Lab Report 1: The Digital Oscilloscope & Fourier Analysis

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October 2023

Contents

1 Abstract

The digital oscilloscope is used to analyse the amplitude waveforms of voltage signals. The functionalities of the oscilloscope and in particular its Fourier analytic functionalities were investigated. The aims of the experiments outlined in part one align with describing the base functionalities of the digital oscilloscope. The experiments outlined in the second part cover the Fourier analytic functionalities of the oscilloscope. Overall, waveforms of voltage signals were successfully captured and the fast Fourier transform functionality was demonstrated and the results indicate the importance of accurate measurement methods and proper use of oscilloscope functionalities in obtaining reliable data for voltage signals.

2 Theory and Introduction

The experiments outlined below aim to dissect the workings of the digital oscilloscope and its Fourier analytic functionalities. The oscilloscope measures the voltage amplitude oscillations of the signals which it receives.

When an alternating current is applied to a Y plate of an analogue scope then the spot is deflected continuously in the x direction at rate that is fixed in time. Analogue oscilloscopes such as cathode ray oscilloscopes can operate at very high frequency but they lack the ability of digital oscilloscopes to take discrete values and perform calculations and analysis on them and adjust the time and voltage scales readily to increase the resolution of visualizations and measurements.

In the case of a digital scope, the voltage is only read in distinct time intervals. On this particular oscilloscope, the number of data points is 2500 no matter the time/div selected. Therefore the sampling rate {Points/Time} is proportional to the sweep rate because the number of points per sweep is constant. The maximum sample rate of this particular oscilloscope is a GSa/s. The Nyquist frequency is half of the sampling rate. It is the highest frequency that can be accurately represented without aliasing where aliasing is when a signal erroneously appears under the alias of another frequency. The expression for the Nyquist frequency is included below:

$$\text{Nyquist frequency} = \frac{f_{eff}}{2} \tag{2.1}$$

The basis of Fourier analysis is the idea that any periodic function f(t), with period T can be represented as the sum of sinusoidal functions with frequencies that are integer multiples of the reciprocal of the period T. The general form of such an expression is outlined below.

$$f(t) = B_0 + \sum_{n=1}^{\infty} A_n \sin(n\omega_1 t) + \sum_{n=1}^{\infty} B_n \cos(n\omega_1 t) \tag{2.2}$$

with

$$\omega_1 = 2\pi, \quad f_1 = \frac{2\pi}{T} \tag{2.3}$$

Where:

$$B_0 = \frac{1}{T}\int_0^T f(t)\,dt \tag{2.4}$$

$$B_n = \frac{2}{T}\int_0^T f(t)\cos(n\omega_1 t)\,dt \tag{2.5}$$

$$A_n = \frac{2}{T}\int_0^T f(t)\sin(n\omega_1 t)\,dt \tag{2.6}$$

Where f_n is the n^{th} frequency harmonic and determining the frequency spectrum is the aim of Fourier analysis. The oscilloscope measures discrete values along a horizontal sweep of 2500 equal time increments and uses the central 2048 of the 2500 to obtain the Fourier transform of the waveform it observes.

3 Apparatus

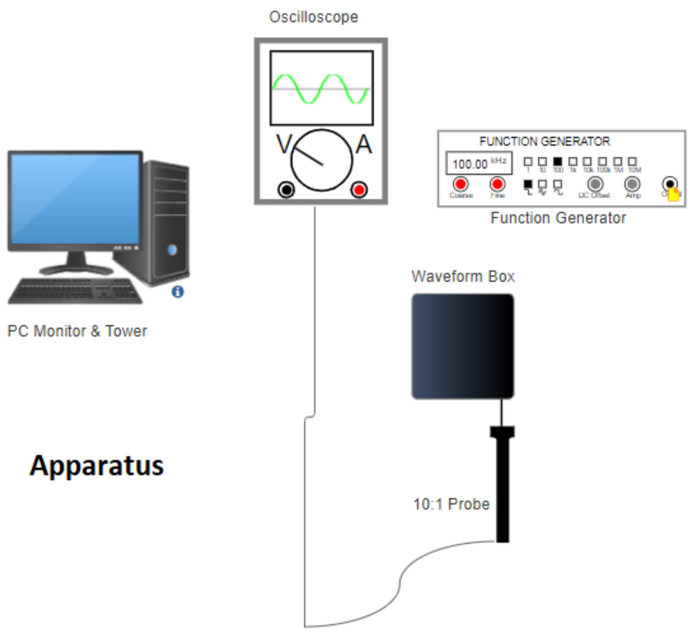

Figure 1: *The Apparatus*

The apparatus associated with this experiment includes:

- An oscilloscope (tektronix tds 1012c-edu)
- A function generator (TG320)
- A PC with Tektronix oscilloscope software installed
- A ”test waveforms box”
- A 10:1 probe (The 10:1 probe has a high impedance which reduces the amplitude to prevent damaging the components of the circuit board.)
- A 1:1 probe

4 Methodology

4.1 Part 1 - Experiment 1:

The purpose of this experiment was to measure the peak-to-peak voltage of a square wave. The 10:1 probe was connected to test point 1 of the "test waveforms box" through the oscilloscope's first channel. The peak to peak voltage (V_{pk-pk}) of the DC coupled system of was determined using the following methods:

- Direct measurement from the screen
- Use of the oscilloscope's measure functionality
- Use of the cursors

The vertical position of the waveform was adjusted on the oscilloscope such that the ground level of the signal was midway up the screen, and the coupling was switched to AC. All following measurements were performed with DC coupling.

4.2 Part 1 - Experiment 2:

In addition, the second 10:1 probe was connected to pin 2 through the second channel.

The time difference was determined between the two waves and the associated phase difference was calculated using the following methods:

- By direct measurement from the screen:
- Through use of the cursors:

The phase difference corresponding to this lag (ϕ) was then calculated: The phase shift, ϕ, was calculated using the following formula:

$$\phi = \frac{2\pi\Delta t}{T}$$

4.3 Part 1 - Experiment 3:

The 10:1 probe was connected to the pin 12 of the waveform box.

The trigger source was set to one and two. The nature and presence of a waveform in each of the channels was noted.

The oscilloscope was set to "rising" as in it was set to trigger on a rising part of the waveform. The trigger level was then set to 0 V and the screen display was noted.

The triggering point indicated by the black arrow ($\downarrow$) was then adjusted to half the amplitude of the waveform.

The oscilloscope was set to "falling" as in it was set to trigger on a falling part of the waveform and the screen display was noted.

The triggering level was then set higher than the maximum voltage, the corresponding waveform was noted.

The triggering level was then set to lower than the minimum voltage, , the corresponding waveform was noted.

The 10:1 probe was connected to the pin 3 of the waveform box. in order to display a discontinuous waveform.

"Hold off" is a functionality of the oscilloscope which triggers the horizontal sweep upon first detecting a rising edge but allows the selected "hold off" time to elapse before re-arming the trigger to look for the next trigger event.

The "hold off" value was decreased until the associated display was unstable and thus; The minimum "hold off" value to achieve a stable display was determined.

The "hold off" value was then increased until the associated display was unstable and thus; The maximum "hold off" value to achieve a stable display was determined.

This was repeated for a falling triggering type and the minimum and maximum "hold off" values for stability were found.

4.4 Part 1 - Experiment 4:

The 10:1 probe was connected to the pin 9 of the waveform box.

The button of the test waveform box provided a single pulse which was observed on the oscilloscope.

The trigger level and time base were set to values appropriate for giving resolution to the pulse.

The pulse height and duration was measured.

The procedure was repeated for both trigger levels of +4.00 ± 0.05 V, and –1.0 ± 0.05 V.

4.5 Part 1 - Experiment 5:

The 10:1 probe was connected to the pin 14 of the waveform box.

Reduced electromagnetic disturbances as much as possible and attempted to capture a stable 100% amplitude modulated waveform.

4.6 Part 2 - Experiment 1:

The 1x probe was connected to the frequency generator with an output of $4.00 \pm 0.05V_{pk-pk}$ and $10.36 \pm 0.05KHz$ sine wave and connected to channel 1.

The fast Fourier transform was selected.

The vertical display was in dBV where dBV = 20 log (V_{rms})

Where V_{rms} is the root mean square value in volts of the component measured.

Measurements on the screen were made using the cursors.

The frequency range, peak frequency, magnitude, time/div, and Nyquist frequency were determined for a range of sampling rates.

4.7 Part 2 - Experiment 2:

The 1x probe was connected to the frequency generator with an output of a $4.00 \pm 0.005Vpk - pk$ and $10.360 \pm 0.005KHz$ sine wave and connected to channel 1.

