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BIT STREAM FREQUENCY SPECTRUM

Objectives:
This lab will introduce how data, or bit streams, look in the frequency spectrum, along with analysis of frequency harmonics and how they affect signal quality, attenuation. If you haven't been introduced to Fourier domain analysis this will be your first time viewing a signal in the frequency domain, where the x-axis is the frequency and the y-axis is the signal strength (scaled by logarithms per decade). To get a better feel for the frequency domain I suggest using the signal generator to view a sinusoidal signal in the frequency domain, adjust the power and frequency and view the output on in the frequency domain.

Preliminary Calculations: The preliminary calculations required us to refresh our memories on frequency domain analysis. Therefore we used the signal generator to view a sinusoidal signal in the frequency domain, and adjusted the power and frequency and viewed the output in the frequency domain.

Results and Discussions:

1. **DATA SIGNAL GENERATION**
   a. Generate a random data signal using a long length Linear Feedback Shift Register, like you built in lab #3, clocked at approximately 10 kHz. Pass the signal through a low pass filter. Ideally you should use one of the Non-white adjustable filters available in the laboratory. If you do not have access to one of these filters, you can approximate it with an R/C circuit such as the one you built in a lab #2. Adjust the cutoff frequency of the filter from 1 kHz to 100 kHz, while watching how it distorts the signal, use a decade resistance box if you are using an R/C circuit. In particular, look at how it distorts data when there are several 1's or 0's in a row, and also look at how it distorts the data when you have a pattern like 01010101; describe this distortion in your report. In digital communication systems we usually don't care if the waveform at the receiver looks like a perfect logic signal, we just need to be able to determine if the original signal was a 0 or a 1. If the cutoff frequency of the low pass filter is very high frequency then this should not be a problem; but as the cutoff frequency is low, it becomes increasingly difficult to determine the logic levels.

   Results 1:

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1. What range of cutoff frequencies allow you to "easily" determine if the original data was a 0 or 1? What data patterns are most difficult to detect? For example, is 000000111111100000 difficult to detect, or 00110011001100110011, or 010101010101, or 00000000100000, or some other string of 0s and 1s?
    a. The frequency range that allows us to easily determine the bits was between 5-10KHz. The higher the frequency the easier the signal passes through the low pass filter. The most difficult data patterns to detect would have been a minimal amount of pulses. All results can be observed within **Figures 1-9.**

