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EE102-02

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LAB 1: INTRODUCTION TO DIGITAL OSCILLOSCOPES

A) PURPOSE

This experiment has been conducted to understand and practice digital oscilloscopes. Sending the desired type and amount of signal, using, and understanding the breadboard structure are other objectives of this experiment. Various types of the lab equipment have been used during the procedure.

B) METHODOLOGY

In the first part of the experiment, the oscilloscope probe has connected to CH1 of the oscilloscope. The probe tip was connected to the test part of the oscilloscope, which is also called the compensation.

The compensation process is done to adjust the probe to have a better view of the signal on the oscilloscope display. Oscilloscope probe compensation is not necessary when the attenuator is set to 1X, but an adjustment is required since the probe will be used at the 10X settings during the experiment process. I used an oscilloscope that has an auto compensation adjustment setting. Therefore, I didn't need to do manual compensation.

Oscilloscope probes are used at 10X, 100X, or 1000X probe attenuation levels to adjust measurement precision. When the probe attenuation level increases, the signal's amplitude decreases, but it becomes more precise. Adjusting the oscilloscope to the desired attenuation factor makes the amplitude seem the same as the signal's amplitude at the tip of the probe.

In the second part of the experiment, the signal generator was also used with the oscilloscope. A sine wave with a 1 kHz frequency and five voltage peak-to-peak have been created by using the signal generator.

$$W_1(t) = 2.5\sin(2\pi * 10^3 t + \theta)$$

The signal generator was connected to the CH1 of the oscilloscope. After using AUTOSET, the wave appeared in the middle of the display. The triggering line has moved above 0V to observe positive edge triggering. After recording data, the line has moved below the 0V to observe the negative edge triggering.

In the third part of the experiment, a triangular wave with 1V peak-to-peak and 2kHz frequency was generated with the signal generator. The triggering knob was used in this part of the experiment

Oscilloscope triggering is a function used to create a stable image of the signal in the oscilloscope display. If the triggering level goes above or below the peaks of the signal, the wave can't be triggered; therefore, an unstable wave will appear in the display. The oscilloscope knob is the rotatable switch that sets the voltage level value that is being wanted to be captured on the signal wave. When the wave reaches the desired voltage, the oscilloscope creates an image of the stabilized signal.

In the fourth part of the experiment, acquisition modes of the oscilloscope were being examined. An oscilloscope is a device that can convert analog signals to digital signals and send them to display for measurements and various applications. Therefore, it could be called as an ADC (Analog to digital) device. Oscilloscopes are used for examining the various type of signals and waves. They can measure different features of the signals like frequency, period, maximum voltage, minimum voltage, rising time, falling time, etc.

During this part of the experiment, a square wave with one voltage peak-to-peak and 5kHz frequency is used. Different acquisition modes of the oscilloscope are being examined in this part.

In SAMPLE acquisition mode, oscilloscopes receive one waveform for each period and send it to display. In PEAK DETECT acquisition mode, oscilloscopes receive two waveforms for each period interval and send them to display. This mode is helpful because it can show slight differences and peaks which happen in a period. In AVERAGE acquisition mode, the oscilloscope takes the average value of 8, 16, 64, or 128 waveforms for each period and sends it to display. This mode is useful when the user wants to receive a clear view of the wave. The average mode avoids the noises of the wave.

In the fifth part of the experiment, a sinusoidal signal with two voltage peak-to-peak, 1kHz frequency, and one voltage DC offset was sent to the oscilloscope probe.

$$W_2(t) = \sin(2\pi * 10^3 + \theta) + 1$$

When an offset value is added to a signal with the signal generator, it adds the desired DC voltage to the whole function of the signal

Different coupling techniques were used during this part. Coupling settings work like a voltage filter in an oscilloscope. For example, for the wave below

$$W_{example}(t) = \mathrm{a} * \sin(bt + c) + d$$

In DC coupling setting, the whole signal could be seen on the oscilloscope display, so it is an all-pass filter,

In AC coupling setting, just the alternating part of the voltage could be seen on display, so it is an ac-pass filter

$$W_{example}(t) \xrightarrow{AC\ Coupling} W_{example2}(t) = \mathrm{a}\sin(bt + c)$$

In the Ground coupling setting, no voltage could be seen on the display; therefore, it is a non-pass filter.

<u>In the sixth part of the experiment</u>, a breadboard, jumper cables, a capacitor with $1\mu F$, a resistance with $1k\Omega$, the signal generator, and the oscilloscope were used.

A breadboard is a functional circuit equipment that helps to create circuits easily without using solder. The structure of a breadboard is represented above.

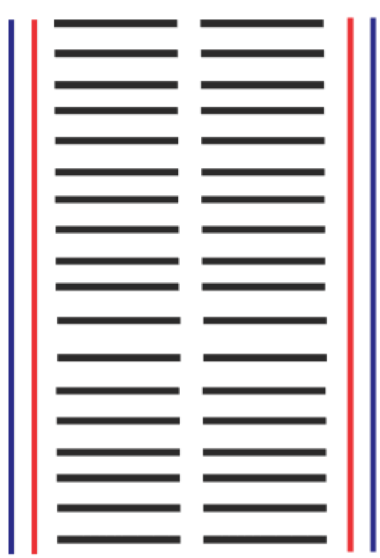


Figure 1: Structure of a breadboard

The lines are uninterrupted conductors, which helps to attach components in series to each other. Red lines are generally used for the high voltage, and blue lines are conventionally used for the ground voltage.

After setting up the circuit below, the signal generator is being used to create the desired signal.

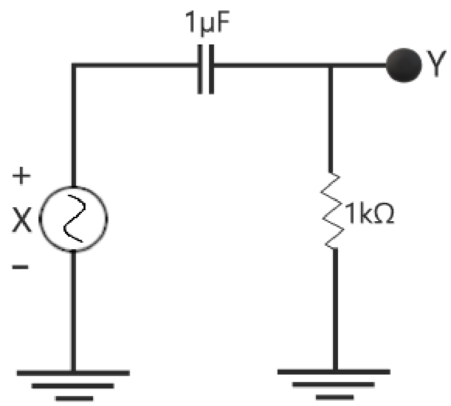


Figure 2: Circuit diagram of 6th part of the experiment

A sinusoidal signal with two voltage peak-to-peak and 1kHz frequency has been connected to the X. Two probes were connected to X and Y and plugged into CH2 and CH1 in order. The phase differences between the signals were calculated with the CURSOR function of the oscilloscope. After recording the results, the same procedure has repeated with a 100kHz sinusoidal signal. Values are again recorded.

Phase differences are calculated mathematically after implementing the experiment.

<u>For X = $\sin(2\pi * 10^3)$ $when\ f = 1kHz$:</u>

$$\text{The impedance of the circuit} = \sqrt{(X_R^2 + X_C^2)} = \sqrt{1000^2 + \frac{1}{2*\pi*10^3*10^{-6}}} = 1000.08\ \Omega$$

$$\text{Phase Difference} = \frac{\arctan\left(\frac{X_C}{X_R}\right)}{2\pi} = \frac{\arctan\left(\frac{\frac{1}{2*\pi*10^3*10^{-6}}}{1000}\right)}{2\pi f} = 0.00002512\ \text{s} = 25.12\mu\text{s}$$

$$\text{Y} = \frac{V(t)}{X} \cdot R = \frac{\sin\left(2\pi*10^3 + \arctan\left(\frac{\frac{1}{2*\pi*10^3*10^{-6}}}{1000}\right)\right)}{1000.08} * 1000$$

Eq1: Value of the X, Y, and phase difference when f = 1kHz

For X = $\sin(2\pi * 10^5)$ $when\ f = 100kHz$:

The impedance of the circuit = $\sqrt{(X_R^2 + X_C^2)} = \sqrt{1000^2 + \frac{1}{2*\pi*10^5*10^{-6}}}$ =1000.0012 Ω

Phase Difference = $\frac{\arctan\left(\frac{X_C}{X_R}\right)}{2\pi} = \frac{\arctan\left(\frac{\frac{1}{2*\pi*10^5*10^{-6}}}{1000}\right)}{2\pi f} = 0.000000002533\ \text{s} = 0.002533\mu\text{s}$

$$Y = \frac{V(t)}{X} \cdot R = \frac{\sin\left(2\pi*10^3+\arctan\left(\frac{\frac{1}{2*\pi*10^5*10^{-6}}}{1000}\right)\right)}{1000.08} * 1000$$

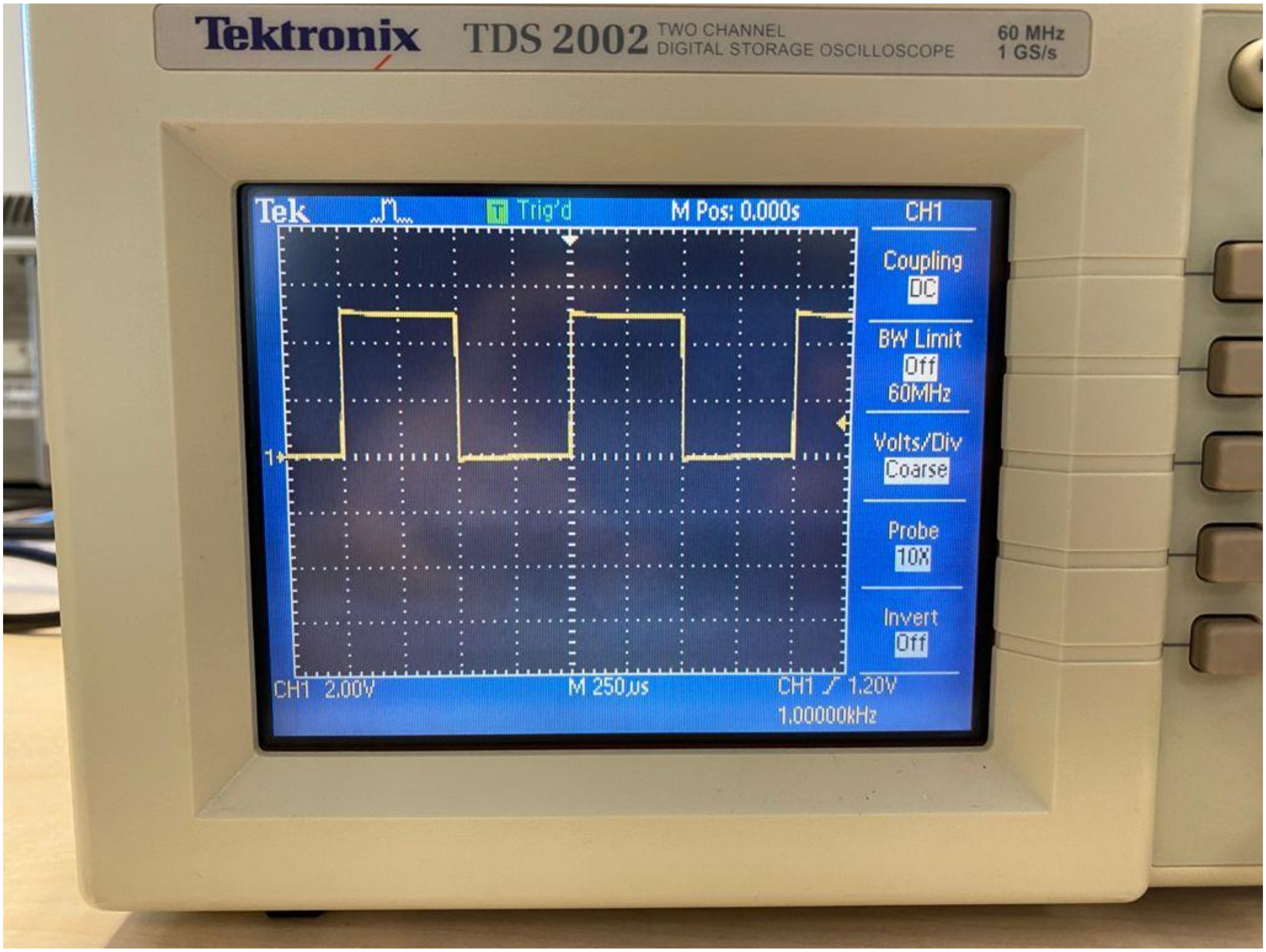
Eq2: Value of the X, Y, and phase difference when f = 100kHz

NOTE1: Because of the inner complexity and structure of the signal generator, the output signal received in the oscilloscope with two times greater than the expected value. The reason for this problem comes from the 50-ohm output resistance prediction of signal generators. Half of the required voltages have sent to the oscilloscope get the correct value on display during the experiment. Also, the required voltage has been sent but received double the expected value.

