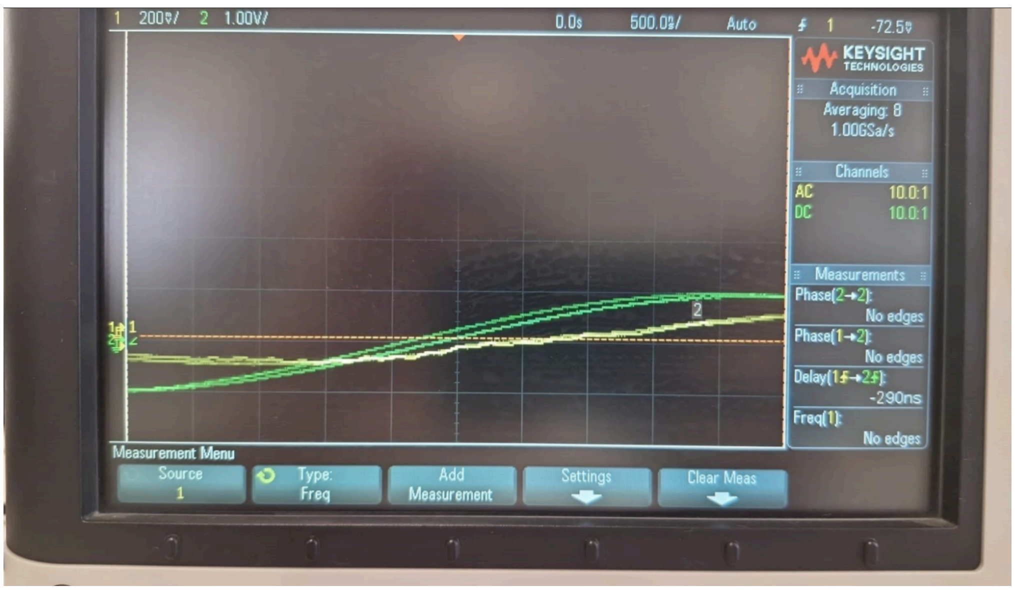

Figure 6.6: Phase difference of the 100kHz signal

CONCLUSION

The aim of this experiment was to learn basic operations with an oscilloscope and a signal generator, as well as designing a sample circuit using probes, jumper wires, a breadboard and basic circuit elements. There is no fixed value to compare the calculations made in part 6. However, several factors could have caused potential errors. One of these factors is oscilloscope measurement errors, including trigger settings not being properly configured, averaging causing discrepancies in the values and sampling rate limitations. Another factor might be signal delays due to the probes and cables. Finally, there might have been human calculation errors such as inaccuracies in cursor placement and circuit-related errors due to environmental factors such as temperature. Several ways to minimize these errors is to use a higher sampling rate, ensuring probes are properly compensated, and repeating measurements multiple times and taking an average to prevent random errors.

Works Cited

Difference between ADC and DAC » Scienceeureka.com. (n.d.). Retrieved February 12, 2025, from https://scienceeureka.com/difference-between-adc-and-dac/

Fernandez, A., & Dang, D. (2013). The Fellowship of the LaunchPad. In A. Fernandez & D. Dang (Eds.), Getting Started with the MSP430 Launchpad (pp. 13–20). *Newnes*. https://doi.org/10.1016/B978-0-12-411588-0.00003-0

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