Trenton Cathcart
November 10, 2022

AMPLITUDE MODULATION

Objectives:
This lab will introduce the primary characteristics of Amplitude Modulation of a Signal, both sinusoidal and digital signals, by looking at the signal characteristics in both the analogue and frequency domain.

Preliminary Calculations: The preliminary calculations required us to refresh our memories on fourier domain analysis, and review class material about these subjects.

Results and Discussions:

1. **DC AMPLITUDE MODULATION**
    a. The signal generators in the lab can produce sine waves, at any amplitude you select (within the range of the equipment). You can control the amplitude one of two ways: by the front panel control for amplitude, or you feed a signal to the Amplitude Modulation input in the back of the signal generators. This input accepts a voltage (varying or otherwise) and changes the amplitude of the signal at the output based on this voltage. In the equation below, this voltage is and it can be a direct signal, a sinusoidal signal, or a digital signal. Connect a DC power supply to the AM Modulation input of a signal generator. Set the front panel amplitude of the sine carrier wave to 1 VPP. Vary the DC voltage at the AM Modulation input. Determine the minimum amplitude you can generate and the maximum amplitude you can generate with the DC power supply at the output of the signal generator.
    b. What is the gain of the AM Modulation input? In other words, what is the ratio that the output amplitude is changed by the input amplitude (if you increase the input amplitude by 1 volt, how many volts does the output amplitude change).
    c. Can the AM Modulation input cause the output amplitude to go negative (to flip)? Would you know it if it happened, or is this something impossible to measure in a laboratory setting?

    Results 1:
    1.
        a. Using the DC power supply, we input a maximum and minimum voltage of 6V and 0V. The output of this was

250mV and 1V respectively. These results can be observed within **Figure 1 & 2** Below.

b. Using the method described within the lab manual, we were able to calculate a gain of 0.185.

c. It was determined to be impossible to measure whether or not the amplitude goes negative, because we cannot determine the waves starting time.

Figure 1: Max Oscilloscope Output

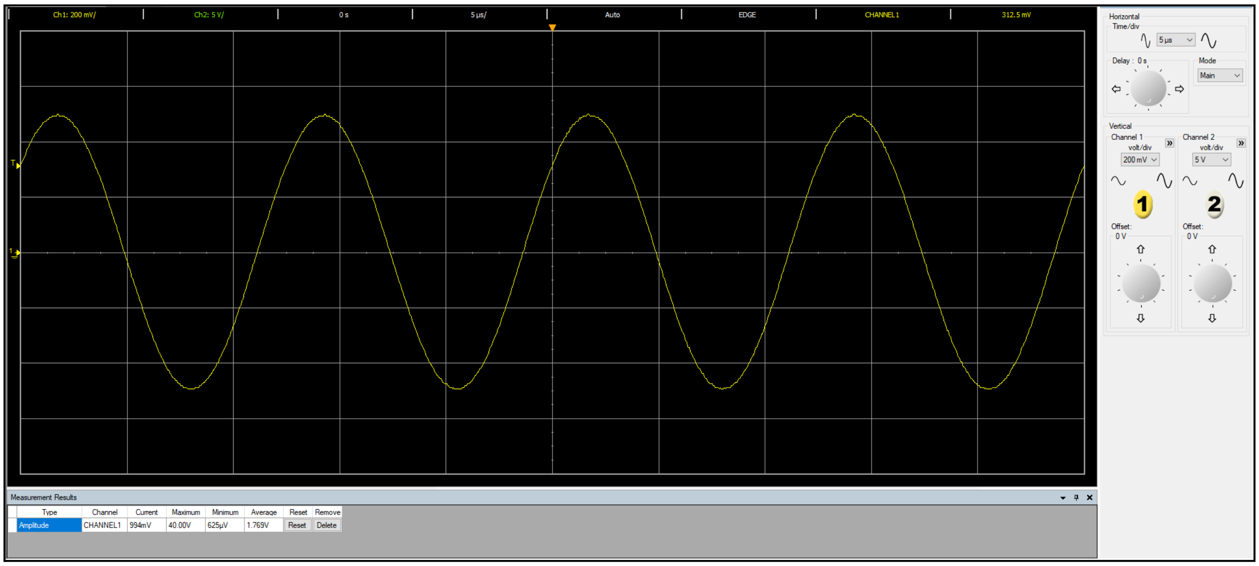
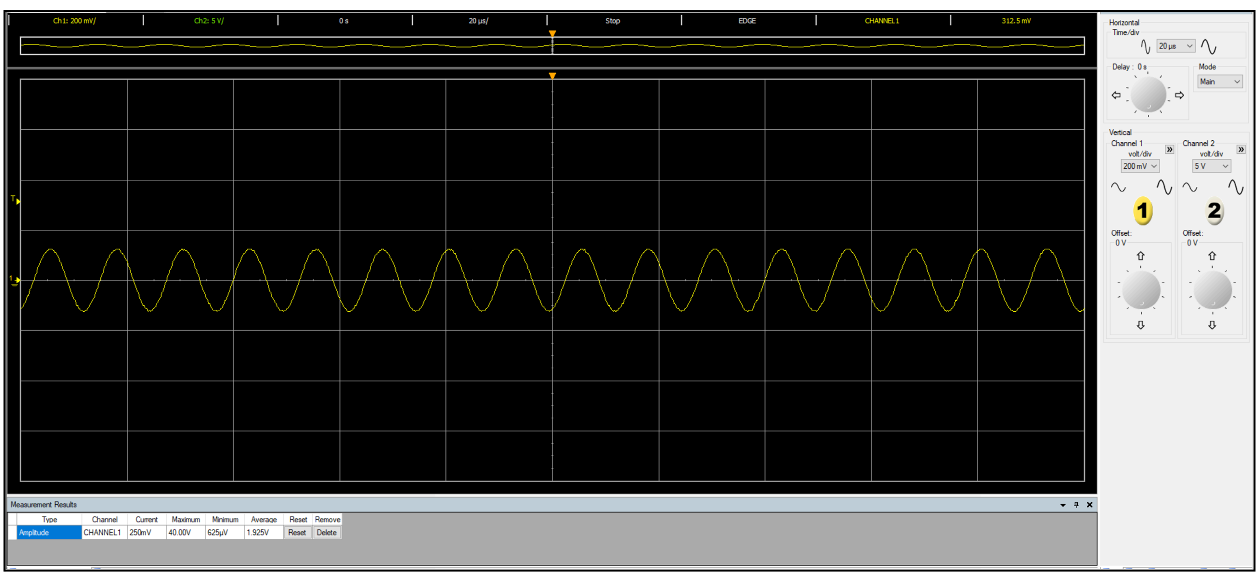


