

1451789

by Joshua Williams

Submission date: 10-Mar-2022 10:20PM (UTC+0000)

Submission ID: 173153792

File name: 17594_Joshua_Williams_1451789_179515_1468196592.pdf (1.45M)

Word count: 4537

Character count: 26639

Course: Bsc Electrical and Electronic Engineering

Module: SGEE5005

Assignment Title: Signals and Modulation

Name: Joshua Williams

University number: 1451789

Date Submitted: 10/03/2022

Word Count: 2718

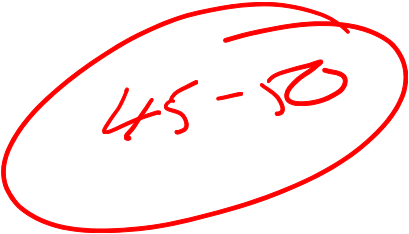
- 
- ① RESEARCH IS A BIT DISTORTED AND LOOKS LIKE A COLLECTION OF CUT-N-PASTE PARAGRAPHS WHICH ARE ONLY LOOSELY CONNECTED.
 - ② BOTH EXPERIMENTS WERE CARRIED OUT AND A BASIC INVESTIGATION CONDUCTED. YOU COULD HAVE USED THE EQUIPMENT TO LOOK DEEPER AT SOME TOPICS.
 - ③ SOME ANALYSIS WAS INCLUDED, BUT YOU MISSED THE COMPARISON OF THEORY/PRACTICAL RESULTS FOR FM.
 - ④ SOME VALID CONCLUSIONS.
 - ⑤ TOO MANY DIAGRAMS IN THE REPORT THAT SHOULD BE IN THE APPENDIX

Table of Contents

Table of Figures	3
1. Executive Summary	4
2. Research into Analogue and Digital Communication Systems and Techniques	5
2.1 Evaluation of Amplitude and Frequency Modulation Techniques	5
2.1.1 Amplitude Modulation Techniques	5
2.1.2 Frequency Modulation Techniques	6
2.2 Evaluation of the Development of Digital Communication Techniques.....	7
2.2.1 Analogue to Digital Converters (ADCs).....	7
2.2.2 PAM and PCM Techniques.....	8
2.2.3 The Digital Communication Synchronous Digital Hierarchy (SDH).....	9
3. Experimental Method for Experiment 1	10
3.1 The Set-up of the Experimental Procedure	10
3.2 Determine the Maximum Frequency deviation and Modulation index	11
3.3 Using a Bessel Table Calculate Required Amplitudes and Produce a Spectrum Wave	11
4. Testing, Results and Analysis for Experiment 1	13
4.1 Practical Activity to Confirm the Calculated Results.....	13
5. Experimental Method for Experiment 2	15
6. Testing, Results and Analysis Experiment 2	16
6.1 Differences between the 4 Bit and 8 Bit Converters.....	16
6.2 The Effect of Changing the Frequency of the Input with Amplitude Held Constant.....	18
6.3 The Importance of Matching the Amplitude of the Input signal to the Range of an ADC	19
6.4 The Relationship between the Input Signal Frequency and the Sampling Rate of the ADC	20
6.5 Investigation into the Validity of the Nyquist Criterion	20
7. Conclusions and Recommendations.....	21
8. Citation List.....	23

Table of Figures

Figure 1 - Single Sideband (Shahjahan, 2020).....	5
Figure 2 - Waveform of Frequency Modulation (Coach, 2022).	6
Figure 3 - Block Diagram of an ADC (Technology, 2022).....	7
Figure 4 - A Continuous Signal Turning into a Digital Signal (Angle, 2008).	8
Figure 5 - PAM Response (Multiplexing, 2022).	8
Figure 6 - PCM Response (Tutorialspoint, 2022).	9
Figure 7 - SDH Diagram (Chapman, 2019).	9
Figure 8 - Experiment 1 Set-up	10
Figure 9 - Spectrum Wave	12
Figure 10 - 2V Peak to Peak Frequency.....	13
Figure 11 - 4V Peak to Peak Frequency.....	13
Figure 12 - 6V Peak to Peak Frequency.....	14
Figure 13 - Pico scope Response (Spectrum Wave).....	14
Figure 14 – Experiment 2 Set-up	15
Figure 15 – 4-Bit ADC	16
Figure 16 - 8-Bit ADC.....	17
Figure 17 - 5 kHz Input.....	18
Figure 18 - Above 6 kHz Input.....	18
Figure 19 - Above 7 kHz Input.....	19

1. Executive Summary

PAST TENSE

The report will follow an investigation of the analogue and digital communication techniques. The first section (Section 2) of the report will provide the research for the topic by using a range of creditable sources to able the findings. The key areas ^{was} ~~were~~ amplitude and frequency modulation. This would then provide an understanding for the testing and analysis of the behaviour of the responses in each experiment. The ADC converter was also investigated this again gave the author an understanding of the behaviour and how they are applied to everyday situations. By doing this, a sound knowledge was gained to provide an overall analysis of the 4-bit and 8-bit converter, which was experimented on in the experimental 2 section of the report. Section 3 of the report was an experiment to evaluate the frequency modulation with a given carrier frequency (445 kHz) with an amplitude of 375mV. From this several theory methods were produced by using a technique to produce a spectrum waveform. To check if the results were accurate a practical experiment was set up to check each of the amplitudes. The second experiment (Section 4) involved analysing to behaviour of the ADC converter. Two different types were investigated which were the 4-bit and 8-bit. These would be analysed through different tests with a range of frequency inputs to evaluate the changes. The final section of the report (Section 5) will have an overall conclusion from what was learned from the report, and what the author can learned from the research and experiments.

2. Research into Analogue and Digital Communication Systems and Techniques

2.1 Evaluation of Amplitude and Frequency Modulation Techniques

2.1.1 Amplitude Modulation Techniques

This is the process in which the wave signal is transmitted by modulating the amplitude of the signal. This is most referred to as AM and is frequently used in transmitting a piece of information through a radio carrier wave (Ju's, 2022).

This type of modulation is used in a few applications which include:

- Broadcast Transmission – AM is extensively used in broadcasting on the long, medium, and short-wave bands. Reasoning being is that it is simple to demodulate this means that the radio receivers are capable of demodulating amplitude modulation which are cheap and easy to produce. This method is being reduced and people are moving towards high quality transmission like frequency modulation (Bharathuniv, 2022).
- Single Sideband (Figure 1) - HF radio links use the amplitude modulation in the single sideband. By using the lower bandwidth and providing more effective use of transmission of power this type of modulation is still widely used for point-to-point HF links (Bharathuniv, 2022).

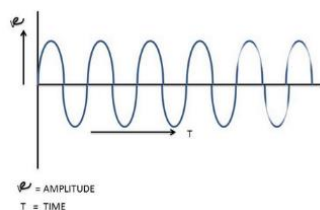


Figure 1 - Single Sideband (Shahjahan, 2020).

2.1.2 Frequency Modulation Techniques

The FM (Frequency Modulation) is the form of modulation in which the carrier wave changes the frequency to correspond to direct changes in the baseband signal. This type of modulation is considered as an analogue form of modulation, as the baseband signal is a typical analogue waveform without the discrete, digital values (Instruments, 2022).

The modulation of the frequency modulation index in most cases is over 1 and usually requires a high bandwidth with the range of 200 kHz. FM functions at a very high frequency range from 88 to 108 Megahertz. Complex circuits are used with infinite number of sidebands this is to help in receiving high quality signals along with high sound quality (Byju, 2022).

NOT LIMITED TO
THIS FREQUENCY.

