Lab 1: Introduction to Digital Oscilloscopes

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Purpose

The purpose of this lab session is to learn how to use lab equipment such as a digital oscilloscope, signal generator as well as the breadboard and its accessories. Learning to use the equipment includes learning how to take measurements properly and use them in a safe manner as well as familiarizing with related terminology.

Methodology

This lab session consisted of six progressive tasks.

-For the first task, I was required to compensate the oscilloscope by using a compensation signal and a special screwdriver that came with the probe. This step was necessary for the probe to return correct measurements.

-For the second task, I applied a specified 5 V peak-to-peak sinusoidal signal with 1kHz frequency. I observed this signal via the oscilloscope with both positive and negative edge triggering.

-For the third task, I applied a 1 V peak-to-peak triangular wave of 2kHz frequency and observed how it changed when the trigger knob on the oscilloscope was rotated.

-For the fourth task, I applied a square wave with a frequency of 5 kHz and 1 V peak-to-peak. After applying the wave, I cycled between different acquisition modes and recorded my observations.

-For the fifth task, I applied a 2 V peak-to-peak sinusoidal signal at 1 kHz frequency alongside a DC offset of 1V. Then, I consecutively applied DC and AC coupling on the oscilloscope.

-For the sixth and final task, I used the breadboard and jumper wires to form a specified circuit (Figure 1). Once it was complete, I applied a sinusoidal voltage signal of 2 Vpp at 1 kHz through X. I measured the voltage difference through both X and Y probes and calculated the phase difference based on the obtained data. I repeated this process, this time with a frequency of 100 kHz.

Results

(Additional images for tasks can be found in the appendices section)

Task 1: For this task, I had to adjust the oscilloscope probe before taking measurements. I hooked the probe up to the oscilloscope from both ends and initiated a correction signal sequence built into the oscilloscope. I checked the selected attenuation factor as the probe I was using had a factor of 10X. There are two possible scenarios when adjusting a probe: overcompensation (Figure 2.2) and under-compensation (Figure 2.3). I tried to level the top of the signal by using a screwdriver that came with the probe upon purchase. I adjusted the signal until I achieved a level top that I was happy with (Figure 2.1).

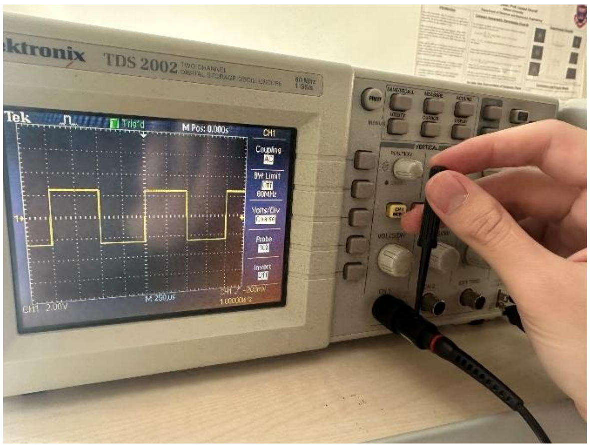

Figure 2.1: Adjusted Signal

Task 2: For this task, I was supposed to apply a sinusoidal signal of 5 Vpp and 1kHz via the signal generator. I removed one end of the probe from the oscilloscope and hooked it up to the signal generator by using a two-edged wire. I applied the signal and used positive and negative edge triggering consecutively. Positive edge triggering (Figure 3.1) puts the part of the signal with a positive slope to the oscilloscope screen's origin. The negative edge triggering (Figure 3.2) option did the same thing except it was the part of the signal with a negative slope. When transitioning from one to the other, it gave the appearance of flipping the signal with respect to the x-axis.

