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Alp Efe Kılıçarslan, 22402390

EEE 102-2

LAB-01: Introduction to Digital Oscilloscopes

Purpose:

The goal of this assignment was to understand the basic principles and mechanics of lab equipment such as signal generators, oscilloscopes and breadboards. Additionally, a simple circuit consisting of resistors and capacitors were created to further comprehend signals.

Methodology:

Task 1) The BNC coaxial plug of the oscilloscope probe was connected to the oscilloscope's Channel 1 port. The probe's hook attachment and grounding clip was attached to the oscilloscope. Using the compensating tool, a small flathead screwdriver, the probe was adjusted to view a rectangular wave on the oscilloscope's digital screen.

Task 2) A signal, which was sinusoidal in nature, was generated using a signal generator. The direct current offset was set to zero. The oscilloscope probe was attached to the output of the signal generator and the grounding clip was connected to a near metal surface – in this case, the chassis of the signal generator. The resulting wave was observed with both positive and negative edge triggering. The resulting wave on the oscilloscope's digital screen were photographed.

Task 3) A signal, which was triangular in nature, was generated using a signal generator. The oscilloscope probe was attached to the output of the signal generator and the grounding clip was connected to a near metal surface. After these steps, the triggering knob was turned in small degrees to observe it's effects on the digital reading of the signal. Multiple photos were taken during this process.

Task 4) A signal, which was rectangular in nature, was generated using a signal generator. The oscilloscope probe was attached to the output of the signal generator and the grounding clip was connected to a near metal surface. Using the three acquisition types -sample, peak detect and average- three different wave formats were observed on the oscilloscope's digital screen and photographed individually.

Task 5) Initially, a signal -which was sinusoidal in nature- was generated using a signal generator. The grounding clip was connected to the ground of the signal generator. Following this, a DC offset was applied to observe how the signal changed. Both DC coupling and AC coupling were used and the images were recorded.

Task 6) A capacitor, a resistor, a signal generator and a breadboard -a modular piece that allows for easy connections between simple components using embedded metal connections allowing for electron transfer- were used to create an RC circuit that matched the given schematic. Two oscilloscope probes were used to measure the voltage for two different points on the circuit, X and Y. The probes that represent these points were connected to Channel 1 and Channel 2 respectively. The grounding clamps were connected to a shared piece of metal. A sinusoidal signal was applied to the circuit using the signal generator. The phase difference between X and Y were measured with two different signal frequencies and photographed to inspect further.

Results:

Task-1) Probe compensation is a process wherein the experimenter uses a built-in oscilloscope signal to tune the probe's capacitance to get an accurate reading. The probe was set to the times ten attenuation factor. Before compensation, the signal on the screen had higher peaks than the rest of the pulse (Figure 1.1) which signified that the probe was overcompensated. Using the compensation tool, a screw near the BNC coaxial plug was located and turned leftwards to get a compensated signal, which was an ideal rectangular wave (Figure 1.2). If this step was skipped, the rest of the tasks would've given flawed results.

