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EE102-01
Lab Report 1
26.09.2022

LAB 1: INTRODUCTION TO DIGITAL OSCILLOSCOPES

Purpose

The purpose of the experiment is to get accustomed to the lab equipment and the digital oscilloscope. In order to have an idea of the experiment, we have read the manual *Digital Oscilloscope Principles* which was uploaded to Moodle.

Methodology

1. Before using the probe, we need to compensate it using the compensation signal of the oscilloscope in order to avoid less accurate measurements. Compensating a probe can be described as balancing its electrical properties to another device, in this case, an oscilloscope. I was able to compensate my probe, which has 10X attenuation factor, in a few steps by using the square wave reference signal of the oscilloscope. Firstly, I attached the probe to the channel1 input connector of the oscilloscope. Then I connected the probe tip to the probe compensation signal and attached the ground clip to ground. After viewing and observing the square waves on the oscilloscope, I made some adjustments using the adjustment tool in order to make the top and bottom edges of the waves straight. When the waves became square, I completed the compensation.
2. In order to generate a 5 V (peak-to-peak) sinusoidal signal that has frequency 1 kHz, I used the signal generator of the oscilloscope. Then, to clear out the DC component of the signal I used AC coupling, which obstructs the DC component of a signal and displays the waveform centered at zero volts. The slope control of the oscilloscope controls whether the trigger point is on the rising or the falling edge of a signal. A rising edge corresponds to a positive slope, whereas a falling edge corresponds to a negative slope.
3. The trigger effect of the oscilloscope helps display the repeating waveforms on the screen. An oscilloscope can have different types of trigger modes and trigger sources. In this step, I used the trigger knob of the oscilloscope to change where the trigger occurs and I observed how it affects the wave.
4. Digital to analog converter (DAC) is a system that turns a digital signal into an analog signal, while an analog to digital converter (ADC) turns an analog signal into a digital signal. DACs are used in televisions, music players, and mobile phones to convert digital data into analog audio and video signals. ADCs are used in microprocessors, microphones, and digital cameras to convert analog data (like sounds) into binary digital data. Oscilloscopes also have analog and digital types. In analog oscilloscopes, the voltage being measured is applied directly to an electron beam that is traveling over the oscilloscope screen, whereas digital oscilloscopes use ADC to turn the measured voltage of the waveform into digital information.
   To observe the acquisition modes of the oscilloscope, I started by generating a 1 V (peak-to-peak) square wave with 5 kHz frequency. Firstly, I used the sample mode (this mode is called "normal" mode in my oscilloscope) in which the oscilloscope creates a waveform point by saving one sample point at each interval of the waveform.

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Then I used the peak detect mode in which the oscilloscope uses the minimum and maximum value sample points of two waveform intervals to generate the waveform. Lastly, I used the average mode where each waveform interval is recorded by the oscilloscope just like in the sample mode. But unlike the sample mode, waveform points from consecutive acquisitions are averaged together to create the final waveform that is displayed.

5. In this step, I used DC offset, along with DC and AC coupling on the signal. The DC coupling displays all components of the input signal, including the DC component which we can apply with offset. The AC coupling obstructs the DC component of the signal, in other words, cancels the offset while displaying the wave.
6. A breadboard has strips of metal underneath and holes in which the leads of the electronic components can be inserted. The components connect to each other through the wires (strips of metal) so a circuit can be constructed using a breadboard. Firstly, I set up the circuit on my breadboard which can be seen in Figure 12. After generating a 2 V (peak-to-peak) 1 kHz sinusoidal signal (with 0 DC offset) as the X signal, I borrowed my friend's probe and connected it to channel 2, which I used for signal Y. I observed the waveforms of these signals after connecting them to their respective channels and connecting the grounds of both channels to the common ground on the breadboard.
   To measure time and voltage differences, we can use the cursors of the oscilloscope. In this case, I used cursors to measure the delay between the X and Y signals. Then I used the following formula to calculate the phase difference:

   $$\phi° = 360° \times f \times \Delta t$$

   where ϕ is the phase difference (in degrees), f is the frequency of the signal and Δt is the time difference between the signals. As the frequency increases, we expect the delay and the phase difference to decrease. This can be explained by the fact that phase difference is proportional to the ratio of the impedance of the capacitor over resistance, which decreases as the frequency increases.

