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HND Electrical And Electronic Engineering

SGEE5005 - Signals & Digital Comms

Assignment - Signals & Modulation

Author: Rhys Davies (1809809)

10th March 2022

- ① EXCELLENT RESEARCH AND AN APPROPRIATE CITATION LIST.
- ② BOTH EXPERIMENTS WERE CONDUCTED IN DETAIL AND YOU USED THE EQUIPMENT EFFECTUALLY AND WITH INITIATIVE TO INVESTIGATE BOTH TOPICS.
- ③ RESULTS AND ANALYSIS WERE DETAILED AND PROVIDED AN ELEMENT INSIGHT INTO BOTH TOPICS.
- ④ CONCLUSIONS WERE GOOD, WITH VALID ARGUMENTS RAISED. MAYBE INCREASE THE CRITICAL ANALYSIS AND REDUCE DESCRIPTIONS.
- ⑤ SOME DIAGRAMS/TABLES ETC WOULD HAVE BEEN BETTER IN THE APPENDIX.

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1. Executive Summary

This assignment focuses research into communication methods are developed and utilised in modern day systems, both wireless and wired to transmit and receive various forms of data whilst achieving methods to reduction in the changing of the data that is transmitted.

This assignment will then investigate the fundamental differences between how data is transmitted, first focussing on the analog 'over the air' methods of A.M (Amplitude Modulation) and F.M (Frequency Modulation). *PAST TENSE*

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We investigate how these 2 methods differ in how they transmit a message of lower frequencies using higher 'carrier' frequencies being used to carry lower message frequencies.

Investigations and research into how these methods are formed will demonstrate how each method is suitable for certain applications together with the advantages and disadvantages that each method introduces.

Further research was also applied to modern techniques of digital forms of communication, and how the use of digital eliminates some issues faced when transmitting data using analog methods.

The assignment then moves onto more calculation and practical experiments are carried out to show a Frequency modulated waveform is constructed, with a full spectrum analysis carried out, showing the overall frequency bandwidth and sideband frequencies. Calculations are compared with physical captured results using a PC based oscilloscope to show how reliable the calculations can be.

Further experiments showing the differences in Analog to digital conversion (ADC) and how the differences in a choice of bit rate during Analog to digital conversion as well as the input voltage amplitude can affect the resultant output quality and 're-construction' of the input signal.

Finally, a summary into the use of ADCs to convert an analog signal is important to ensure that a signal is converted to be transmitted successfully whilst keeping bandwidth use as an important factor.

2. Research into Analogue and digital communication systems and techniques

Modulation is a process in which information is converted by means of 'encoding' from the source for the sole reason to optimise the signal for efficient and successful transmission.

In terms of analog modulation, there are two types:

'Amplitude Modulation (AM) is a type of modulation where the amplitude of the carrier signal is changed in accordance with the amplitude of the information signal. This type of modulation means that the phase and frequency is kept constant but amplitude is the only variable factor. (Omnisci, 2022)

'Frequency Modulation (FM) is a type of modulation where the frequency of the carrier signal is altered by the amplitude of the information signal. Here, phase and amplitude is kept constant but the frequency is the only variable factor but less sensitive to additive noise than AM. (Communication Systems, 2010)

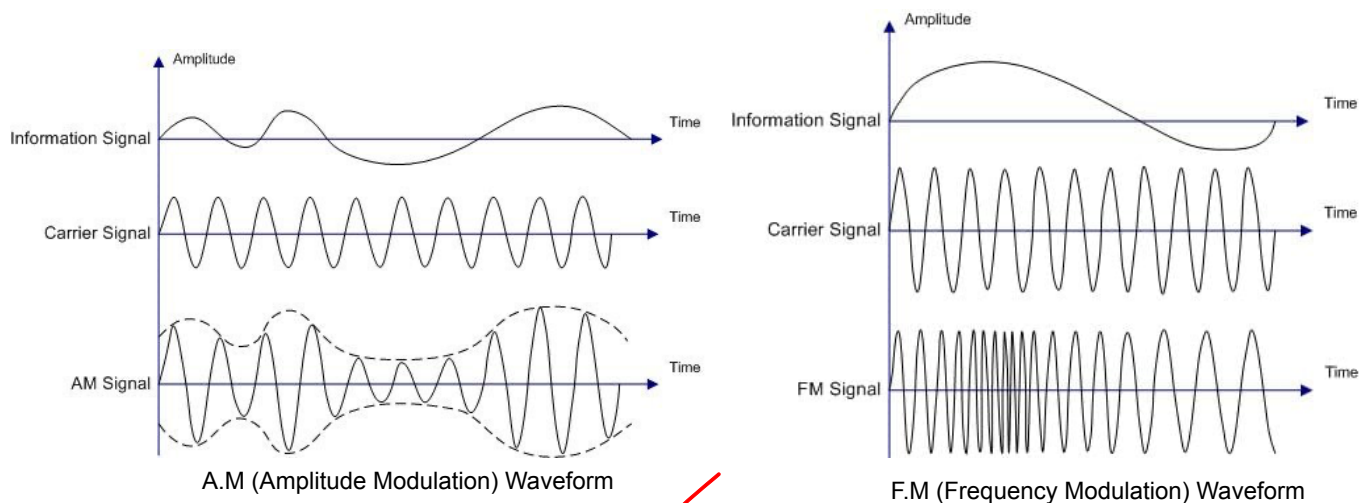


Figure 1 - A.M vs F.M Signal differences (ScienceABC, 2022)

As digital data is primarily found on electronic devices, and are fast becoming the medium to store and process data, then digital communications is preferred as the data is already in the correct format.

Digital communications also offer better quality of signal through transmission, an increase in signal security against inter transmission interception, less susceptible to noise and interference, requires less power to transmit and allows for easier types of data, such as voice, text and images, to be easily integrated (Wireless Digital Communication, 2017)

When designing a communication system, factors such as the overall cost, complexity of operation, as well as power consumption whilst being able to minimise the use of bandwidth as it allows for other forms of transmission to be possible at the same time using the same medium and/or equipment. (Digital Communications, 2009)

The digitisation of analogue signals means that large amounts of bandwidth are required but the signal-to-noise ratio would be greatly reduced.

Resources of bandwidth can be altered/reduced with the compromise of increased/decreased energy usage, in the form of power for transmission (Digital Communications, 2009)

An important tool in achieving successful but compressed signal transmission is the use of CODECs.

CODEC (coder/decoder) are formed with an Analog to digital convertor, together with multiplexers, clocks and synchronising circuits in the transmitter part, this converts the continuous analog signal into a defined 'sequence of codewords'. (ECS, 2008)

A receiver then houses a Digital to Analog receiver, which will need to convert binary voltage pulses and reverse the procedure to re-form into a continuous analog signal. (Digital Communications, 2009)

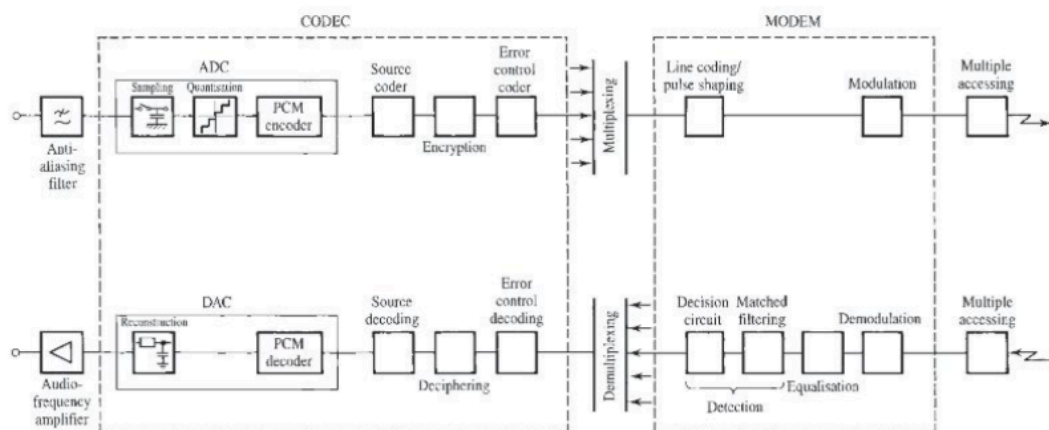


Figure 2 - A.M vs F.M Signal differences (Digital Communications, 2009)

The use of CODECs in the process of ADC (Analog to digital conversion) has vastly noticeable benefits:

They are able to encode and decode whilst able to filter out and remove any form of external/internal interference & noise.

This does mean the transceiver circuits are more complex than needed, but ensures that the transmitted and received signals are almost error free. (Digital Communications, 2009)

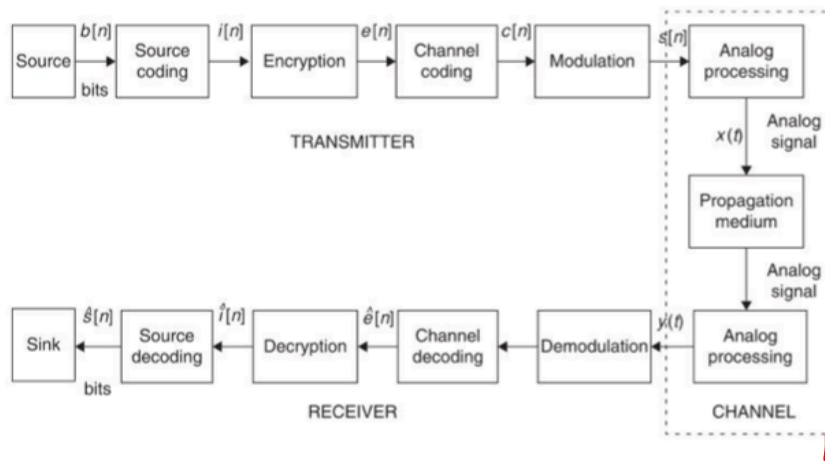


Figure 3 - Components of a typical Digital Communication System (Wireless Digital Communication, 2017)

The sequence to transmit the data is broken down into key sections:

1. Source - Any digital information that may/not have been sampled from an analog source
2. Source Coding - Compresses the source to reduce the number of bits to be sent
3. Encryption - Scramble the data for unintended recipients
4. Channel Coding - Adds redundancy to the encrypting sequence for distortions
5. Modulation - Coded data is mapped to a specific signal frequency for transmission
6. Analog Processing - Data is converted to corresponding analog so it can be transmitted on a frequency
7. Propagation Medium - Represents the transmission medium (wireless, wired, optical)
8. Analog Processing - Removes noise, oscillators and converts back to digital
9. Demodulation - Equalisation, sequence detection and removal of distortion
10. Channel Decoding - Uses the added redundancy by the Channel coder to remove errors
11. Decryption - Applied inverse transformation to descramble the data
12. Source Decoding - Decompresses the bits of data back to original status
13. Sink - Receiving equipment of the data

(Wireless Digital Communication, 2017)

PCM (Pulse Code Modulation) was originally developed to tackle the increasing issue that noise was being introduced into a signal when it required to be amplified numerous times when transmitted along a very large distance. Because of the analog signal would degrade and then be re-amplified, then interference voltages would also be amplified. This means that the original voltage would be difficult to decipher against interference. The use of 'Dot-dash' style encoding meant that other voltage amplitudes could be ignored and only these signals were not affected (ETHW, 2022)

Assignment - Signals & Modulation

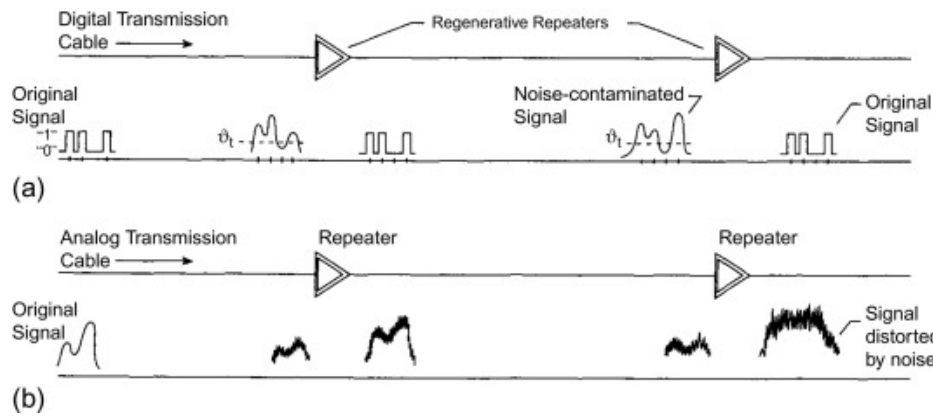


Figure 4 - Analog Vs PCM Transmission (Electronics and Communications for Scientists and Engineers - 2020)

The key advantage is that PCM produces a series of pulses at a specific amplitude, then the amplitude height is key to recognise whether the data would be accepted or rejected. Which means it can be processed and re-transmitted easily as there are only 2 states to consider. This leaves the length of the pulse to understanding the type of data that was being transmitted. (Electronics and Communications for Scientists and Engineers (2020))

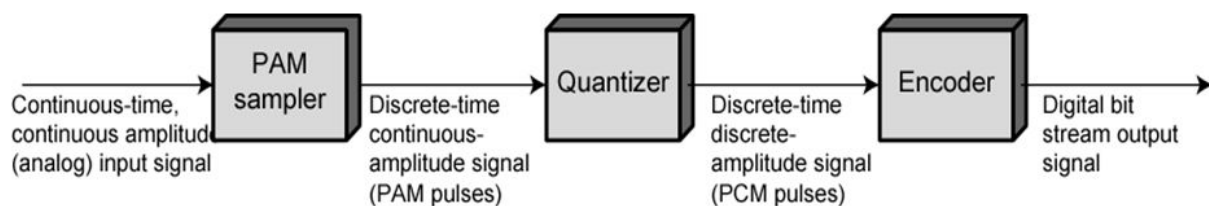


Figure 5 - Block Diagram of Pulse Code Modulation (Elprocus - 2022)

During the use of PCM, PAM (Pulse Amplitude Modulation) is used. It is a technique of modulating an analog signal by sampling the incoming analog waveform as specific intervals and then the samples are checked to be directly proportional to the amplitude of the signal. (Watelectronics, 2022)

PAM exists in two forms:

Flat Top PAM:

Each pulse that is sampled is produced directly proportional to the amplitude of the sampled signal at each occurrence. During the pulse, the amplitude will remain constant throughout the pulse length. As the pulse amplitude is kept constant, then this can remove noise.

Natural PAM:

Here, each pulse is still directly proportional to the amplitude of the sampled signal at each occurrence, but the difference is that the pulse amplitude will match the signal amplitude during the length of the sample. This is a more accurate representation of the input signal but because of the varying amplitude of the individual pulses, this can be susceptible to further interference and errors. (Watelectronics, 2022)

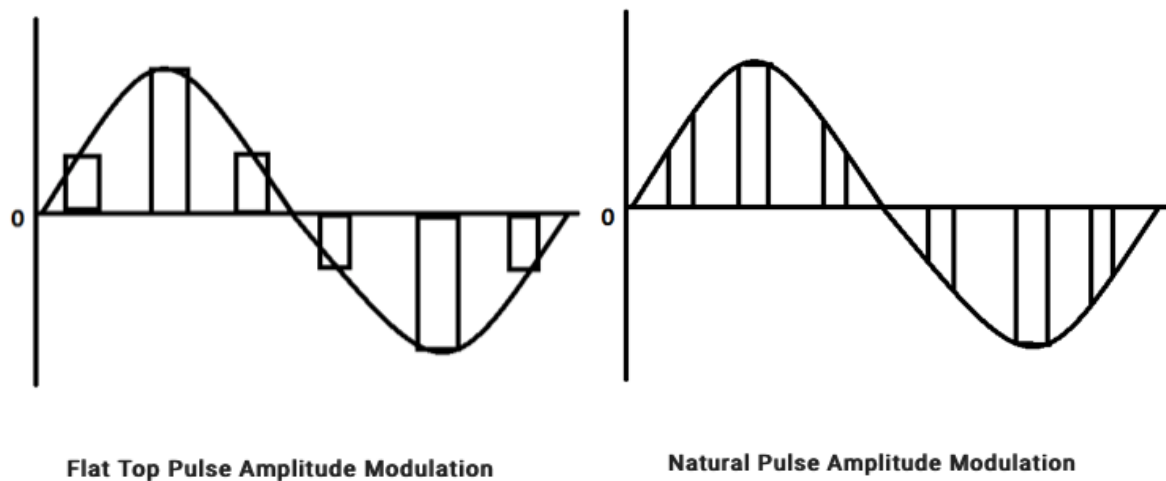


Figure 6 - Flat Top Vs Natural PAM Waveforms (Watelectronics - 2022)

With data now able to be converted and transmitted, the challenge was to develop methods on how transmit large amounts of data of different data packet sizes, over long distances.