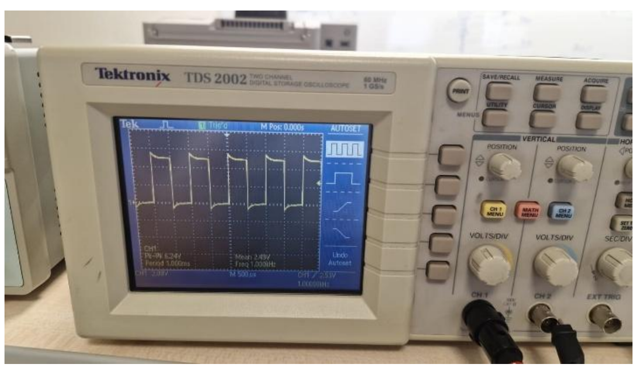

Figure 1.1: An overcompensated signal

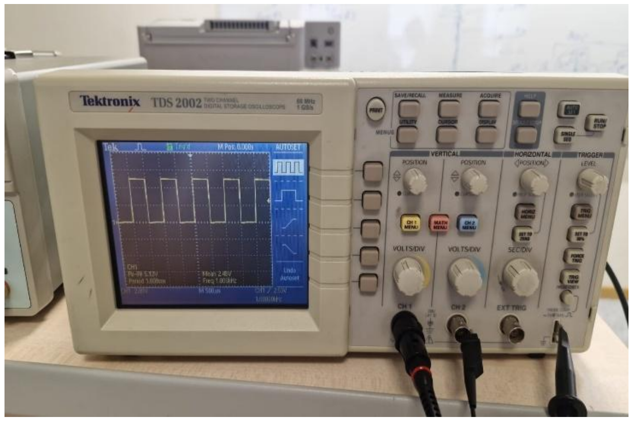

Figure 1.2: A Compensated Signal

Task-2) Using the dials on the signal generator, a 5 Volt peak to peak sinusoidal wave with a frequence of 1 kHz was measured by the oscilloscope. Since there was no direct current offset being applied, the sum of the minimum and maximum values of the signal was equal to zero (Figure 2.1). After this was done, the “TRIG MENU” button was pressed on the oscilloscope. This displayed a setting wherein the user could change the slope setting. Using this button, the signal was set to positive edge triggering -rising slope- (Figure 2.2) and negative edge triggering -falling slope- (Figure 2.3). With these options, it was observed that either signal was the inverse of the other. In the positive edge triggering mode, the signal shows an increasing behavior according to the origin, whereas the negative edge triggering mode shows the opposite.