Results

1. I compensated my probe by applying the steps mentioned above. The compensation was complete when the waves became square. Figure 1 shows the square waves before compensation, and Figure 2 shows the square waves after compensation.

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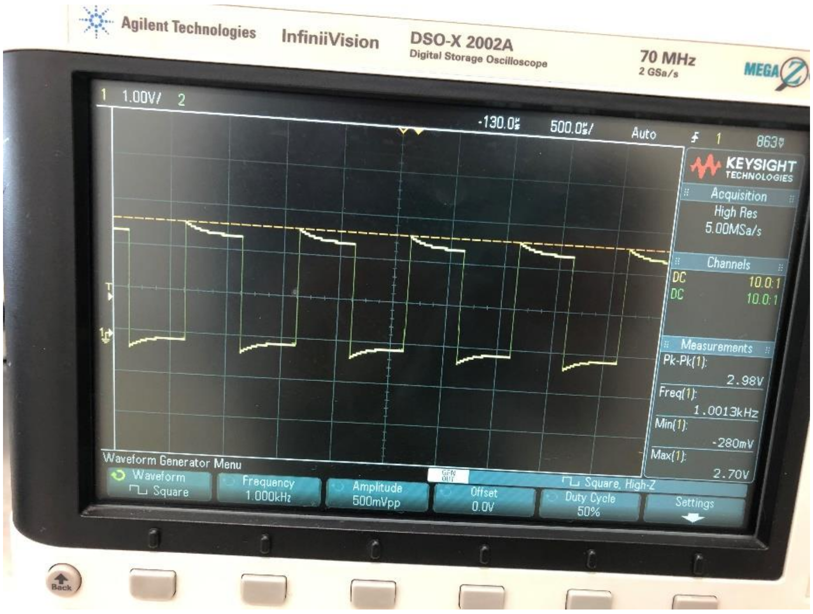

Figure 1: Square waves before compensation

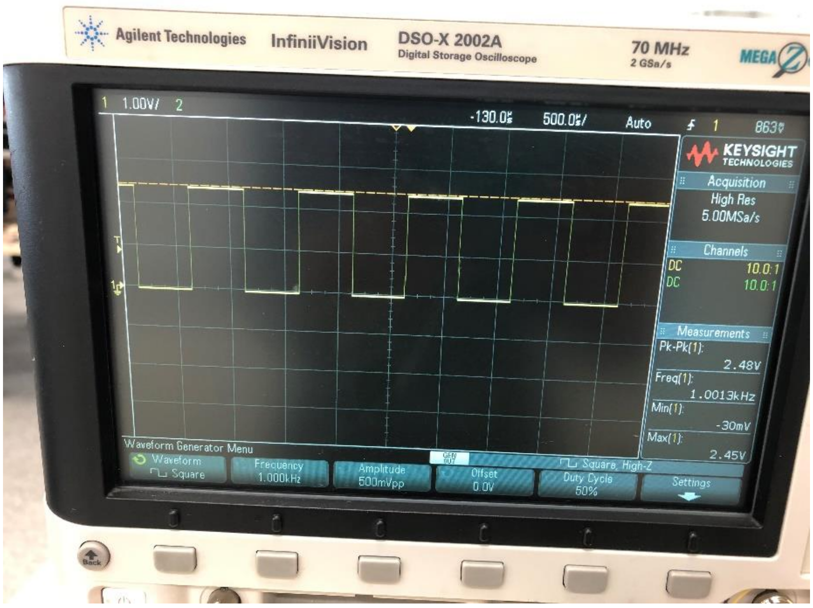

Figure 2: Square waves after compensation

2. I generated the 5V (peak-to peak) wave with 1 kHz frequency and no DC component. Then I applied positive and negative edge triggering. After I used the positive edge triggering, the trigger point stayed on the rising edge of the signal, which can be seen in Figure 3. And after using the negative edge triggering, the trigger point stayed on the falling edge of the signal, which can be seen in Figure 4. I also observed that the signal with positive edge triggering and the signal with negative edge triggering are symmetrical with respect to the y-axis.