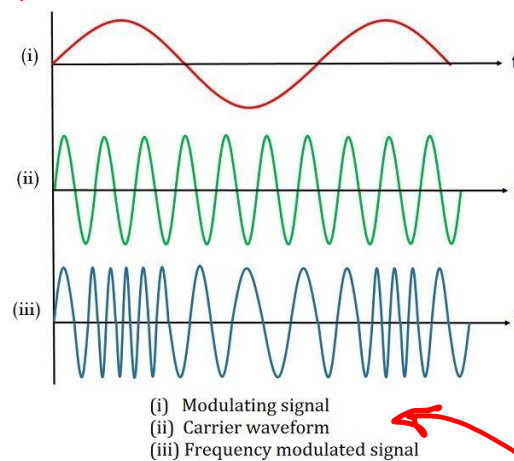


Figure 2 - Waveform of Frequency Modulation (Coach, 2022).

Figure 2 is showing each of the waveforms. (i) is the slow sine wave, is used to modulate and to impress itself on the other two signals as they are faster. The middle carrier (ii) is the alteration of the carrier amplitude. This is the AM signal as it is an audible signal it wanes in the amplitude and the carrier frequency remains the same. The bottom waveform (iii) is the impressed upon the carrier by alteration of carrier frequency. The audible signal with FM would rhythmically change frequency (warble) and the carrier loudness or amplitude will remain unchanged (Gate, 2013).

?

Applications

Communication systems – touched on previously, the two types used are analogue and digital frequencies. The data signal is continuously varying on the sine carrier wave. The properties include frequency, amplitude, and phase. These are used to produce the AM, PM,

and the phase modulation. The digital modulation works like analogue, the digital transmits binary signals (0-1) (Heavy.AI, 2022).

Vibration Analysis – this is the process of measuring and analysis of vibration patterns with signals and frequencies of machinery to detect abnormal vibrations and to analyse the health of machines and the components. The process of demodulation can directly detect modulation frequencies and can be used to recover information content from the modulated carrier wave (Heavy.AI, 2022). *CONTEXT?*

2.2 Evaluation of the Development of Digital Communication Techniques

2.2.1 Analogue to Digital Converters (ADCs)

This component is very important when dealing with digital systems communicating with real time signals. As the progress of IoT (Internet of Things) is ever more involved in everyday life, the real-world/time signals must be processed by the digital systems to accurately provide key information (Gudino, 2018).

An ADC is used when the need of an analogue sensors to communicate with a microcontroller, it is not possible for a microcontroller to communicate directly as the microcontroller only understands digital signals that are formed by 1's and 0's. Meaning that this system needs an intermediate device that converts the analogue signals into digital for the controller signals to understand. The integrated circuit (ADC) which can do this function (Lakshan, 2020).

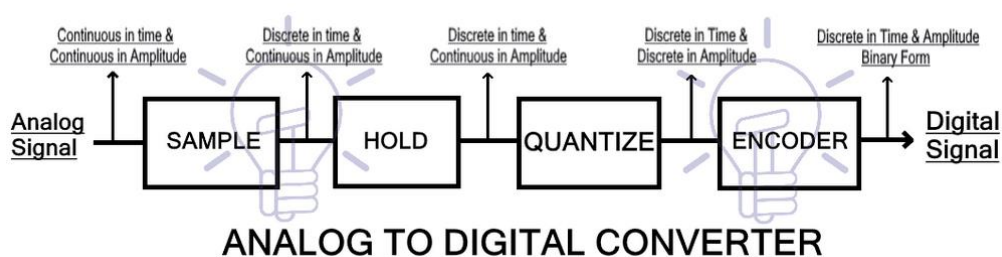


Figure 3 - Block Diagram of an ADC (Technology, 2022).

Figure 3 is a typical block diagram, the sample block is where the analogue signal is applied and where it is sampled to a specific frequency. The hold block is where the value is maintained and held, which is an analogue value. The quantise block, is where the value is quantised into a discrete value. The encoder will then convert the discrete amplitude into the binary value (Technology, 2022).

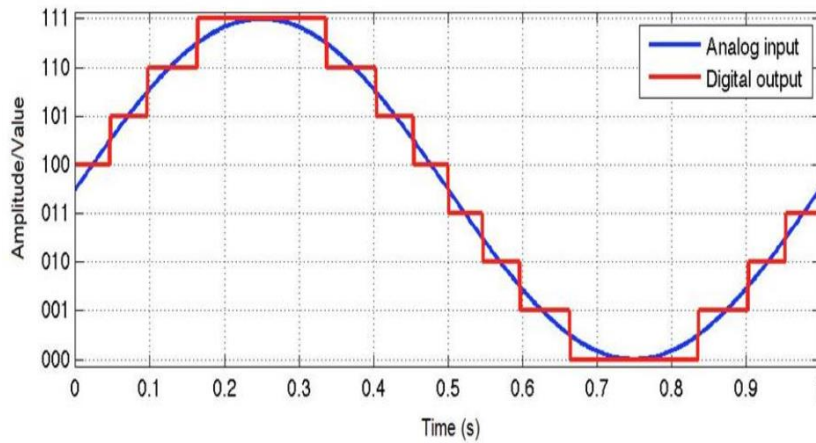


Figure 4 - A Continuous Signal Turning into a Digital Signal (Angle, 2008).

Figure 4 is the best representation of what both signals look like. The analogue has a continuous sequence throughout. These signals come from sound, temperature, light, and motion. The digital value comes in the form of discrete values, the signal is broken down by the determination of the time series or sampling rate (Gudino, 2018).

The sampling rate (also known as sampling frequency) can be linked to the ADCs speed. The sampling rate is measured by samples per second (SPS) or frequency it would be Hz. This shows how many samples can be taken within one second. More sampling the ADC can produce the higher frequencies it can handle (Gudino, 2018).

2.2.2 PAM and PCM Techniques

Pulse Amplitude Modulation (PAM) - is the signal that is to be transmitted will be sampled over certain intervals. The samples are made proportional to the modulating signals amplitude. The PAM is mostly used for transmitting digital data and is widely used in Ethernet communication (WatElectronics, 2020).

Equal intervals are used, and this is called the sample and hold method. The signal is read and held for an instance. The value is then displayed in the waveform and is generalised over a short period (Multiplexing, 2022).

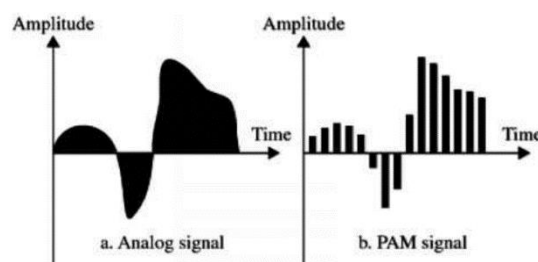


Figure 5 - PAM Response (Multiplexing, 2022).

Pulse Code Modulation (PCM) – is a representation of the analogue signal which takes samples of the amplitude of an analogue signal at a regular interval. The sampled analogue value is changed to a binary value (Gartner, 2022).

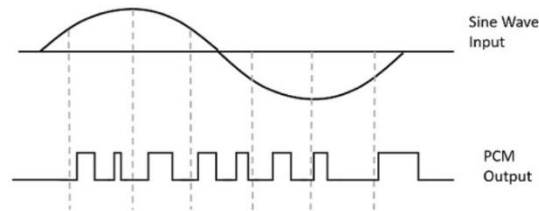


Figure 6 - PCM Response (Tutorialspoint, 2022).

Figure 6 is the PCM is showing the output and from this the analogue information is put into a binary sequence and the response is showing this (Tutorialspoint, 2022).