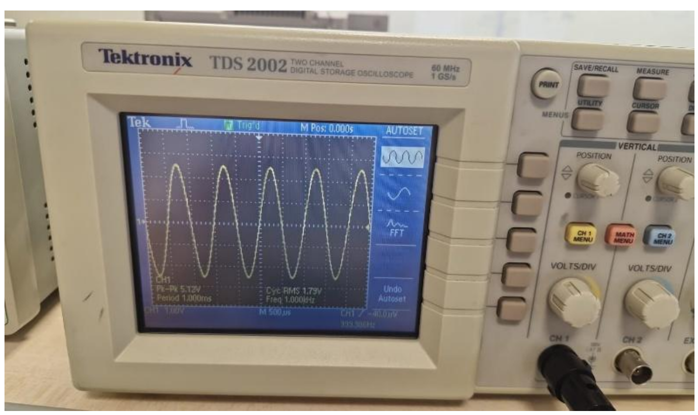

Figure 2.1: A sinusoidal signal

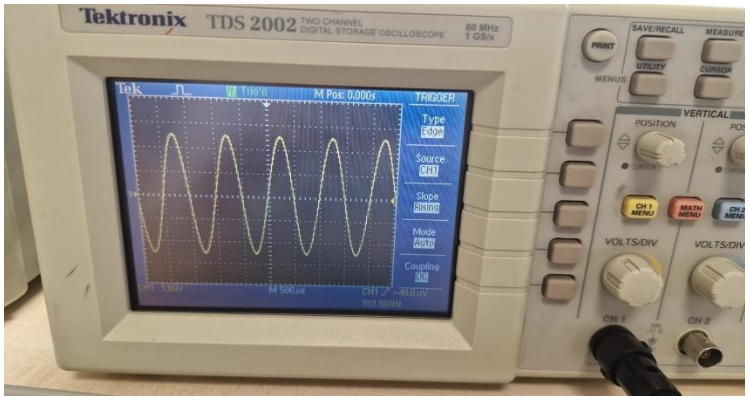

Figure 2.2: Positive edge triggering selected

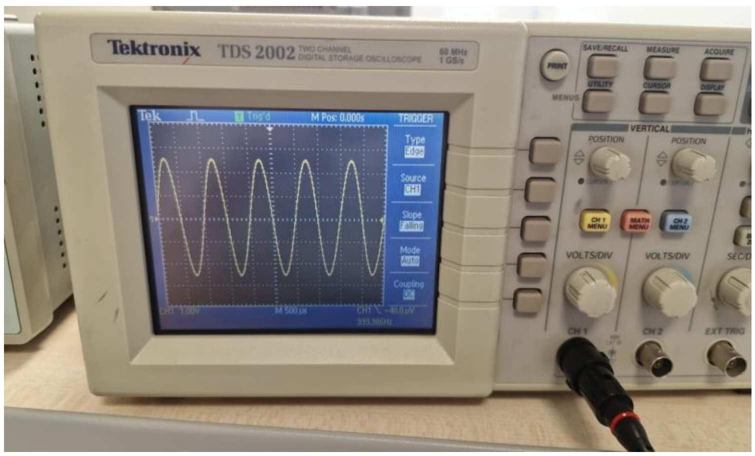

Figure 2.3: Negative edge triggering selected

Task-3) By adjusting the dials on the signal generator, a 1 Volt peak to peak triangular wave with a frequence of 2 kHz was measured and displayed on the oscilloscope (Figure 3.1). Using the dial labeled "Trigger" and turning it slightly, an arrow that was on the right side of the oscilloscope screen was moved upwards or downwards by adjusting the dial rightwards or leftwards respectively. This moved the signal to the direction that the dial was turned to and allowed the signal to be measured from the selected amplitude from the origin. This concept, called "triggering", is done by letting the arrow down at a certain amplitude and measuring when that amplitude coincides with the oscilloscopes vertical plane. When the arrow was moved out of the signal's amplitude, the wave was no longer visibly static and had a noise-like behavior (Figure 3.2). This is due to the reason that the received signal is under the set threshold, making it unstable to measure.

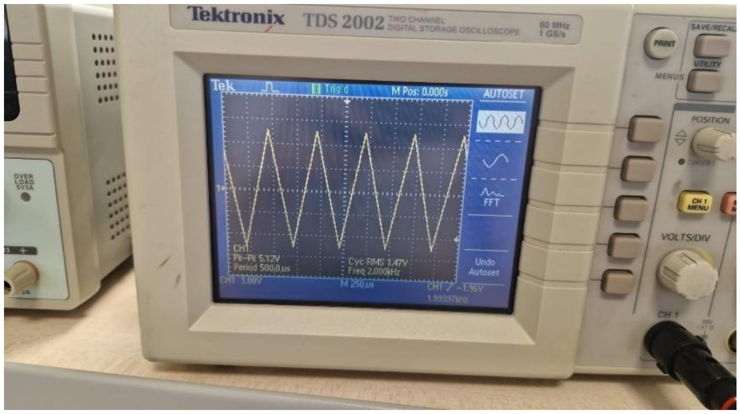

Figure 3.1: Triangle wave with triggering moved downwards

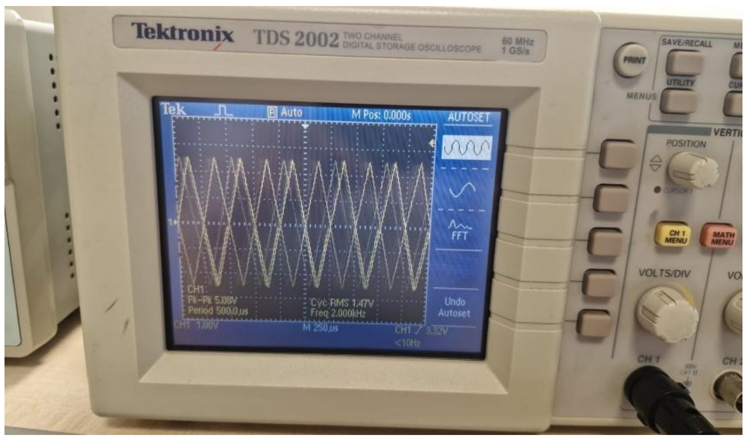

Figure 3.2: Triangle wave with triggering point larger than amplitude

Task-4) DACs (digital to analog converters) turn stepped or binary data into continuous signals. ADCs (analog to digital converters) transform continuous analog signals into digital signals. Some use cases for DACs are for electrical audio generation instruments, video display screens and signal generators. Some use cases for ADCs are microcontrollers, sensors and oscilloscopes. In this laboratory assignment, the oscilloscope that was used contained an ADC to turn analog voltage signals into digital video outputs. Using the dials on the signal generator, a 1 Volt peak to peak square wave with a frequency of 5 kHz was generated and viewed on the oscilloscope. By pressing the “Acquire” button located on the oscilloscope, a menu wherein three acquisition modes were located was displayed. By default, the oscilloscope used the “Sample” mode, which captures many individual samples in different points in time to create a wave (Figure 4.1). This mode works well for signals without sudden changes but is insufficient otherwise. After this, the acquisition mode was set to “Peak Detect”, which uses the highest and lowest values in a given interval (Figure 4.2). This mode is better suited for signals with sudden changes. This mode allowed the oscilloscope to display a peak before every rectangular pulse. Lastly, the “Average” mode was selected. This acquisition mode allows the oscilloscope to average multiple waveform acquisitions to reduce noise. These properties allow it to get the best results for repeating simple signals that aren’t one-time transient events. Using this mode, the least noisy signal was displayed on the oscilloscope (Figure 4.3).