Figure 2: Minimum Oscilloscope Output



2. AC AMPLITUDE MODULATION

a. Set the signal generator to produce a sine carrier wave, fc, (see assignment table below). Replace the DC power supply on the AM Modulation input with a second signal generator, set to produce a, fm, message sine wave (see assignment table below). Vary the amplitude of the fm wave and describe what effect this has on the fc modulated signal as you watch it on the oscilloscope. Adjust the amplitude of the AM Modulation message input until the amplitude of the carrier sine wave varies from 0.5 to 1.5 volts. Confirm this is correct by looking at the carrier signal and the message signal on the oscilloscope at the same time.
b. Can you now determine if the AM modulation message input can cause the amplitude of the output signal to go negative (to flip)? If so, describe how.
c. Look at the message sine wave on a spectrum analyzer. Does it have a characteristic frequency response on the spectrum analyzer? Toggle between DSBSC and DSBUC and note the differences in the spectrum of the AM signal.

Results 2:

1.
    a. We first varied the amplitude of the fm wave, this seemed to have increased the peaks and decreased the troughs. We then adjusted the AM message input from 0.5V to 1.5V. This seemed to have decreased the amplitude of the carrier peaks, while the message frequency seemed to have stayed the same. This result can be observed below within **Figure 3 & 4.**
    b. We cannot determine if the amplitude of the output flipped because we do not have t=0. This can be observed within **Figure 7**
    c. The carrier frequency seems to disappear whenever it switches to DSBUC. This can be observed within **Figure 5 & 6**

