

PSDE5014SGEE5005

Assignment 1

by Daniel Ince

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Signals and Digital Communications

PSDE5014/SGEE5005 – MIKE HALL

DANIEL INCE

Assignment 1

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1. Executive Summary

This assignment explores frequency modulation techniques and the process of converting an analogue signal to digital. Research was carried out across a broad range of signal transmission and processing subjects.

The first practical experiment undertaken was to modulate the frequency of a carrier wave based on the message signal. Through carrying out correct equipment setup and experiment, it was discovered that the peak-to-peak voltage of the modulation generator determined the range in frequency. Further exploring this and looking at the frequency spectrum, a pattern was evident in the spread of the peaks and was dependant on the modulation index. Calculating values for this particular set up using the Bessel function table allowed a theoretical spectrum to be drawn and compared to that of the practical while also relating to the theory.

The second task was to investigate the changes to a signal using an analogue to digital converter (ADC). Differences were observed between 4-bit and 8-bit ADCs, and the effect of this on the quantisation levels. The Nyquist theorem was explored and found to have a significant impact on the quality of signal. The practical coincided with the theory and research to find these outcomes.

2. Research

Frequency Modulation

A form of modulation that varies the carrier frequency with respect to an input signal, while the amplitude remains constant is frequency modulation. Modulation is the process of adding sine waves together, an input signal and a carrier.

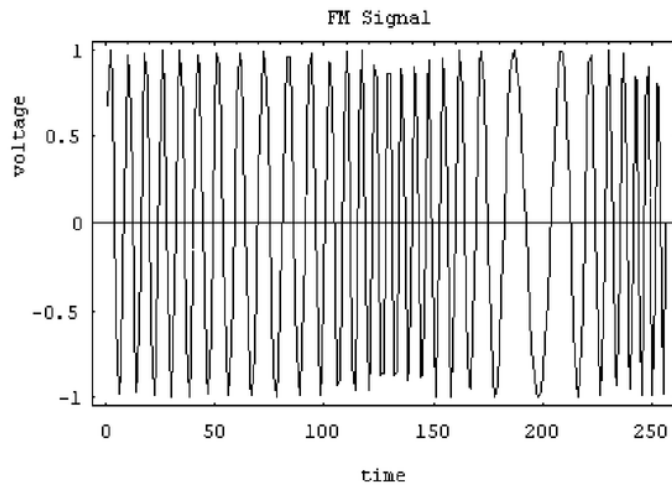


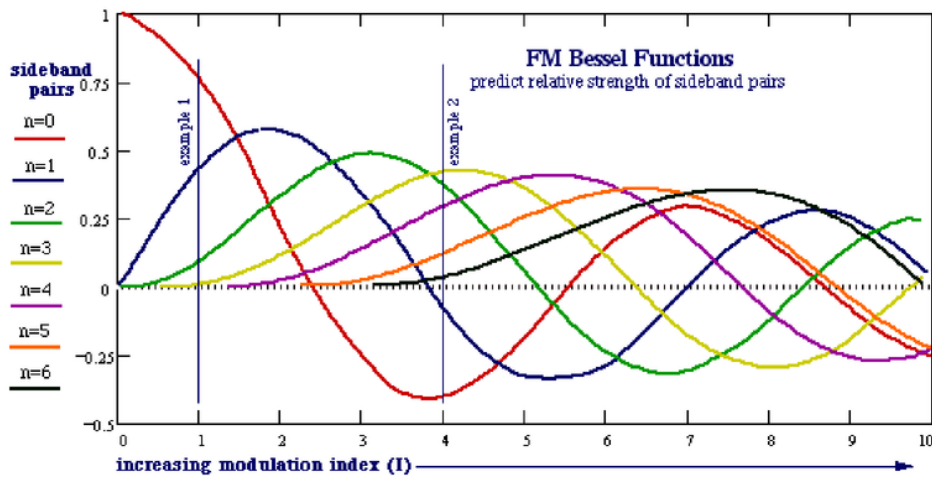
Figure 1: <https://fas.org/man/dod-101/navy/docs/es310/FM.htm>

Over time, the frequency of the carrier varies in accordance with the amplitude of the input signal, shown in figure 1, the amount in increase or decrease of frequency follows the magnitude of the input signal. The document *Frequency Modulation* states, "When modulation is applied, the output frequency will swing above and below the unmodulated carrier frequency." (Bertrand, 2002, p. 4)

The modulation frequency compared to the amount of deviation in frequency is known as the modulation index, this is calculated by dividing the deviation by the modulation frequency. When the highest frequency is used to calculate the modulation index, the outcome is known as the deviation ratio.