NOTE2: I forgot to use 10X probe in some of the parts during the experiment and used 1X instead. It is not a significant problem.

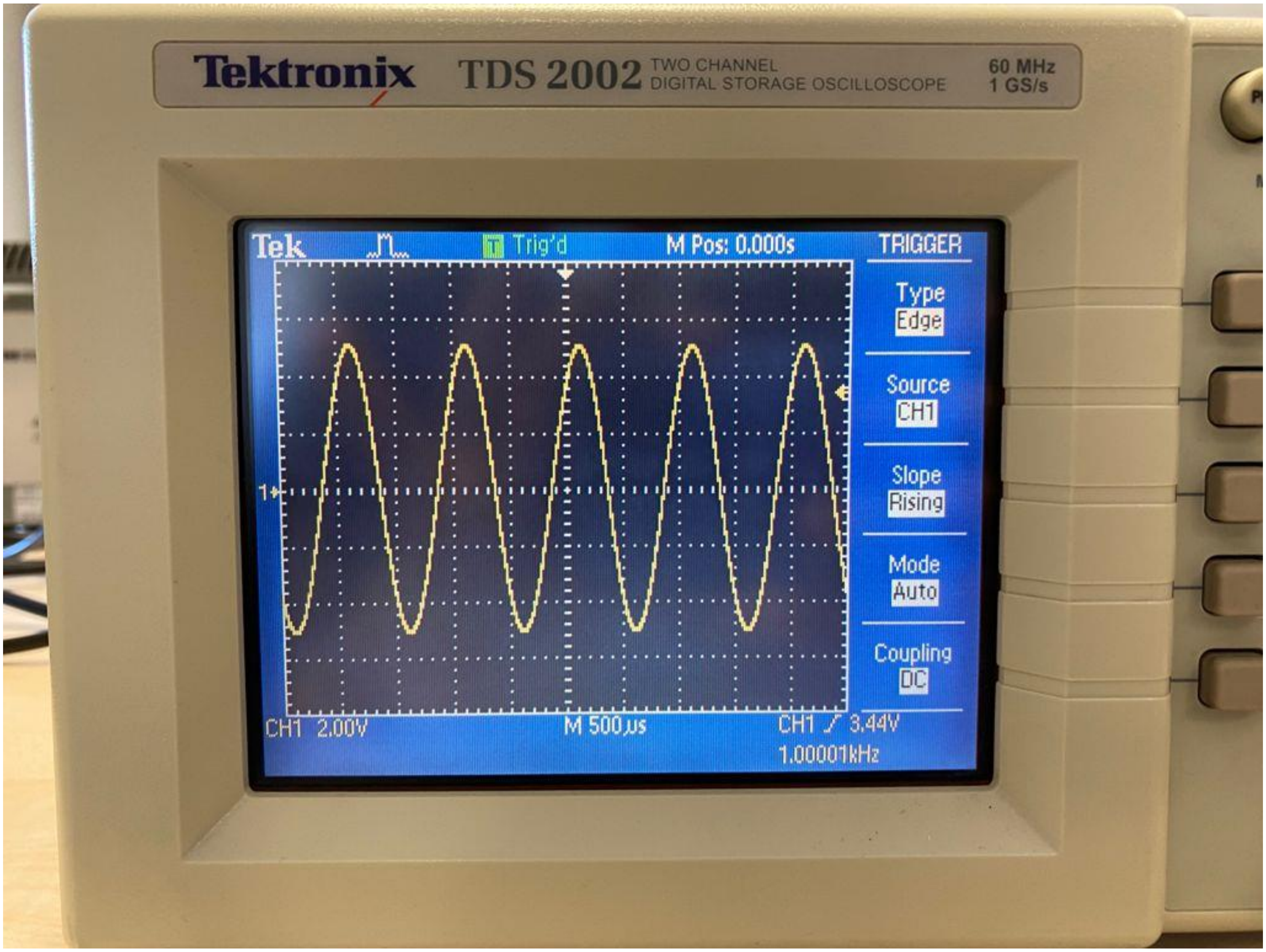
C)RESULTS

In the first part of the experiment, the probe is compensated automatically, and the image below occurred on the oscilloscope screen.

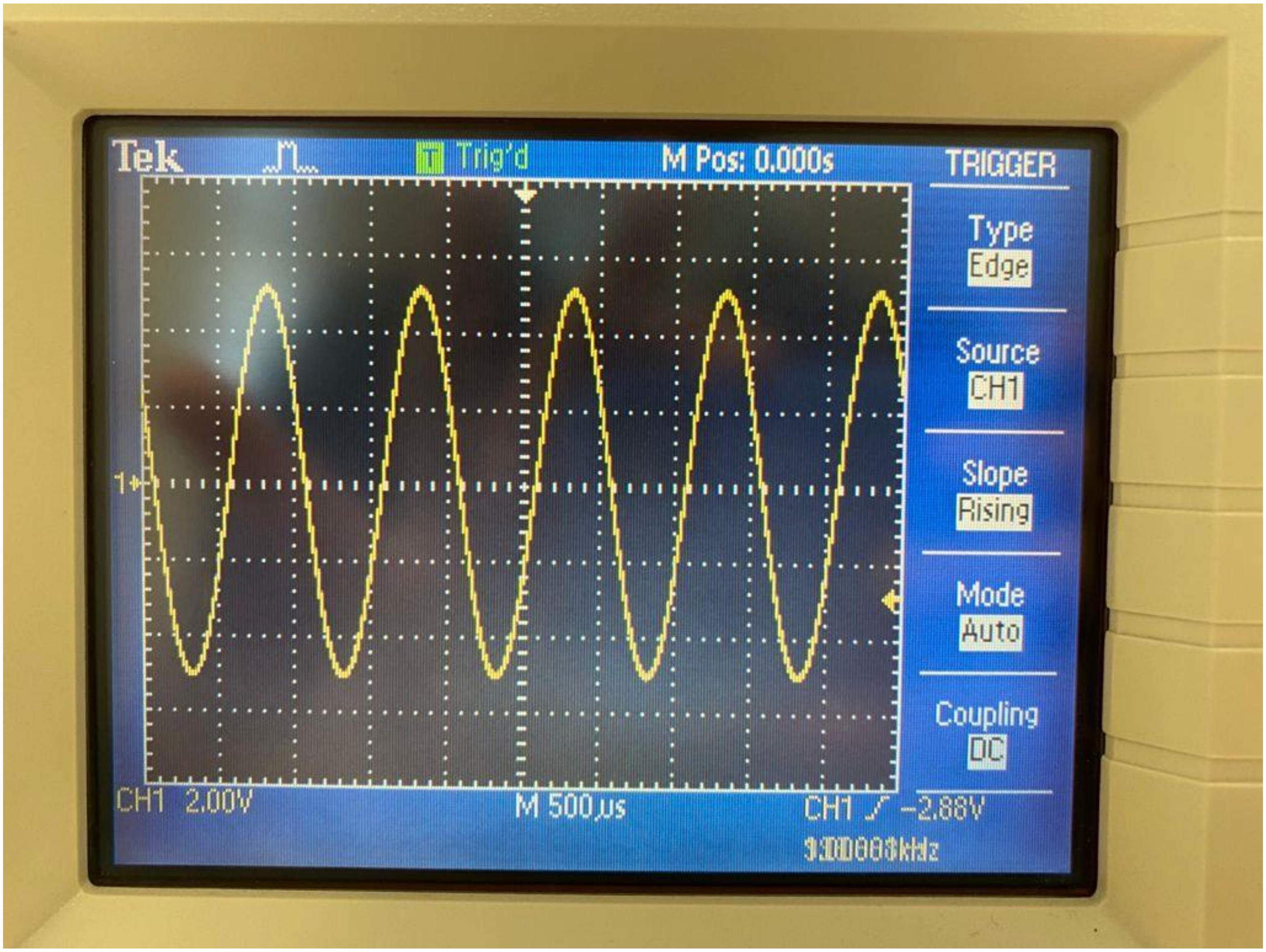


(Image 1: First part of the experiment)

In the second part of the experiment, the signal was triggered both from the positive edge and the negative edge, as seen from the images below.



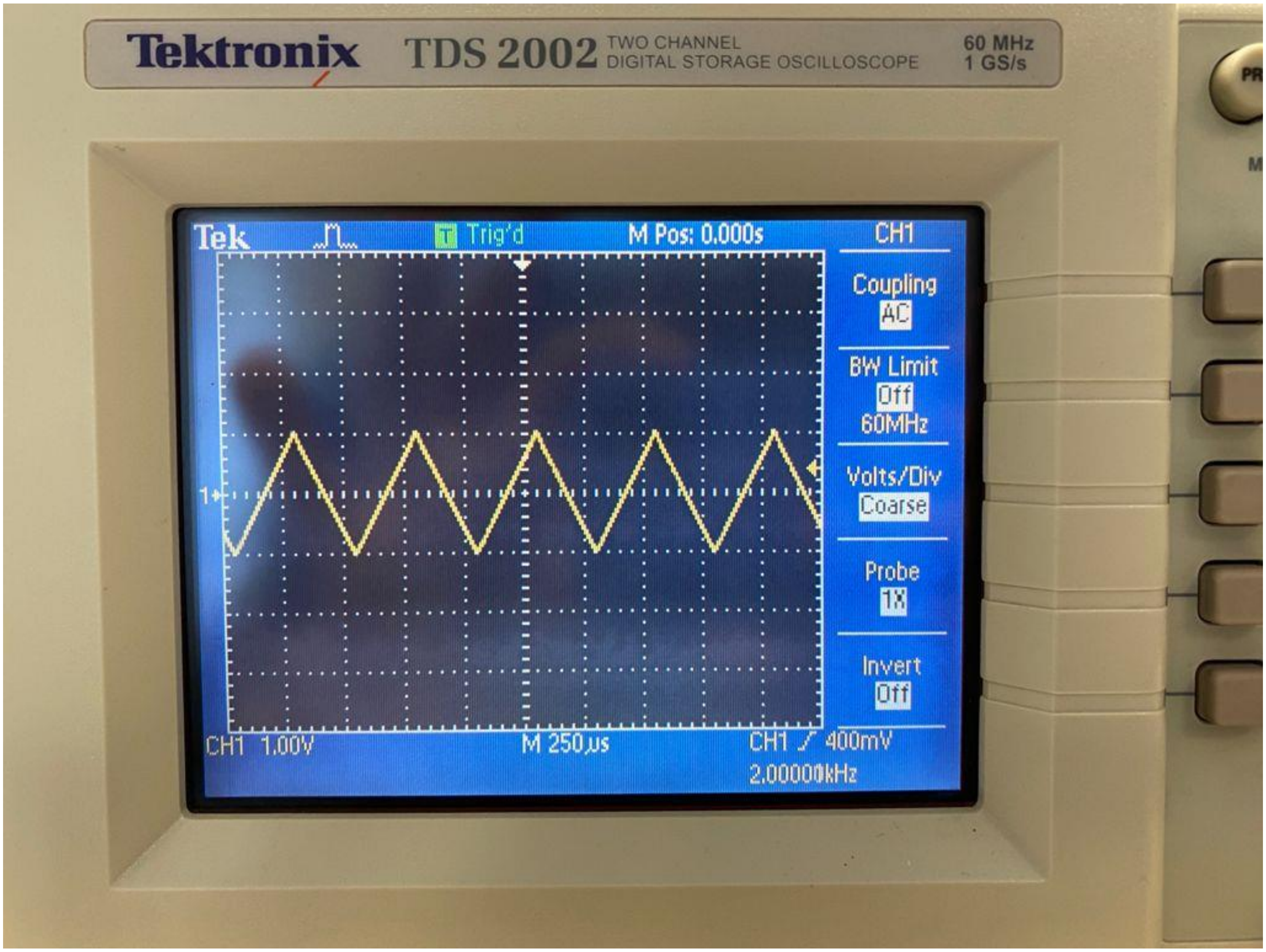
(Image 2: Second part of the experiment, sinusoidal wave with positive triggering)