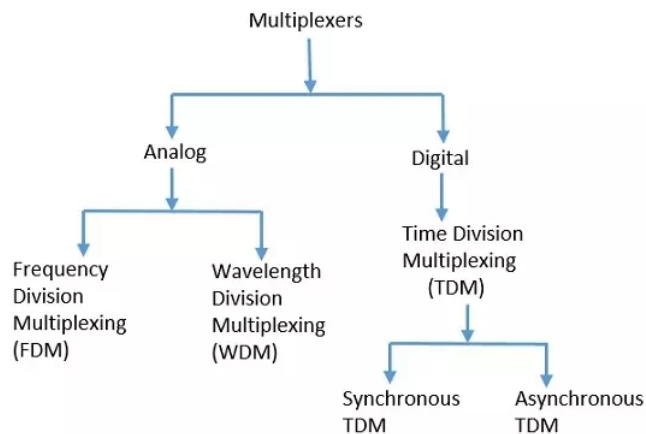


Figure 7 - Multiplexing Segregation By Type (Tutorialspoint - 2022)

Digital multiplexing was developed to achieve the facility to transmit various forms of data simultaneously over the same medium. This would be achieved by the use of 'time division multiplexing' (TDM). This form utilises multiplexers which use PCM codewords or PCM style binary pulses at different defined levels, which allow more than one source of information to share the same transmission medium without cross inferences (Digital Communications, 2009)

Digital multiplexing was developed into 2 methods, SDH (Synchronous Digital Hierarchy) was developed older style PDH (Plesiochronous Digital Hierarchy) as the system eliminates potential synchronous errors between transmissions as some signals would be transmitted at different clock frequencies. Synchronous multiplexing means that data transfer rates were able to be increased and provide a more flexible network communications protocol. (Carritech, 2022)

PDH - 'Plesiochronous Digital Hierarchy'	SDH - 'Synchronous Digital Hierarchy'
In PDH, reference clock is not synchronized throughout the network.	In SDH, Reference clock is synchronized throughout the network.
There is no synchronization between payload and frame.	There is synchronization between payload and frame.
PDH system has different frame structures at different hierarchy levels.	SDH system has consistent frame structures throughout the hierarchy.
Physical cross-connections are provided on the same level in PDH.	Digital cross-connections are provided at different signal levels in SDH.
In PDH, rates are derived from basic rate of 1.544 Mbps. The maximum capacity is about 566 Mbps.	In SDH, rates are derived from basic rate of 155.52 Mbps. The maximum up to 40 Gbps rates can be derived from basic rate mentioned.
There is no universal standard for PDH.	Universal standard exists for SDH.
PDH is incompatible with other signals such as ATM, FDDI, DQDB etc.	SDH is compatible with other signals such as ATM, FDDI, DQDB etc.
Multipling method used in PDH is complex.	Multipling method used in SDH is simple.
Implementation cost of PDH is lower.	Implementation cost of SDH is higher.

Figure 8 - PDH Vs SDH Characteristics (RF Wireless World - 2022)

✓ Good RESEARCH & CITATION).

3. Experimental Method for Experiment 1

Using the provided values for an FM signal:

- Carrier Amplitude (E_c) = 375mV
- Carrier Frequency (f_c) = 455kHz
- Frequency of Message (f_m) = 10kHz
- Amplitude of Signal (E_s) = 2V

Using these values, we can now calculate other critical parameters to Analyse the waveform and form an eventual Spectrum Analysis.

Frequency Deviation Constant (K) = 10kHz/V

$$\begin{aligned}\text{Frequency Modulation } (\Delta f) &= E_s * (f_m * K) \\ &= 2 * (10000 * 2) \\ &= 40\text{kHz}\end{aligned}$$

$$\begin{aligned}\text{Modulation Index (mf)} &= \frac{\Delta f}{f_m} \\ &= \frac{40\text{kHz}}{10\text{kHz}} = 4\end{aligned}$$

With a modulation Index of '4', using the Bessel table to find the co-efficients:

Modulation index	Sideband								
	Carrier	1	2	3	4	5	6	7	8
0.00	1.00								
0.25	0.98	0.12							
0.5	0.94	0.24	0.03						
1.0	0.77	0.44	0.11	0.02					
1.5	0.51	0.56	0.23	0.06	0.01				
2.0	0.22	0.58	0.35	0.13	0.03				
2.41	0	0.52	0.43	0.20	0.06	0.02			
2.5	-0.05	0.50	0.45	0.22	0.07	0.02	0.01		
3.0	-0.26	0.34	0.49	0.31	0.13	0.04	0.01		
4.0	-0.40	-0.07	0.36	0.43	0.28	0.13	0.05	0.02	
5.0	-0.18	-0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02

Figure 9 - Bessel Table for Coefficients

The Bessel table highlights the coefficients multiples as well as how many sideband frequencies either side of the 'central' carrier frequency we need to consider and calculate.

- @ 455kHz, $E_c * J_0 = 375\text{mV} * 0.40 = 150\text{mV}$
- @ 465kHz & 445kHz, $E_c * J_1 = 375\text{mV} * 0.07 = 26.25\text{mV}$
- @ 475kHz & 435kHz, $E_c * J_2 = 375\text{mV} * 0.36 = 136\text{mV}$
- @ 485kHz & 425kHz, $E_c * J_3 = 375\text{mV} * 0.43 = 161.25\text{mV}$
- @ 495kHz & 415kHz, $E_c * J_4 = 375\text{mV} * 0.28 = 105\text{mV}$
- @ 505kHz & 405kHz, $E_c * J_5 = 375\text{mV} * 0.13 = 48.75\text{mV}$
- @ 515kHz & 395kHz, $E_c * J_6 = 375\text{mV} * 0.05 = 18.75\text{mV}$
- @ 525kHz & 385kHz, $E_c * J_7 = 375\text{mV} * 0.02 = 7.5\text{mV}$

Appendix

Making a graph from these calculations results in:

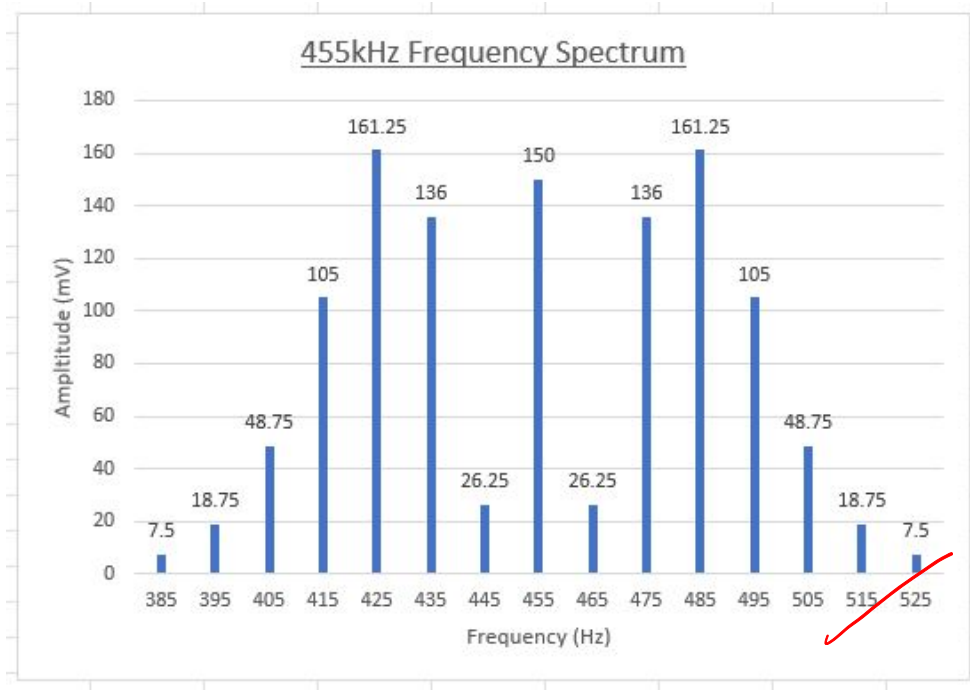


Figure 10 - Calculated 455kHz Frequency Spectrum

Resulting Bandwidth across all calculated sideband frequencies:

$$525\text{kHz} - 385\text{kHz} = 140\text{kHz}$$

4. Testing, Results and Analysis for experiment 1

A 455kHz carrier frequency with an 375mV amplitude was combined with a 10kHz sine wave 'message' signal with a 2V amplitude into a Picoscope, and using the appropriate software, the spectrum analyser function was used to show the frequency spectrum.

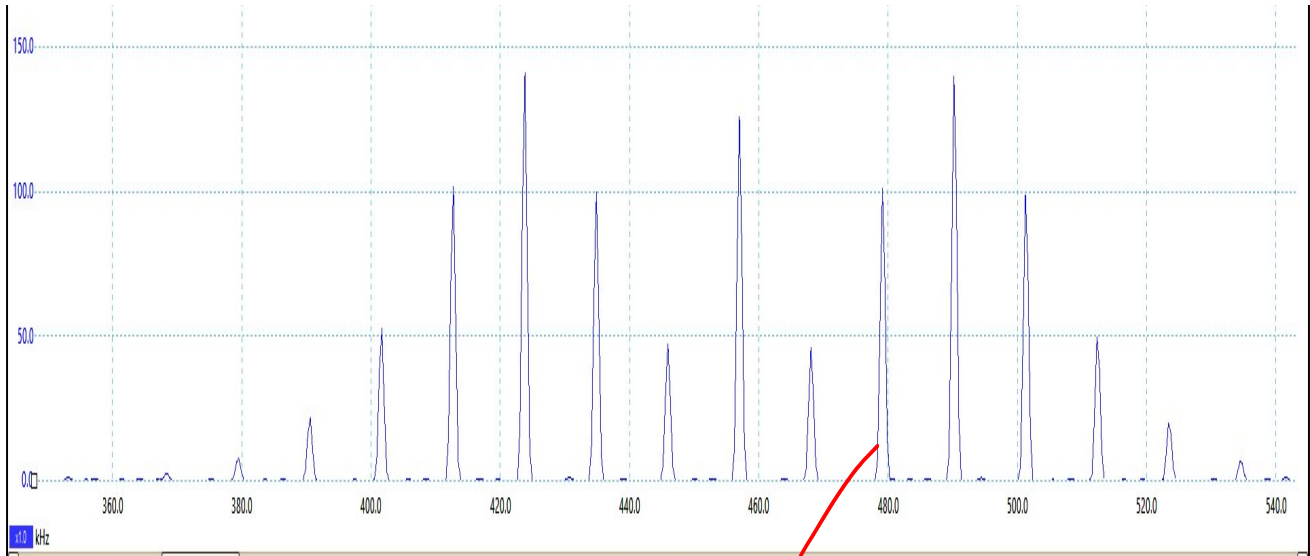


Figure 11 - Physical 455kHz Spectrum Analysis

Resulting Bandwidth across all **physical** sideband frequencies:

$$535\text{kHz} - 379.4\text{kHz} = 155.6\text{kHz}$$

Tabulating this graph showing each sideband frequency and amplitude, comparing with the calculated shows the differences.

455kHz Frequency Spectrum - Comparison				
Frequency		Amplitude		
Calculated	Physical	Calculated	Physical	
385	379.4	7.5	3.3	
395	390.0	18.5	8.5	
405	401.87	48.75	53.7	
415	412.5	105	105	
425	423.75	161.25	141	
435	434.375	136	100	
445	445.625	26.25	45	
455	456.875	150	125	
465	468.125	26.25	40	
475	479.375	136	105	
485	490.00	161.25	141	
495	501.25	105	95	
505	512.5	48.75	50	
515	523.125	18.5	20	
525	535.00	7.5	8.3	

Figure 12 - Physical 455kHz Spectrum - Comparison Table

I WOULD SUGGEST TABLE IN APPENDIX, GRADUATE HERE.

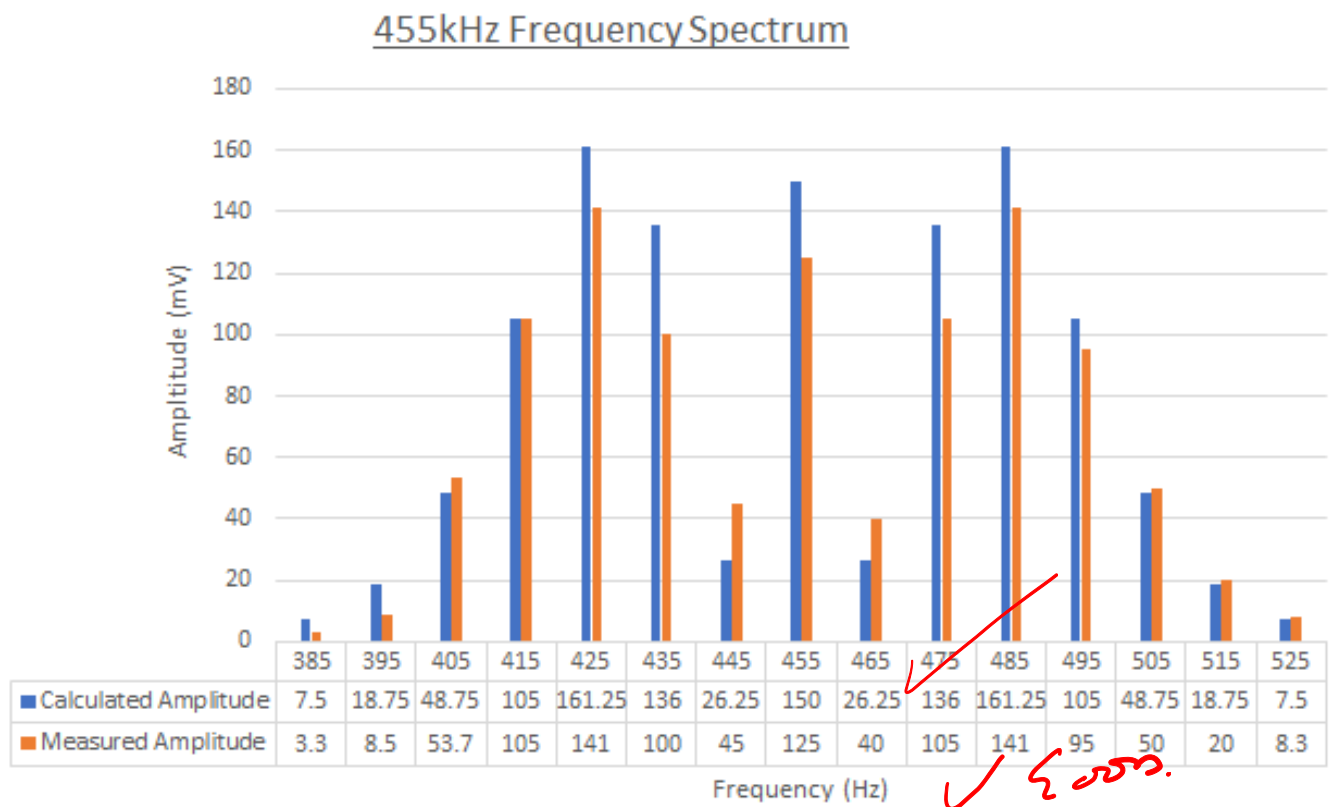


Figure 13 - Physical 455kHz Spectrum - Calculated Vs Physical Comparison Graph

Isolating the differences in the central and sideband frequencies, shows how the central frequency as well as the steps between the sidebands are also wider than calculated.