The FM side frequencies are representative parts of the total signal. The amplitude of them is a result of the modulation index, the distance between them is equal to the frequency of the signal and the amount of them is determined by the Bessel function table.

When observing the frequency spectrum of an FM signal, the amount of sidebands it contains is based on the modulation index. *Frequency Modulation* states, "The relative amplitude of the spectral components of an FM signal depend on the values of $J_n(\beta)$." (Technology, Holon Institute of, n.d.)



Graph 1: Bessel function

It is exhibited in the graph above taken from *Principles of Audio-rate Frequency Modulation*, that the strength of the carrier decreases as the modulation index increases. However as this happens, the other sidebands begin to gain strength and become apparent or significant. This means that when the modulation index is zero, the carrier is at its highest possible strength. (Hass, 2017) The Bessel function table is shown below, taken from *Frequency Modulation (fm) Tutorial*. (Armstrong, 2008)

β	J0	J1	J2	J3	J4	J5	J6	J7	J8
0	1								
0.25	0.98	0.12							
0.5	0.94	0.24	0.03						
1.0	0.77	0.44	0.11	0.02					
2.0	0.22	0.58	0.35	0.13	0.03				
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	

Table 1: Bessel Function Table

Amplitude modulation

AM involves varying the carrier amplitude based on the message signal amplitude. For this, the frequency is kept constant, however this means noise can impact the quality of the signal easily, as it adds to the amplitude.

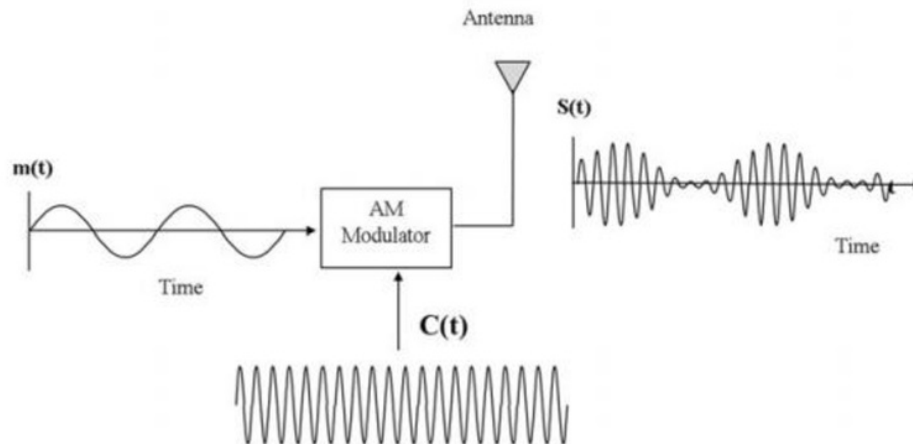


Figure 2: Amplitude modulation

Figure 2 shows how the message signal and carrier are combined in the AM modulator, the carrier is generated by an oscillator set to the desired frequency.

For AM, the carrier frequency peak is the highest when looking at the spectral response. *Radio Frequency Modulation Made Easy* states how AM is inefficient; "Notice that the power is distributed among the sidebands and the carrier, where the carrier does not contain any information. Only the sidebands contain the information." (Faruque, 2017, p. 22)

