

Aled Edgell Assignment 1 FINAL

by Aled Edgell

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1.Executive summary

The project involved carrying out research into analogue and digital signals processing techniques, frequency modulation experiments as well as an analogue to digital converter experiment. The primary aim is to gain a better understanding of signals and digital communications. Research was carried out into amplitude and digital modulation and digital communication techniques. Following the mathematic process for calculating the results of the frequency modulation generator the practical experiment was carried out to test those calculations and the analogue to digital converter was tested to gain an understanding of how the system worked.

After testing the system, the results showed that the mathematical equations carried out had successfully compared to the practical experiment, which was carried out in a team of three of us. However further testing the frequency modulation circuit would prove beneficial to prove that the process could be repeated.

2. Research

Amplitude modulation is used in radios and communication devices. Some uses for this system is in broadcasting transmissions and quadrature amplitude modulation, which is used in both wi-fi systems and mobile phones. Amplitude modulation is needed for transmitting these signals. To do this the amplitude of the signal from the device creating the noise for example the speaker is used to alter the carriers amplitude this is a high frequency signal that is used with the signal to transmit it. "This means that the radio frequency signal has a representation of the sound wave superimposed in it" (Electronicsnotes, Amplitude Modulation). This is done by superimposing the carrier signal between the signals lower sideband and its upper sideband, creating the complete signal required to transmit sound. Frequency modulation works very similar to this in regards that the signal affects the carrier. However, while amplitude modulation affects the amplitude of the carrier based on the signal the frequency modulation system will affect the frequency of the carrier depending on the carrier's waveform. For example, it could be created so that when the signal reaches its peak the frequency of the carrier will be the slowest it will be where as the opposite is true when it reaches its trough as its frequency is at its fastest. To calculate the average frequency of the carrier as it changes the maximum and the minimum frequency are added together and then divided by 2. Some applications for FM technology include the same as the amplitude modulator however the frequency modulation system is likely to be greatly affected by noise than the amplitude modulator as it will have less of an impact.

An analogue to digital converter (ADC) is a very common device to be used in most circuits. The reason for this is because computers and many other logic based systems use digital systems. While analogue computers are possible they are much more expensive and take up more space than the digital counterpart. Because of the difference a ADC system will be used to sample an analogue signal coming in at a set sample rate, while the amount of samples per second makes the system more accurate it will greatly increase the amount of information that will need to be handled by the digital system, this is also affected by how many bits are used for the sampling. This also must be dependent on the amplitude of the system compared to the resolution as this will affect the best choice to use. If a system used 8 bits for sampling a small amplitude and had a large value resolution, then the full quantization range would not be used where a 4 bit system would be more effective as it would produce less information for the digital system to handle. This will be shown during the practical experiment, also it will show the effect of not sampling often enough.

There are other ways besides an analogue to digital converter using sampling. One of these involves using both a pulse amplitude modulation (PAM) and pulse code modulation (PCM) systems to complete this. For example in a 2-PAM system which will receive the analogue signal from the instrument being used and during its pulse sample it will be given either a positive or negative value. Positive at the peak and negative when at the trough, this is similar to the quantization points on the analogue to digital converter discussed earlier however rather than a continuous sampling it only records the information when the sampling pulse is active. Similar to the pulse amplitude modulation the pulse code modulation only samples the analogue signal when the pulse is active. However, unlike the pulse amplitude modulation system where it records a section of the signal this one only samples the value at that instant in time which creates an output signal similar to a line graph with horizontal points showing the amplitude. However, this is not useable by a digital system as they would only show pulses of the signal, therefore it must first go through a quantization system. The end result of this is similar to that of the analogue to digital converter used earlier, the main difference being that the pulse code modulator produces less data as it is only looking at the instantaneous values not a continuous one. However, due to this it is

possible to miss pieces of information for example if there is a spike in the signal coming in and the sample time is fairly short then it runs the risk of missing that information.

One of the more complex ways of transmitting information is with Quadrature Phase Shift Keying (QPSK) which is able to transmit 2 bits information at a time without the need of an additional carrier frequency. However, doing this is relatively complicated similar to a PSK system when the bit count is equal to 0 the wave remains the same however when the bit value is equal to 2 which would be the PSK's 1 will result in the waveform inverting from that point onwards. For example if it was starting to decline towards the trough it will invert and start increasing to the peak. The other binary values cause a different reaction to the modulated frequency a bit value of 1 on the QPSK system will result in the waveform starting from its peak point again as normal, where as if the bit value is equal to 3 it will have the opposite effect where the modulated frequency will jump to its trough value and continue from there. This is an alternative to the quadrature amplitude modulation (QAM) system that uses 2 carrier frequencies however to stop them from overlapping each other they are set apart by a 90° phase angle.

Plesiochronous Digital Hierarchy (PDH) requires a pulse code modulation generator to allow the information to be used by the plesiochronous digital hierarchy to transport the signal, while this system can be used for radio signals it is more common used for point to point connections. The system works by pairing 4 copper coaxial cables for each E-carrier. This is then repeated with E1 being connected to a total of 4 cables and E5 being connected to 256 copper cables "the data rate on the high-speed channel will simply be the aggregate of the data rates on the lower-speed channels" (Carritech telecommunications, Plesiochronous Digital Hierarchy, 2018). Synchronous Digital Hierarchy (SDH) is an improved version of the plesiochronous digital hierarchy however it has a more precise timing and has a simpler multiplexing and demultiplexing technique is used. However it is still paired the same way as the PDH systems.

3.Experimentation method

Before beginning the modulation experiment the modulation index and the required amplitude must first be calculated this is shown below.

$$\Delta f = 20\text{KHz} * 2 = 40\text{KHz}$$

$$\text{Modulation index} = \Delta f / f_s = 40\text{KHz}/10\text{KHz} = 4$$

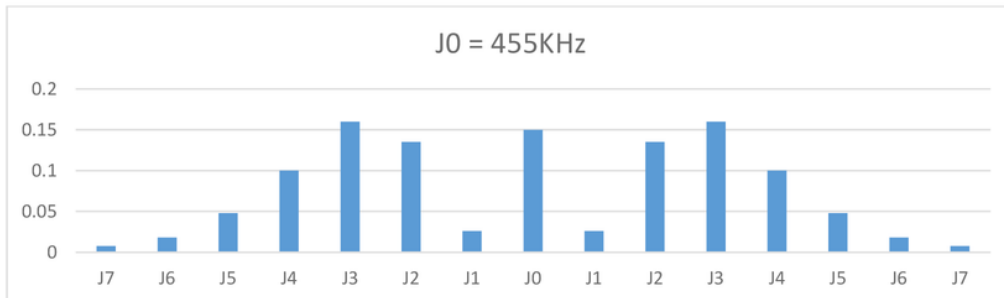
To calculate the bandwidth the values from the Bessel table shown below will be multiplied by E_c to complete the spectrum which can be seen below (Figure 1).

$$E_c = 375\text{mV} \quad f_c = 455\text{KHz} \quad f_s = 10\text{KHz}$$

Modulation Index	J0	J1	J2	J3	J4	J5	J6	J7	J8	J9
0	1									
0.25	0.98	0.12								
0.5	0.94	0.24	0.03							
1	0.77	0.44	0.11	0.02						
1.5	0.51	0.56	0.23	0.06	0.01					
2	0.22	0.58	0.35	0.13	0.03	0.01				
3	0.26	0.34	0.49	0.31	0.13	0.04	0.01			
4	0.4	0.07	0.36	0.43	0.28	0.13	0.05	0.02		
5	0.18	0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	0.01

$$J_0 = 0.15 \quad J_1 = 0.026 \quad J_2 = 0.135 \quad J_3 = 0.16 \quad J_4 = 0.1 \quad J_5 = 0.048 \quad J_6 = 0.018 \quad J_7 = 7.5\text{m}$$

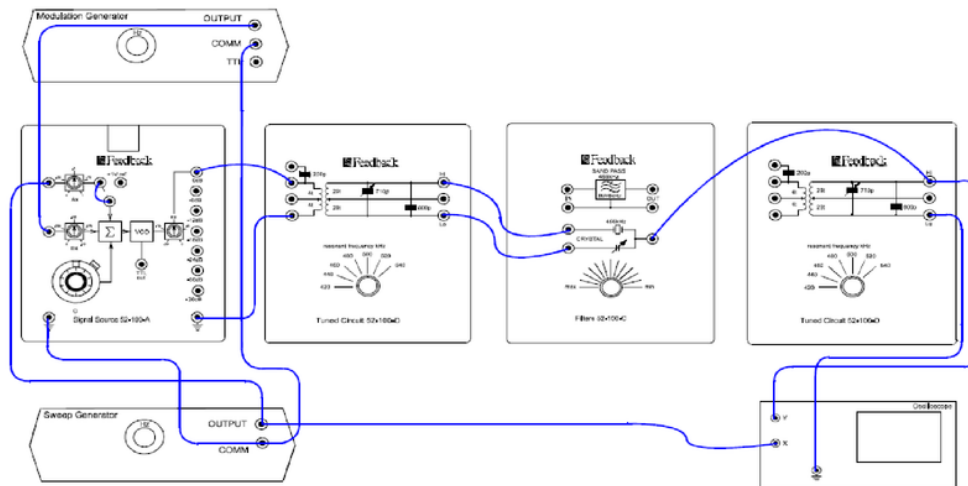
Figure 1: Calculate Spectrum for FM circuit.



$$\text{Bandwidth} = 140\text{KHz} \quad \text{Max frequency} = 525\text{KHz} \quad \text{Min frequency} = 385\text{KHz}$$

After this was accomplished a practical activity was carried out to allow a comparison between the two results. This was carried out under the instructions given in the assignment. The results will be shown later in the assignment. The board was wired together using the wiring diagram shown below which was provided in the brief (Figure 2).