Figure 3: 0.5V AM

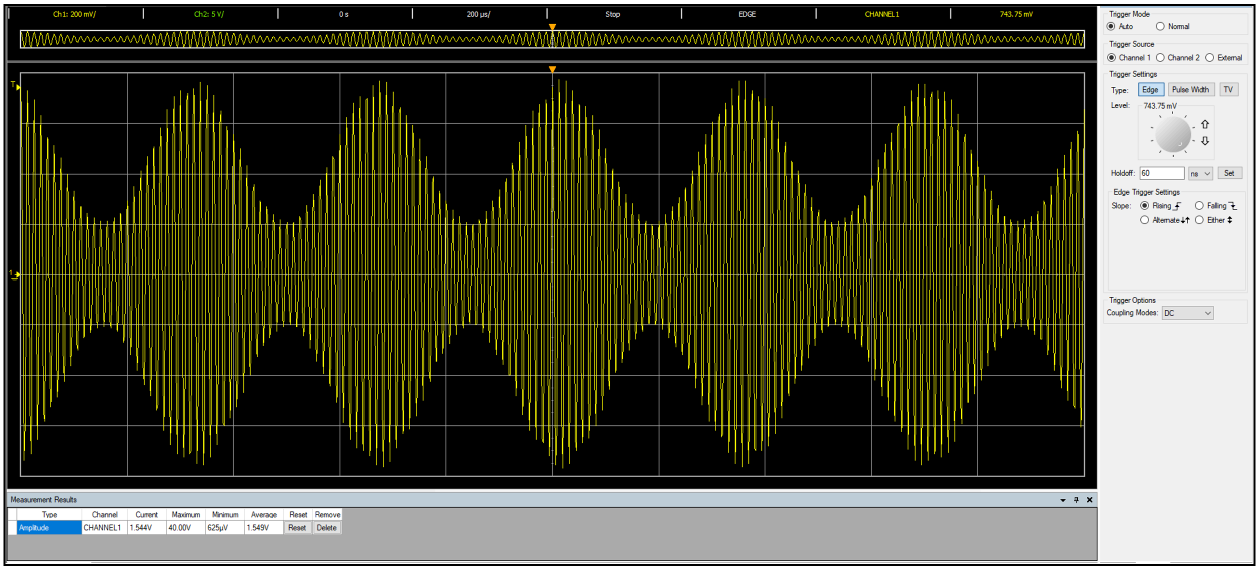


Figure 4: 1.5V AM

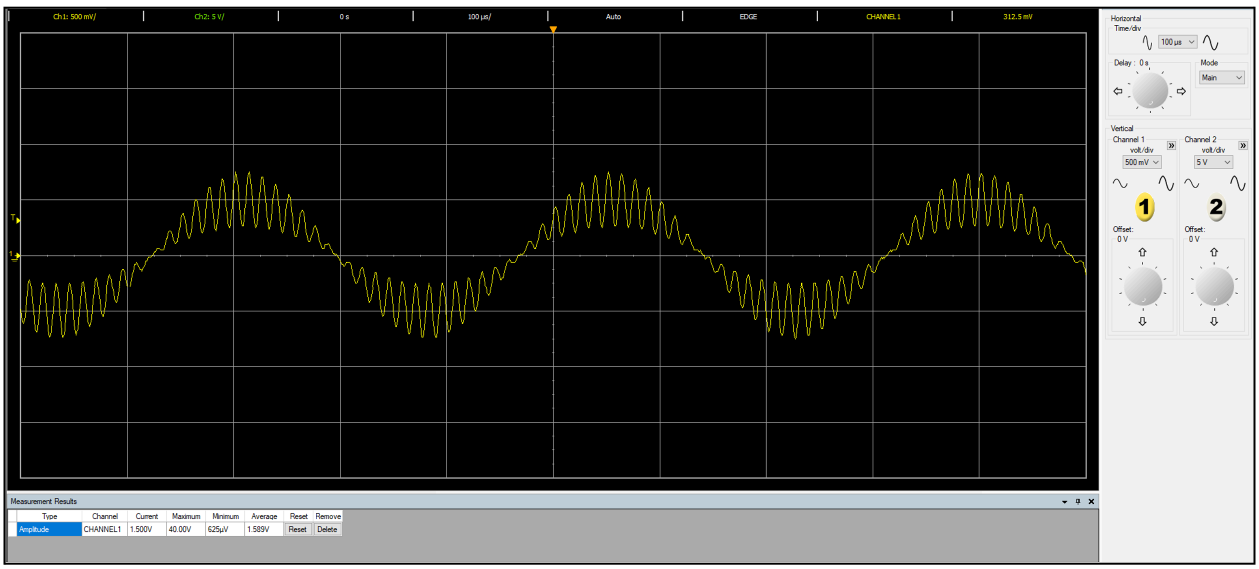


Figure 5: DSBSC

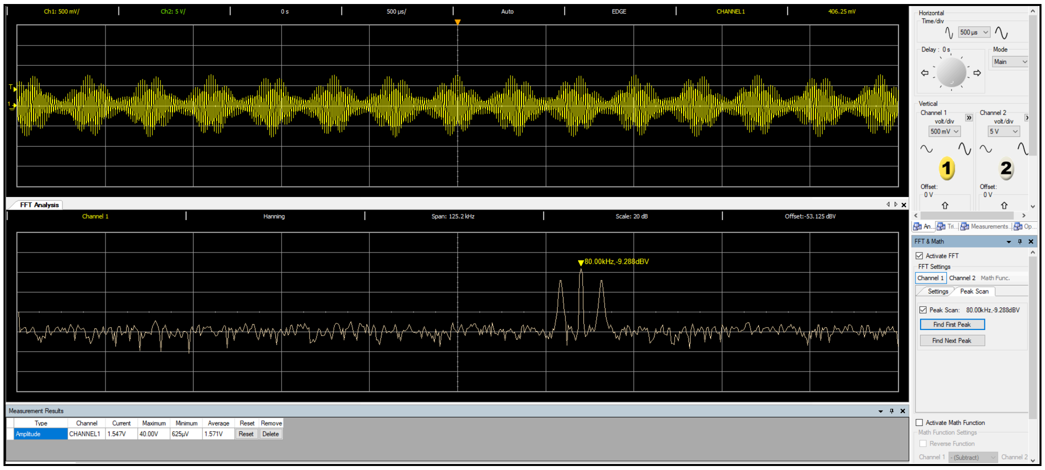


Figure 6: DSBUC

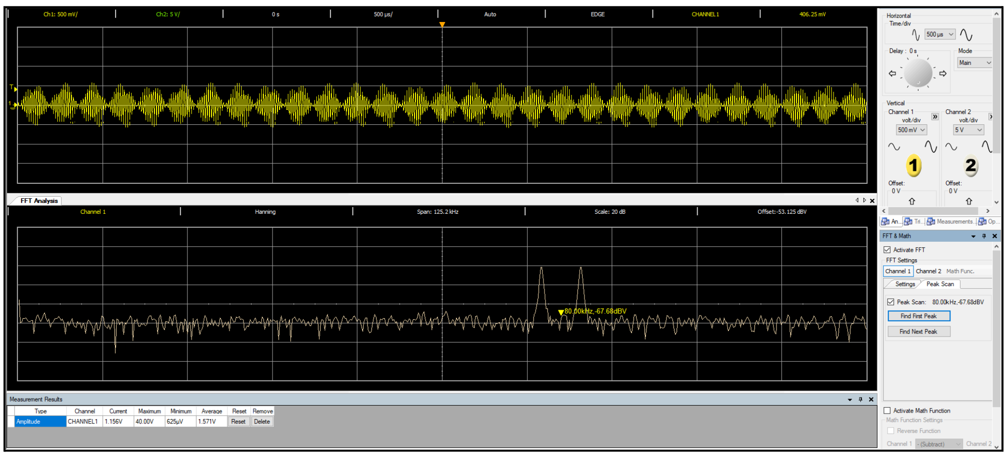
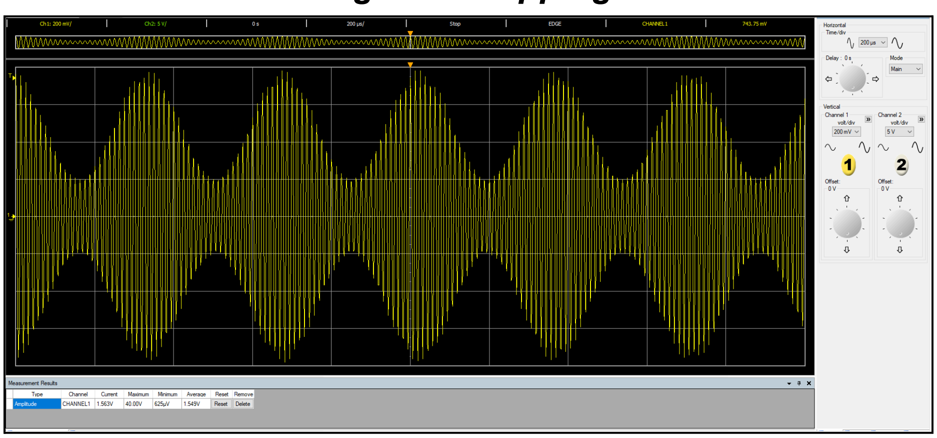