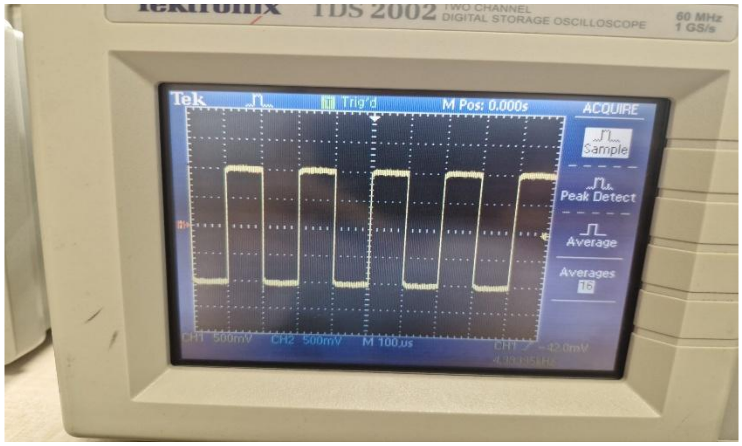

Figure 4.1: Square wave with sample acquisition

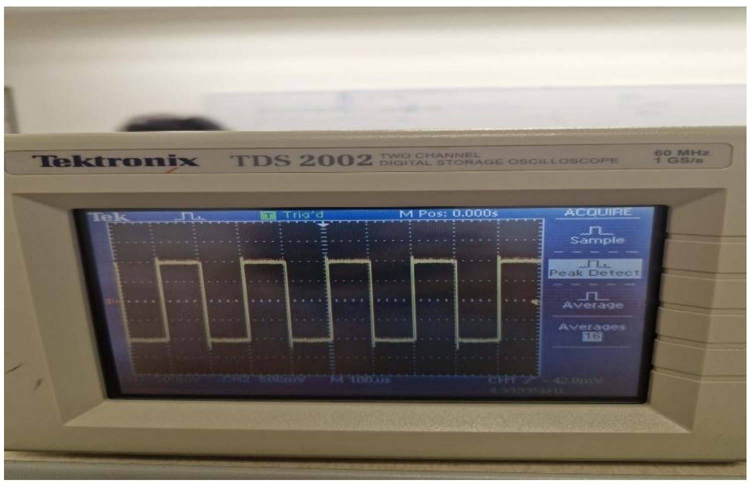

Figure 4.2: Square wave with peak detect acquisition

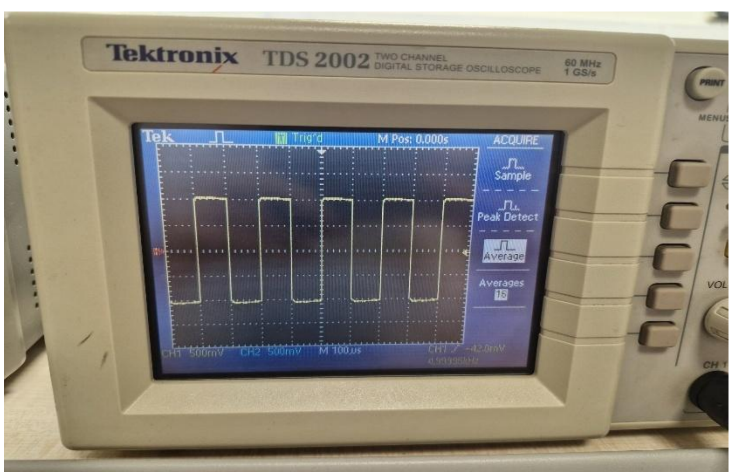

Figure 4.3: Square wave with averaging acquisition

Task-5) The values on the signal generator were modified and 2 Volt peak to peak sinusoidal wave with a frequency of 1 kHz was generated. Additionally, a DC offset with an amplitude of 1 Volt was applied to the signal. After the signal was generated, the “TRIG MENU” button on the oscilloscope was pressed to display a menu where the coupling of the acquired signal could have been changed. Initially, the oscilloscope was set to DC coupling. DC coupling measures both the AC and DC signals received by the probe and displays it as such on the oscilloscope. It is used when both current types are important for the circuit. Due to the selected values, a sine wave that oscillates between 0 Volts and 2 Volts were observed on the oscilloscope (Figure 5.1). After setting the coupling to AC coupling, which only detects AC part of the waveform and is used when only AC variations are desired to be analyzed, the sine wave shifted down by 1 Volt. This made the signal oscillate between -1 Volt and 1 Volt in a sinusoidal manner (Figure 5.2).