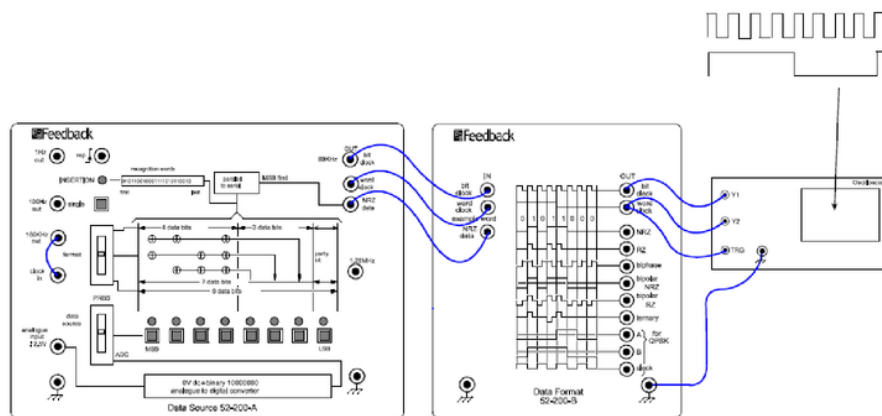
Figure 2: FM circuit diagram.



The testing equipment used was a Pico scope with 2 channels 1 on the input into the circuit measuring the signal from the function generator and the other was connected to the output of the circuit reading the processed value. To inject the signal into the circuit a modulation generator will be used.

Other than the FM system another was tested which was a solely practical experiment to examine the effect of an Analogue to Digital Converter (ADC) The purpose of this test is to examine the effect of changing the quality of the conversion from 4 bit to 8 bit and the relationship between the signal frequency and the sample rate and how adjusting the amplitude also affect this. Below is the wiring diagram used to create this (Figure 3).

Figure 3: ADC circuit diagram.



The results of the test will be shown in the next part of the assignment with the result of the FM experiment. These tasks were carried out in a team of three including myself, Sean Jones and Phillip Rowe.

4. Testing, results and analysis

Testing the FM system:

The first test that was carried out on this system was to change the amplitude of the modulation generator in steps of 1v which we carried out 3 times to observe this change. The first one can be seen below (Figure 4 & 5).

Figure 4: Setting FM circuit input to 6V p-p.

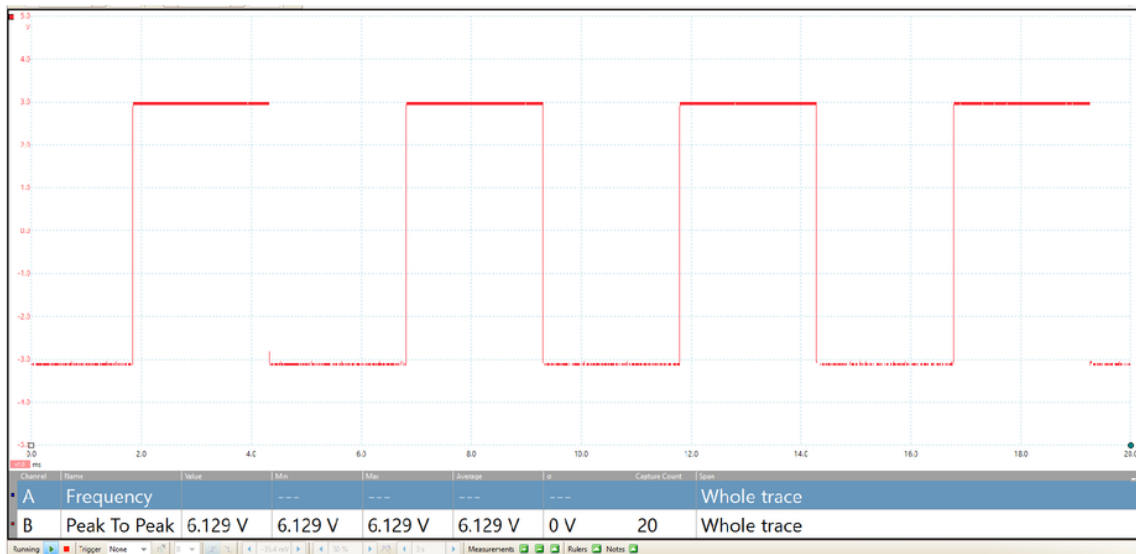
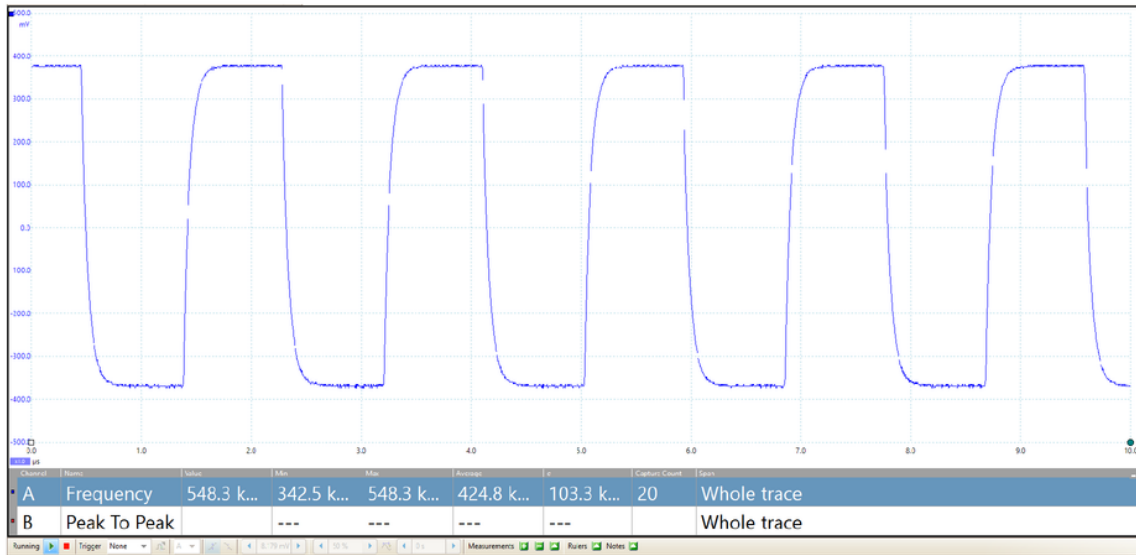


Figure 5: Results of setting FM circuit input to 6V p-p.



Once the amplitude had been set at 6V p-p the frequency was measured and the frequency deviation can be seen as 103k. For the second test the amplitude will be reduce to 4Vp-p (Figure 6 & 7).

Figure 6: Setting FM circuit input to 4V p-p.