A sample rate of 25.0 ± 0.5 kSa/s was selected.

The frequency generated by the function generator was increased until it reached 2 divisions from the right.

The peak frequency when the peak reached the right-most edge of the oscilloscope display was measured and compared to the generated value of $26.66 \pm 0.05kHz$.

As the signal frequency exceeded the Nyquist Frequency, the frequency behaviour of the oscilloscope was noted.

The frequency was then measured two divisions from the left.

At two time divisions from the right-hand wall, the waveform frequency f_w were then determined alongside the peak frequency f_p.

The relationship between the peak frequency and the waveform frequency was then determined.

This was repeated with a sampling rate of $100kSa/s$ compared to the waveform frequency at $49.4 \pm 0.05kHz$.

4.8 Part 2 - Experiment 3:

The aim of this experiment is to determine how the width and shape of the depends on the choice of window function and on the sampling rate.

Qualitative comparisons were made between the different windows as waveform data of each measurement achieved as the screen grabs were not sufficient for data analysis. Better practise would involve taking data points directly for all captured waveform rather than interpreting the displays. The amplitude of the waveform was measured and the frequency was kept constant at $10.0 \pm 0.5kHz$.

The frequency spectrum was noted for the rectangular window and susceptibility to a change was noted against the sample rate.

This was repeated for the flattop and Hanning windows.

4.9 Part 2 - Experiment 4:

The aim of this experiment was to record the frequency spectrum of a square wave.

The square wave output of the function generator with of $4.000.005V_{pk-pk}$ and $10.360 \pm 0.005KHz$ and a sample rate of $1.000 \pm 0.005MSa/s$ was chosen. The amplitude and frequency of the first five peaks were noted.

The sample rate was increased to 10.00 ± 0.05 MSa/s and it was noted whether of not the frequency spectrum displayed was aliasing.

The sample rate was decreased to 500.0 ± 0.5 kSa/s and it was noted whether or not the frequency spectrum displayed was aliasing.

4.10 Part 2 - Experiment 5:

The aim of this experiment was to record and measure the frequency spectrum of a single isolated rectangular pulse.

The button of the test waveform box provided a single pulse which was observed on the oscilloscope as it was observed in Part 1 Experiment 4.

The pulse width and height were measured:

The amplitude and frequency of the first three minima and maxima were then determined and tabulated for the frequency spectrum.

4.11 Part 2 - Experiment 6:

The aim of this experiment is to measure a square wave with period T and width τ where $T >> \tau$.

The function generator was used to generate a waveform of width $\tau = 6.10 \pm 0.05\mu s$ and period $T = 102.0 \pm 0.5\mu s$.

The frequency spectrum was then obtained for a sample rate of $10.0 \pm 0.5MSa/s$. The frequencies the first three minima and maxima were determined and tabulated.

The frequency spectrum was then obtained for a sample rate of $2.5 \pm 0.05MSa/s$. The frequencies the first four maxima were determined and tabulated.

The frequency spectrum was then obtained for a sample rate of $1.00 \pm 0.05MSa/s$ and an appropriate frequency which displayed the envelope function rather than the details contained within. The frequencies the first three minima and maxima were then determined for the envelope function.

5 Results

5.1 Part 1 - Experiment 1:

The peak to peak voltage (V_{pk-pk}) of the DC coupled system of was determined:

- By direct measurement from the screen: $V_{pk-pk} = 2.0 \pm 0.5V$
- Though use of the oscilloscope's measure functionality: $V_{pk-pk} = 2.000 \pm 0.005V$
- Through use of the cursors: $V_{pk-pk} = \pm 0.05V$

The oscilloscope's measure functionality ($\delta V_{pk-pk} = 0.005V$) gives the most accurate results as it is not subject to as much error imposed by taking measurements by eye as demonstrated by the level of error present in direct measurement from the screen and through use of the cursors being ($\delta V_{pk-pk} = 0.5V$) and ($\delta V_{pk-pk} = 0.05V$) respectively. The use of cursors was more accurate as one may take the data as displayed numerically by the software of the oscilloscope rather than the full error contribution by human measurement limitations.