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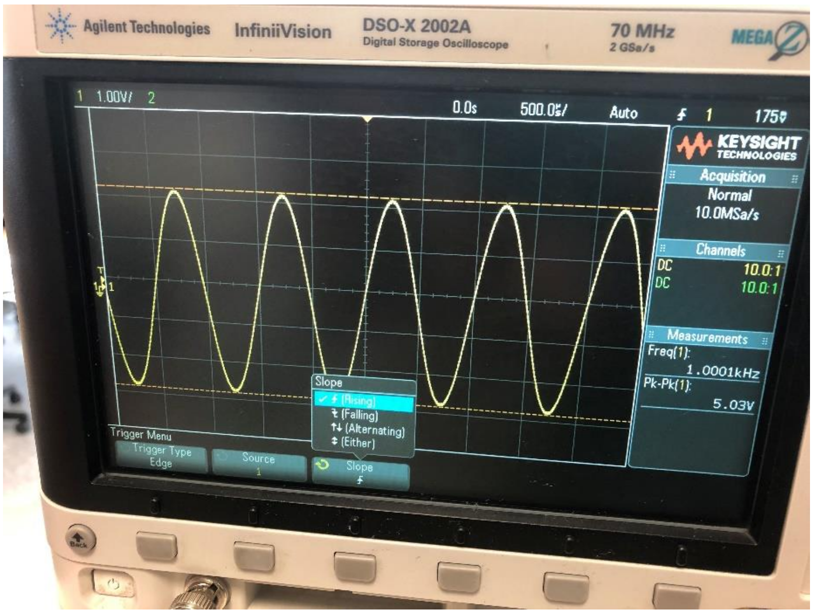

Figure 3: Signal with positive edge triggering

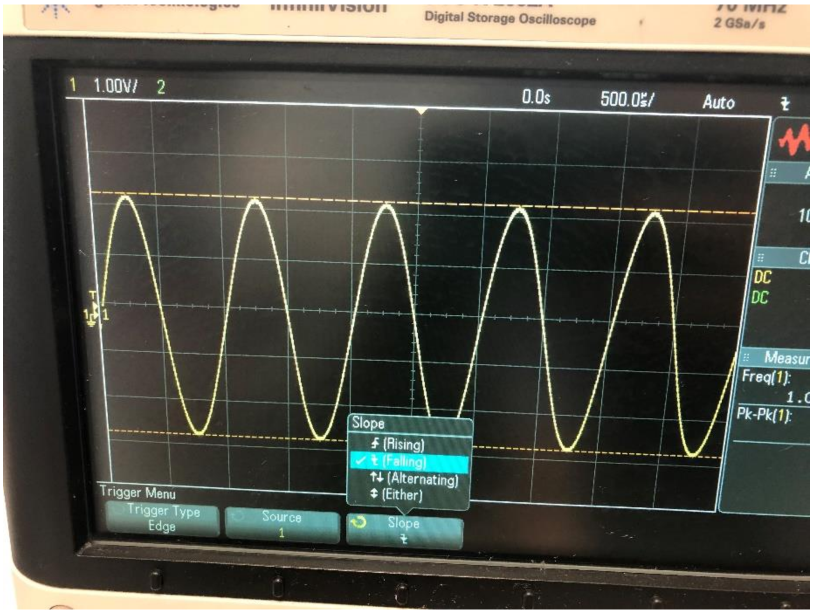

Figure 4: Signal with negative edge triggering

3. Again, I used the signal generator to generate a 1 V (peak-to-peak) triangular wave that has frequency 2 kHz. When I turned the trigger level knob, the location of the trigger point changed on the edge. As I kept on turning it, the trigger level kept on changing, which caused the waveform to move horizontally. Eventually, the trigger point got separated from the signal and the signal became unstable. Figure 5 displays the triangular wave with trigger applied and Figure 6 displays the unstable signal after

turning the trigger level prob to the point where the trigger loses contact with the wave.