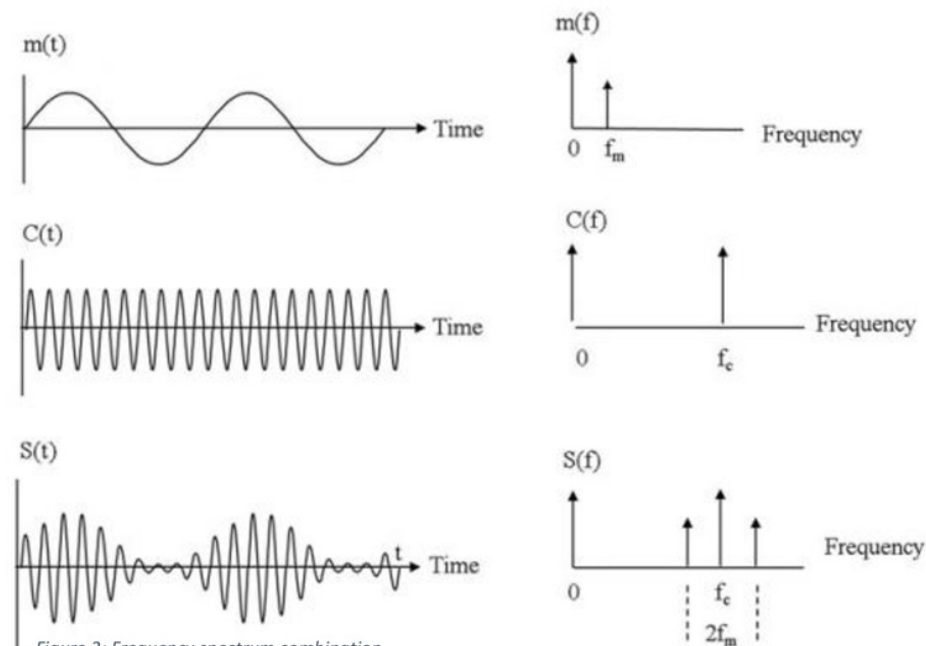


Figure 3: Frequency spectrum combination

In figure 3, the frequency spectrum can be seen for the final signal, the carrier component is the highest and also the message frequency is also added to this, the difference between the message signal peaks is the bandwidth, hence $Bandwidth = 2fm$. These sidebands are the two main frequency components and they contain the same information.

To demodulate an AM signal, a device called an envelope detector is used (figure 4).

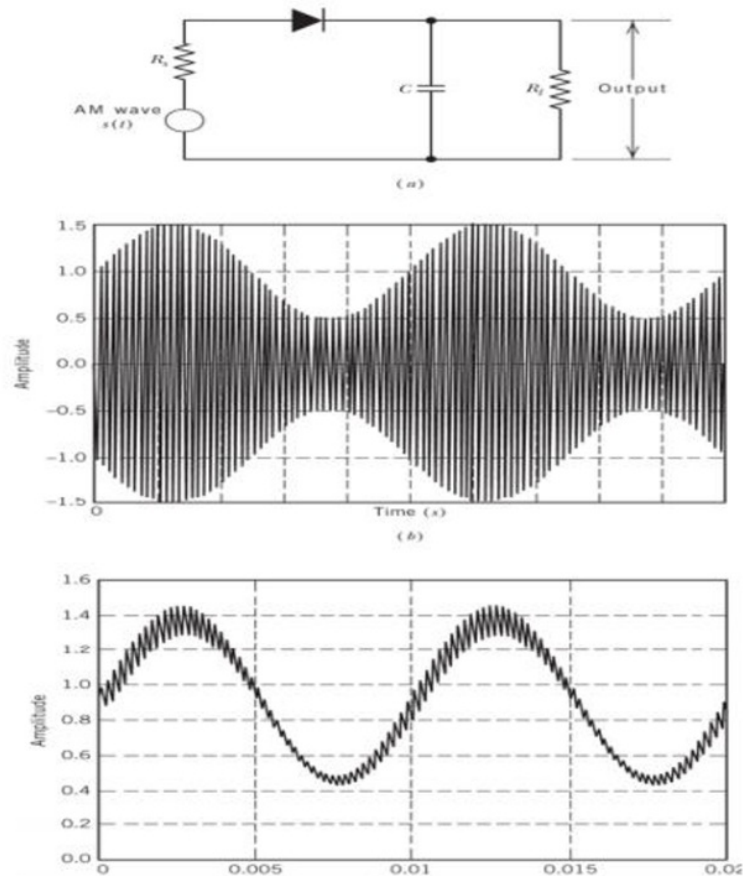


Figure 4: Envelope detector

The envelope detector, halfwave rectifier which charges the capacitor based on the amplitude of the input signal. Due to the nature of the diode, there will be some leakage back, leading to distortion. There is also added ripples created from the capacitor beginning to slightly discharge in-between wave peaks. There is slight discharge before the next peak charges the capacitor back up to the correct amplitude. These ripples can be seen on the bottom graph.