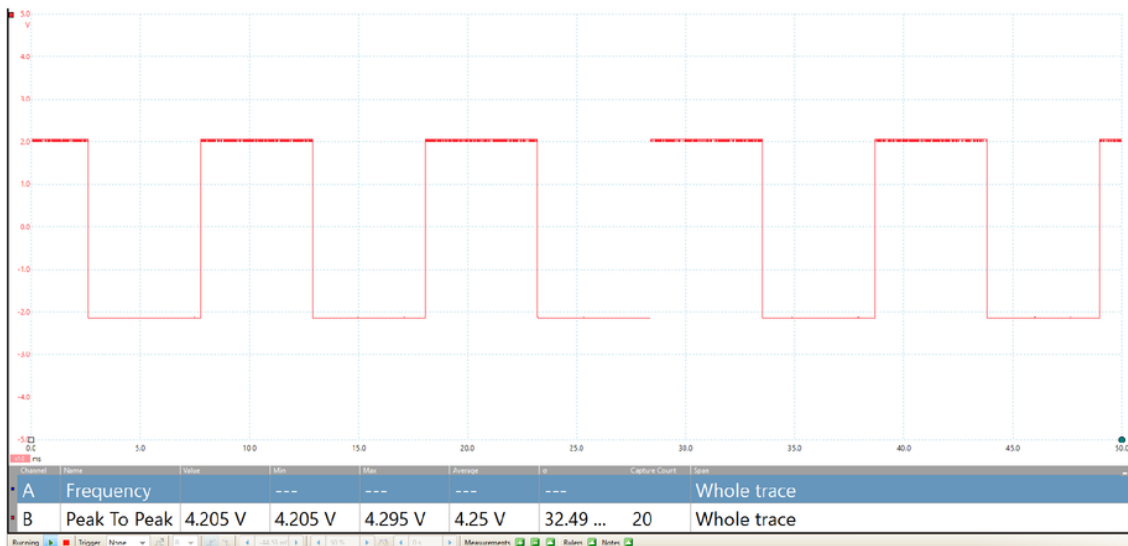
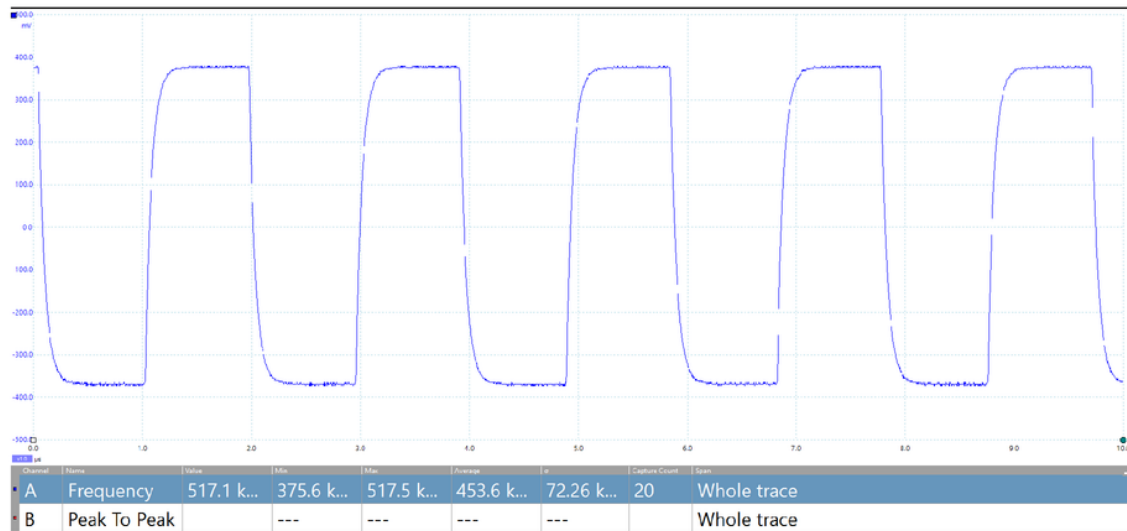


Figure 7: Results of setting FM circuit input to 4V p-p.



As can be seen from the second frequency measurement the deviation has decreased down to 72.26K. The final amplitude was set to 2V p-p the results of the test can be seen below (Figure 8 & 9).

Figure 8: Setting FM circuit input to 2V p-p.

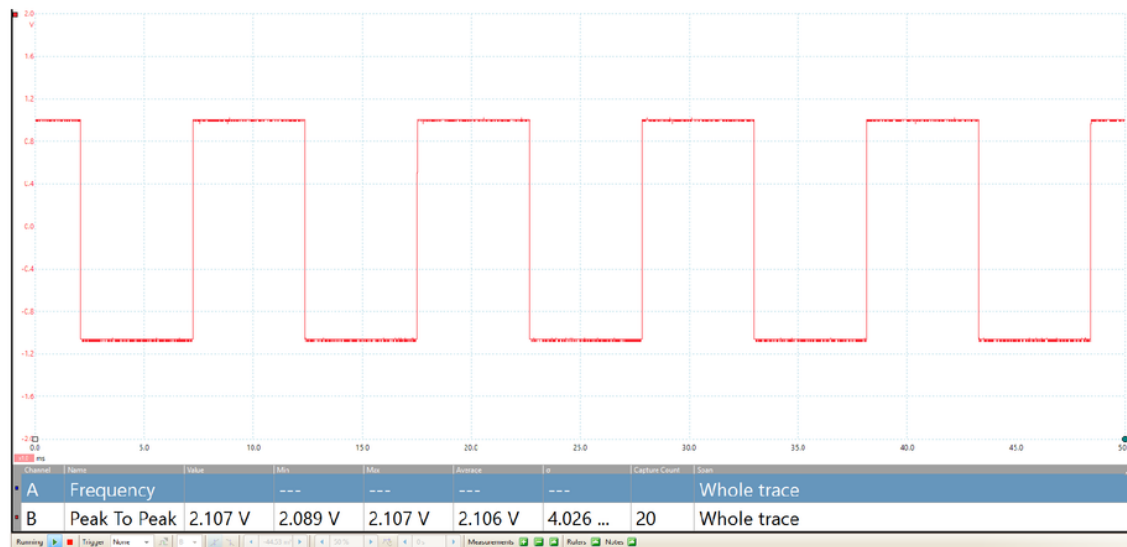
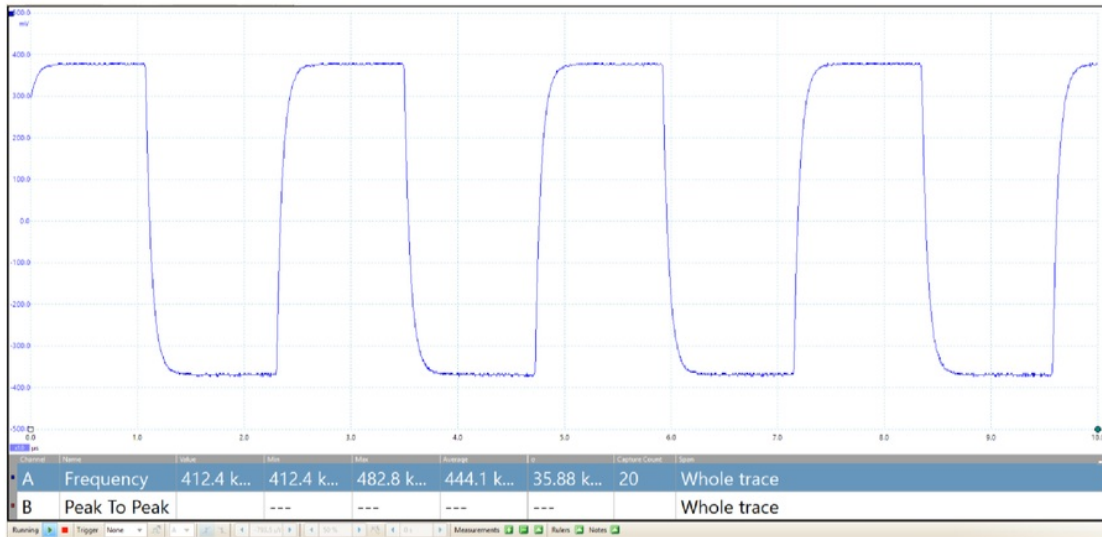
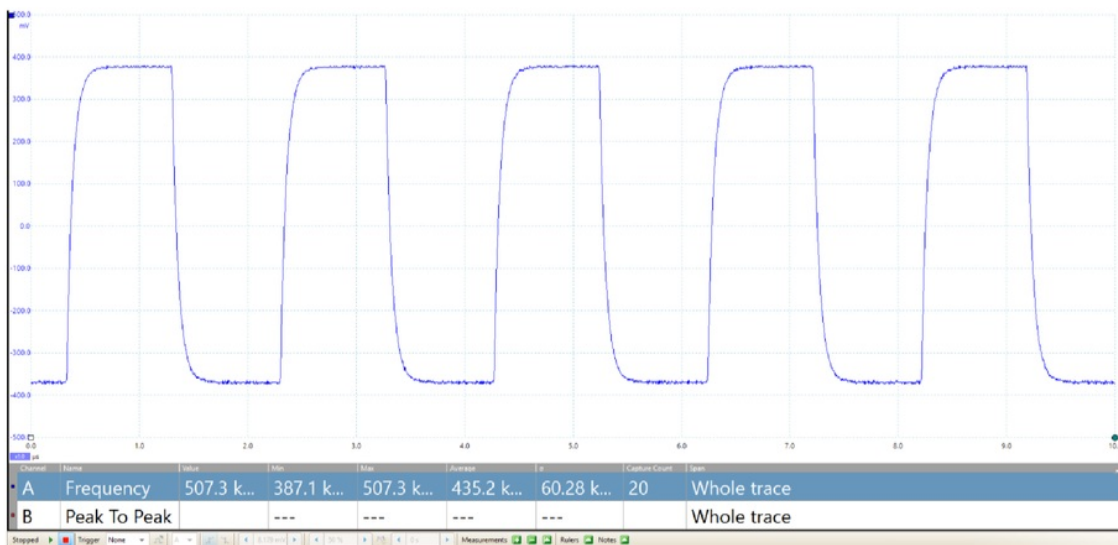


Figure 9: Results of setting FM circuit input to 2V p-p.