No difference was noted in the measurements between AC and DC coupling. The peak to peak voltage (V_{pk-pk}) remained the same. Theoretically it would have been possible to see a difference in the absolute voltage given that in the case of the DC coupling, the contribution of the DC component of the current may have increased the absolute value of the voltage which would have shifted the position waveform up in voltage equal to the DC offset. This offset was not detected possibly due to the DC component of the signal being negligible or due to methodological error.

Ac coupling uses a capacitor to block the DC component of a signal. This prevents the offset of the DC component of the signal from shifting the absolute value of the voltage. Contrasting this; DC coupling lets both the AC and DC components of the signal through. AC coupling may be used to preserve circuits against high amplitude DC components but DC coupling is important to use in order to analyse all components of a current with both alternating and direct components.

5.2 Part 1 - Experiment 2:

The waveform associated with the second pin had the same frequency but was lagging behind its counterpart waveform associated with the first pin. The time difference was determined:

- By direct measurement from the screen: $\Delta t = 1.0 \pm 0.5 \mu s$
- Through use of the cursors: $\Delta t = 1.04 \pm 0.05 \mu s$

The phase shift, ϕ, was given by the formula:

$$\phi = \frac{2\pi \Delta t}{T}$$

By direct measurement from the screen:

$$\phi = \frac{2\pi \pm \pi}{2.0 \pm 0.5}\,\mu s$$

$$\rightarrow \phi = \pi \pm 0.6\,\mu s$$

Through the use of the cursors:

$$\phi = \frac{2\pi \pm \frac{\pi}{20}}{2.0 \pm 0.05}\,\mu s$$

$$\rightarrow \phi = \pi \pm 0.06\,\mu s$$

5.3 Part 1 - Experiment 3:

The horizontal sweep triggers periodically such that it starts at the same point of a repetitive waveform.

It is not possible to obtain a stable display of a continuous but non-repetitive signal as there is no period the horizontal sweep can trigger at that will result in on horizontal sweep being continuously similar to the next.

When the trigger source was one, it was noted that a waveform was found as the trigger source stabilized in channel one while there was none in channel two. There was an overlapping pattern of alternating waveforms in quick succession discovered when the triggering was set to AC line.

The oscilloscope was set to "rising" as in it was set to trigger on a rising part of the waveform. The trigger level was then set to 0 V and the screen display was noted:

The triggering point indicated by the black arrow ($\downarrow$) was then adjusted to half the amplitude of the waveform.

The oscilloscope was set to "falling" as in it was set to trigger on a falling part of the waveform and the screen display was noted.

The display differs when it is set to "falling" rather than "rising" because the horizontal sweep begins at different points along the time domain of the waveform as the oscilloscope attempts to trigger the horizontal sweep when the voltage is rising or falling depending on its corresponding setting.

When the triggering level was then set higher than the maximum voltage this resulted in an unstable waveform pattern as the oscilloscope may have struggled to find a stable trigger point because the signal's voltage level changed very rapidly.

When the "hold off" value was decreased until the associated display was unstable thus determining the minimum "hold off" value to achieve a stable display to be $20.0 \pm 0.05\mu s$.

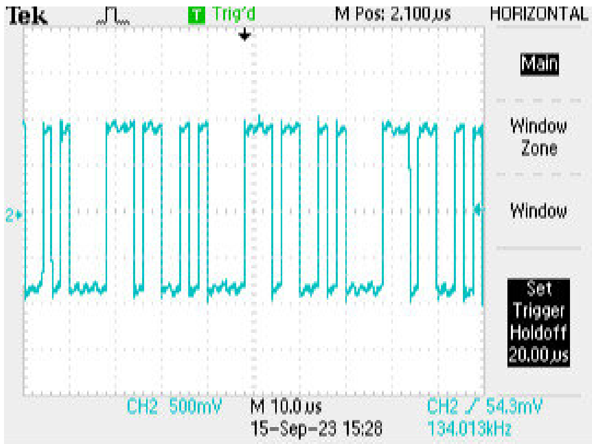

Figure 2: Oscilloscope Display of Complex Repetitive Waveform

The "hold off" value was then increased until the associated display was unstable and thus; The maximum"hold off" value to achieve a stable display was determined to be $29.6 \pm 0.05\mu s$

This was repeated for a falling triggering type and the minimum and maximum "hold off" values for stability were found to be $16.0 \pm 0.05\mu s$ and $30.0 \pm 0.05\mu s$ respectively. Which suggests there is little difference due to the triggering types used in determining the range of "hold off" time display stability.