The advantages are that it is very good over long-distance communication, efficiency of the transmitter is very high and higher noise immunity. Disadvantages include bandwidth is very high and the complexity of the process with encoding and decoding of the quantisation circuit (BYJU's, 2022).

2.2.3 The Digital Communication Synchronous Digital Hierarchy (SDH)

Synchronous Digital Hierarchy (SDH) is a group of fibre optic transmission rates which transport different type of signals with different capacities. This type allows a low-bit rate data streams allowing a combination of high-rate data streams (Zola, 2022).

The functioning of SDH is that it combines the n signals with a bit rate of b and to from data streams by $n \times b$ on the synchronously clocked network. This is inserted in higher hierarchy levels and then removed, again use via add and drop (NFON, 2022).

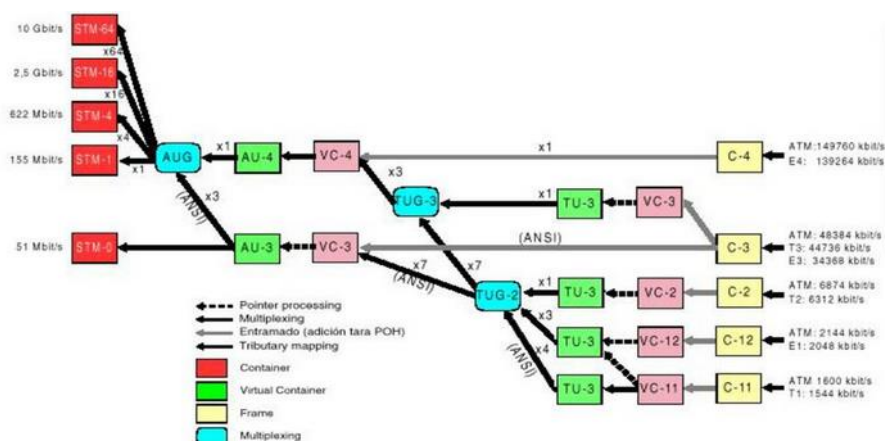


Figure 7 - SDH Diagram (Chapman, 2019).

3. Experimental Method for Experiment 1

3.1 The Set-up of the Experimental Procedure

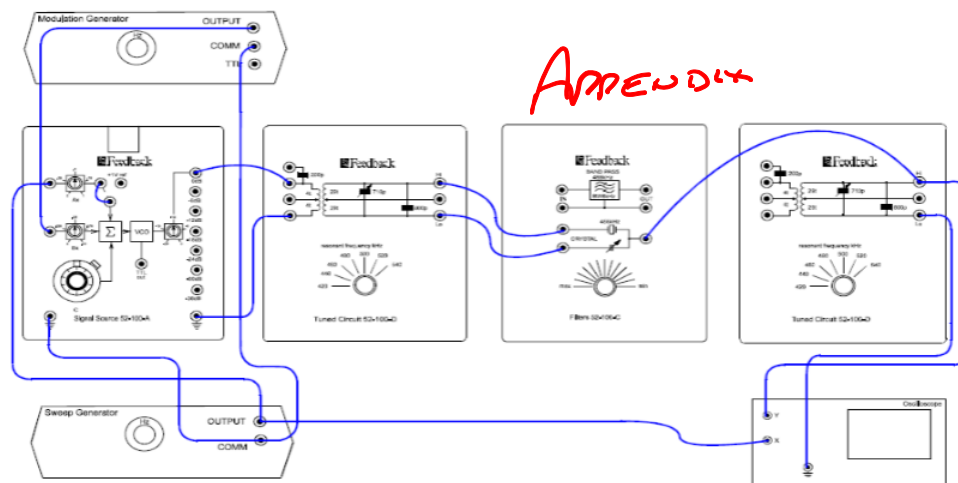


Figure 8 - Experiment 1 Set-up

Firstly, the mathematical part of this experiment was completed to ensure the modulation index would be found, and from this the coefficients could be found (Section 3.2 and 3.3).

Shown in Figure 8 is the configuration of the equipment, by connecting a power supply to the module, then to the signal source board and connected to a Picoscope which gave the results for each of the tasks. The first task was to set-up the frequency modulated signal by setting to Channel A. This gave the frequency and the peak-to-peak measurements. To display the spectrum waveform, the Picoscope was set to spectrum analyser mode. The scales were to set linear to get an accurate result for the waveform.

3.2 Determine the Maximum Frequency deviation and Modulation index

Maximum frequency deviation (Δf)

$$\Delta f = 20\text{kHz} \times 2 = 40\text{kHz}$$

Modulation Index (mf)

$$mf = \frac{\Delta f}{f_s} = \frac{40}{10} = 4 \text{ kHz}$$

IT IS JUST A NUMBER

3.3 Using a Bessel Table Calculate Required Amplitudes and Produce a Spectrum Wave

The Bessel table (Table 1) this was to work out the amplitudes at different frequencies. As the modulation index was 4kHz these carrier values were used to calculate each of the amplitudes at different frequency points.

Modulation index	Sideband																
	Carrier	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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								

Approx.

Table 1 - Bessel Table (Andy, 2013).

As the carrier amplitude was 375mV, this was then multiplied by the carrier values in the Bessel table to give the following coefficients. The modulation index determines the number of coefficients, and the carrier will determine the amplitude of the carrier.

$$455 \text{ kHz} = EC \times j0 = 3.75 \times 10^{-3} \times 0.40 = 150\text{mV}$$

$$445 \text{ \& } 465 \text{ kHz} = EC \times j1 = 3.75 \times 10^{-3} \times 0.07 = 26.25\text{mV}$$

$$435 \text{ \& } 475 \text{ kHz} = EC \times j2 = 3.75 \times 10^{-3} \times 0.36 = 135\text{mV}$$

$$425 \text{ \& } 485 \text{ kHz} = EC \times j3 = 3.75 \times 10^{-3} \times 0.43 = 161.25\text{mV}$$

$$415 \text{ \& } 495 \text{ kHz} = EC \times j4 = 3.75 \times 10^{-3} \times 0.28 = 105\text{mV}$$

Approx.

$$405 \text{ \& } 505 \text{ kHz} = EC \times j5 = 3.75 \times 10^{-3} \times 0.13 = 48.75\text{mV}$$

$$395 \text{ \& } 515 \text{ kHz} = EC \times j6 = 3.75 \times 10^{-3} \times 0.05 = 18.75\text{mV}$$

$$385 \text{ \& } 525 \text{ kHz} = EC \times j7 = 3.75 \times 10^{-3} \times 0.02 = 75\text{mV}$$

From these values a table was formed and from this the spectrum wave can be analysed.

Frequency	Amplitudes
385	7.5
395	18.75
405	48.75
415	105
425	161.25
435	135
445	26.25
455	150
465	26.25
475	135
485	161.25
495	105
505	48.75
515	18.75
525	7.5

Appendix.

Table 2 - Amplitudes

Table of amplitudes (Table 2) is showing the values that were calculated and from this the spectrum wave graph can be executed.