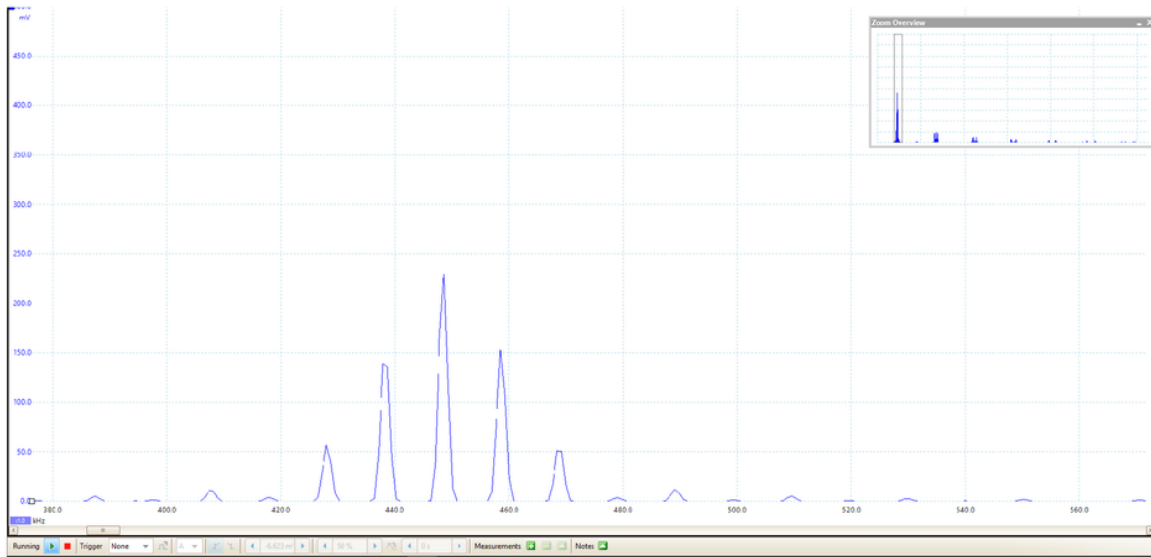
The final test of adjusting the amplitude shows that the frequency deviation has dropped again to 35.55K. And as can be seen when comparing it to the other 2 the frequencies have been swapping between the positive and the negative side slower than they were originally. Before the next part of the experiment could take place the B control signal on the board until the deviation became exactly 60 KHz (Figure 10) and the A controller was adjusted to 0.2 and C was set to 455KHz.

Figure 10: Setting FM circuit frequency deviation to 60KHz.



Once these were done the final part of the FM experiment was carried out using the spectrum analyser when the amplitude is set to 2Vp-p and the modulation generator is set to 20KHz. The findings of the test can be seen below (Figure 11) which has been zoomed in on the 450Khz area.

Figure 11: FM circuit spectrum analysis.

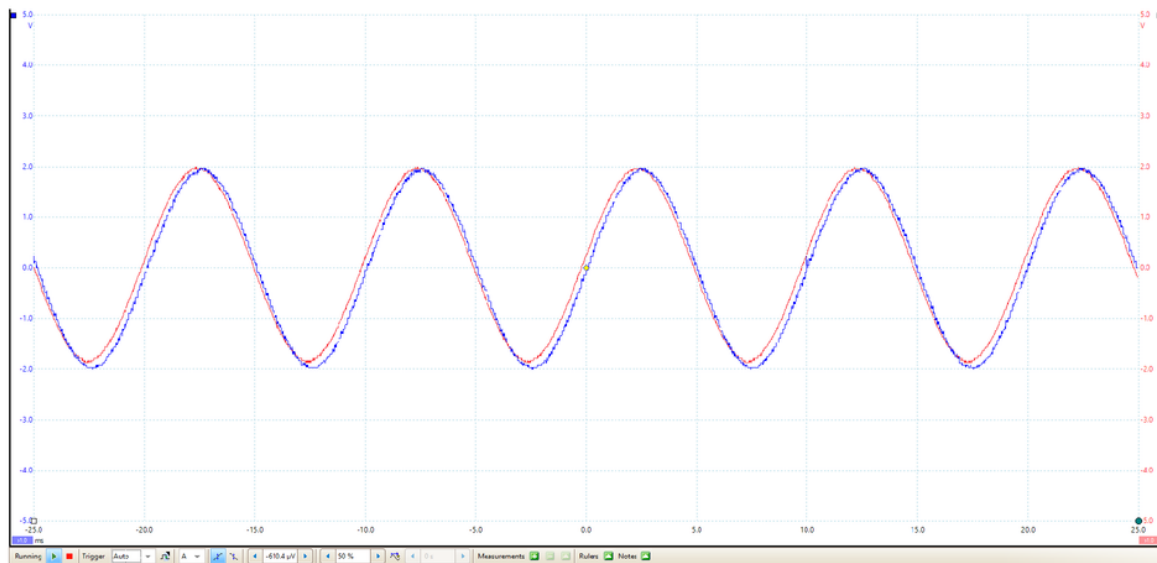


As can be seen comparing this to the calculated version they are quite different with the slightly different amplitude and spacing of the points. This is likely due to human error setting up the machine as everything was adjusted with hand knobs which are not as accurate as they could be. However, the general shape is still present in this spectrum.

Testing the ADC system:

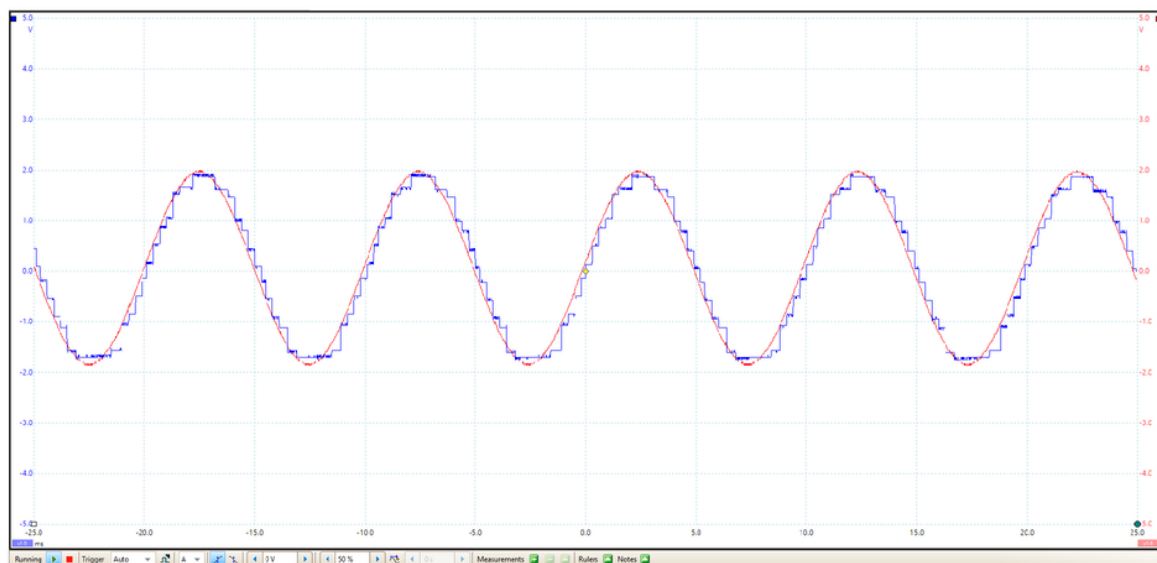
The first practical experiment was to observe the difference when the ADC is either set to 4 bit or 8 bit. To do this the modulation generator was set up to give a 4Vp-p input at a frequency of 100Hz. Below is the both the input and output results from the 8 bit system (Figure 12) red as the input blue as the output.

Figure 12: Setting ADC system at 4Vp-p at 100Hz using 8 bit system.



The Pico scope shows that the 8 bit system has accurately sampled the input. However there is a slight error where the amplitudes p-p voltage has slightly increased and the waveform is slightly lagging behind the input at some points. This is a much better output than the 4 bit system (Figure 13).

Figure 13: Setting ADC system at 4Vp-p at 100Hz using 4 bit system.



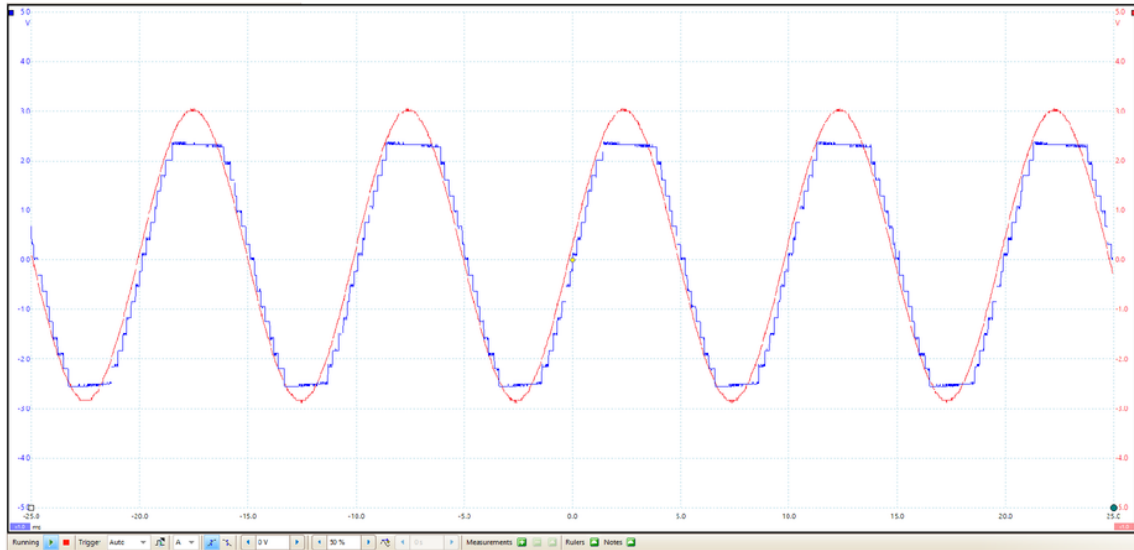
The output of the 4 bit still lags slightly however the p-p voltage is smaller. This is due to the same reason that the waveform isn't as smooth as it was in the 8 bit this is because of the quantization which will be shown better later, but this is because the 8 bit system has a total of 256 steps which makes it very accurate however, the 4 bit system has only 16 steps which makes it less accurate but is easier for a system to read as there is less information for it to read. This results in a balance between the 2 to be found. After the first experiment the system was set to a 100Hz input at 0V and slowly increased in intervals to see when a new quantization level is needed the first one is shown below (Figure 14).