5.4 Part 1 - Experiment 4:

The pulse height was measured to be $1.0 \pm 0.5V$, it had an uneven rather than horizontal peak likely due to the a source of noise voltage present in an imperfect 10:1 probe through which the pulse travels. The pulse duration was determined to be $8.0 \pm 0.5\mu s$.

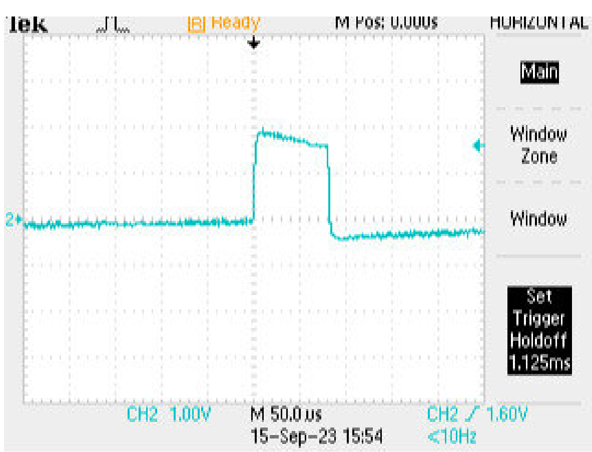

Figure 3: Oscilloscope Display Single Square Pulse

The procedure was repeated for both trigger levels of $+4.00 \pm 0.05V$, and $-1.0 \pm 0.05V$.

The following was determined:

4V Trigger level did not capture the pulse

-1V Trigger level did not capture the pulse

The trigger level set must be within the voltage range of the pulse one intends to capture; Which aligns with the above results.

5.5 Part 1 - Experiment 5:

The equation for a 100% modulated waveform: $V(t) = A_{\text{mod}} \cos(\omega_{\text{av}} t)$ or $V(t) = 2A\cos(\omega_{\text{mod}} t)\cos(\omega_{\text{av}} t)$

can be shown using the trigonometric identity: $\cos(\alpha) + \cos(\beta) = 2\cos\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$

given that: $V(t) = A\cos(\omega_1 t) + A\cos(\omega_2 t)$.

Upon attempting to measure a 100% modulated waveform a stable pattern was not immediately visible. Every permutation of the trigger level was attempted but no stable waveform was achieved.

The horizontal display resolution on the oscilloscope required to get a waveform display which was not dominated by voltage fluctuations was smaller than the period and thus determining the carrier and modulation frequencies was not possible. The experiment should be repeated in a location with less electromagnetic disturbances to best achieve this objective. Every

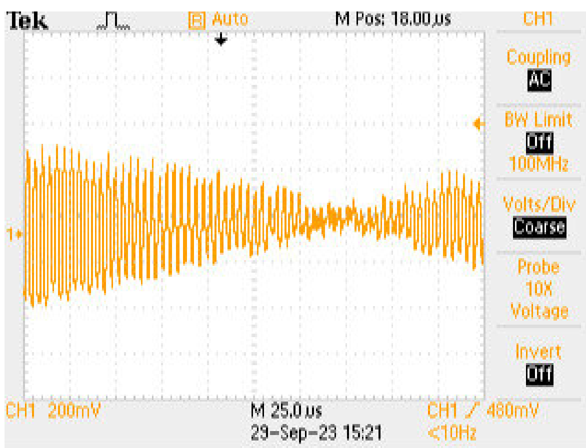

Figure 4: Best Achieved Image of 100% Modulated Waveform

feasible permutation of the experimental circumstance was attempted but the carrier frequency and the modulation frequency were not found. If this was possible to achieve, the carrier frequency and the modulation frequency would be determined by finding the points of largest contribution and least contribution to amplitude of both the carrier sinusoid and the modulation sinusoid and solving for their frequencies as the overall waveform is the sum the two.