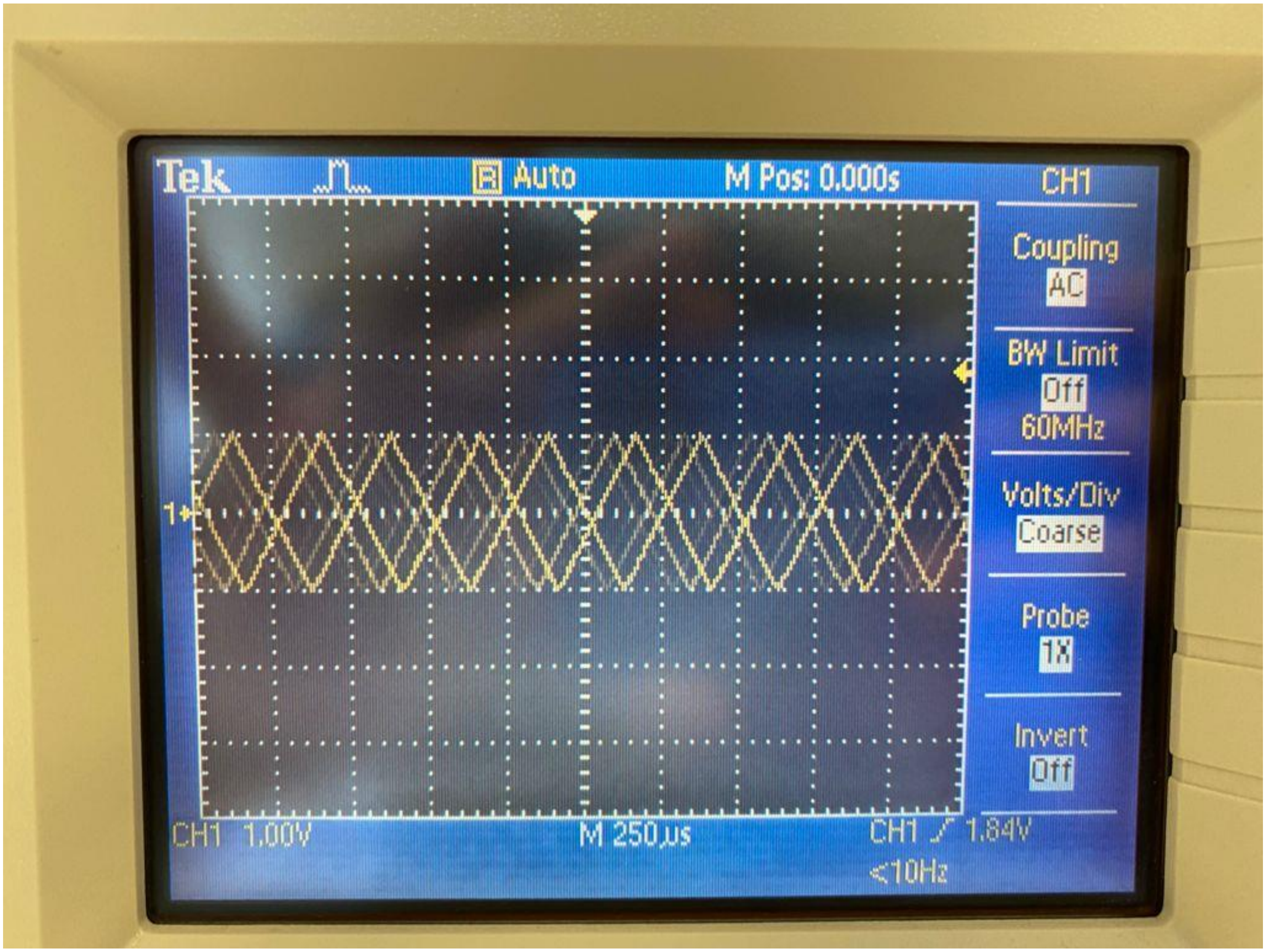
(Image 3: Second part of the experiment, sinusoidal wave with negative triggering)

Positive triggering happens when you trigger the signal above the 0V level (Image 2), and negative triggering happens when the signal is triggered below the 0V level (Image 3). Because the slope is at the rising condition, the negative triggering shifted the signal a bit forward.

In the third part of the experiment, the triangular wave disappeared. An unstable image was created on the display when the triggering voltage level surpassed the maximum voltage levels of the signal. The triggering decides at which voltage to capture the image of the signal, so images below occurred during the experiment



(Image 4: Third part of the experiment, sinusoidal wave when it is triggered)



(Image 5: Third part of the experiment, triangular wave without triggering)

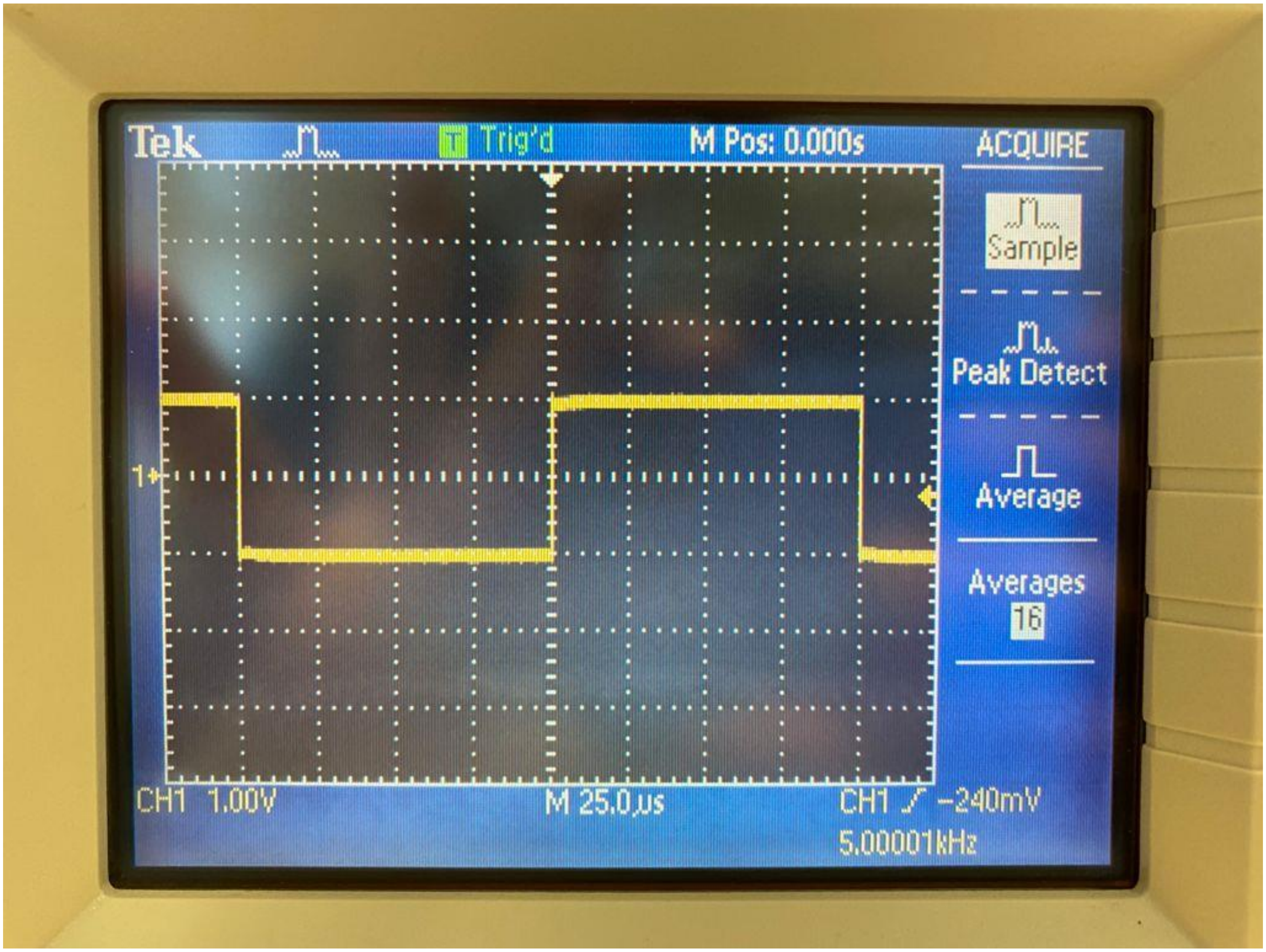
NOTE: Additional images are at the appendices with half of the voltage sent from the signal generator (Check Image 16)

In the fourth part of the experiment, different modes of the oscilloscope are being tested. Results are explained with the images below.

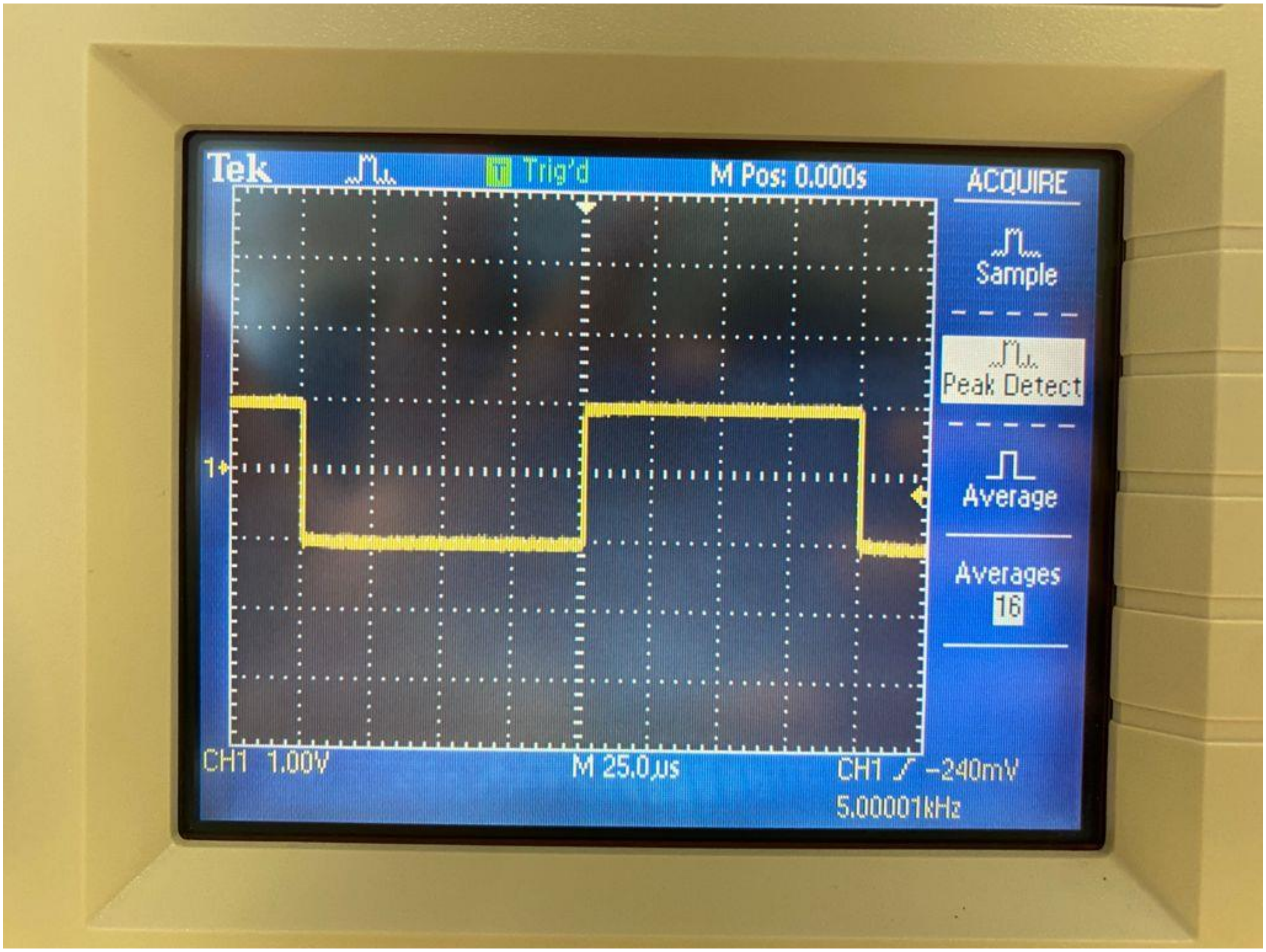
In Image 6: The wave is acquisition with SAMPLE mode. It is the default signal that could be seen from an oscillator.