Figure 14: ADC system 4 bit quantization at 2Vp-p.



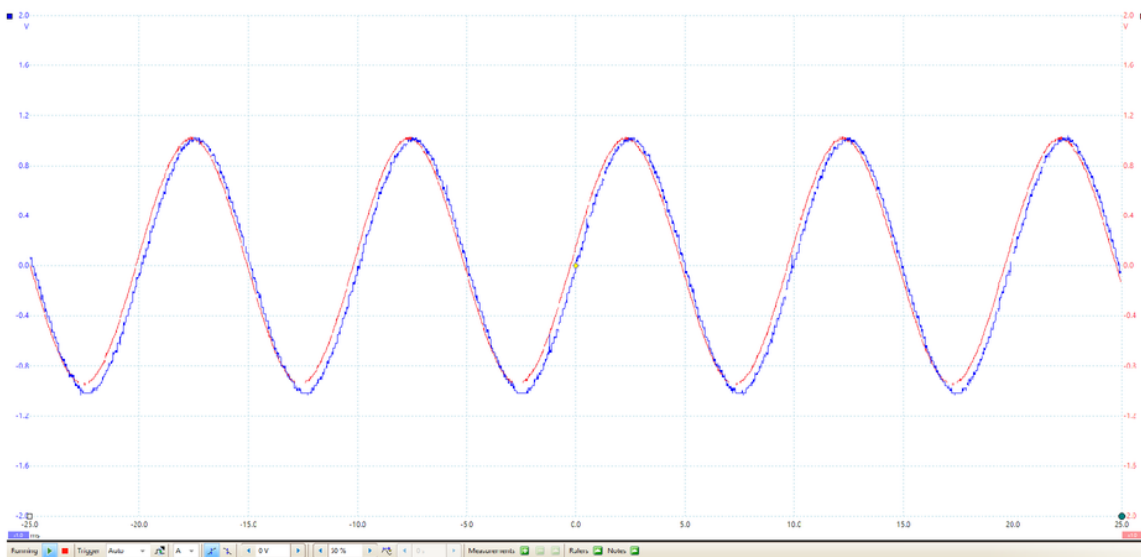
The first measurement is at 2V p-p when set to a 4 bit system. This is using 8 quantisations which is the amount of steps generated to plot the waveform. To show the change in quantisation the amplitude was increased to 6V p-p (Figure 15).

Figure 15: ADC system 4 bit quantization at 6Vp-p.



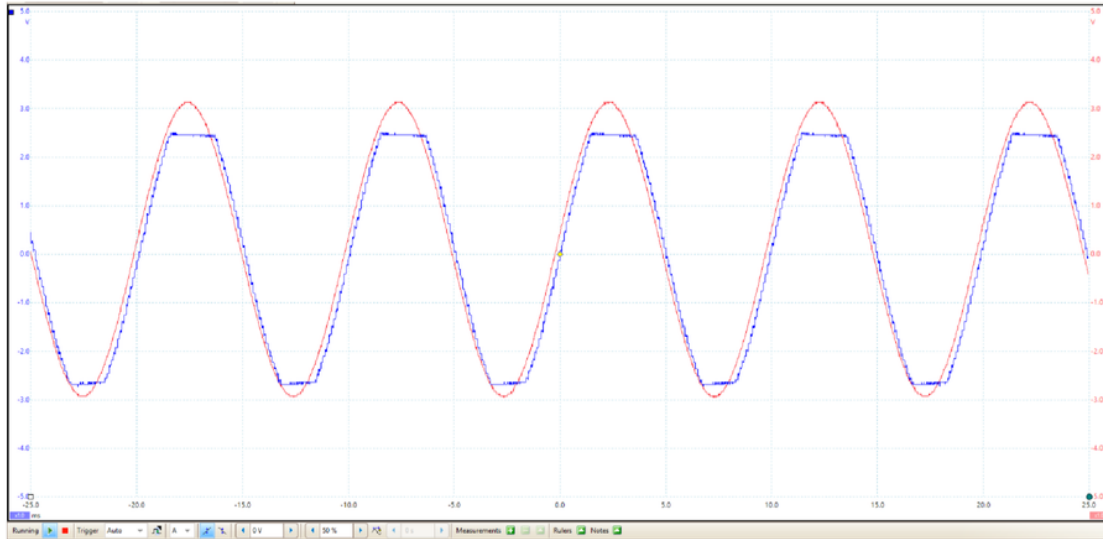
The quantization of the waveform has increased to 16, while this has increased the difference between the two points as this is the resolution. The peaks and troughs of the graph have been cut off as the system has a maximum output of 5V p-p. This experiment was repeated using 8 bit at the same voltage levels the first being the 2V p-p (Figure 16).

Figure 16: ADC system 8 bit quantization at 2Vp-p.



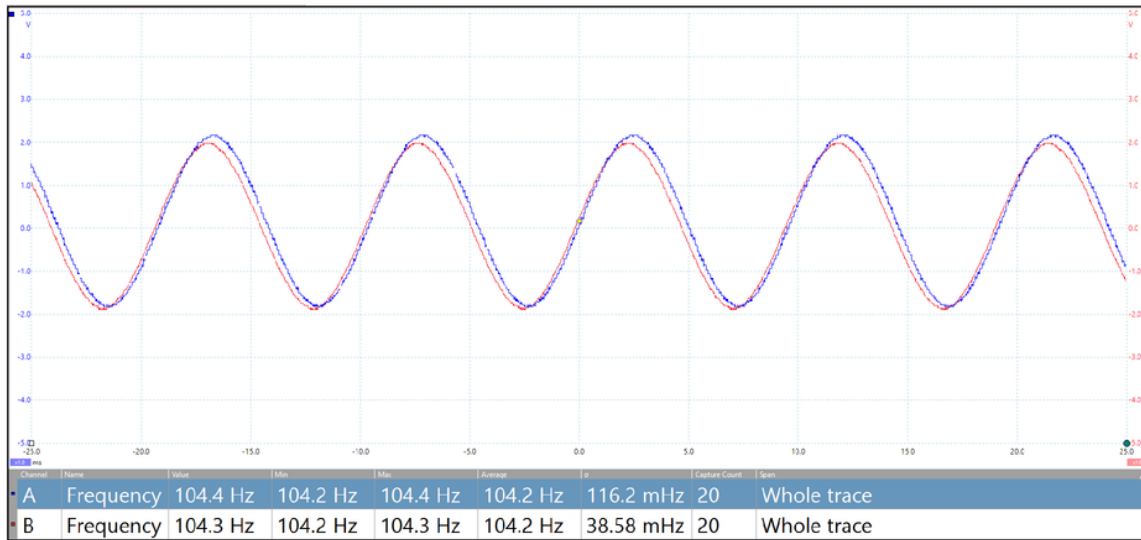
The 8 bit system is much more accurate than the 4 bit as was shown earlier however this is not using its full quantization range to do this the p-p voltage was increased to 6V (Figure 17).

Figure 17: ADC system 8 bit quantization at 6Vp-p.



The peaks and troughs are again capped as the system has a max amplitude of 5V p-p however when comparing the 2 waveforms the second is much clearer due to the increase in the amount of steps. The final experiment was to analyse the effect of aliasing the ADC was set to 8 bit and the frequency was set at 100Hz at 4V p-p (Figure 18).

Figure 18: ADC system set to 100Hz at 4V p-p using 8bit sampling.



The frequency was increased while the amplitude was left the same. The first test was carried out in to show the system at 100Hz (Figure19), at 1KHz (Figure 20) and 10KHz (Figure 21).

Figure 19: ADC aliasing at 100Hz.