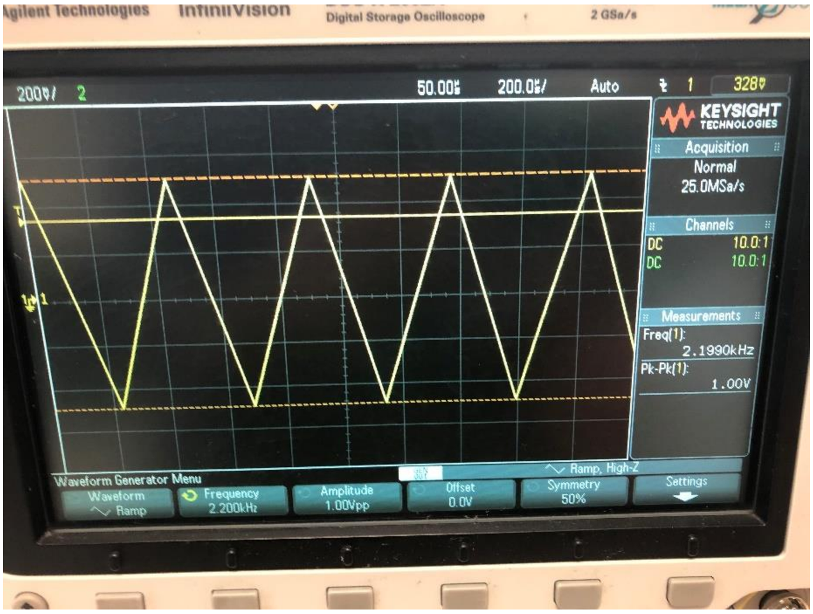

Figure 5: Triangular wave with triggering

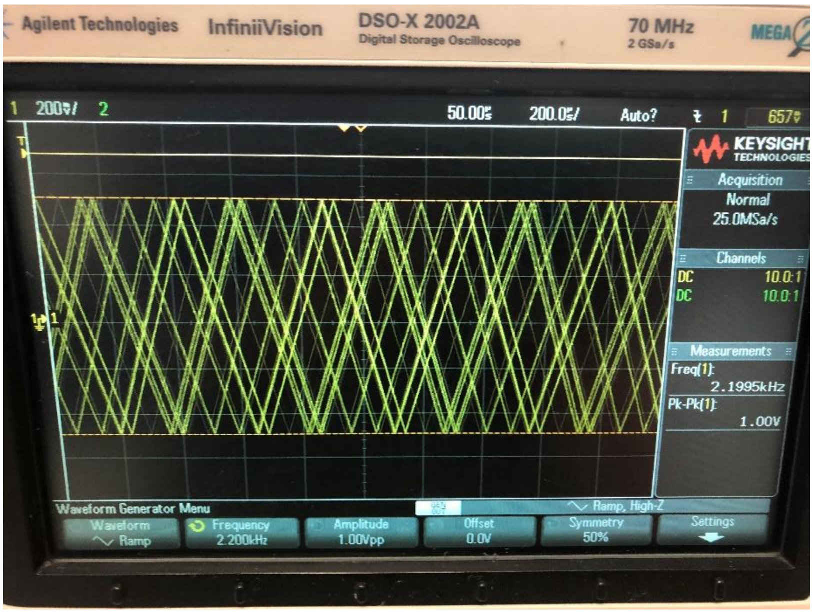

Figure 6: Unstable wave after trigger loses contact with the wave

4. After generating a 1 V (peak-to-peak) square wave with 5 kHz frequency, I first used the sample mode. The waveform generated by this mode can be observed in Figure 7. Then I used the peak detect mode, which can be seen in Figure 8. Lastly, I used the average mode which is shown in Figure 9.

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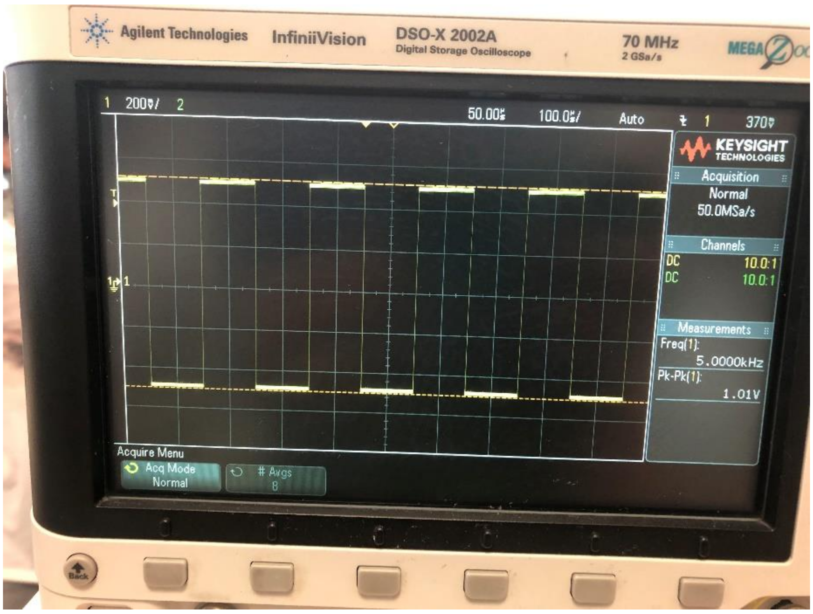