5.6 Part 2 - Experiment 1:

The frequency range, peak frequency, magnitude, time/div, and Nyquist frequency were determined for a range of sampling rates:

Measured from waveform: $V_{pk-pk} = 4.40V$ $dbV = 9.85 \pm 0.05$ results in rms of $3.1 \pm 0.03V$

Sample Rate	Frequency range	Peak Frequency	Mag	$\frac{Time}{Division}$	Nyquist Frequency
2.5 kSa/s	1.240 kHz	0.260 Hz	3.05 V	100 ms	1.250 kHz
5 kSa/s	2.480 kHz	0.260 Hz	3.05 V	50.0 ms	2.500 kHz
10 kSa/s	4.930 kHz	0.260 Hz	3.05 V	25.0ms	5.000 kHz
25 kSa/s	12.40 kHz	10.35 kHz	3.05 V	10.0 ms	12.500 kHz
50 kSa/s	24.80 kHz	10.40 kHz	3.05 V	5.0 ms	25.000 kHz
100 kSa/s	49.60 kHz	10.40 kHz	3.05 V	2.50 ms	50.000 kHz
250 kSa/s	124.0 kHz	10.50 kHz	3.05 V	1.0 ms	100.000 kHz
500 kSa/s	248.0 kHz	10.0 kHz	3.05 V	500 μs	200.000 kHz
1 MSa/s	496.0 kHz	10.0 kHz	3.05 V	250 μs	400.000 kHz

Table 1: Displayed Spectrum Properties vs Sampling Rate for Sine Wave

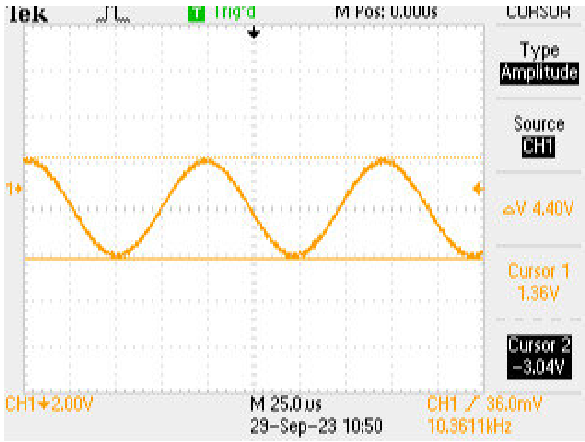

Figure 5: Measured Waveform

5.7 Part 2 - Experiment 2:

When the sample rate of $25.0 \pm 0.5 kSa/s$ was selected and frequency generated by the function generator was increased until it reached 2 divisions from the right, the peak frequency when the peak reached the righthand of the oscilloscope display and was measured to be $23.60 \pm 0.05 kHz$ which was near the generated value of $26.66 \pm 0.05 kHz$. As the signal frequency exceeded the Nyquist Frequency, the oscilloscope lead to the frequency decreasing. The frequency was therefore measured 2 divisions from the left. At two time divisions from the right-hand wall, the waveform frequency f_w was determined to be $499.51 \pm 0.05 kHz$ while the peak frequency f_p was determined to be $1.00 \pm 0.05 kHz$. This demonstrates a roughly linear relationship between the peak frequency and the waveform frequency. This was repeated with a sampling rate of $100 kSa/s$ which was found to behave roughly similar to the waveform frequency at $49.4 \pm 0.05 kHz$.

5.8 Part 2 - Experiment 3:

The fast Fourier transform operates on the inner 2048 points captured by the oscilloscope. As a result finite length discontinuities may be introduced which affect the overall display of the frequency spectrum. To avoid such issues, the waveform is forced to zero at the first and as of the time divisions by multiplying the record by one of three elected window functions. The Hanning curve, the flattop and the rectangular functions each affect the frequency spectrum when multiplied. The Hanning window gives the best frequency resolution as it gives the

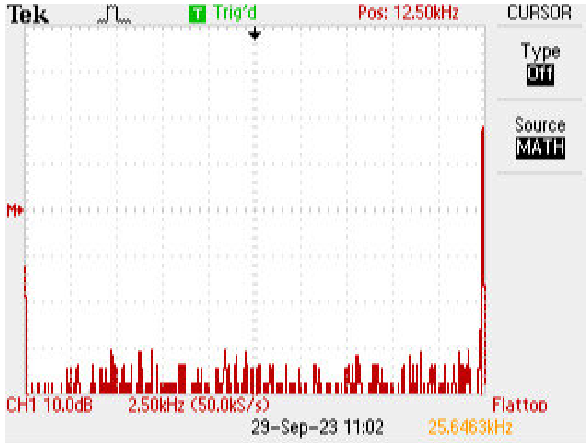

Figure 6: Signal Waveform at Nyquist Frequency

Peak	Frequency	Amplitude
1	10.0kHz	5.45dB
2	30.0kHz	-4.15dB
3	50.0kHz	-8.55dB
4	70.0kHz	-11.7dB
5	90kHz	-13.7dB

narrowest peaks while constantly the flattop window gives the most accurate amplitude values. This theory aligns with results outlined below.

