Bilkent University Electrical and Electronics Department

EE102-01 Lab 1 Report:

Introduction to Digital Oscilloscopes

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Purpose:

The main objective of this laboratory experiment was to examine and get used to the primary operations of digital oscilloscopes and signal generators. Also, we learned to design simple circuits by using breadboards.

Methodology:

In the experiment, the oscilloscope and the signal generator were our primary tools. The experiment consisted of 6 different parts.

For part 1/6: Oscilloscope probes were compensated using a specialized screwdriver. The compensation procedure is carried out to adjust the probe for a better signal display on the oscilloscope screen. The oscilloscope probe that was used throughout this experiment was set to 10X attenuation level and therefore, was adjusted accordingly. If the compensation was poorly adjusted one of two possibilities would happen: under-compensation **(Figure 1.1)** and over-compensation **(Figure 1.2)**.

For part 2/6: A 5V peak-to-peak sinusoidal signal whose frequency is at 1kHz was generated by the signal generator and the triggering function was examined. The triggering slope function was set to both "Rising" and "Falling". On "Rising" mode, the origin of the signal had a positive slope whereas on the "Falling" mode, the origin had a negative slope. Also, the main aim for this part of the experiment was to understand the difference between positive and negative edge triggering. Therefore, both positive and negative edge triggering was performed by setting the trigger slope function both to "Rising" and "Falling" leaving us with a combination of four different outcomes.

For part 3/6: A 1V peak-to-peak 2kHz triangular wave was created and the triggering knob was used throughout this part of the experiment. The triggering function is used to create a stable image on the oscilloscope screen, it captures the moment when the instantaneous voltage of the signal reaches the specific value determined by the trigger level. This stable form is observed if and only if the triggering level is inside the range of the amplitude of the signal. If the triggering level goes above or below the peak values of the signal, the wave can't be triggered anymore and therefore, an unstable waveform will appear on the screen.

For part 4/6: A 1V peak-to-peak 5kHz square wave was applied and several acquisition modes were observed such as “normal”, “peak detect” and “averaging”. In normal mode, the oscilloscope acquires and displays each individual sample of the input signal. It essentially captures and shows the raw, unprocessed data points. It is the most commonly used mode among them all. Peak detect mode captures and displays the highest and lowest data points from each acquisition cycle. It tracks the signal's peaks and valleys, effectively detecting and storing the extreme values. It is beneficial when you want to capture and analyse glitches or spikes. Finally, in averaging mode, the oscilloscope acquires multiple waveform cycles and calculates the average of the samples for each point in time. This process helps reduce noise and provides a smoother and more stable waveform display.

Digital-to-Analog-Converter (DAC) is a device that transforms digital data (usually in binary form) into an analog signal. It takes discrete digital values and produces a continuous analog output. DACs are commonly used in various applications where digital systems need to interface with analog components, such as speakers. Analog-to-Digital-Converter (ADC) is a device that converts analog signals into digital data. It takes continuous analog inputs and quantizes them into discrete digital values. ADCs are found in many applications, including measuring analog sensor data (like temperature or voltage) or even speakers. The primary function of an oscilloscope is to measure and display analog voltage waveforms as digital representations on its screen. To do this, it uses an ADC to sample and digitize the incoming analog signal.

For part 5/6: A 2V peak-to-peak 1kHz sinusoidal signal was applied by the signal generator **(Figure 5.1)**. Then, a 1V DC offset was introduced to the previous signal. This led to the wave shifting 1V into the positive vertical axis in DC coupling mode. After that, AC coupling mode was selected, and the results were compared.

For part 6/6: An RC circuit **(Figure 6.1)** was assembled using a breadboard, a 1μF capacitor and a 1kΩ resistor. The visual representation of the circuit can be seen in **Figure 6.2**. A 2V peak-to-peak 1kHz voltage was applied as the input and the signal was examined via 2 different points in the circuit (point X and point Y). A breadboard is a prototyping tool for building and testing circuits. It consists of a flat board with a grid of holes that are connected internally in a way that allows us to easily create connections between components without having to use solder. The X signal was plugged into CH1, and the Y signal was plugged into CH2. Time and voltage differences between the two signals were measured. Then, the delay and phase difference were measured using the oscilloscope. After that, the frequency was changed to 100kHz, and all the measurements were performed again with the same circuit.

Results:

Part 1/6: When the probe was compensated accordingly, the following image would appear on the screen.

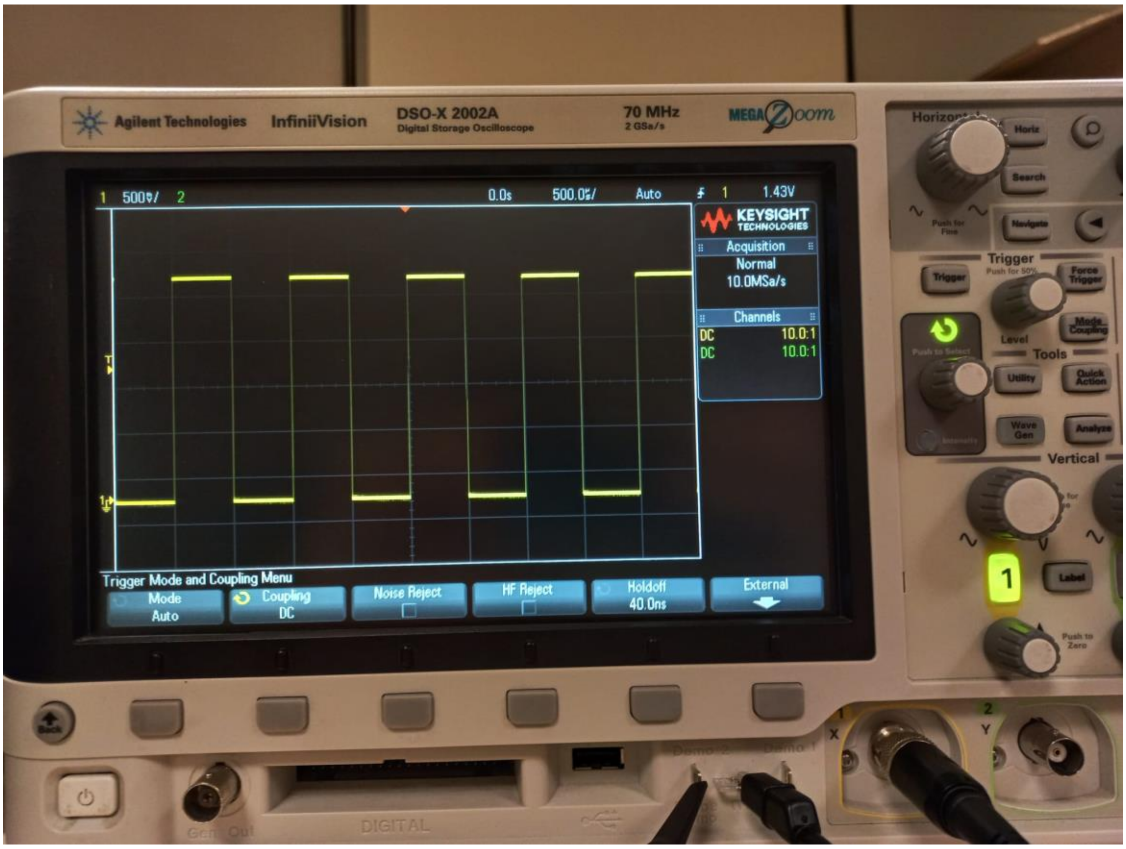

Figure 1.3: Accurately Compensated Signal

Part 2/6: The signal was triggered both from the positive edge **(Figure 2.1)** and the negative edge **(Figure 2.2)** as shown in the two images below. Since the trigger slope function was set to “Rising”, more positive edge triggering led to the signal moving in the negative horizontal direction.