455kHz Frequency Spectrum - Frequency Comparison		
Calculated	Physical	Δ Difference
385	379.4	5.6
395	390.0	5
405	401.87	3.13
415	412.5	2.5
425	423.75	1.25
435	434.375	0.625
445	445.625	-0.625
455	456.875	-1.875
465	468.125	-3.125
475	479.375	-4.375
485	490.00	-5
495	501.25	-6.25
505	512.5	-7.5
515	523.125	-8.125
525	535	10

Figure 14 - Physical 455kHz Spectrum - Frequency Comparison Table

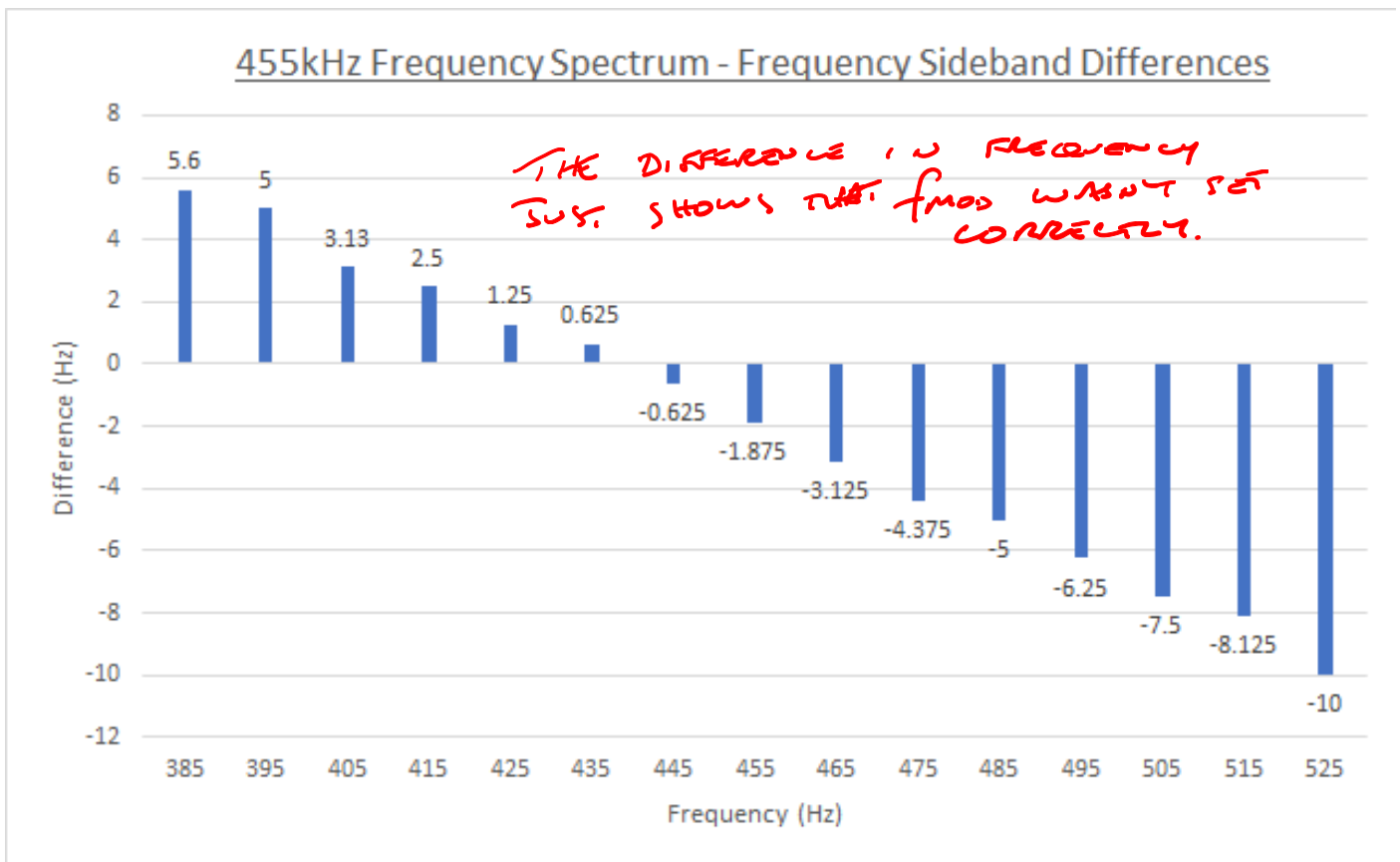


Figure 15 - 455kHz Frequency Spectrum - Calculated Vs Physical - Frequency Comparison Graph

The following table also shows the differences in amplitude for each sideband frequency.

455kHz Frequency Spectrum - Amplitude Comparison		
Calculated	Physical	Δ Difference
7.5	3.3	4.2
18.5	8.5	10
48.75	53.7	-4.95
105	105	0
161.25	141	20.25
136	100	36
26.25	45	-18.75
150	125	25
26.25	40	-13.75
136	105	31
161.25	141	20.25
105	95	10
48.75	50	-1.25
18.5	20	-1.5
7.5	8.3	-0.8

Appendix .

Figure 16 - Physical 455kHz Spectrum - Amplitude Comparison Table

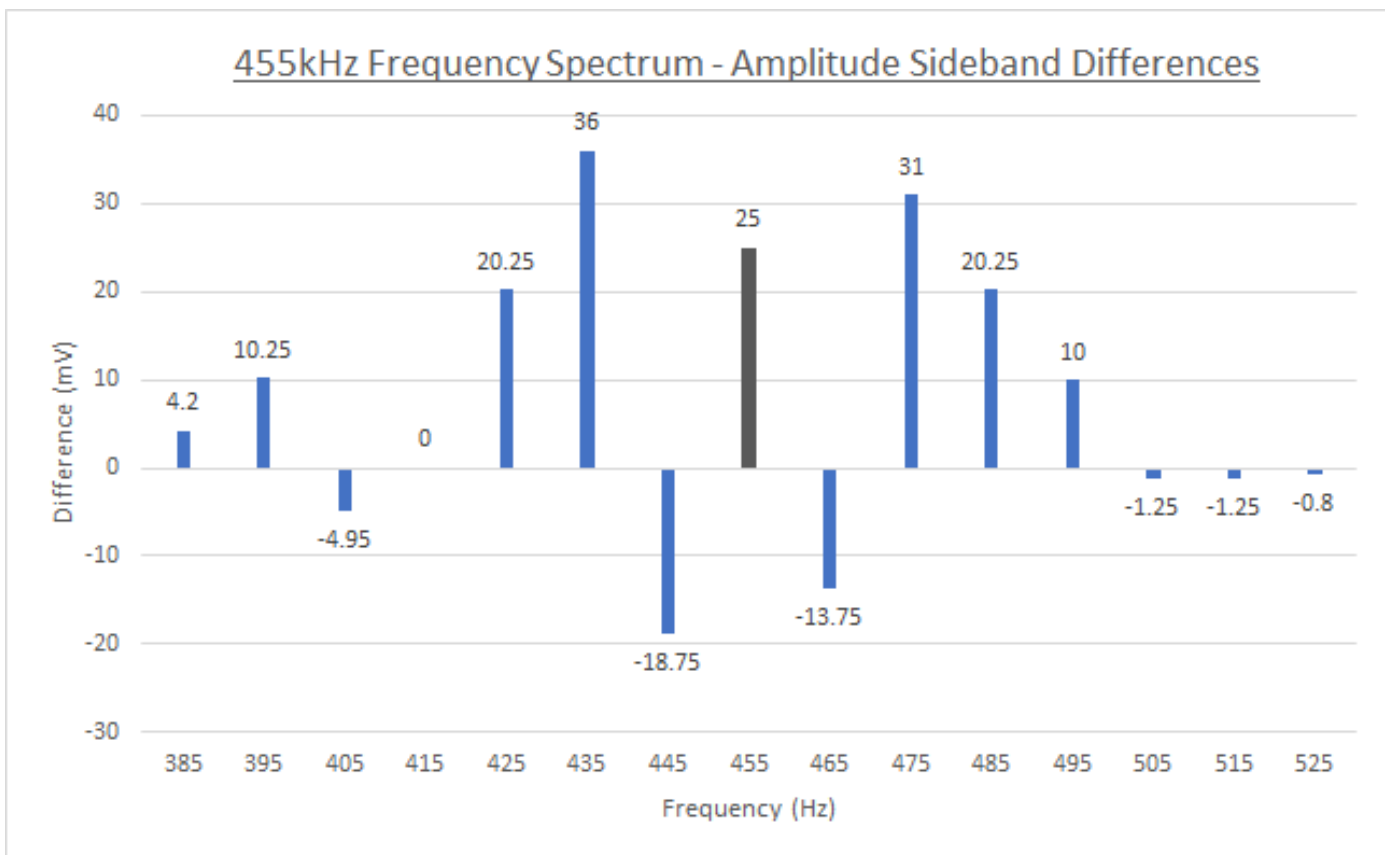


Figure 17 - 455kHz Frequency Spectrum - Calculated Vs Physical - Amplitude Comparison Graph

Analysis:

The spectrum analyser results from the Picoscope software are slightly different from the calculated results due to the fact that the sine wave produced by the carrier hardware was not perfectly clean and uniform sinusoidal in nature. This difference in waveform shape affects the overall frequency spectrum results.

Although the general spectrum analyser waveform shapes were somewhat matching, the individual amplitude of the sideband frequencies were noticeably different than calculated figures. Possible explanation could include a lower carrier amplitude which would result in lower sideband voltages.

The physical spectrum analyser also shows that the central carrier frequency wasn't perfectly matched to the requested 455kHz frequency calculation, which would then result in bigger frequency steps between the sidebands and offset amplitude peaks, which is what was evident in the analysis.

Other factors in the difference between calculated and physical results rely on the assumption that the 455kHz waveform is a perfect frequency waveform with no frequency deviation. As this waveform is produced by an electronic device, then the waveform would result in interference as well as harmonic frequencies/'jitter' that exist on the produced frequency.

✓✓ Good.

5. Experimental Method for experiment 2

To test the capabilities and performance of 4 bit and 8 bit ADCs, a test rig featuring an ADC with the following specifications:

Sample rate = 10,000 samples/second and Range = 5Vp-p

Using a frequency generator, able to produce a variation of voltages, frequencies and offsets, if required.

Tests to be carried out:

- Increase Frequency and observe/record output
- Increase Amplitude up to and beyond the 5V limit and observe/record output
- Measure Quantisation Level

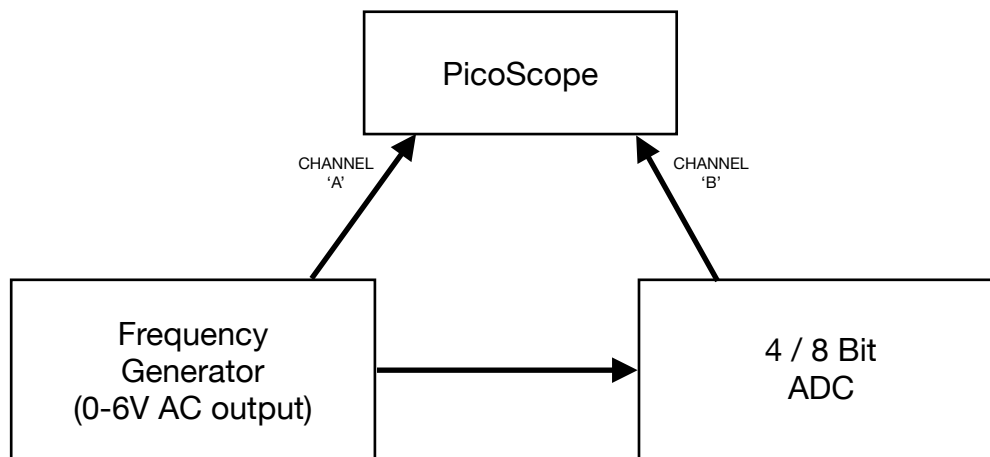


Figure 18 - Analog > Digital Convertor - Circuit Setup



Figure 19 - Analog > Digital Convertor - Test Bench Setup

Quantisation Levels:

To calculate the maximum possible quantisation levels that can be produced by the 4 and 8 bit ADC configuration, the following calculations can be carried out:

4 Bit ADC:

A 4 Bit output equates to a possible 16 binary number.

$$4 \text{ Bit Quantisation Step (V)} = \frac{ADCM_{ax}V}{2^n}$$

Where n = No of Bits of ADC

$$= \frac{5V}{2^4}$$

$$= \frac{5V}{16}$$

= 0.3125V per step available

8 Bit ADC:

An 8 Bit output equates to a possible 256 binary number.

$$8 \text{ Bit Quantisation Step (V)} = \frac{ADCM_{ax}V}{2^n}$$

Where n = No of Bits of ADC

$$= \frac{5V}{2^8}$$

$$= \frac{5V}{256}$$

= 0.0196V per step available

The difference between the 4 bit and 8 bit quantisation steps means that there is a 16x increase in accuracy due to the decreased voltage steps between each quantisation level.

Because of the increase in the number of available quantisation steps, then the ADC is able to convert with a greater accuracy of amplitude as it can detect and reflect any voltage differences across a 0.0196V increase in voltage in an 8 bit ADC against a 0.3125V increase for 4 bit ADC.

6: Testing, results and analysis for experiment 2

Using a 100Hz @ 4V p-p input signal into the ADC convertor set to '4 bit', the digitally reconstructed waveform is shown as below:

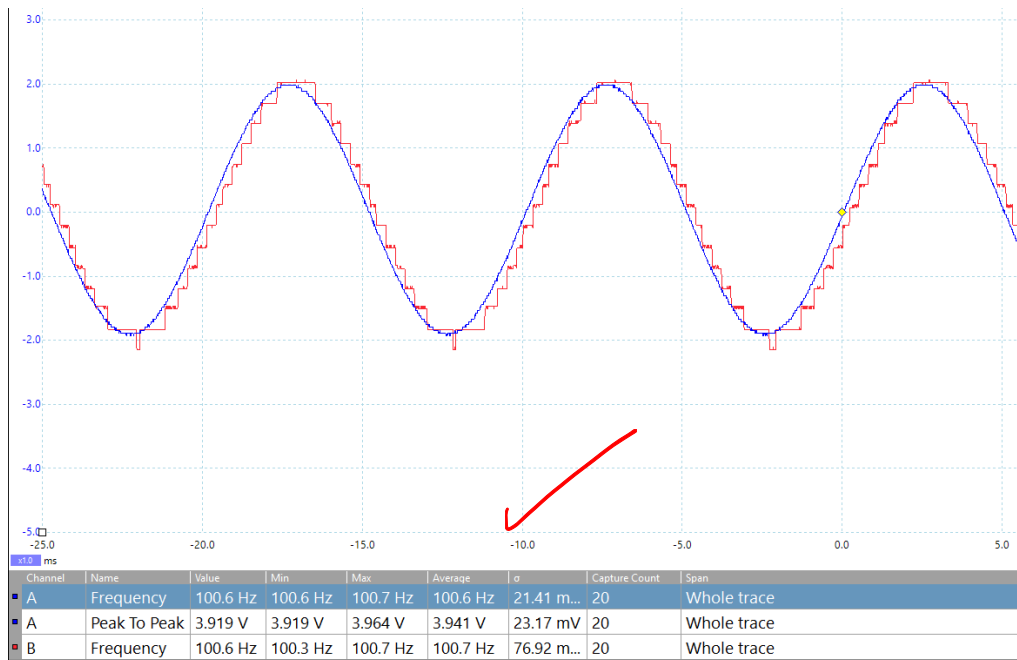


Figure 20 - 100Hz / 4V peak-peak Input - 4 bit ADC Output

Changing the ADC convertor to '8 bit', the digitally reconstructed waveform is shown as below:

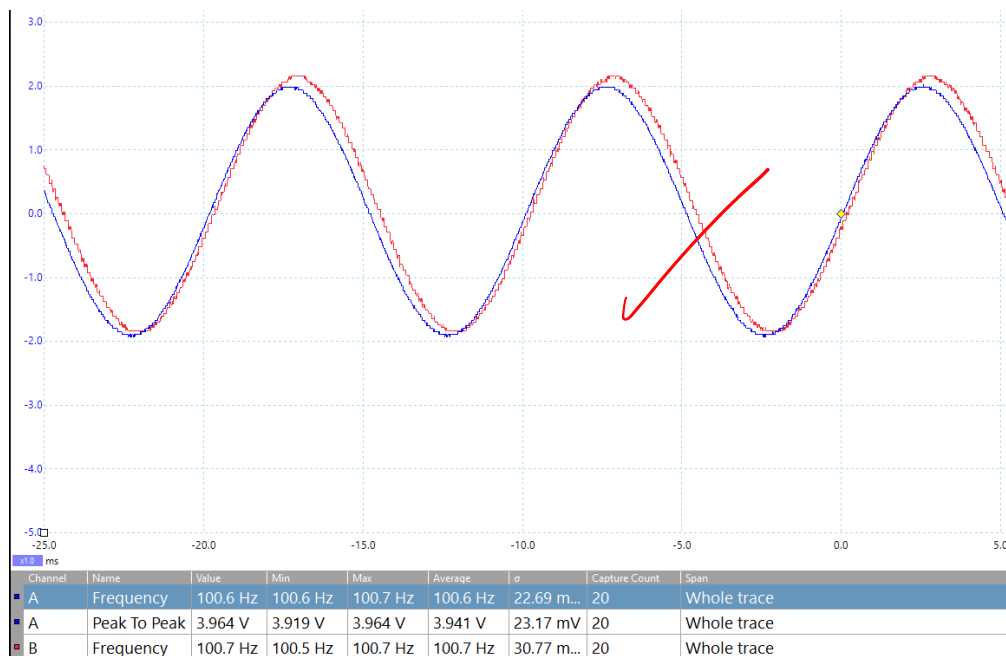


Figure 21 - 100Hz / 4V peak-peak Input - 8 bit ADC Output

With the ADC convertor set to 8 bit, the output has been reconstructed with a more accurate representation of the pure sine wave. This is achieved with a much higher bitrate (8 bit vs 4 bit) with more complex data can be created and transmitted. With a 5V ADC 'max' limit, a 4 bit conversion only equates to 16 decimal numbers, or quantisation steps available compared with 256 for an 8 bit conversion.