In Image 7: The wave is acquisition with PEAK DETECT mode. It is noisier than the SAMPLE mode but is more detailed for examining the stability and difference of the signal

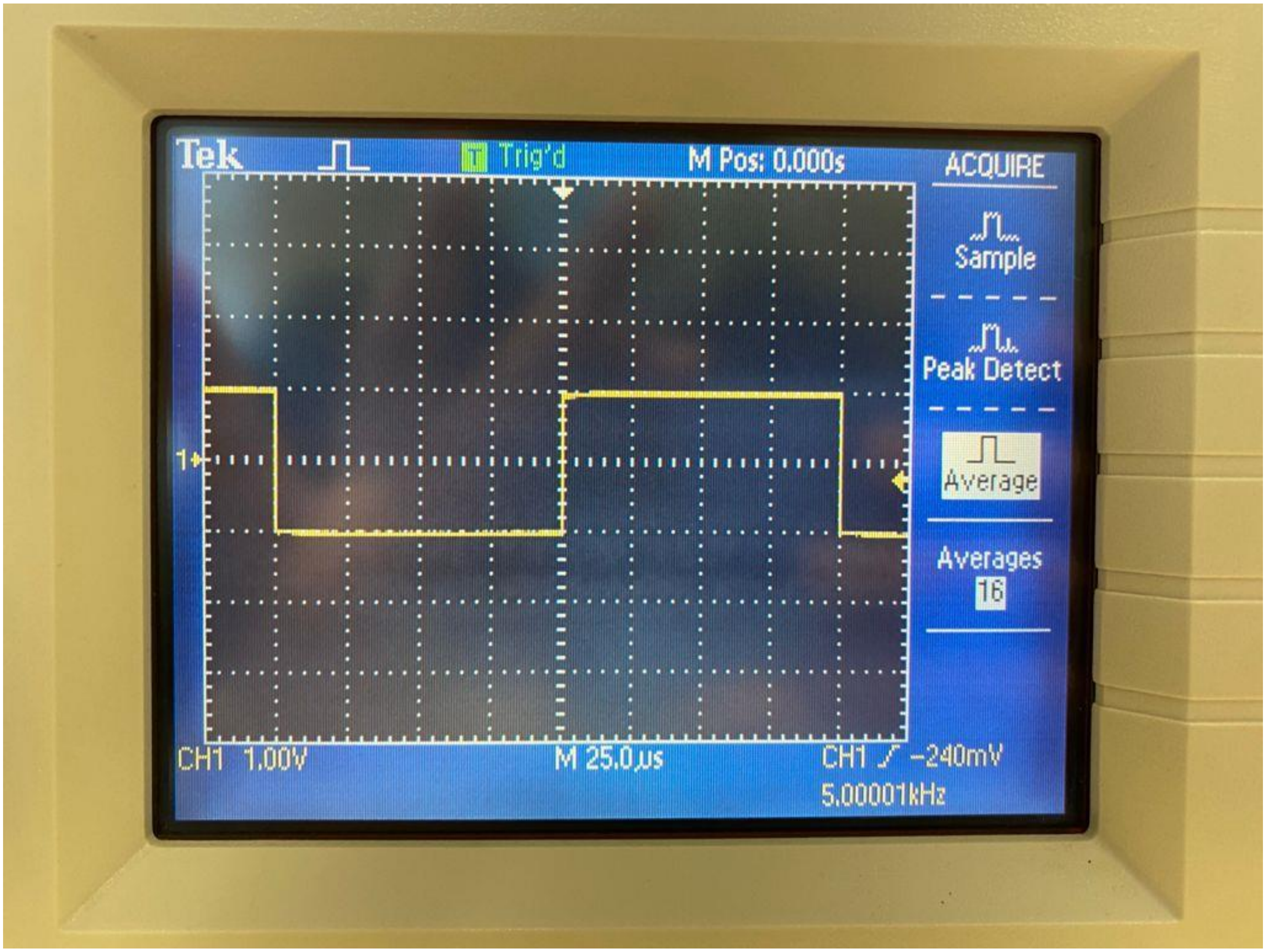
In Image 8: The wave is acquisition with AVERAGE mode. It is an average of 8 signals, and therefore there is a smoother image than the SAMPLE mode.



(Image 6: Fourth part of the experiment, signal acquired in SAMPLE mode)



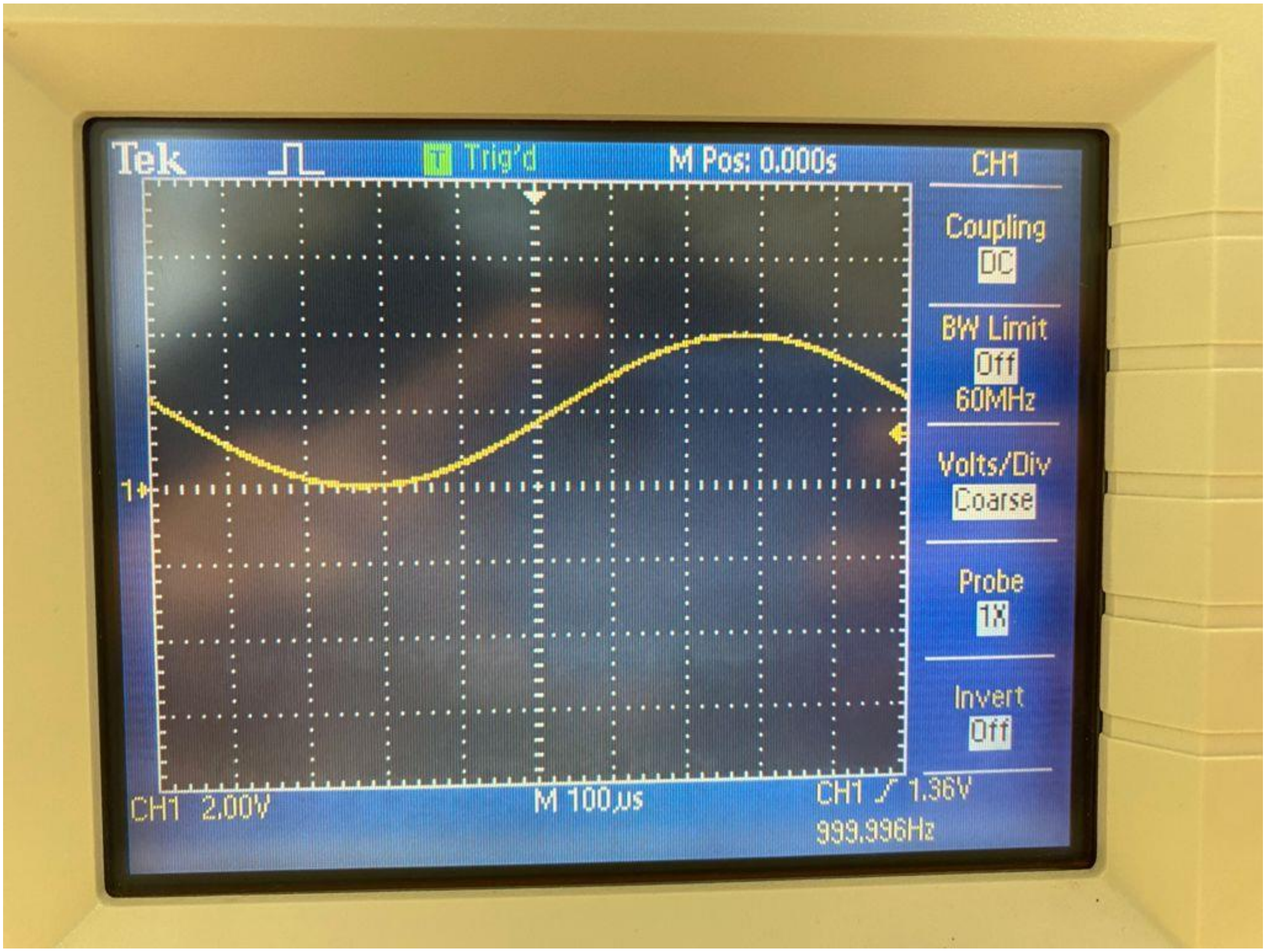
(Image 7: Fourth part of the experiment, signal acquired in PEAK DETECT mode)



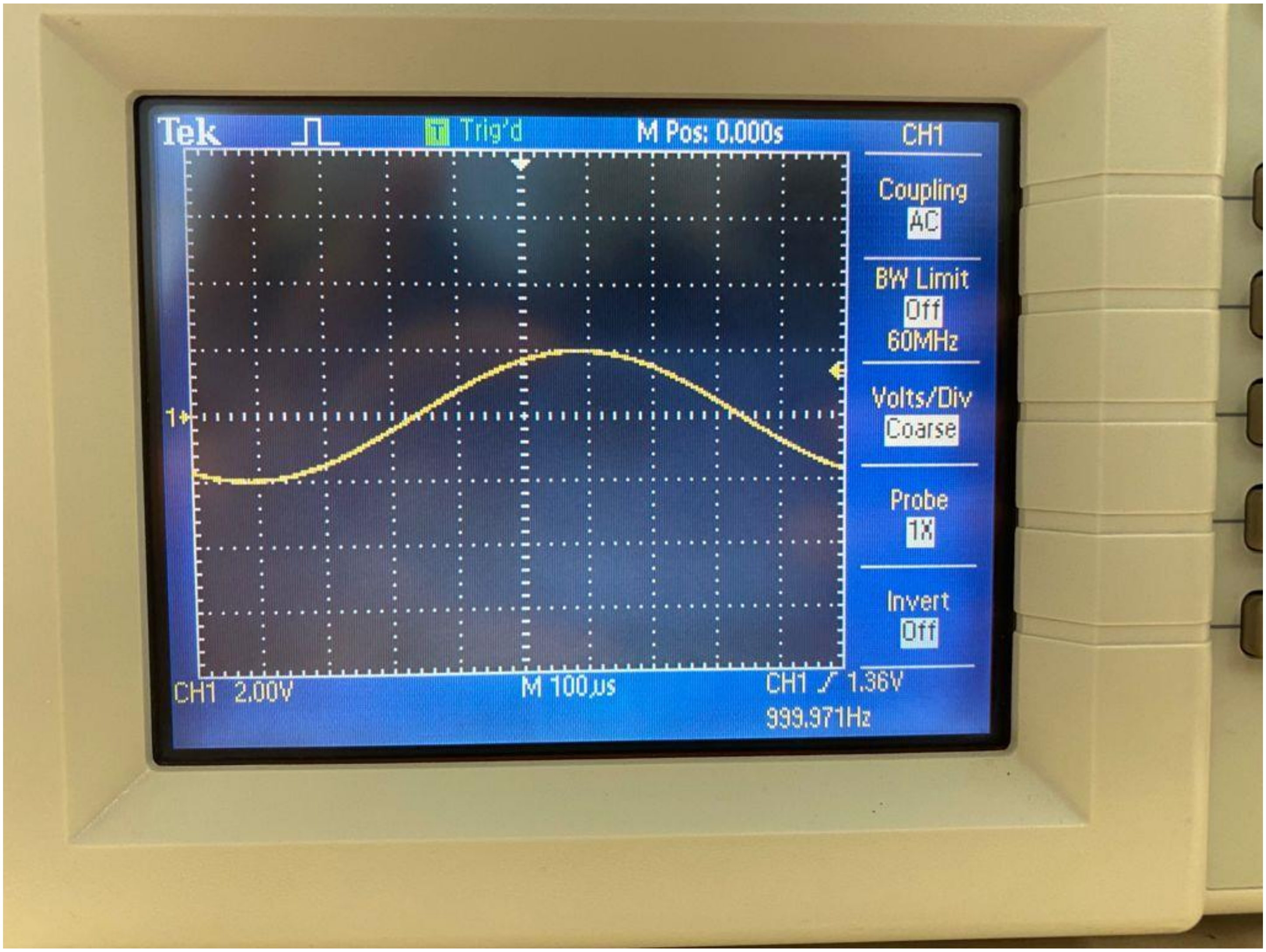
(Image 8: Fourth part of the experiment, signal acquired in AVERAGE mode)