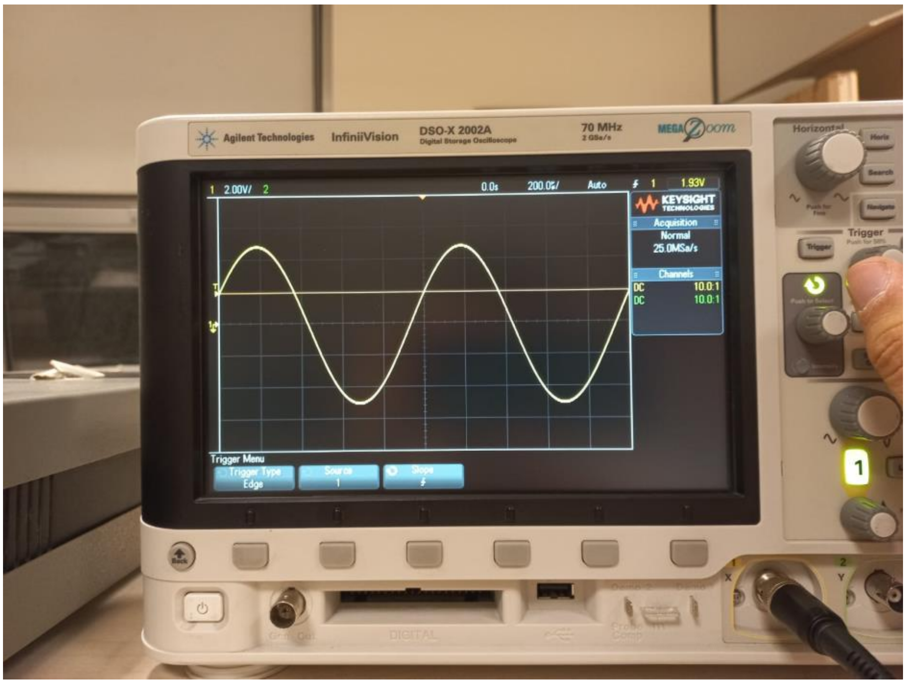

Figure 2.1: Positive Edge Triggering with a Rising Slope

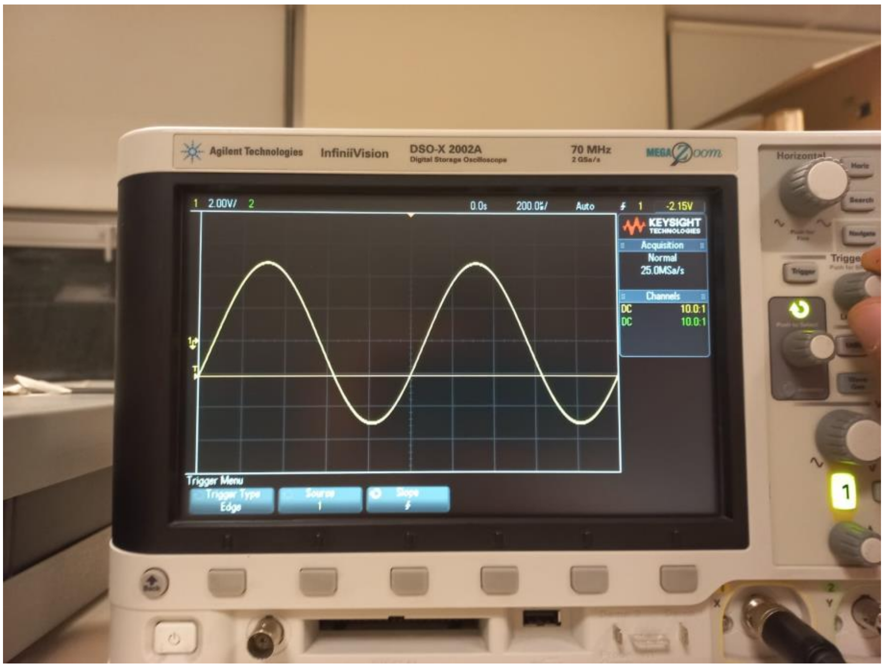

Figure 2.2: Negative Edge Triggering with a Rising Slope

Using the “Falling” slope function will lead to the signal moving in the positive horizontal direction as the trigger level goes from negative **(Figure 2.3)** to the positive edge **(Figure 2.4)**.

Part 3/6: The trigger level determines at which voltage the wave gets captured. If it is beyond the peak limits of the signal an unstable waveform appears on the screen **(Figure 3.1)**. If it is within the limits of the signal, the wave becomes stable **(Figure 3.2)**.