Analogue to digital converters

There are many different types of ADC, each with different characteristics useful for a given application. "ADCs' have relatively low input impedance, and they require their input signal to be DC or slowly varying, with amplitude within specific margins, usually less than $\pm 10V$ " (Ramon Pallas-Areny, 2001, p. 4)

Flash ADC

This type of ADC is the simplest and fastest due to its constitution, made up of many comparators that compare the input voltage with a reference voltage.

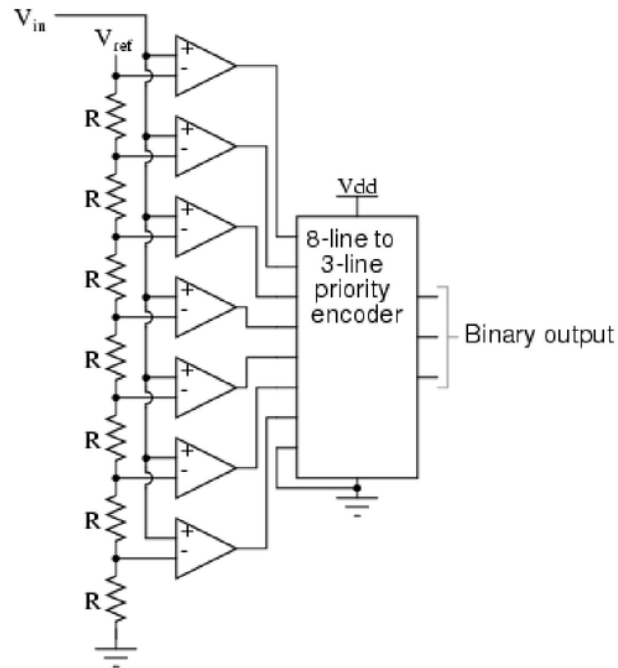


Figure 5: Flash ADC

The resistors progressively alter the potential difference of the reference voltage for each comparator progressing along. This means that a given voltage input will be higher or lower than a selection of the reference voltages for each comparator. The encoder priorities the highest comparator input and subsequently outputs a 3-bit value. As stated by *Lessons in Electric Circuits*, "Unfortunately, it is the most component-intensive for any given number of output bits." (Faruque, 2017)