Figure 1: 1KHz

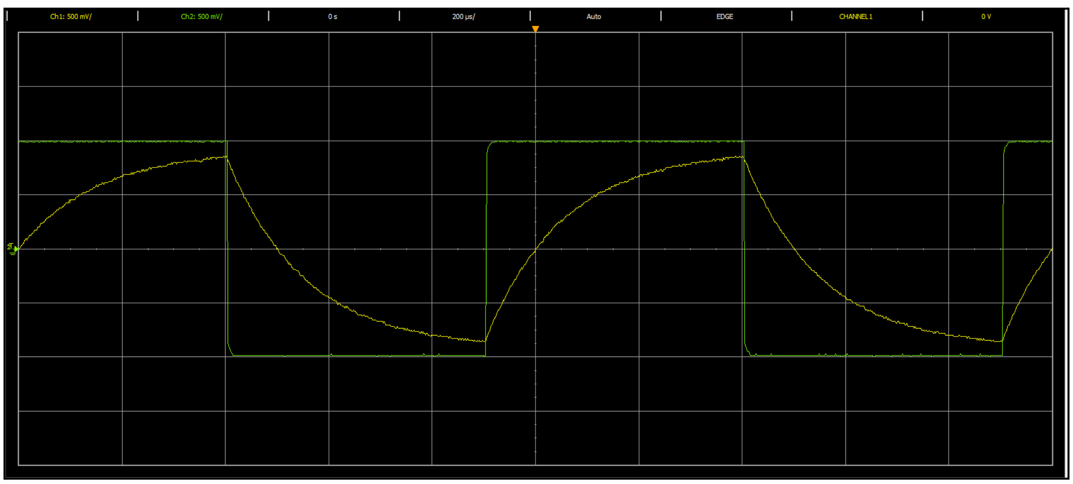


Figure 2: 5KHz

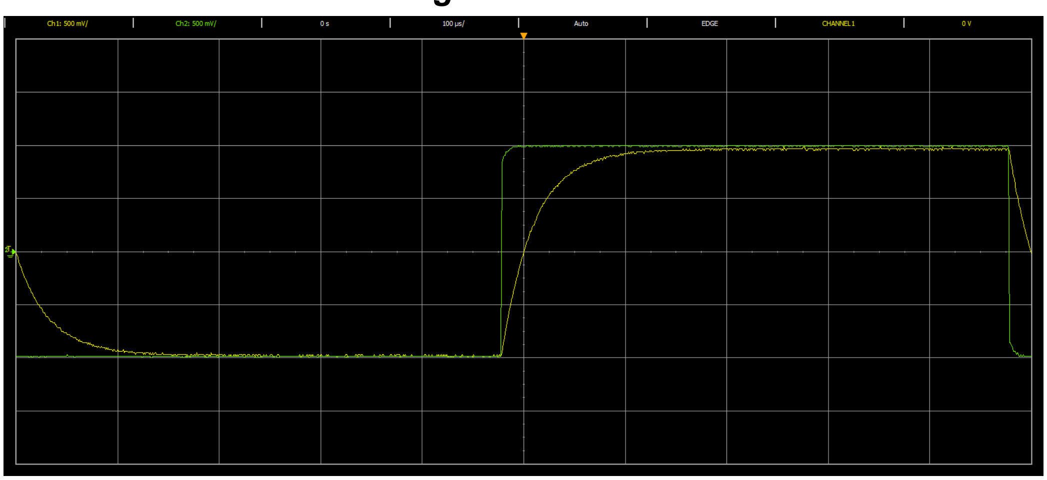


Figure 3: 10KHz

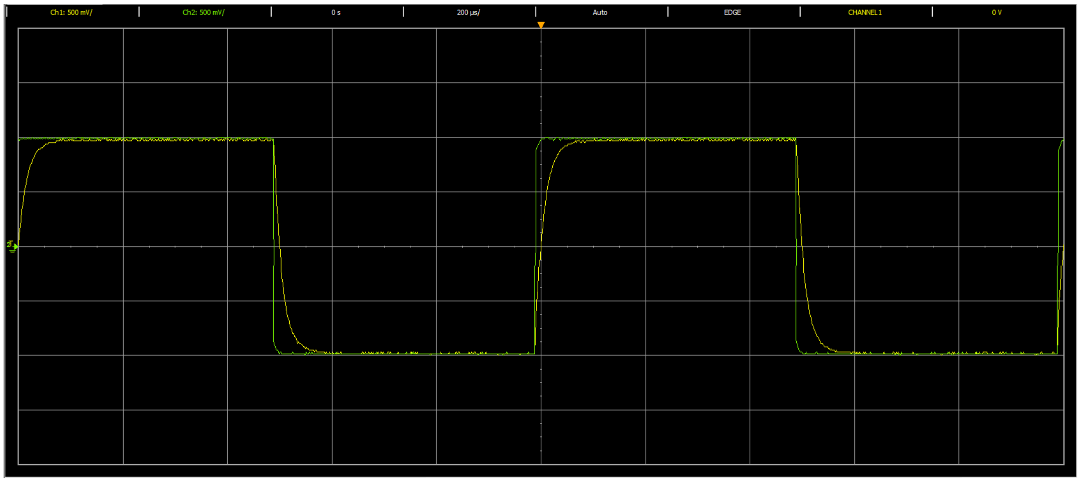


Figure 4: 25KHz

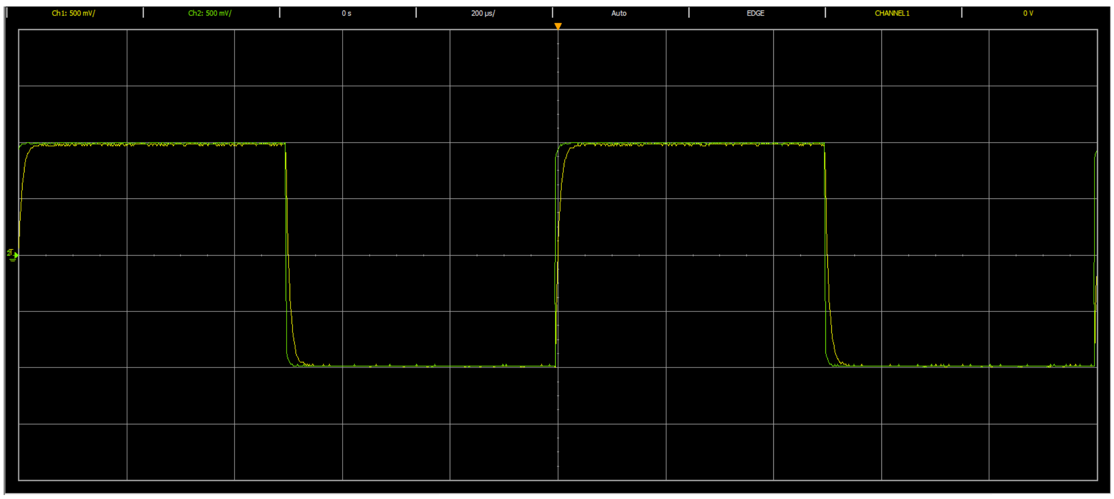


Figure 5: 50KHz

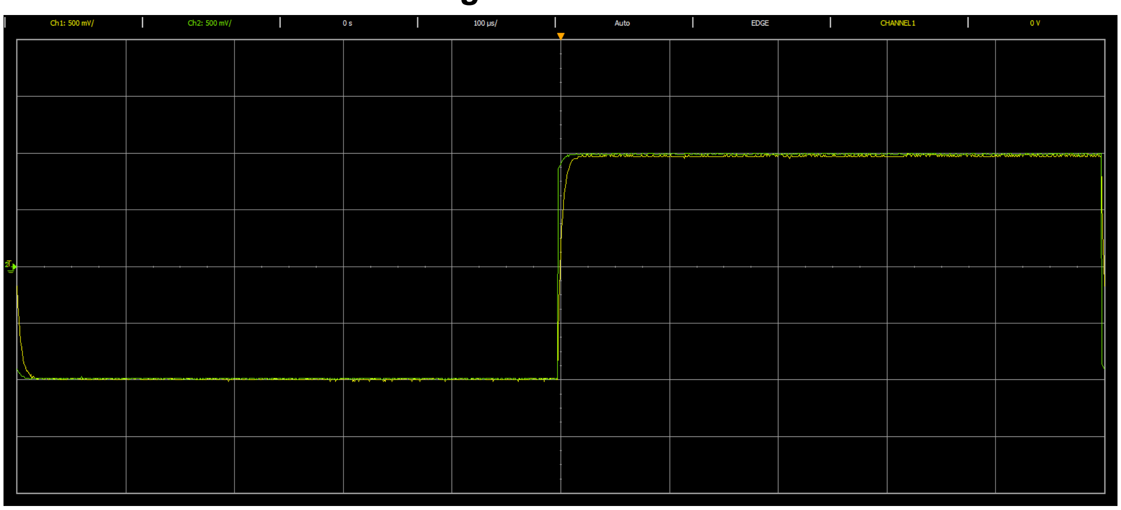


Figure 6: 72KHz

Figure 7: 85KHz

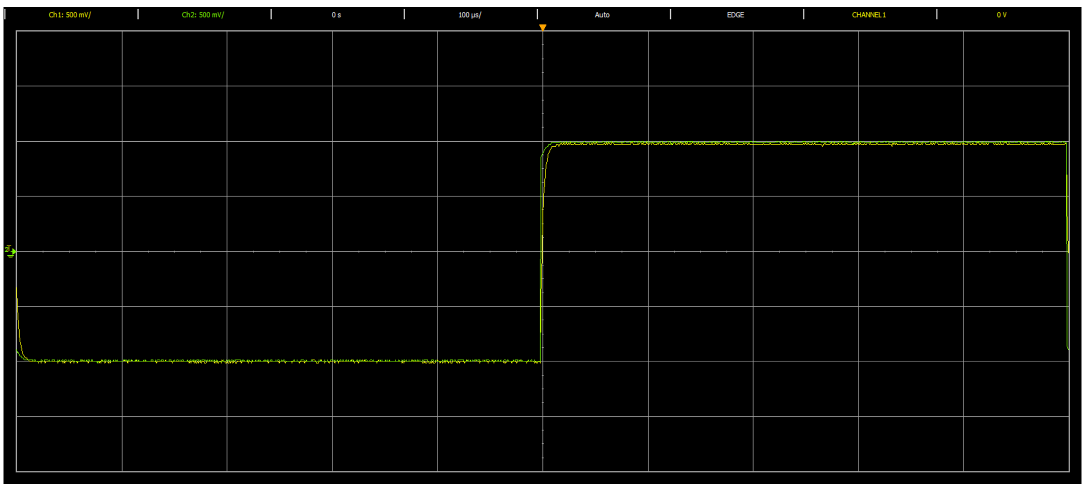


Figure 8: 100KHz

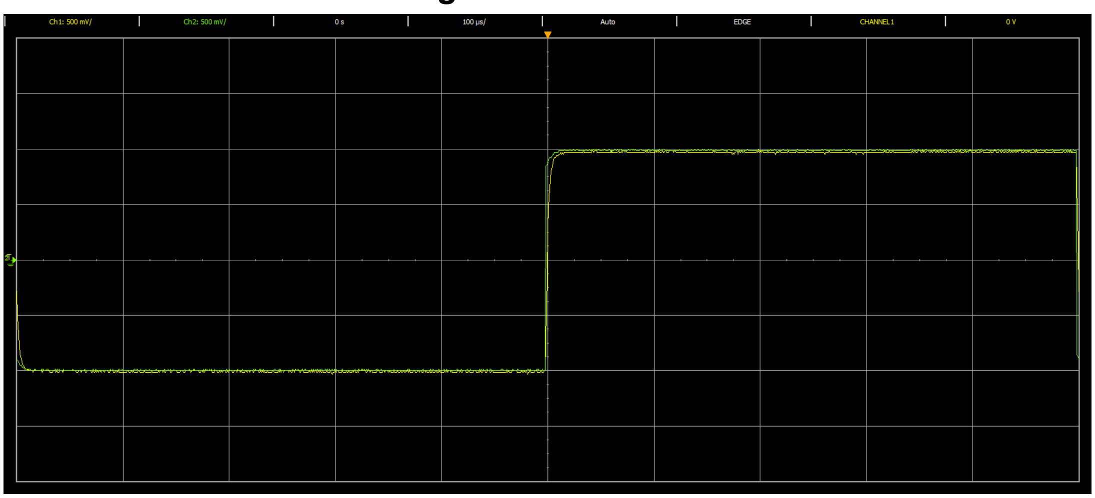


Figure 9: Resistance-Frequency Relation

Resistance (Ohms)	Frequency (KHz)
720	100
850	85.11
1000	72.34
1400	51.67
2800	25.837
7000	10.335
14000	5.167
70000	1.0335

2. **SINE WAVE FREQUENCY SPECTRUM**
   a. We now want to look at what frequencies the digital signal is using. The spectrum analyzer will do this for us. Start by connecting a sine wave generator to the spectrum analyzer. Have one person in your lab team set the amplitude and frequency of the sine wave generator, and then have someone else (who can't see these settings) see if they can figure them out by looking at the spectrum analyzer display. Use the 'Peak Scan' tool on the digital oscilloscope to accurately view the peak of the sinusoidal wave.

   Results 2:
   1. Using the spectrum analyzer, we set the amplitude and frequency of the sine wave to a given value and had another member try to guess the waveform using the spectrum analyzer. The input waveform can be observed within **Figure 10 and 11.** While the frequency domain from the spectrum analyzer can be seen within **Figure 11.**