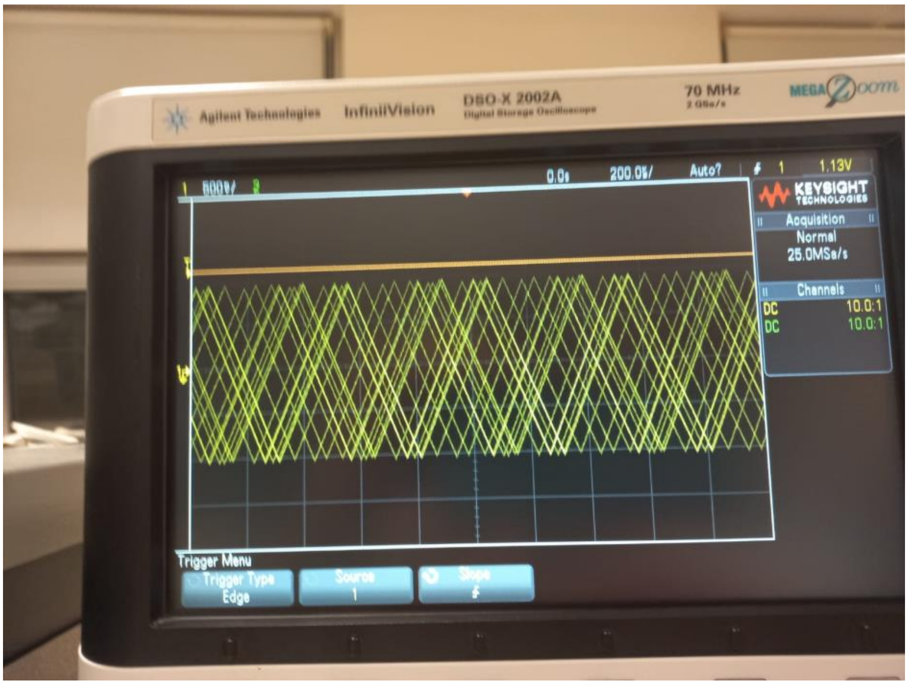

Figure 3.1: An unstable waveform without triggering

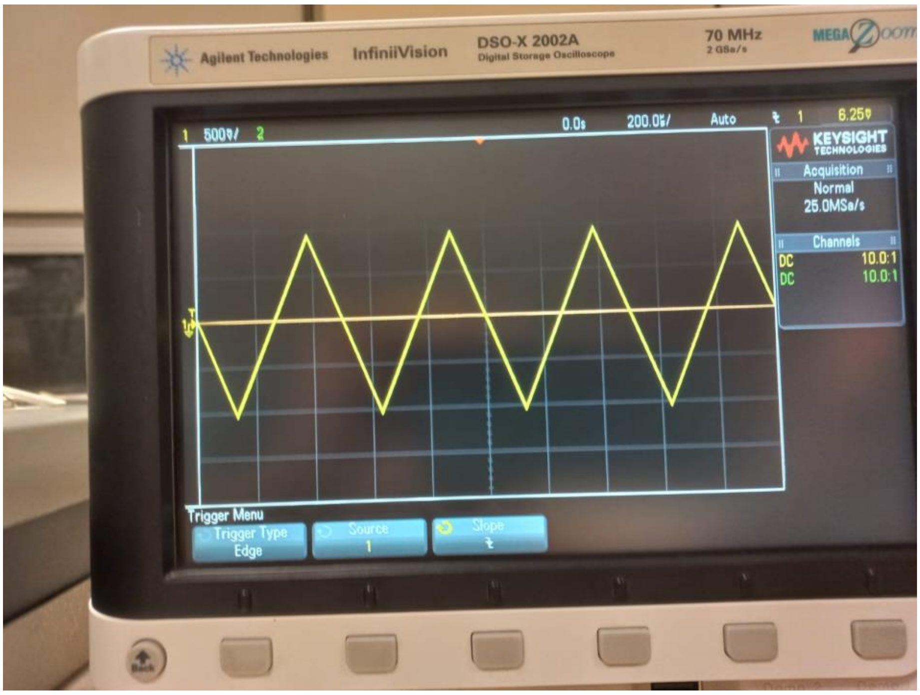

Figure 3.2: A stable wave with triggering

Part 4/6: Several acquisition modes have been observed and can be seen in the images below such as “Normal” mode **(Figure 4.1)**, “Peak Detect” mode **(Figure 4.2)** and “Averaging” mode **(Figure 4.3)**.

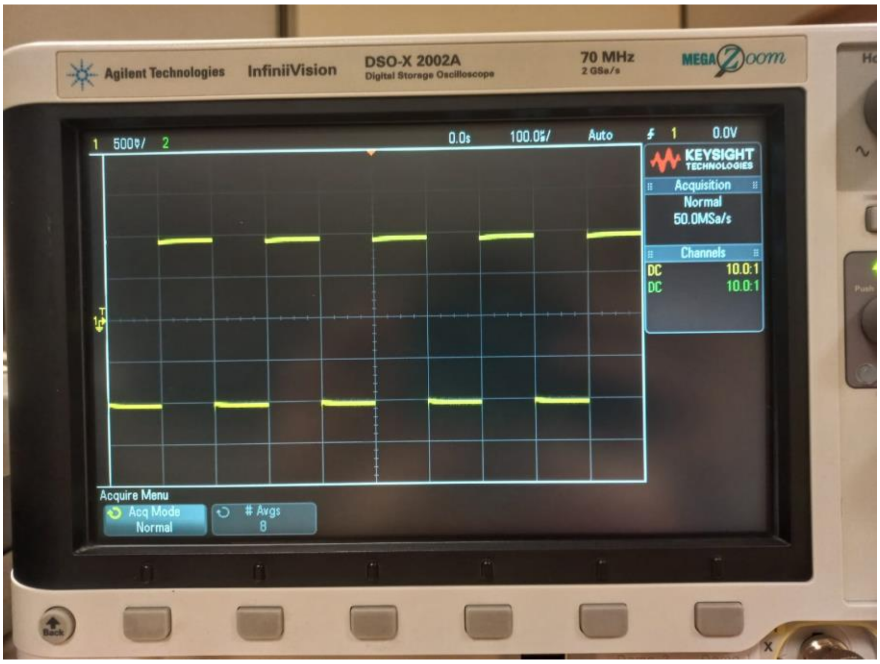

Figure 4.1: A signal acquired by the normal mode

Figure 4.2: A signal acquired by the peak detect mode

Figure 4.3: A signal acquired by the averaging mode

Part 5/6: The signal with a 1V DC offset was seen as a combination of both AC and DC waves in AC coupling mode **(Figure 5.2)**. However, AC coupling mode acts as an AC-only filter and filters the 1V DC offset **(Figure 5.3)**. Two coupling mode's effects on the screen is shown below.