NOTE: Additional images are at the appendices with half of the voltage sent from the signal generator (Check Image 17, Image 18, Image 19)

In the fifth part of the experiment, the signal is seen as the combination of AC and DC voltages when the coupling is at DC mode. Only the AC part of the signal could be seen on the oscilloscope display in AC coupling mode.



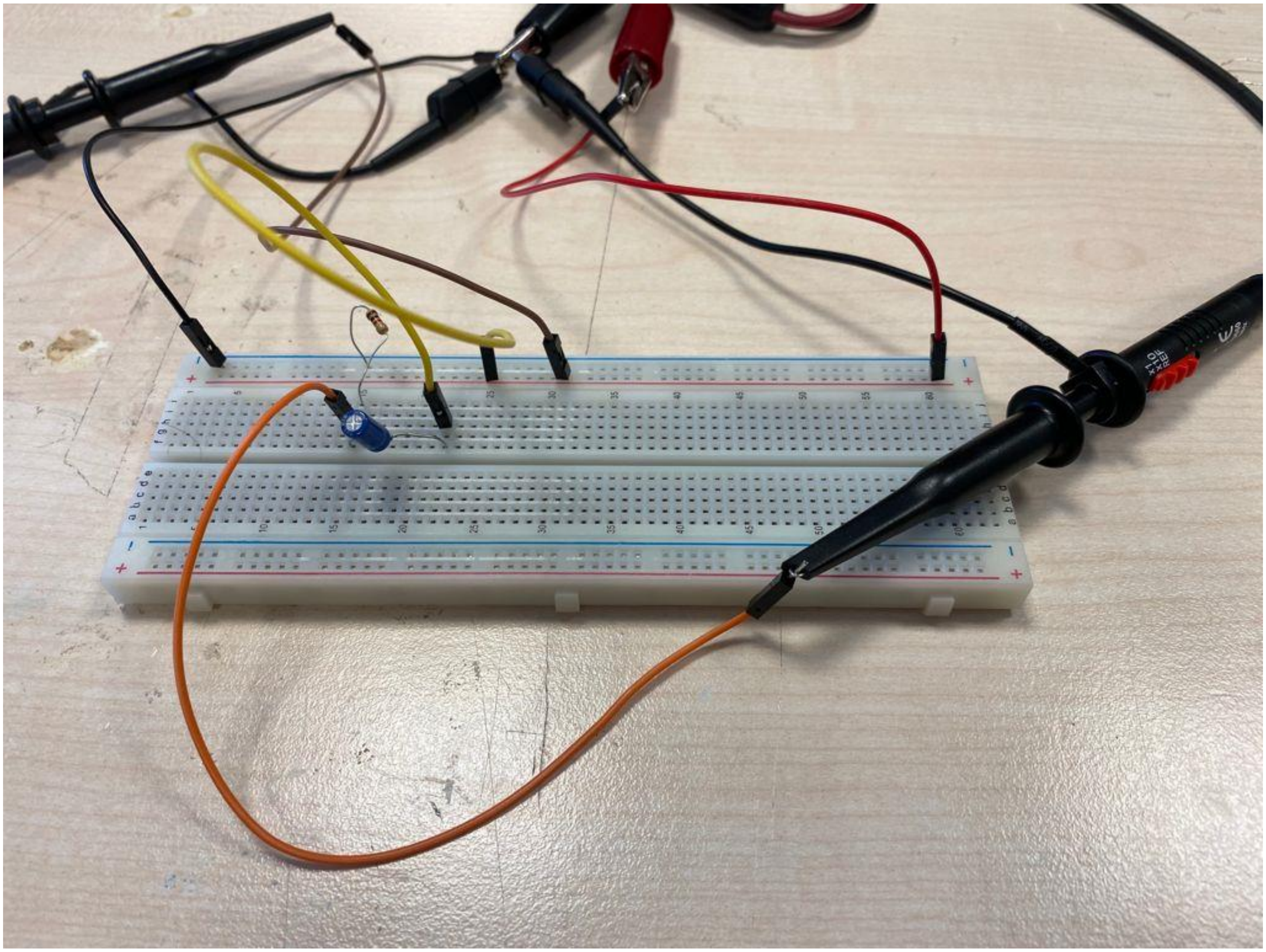
(Image 9: Fifth part of the experiment, coupling is set to DC, both AC and DC voltages could be seen)



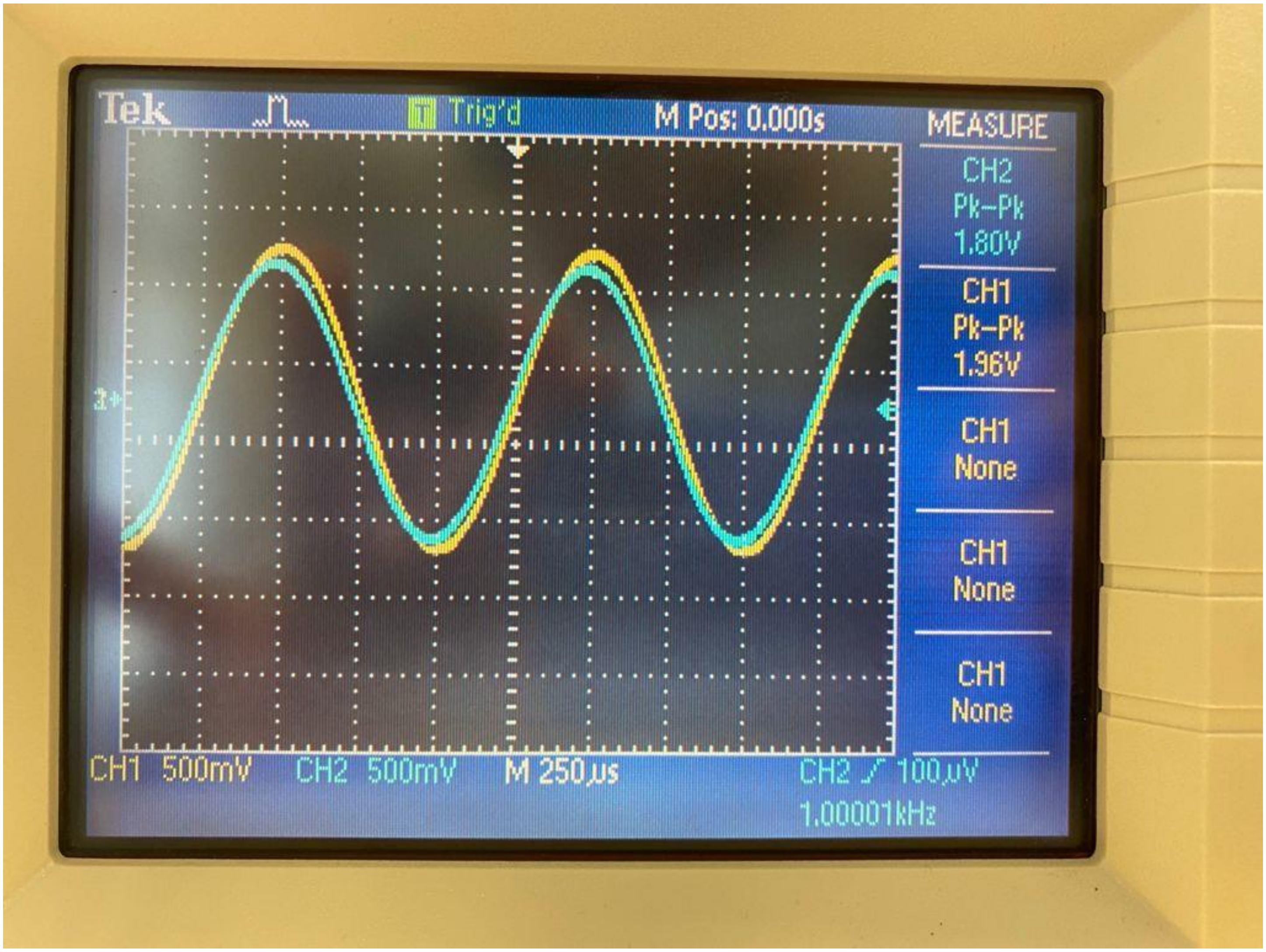
(Image 10: Fifth part of the experiment, the coupling is set to AC, only AC voltage could be seen)

NOTE: Additional images are at the appendices with half of the voltage sent from the signal generator (Check Image 20, Image 21)

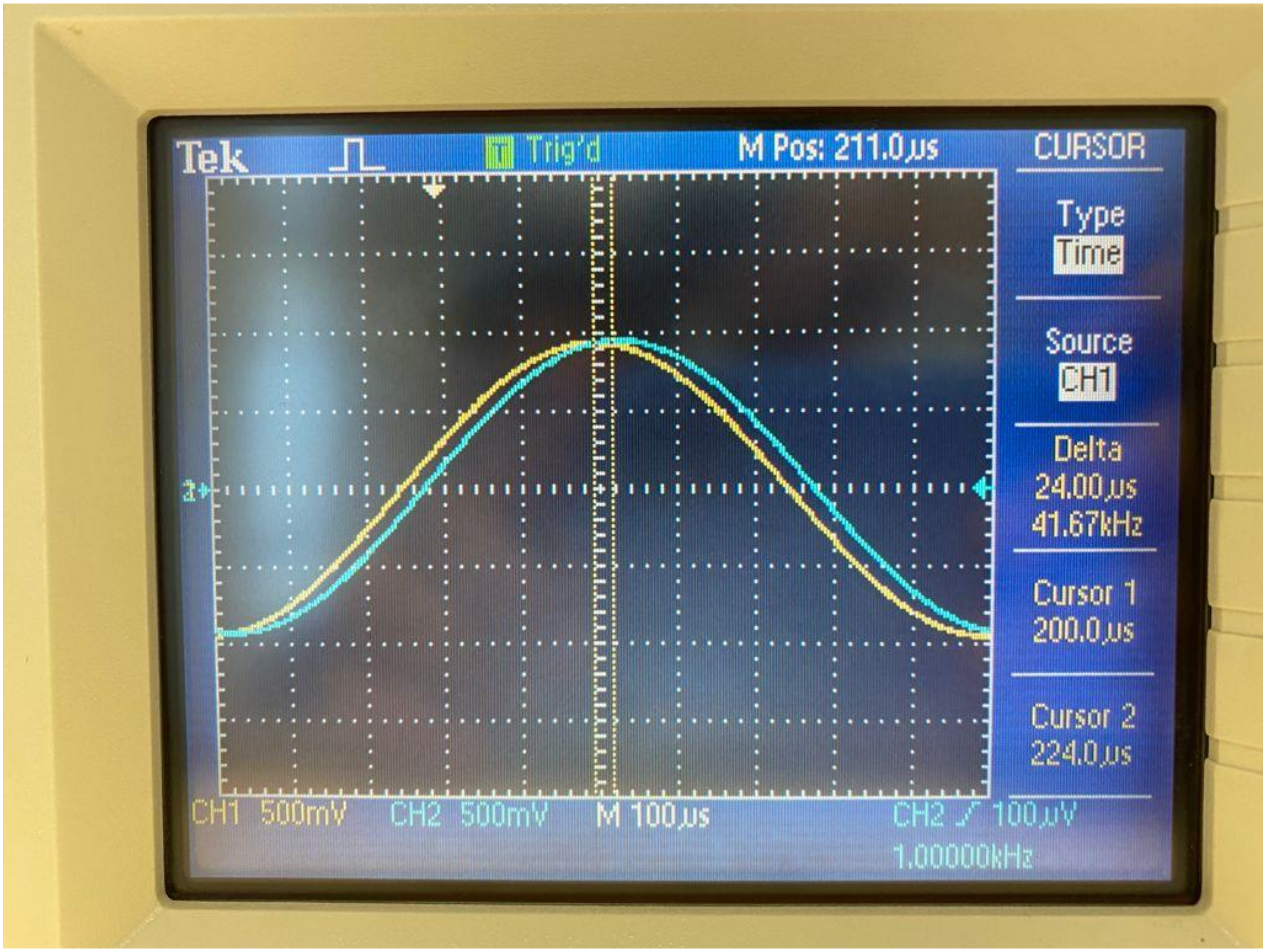
In the sixth part of the experiment, the circuit in the lab manual was set, and the experiment was conducted. The phase difference was too small, as expected in the methodology part (Eq1 and Eq2). With a higher frequency, the phase difference got smaller, and it became impossible to measure the value of the difference with the CURSOR function. Therefore the data was recorded as 0s.