Figure 7: Waveform in sample (normal) mode

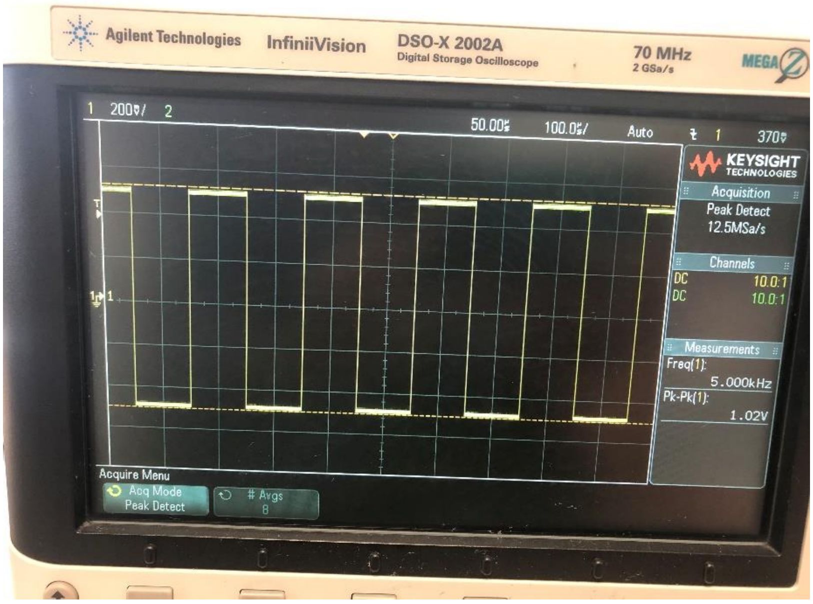

Figure 8: Waveform in peak detect mode

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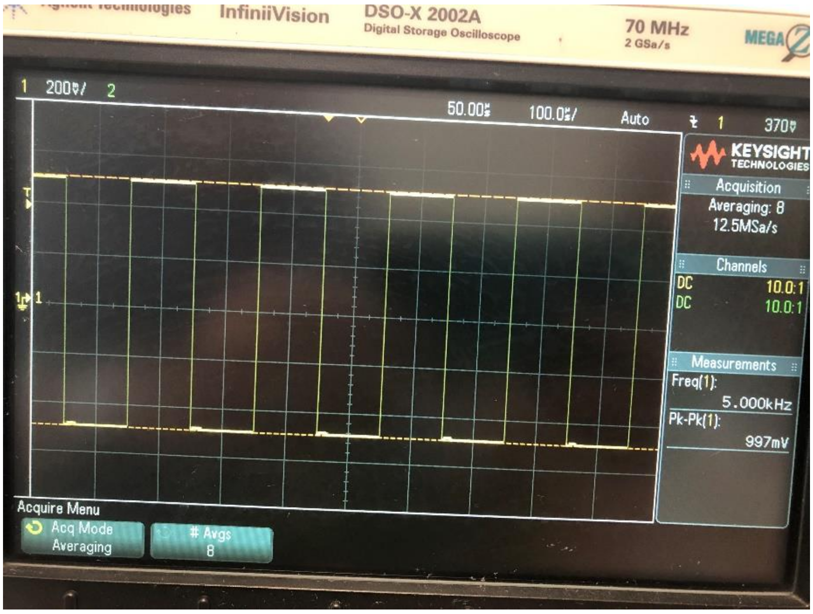

Figure 9: Waveform in average mode

5. After generating a sinusoidal signal with 2 V (peak-to-peak) amplitude and 1 kHz frequency, I applied a 1V DC offset. First, I used DC coupling. As expected, all components of the signal including DC component could be observed with DC coupling. Then, I used AC coupling which blocks the DC component of a signal. After switching coupling from DC to AC, the waveform moved to the middle in other words it got centered at zero volts unlike the signal with DC coupling. It can be said that applying AC coupling to a signal cancels the effects of the DC offset, and the signal looks as if no offset is applied on it. Figure 10 shows the signal with DC coupling, and Figure 11 shows the signal after AC coupling.