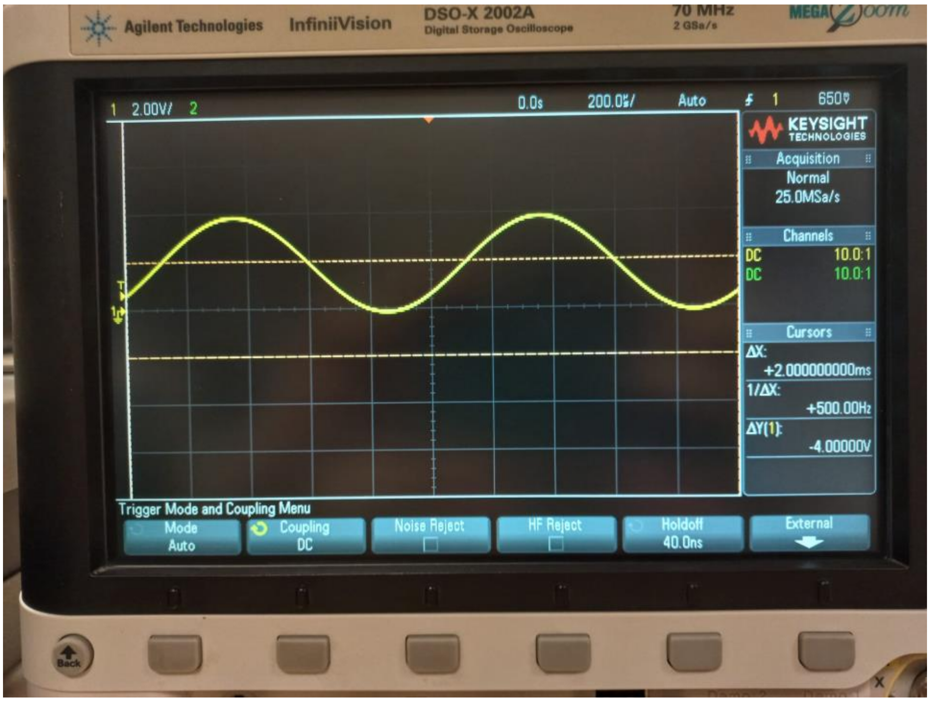

Figure 5.2: The signal with 1V DC offset on DC coupling

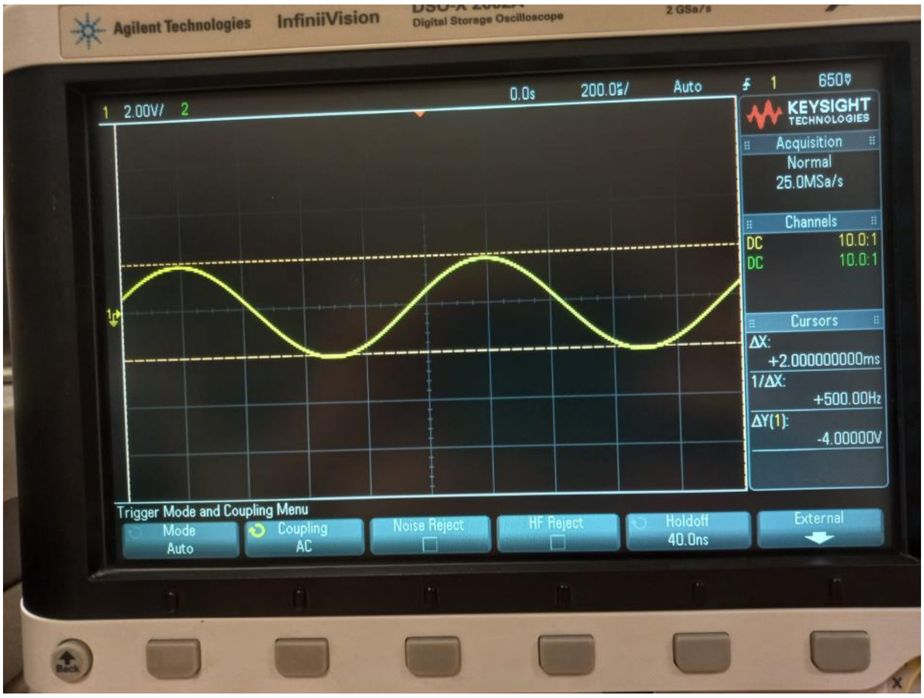

Figure 5.3: The signal with 1V DC offset on AC coupling

Part 6/6: First, the peak-to-peak voltage and frequency values were measured for signal X and Y both with 1kHz **(Figure 6.3)** and 100kHz **(Figure6.4)**. Using the 1 kHz signal from the generator, the frequency for signal X was 999.28Hz and for signal Y it was 999.68Hz. Peak-to-peak voltage for signal X was 3.0V and for signal Y it was 3.9V. When 100kHz signal was used, the frequency for signal X was 100.08kHz and its peak-to-peak voltage was 4.0V; for the signal Y, the frequency was 90.84kHz and peak-to-peak voltage value was 3.9V.