Changing the input amplitude for a 4 bit ADC:

With the ADC set at 4 Bit output and a 100Hz input, the amplitude was raised slowly from 0V to 6V p-p, observing the output ADC waveform:

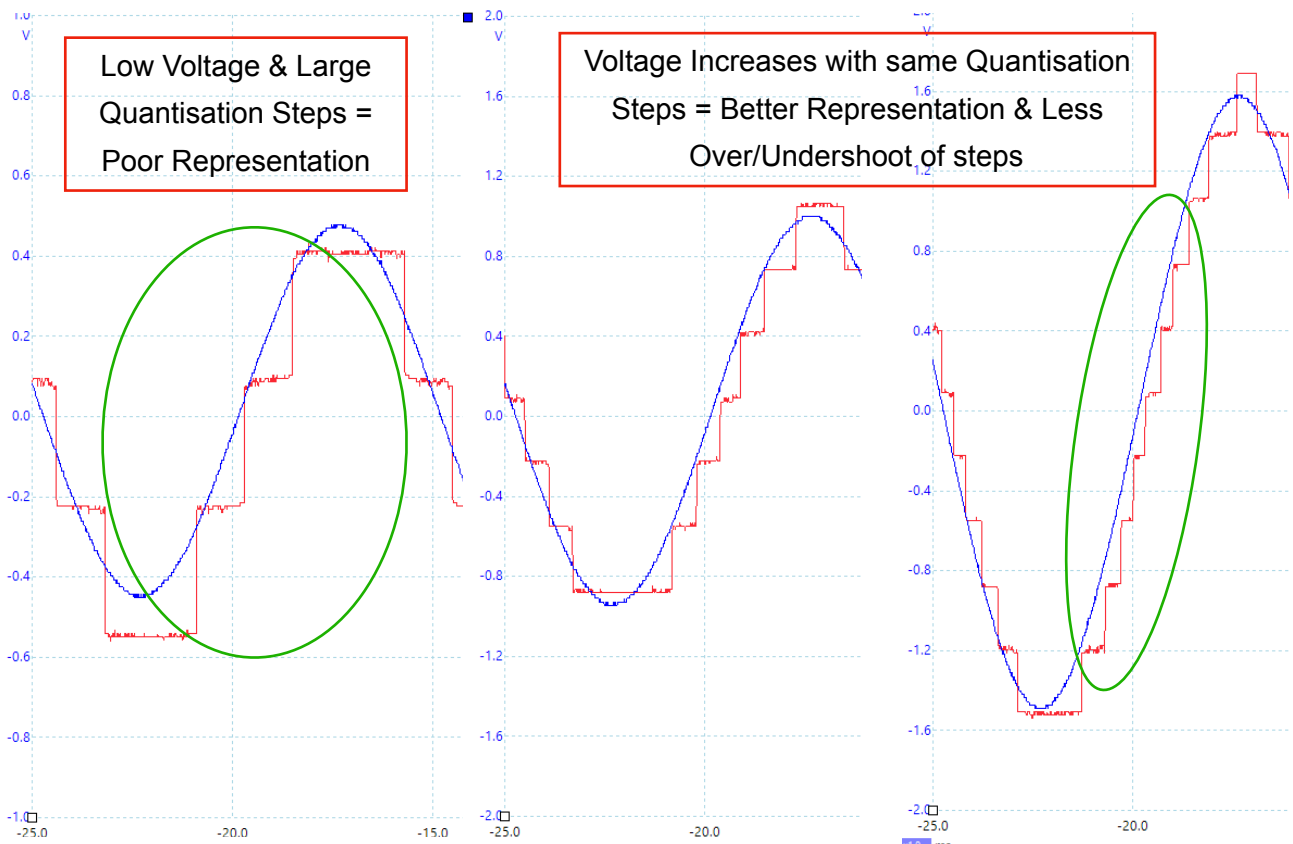


Figure 22 - 100Hz / 1V & 2V & 3V peak-peak Input - 4 Bit ADC Output

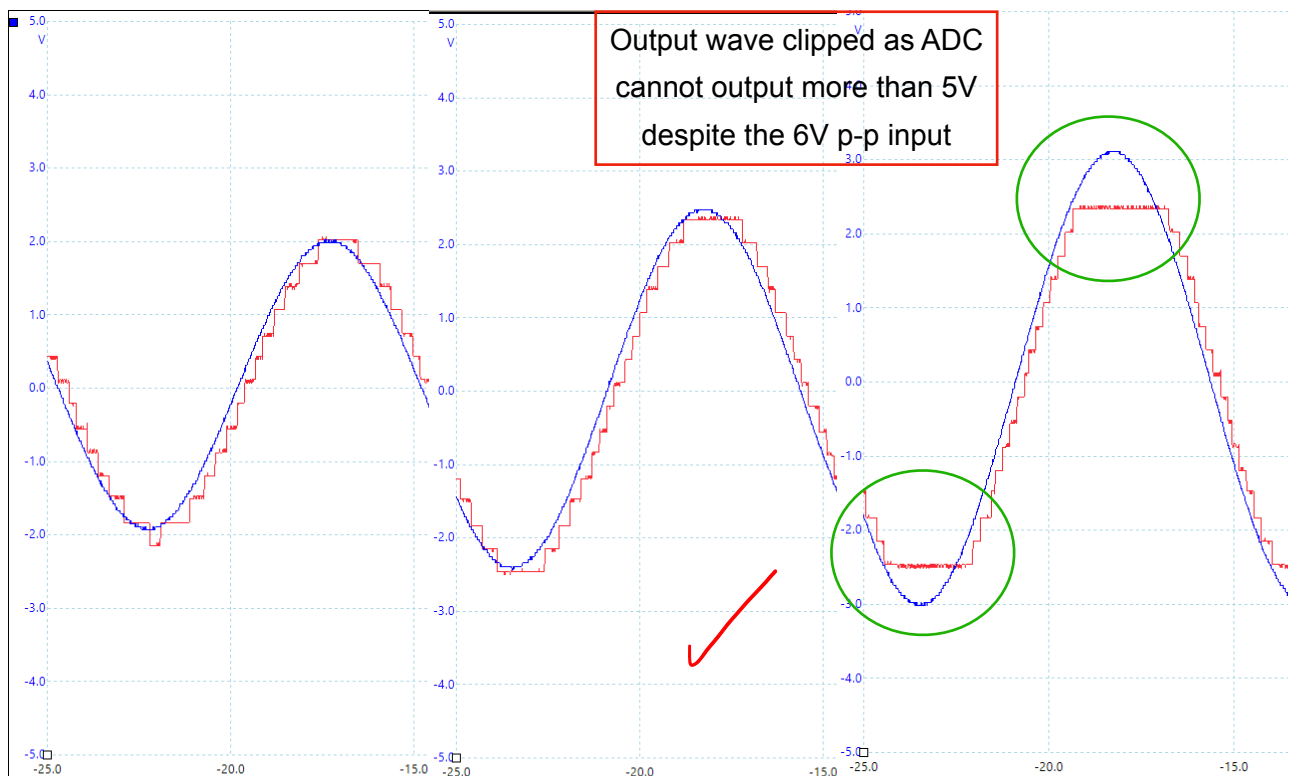


Figure 23 - 100Hz / 4V & 5V & 6V peak-peak Input - 4 bit ADC Output

As the amplitude increased from 0V to 6V, the ADC convertor 'creates' more quantisation levels according to the bit conversion selected. In this case, with 4 bit selected, a new quantisation level is created when the input signal rises every 0.312V or 312mV p-p.

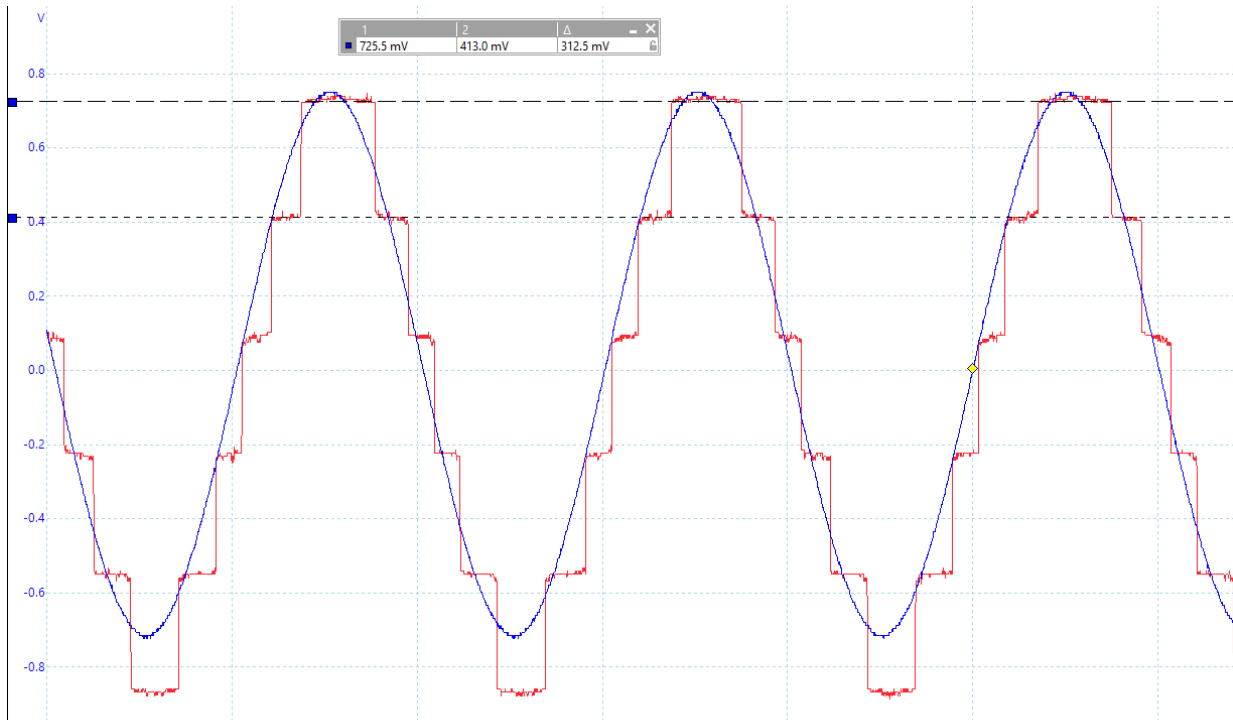


Figure 24 - 100Hz / 4V peak-peak Input - 4 bit ADC Output - Quantisation Level Measurement

The above figure shows a physical measurement of 312.5mV against a 312.5mV calculated measurement.

To confirm the calculated and measured quantisation steps, which proves an effective 4 bit ADC conversion, a simple table calculating the quantisation steps against the input voltage can be formed which should create the required amount of steps.

$$\text{No of Quantisation Steps} = \frac{\text{Input}(p - p)\text{Voltage}}{0.312}$$

Quantisation Steps - 4 Bit ADC		
Input Voltage (V)	Calculated	Actual
0.937	3.003	3
1.953	6.2596	6
3.074	9.852	10
3.964	12.705	13
4.916	15.756	15
6.128	19.64	15

Figure 25 - Quantisation Comparison Table - 4 bit ADC Output

Changing the input amplitude for an 8 bit ADC:

With the ADC set at 8 Bit Output, and a 100Hz input, the amplitude was raised slowly from 0V to 6V p-p, observing the output ADC waveform:

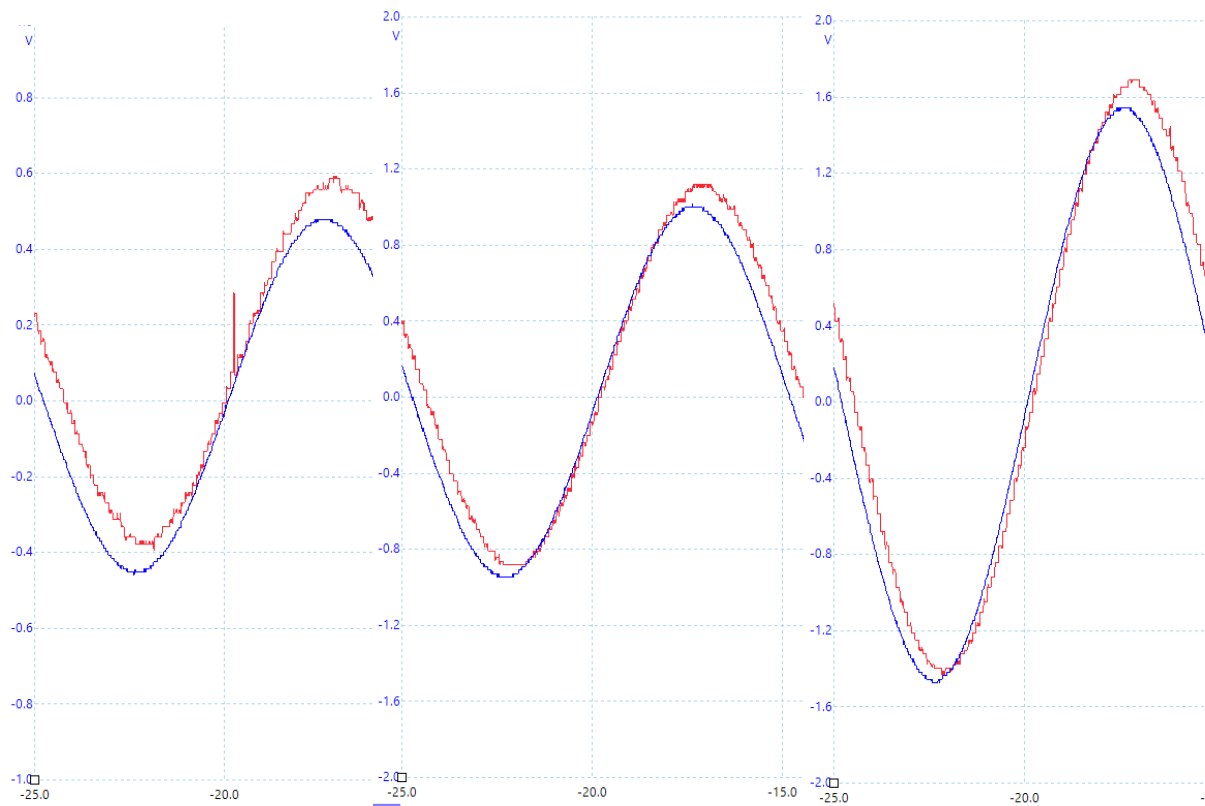


Figure 26 - 100Hz / 1V & 2V & 3V peak-peak Input - 8 Bit ADC Output

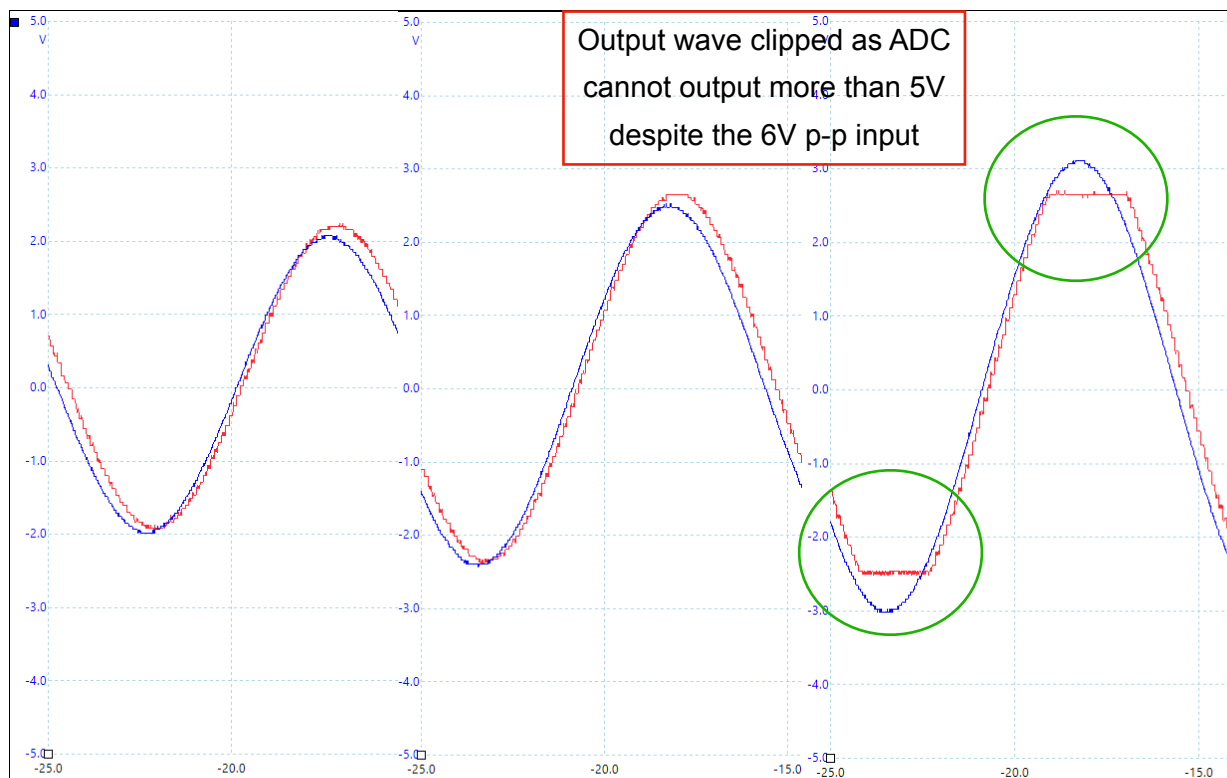


Figure 27 - 100Hz / 4V & 5V & 6V peak-peak Input - 8 bit ADC Output

As the amplitude increased from 0V to 6V, the ADC convertor 'creates' more quantisation levels according to the bit conversion selected. In this case, with 8 bit selected, a new quantisation level is created when the input signal rises every 0.0196V or 19.6mV p-p.

The wave forms shows that the ADC convertor is only capable of a 0-5V input, hence the output wave form has been clipped to a maximum peak-peak of 5V despite the increase of the input voltage amplitude to 6V.

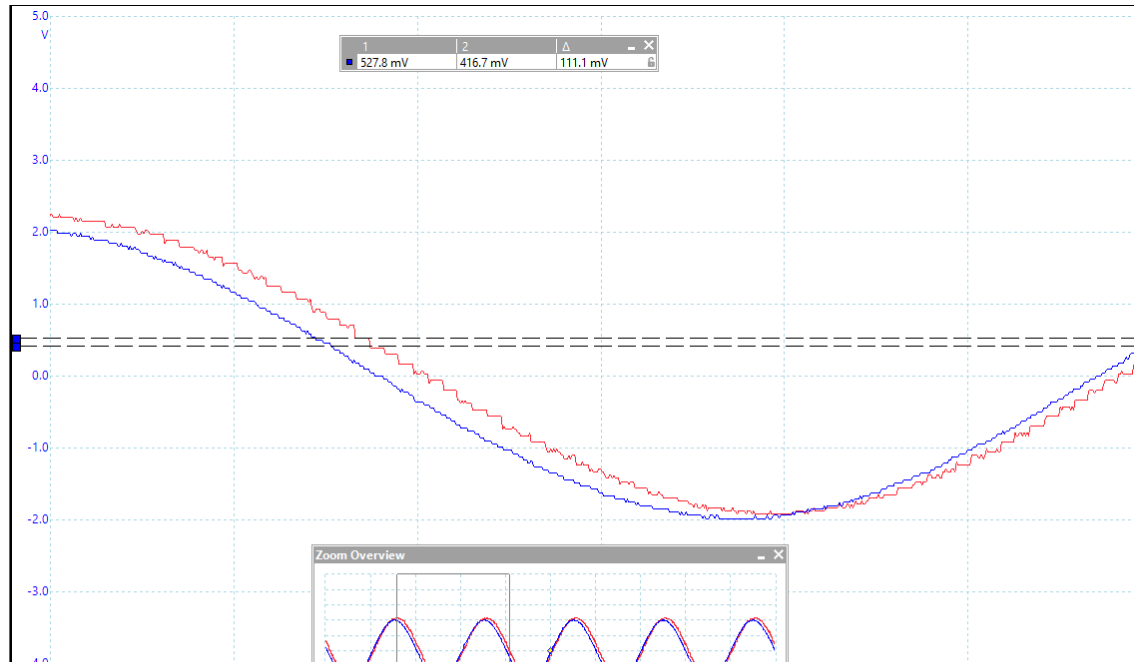


Figure 28 - 100Hz / 4V peak-peak Input - 8 bit ADC Output - Quantisation Level Measurement

The above figure shows a measurement of 111mV against a 19.6mV calculated measurement. This is most likely due to a lower/slower sampling rate of the ADC being 10kHz against a required sampling rate of 25kHz to achieve the 19.5mV quantisation level steps at the point where the voltage is changing the fastest (steepest part of the wave).

$$\text{No of Quantisation Steps} = \frac{\text{Input}(p - p)\text{Voltage}}{0.0196}$$

Quantisation Steps - 8 Bit ADC		
Input Voltage (V)	Calculated	Actual
0.945	48.214	-
1.976	100.81	-
3.031	154.64	-
4.061	207.194	-
4.955	252.806	-
6.126	312.55	-

7
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THIS TABLE.

Figure 29 - Quantisation Comparison Table - 8 bit ADC Output

Changing the input frequency for a 8 bit ADC:

To investigate the 8 bit ADC behaviour when the frequency changes, a 4V p-p voltage was applied, with the frequency ramped up from 1kHz whilst observing the resultant output.

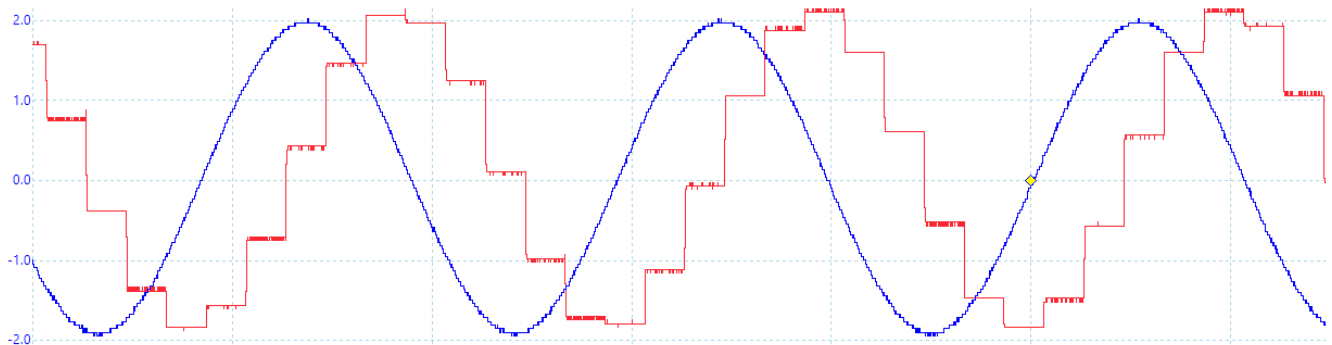


Figure 30 - 1KHz 4V peak-peak Input - 8 bit ADC Output

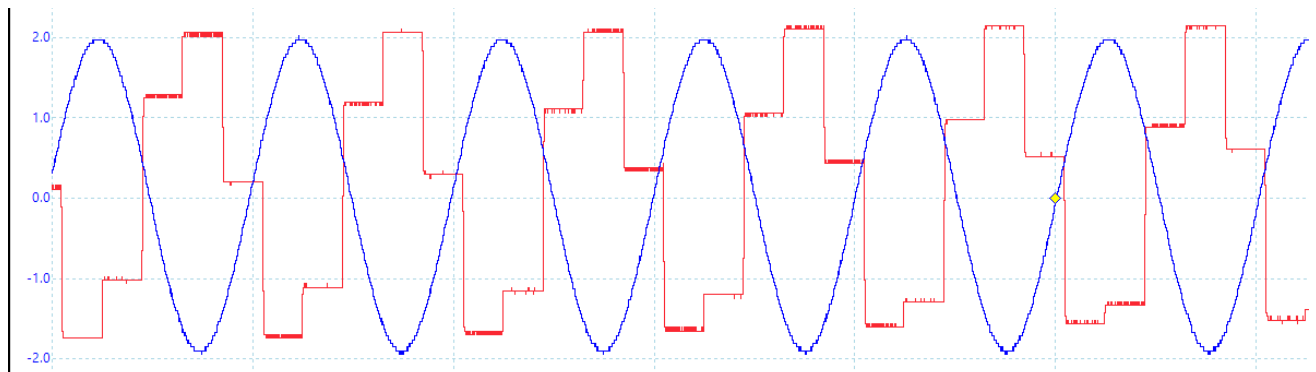


Figure 31 - 2KHz 4V peak-peak Input - 8 bit ADC Output

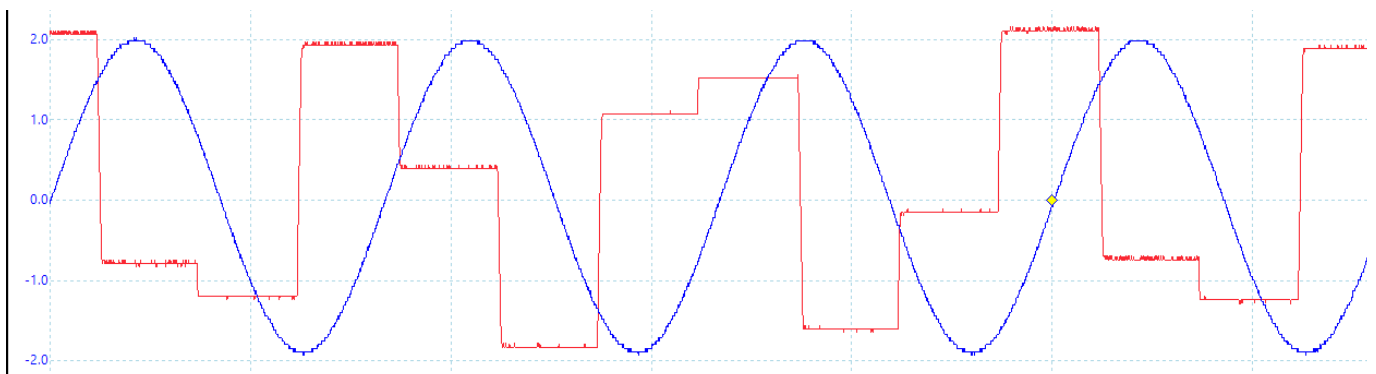


Figure 32 - 3KHz 4V peak-peak Input - 8 bit ADC Output

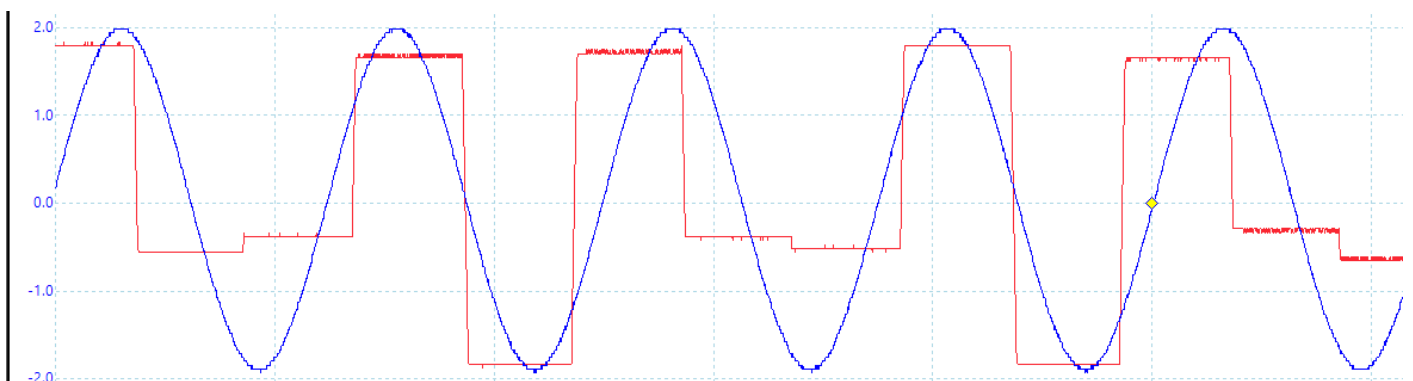


Figure 33 - 4KHz 4V peak-peak Input - 8 bit ADC Output

Assignment - Signals & Modulation

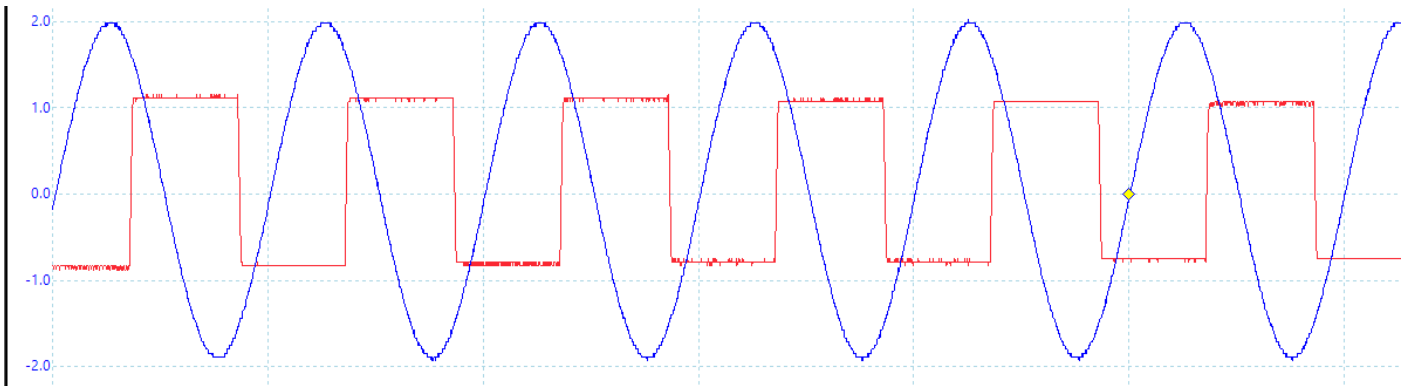


Figure 34 - 5KHz 4V peak-peak Input - 8 bit ADC Output

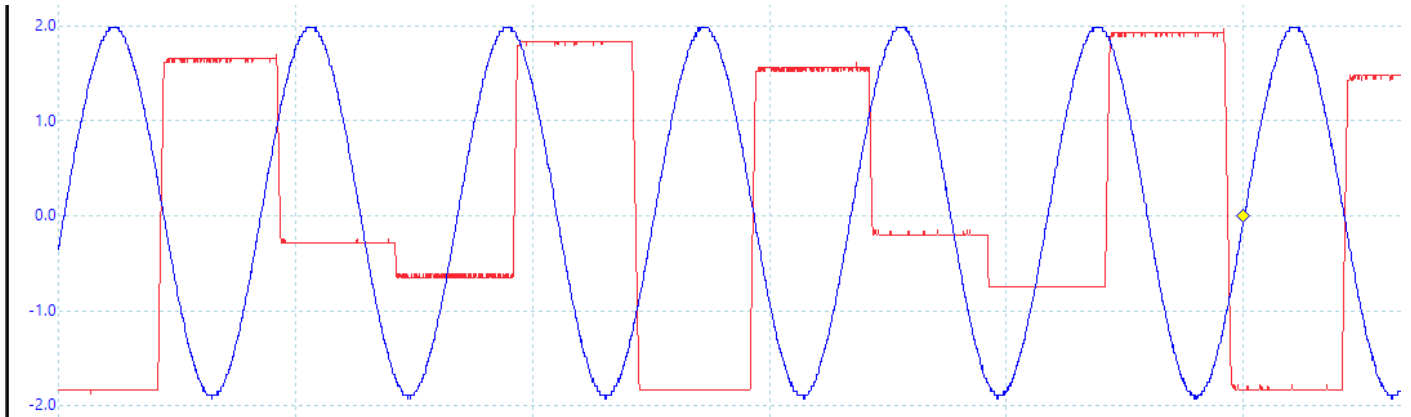


Figure 35 - 6KHz 4V peak-peak Input - 8 bit ADC Output

The results of various frequencies are recorded in the below table, showing the differences between the input and output frequencies, together with the consistency of the output waveform. (See appendix for other frequency waveform captures)