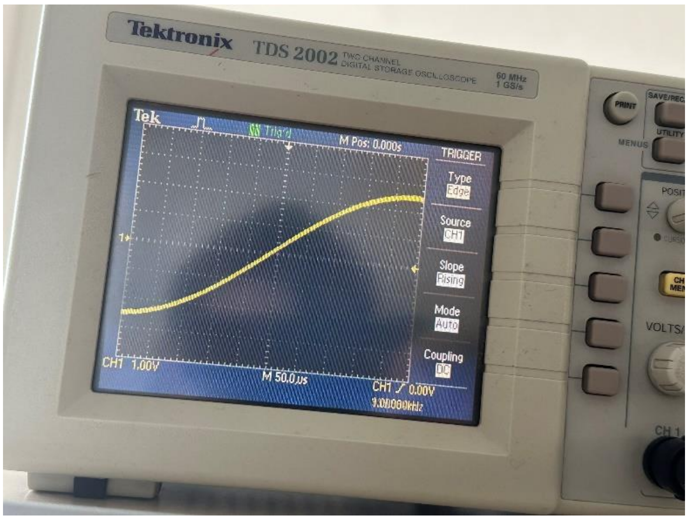

Figure 3.1: Positive Edge Triggering

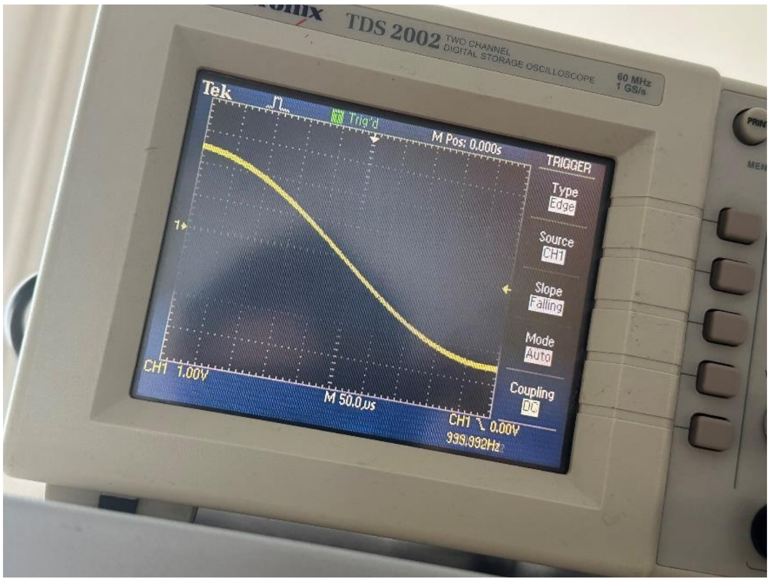

Figure 3.2: Negative Edge Triggering

Task 3: For this section, I was to apply a 1 Vpp triangular wave of 2 kHz frequency and see how it changed when I turned a specific “knob”. This knob, when turned, specified a voltage value on the small right-hand y-axis of the screen and put the part of the wave with that voltage on the center y-axis. This knob utilized a function called triggering, which can be described as filtering the signal for specific voltage values. When the trigger edge exceeded the max voltage of the signal (Figure 4.3), the signal became extremely unstable due to the oscilloscope not being able to find a signal of that voltage as no such signal existed.