Qualitative comparisons were made between the different windows as waveform data of each measurement achieved as the screen grabs were not sufficient for data analysis.

The amplitude of the waveform remained the same at $3.1 \pm 0.5dBV$. The frequency was kept constant at $10.0 \pm 0.5kHz$.

The rectangular wave resulted in an exaggerated flared base to the waveform which was very susceptible to a change in sample rate.

The flattop gave a waveform which was increased in width as the sampling rate increased.

The hanning window gave wavewidth with the wave width only increasing minimally with the sampling rate.

5.9 Part 2 - Experiment 4:

The amplitude and frequency of the first five peaks are shown below:

The sample rate was increased to 10.00 ± 0.05 MSa/s and it was noted whether the frequency spectrum displayed was aliasing as it is far exceeding the Nyquist frequency.

The sample rate was decreased to 500.0 ± 0.5 kSa/s and it was noted that the frequency spectrum displayed was aliasing as it was smaller than the Nyquist frequency.

5.10 Part 2 - Experiment 5:

The aim of this experiment was to record and measure the frequency spectrum of a single isolated rectangular pulse.

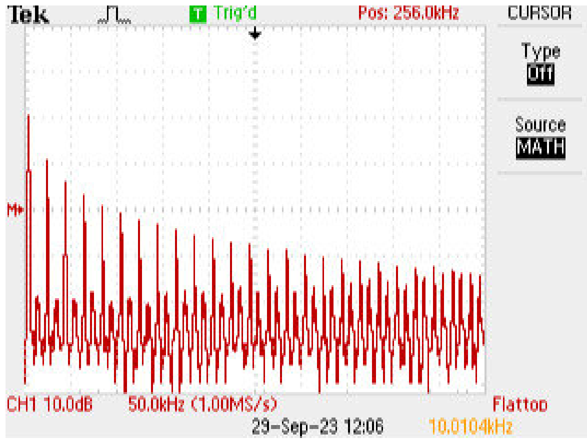

Figure 7: Frequency Spectrum at Nyquist Frequency

The button of the test waveform box provided a single pulse which was observed on the oscilloscope as it was observed in Part 1 Experiment 4.

The pulse width and height were measured.

The amplitude and frequency of the first three minima and maxima were then determined and tabulated for the frequency spectrum.

Minimum	Frequency
1	12.5 kHz
2	25.0 kHz
3	37.5 kHz

5.11 Part 2 - Experiment 6:

The aim of this experiment is to measure a square wave with period T and width τ where $T >> \tau$.

The function generator was used to generate a waveform of width $\tau = 6.10 \pm 0.05 \mu s$ and period $T = 102.0 \pm 0.5 \mu s$. The pulse width was unaffected by the frequency but the period did.

The frequency spectrum was then obtained for a sample rate of $10.0 \pm 0.5 MSa/s$. The frequencies the first three minima and maxima were determined and tabulated.

The frequency spectrum was then obtained for a sample rate of $2.5 \pm 0.05 MSa/s$. The frequencies the first four maxima were determined and tabulated. The frequency spectrum was then obtained for a sample rate of $1.00 \pm 0.05 MSa/s$ and an appropriate frequency which displayed the envelope function rather than the details contained within. The frequencies the first three minima and maxima were then determined for the envelope function.

Maximum	Amplitude	Frequency
1	-7.75dB	0
2	-36.9dB	17.5 kHz
3	-41.3dB	30.5 kHz

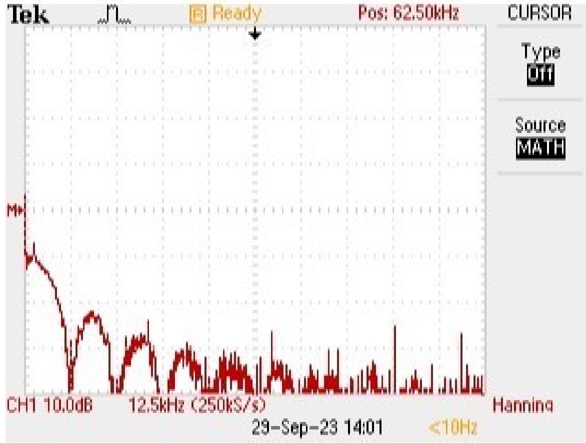

Figure 8: Frequency Spectrum of a Single Isolated Rectangular Pulse

Minimum	Frequency
1	160 kHz
2	320 kHz
3	480 kHz

6 Sources of Error & Error Propagation:

- Gaussian error of quotients was used to propagate the error of the phase shift $\delta\phi$:

$$\delta\phi = \overline{\phi}\sqrt{\left(\frac{\delta\Delta t}{\overline{\Delta t}}\right)^2 + \left(\frac{\delta T}{\overline{T}}\right)^2}$$

- The error of the peak to peak voltage (δV_{pk-pk}), the phase difference ($\delta\phi$), and time measurements (δt) were determined by the method of measurement used to determine each value:
- For direct measurement from the screen, the order of precision was determined to be of the order 10^-1 as direct screen measurements are particularly vulnerable to human error.
- For measurements determined through use of cursors the order of precision was determined to be of the order 10^-2 as they are prone to human error but less so due to being directly taken within the software of the oscilloscope.
- For measurements taken using the measure functionality of the oscilloscope the order of precision was taken as indicated by the software.
- The oscilloscope displays an order of precision of $0.005\mu s$ for measurements of hold off value but due to the implicit human uncertainty of deciding when stability is observed; the associated maximum and minimum hold off values of stability were determined to be $0.005\mu s$.

7 Conclusions

In conclusion, this experiment provided valuable insights into waveform analysis through use of the digital oscilloscope, measurement techniques, and the impact of sampling rates and

Maximum	Amplitude
1	-25.3d B
2	-38.5 dB
3	-43.7 dB

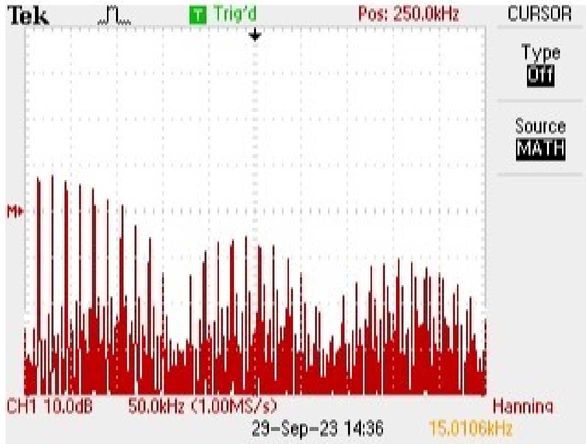

Figure 9: Envelope Function

window functions on frequency spectra. The results indicate the importance of accurate measurement methods and proper oscilloscope functionalities in obtaining reliable data for voltage signals.

The Peak-to-peak voltage ($Vpk - pk$) of a square wave was measured using different methods with the oscilloscope's measure functionality providing the most accurate results.

The phase shift (ϕ) between two waveforms was measured using both direct screen measurements and cursors with the phase difference being found to be $\pi \pm 0.06\mu s$ when using the cursors.

There is little difference due to the triggering types used in determining the range of "hold off" time display stability.

It was determined that the trigger level set must be within the voltage range of the pulse one intends to capture.

A single pulse was observed and measured using different trigger levels and it was found that the trigger level must be set within the voltage range of the pulse to capture it.

Measurement of a 100% modulated waveform was attempted but difficulties were faced in achieving a stable pattern as Electromagnetic disturbances likely the measurements.

The frequency spectrum of a sine wave was analyzed at different sampling rates. with the Hanning window providing the best frequency resolution.

Frequency aliasing was observed when the signal frequency exceeded the Nyquist frequency and a linear relationship was identified between the peak frequency and the waveform frequency. Thus aliasing was determined to be minimized at the Nyquist frequency.

Different window functions were applied to the waveform data for the fast Fourier transform and compared.

The frequency spectrum of a square wave was recorded at various sample rates. Aliasing was observed at lower sample rates.

Frequency spectrum of an isolated rectangular pulse was measured, and the first three minima and maxima were identified successfully.

Frequency spectrum of a square wave with specific period and width was measured at different sample rates.

The breadth of functionalities of the digital oscilloscope were investigated to varying levels of success.

List of Figures