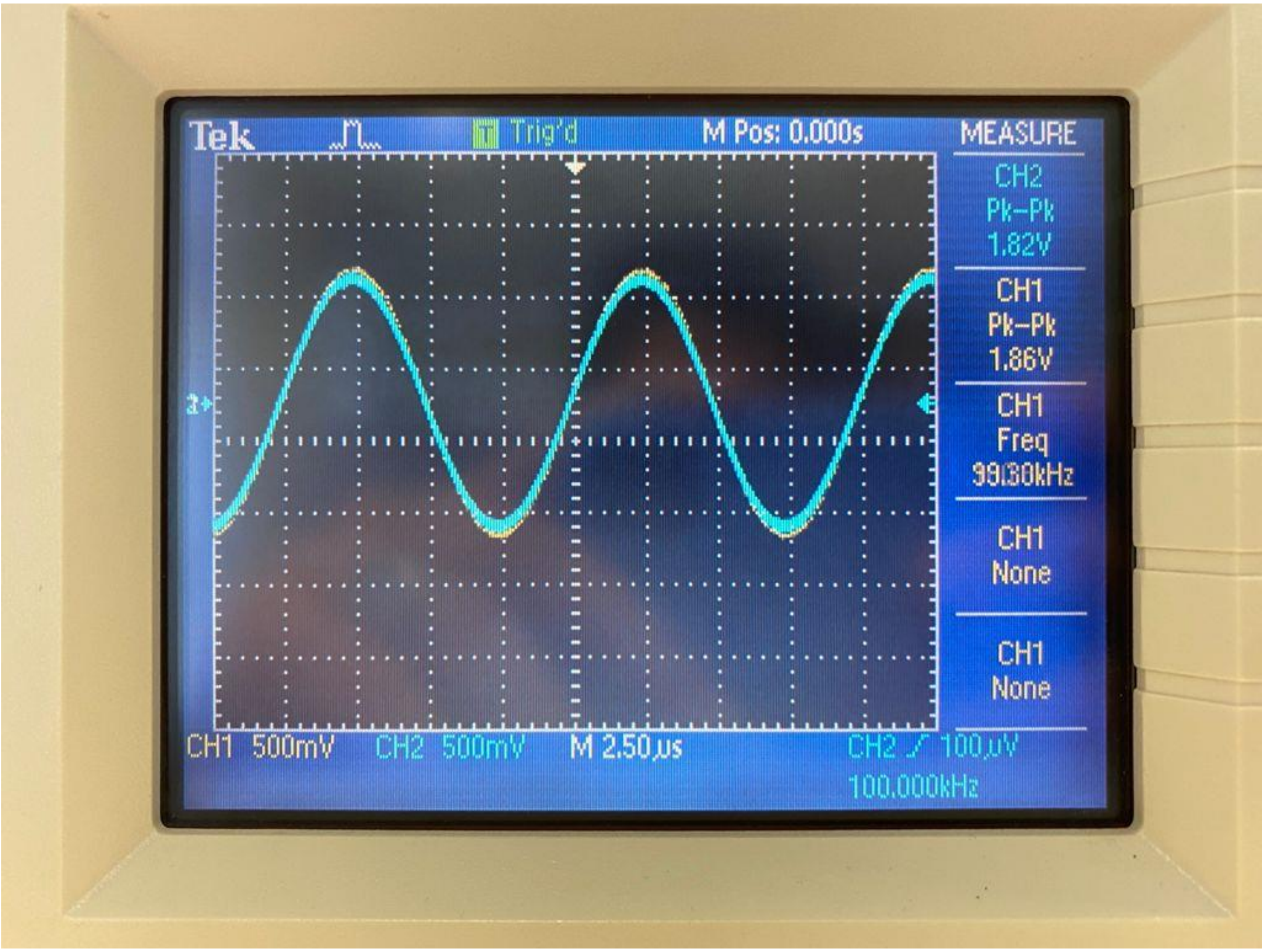
(Image 11: Sixth part of the experiment, the circuit)



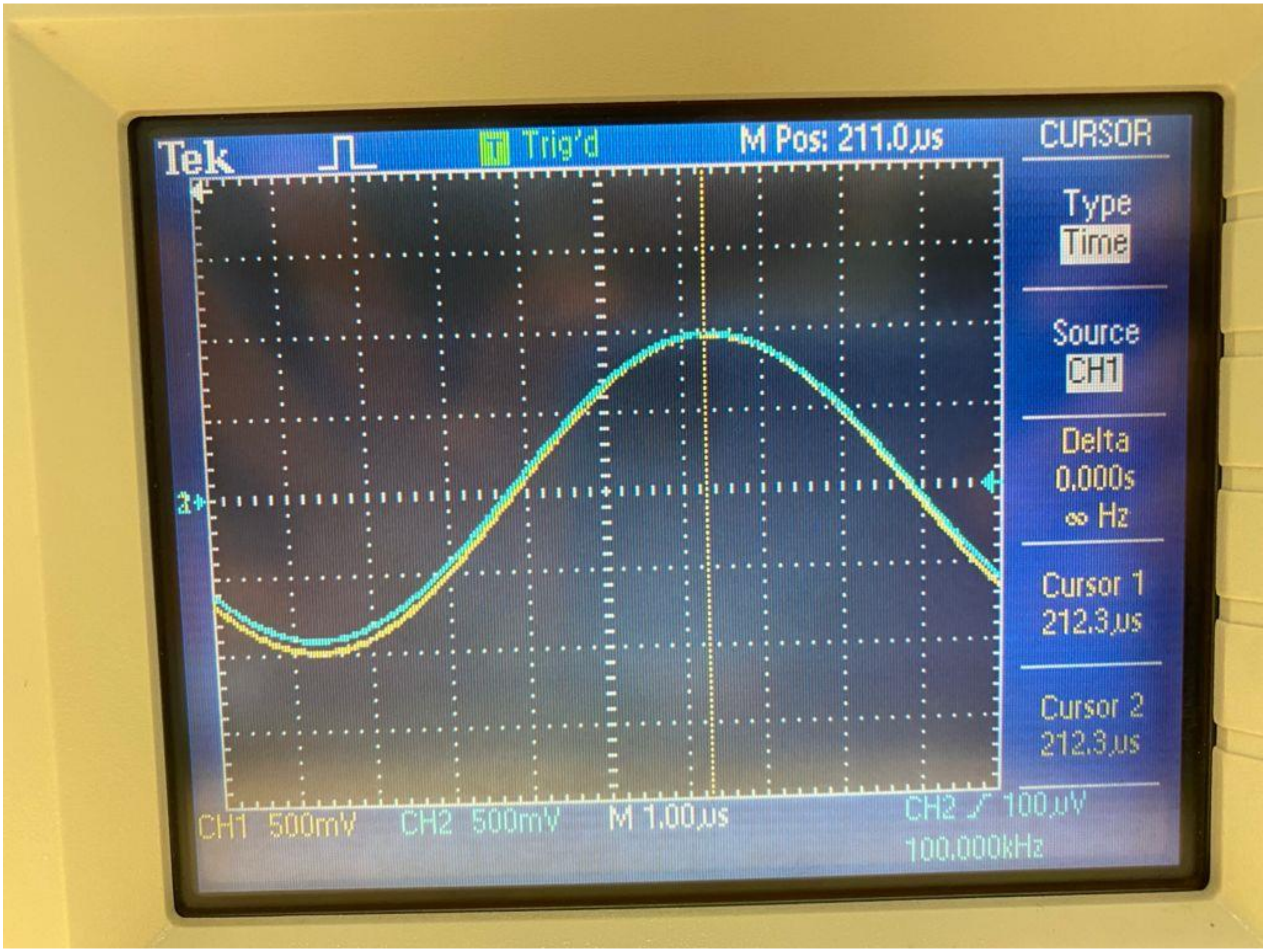
(Image 12: Sixth part of the experiment, the circuit with 1kHz frequency applied to the X node)



(Image 13: Sixth part of the experiment, the phase difference when 1kHz frequency applied to the X node is equal to 24 nanoseconds)



(Image 14: Sixth part of the experiment, the circuit with 100kHz frequency applied to the X node)