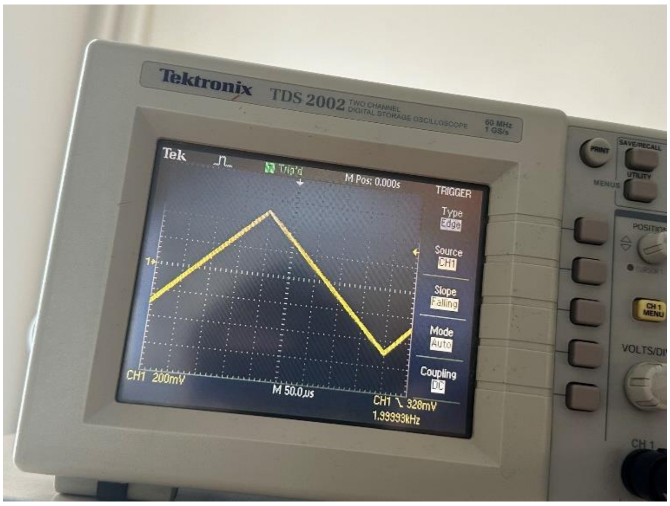

Figure 4.1: Positive Voltage Specified

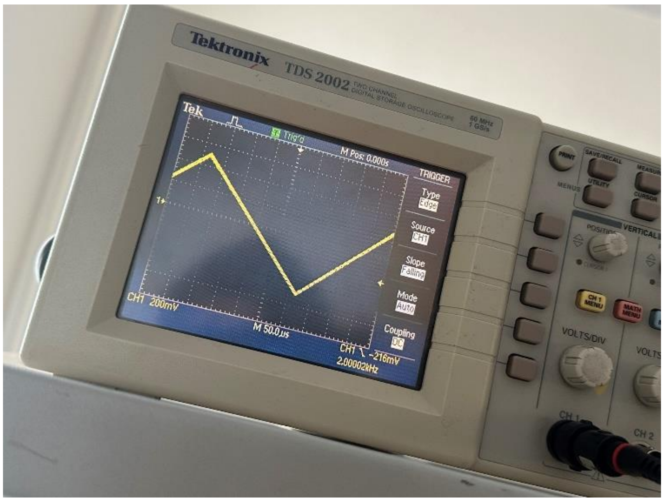

Figure 4.2: Negative Voltage Specified

Figure 4.3: Max voltage exceeded

Task 4: A digital-to-analog converter (DAC) can be defined as a system that has an input of digital data -a line of binary strings- which is converted by the system into an analog signal [1]. An analog-to-digital converter (ADC), on the other hand, is a system that converts analog signals -such as voltage- into digital information [2]. Some examples of ADC are cell phones and digital cameras. Some examples of DACs are televisions and modems. Oscilloscopes -specifically the digital ones- use ADC in the sense that they receive analog voltage data and convert it to a digital string of data which in turn is displayed on screen. As for the task, I was asked to apply a 1 Vpp square wave with a 5 kHz frequency to the oscilloscope. Once the signal was applied, I cycled between three different modes found under the acquisition menu of the oscilloscope: sample(Figure 5.1), peak detect(Figure 5.2), and average(Figure 5.3). The sample mode is the standard mode type that loads when the oscilloscope is started and measures the signals in real-time. The peak detect mode records the maximum and minimum points between an interval and uses these values to project a wave pattern on the screen. This mode is useful for seeing narrow discrete pulses. The average mode samples the waveform for a period and then uses the data it has gathered to produce a waveform that is the average of the ones it has recorded. This mode produces a smoother line than real-time sampling upon observation.