Figure 7: Flipping



3. **FREQUENCY SPECTRUM OF SINUSOIDAL AMPLITUDE MODULATION**
    a. Look at the carrier sine wave on the spectrum analyzer both when there is nothing on the AM Modulation input (no message), and when there is a message sine wave at the AM Modulation input. What happens to the spectrum of the modulated carrier signal as you vary the amplitude of the message signal? How does the amplitude of the message signal impact

the bandwidth (range of frequencies used) of the modulated carrier signal? Vary the frequency of the message signal, by ±20%. What is the variation in the bandwidth of the modulated signal? Justify using numbers and images.

Results 3:

1.
    a. The spectrum seems to spread out whenever there is a message within the carrier signal. The amplitude of the message signal seems to increase other harmonics toward the carrier frequency. We then varied the frequency of the message signal by 20%. These results can be observed within **Table 1.** It was observed that the variation of 0.03 Khz/% was calculated. The oscilloscope output can be observed within **Figure 8.**

Figure 8: Oscilloscope of 20%

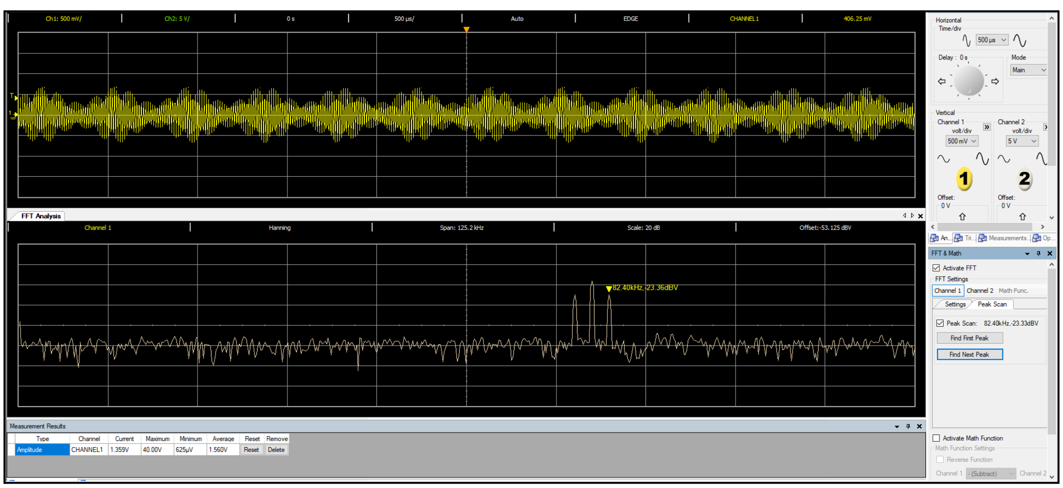


Table 1: Varying by 20%

Frequency	dBV	Variation
83.6 Khz	-23.3	0.03 Khz/%
82.4 Khz	-23.6	

4. FREQUENCY SPECTRUM OF BIT STREAM AMPLITUDE MODULATION

a. Switch out the message sine wave, for an RZ pulse wave, at the message frequency. Look at the modulated carrier signal on both the oscilloscope and spectrum analyzer. Describe how they look different from the sine carrier wave that was used. What is a good measured value of bandwidth of the modulated signal (range of frequencies used)? Describe the modulated wave mathematically using the techniques learnt in lecture.

b. Now replace the RZ message wave with an NRZ pulse wave (square wave), at the message frequency. Look at the modulated carrier signal on both the oscilloscope and spectrum analyzer. Describe how they look different from the sine carrier wave that was used. What is a good measured value of bandwidth of the modulated signal (range of frequencies used)? Describe the modulated wave mathematically using the techniques learnt in lecture.

c. Replace the NRZ wave with a pseudorandom bit stream, obtained from the FPGA board. Make sure to lower the bitrate to be much lower than the assigned carrier frequency. Make sure to first measure the data rate of the bit stream before connecting it to the modulating input of the signal generator. Look at the modulated carrier signal on both the oscilloscope and spectrum analyzer. Describe how they look different from the sine carrier wave that was used. What is a good measured value of bandwidth of the modulated signal (range of frequencies used)? Describe the modulated wave mathematically using the techniques learnt in lecture. For the math, assume just a single pulse as the bit transmitted. The main goal is to observe the sinc profile and not the null bandwidths.