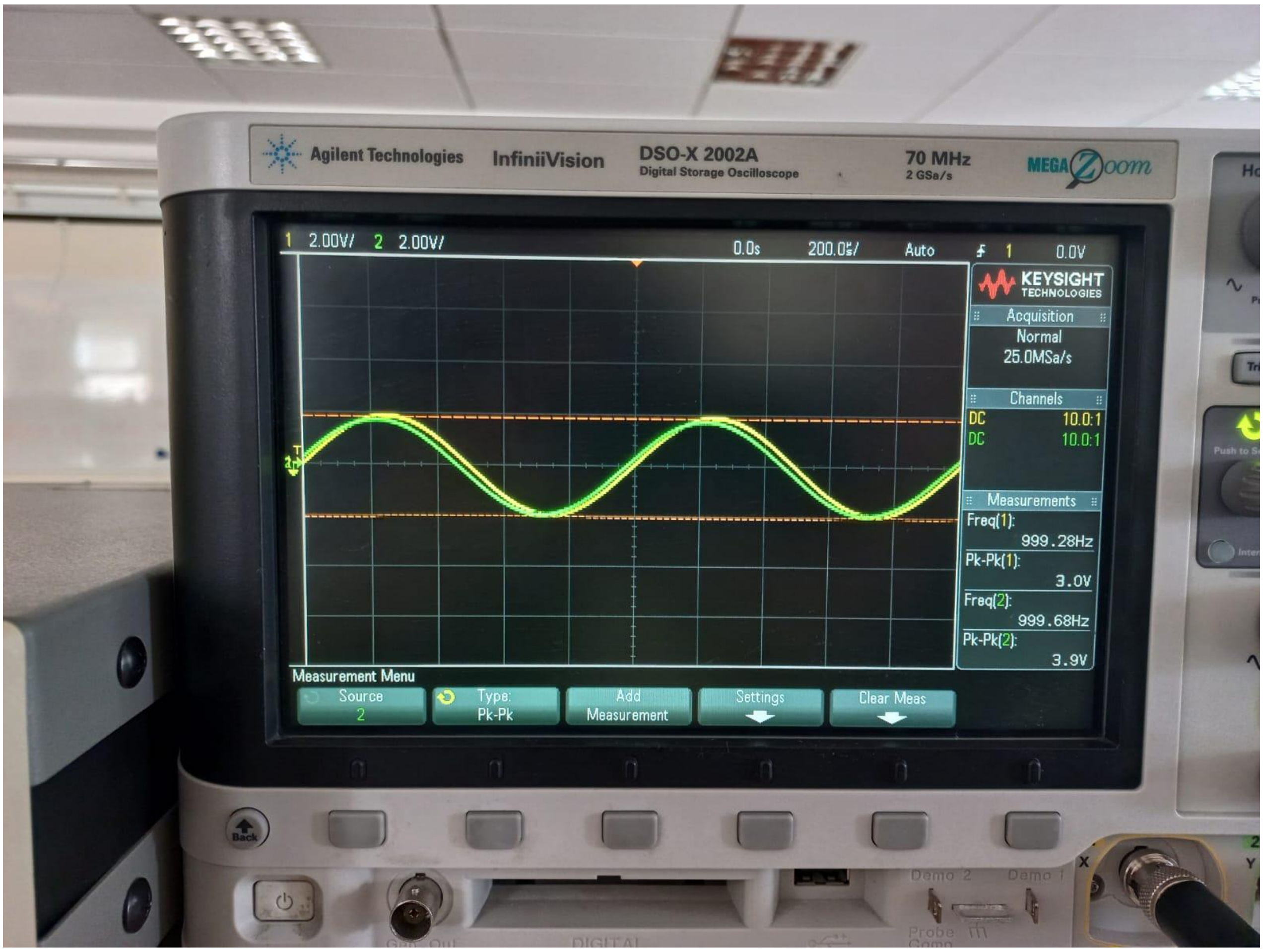

Figure 6.3: Frequency and Pk-Pk values for the 1kHz signal

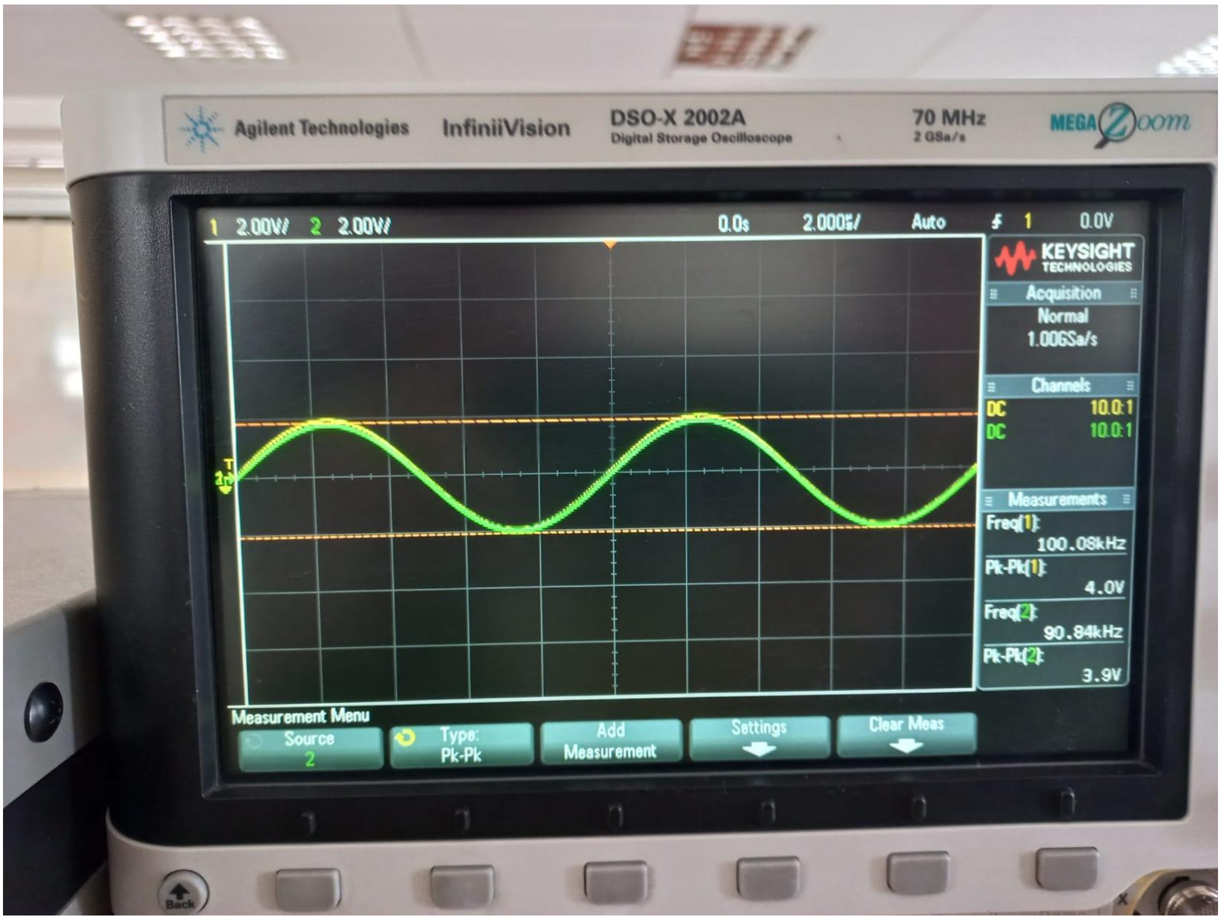

Figure 6.3: Frequency and Pk-Pk values for the 100kHz signal

Then, the delay and the phase difference was measured for both the 1kHz signal **(Figure 6.5)** and the 100 kHz **(Figure 6.6)** signal. Since the oscilloscope model that was used could measure the phase difference right away, there was no need to calculate the phase difference manually. For the 1kHz signal, delay between signal X and Y was 3.32µs and the phase difference was 3.30°. For the 100kHz signal, the delay between signal X and Y was –1ns and the corresponding phase difference was –0.04°. It is observed that the change in frequency does not change the amplitude of the signal, but it drastically changes the delay and therefore, the phase difference. When the frequency got higher, delay value decreased significantly.