Figure 10: Oscilloscope output

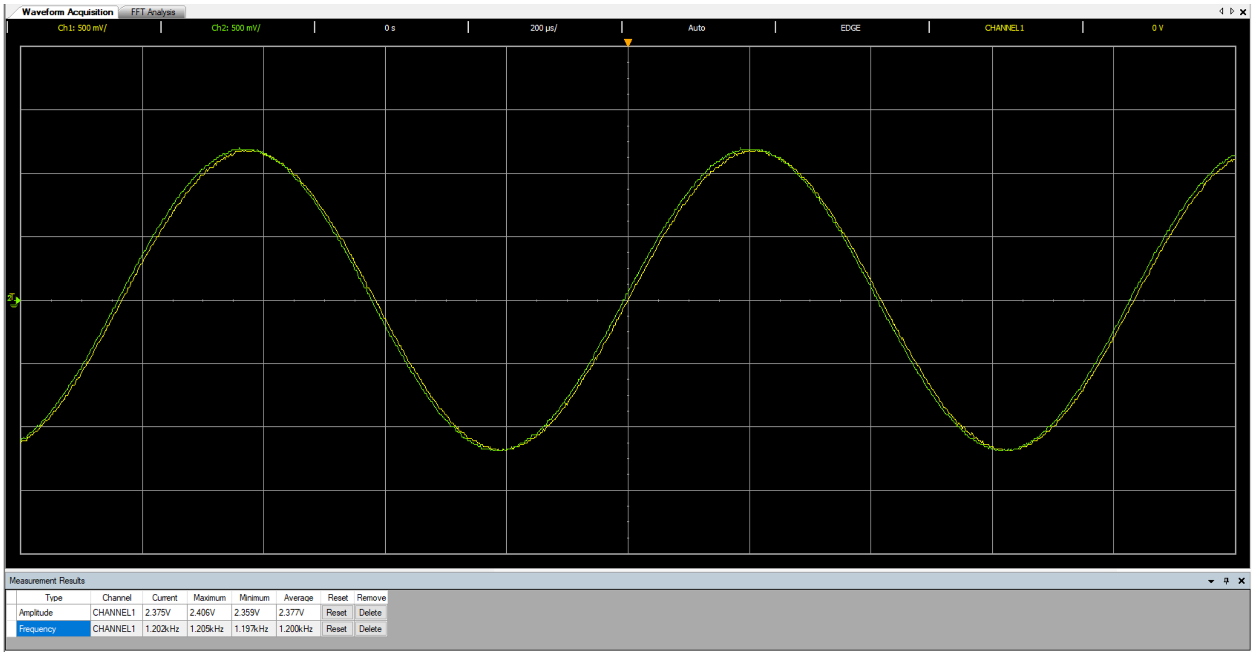
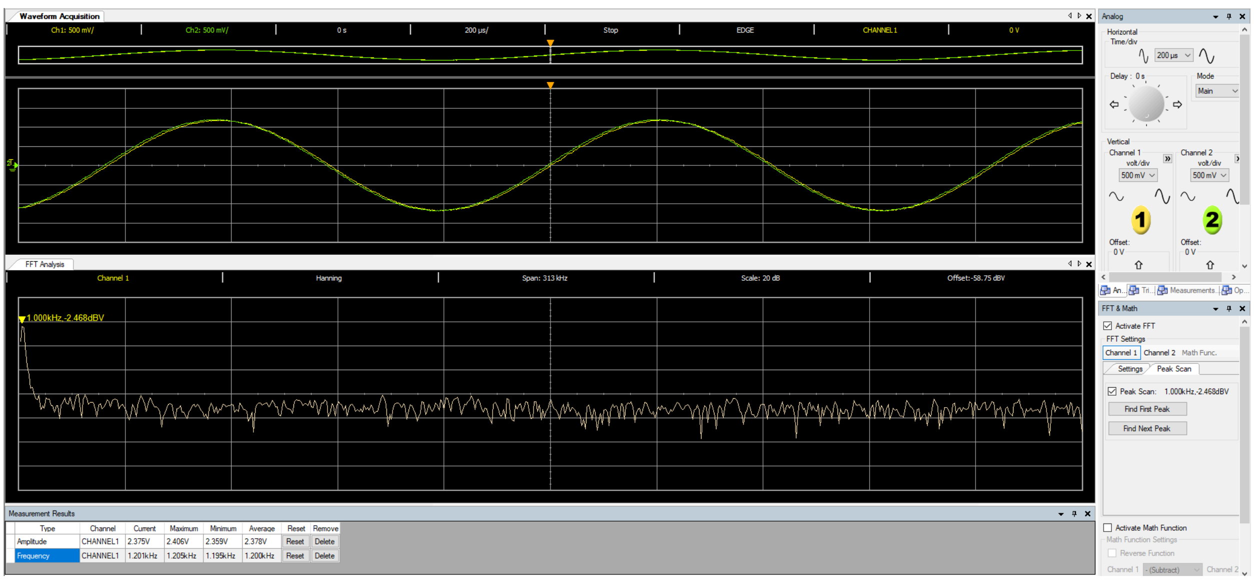


Figure 11: Spectrum analyzer



3. DATA FREQUENCY SPECTRUM

a. Put the random data signal into a spectrum analyzer, then determine what range of frequencies it uses. Sketch the plot in your report. If possible plot it both on a linear scale (unscaled), and a dB scale (logarithms per decade).

Results 3:

1. Relate the observed data rate to the first null frequency of the spectrum. What does the spectrum look like? What mathematical

function will you use to describe the observed spectrum? Describe how the plot changes if you alter the clock frequency of the data signal, and if you alter the amplitude of the data signal.

a. A random data signal was introduced to the spectrum analyzer. The Plot of db would look like a decaying exponential, this was determined by observing the db value for decreasing harmonics. The spectrum seems to be quite level, no large spikes for any given frequency, but it does seem to decrease as the frequency increases. This can be observed within **Figure 12 & 13.** The mathematical function used to describe the observed spectrum was 2(2)^0.5*(10^(db/20)). This calculated the vpp for any given frequency. If the clock frequency was decreased the data would become more readable, and opposite if the frequency was increased.