Results 4:

1.
   a. The modulated wave mathematically explained can be observed within **Formula 1.** It was observed that there were more harmonics because of the input of a square wave. A good range of frequencies would be from 53 Khz to 83 Khz. This can be observed within **Figure 9.**

Formula 1: waveform

$$\boxed{Rect(t)\sin(1600\pi t)Comb(t) \overset{FFT}{\Longrightarrow} Sinc(f)Comb(f)}$$

   b. The modulated wave mathematically explained can be observed within **Formula 2.** A good range of frequencies would be from 60 Khz to 100 Khz. This can be observed within **Figure 10.**

Formula 2: waveform

$$\boxed{(Rect(t) - Rect(-t))\sin(1600\pi t)Comb(t) \overset{FFT}{\Longrightarrow} Sinc(f)Comb(f)}$$

c. The modulated wave mathematically explained can be observed within **Formula 3.** A good range of frequencies would be from 0.8 Khz to 1.6 Khz. This can be observed within **Figure 11.**

Formula 3: waveform

$$\boxed{\sum_{i=0}^{n} 3Rect(t-i)\sin(1600\pi t) \xrightarrow{FFT} Sinc(f)Comb(f)}$$

Figure 9: Part a

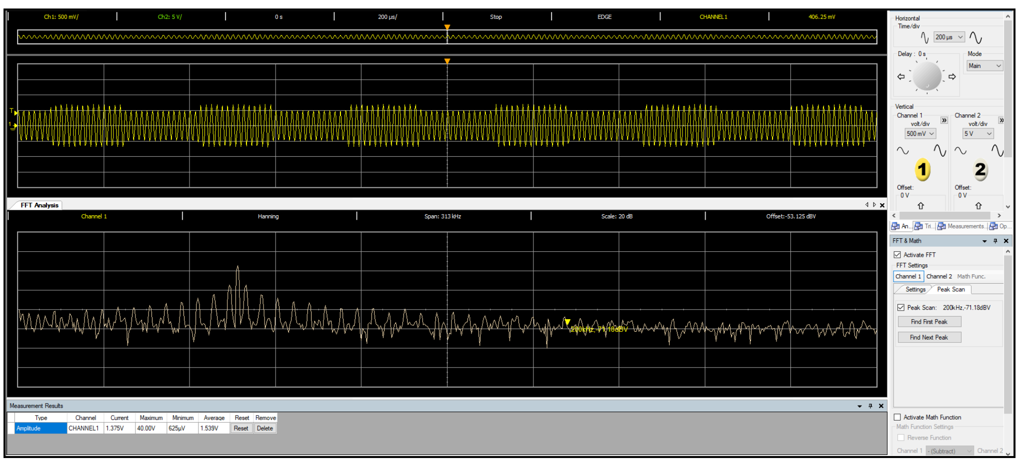


Figure 10: Part b

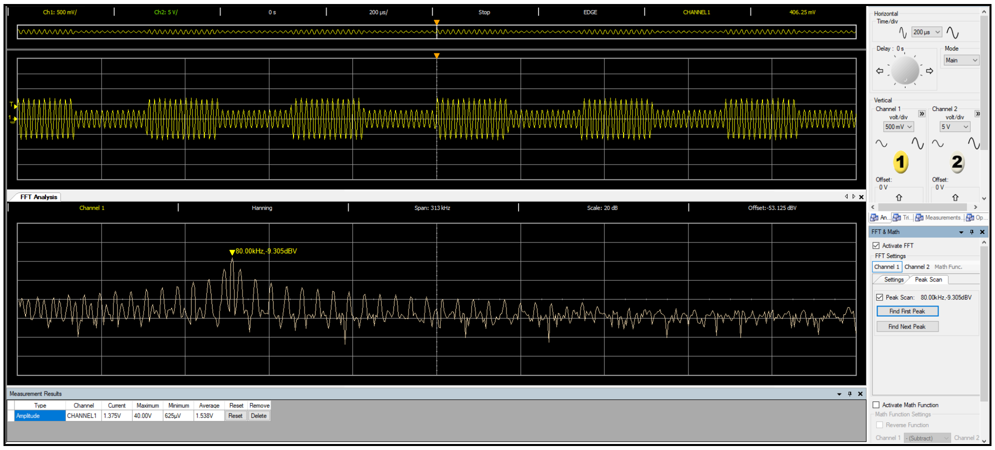
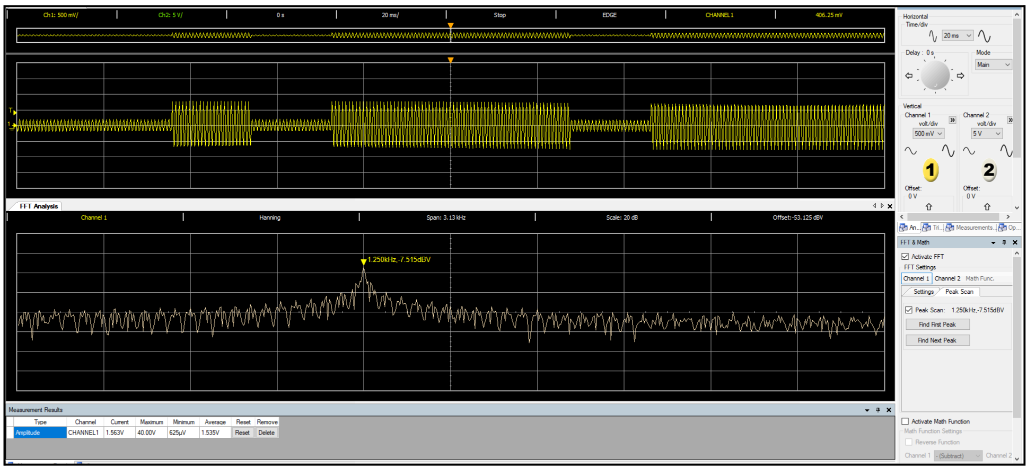


Figure 11: Part c



5. FILTERED BIT STREAM AMPLITUDE MODULATION

a. For this part, the message signal will be the one used in part 4c). The bandwidth of the modulated signal should be very large in the previous step if we consider multiple null frequencies in our calculations. Try limiting the bandwidth by filtering the bit stream before it enters the AM Modulation input using a low-pass filter made of a decade resistance box and capacitor (as you did in Lab 4 and 5). Follow the steps below: Look at the filter output (before the modulation input) on both the oscilloscope and spectrum analyzer. Adjust the bandwidth to be as low as possible while still maintaining a receivable signal, where the high and low levels are clearly seen on the oscilloscope. Note how this affected the range of frequencies used by the signal on the spectrum analyzer (the Bandwidth).