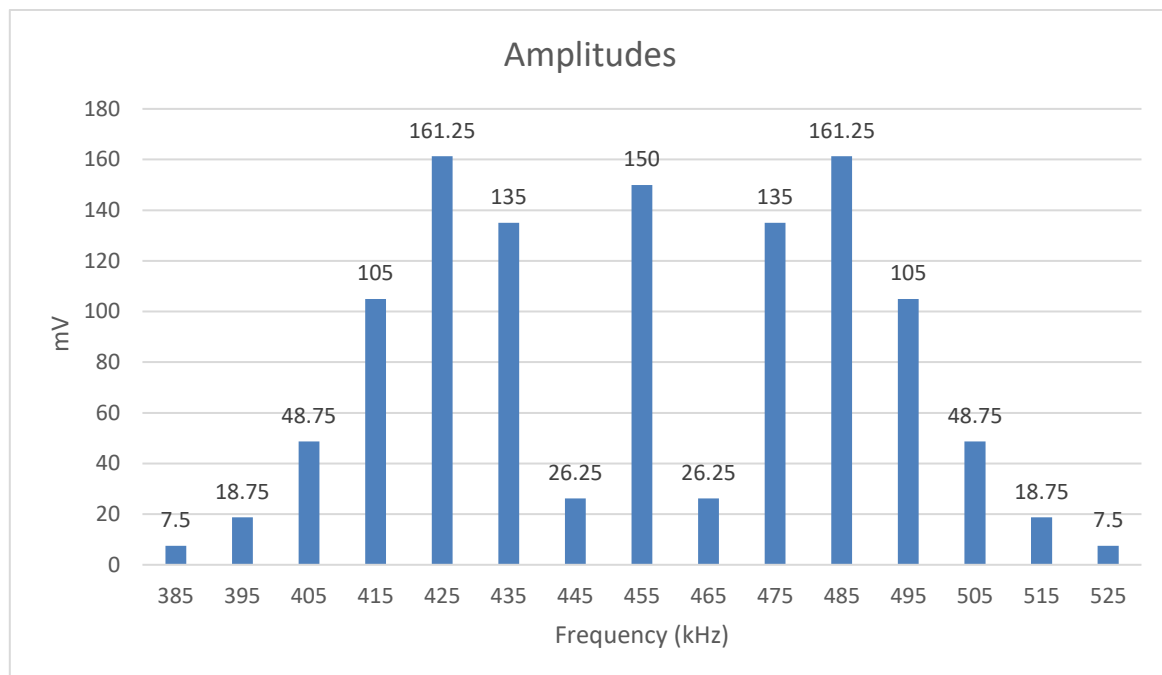


Figure 9 - Spectrum Wave

By plotting the graph (Figure 9) this can now determine the spectrum wave performance. The bandwidth is calculated by $525 - 385 = 140 \text{ kHz}$. From this response it is evident that the greater Modulation Index, the more sidebands it will have. By using the calculated values, a comparison with a real time response can occur and compare each outcome.

4. Testing, Results and Analysis for Experiment 1

4.1 Practical Activity to Confirm the Calculated Results

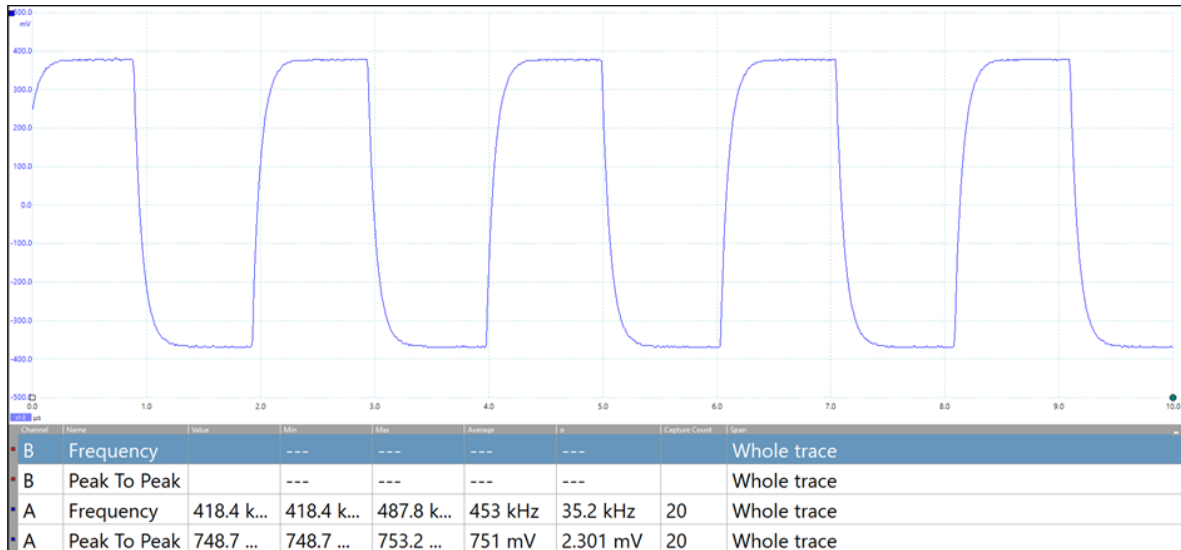


Figure 10 - 2V Peak to Peak Frequency

Figure 10 is showing the input of 2V this shows a narrow bandwidth, but the frequency has an average of 453 kHz.

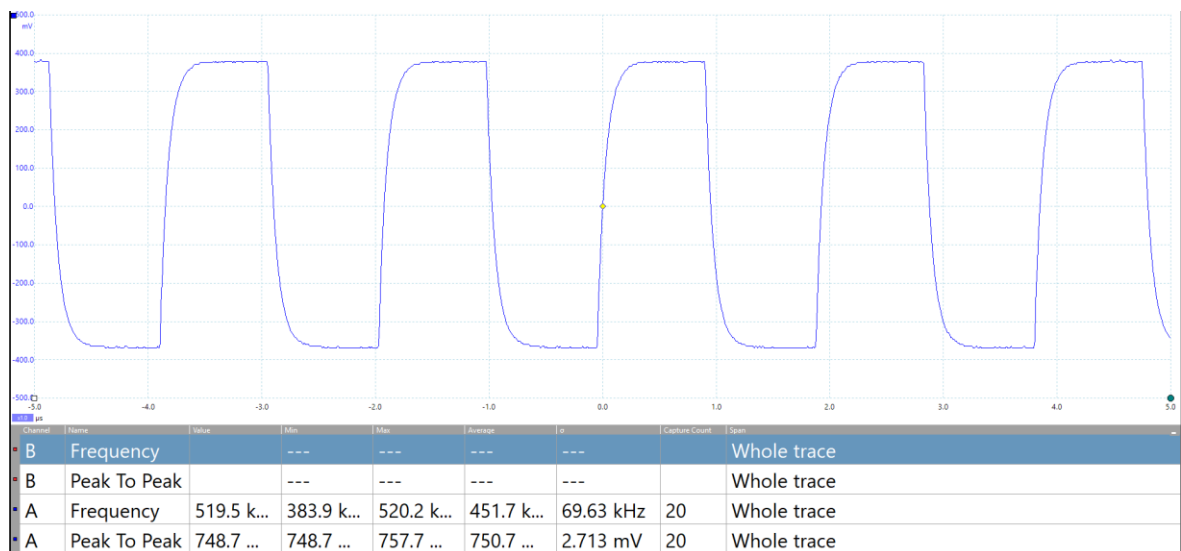


Figure 11 - 4V Peak to Peak Frequency

Figure 11 is showing the 4V input which has produced a lower average frequency which is 451.7 kHz. Little changed has occurred with doubling the input.

FIGURE 10 → 12 AREN'T
NEED FOR THE EXPERIMENT.