Frequency - 8 Bit ADC			
Input Frequency (kHz)	Output Frequency (kHz)	Δ Frequency (kHz)	Output Frequency Deviation
0.958	0.960	0.002	13.14Hz
1.987	1.986	-0.001	20.68Hz
2.995	3.021	0.026	94.41Hz
3.978	3.997	0.019	116.3Hz
4.19	4.187	-0.003	40.85Hz
4.397	4.375	-0.022	76.44Hz
4.607	4.616	0.009	140.5Hz
4.812	4.726	-0.086	366Hz
5.006	5.00	-0.006	633.1mHz
5.197	4.74	-0.457	317.5Hz
5.397	4.593	-0.804	145.3Hz
5.59	4.368	-1.222	72.17Hz
5.8	4.218	-1.582	45.53Hz

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COLUMN 4 - WHAT
DOES IT MEAN?

Frequency - 8 Bit ADC			
6.021	3.994	-2.027	100.5Hz
7.069	2.984	-4.085	101.3Hz
8.095	1.892	-6.203	57.47Hz
9.01	0.995	-8.015	19.3Hz
10.18	-	-10.18	-

Figure 36 - Input/Output Frequency Comparison Table - 8 bit ADC Output

THE TABLE AND DIAGRAMS ABOVE SHOULD BE IN THE APPENDIX, JUST HAVE THE GRAPH. (HOLE)

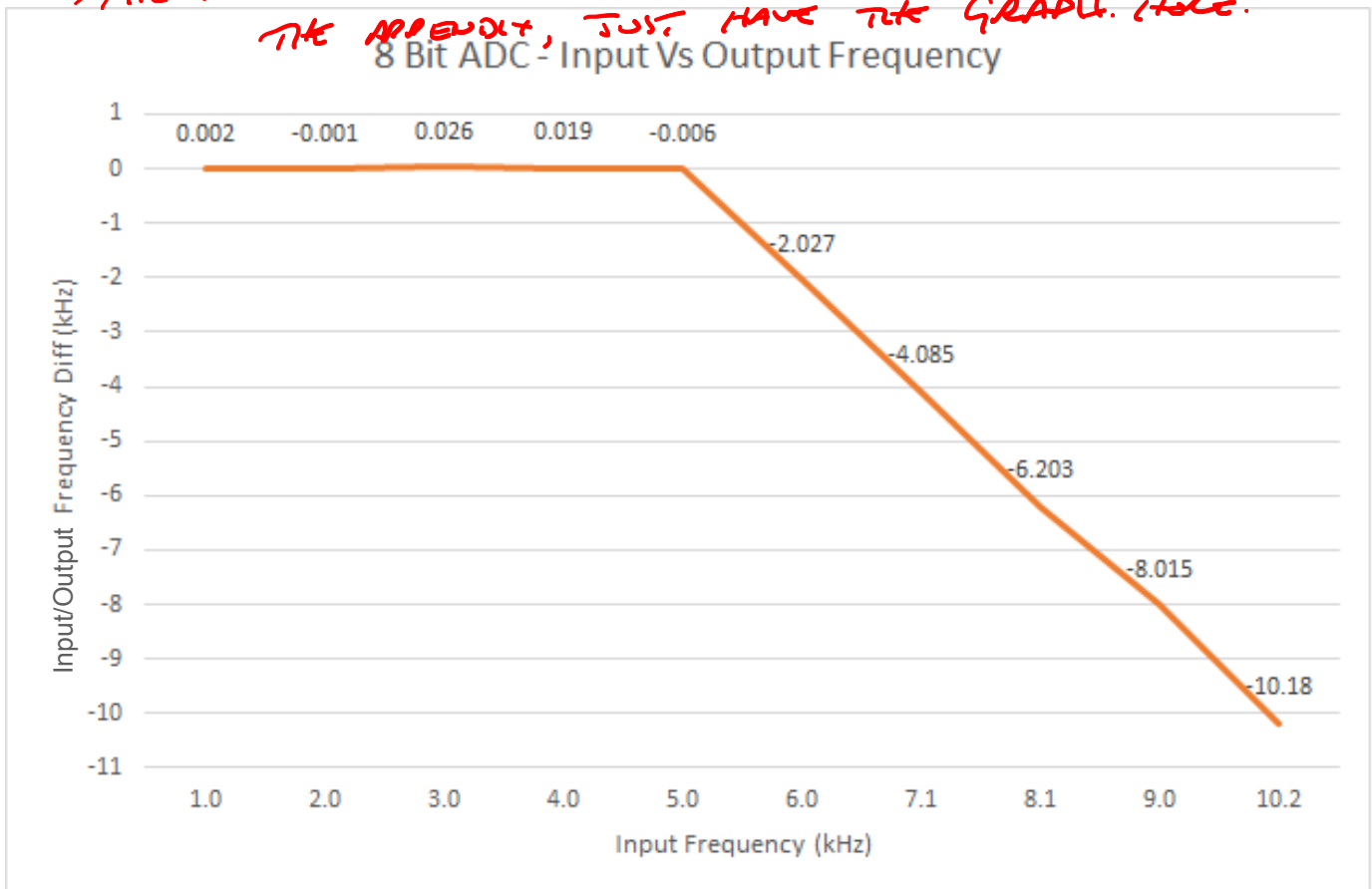


Figure 37 - Input/Output Frequency Comparison Graph - 8 bit ADC Output

Testing Full Range of the 8 Bit ADC:

Frequency Conversion - 8 Bit ADC		
Input Frequency	Output Frequency	Δ Difference
100.6Hz	100.6Hz	0Hz
1.003kHz	1.003kHz	0kHz
10.26kHz	258.5kHz	10.002kHz

Figure 38 - Input/Output Frequency Range Comparison Table - 8 bit ADC Output

Analysis:

The graph shows that beyond 5kHz, the 8 bit ADC is incapable of tracking and re-creating the input frequency.

More over, the waveforms show that the resultant output amplitude starts to oscillate as the sampling frequency is not sufficient to track and create an accurate digitised output frequency. This is due to the sampling frequency ratio limit of 2x is close to the input frequency, and each sampling cycle is only sampling lower parts of the waveform and 'missing the peak', allowing for errors between the input and output.

The graphs prove the nyquist theorem that an ADC with a sampling frequency of at least twice the input frequency is cable of producing a correct output frequency.

As the input frequency raises to the sampling limit of the ADC (10,000 samples/sec or 10kHz) then the waveform shows that the amplitude is around 50% of the input waveform with significant phase shift between the input and output waveforms. This is due to the sampling point picking up on the input waveform as it is increasing and decreasing, which snapshots a lower amplitude output. As long as the frequency matches, this error can be rectified with amplification later in the process.

7. Conclusions And Recommendations

The research and experiments prove that transmission of data is of utmost importance when moving large amounts of data, but the the challenge is transferring that data so that was is received, directly replicates what was sent without the insurance of any sort of errors. The use of ADCs show that a digital signal, converted from an analog source, is much easier to transmit and analyse with the view to remove any errors than purely trying to transmit a purely native analog signal as the voltage is variable than any additions or subtractions are difficult to ascertain whether they are part of the source or unwanted interference.

The use of ADCs convert this signal into a format that has much easier methods to analyse as well as being able to 'stack' through the use of multiplying as the digital signals can be offset in terms of amplitude as well as frequency without comprising on pulse length.

This means that digital signals can be sent and received along the same medium at the same time without relying on a dedicated medium per transmission.

In terms of a 4 bit conversion, although the 10kHz sampling rate was adequate for the large quantisation steps, because there are big voltage steps between quantisation levels, the output waveform does not accurately represent the input sine-wave voltage. Because of the sampling rate and large quantisation steps, this creates undershoot and as well as overshoot in the output waveform compared with the input waveform shape as the ADC requires the input waveform to rise to the next quantisation voltage level.

As a result, correct operation of an ADC requires a sufficient voltage range, the correct bit rate, as well as sampling rate to achieve an accurate 're-representation' of the input signal without too much data transfer, which results in unnecessary bandwidth usage.

When increasing the input frequency into the ADC, the (10,000 samples/sec or 10kHz refresh rate) means that the ADC voltage input limit is 5kHz where the effective zero crossing and peak to peak values can be measured and translated to the output without causing significant errors.

Tests and waveforms show that frequencies near this limit still would not produce a linear amplitude matching the input voltage amplitude as the sampling would synchronise with the input frequency and would pick up on random points throughout the waveform rather than the actual peak to peak value, producing periodic lower amplitude on certain waveforms.

This would conclude that a suitable ADC needs a p-p range that can handle the maximum voltage input as well as a high enough sample to reproduce the input waveform accurately, maintaining the same amplitude without any noticeable deviation in frequency or amplitude of the waveform.

The experiments and research also concludes that if an ADC is to be used, then one with a rated sampling rate should be greater than at least twice the highest frequency of the input signal to be used.