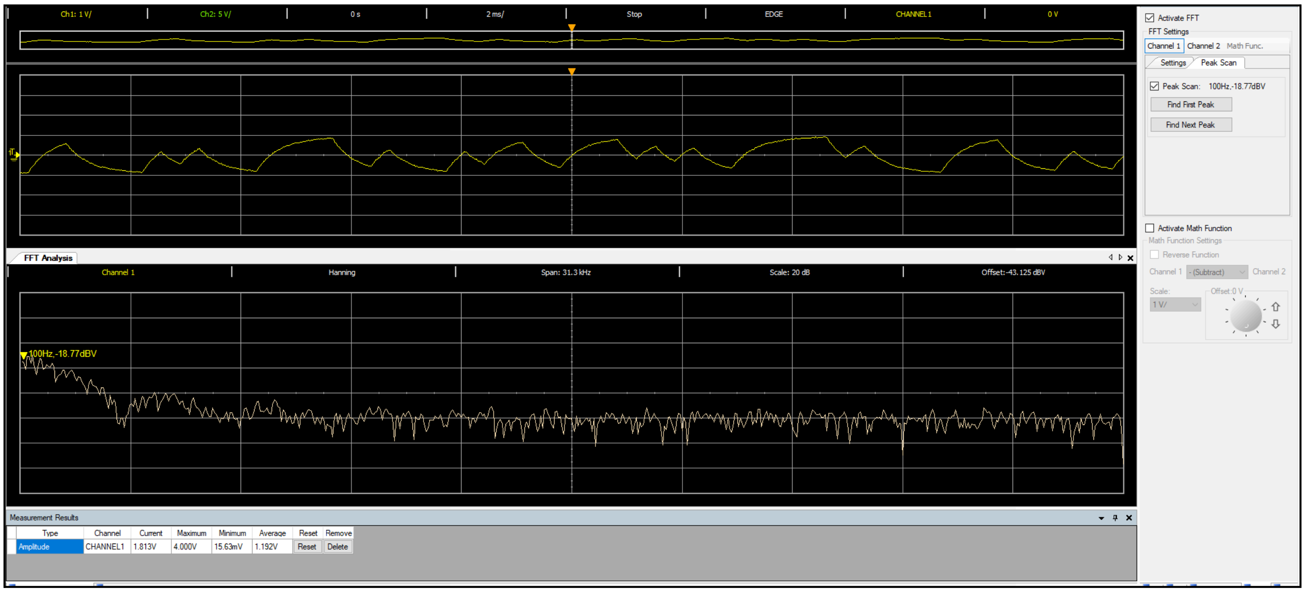
b. Use the filtered bit stream to modulate the carrier signal. How much did the filter reduce the overall range of frequencies used (bandwidth) of the modulated carrier signal compared to the unfiltered modulation of the carrier signal?

Trenton Cathcart
November 10, 2022

Results 5:

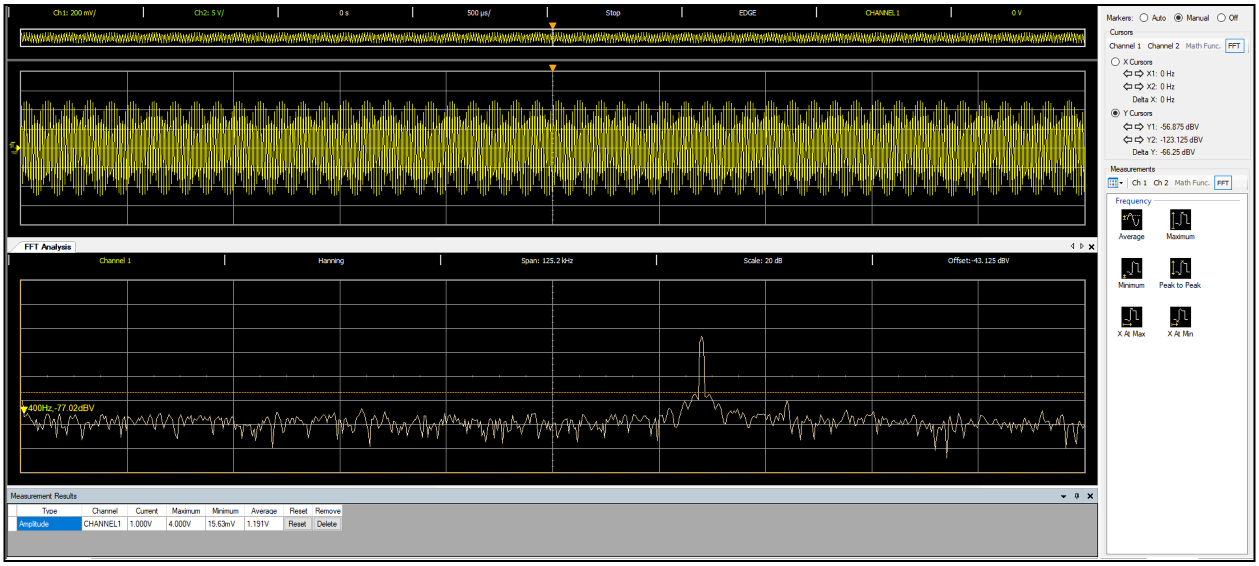
1.
    a. It was observed that the bandwidth seems to have been attenuated and this can be observed within **Figure 12.**