Digital ramp ADC

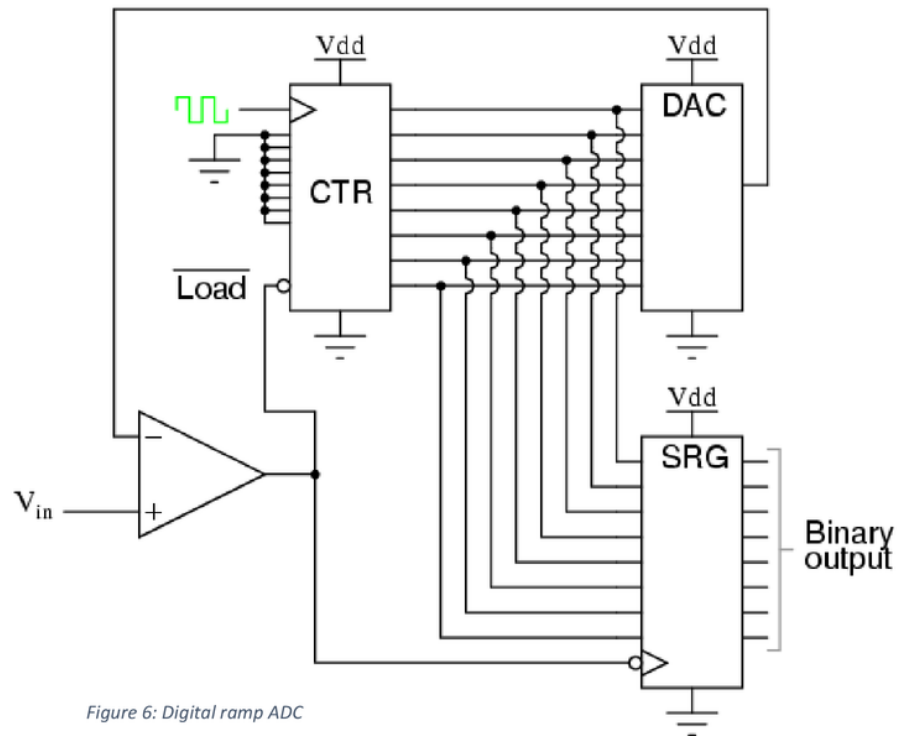


Figure 6: Digital ramp ADC

The digital ramp ADC uses a counter and a digital to analogue converter to ramp up the value until it matches that of the voltage input to the comparator. The other input is the DAC output, when this exceeds the voltage input, the comparator output goes low and is logged in the shift register, this process is repeated as the voltage input changes.

Successive Approximation ADC

This circuit is similar to the counter ADC but counts starting with the MSB and working towards the LSB. If the output from the comparator changes based on the voltage input matching that of the counted bit, the output is logged in the shift register and output. The advantage of this over the normal counter is that it counts in much larger increments and therefore matches the input quicker.

Delta-Sigma ADC

This type of ADC does not use a DAC such as the other circuits do, instead uses integrators, comparators and D-type flip flop.

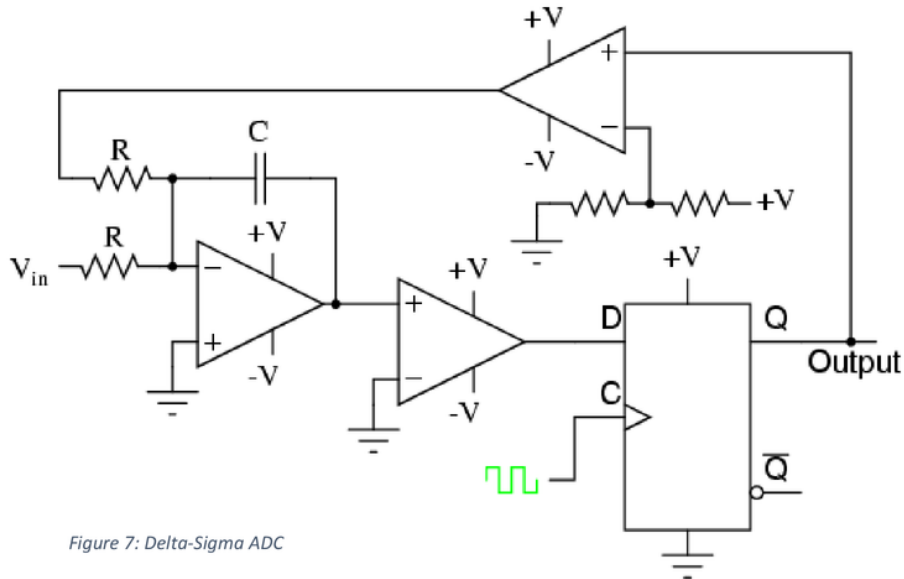


Figure 7: Delta-Sigma ADC

It is explained in *Lessons in Electronic Circuits*, this ADC uses a voltage rate of change produced by the integrator compared against a reference comparator that outputs to the D-type flip flop. "This is the delta-sigma concept in action: the first comparator senses a difference (Δ) between the integrator output and zero volts. The integrator sums (Σ) the comparator's output with the analog input signal." (Faruque, 2017)