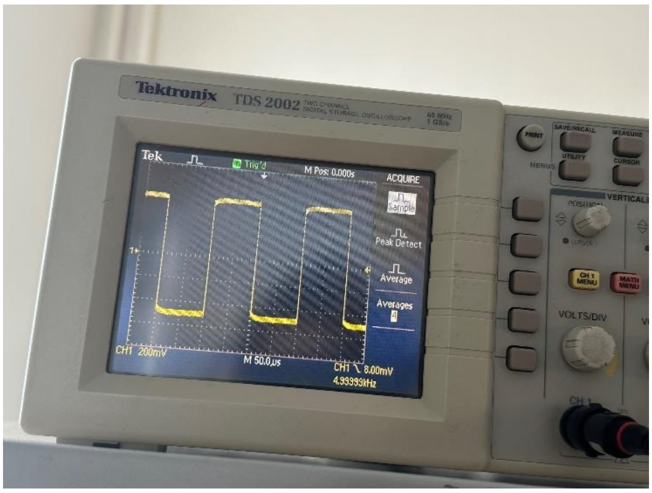

Figure 5.1: Sample mode

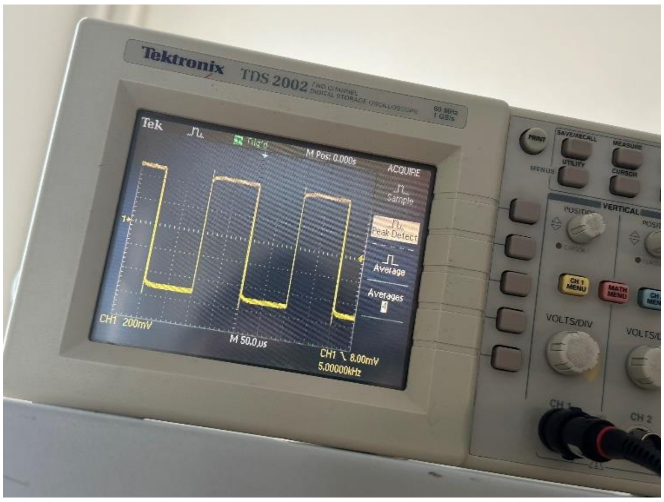

Figure 5.2: Peak detect mode

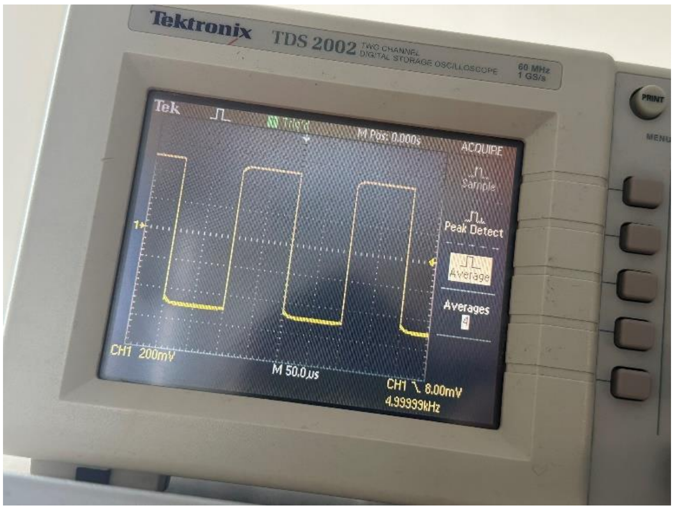

Figure 5.3: Average mode

Task 5: This task required that I generate a sinusoidal signal with 2 Vpp amplitude and 1 kHz frequency alongside a DC offset of 1 V and transmit it to the oscilloscope. Once transmitted, I observed this signal in DC(Figure 6.1) and AC(Figure 6.2) coupling modes successively. It was observed that -under AC coupling- the signal was 1V lower than its DC counterpart. This was due to the AC coupling method eliminating the DC component of the wave, and thus being shown lower on the y axis. The DC coupling mode, on the other hand, evaluates both DC and AC components.