Figure 12: Spectrum Analyzer for Random bit stream

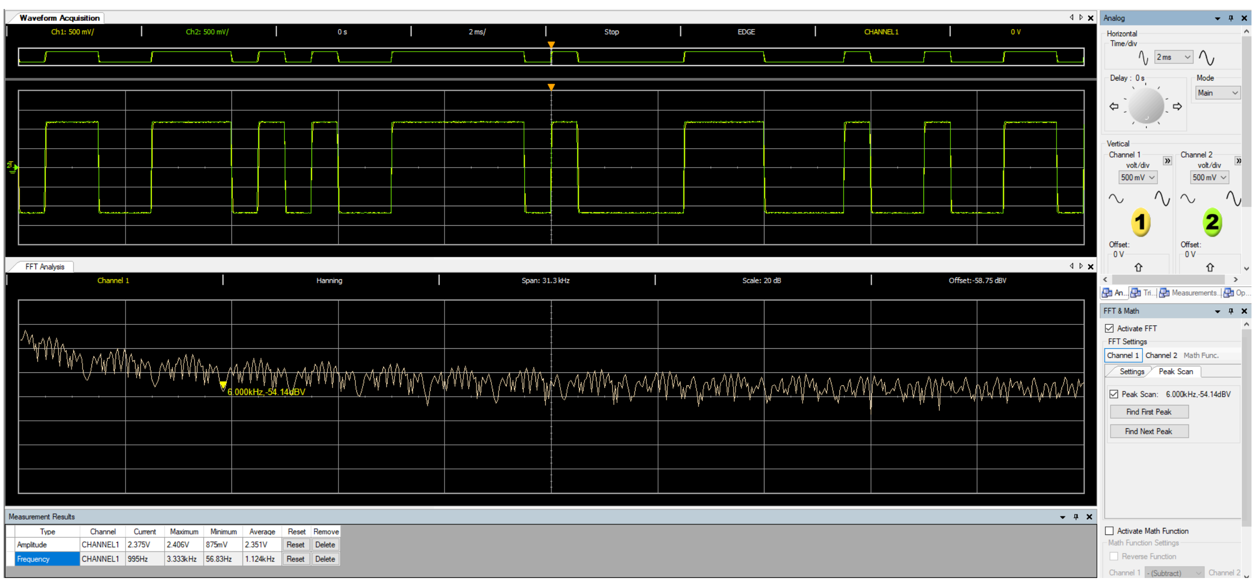
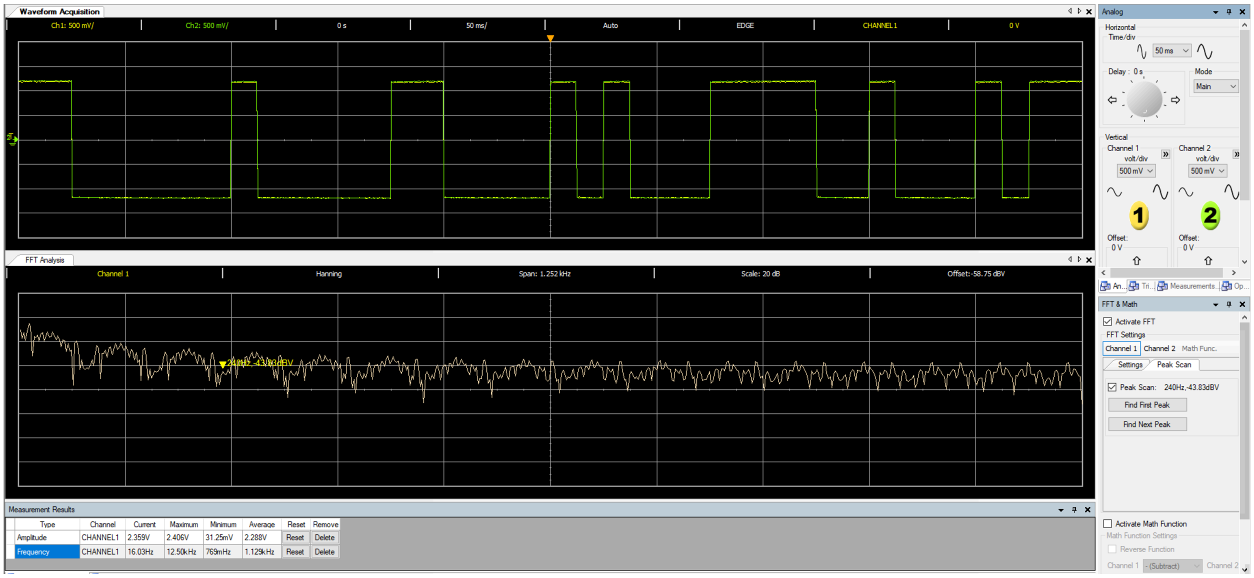