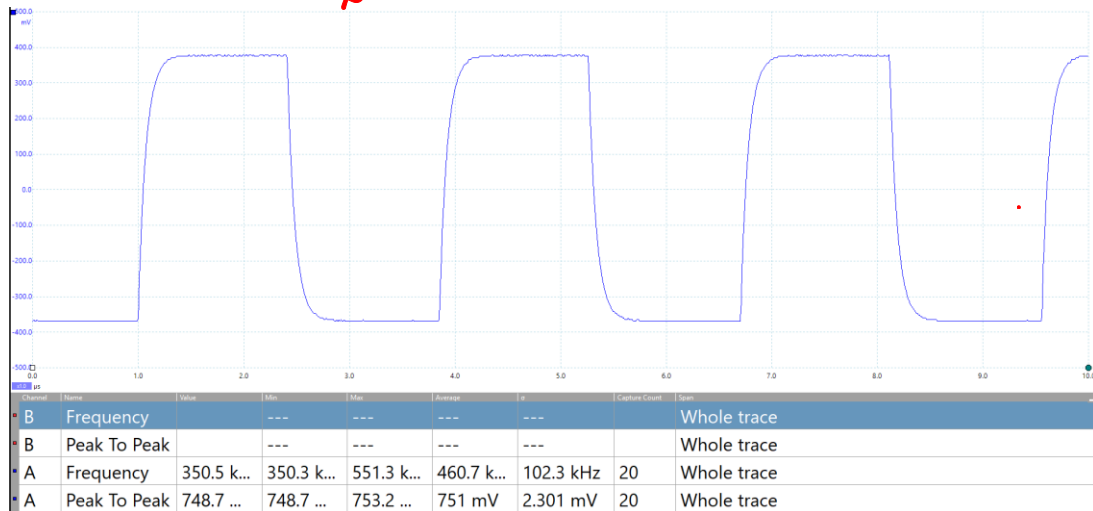


Figure 12 - 6V Peak to Peak Frequency

By increasing the voltage by another 2V (Figure 12) has produced a greater carrier wave frequency.

From the above responses it is evident that the signal change will produce a greater carrier frequency. By increasing the input, it does not change the carrier wave amplitude. This shows that the research is correct as the amplitude of the modulated wave stays the same.

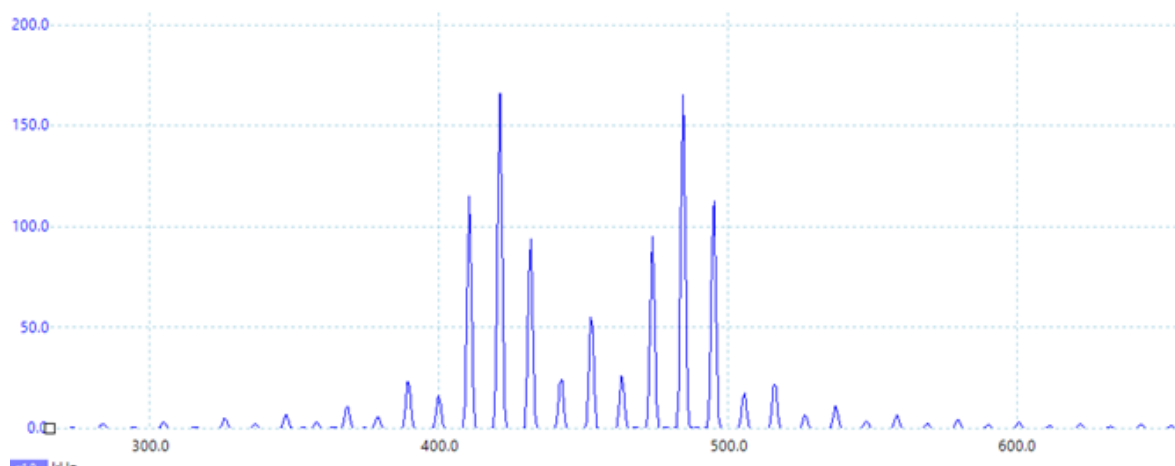


Figure 13 - Pico scope Response (Spectrum Wave)

Figure 13 is showing the Pico scope response of the spectrum wave. Carrying on from the other task the Pico scope was set to "Spectrum Analyser Mode" and the output of the modulation generator was set to 2V peak – peak. By linearising the scale, the graph produced was very similar to the calculated. The sideband amplitudes are very accurate and show the same trend as the calculated.

YOU NEEDED TO COMPARE THE
CALCULATED NUMBERS WITH YOUR
PRACTICAL RESULTS.

5. Experimental Method for Experiment 2

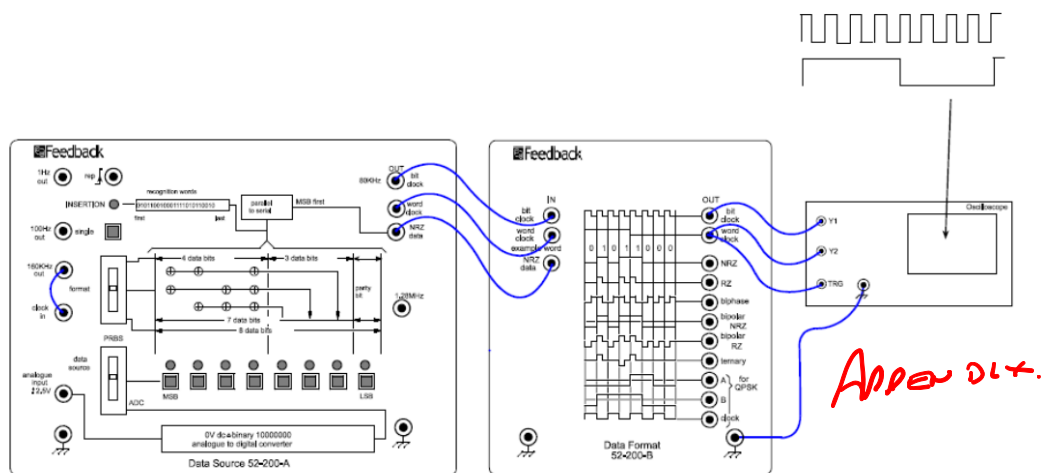


Figure 14 – Experiment 2 Set-up

Figure 14 is the experimental set up for the ADC this will involve several procedures to analyse the performance and behaviour of this type of conversion. The Pico scope will be used again in this task to analyse each of the responses. The specification of this type of ADC is that the range is 5V P-P and a sampling rate of 10,000 samples/second.

By using the Feedback Ltd experimental kit, the first set-up was to set the ADC to 4-bit and 8-bit. A comparison was made to see the difference responses and the effect by having a different number of bits.

The second part of the experiment was set if the frequencies were held at a constant. By setting the kit to 4-bit and 8-bit this will have different input amplitudes to monitor the change of the different frequencies and how each perform.