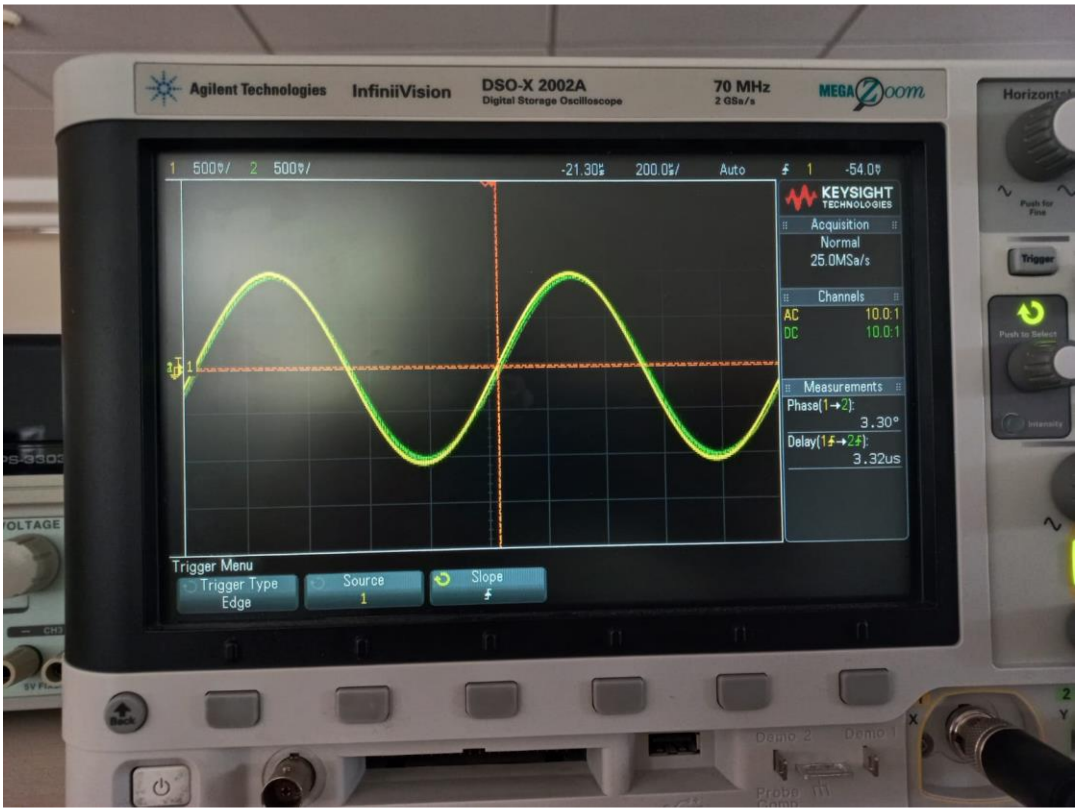

Figure 6.5: Delay and Phase Difference values for the 1kHz signal

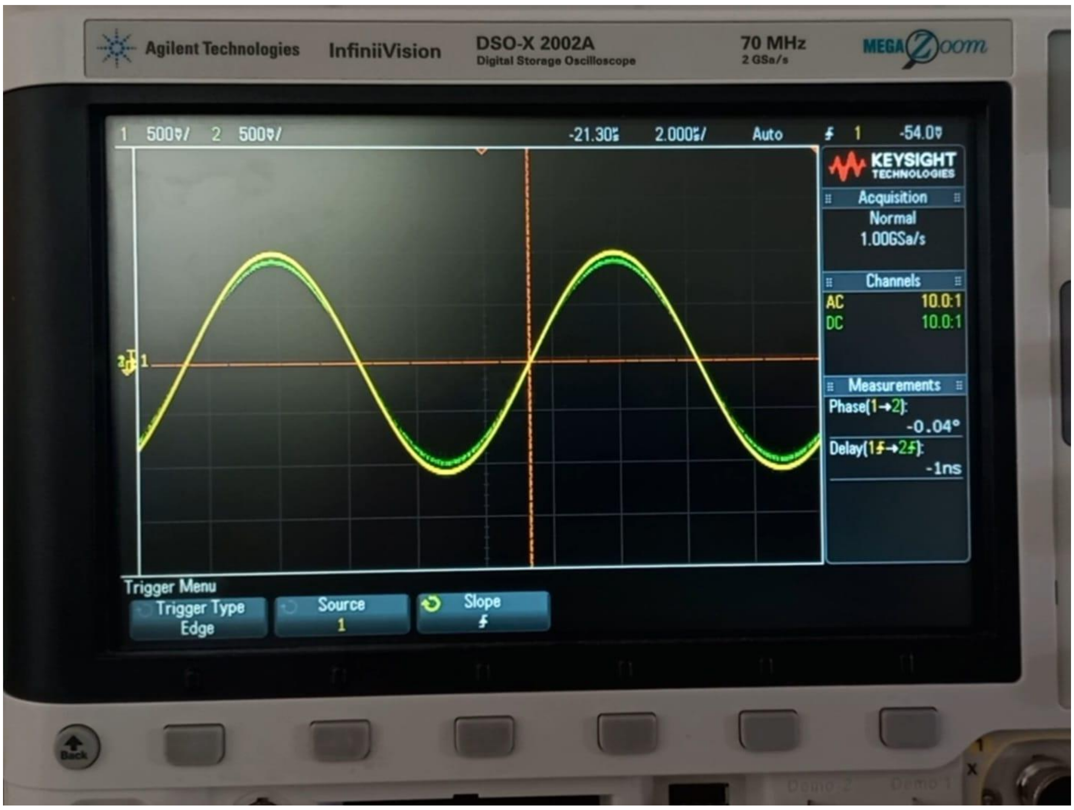

Figure 6.6: Delay and Phase Difference values for the 100kHz signal

Conclusion:

The general aim of this experiment was to become familiar with the typical functions of both an oscilloscope and a function generator. The results of the experiment generally aligned with the expected outcomes, and there was a foreseeable margin of error in the output data. This error might be caused by factors such as the resolution of the oscilloscope and function generator, as well as the quality of the oscilloscope probe and the function generator's cable. Additionally, there were instances where the amplitude specified by the function generator did not match the amplitude measured by the oscilloscope, resulting in a 1/2 ratio difference. This situation may be explained by the signal generator being terminated by a high impedance rather than the expected 50 ohms impedance. It is important to note that throughout the experiment, the voltage values were not altered in any way and was inputted to the signal generator as it was given in the lab manual.

Appendices:

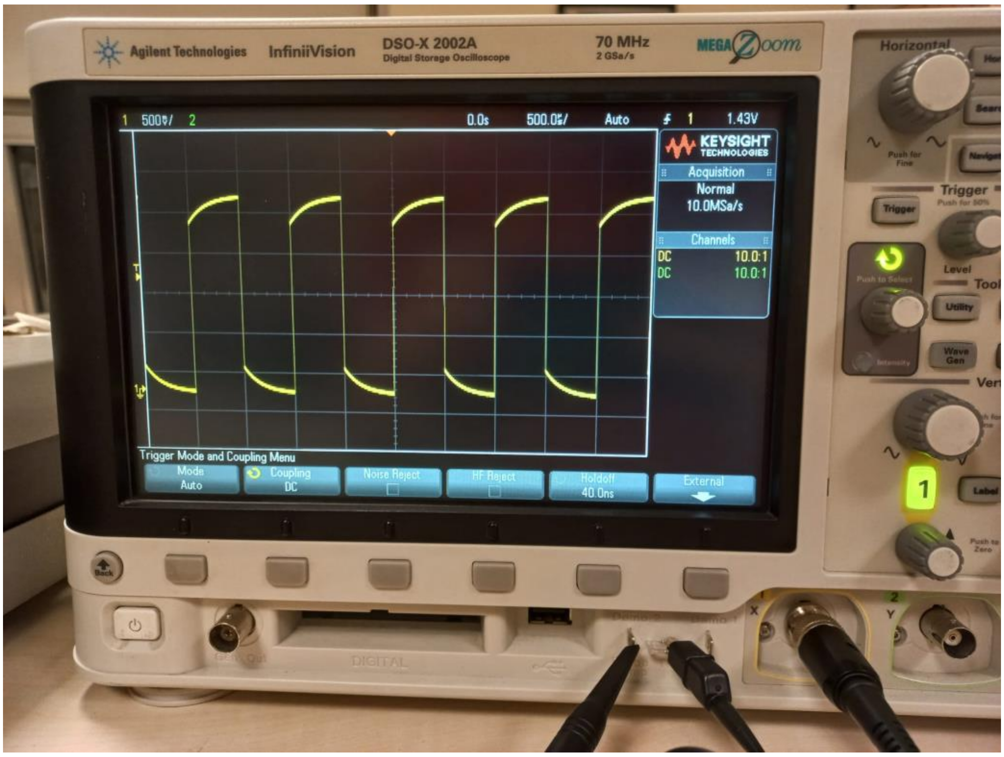

Figure 1.1: Under-compensated signal

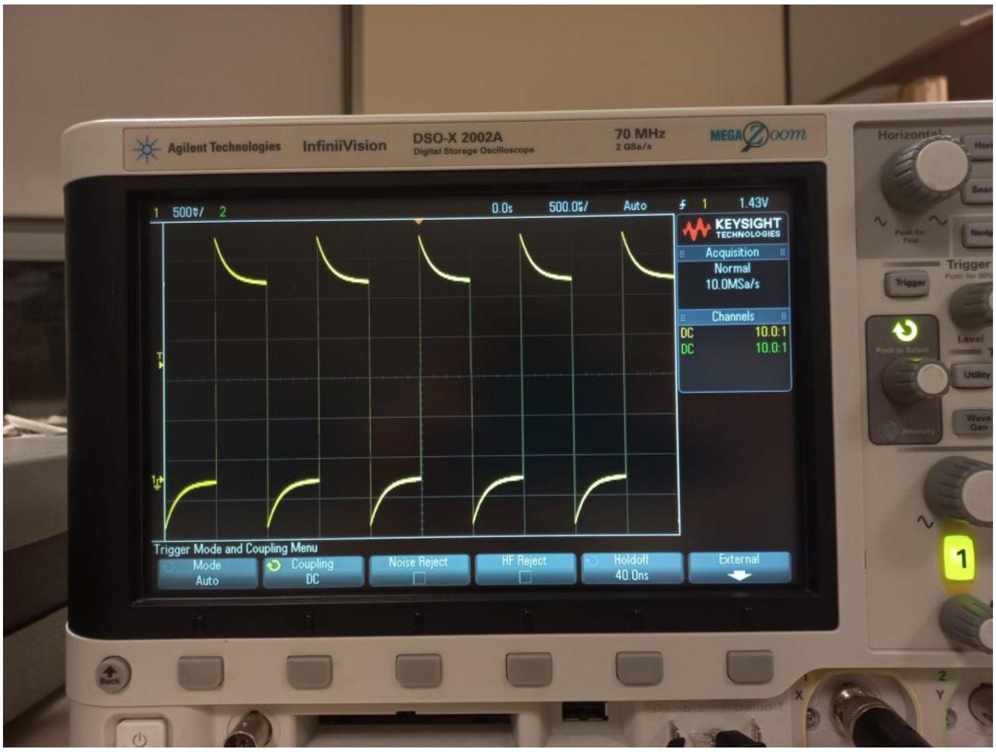

Figure 1.2: Over-compensated signal

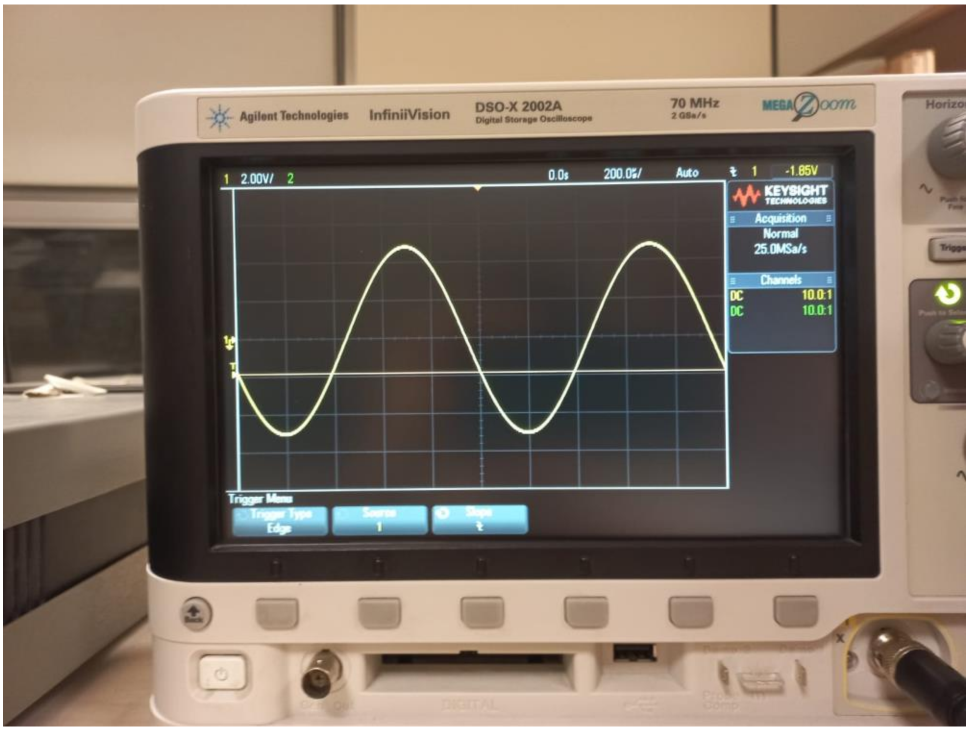

Figure 2.3: Negative Edge Triggering with a Falling Slope

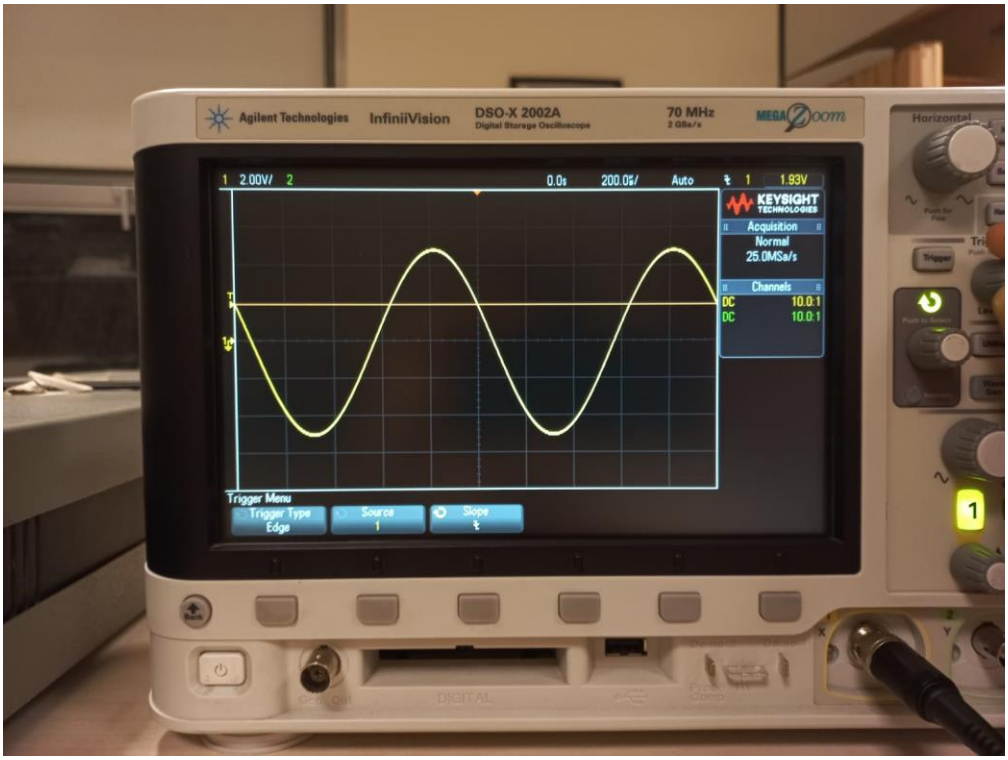