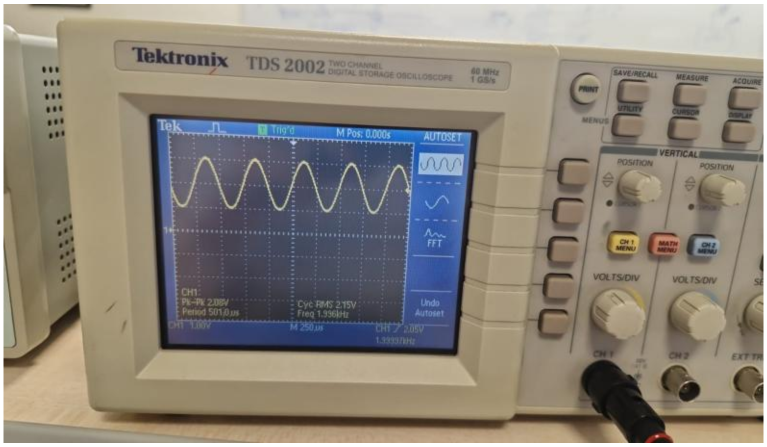

Figure 5.1: Sinusoidal signal with DC coupling

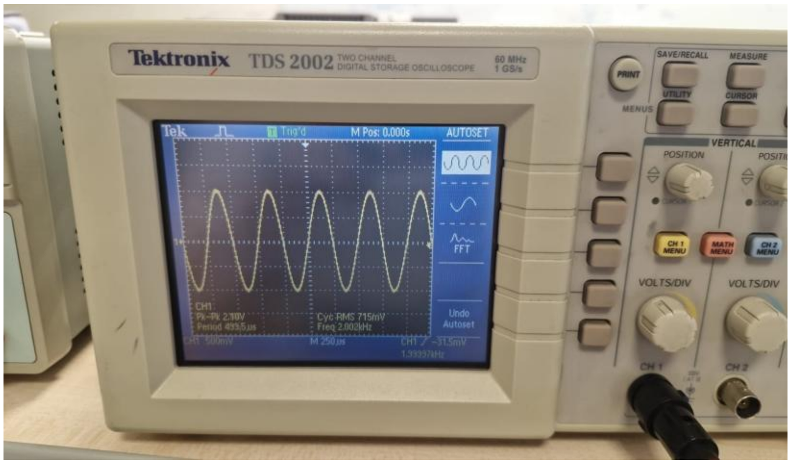

Figure 5.2: Sinusoidal signal with AC coupling

Task-6) In this task, using the given schematic in the lab sheet, a circuit using a 1000 Ohm resistor, 1 microfarad capacitor, male to male jumper cables, a breadboard, a signal generator and two oscilloscope probes were connected (Figure 6.1). The yellow cable was connected to Channel 1 and labeled X whereas the other probe was connected to the resistor, connected to Channel 2 and labeled as Y. Using the signal generator, both a 1 kHz and a 100 kHz sinusoidal signal with a peak-to-peak voltage of 2 Volts were given to the circuit (Figure 6.2). Using the built-in delay acquisition mode and adjusting the cursors on the waveforms, the phase difference between the waves were calculated using the following two equations.

$$\Phi = \tan^{-1}(\frac{1}{\omega RC})$$

where Φ is the phase difference, ω is the frequency times two pi, R is resistance and C is capacitance. Additionally:

$$t = \frac{\Phi T}{360°}$$

where t is the delay and T is the period.

Using these equations, the ideal delay and phase difference was calculated for both frequencies. For the 1 kHz, the ideal delay was 26.3 microseconds and for the 100 kHz signal the delay was 263 nanoseconds. Additionally, the phase difference for both signals were measured to be 9.47 degrees. These closely matched the measured values for both the 1 kHz signal (Figure 6.3) and the 100 kHz signal (Figure 6.4). From there results, it could be inferred that a higher frequency results in a lesser delay for RC circuits.