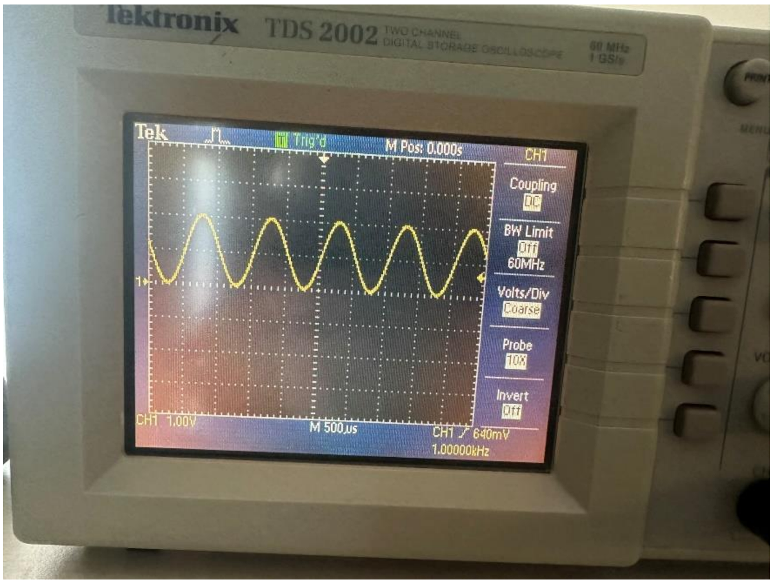

Figure 6.1: Signal under DC coupling

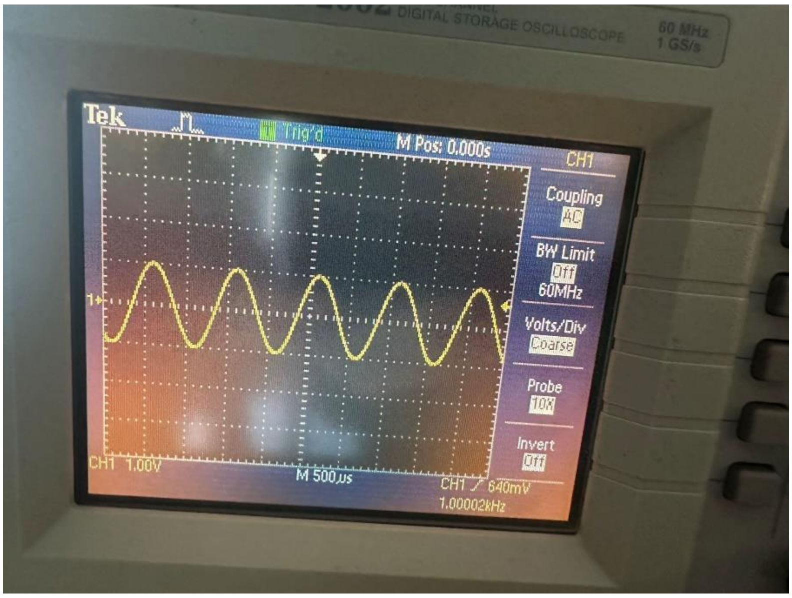

Figure 6.2: Signal under AC coupling

Task 6: A breadboard consists of a plastic place with many holes in it -called female input pins- which connect to tiny metal plates underneath. These plates consist of two rows on each side running in a column and shorter ones in between the sides running in rows. The two column rows on each side consist of a red and blue line each, called the voltage and ground lines respectively. The breadboard operates by the insertion of external accessories such as male-male jumper wires, thus it being a general template for circuit building. In this section, I built a specified circuit (Figure 1) by using a breadboard and its accessories. Once completed, I utilized two oscilloscope probes mounted to the same oscilloscope to measure signal data from two different points on the circuit (Figure 7.3). Channel 1 was connected to the X signal and channel 2 to the Y signal. Then, the ends of the signal generator cable were connected to X and given a 2Vpp sinusoidal signal at 1 kHz frequency. Both signals were projected onto the oscilloscope screen simultaneously and were zoomed into (Figure 7.1). 3.6 µs time difference between the signals was observed. We can use the information that 1 period equals 2π radians to evaluate a phase difference value. The phase difference of the first signal is 7.2π*10^-9 radians. When this was repeated with the signal's frequency bumped up to 100 kHz (Figure 7.2), the time difference was measured at 10 ns. This can be converted to a phase difference value of 20π*10^-12 radians. From these two values, we can conclude that the phase difference between the two signals decreases as the frequency increases.

Conclusion

The aim of this experiment was to get used to operating an oscilloscope correctly and accurately, familiarizing oneself with its features and its related terminology as well as learning how to build a basic circuit via a breadboard. The experiment -overall- was successful as I, the student, learned how to use an oscilloscope and demonstrated it throughout the experiment with minimal issues. The data obtained from the equipment are mostly consistent with our theoretical expectations. However, these values have a percentage of error due to external factors. For instance, as can be observed in some of the images, the frequency and voltage values of the signals are not picked up by the oscilloscope as constant values. This was likely due to the non-theoretical real-world nature of the experiment, which means there were unaccounted-for external factors in play such as the small amount of resistance provided by the wiring, the condition of the equipment as aged or heavily used equipment wearing out over time meaning inconsistent input or measurements as well as the small percentage error caused by the physical limitations of the equipment itself. One thing that struck me was the oscilloscope -when prompted by a signal from the signal generator- measured twice the supposedly sent amount. This could potentially be due to the possibility of the signal generator not being terminated by an impedance of 50 Ohms but rather by high impedance. We were warned about this possibility in the lab manual and being weary of this issue taught us the importance of double-checking the data.