6. Testing, Results and Analysis Experiment 2

6.1 Differences between the 4 Bit and 8 Bit Converters

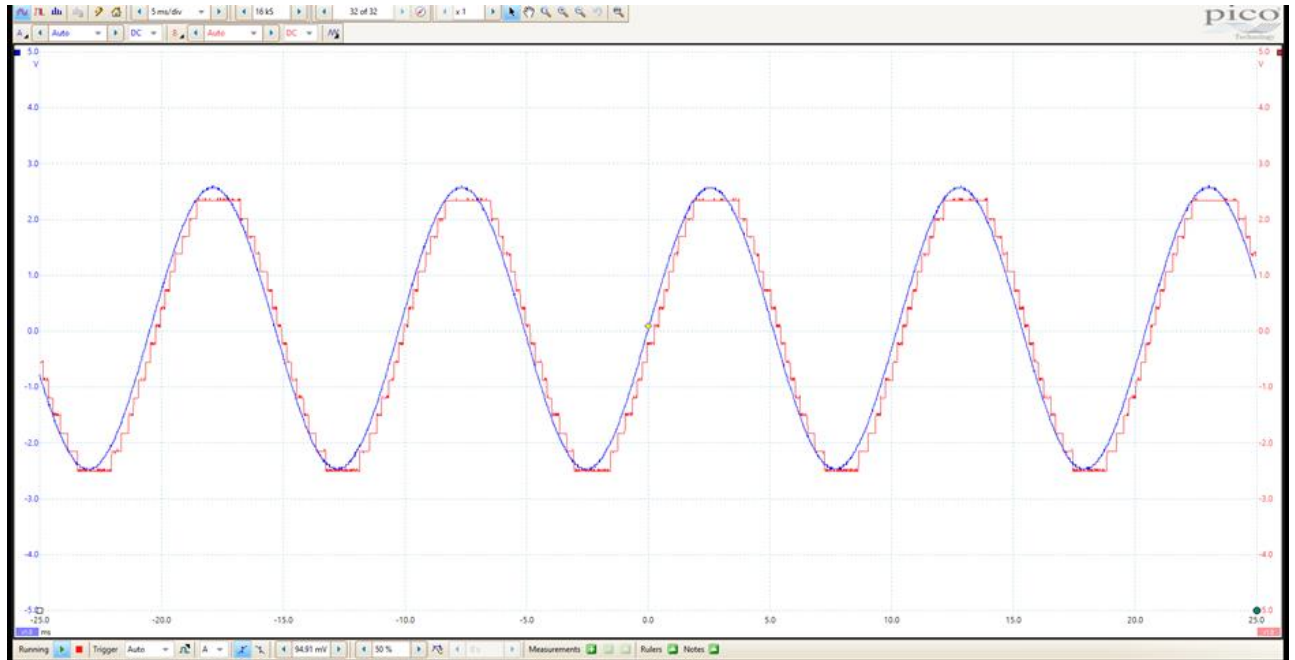


Figure 15 – 4-Bit ADC

The first ADC was the 4-bit (Figure 15) this was completed by setting the ADC to 4-bit. Analysing the performance, the evidence shows that the 4-bit has a more stepped digital signal (Red response). The analogue signal has stayed cautious without much interruption. ? The resolution of this response is low.

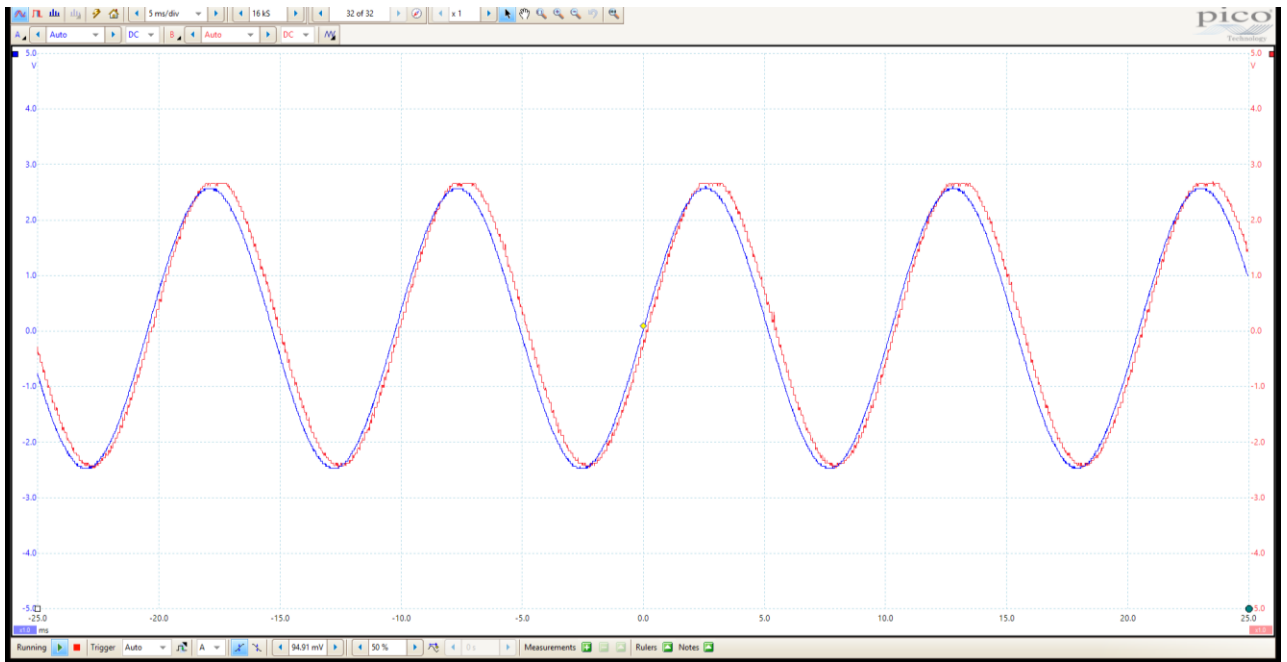


Figure 16 - 8-Bit ADC

The ADC was now set to 8-bit (Figure 16) this is showing a similar analogue signal as the 4-bit, but the resolution is slightly better. On the other hand, the digital signal (Red response) is far better than the 4-bit digital signal. *WHAT DOES 'BETTER' MEAN?*

The difference between the two are evident and this is down to the resolution of the 4-bit in one part being 15 (24-1) and the 8-bit in one part is 255 (28-1). The unknown continuous analogue signal is converted into "n"-bit which is the binary number of 2ⁿ bits. This is what the analogue digital converter does to achieve this resolution.

NO IDEA WHAT THESE MEAN.

6.2 The Effect of Changing the Frequency of the Input with Amplitude Held Constant

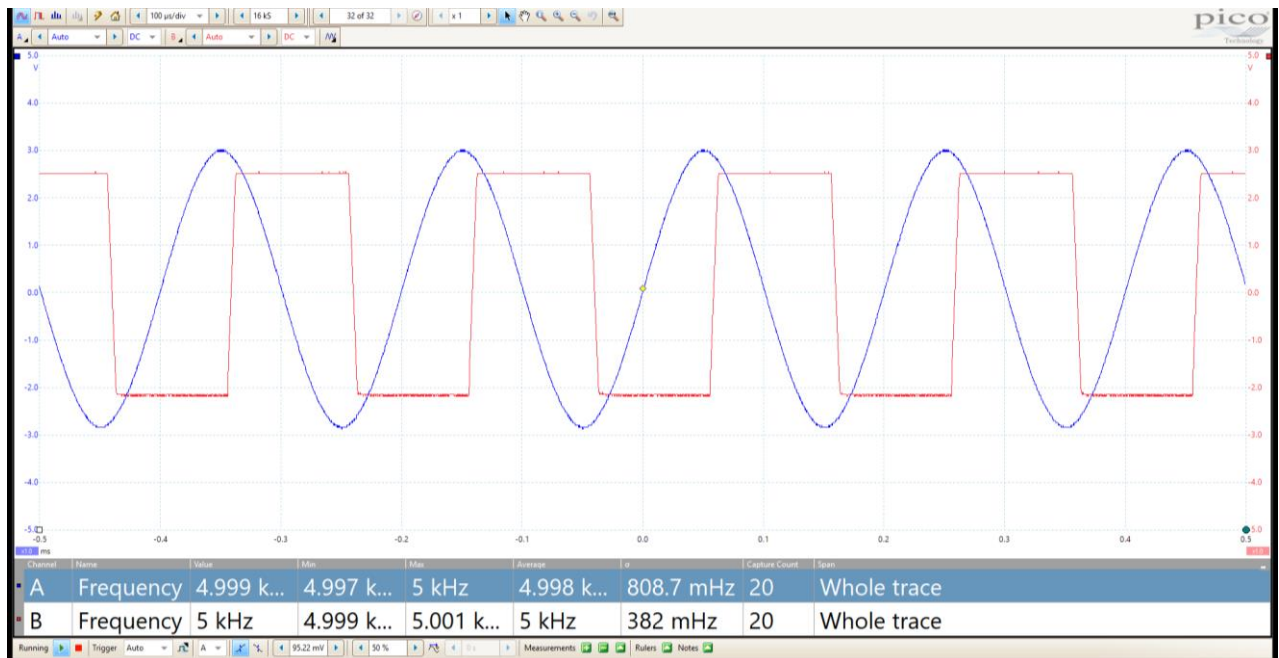


Figure 17 - 5 kHz Input

The second part of the ADC testing is to look at the change in frequency input. The 8-bit ADC will be used in this test. The set frequency is 5 kHz (Figure 17) this shows the response being steady regarding the digital wave.