PAM and PCM techniques

Pulse amplitude modulation

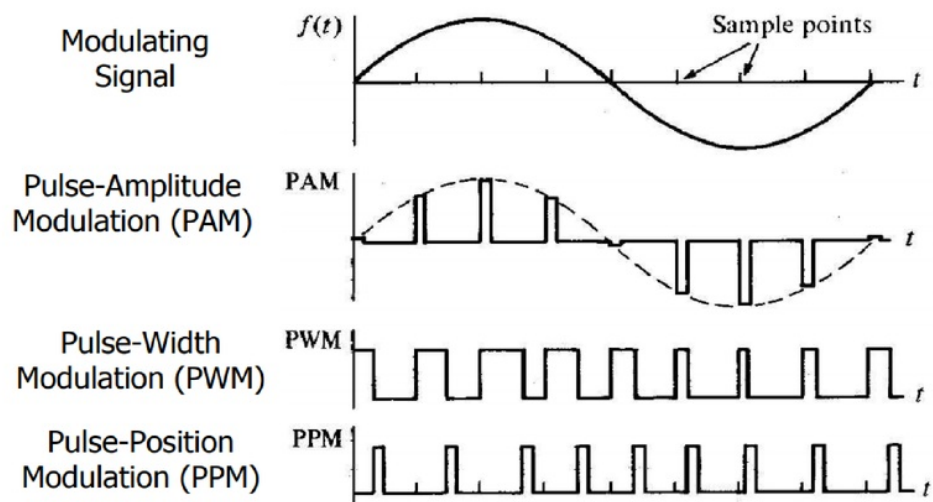


Figure 8: Pulse modulation

This technique translates a waveform into a digital pulsed signal based on the amplitude of the input wave, shown in figure 8. (Yang, 2003, p. 5) The two PAM techniques are:

Flat top PAM – This ensures that the entirety of the pulse is the amplitude that matches that of the input signal at the time of sampling, shown in Figure 9.

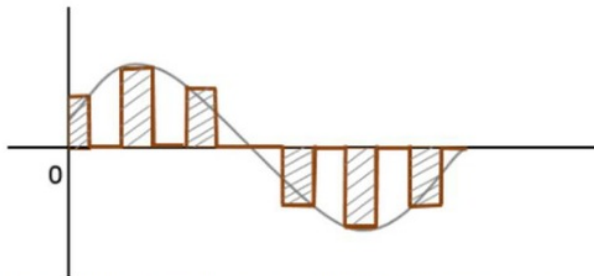


Figure 9: <https://www.elprocus.com/pulse-amplitude-modulation/>

Natural PAM – Matches the pulse amplitude to that at the time of pulse, and also follows the wave amplitude for the duration of the pulse, shown in figure 10.

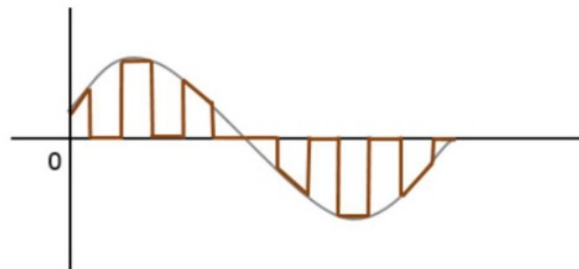


Figure 10: <https://www.elprocus.com/pulse-amplitude-modulation/>

The PAM output signal is generated by an Oscillator circuit, with the frequency of the circuit being varied with a potentiometer. A square wave generator controls the timing of the pulses generated and can be changed by varying the capacitance and resistance of the circuit. (Electronics Projects Focus, 2019)

Pulse code modulation

A technique that converts analogue signals into a digital representation. To do this, the waveform amplitude must first be categorised into different sections, known as quantization levels.