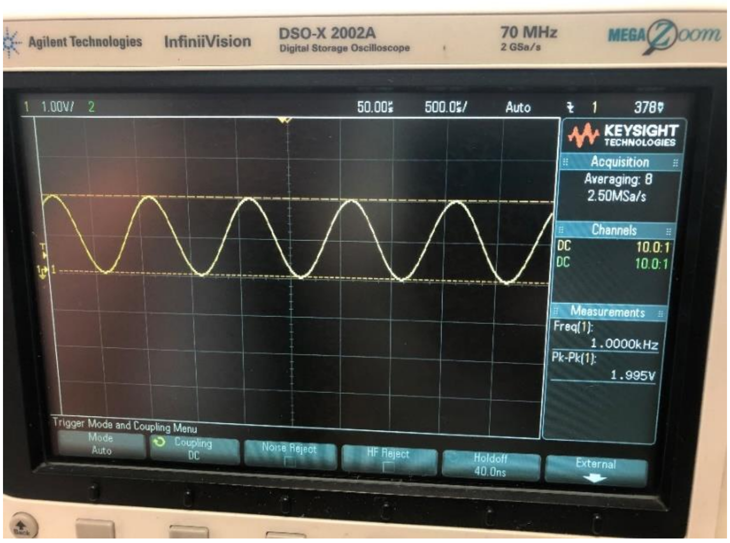

Figure 10: Signal with DC coupling

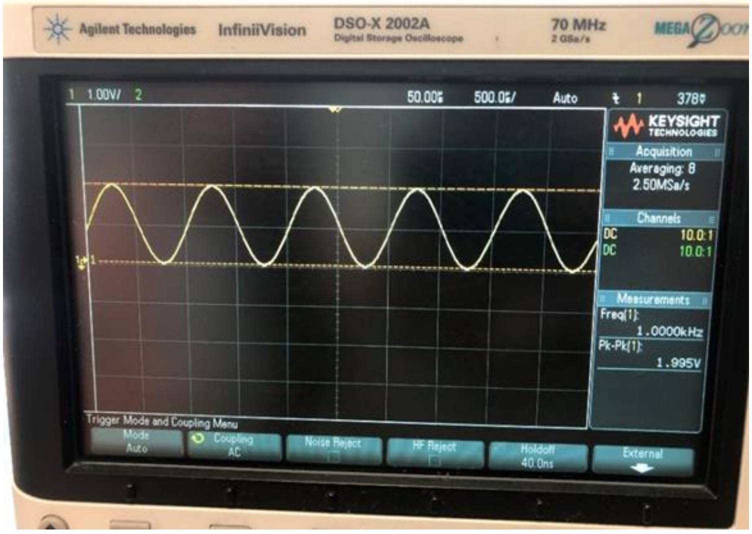

Figure 11: Signal with AC coupling

6. I set up the circuit on the breadboard which can be seen in Figure 12. After setting up the circuit and generating the X and Y signals, I calculated the delay and the voltage difference. The voltage difference was 0 Volts, and the delay turned out to be 30 microseconds (μs). After increasing the frequency of the signal from 1 kHz to 100 kHz, I calculated the delay again as 50 nanoseconds (ns). Using the above-mentioned formula, I calculated the phase difference for 1 kHz as 10.8 degrees, and as 1.1 degrees for 100 kHz. As expected, the phase difference decreased, in fact nearly became 0 when the frequency was increased. The phase difference of the signals with 1 kHz frequency can be seen in Figure 13, and Figure 14 shows the phase difference when the frequency is increased to 100 kHz.