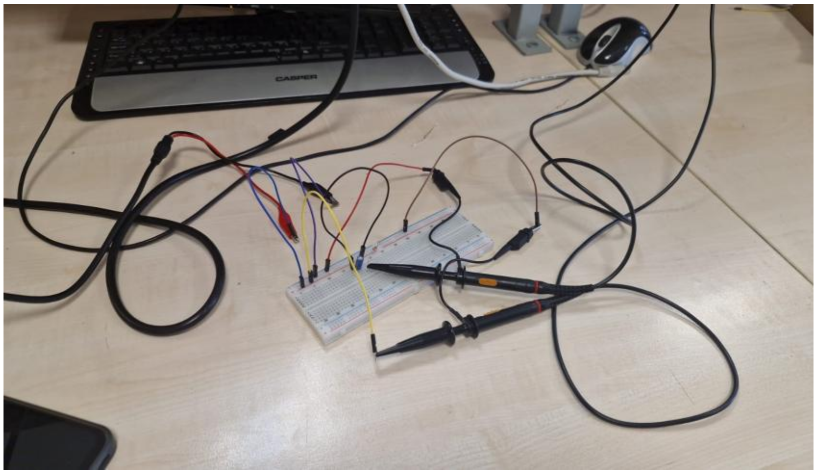

Figure 6.1: The circuit based on the schematic

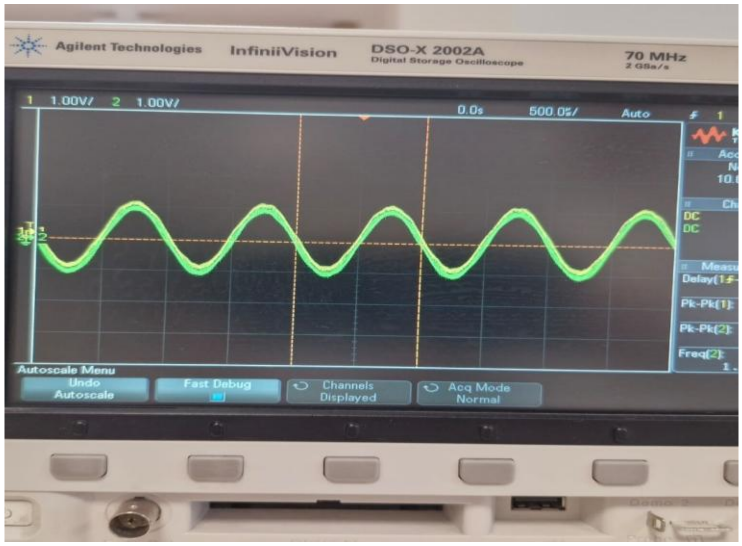

Figure 6.2: X and Y for 1 kHz on top of each other

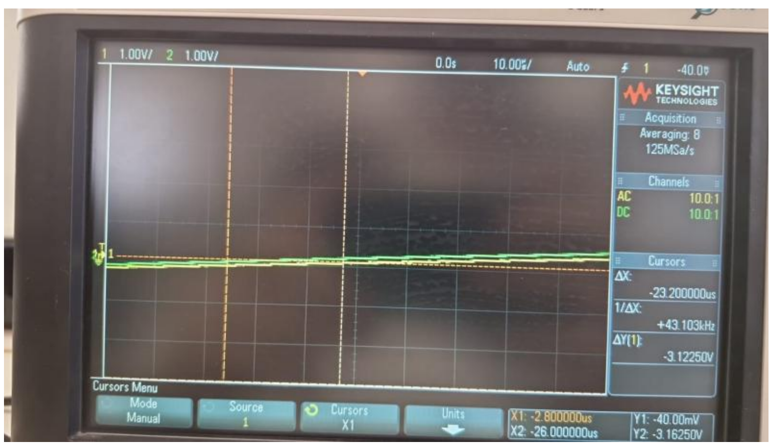

Figure 6.3: Measured delay of 23.2 microseconds for 1 kHz signal

Figure 6.4: Measured delay of 290 nanoseconds for 100 kHz signal

Conclusion:

The purpose of this experiment was to understand measuring devices better. The mechanisms and applications for oscilloscopes were understood with a higher quality of comprehension. The experiments that were conducted also explained how signal generators worked and how to change their values to the desired ones. A simple RC circuit was designed to better understand probing for closed circuits. For every given task, the observed values and plots closely matched the expected outcomes. Some deviation was observed for certain tasks, which could have been caused by faulty equipment and user error when measuring. Overall, the purpose of this laboratory assignment was achieved with remarkable success.

References:

- R&S®Essentials, *Understanding probe compensation,* https://www.rohde-schwarz.com/fi/products/test-and-measurement/essentials-test-equipment/digital-oscilloscopes/understanding-probe-compensation_254520.html
- Tektronix, *What acquisition modes are available on most Tektronix oscilloscopes?,* https://www.tek.com/en/support/faqs/what-acquisition-modes-are-available-most-tektronix-oscilloscopes