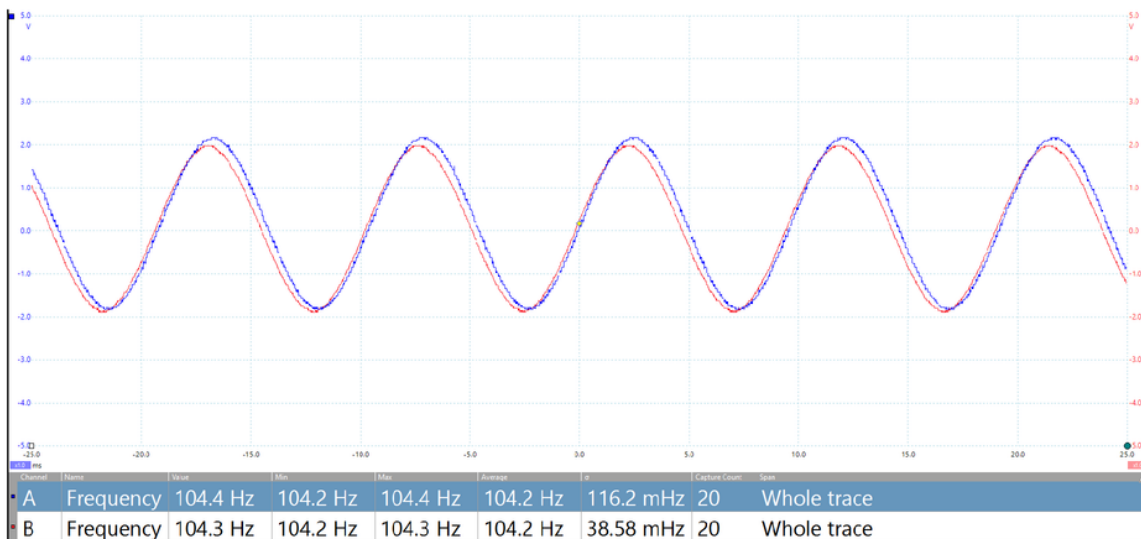


Figure 20: ADC aliasing at 1KHz.

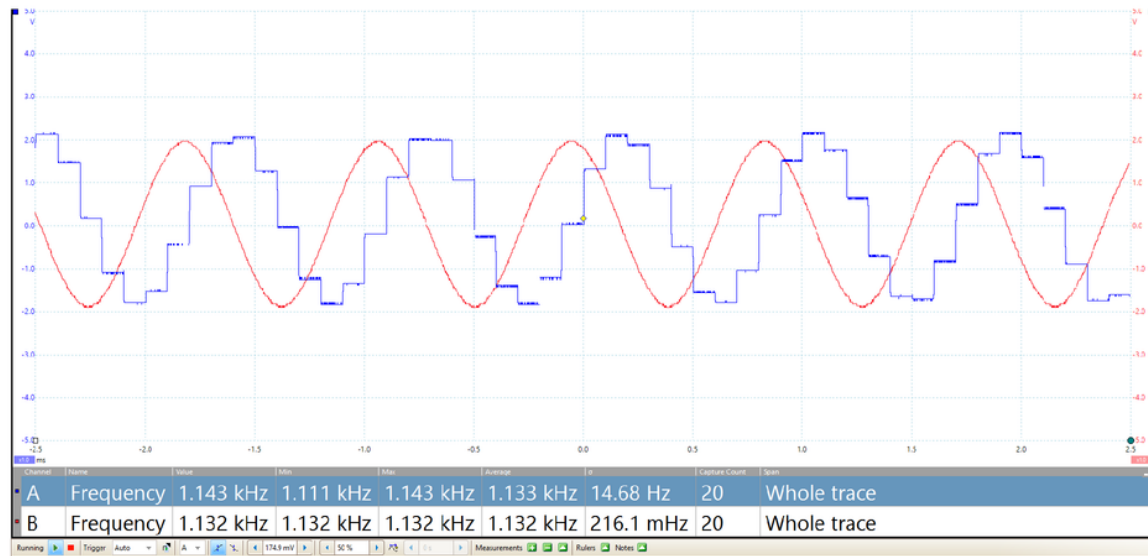
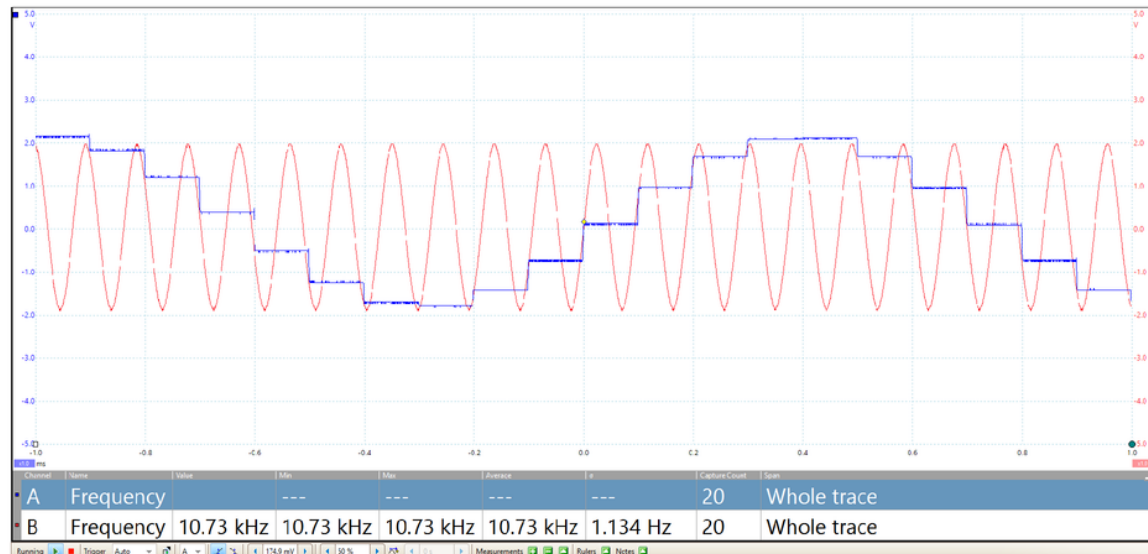


Figure 21: ADC aliasing at 10KHz.



As can be seen from the 100Hz test the waveform is what it should be however as the frequency is increased the system isn't sampling often enough to accurately convert the signal into its digital counterpart which is known as aliasing. This will be tested further in the final test which requires the input frequency to be set to 4KHz and will be increased in different increment until it reaches 10KHz. The results of this experiment can be seen below (Figure 22, 23, 24, 25, 26, 27, 28, 29 & 30).

Figure 22: ADC aliasing at 4KHz.

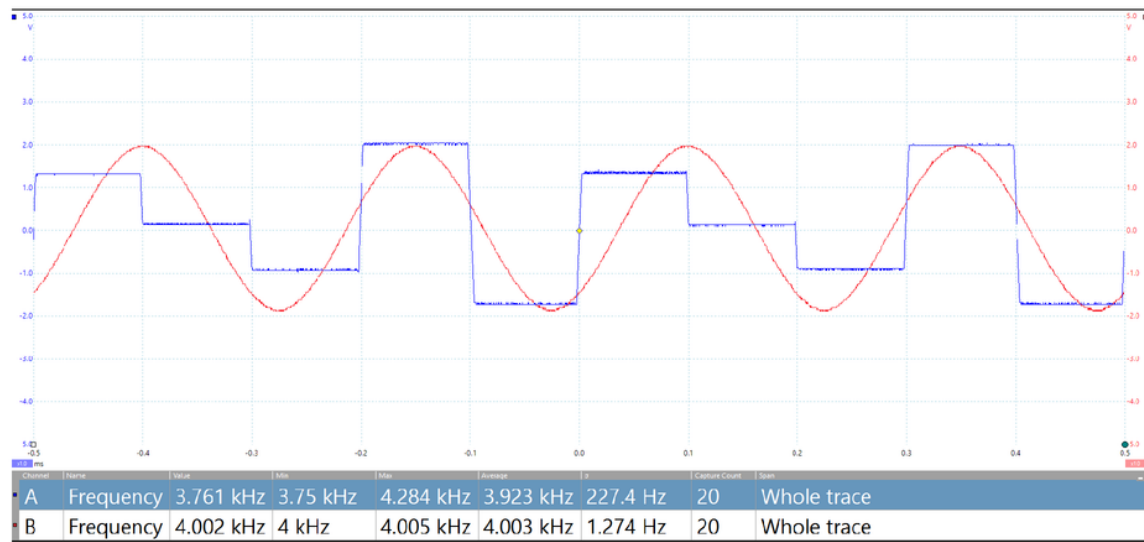


Figure 23: ADC aliasing at 4.5KHz.

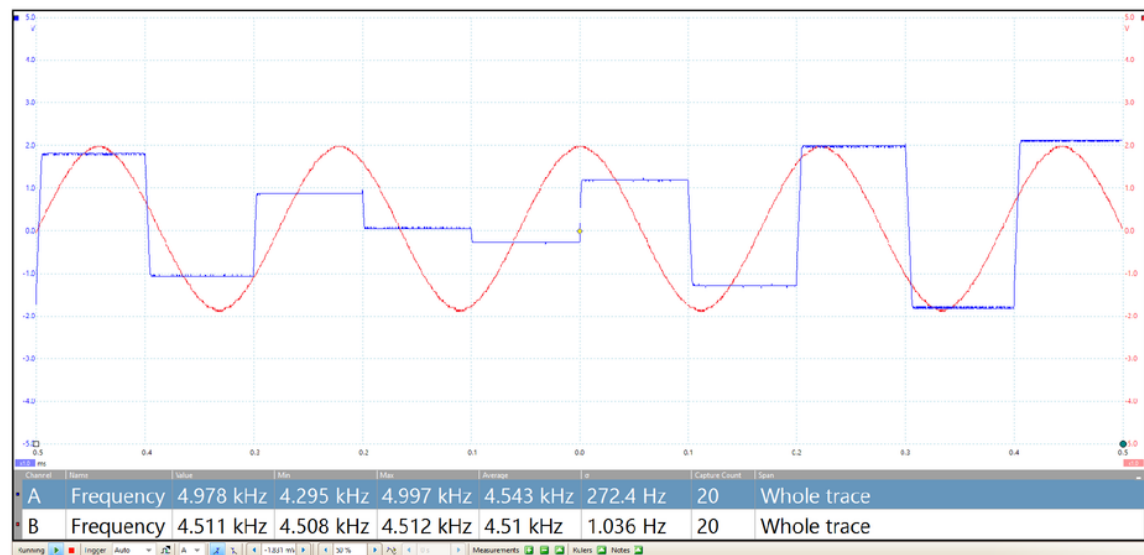


Figure 24: ADC aliasing at 5KHz.