Figure 12: Part a



    b. Using the filtered bit stream to modulate the carrier signal. It seems that the overall bandwidth shrunk compared to the non filtered bit stream. This can be observed within **Figure 13.**

Figure 13: Part b



6. DEMODULATION OF BIT STREAM

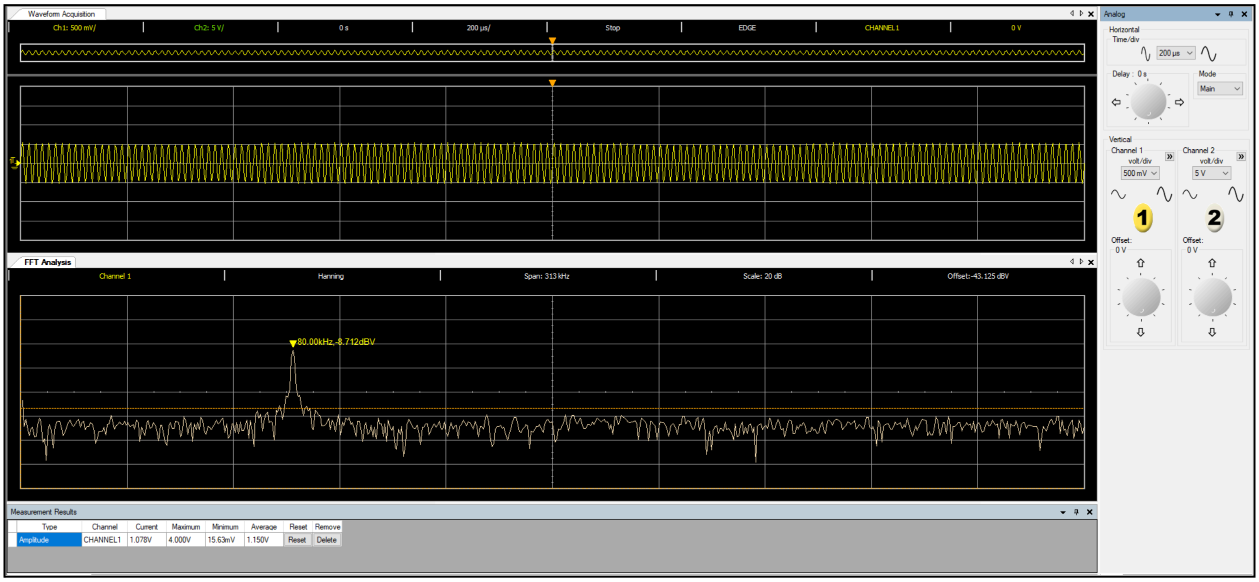
a. Method 1: Now let's extract the data from the modulated signal. You can do this using an envelope detector as discussed in class (or by looking up an example online). Build an envelope detector using a diode, capacitor and decade resistance box. The envelope detector will allow you to demodulate the amplitude modulated bit stream and extract the data of the bit stream. With the set data rate of the random bit stream, what RC time constant do you need in the envelope detector to obtain a reasonably good extraction of bit stream at the output of the envelope detector? What happens if the RC time constant of the envelope detector is too large? What happens if it is too small? (Too large or too small relative to the RC time constant found in part 6, A). What type of distortion at the envelope detector output seems impossible to remove?

Results 6:

1.
    a. We first built the envelope circuit using a diode in series with a parallel capacitor and resistor. This allowed us to demodulate the amplitude of the modulated bit stream. The time constant was calculated to be 0.00047. We noticed that it was impossible to remove the peaks of the sine wave while adjusting the time constant. If the time constant was increased using the decade board it was observed that the signal seemed to be attenuated, while if the time constant was decreased it seemed to be compressed. These results can be observed within **Figure 14.**

Trenton Cathcart
November 10, 2022

Figure 14: Method 1



7. DEMODULATION OF SINUSOIDAL SIGNAL

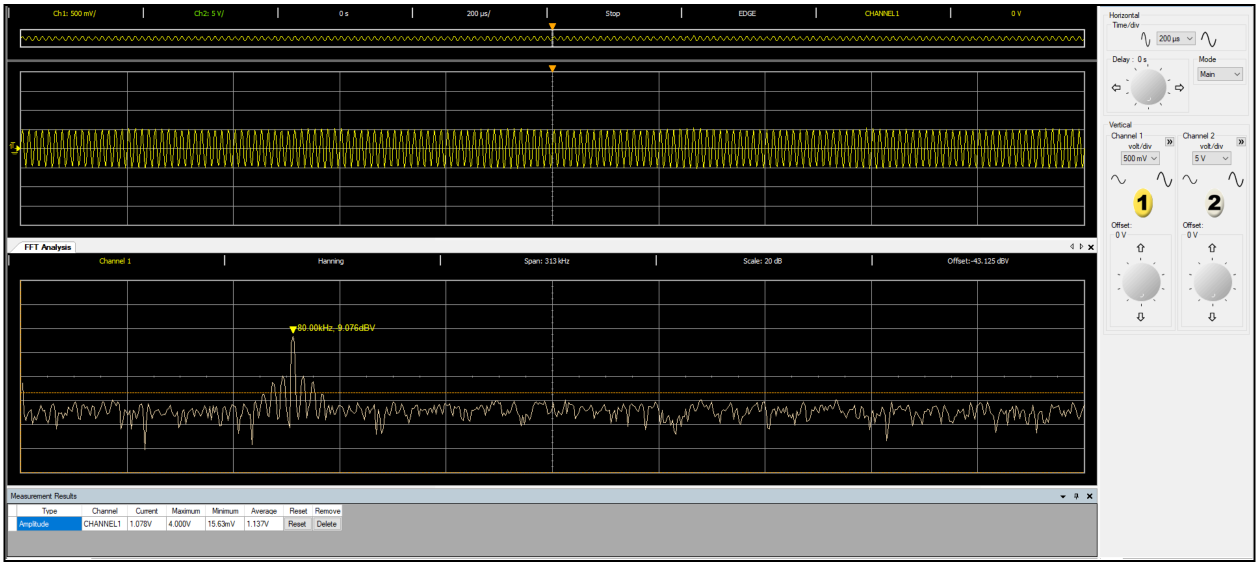
a. Repeat Part 6 for a sine wave message signal. Questions for Method 1: Pass the modulated signal through the envelope detector, to try to recover the message frequency. Does this work? Watch for distortion from a poorly chosen RC time contact in the envelope detector. Also watch for clipping caused by the diode not having enough voltage to turn on / forward bias / when the amplitude of the 1 MHz signal is small (less than 700 mV).