Figure 13: Spectrum analyzer for random bit stream with peak scan



4. FILTERED DATA FREQUENCY SPECTRUM

a. Put random data through a low pass filter and look at the output of the low pass filter on the spectrum analyzer. Reduce the cutoff frequency of the filter, until the data starts getting so badly distorted, that you can no longer clearly make out all the 1's and 0's (when viewed on an oscilloscope)

Results 4:

1. Once you find that point, look at the spectrum analysis of the signal. What range of frequencies seem to be absolutely essential for a distinguishable signal, and what frequencies are there just to make the signal look pretty? By absolutely essential, I mean what frequencies are required so that a receiver would be able to distinguish logical 1's and 0's. By pretty, I mean frequencies that give us sharp edges on those 1's and 0's; but does not affect the accuracy of a 1 or a 0 being distinguished by a receiver?
    a. The random data stream was then sent through a low pass filter and the output was observed on the spectrum analyzer. The cutoff was reduced and the bits became unreadable at about 7,100,000. This can be observed within **Figure 14.** It was observed that the channel 1 signal doesn't matter past cursor 2. In channel 2, the original signal is useful for interpretation.

Figure 14: Spectrum analyzer output

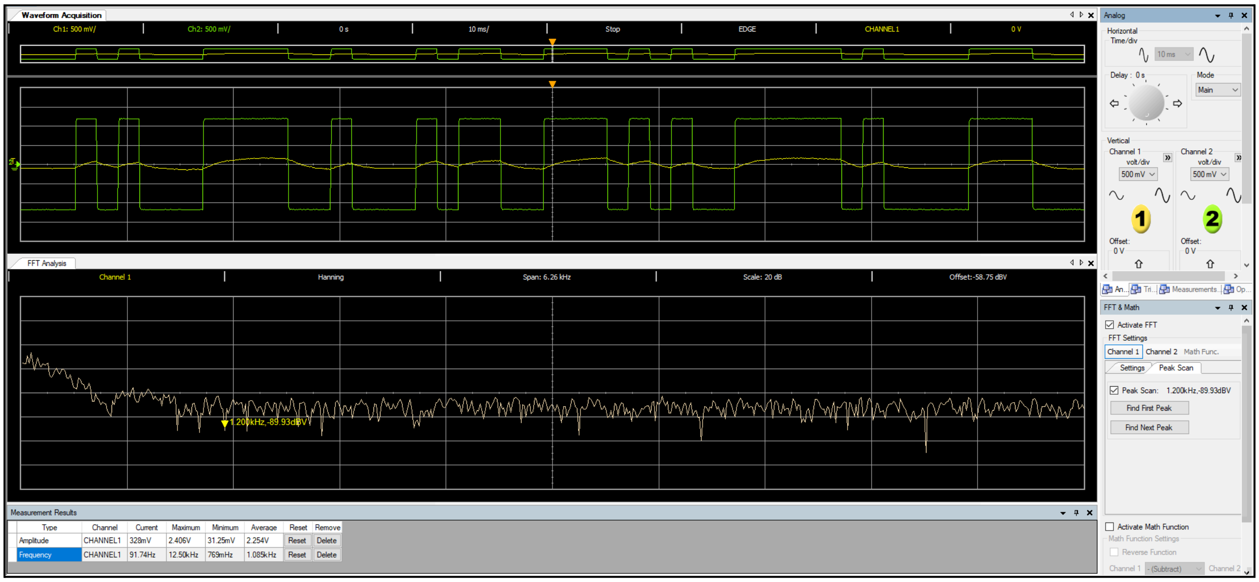


Figure 15: Spectrum analyzer minimum readability

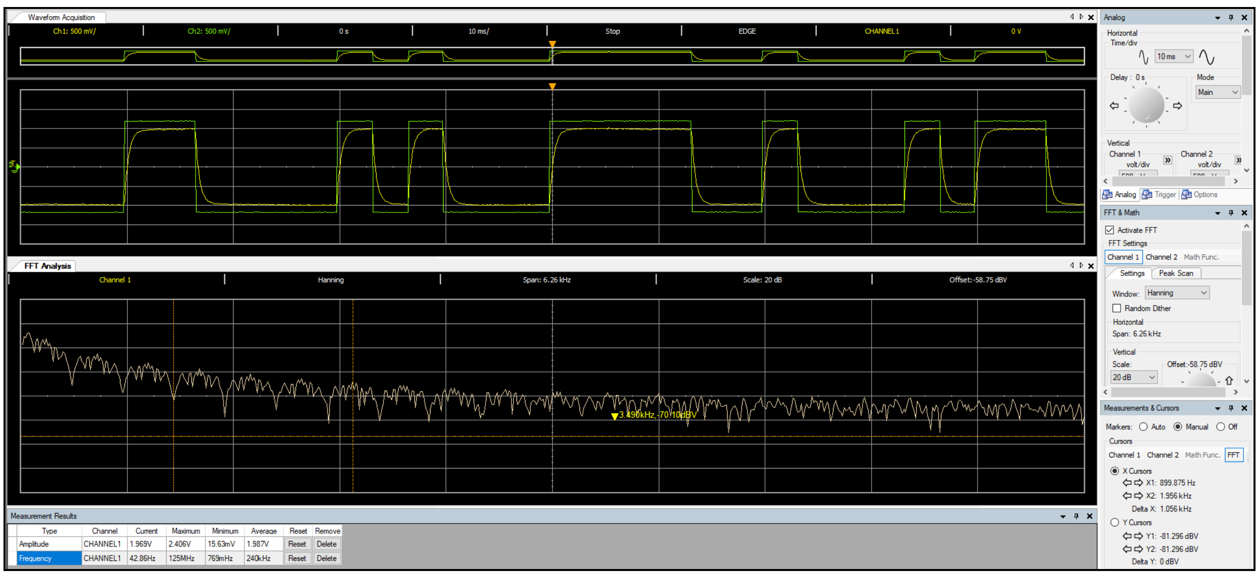


Figure 16:

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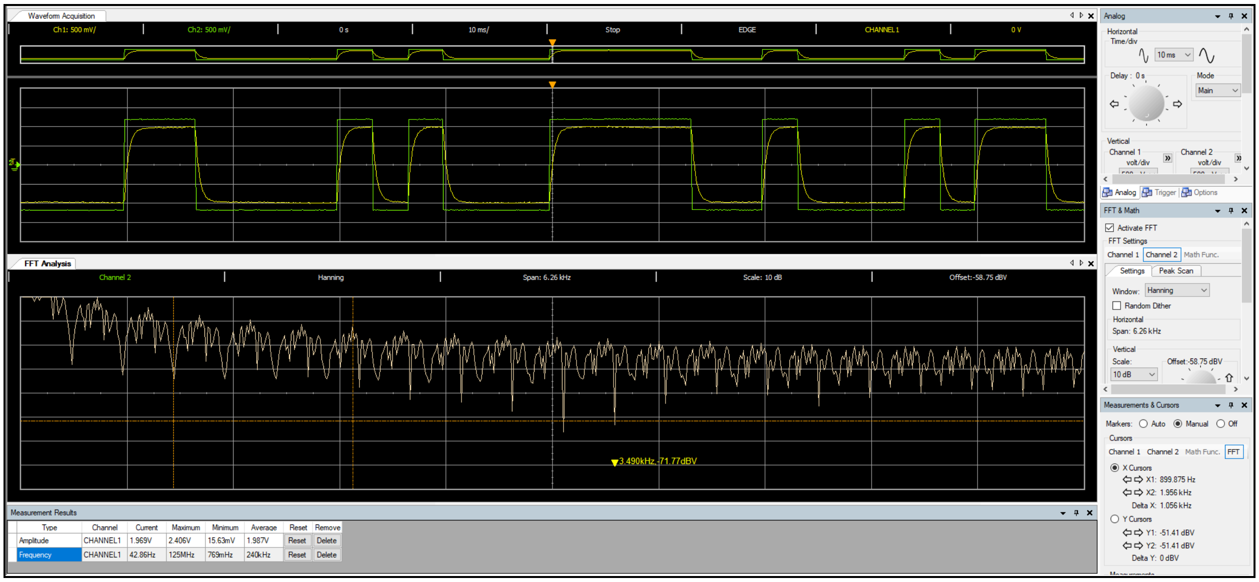

Type	Channel	Current	Maximum	Minimum	Average	Reset	Remove
Amplitude	CHANNEL1	1.969V	2.406V	15.63mV	1.987V	Reset	Delete
Frequency	CHANNEL1	42.86Hz	125MHz	769mHz	240kHz	Reset	Delete

Conclusion: In this lab we were introduced to the use of the frequency domain of signal analysis. This lab showed how data looks in the frequency spectrum, along with analysis of frequency harmonics and how they affect signal quality. It was learned that frequency ranges can negatively and positively affect the attenuation of a signal's peak, and whether or not it is read by a receiver.