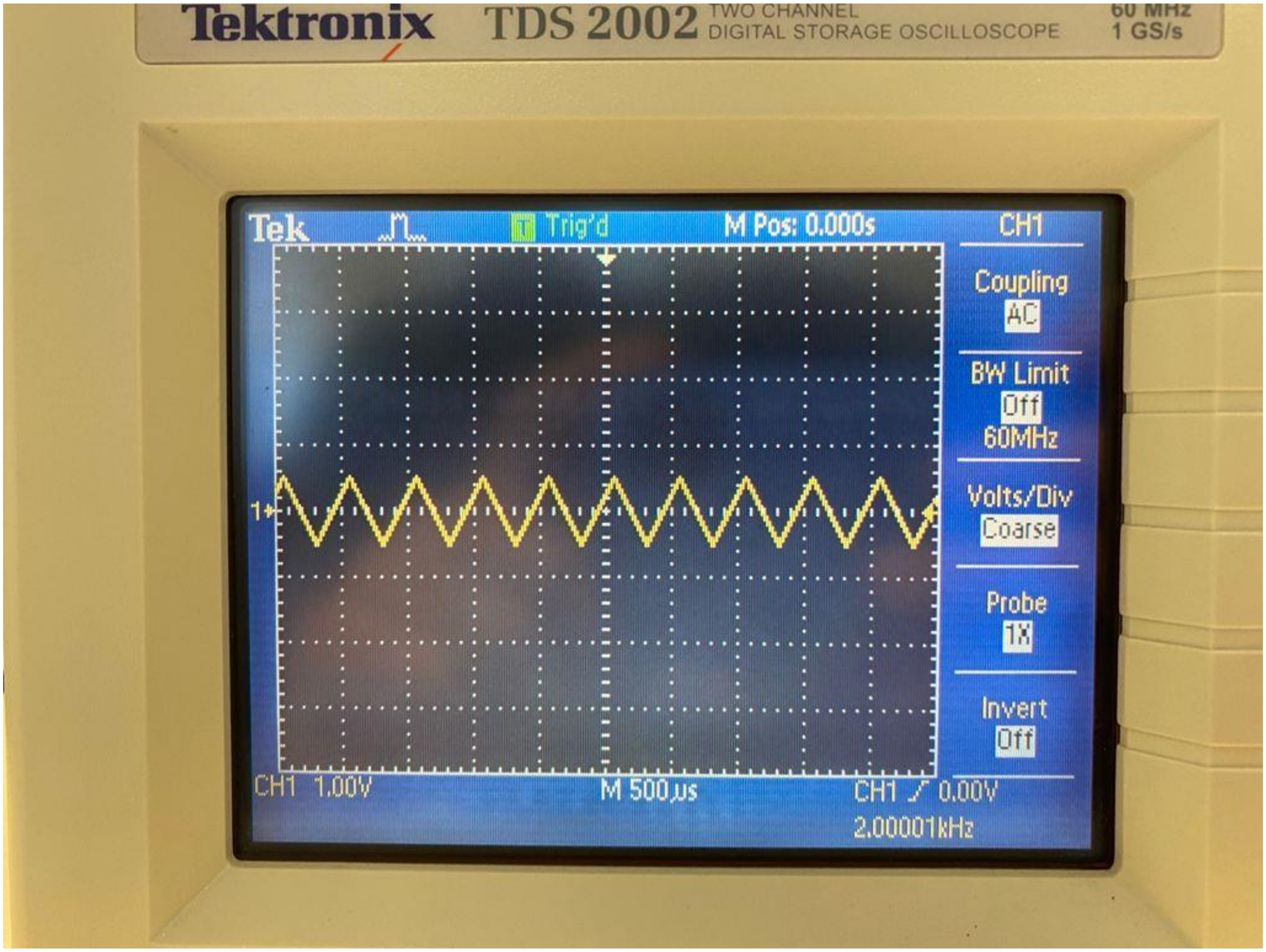
(Image 15: Sixth part of the experiment, the phase difference when 1kHz frequency applied to the X node is equal to nearly 0 nanoseconds)

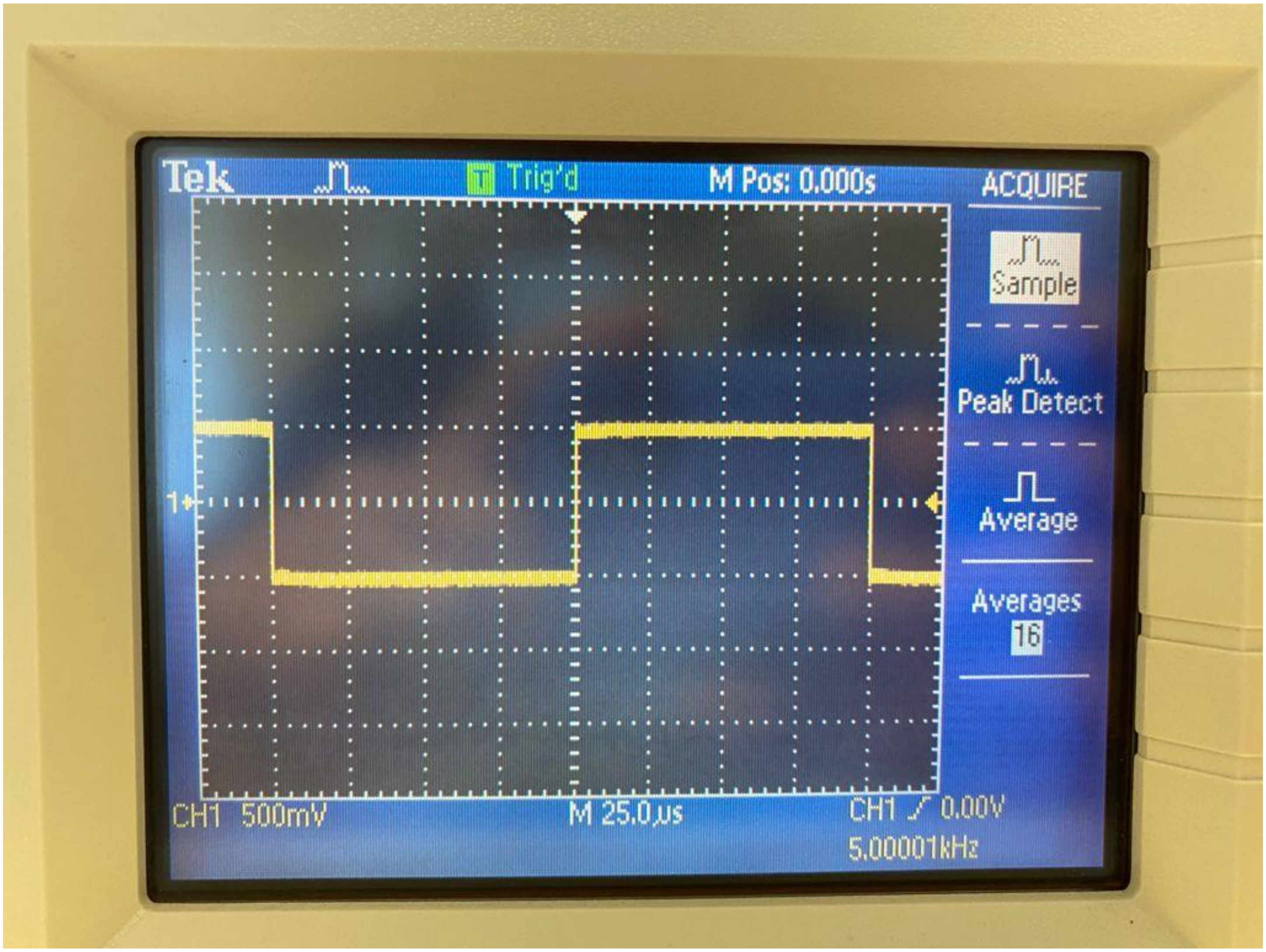
As calculated with Eq1 and Eq2, the experimental values appear close to the theoretical ones. For the first part, the experimental was 25.12 nanoseconds, and 24 nanoseconds have been seen in the oscilloscope display, so the error is nearly %4. When the frequency increased, the phase difference got so smaller that it was impossible to capture that distance on the oscilloscope. The theoretical phase difference value of the 100kHz was 0.002533μs which is a number really close to zero. So, it could be stated that the experiment was successful, and there were no huge errors.