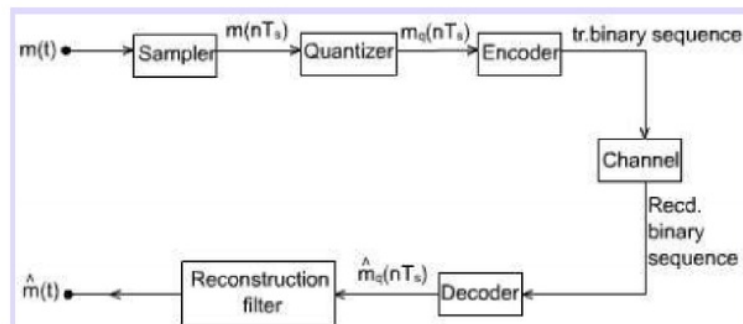
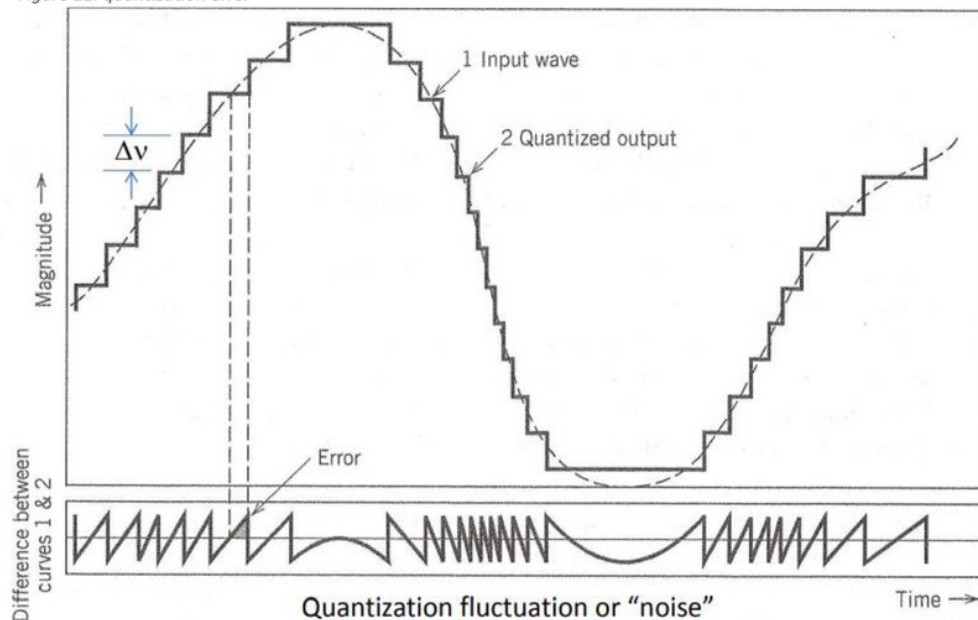


Figure 11: PCM system

Figure 11 (Rao, n.d.) shows the route the data follows in order to encode and decode PCM. As described in *Digital Transmission of Analogue Signals*, "The quantizer converts each sample to one of the values that is closest to it from among a pre-selected set of discrete amplitudes." (Rao, n.d.) This means that the original value will be changed to the closest quantization level and some information will be lost as it jumps to meet these levels as shown in figure 12 (Sonoma University, 2017).

Figure 12: quantization error



Information can also be lost depending on the sampling rate, a way to avoid this is by having the minimum sample rate set by the Nyquist Theorem. This theorem determines that the sampling frequency, must be at least double the maximum frequency of the input signal. This is done to reduce the chance of aliasing and sampling error.

Increasing the size of PCM increases the amount of quantization level, for example a higher resolution and more bits will result in smaller quantization levels and therefore less information lost as the jump to match the level is much smaller.

Modulation schemes

Modulation shift-keying is typically done through changing amplitude, frequency, and phase of the carrier based on the binary input. The simplest is amplitude shift keying, which translates 1s and 0s into high amplitude and low amplitude respectively.

Frequency shift keying (FSK)

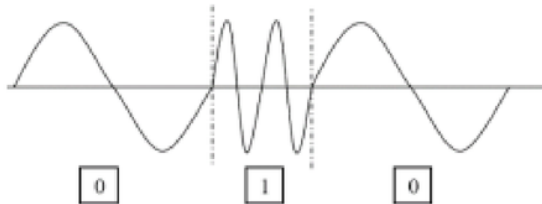


Figure 13: Changing frequency based on binary values

As shown in figure 13 from *Adaptive Modulation* (Masood, 2013), FSK alters the frequency to translate the binary code. As with FM transmission, noise does not affect this form of modulation as much as with ASK.