8. Citation list

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9. Appendix

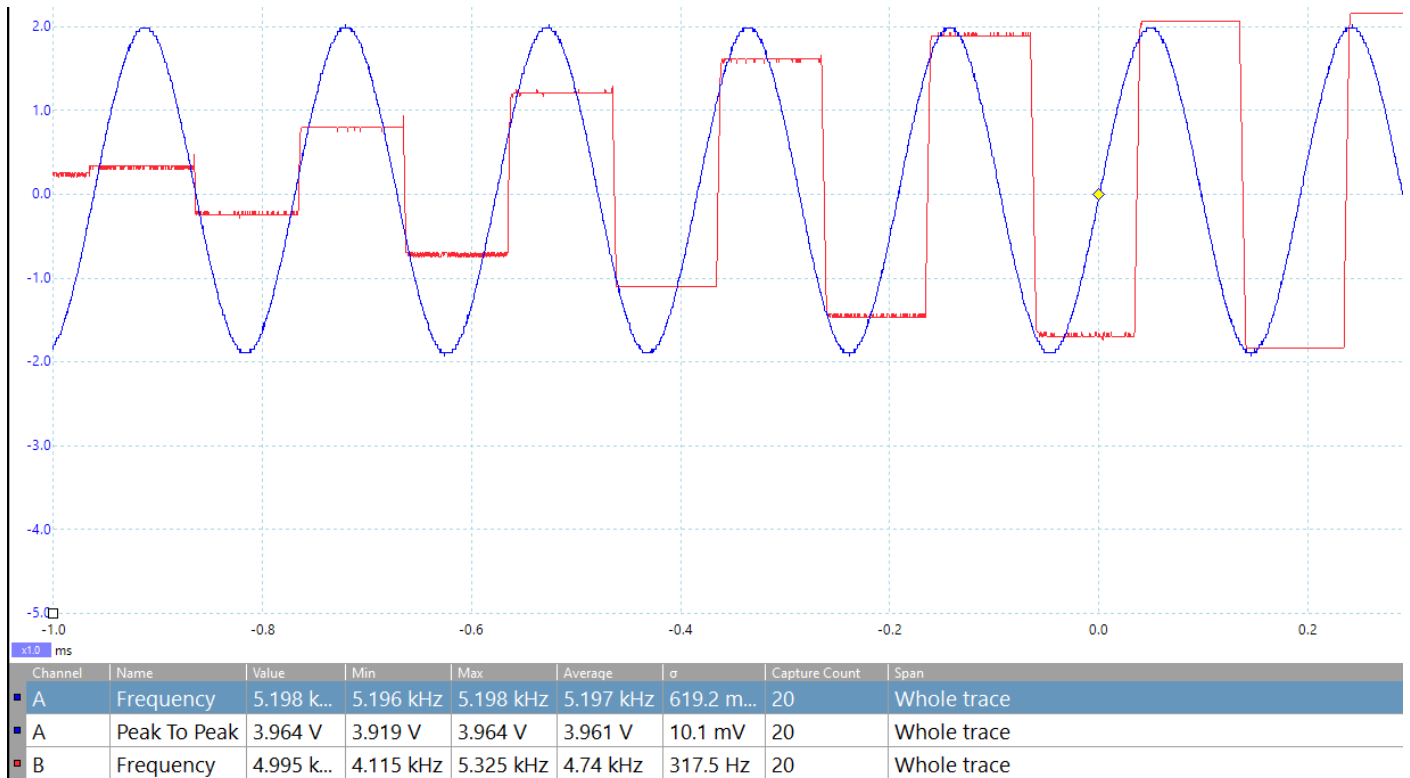


Figure 39 - 5.2KHz 4V peak-peak Input - 8 bit ADC Output

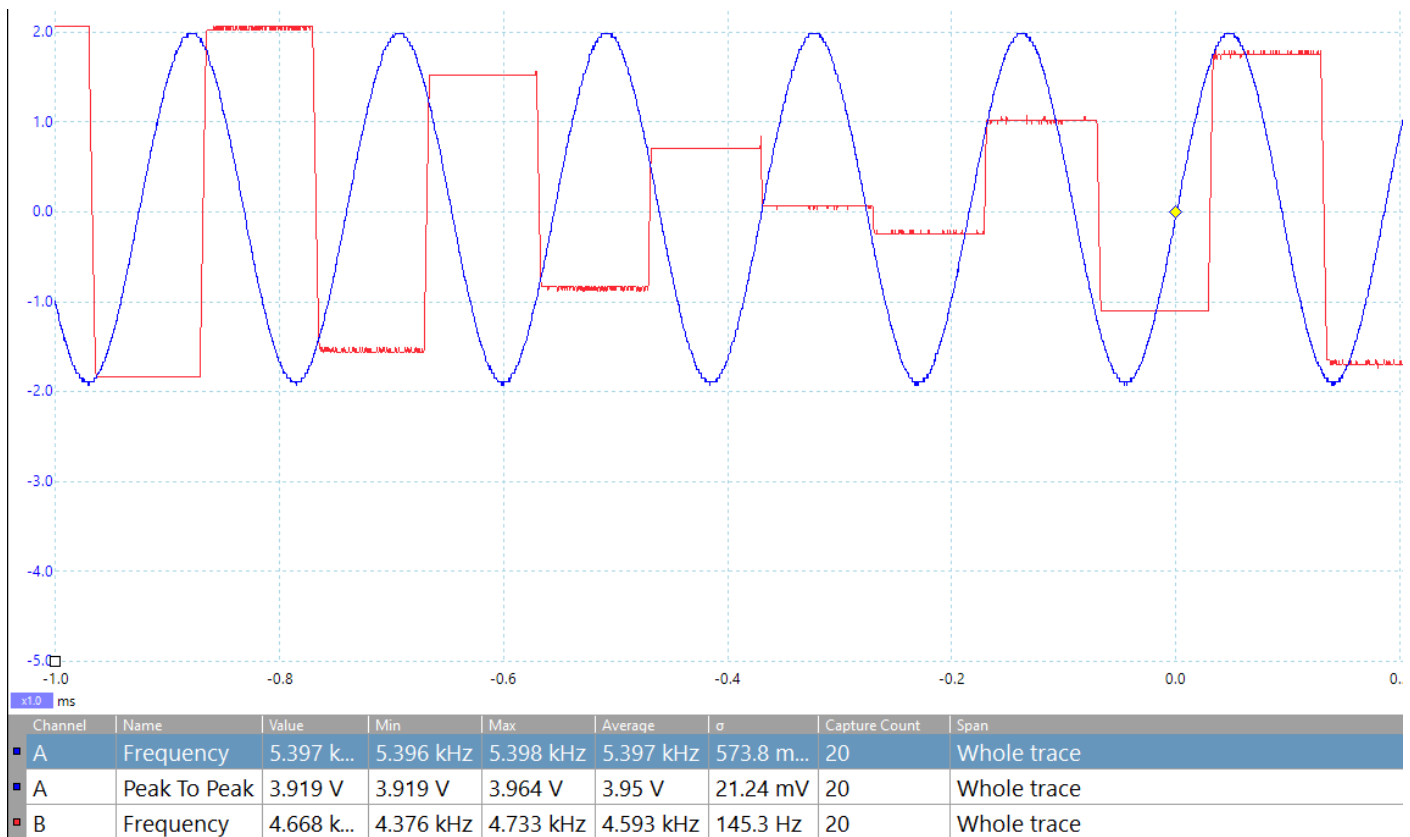


Figure 40 - 5.4KHz 4V peak-peak Input - 8 bit ADC Output

Assignment - Signals & Modulation

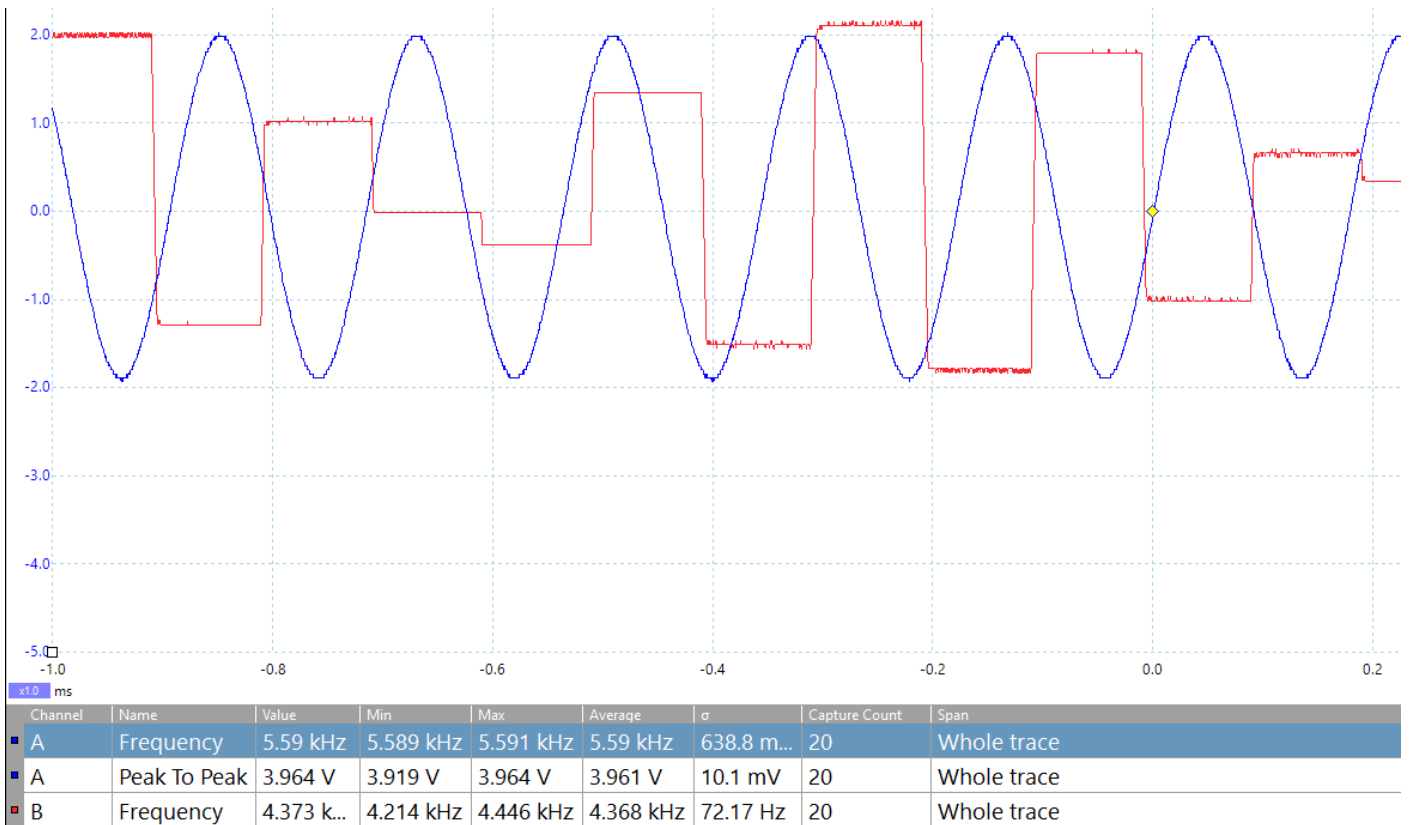


Figure 41 - 5.6KHz 4V peak-peak Input - 8 bit ADC Output

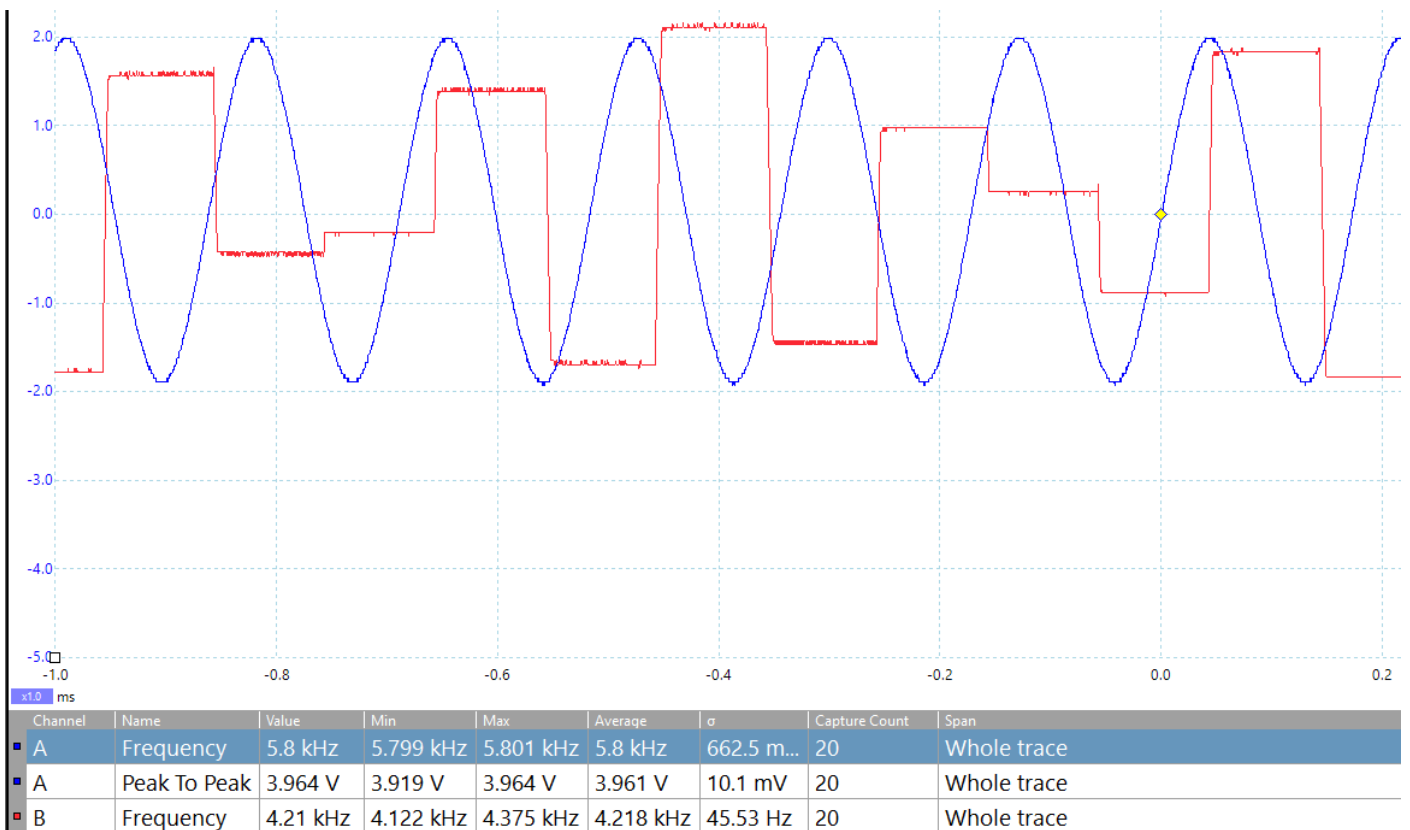


Figure 42 - 5.8KHz 4V peak-peak Input - 8 bit ADC Output

Assignment - Signals & Modulation

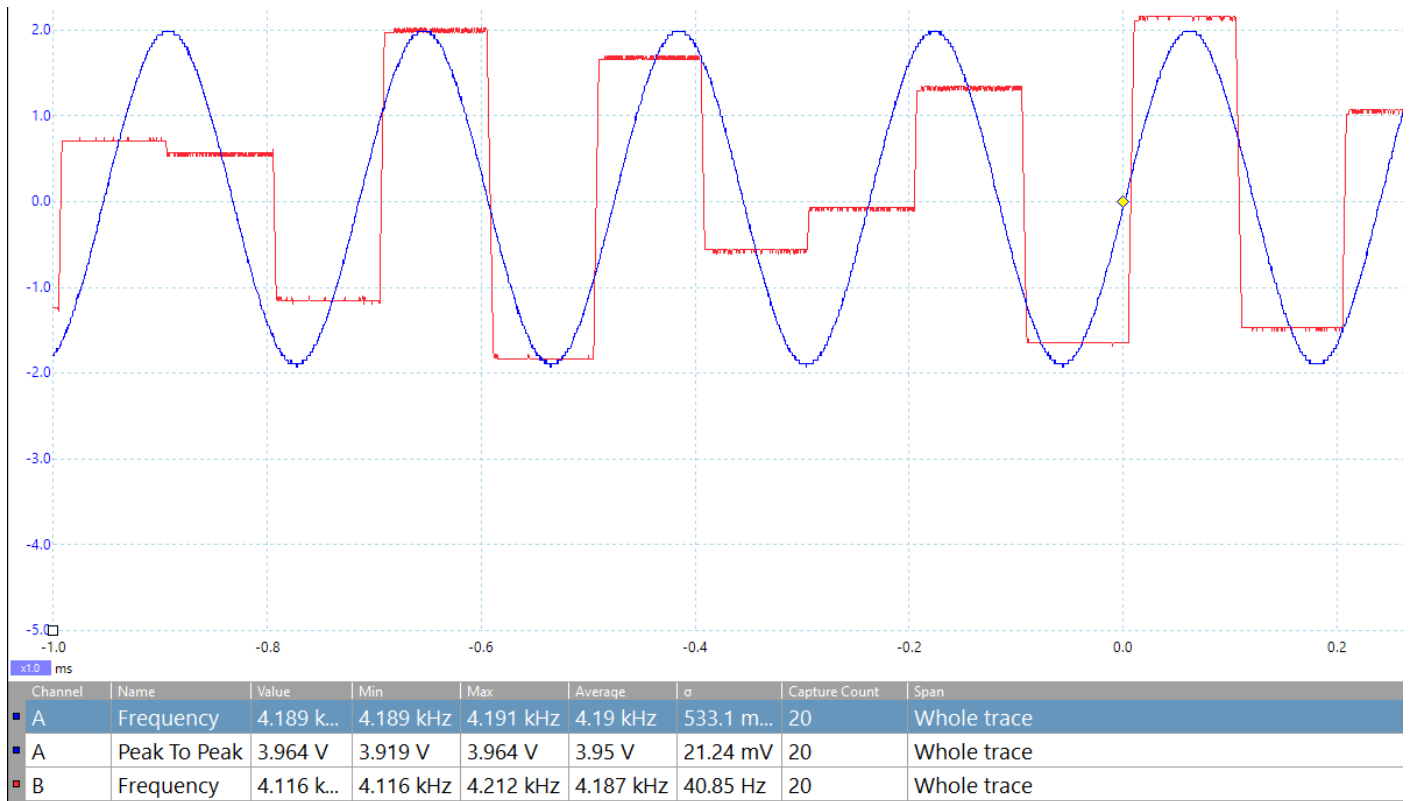


Figure 43 - 4.2KHz 4V peak-peak Input - 8 bit ADC Output

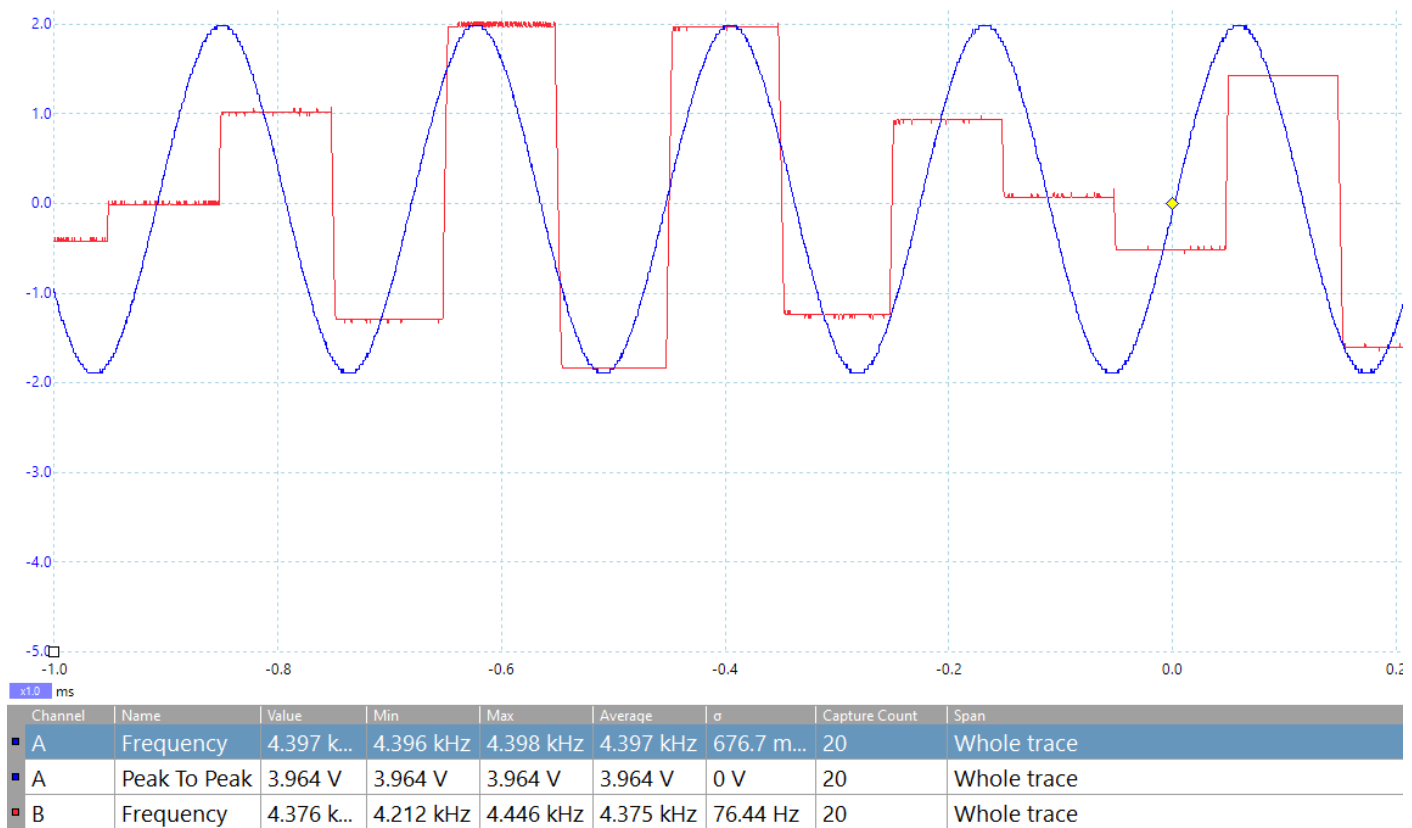


Figure 44 - 4.4KHz 4V peak-peak Input - 8 bit ADC Output

Assignment - Signals & Modulation

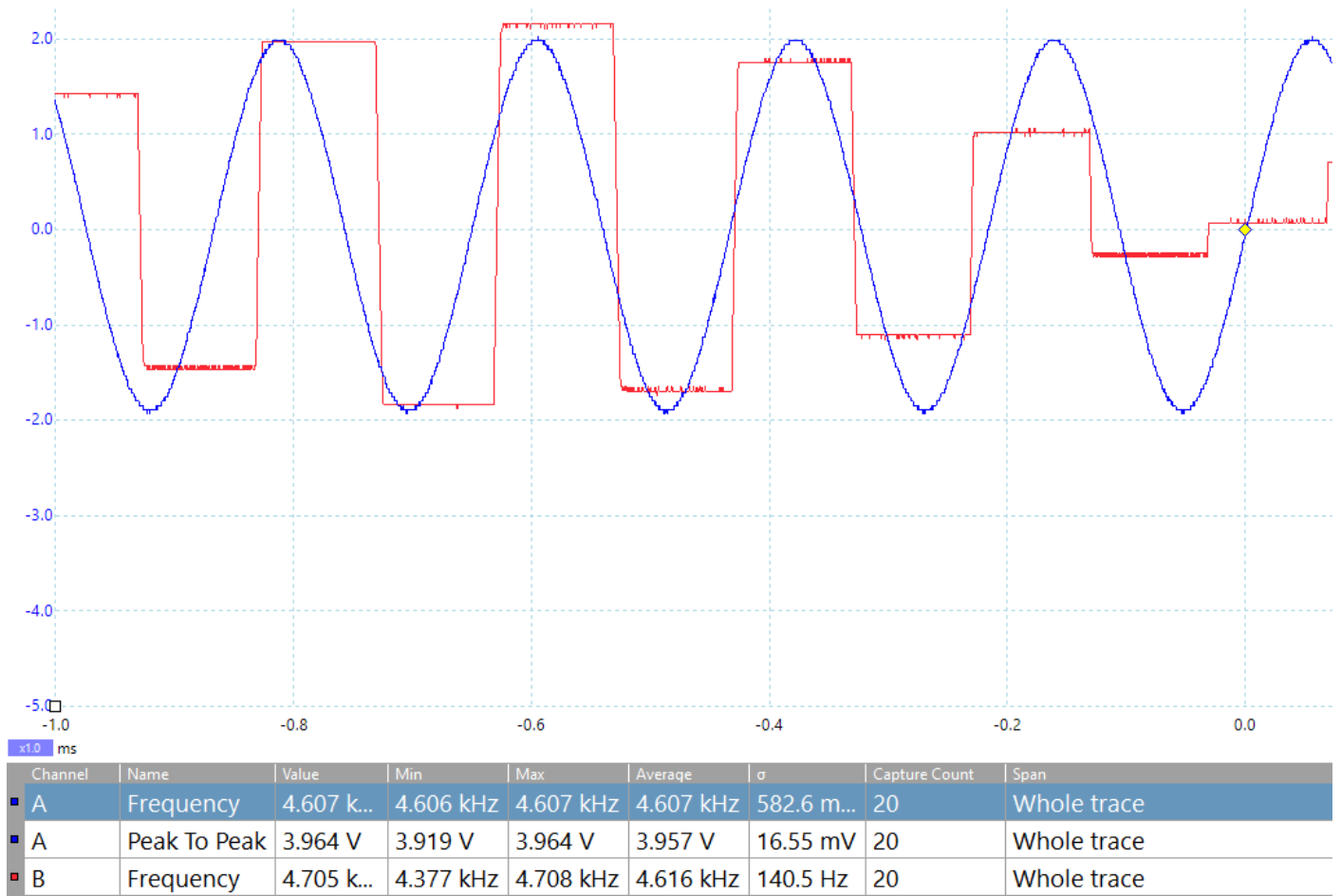


Figure 45 - 4.6KHz 4V peak-peak Input - 8 bit ADC Output

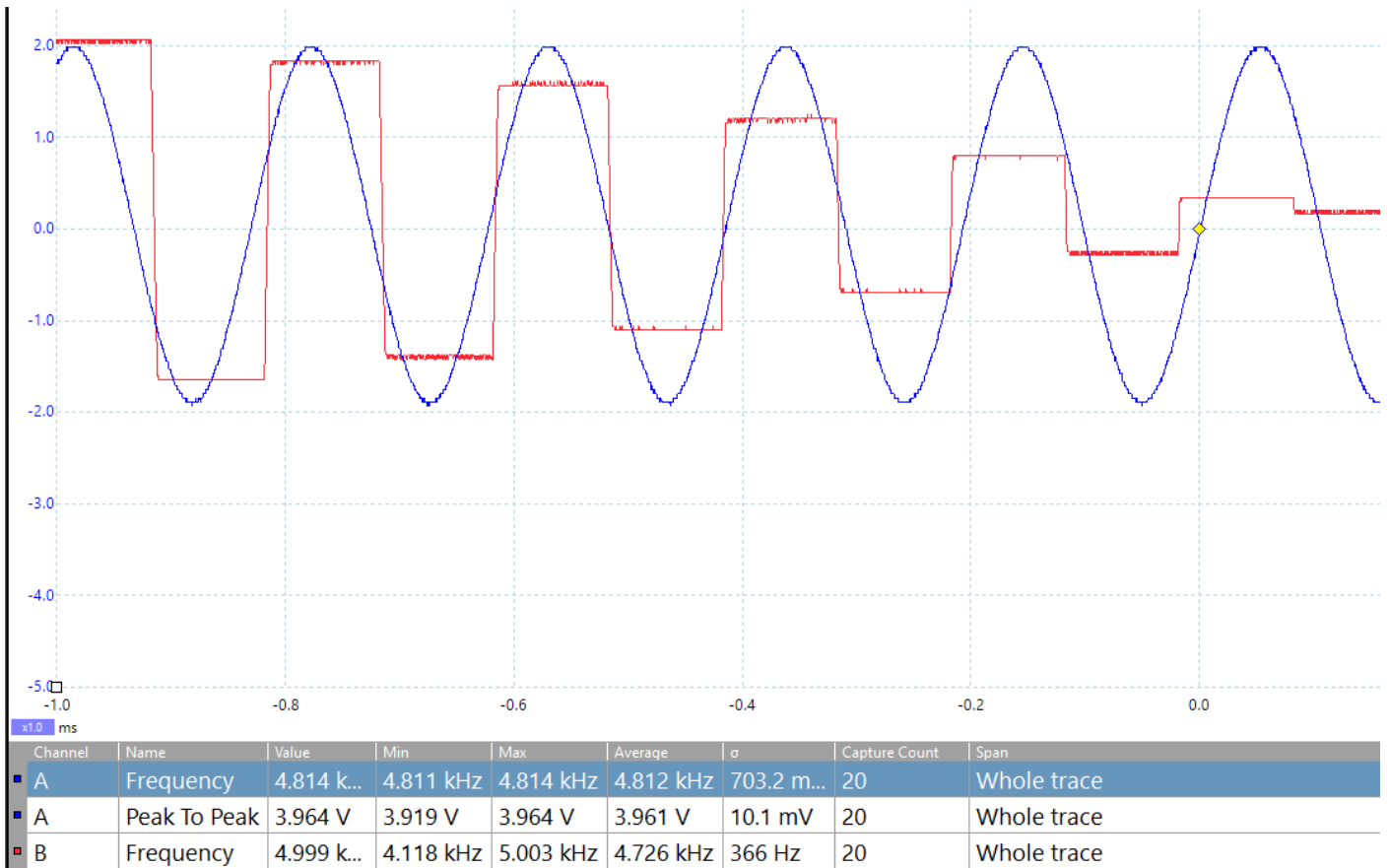


Figure 46 - 4.8KHz 4V peak-peak Input - 8 bit ADC Output

Assignment - Signals & Modulation

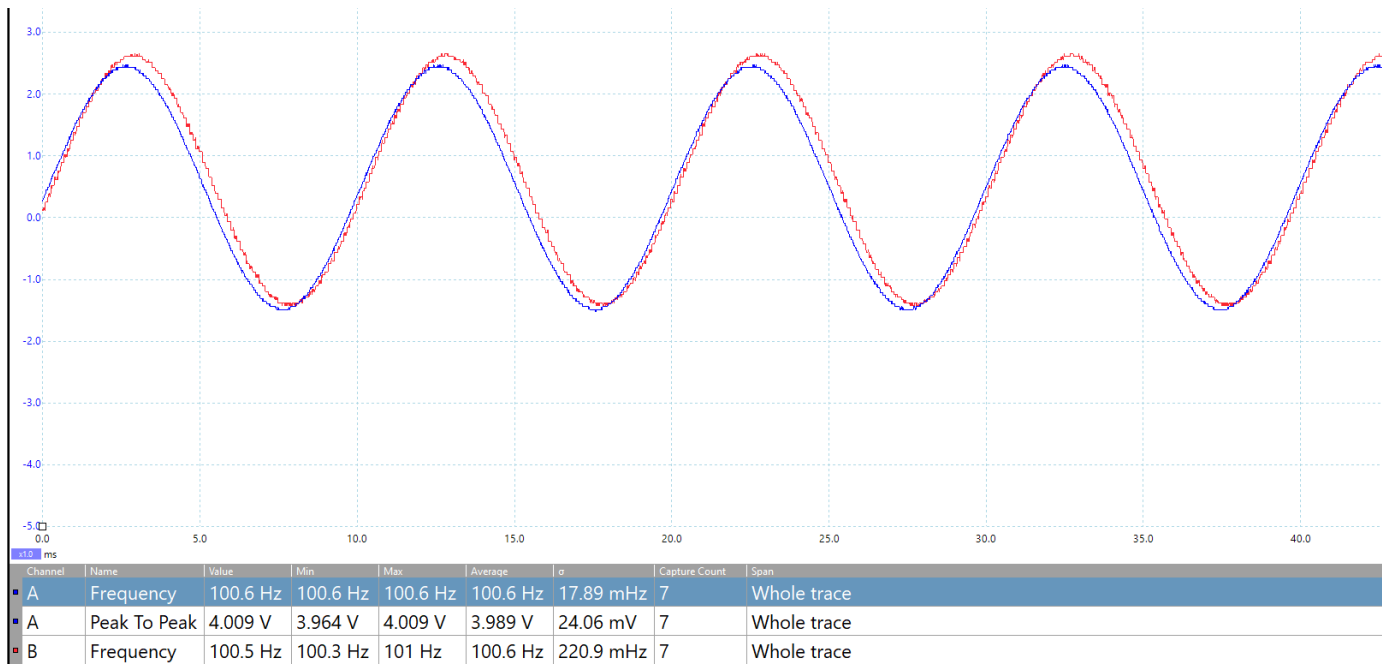


Figure 47 - 100Hz 4V peak-peak Input - 8 bit ADC Output

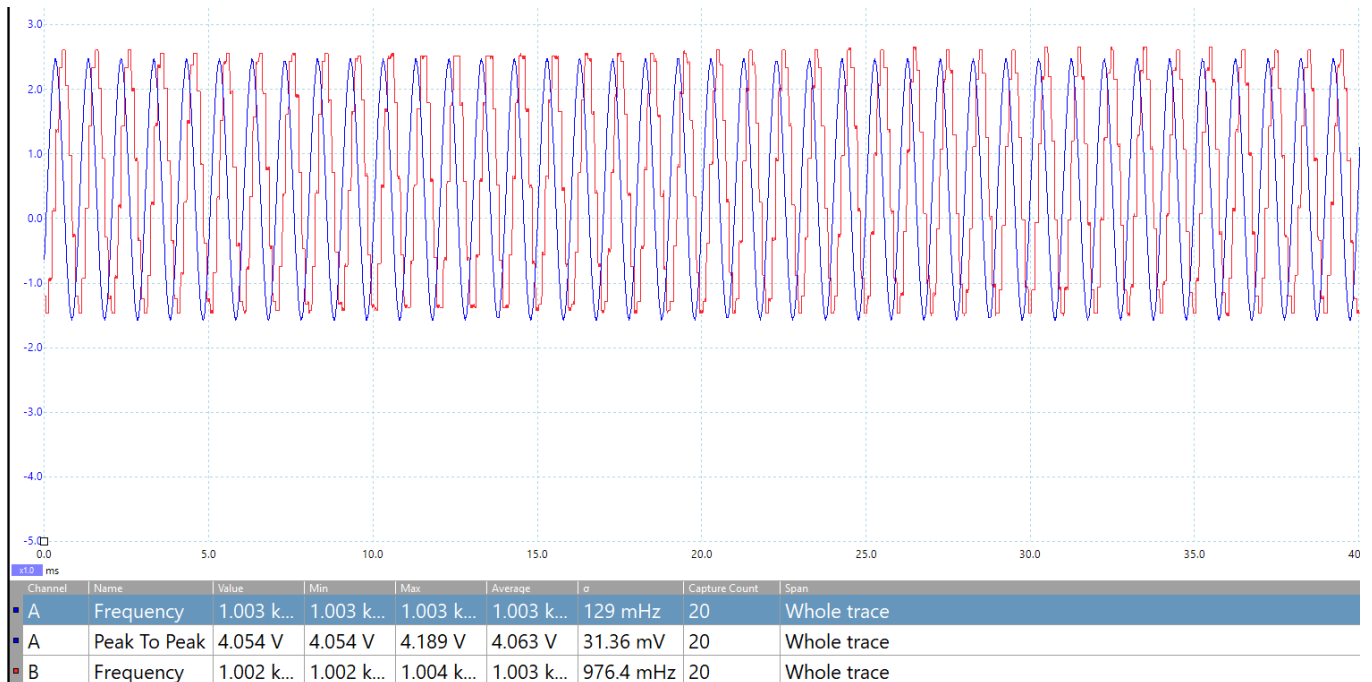


Figure 48 - 1KHz 4V peak-peak Input - 8 bit ADC Output

Assignment - Signals & Modulation



Figure 49 - 10KHz 4V peak-peak Input - 8 bit ADC Output

FINAL GRADE

GENERAL COMMENTS

Instructor

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RHYS DAVIES

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RESEARCH-INFORMED LITERATURE

 There was evidence of extensive further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was very good and demonstrated a deep underlying appreciation of the subject. Your references were consistently applied and appropriate to the task and your reference list was of an appropriate length for this assignment.

8

KNOWLEDGE AND UNDERSTANDING

 The knowledge and understanding of the subject demonstrated by this assignment was generally excellent. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a high degree. You have demonstrated a highly competent critical understanding of the main concepts and expanded your knowledge well beyond that contained in the course notes.

26

ANALYSIS

 Your analysis of the task was excellent, both in class and as shown in this assignment. You have demonstrated highly competent analytical skills and your approach to the task was highly logical. You carried out a detailed evaluation of the results

25

and included an excellent conclusion relating your practical results to accepted theory. You have demonstrated a capacity for independent thought and your interpretation of the quantitative and qualitative data was excellent with sound judgements based on wholly valid arguments.

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally exceptional. You used both the basic and advanced features of the resources appropriately when conducting both experiments and you used appropriate advanced options for testing and evaluating the circuit performance. You managed to evaluate in detail that the circuits functioned within the specification and achieved this by rarely asking for assistance thus demonstrating some advanced problem solving skills. Your results were comprehensive and allowed for a detailed conclusion to be attempted.

18

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was written in a professional and confident style, however you still need to be more efficient with your word count. The report was very well presented, however you need to be more selective with where you put diagrams and graphs, only put those essential for the explanation in the report, the rest can be referred to in the appendix.

8