Appendices

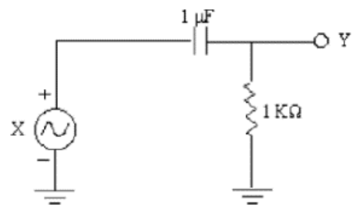

Figure 1: Specified Circuit

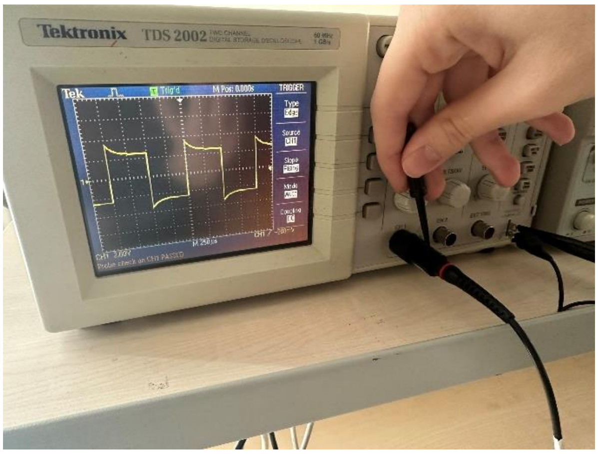

Figure 2.2: Overcompensated Signal

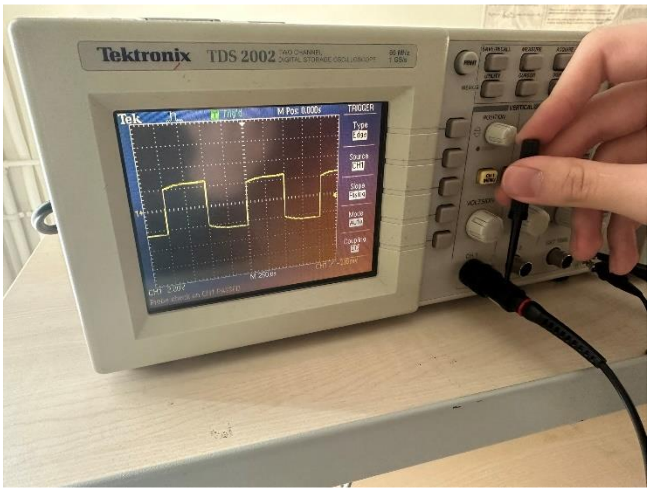

Figure 2.3: Undercompensated Signal

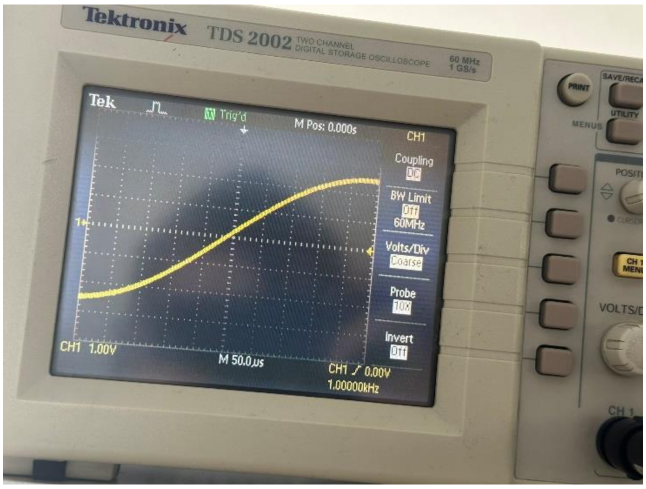

Figure 3.3: 5Vpp 1kHz sinusoidal signal

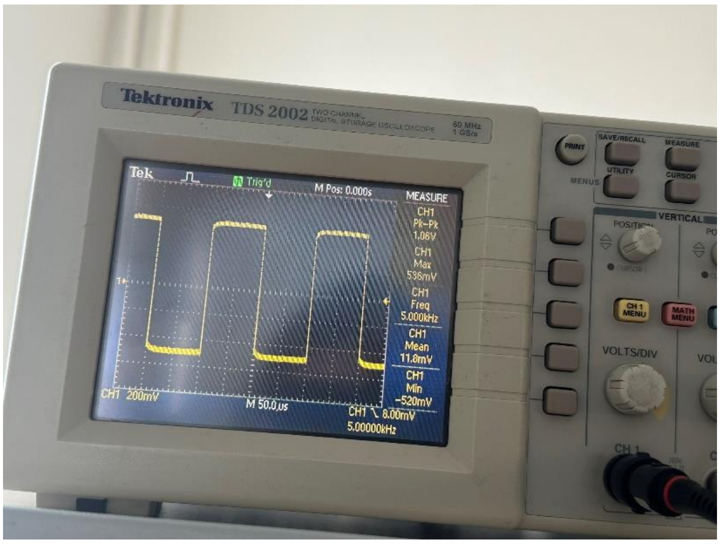

Figure 5.4: The initial square wave

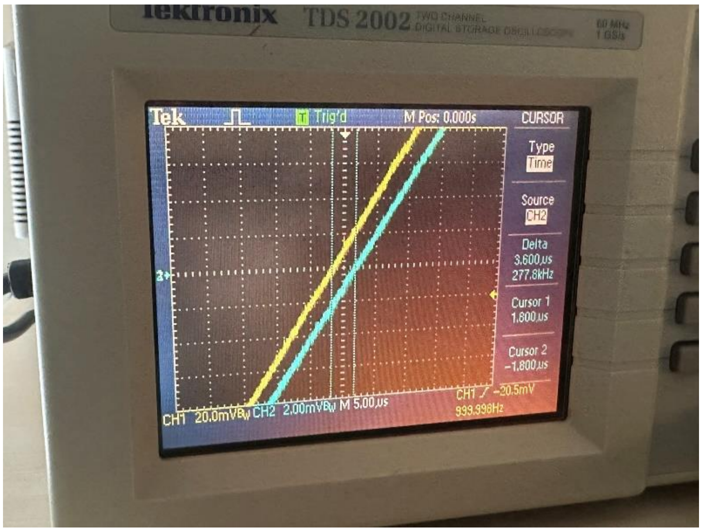

Figure 7.1: X and Y signals at 1kHz

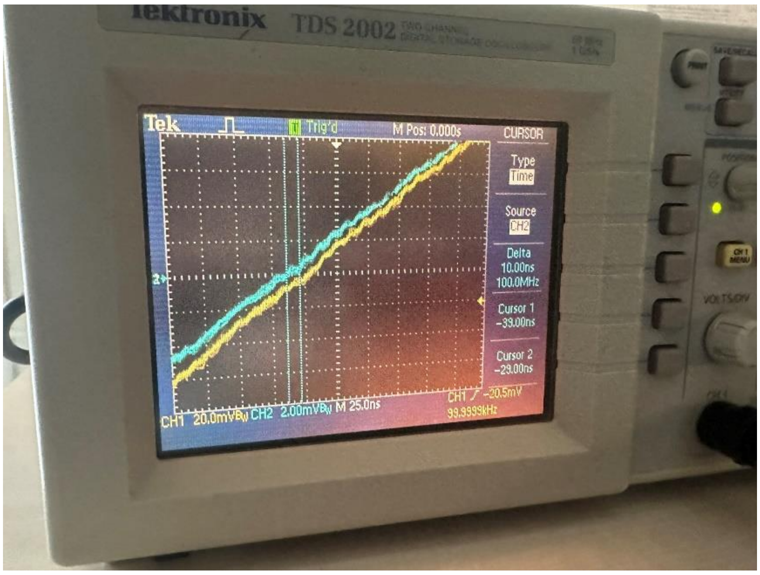

Figure 7.2: X and Y signals at 100kHz