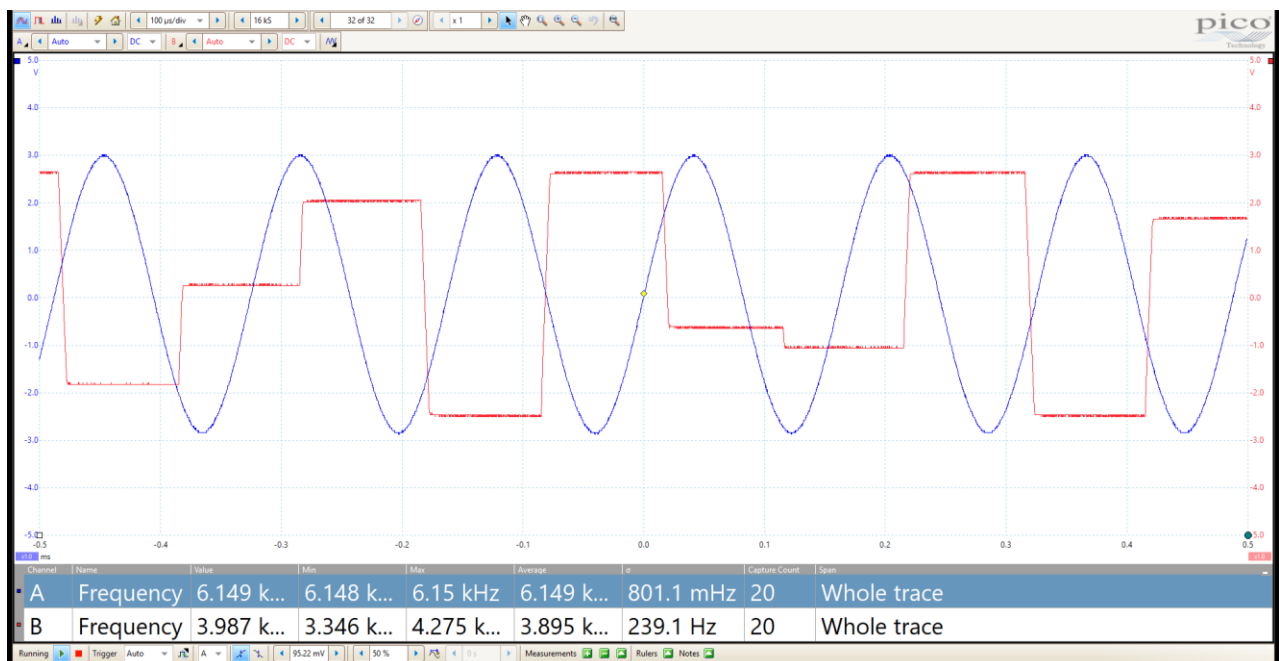


Figure 18 - Above 6 kHz Input

f_{in}	f_{out}
1k	1k
2k	2k
5k	5k
10k	3k

A TABLE OF RESULTS
WOULD HAVE BEEN
BETTER.

When applying above a 6 kHz input (Figure 18) the distortion really occurs with the digital output having greater steps. The analogue input stays consistent again. This example shows a great amount of aliasing as the image is greatly different from the original.



Figure 19 - Above 7 kHz Input

Setting the input frequency above 7 kHz (Figure 19) this is showing the sampling rate is very slow and the signal frequency is much higher (the wider waves in blue). Showing a reconstruction of the original image is not possible, the digital output signal (red response) is not as close to the original meaning that the sampling rate is not matching to keep up to date with the analogue signal. This is another example of aliasing.

6.3 The Importance of Matching the Amplitude of the Input signal to the Range of an ADC

By matching the input signal, it will provide an ideal ADC. From the testing it is evident that the bandwidth is mainly characterised by the sampling rate. As the larger the signal frequency the slower it is. When the ADC is functioning to its capability the ENOB (effective number of bits) are equal. By matching the amplitude and signal gives a better digital output meaning a better resolution and better quality of signal.

*YOU HAVEN'T REALLY INVESTIGATED
THIS IN ANY DETAIL.*

6.4 The Relationship between the Input Signal Frequency and the Sampling Rate of the ADC

The practical experiment shows that the sampling rate depends on the clock frequency. By increasing the sampling rate, it increases the overall conversion and making it more accurate. The importance of having this relationship between the two is that choosing the correct input frequency will determine the functioning of the sampling rate and resolution.

6.5 Investigation into the Validity of the Nyquist Criterion

This method requires the sampling rate to be twice the required input signal and if this does not occur the signal will be lost. By decreasing the sampling frequency ~~by~~ ^{BELOW} twice the amount of the analogue signal, aliasing will occur. From the results (Figure 19) this is evident this theory is accurate as the frequency was increased to almost double and the output signal was getting lost which was Channel B in this task.

Conclusion
?

7. Conclusions and Recommendations

To conclude the report, several findings were sourced and analysed. This was through the method of research and practical elements. The first section was the research part of the assignment, from this an understanding for the tasks were gained. The FM modulation was analysed, the behaviour was that the carrier wave changes its frequency to correspond with the baseband signal. This point was then applied to the testing as this gave an understanding on how this type of modulation functions. Another section of research was looking at digital communication techniques and the main point from this was the ADC converter. The learning from this is that it performs a key role in digital systems and communication with real time signals. With the introduction of industry 4.0 and the IoT being more evident this would play a major part any future communications. Also, the waveforms were discussed for the ADC, and this could give the author an understanding of the behaviour when analysing in Experiment 2. Overall, the research showed what each modulation does through practical and application. Both are widely used in communication including transmission links. The first experiment was to analyse the frequency modulation, the calculations provided the foundation to compare with the practical. The practical results shown that the theory was accurate in comparison. The peak-to-peak experiments showed that increasing the input voltage would increase the size of the bandwidth. With assistance from the research, it shows that this occurs, and the modulated wave stays the same. When each of the peak-to-peak were investigated, the spectrum waveform was produced. A comparison was made with the calculated and practical. Both waveforms were accurate as they were very similar and from this it is evident that the greater value for the modulation index would give more sidebands. When calculating the modulation index the value will give an insight into how the waveform would behave before using the Bessel table. From this is experiment it is clear the signal would rhythmically change frequency and the carrier amplitude would stay the same. This shows that the research was correct, and the practical element proved this theory. The second experiment was involving two types of ADCs which were 4-bit and 8-bit. Looking at the two results the operating of the 4-bit had a low accuracy as this only has 16 levels on the output. By increasing the bits (8-bit) more levels are achieved which had 256 levels, meaning good accuracy. The taking from this is that the optimum quantisation and resolution is achieved by the 8-bit ADC as the most levels improves the accuracy. The second part of this section required to analyse the 8-bit with the effect of changing the input frequency and keeping the amplitude constant. From the results it is evident that sampling theorem was proved, as the increase in the input frequency decreased as the 5 kHz input was at the maximum operating limit. When the input frequency

100
DESCR. PIV

was increased to 6 kHz the output frequency decreased to 2kHz. The findings show to optimise the ADC as it should sample twice input frequency. When comparing experiment 1 with the research it shows that the frequency carrier waves change and corresponds with the baseband signal. This was evident as the narrow bandwidth occurred at low frequency and the more input being applied gave a greater bandwidth. The second experiment when comparing with research is that the greater sampling rate on the ADC handles the frequency better, by applying more bits (8-bit in the experiments case) the better accuracy. Overall, what was learned is that frequency modulation requires a high frequency to perform best. An ADC relies on a high number of bits to achieve the best accuracy. ?