Figure 2.4: Positive Edge Triggering with a Falling Slope

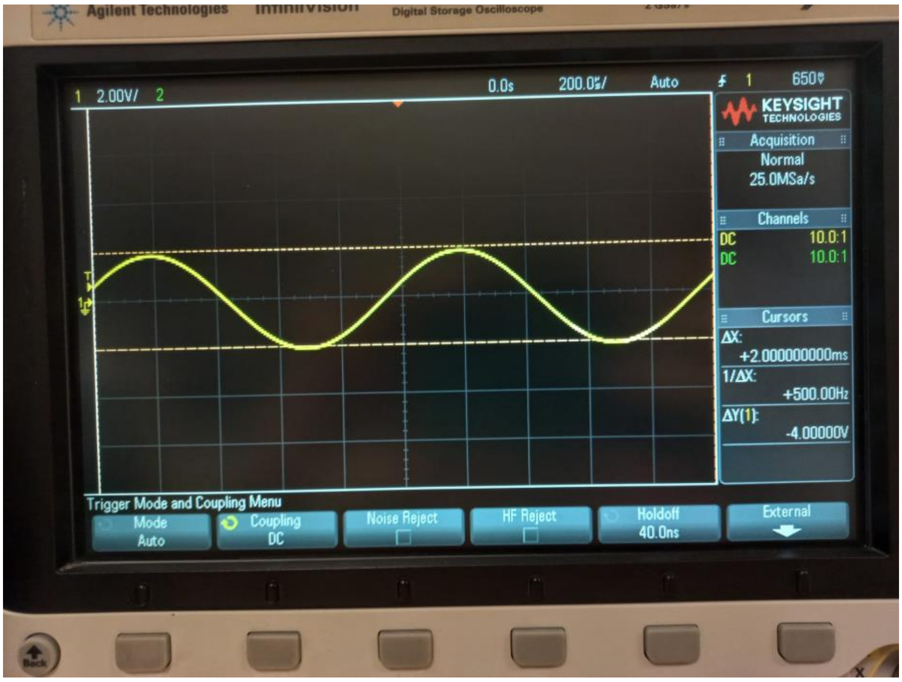

Figure 5.1: 2V Pk-Pk 1kHz sinusoidal signal

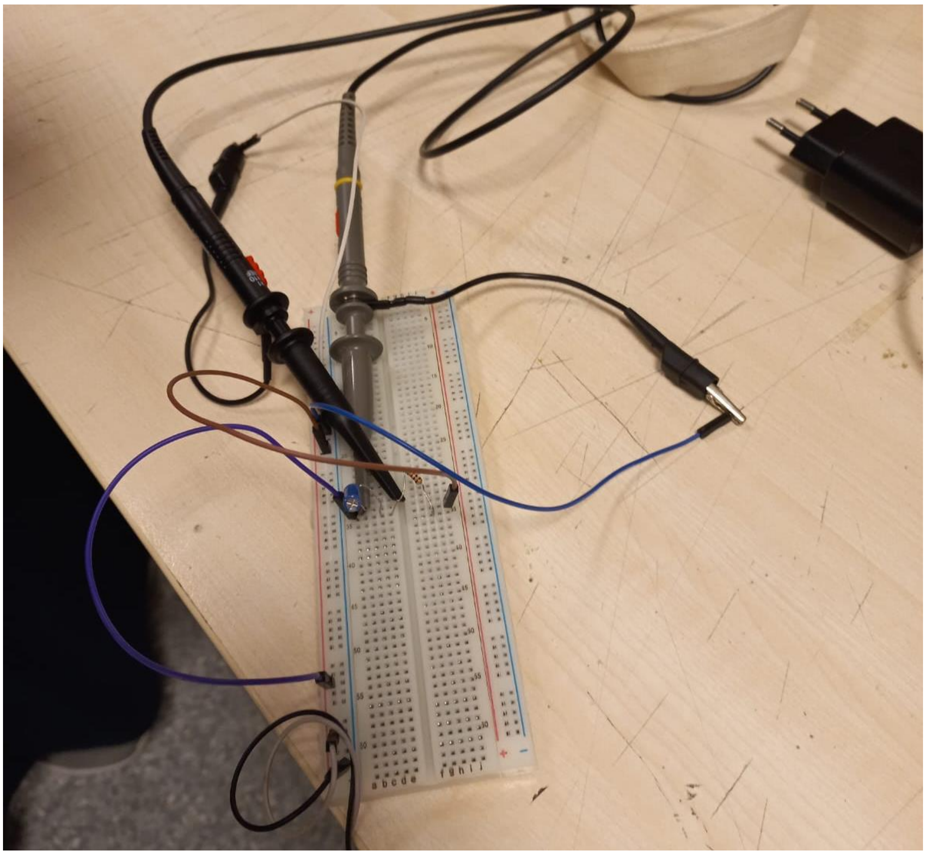

Figure 6.1: The RC Circuit that was assembled

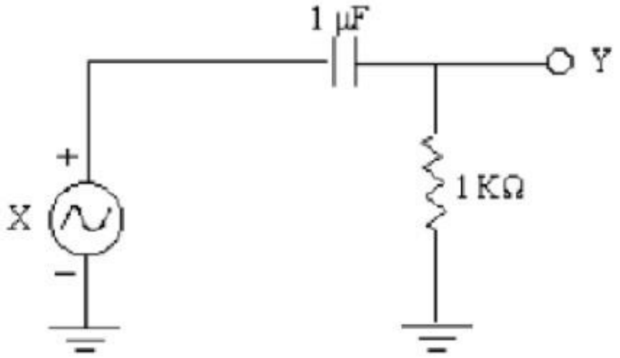

Figure 6.2: Visual representation of the RC Circuit that was assembled