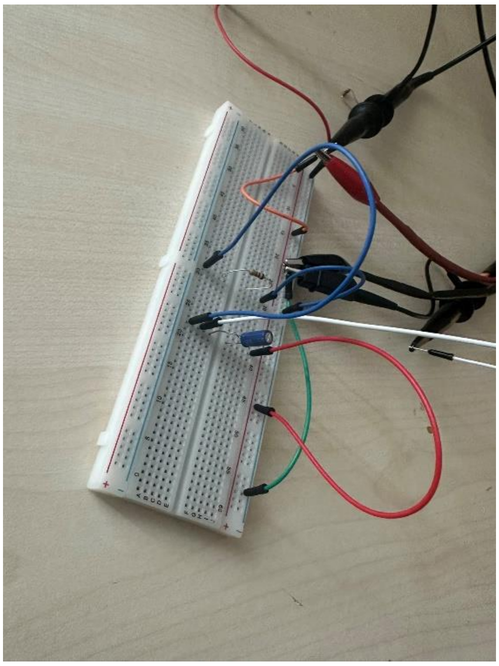

Figure 7.3: The breadboard circuit

Citations

1) Wiggins, C., Lopez, J., Dixon, R., Nguyen, N., Isaacs, A., Editor, D., Williams, J., & Phillips, G. (2024, February 15). Digital to analog conversion. DevX. https://www.devx.com/terms/digital-to-analog-conversion/#:~:text=A%20digital%20to%20analog%20converter%20(DAC)%20takes%20digital%20data%20as,%2C%20or%20sigma%2Ddelta%20modulation.

2) Kirvan, P. (2022, July 13). What is analog-to-digital conversion (ADC)?. WhatIs. https://www.techtarget.com/whatis/definition/analog-to-digital-conversion-ADC