Results 7:

1.
    a. Passing the modulated signal through the envelope detector to recover the message did not work, it seemed as if we received the same results from step 6, except with more harmonics within the frequency domain. It also seemed to have a slight clipping amount due to the diode's turn on voltage of 0.7V.

Figure 15: Part a

Trenton Cathcart
November 10, 2022



8. AMPLITUDE MODULATION TRANSMISSION

a. If you have a commercial AM radio, tune it to a suitable choice of an AM frequency, and place it next to your modulated sine wave output. Make sure to use the same carrier frequency of your choice. Test the AM radio receiver for the following signals • A sine message wave at the frequency assigned above. • Square wave at the fundamental frequency assigned above. • A random bit stream at a low audio range data rate. See if you can hear the audio signal coming out of the speaker.

b. What does the speaker of the AM radio produce if the voice or music is replaced by a 1 kHz sine wave? by a 1 kHz square wave? by a random bit stream?

c. Place a long wire on the oscilloscope input to act like an antenna. See if you can detect, in the time domain, any local commercial radio broadcasters operating in the range of frequencies from 530 kHz to 1700 kHz.

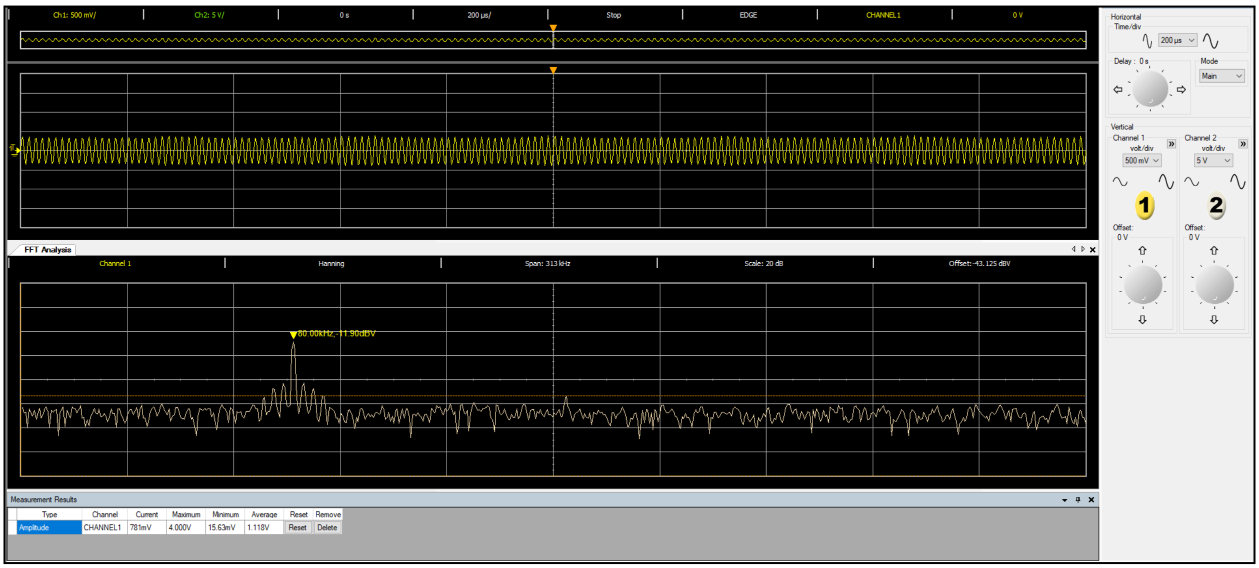
Results 8:

1.
   a. For step 8 we tuned it to a 101.3 frequency, and placed it next to our modulated sine wave output. We could kind of hear the transmission coming out but it was not very coherent.
   b. If the voice or music is replaced by a 1 kHz sine wave, we would hear a low pitched constant ringing. Using a 1 kHz

square wave, we heard a constant louder buzz. The Pseudo Random bit stream sounded like a choppy low pitch buzz

c. Placing a long wire on the am radio and using the frequency of 1100 Khz we were able to tune into a radio channel and make out some sort of audio. These results can be observed within **Figure 16.**

Figure 15: Am oscilloscope output



Conclusion: In this lab we were introduced to the use of amplitude modulation and the uses for combining certain waveforms. We then hypothesized that signals are encrypted in the manner using designated frequencies for a chosen receiver. This leads to the use of a fourier transform to decompose a signal into its frequencies. This allows the sender to store messages within the carrier frequency and ensure that only channels tuned into a desired frequency can read the message.