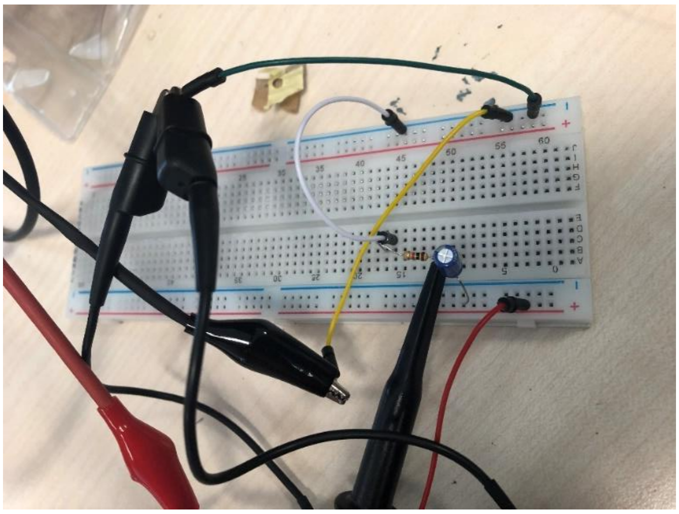

Figure 12: Circuit set up on breadboard

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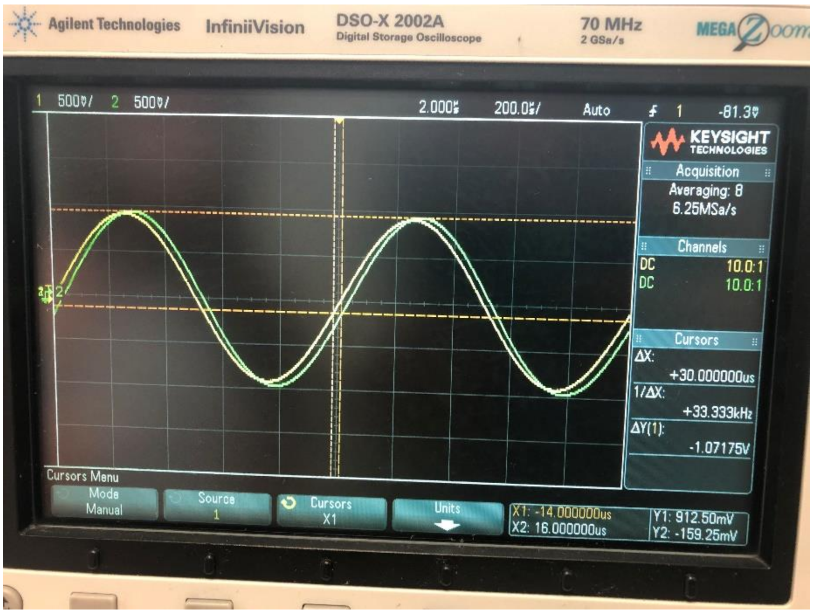

Figure 13: Phase difference of the signals with 1 kHz frequency

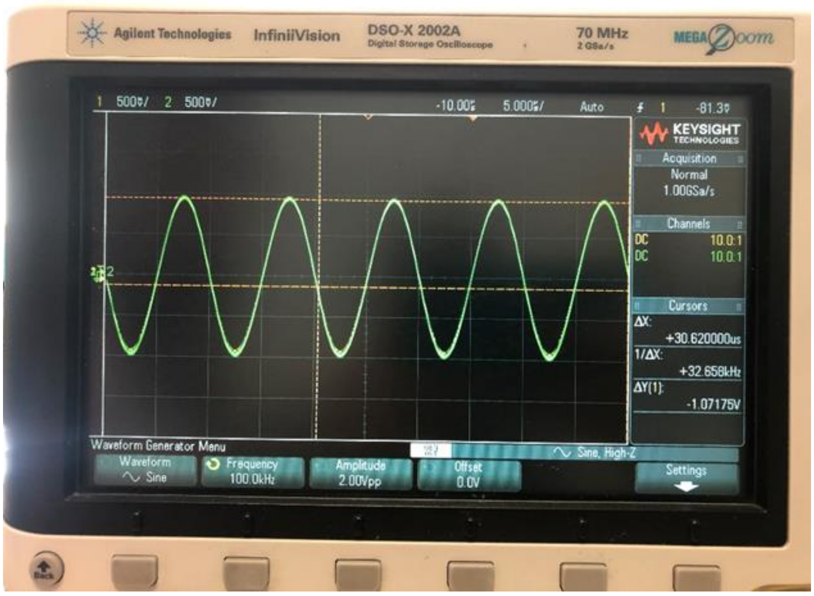

Figure 14: Phase difference of the signals with 100 kHz frequency

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Conclusion

The purpose of this experiment was to get used to lab equipment like digital oscilloscopes, breadboards, capacitors, and resistors. Before the lab, I read a manual about the digital oscilloscope in order to have an idea. The results of the steps turned out as I was expecting, based on what I learned from the manual. I can say that this experiment was successful because it fulfilled its purpose. With this experiment, I got into the basics of using an oscilloscope and demonstrated everything I learned, such as compensating the probe, using trigger and acquisition modes, and setting up circuits on a breadboard.

References

digital_oscilloscope_principles.pdf

http://www.sengpielaudio.com/calculator-timedelayphase.htm