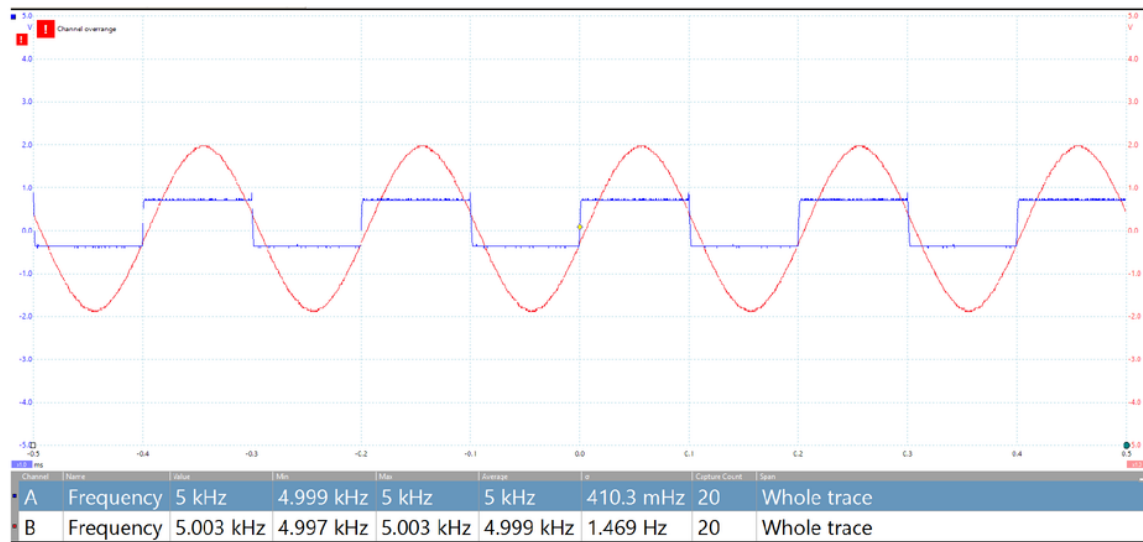


Figure 25: ADC aliasing at 5.5KHz.

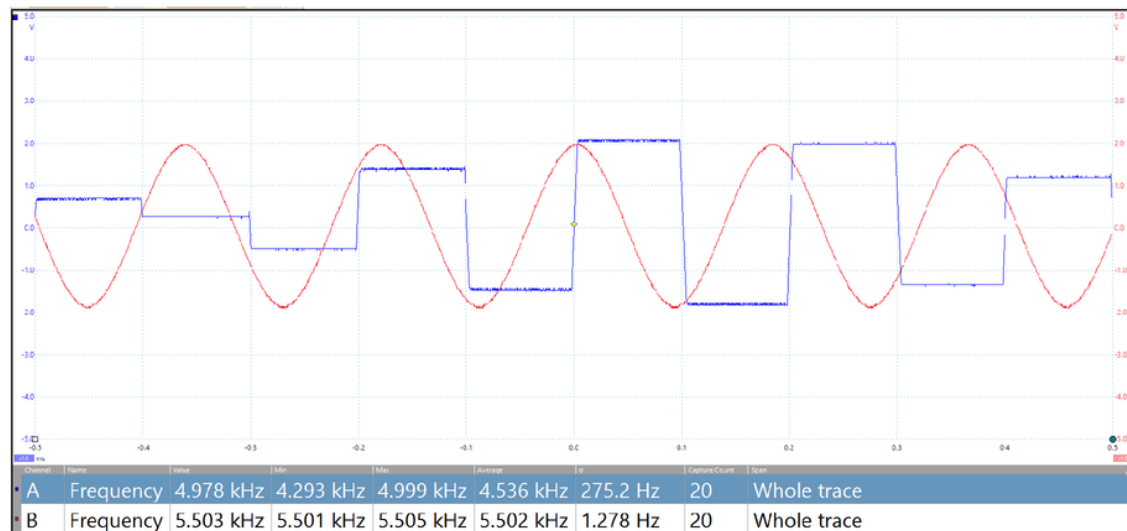


Figure 26: ADC aliasing at 6KHz.

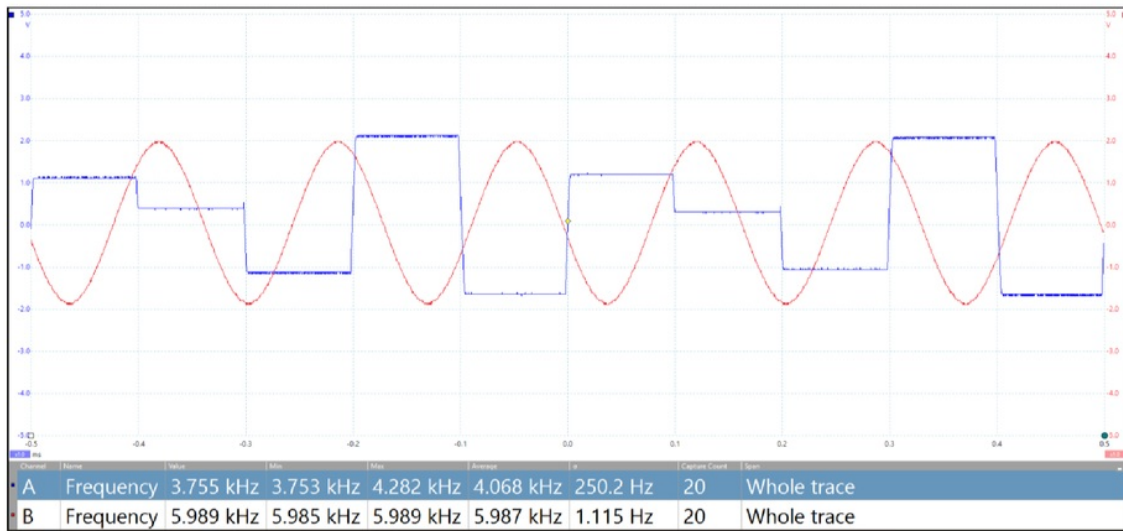


Figure 27: ADC aliasing at 7KHz.

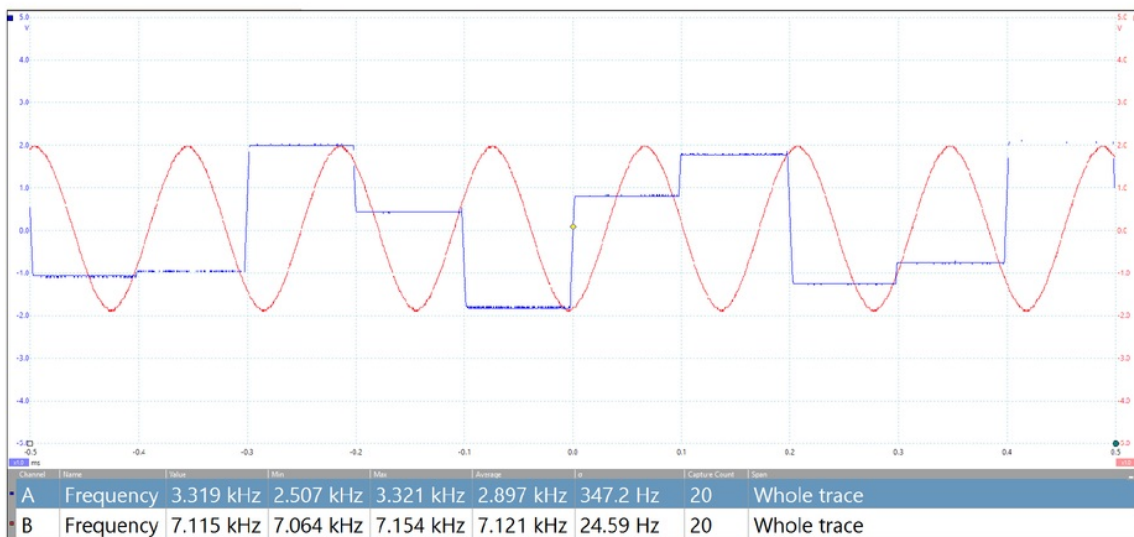


Figure 28: ADC aliasing at 8KHz.