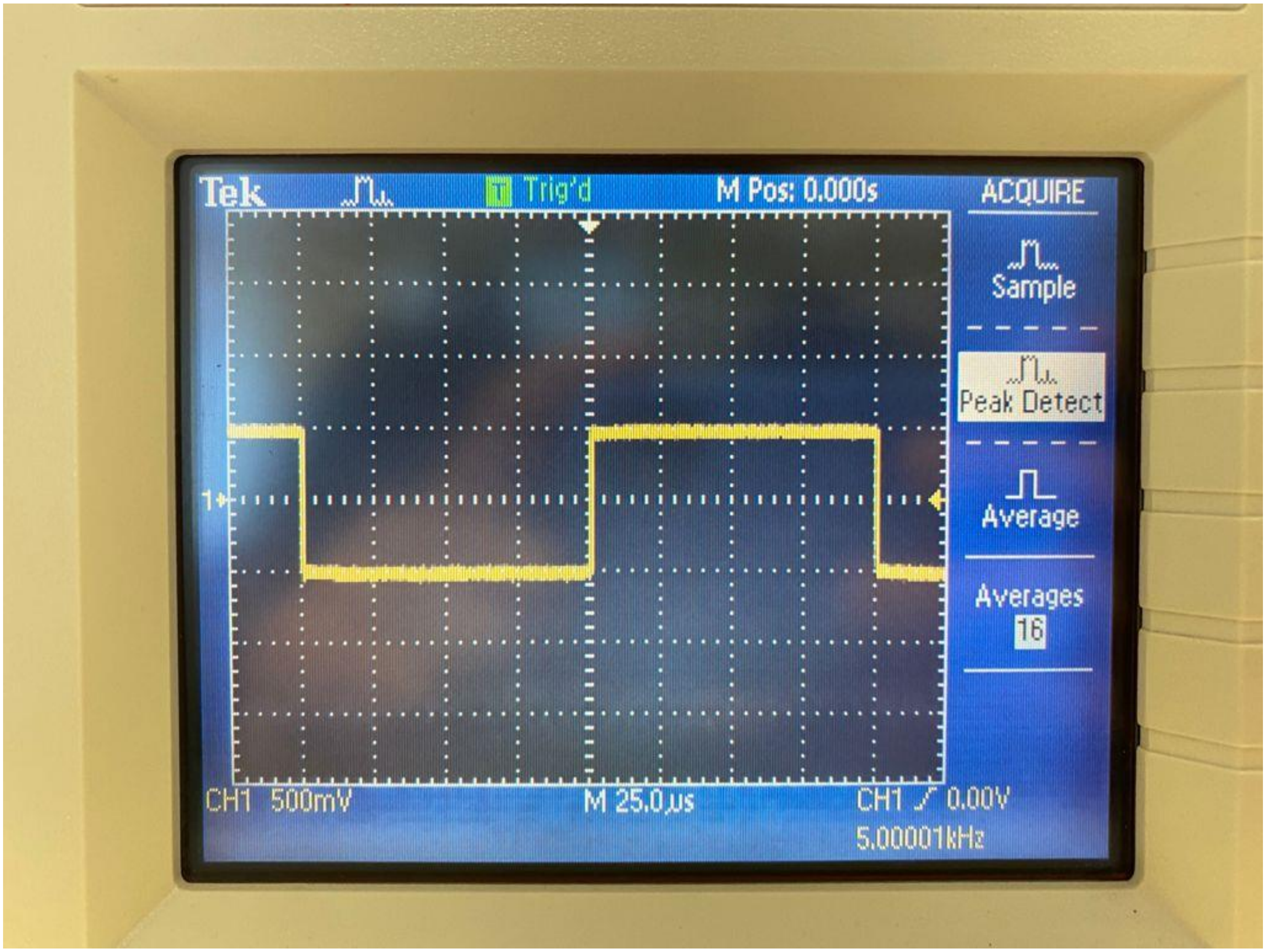
D)CONCLUSION

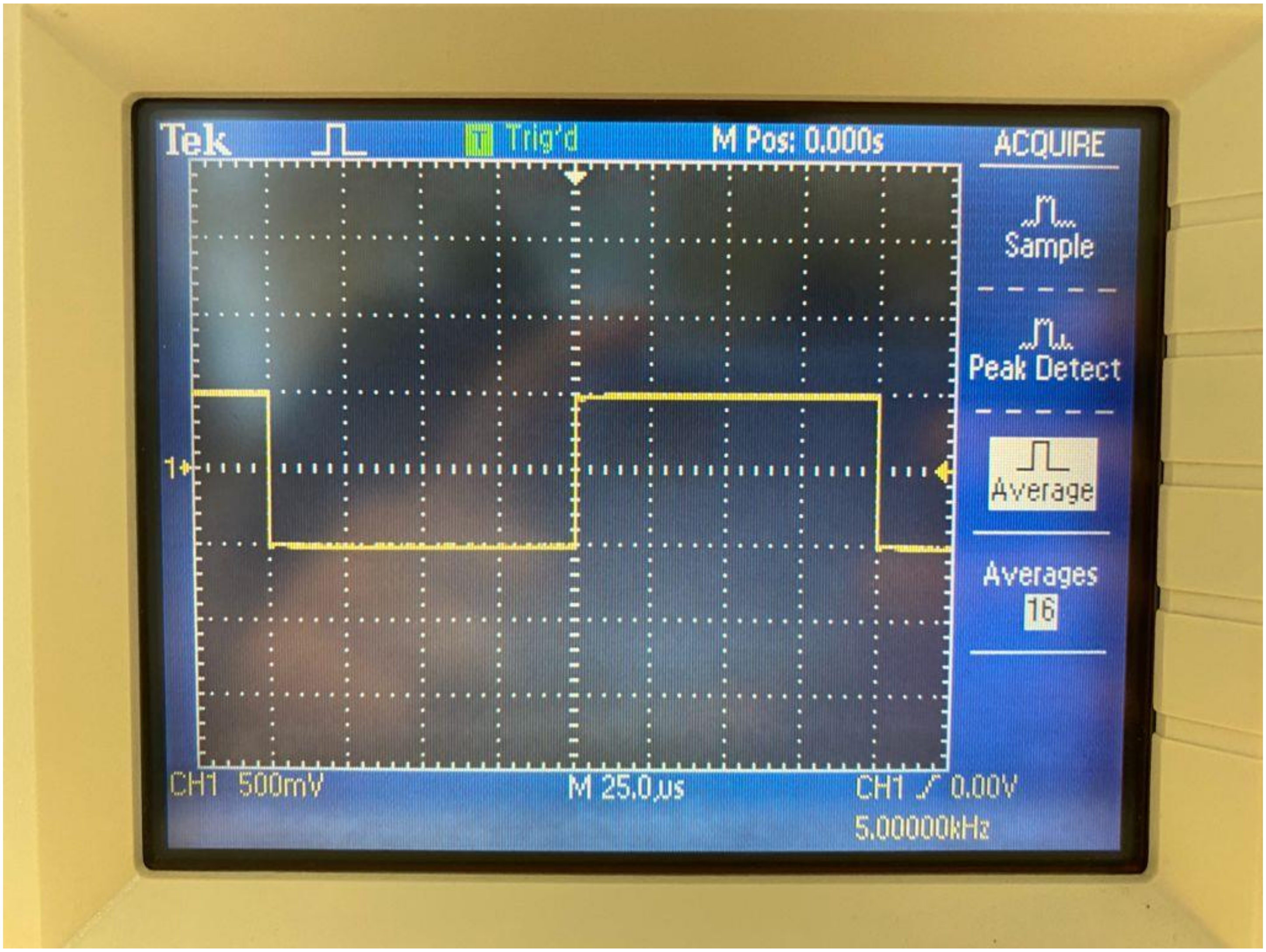
This experiment aimed to understand the applications of basic digital laboratory equipments like oscilloscope, signal generator, oscilloscope probe, etc. It could be stated that this experiment was conducted successfully because the error ratings were law and no significant problems occurred during the experiment. This experiment was also helpful for preparing for the future digital labs

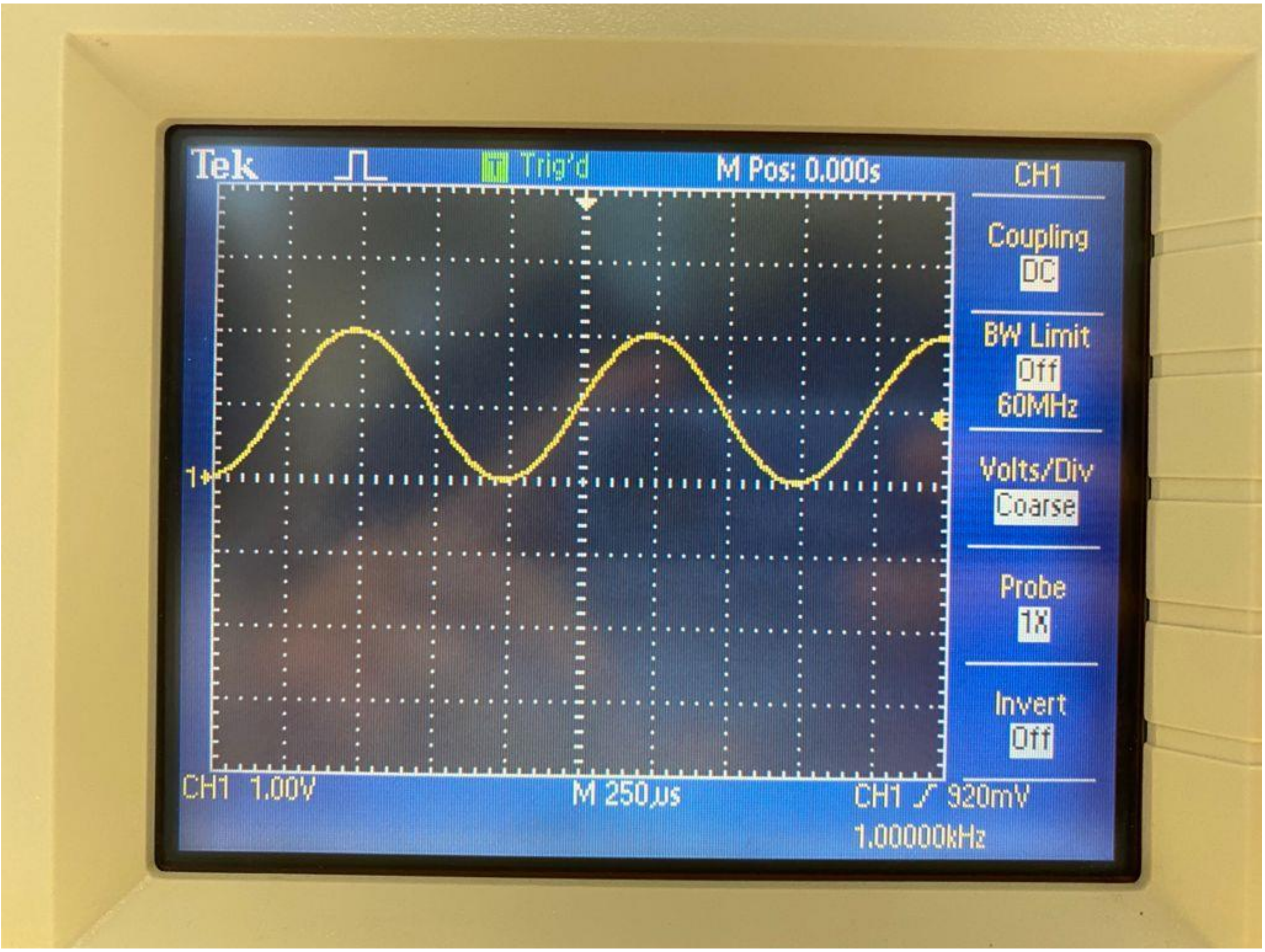
E) APPENDICES

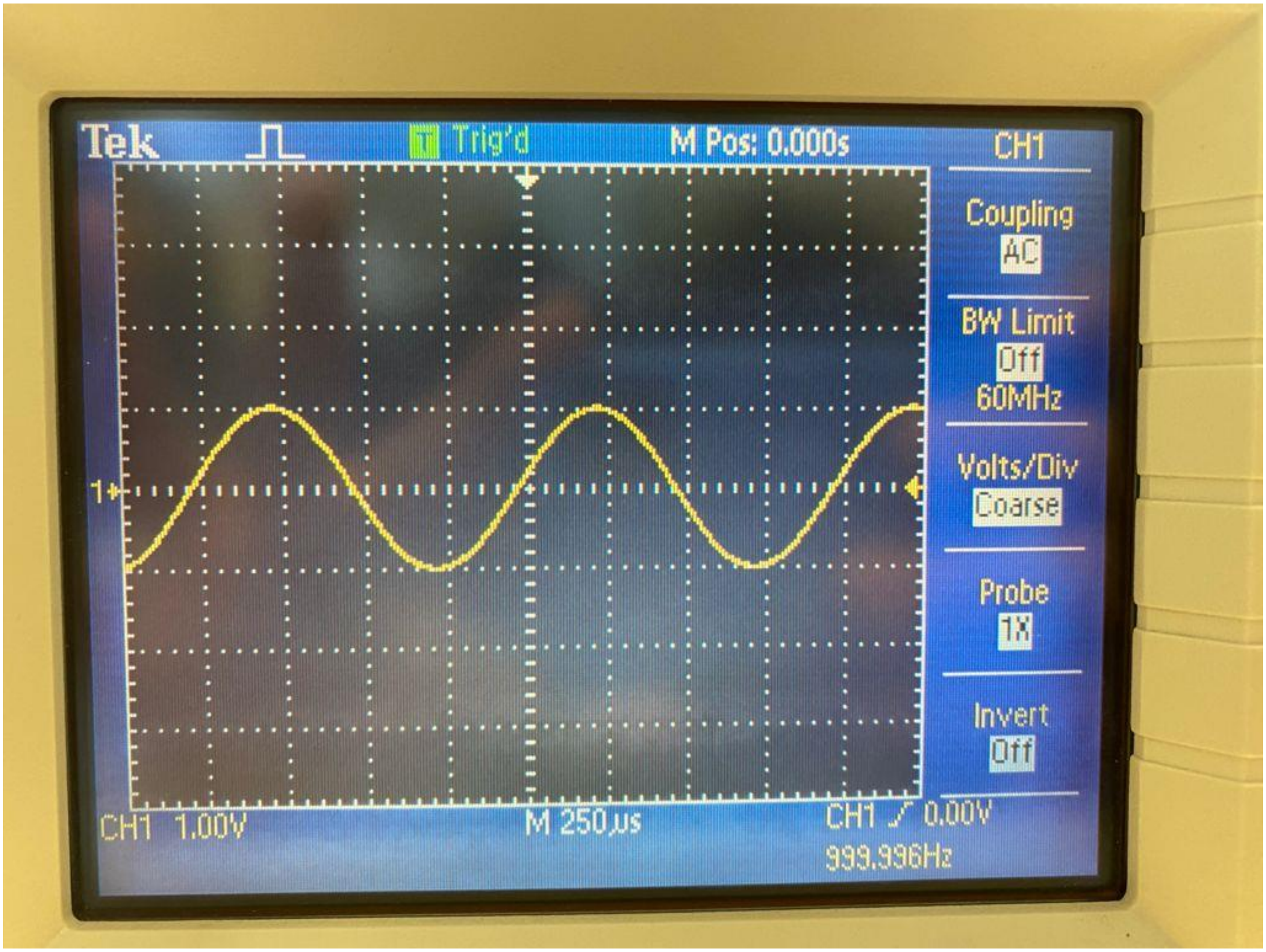

Tektronix
TDS 2002 TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE
60 MHz
1 GS/s
Tek
Trig'd
M Pos: 0.000s
CH1
Coupling
AC
BW Limit
Off
60MHz
Volts/Div
Coarse
Probe
1X
Invert
Off
CH1 1.00V
M 500µs
CH1 ⁄ 0.00V
2.00001kHz
(Image 16)


Tek
Trig'd
M Pos: 0.000s
ACQUIRE
Sample
Peak Detect
Average
Averages
16
CH1 500mV
M 25.0µs
CH1 ⁄ 0.00V
5.00001kHz
(Image 17)


Tek
Trig'd
M Pos: 0.000s
ACQUIRE
Sample
Peak Detect
Average
Averages
16
CH1 500mV
M 25.0µs
CH1 ⁄ 0.00V
5.00001kHz
(Image 18)


Tek
Trig'd
M Pos: 0.000s
ACQUIRE
Sample
Peak Detect
Average
Averages
16
CH1 500mV
M 25.0µs
CH1 ⁄ 0.00V
5.00000kHz
(Image 19)


Tek
Trig'd
M Pos: 0.000s
CH1
Coupling
DC
BW Limit
Off
60MHz
Volts/Div
Coarse
Probe
1X
Invert
Off
CH1 1.00V
M 250µs
CH1 ╱ 920mV
1.00000kHz
(Image 20)


Tek
Trig'd
M Pos: 0.000s
CH1
Coupling
AC
BW Limit
Off
60MHz
Volts/Div
Coarse
Probe
1X
Invert
Off
CH1 1.00V
M 250µs
CH1 ⁄ 0.00V
999.996Hz
(Image 21)