WOULD HAVE BEEN BETTER TO CONCLUDE FM AND ADCs SEPARATELY, RATHER THAN SWITCHING TO AND FROM.

FOR ADCs, YOU COULD HAVE INVESTIGATED DATA RATES AND WHY IT IS IMPORTANT TO MAXIMISE THEM.

8. Citation List

Andy, 2013. *Using Bessel function graph to finde out side bands*. [Online]
Available at: <https://electronics.stackexchange.com/questions/73334/using-bessel-function-graph-to-finde-out-side-bands>
[Accessed 07 March 2022].

Angle, D., 2008. *Quantization in ADCs*. [Online]
Available at: <https://dwellangle.wordpress.com/2008/05/21/quantization-in-adcs/>
[Accessed 07 March 2022].

Bharathuniv, 2022. *AM, PM and FM*. [Online]
Available at: https://www.bharathuniv.ac.in/page_images/pdf/AM,-PM-and-FM-modulation-Gomathi.pdf
[Accessed 13 Janaury 2022].

Byju, 2022. *Frequency Modulation*. [Online]
Available at: <https://byjus.com/jee/frequency-modulation/>
[Accessed 06 March 2022].

BYJU's, 2022. *Pulse Code Modulation*. [Online]
Available at: <https://byjus.com/physics/pulse-code-modulation/>
[Accessed 07 March 2022].

Chapman, J., 2019. *Synchronous Digital Hierarchy*. [Online]
Available at: <https://slideplayer.com/slide/12852511/>
[Accessed 07 March 2022].

Coach, E., 2022. *Waveform for frequency modulation*. [Online]
Available at: <https://electronicscoach.com/frequency-modulation.html/waveform-for-frequency-modulation>
[Accessed 06 March 2022].

Gartner, 2022. *PCM (Pulse Code Modulation)*. [Online]
Available at: <https://www.gartner.com/en/information-technology/glossary/pcm-pulse-code-modulation>
[Accessed 07 March 2022].

Gate, R., 2013. *Amplitude and Frequency Modulation*. [Online]
Available at: <https://www.researchgate.net/figure/Amplitude-and-Frequency-Modulation->

Illustration-Three-sinusoidal-waveforms-are-shown_fig1_235373370

[Accessed 07 March 2022].

Gudino, M., 2018. *Engineering Resources: Basics of Analog-to-Digital Converters*. [Online]
Available at: <https://www.arrow.com/en/research-and-events/articles/engineering-resource-basics-of-analog-to-digital-converters>

[Accessed 07 March 2022].

Heavy.AI, 2022. *Frequency Modulation Definition*. [Online]

Available at: <https://www.heavy.ai/technical-glossary/frequency-modulation>

[Accessed 07 March 2022].

Instruments, N., 2022. *Frequency Modulation (FM)*. [Online]

Available at: <https://www.ni.com/en-gb/innovations/white-papers/06/frequency-modulation--fm-.html>

[Accessed 06 March 2022].

Ju's, B., 2022. *Amplitude Modulation*. [Online]

Available at: <https://byjus.com/jee/amplitude-modulation/>

[Accessed 06 January 2022].

Lakshan, 2020. *Why Do You Need an Analog-to-Digital Converter (ADC)?*. [Online]

Available at: <https://www.seeedstudio.com/blog/2020/06/16/why-do-you-need-an-analog-to-digital-converter-adc-m/>

[Accessed 07 March 2022].

Multiplexing, D., 2022. *Pulse Amplitude Modulation PAM*. [Online]

Available at: <https://www.fishercom.xyz/division-multiplexing/pulse-amplitude-modulation-pam.html>

[Accessed 07 March 2022].

NFON, 2022. *SDH*. [Online]

Available at: <https://www.nfon.com/gb/get-started/cloud-telephony/lexicon/knowledge-base-detail/sdh>

[Accessed 07 March 2022].

Shahjahan, S., 2020. *Single Sideband Suppressed Carrier (SSB) Signal Amplifier*. [Online]

Available at: <https://circuits-diy.com/single-sideband-suppressed-carrier-ssb-signal-amplifier/>

[Accessed 13 January 2022].

Technology, E., 2022. *Analog to Digital Converter (ADC) – Block Diagram, Factors & Applications*. [Online]

Available at: <https://www.electricaltechnology.org/2019/02/analog-to-digital-converter-adc.html>

[Accessed 07 March 2022].

Tutorialspoint, 2022. *Pulse Code Modulation*. [Online]

Available at:

https://www.tutorialspoint.com/digital_communication/digital_communication_pulse_code_modulation.htm

[Accessed 07 March 2022].

WatElectronics, 2020. *What is Pulse Amplitude Modulation & Its Working*. [Online]

Available at: <https://www.watelectronics.com/what-is-pulse-amplitude-modulation-its-working/>

[Accessed 07 March 2022].

Zola, A., 2022. *Synchronous Digital Hierarchy (SDH)*. [Online]

Available at: <https://www.techtarget.com/searchnetworking/definition/SDH>

[Accessed 07 March 2022].

FINAL GRADE

GENERAL COMMENTS

Instructor

44/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

GRADING FORM: CSG-RUBIC

JOSHUA WILLIAMS

44

RESEARCH-INFORMED LITERATURE



There was very good evidence of further reading and research from credible and reliable sources. Your references were appropriate to the task and applied with few errors or inconsistencies. Your reference list was of an appropriate length for this assignment.

6

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was generally adequate. The experiments worked and the

13

explanation of how this was achieved was included, but only to a descriptive level, there was little evidence of any critical understanding. Your report lacked depth and detail at times and didn't really extend your knowledge beyond that contained in the course notes. Further work – Research results need to be in much more detail and written in a more logical and clearer way.

ANALYSIS



Your analysis of the task was generally satisfactory, both in class and as shown in this assignment, however it did tend more towards descriptive rather than analytical. You have demonstrated some analytical skills and your approach to the task was logical. You wrote a short conclusion that demonstrated some skills in analysing quantitative and qualitative data, however this was generally basic in nature. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory and provide a detailed critical analysis of this.

12

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally adequate. You used the resources appropriately when conducting both experiments and you used appropriate options for testing and evaluating the circuit performance. You managed to confirm that the results of both experiments were within the specification and achieved this by

9

only asking for assistance when appropriate thus demonstrating some basic problem solving skills. Your results were adequate and allowed for a reasonable conclusion to be attempted.

SKILLS FOR PROFESSIONAL PRAC.



Your written report was reasonably well presented in terms of content and layout and was mostly structured in a coherent way, however you should endeavour to use the available word count more effectively in future. You need to be much 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.

4