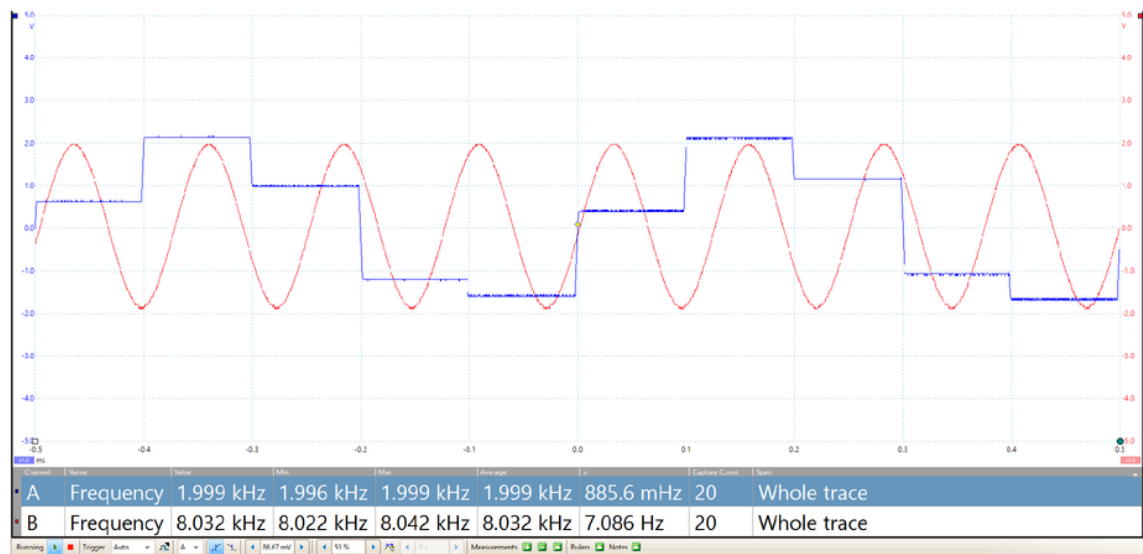


Figure 29: ADC aliasing at 9KHz.

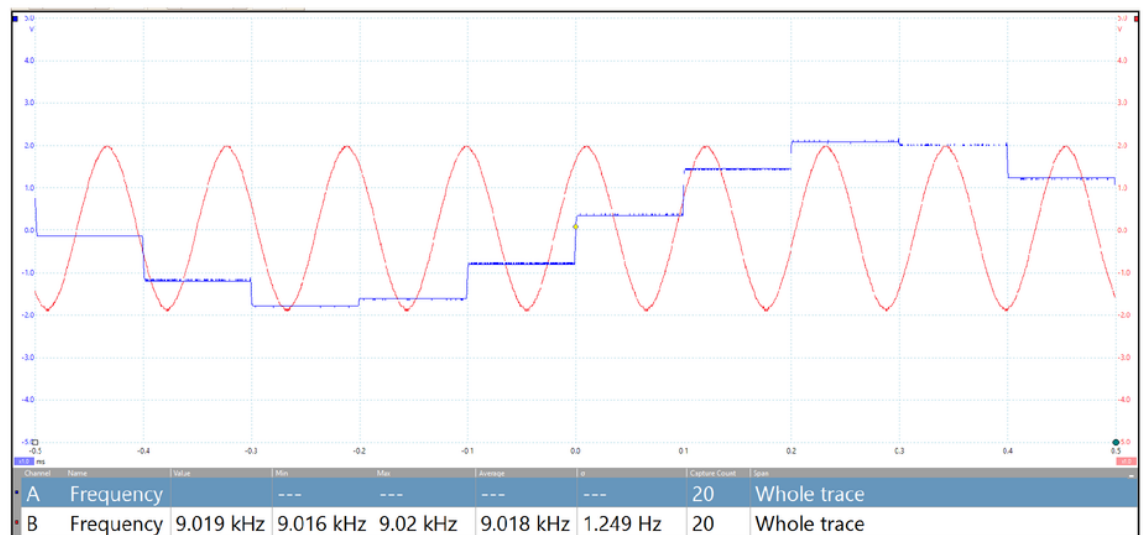
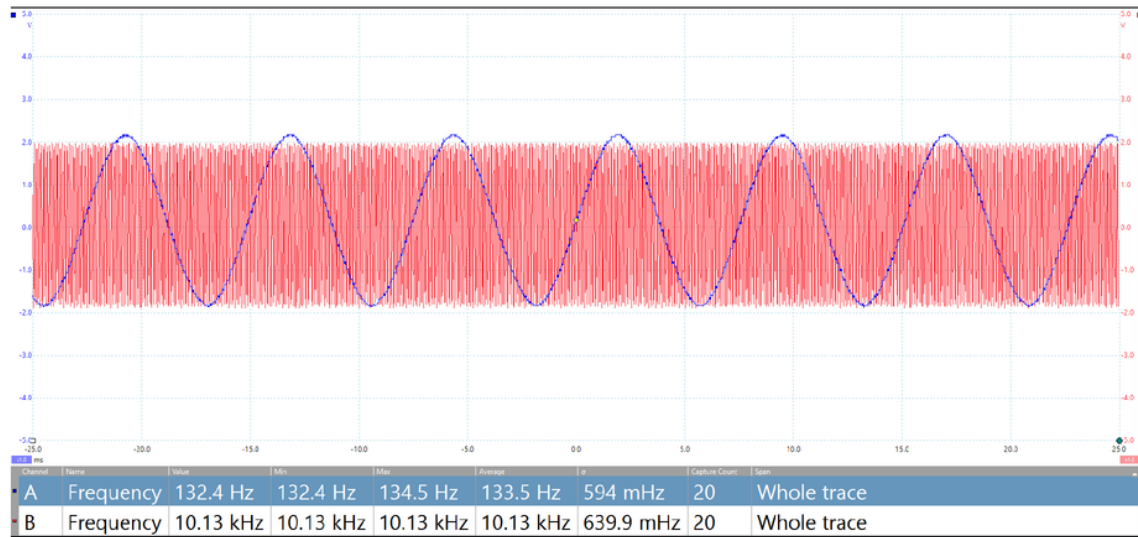


Figure 30: ADC aliasing at 10KHz.



Examining the waveforms from the test it is obvious that by increasing the frequency of the modulation generator past the capabilities of the ADC system will result in incorrect information to be processed even when slightly increased. In the most extreme test with the modulation generator set at 10KHz the output frequency was reading 134Hz which is almost a factor of 100 difference which results in the signal being useless once converted to a digital signal.

5. Conclusions and Recommendations

The purpose of testing the frequency modulation circuit was to allow an accurate comparison to be made between the theoretical values obtained with the practical experiment to observe the differences between the two of them. The main test for this was to analyse the spectrum from the FM circuit. When this was compared to the theoretical values obtained from the calculation and using the Bessel table, the general shape that was calculated was roughly the same. However, the amplitude and the positioning of some of the spikes were different than calculated, this may have been due to both calculation rounding error and the positioning of the variables on the circuit board as they were hand adjusted which lacks accuracy. The other test on this system was to observe the effect of adjusting the amplitude of the frequency modulation without adjusting the frequency. This showed that the frequency deviation was decreasing as the amplitude of the input from the modulation generator was also being reduced. Also, the time between switching between the peak and trough were becoming slightly longer with the decrease to the amplitude. To improve the accuracy of the results, the only one of concern being the spectrum analysis while replacing the board is an option to minimise the effect of human error the best choice would be to repeat the calculation at a different frequency set point and analyse the new spectrum and compare with the new calculated values to highlight and discrepancies or to see if they persist.

The second test was to examine the characteristics of the Analogue to Digital Converter. The first thing the experiments shown was the difference between the ADC using a 4 bit system or a 8bit system this demonstrated the difference between the amount of quantisations and how it made the output more accurate however it meant more information for the digital system to process this was effected by the systems 5V p-p limit that it has however the results of the experiment are still clear. The second test was to observe the effect of adjusting the frequency of the system without altering the amplitude, this introduced aliasing which is when the sample rate of the system isn't fast enough to create the correct digital equivalent and because of the resolution which is the distance between two quantization points never changes the digital part had to jump to the nearest quantization. The results of this support the theory behind this as it was what was expected to happen during the test.

6.Citation List

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ENGAGEMENT WITH LITERATURE



There was some evidence of further reading and research and your interpretation and understanding of the additional research was OK. The sources referenced were sufficient at this level however you need to include more in-text citations using the Harvard reference system.

3

KNOWLEDGE AND UNDERSTANDING

The knowledge and understanding of the subject



demonstrated by this assignment was reasonably detailed and mainly accurate. There were few gaps in your knowledge of the basic concepts and your understanding of the higher level concepts was demonstrated to a limited degree - you could have explained in more detail how the experiment related to theory. Further work – Your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

18

COGNITIVE AND INTELLECTUAL



Your analysis of the task was mainly descriptive and superficial and lacked a lot of the required detail. Your conclusions were also mainly descriptive and there were several instances of flawed understanding. There was little evidence of critical analysis with most results accepted uncritically as fact and without explaining the underlying principles. You did however demonstrate some basic analytical skills and your approach to the task was logical.

8

PRACTICAL APPLICATION



Your application of practical skills for this task was generally good. You used the resources available appropriately when carrying out the experiments and you used appropriate options for testing and evaluating the circuit performance. You managed to setup an effective experiment that functioned within the specification and achieved this by only asking for assistance when appropriate.

14



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was generally good and contained most of the required detail, it was also written in a coherent and logical way. The available word count was in the main effectively used.

5