Phase shift keying (PSK)

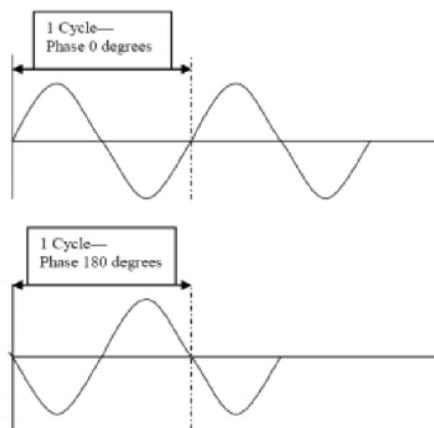


Figure 15: 180 degrees phase shift

This type of modulation alters the phase by 180 degrees, changing each cycle based on the binary code.

A variation of this is Quadrature Phase Shift Keying, as stated in *Adaptive Modulation*, “QPSK adds two more phases: 90 and 270 degrees. Now two symbols per bit can be transmitted.” (Masood, 2013) This means that 00, 01, 10 and 11 can be translated as a comparison is done between the current phase and previous phase state.

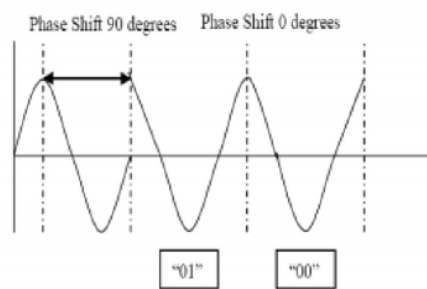


Figure 14: Quadrature phase shift

Binary Input	Phase Shift
00	0 Degrees
01	90 Degrees
11	180 Degrees
10	270 Degrees

16-QAM

This is 16 state quadrature amplitude modulation, this scheme enables 4-bits to be represented at once. The sixteen states are represented in the constellation shown in figure 16 (Cisco Systems, 2001).

Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0

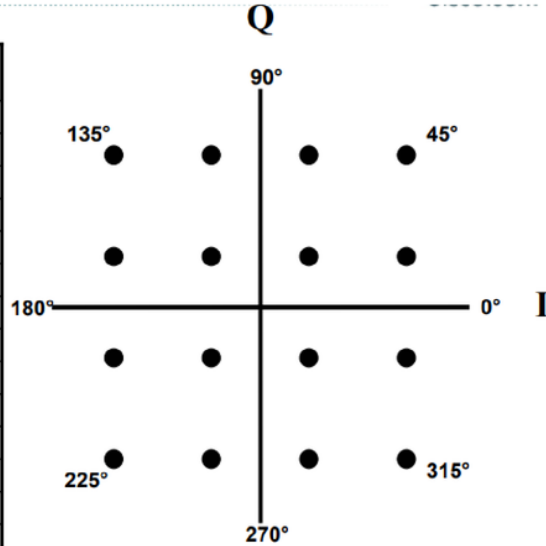


Figure 16: 16-QAM Constellation

The states are determined by the amplitude and phase of the wave, with each state having its own value for each. The optimum power for the wave is at the furthest point at the 45° angle phase shift in each quadrant.

Plesiosynchronous Digital Hierarchy (PDH)

This is a digital hierarchy designed for transporting large amounts of data across transmission networks. *A review of Plesiochronous Digital Hierarchy (PDH) and Synchronous Digital Hierarchy (SDH) states, "it uses a basic multiplex of 2Mbps with other stages of 8, 34 and 140Mbps."* (Olabenjo Babatunde, 2014) It uses pulse code modulation to transmit multiple signals across one line through time domain multiplexing. Extra bits are added for each bit stream in order to differentiate between the streams, these are known as justification bits.

This type of hierarchy is almost synchronous and so means it comes with many limitations. The stream of data has to be controlled by a clock rate. The different levels of bit rates means that there is a lot of multiplexing, meaning it is inefficient.

Synchronous Digital Hierarchy (SDH)

SDH was created to standardise the hierarchy for telecommunications and also improve the performance.

This form uses time division multiplexing that has very precise timing. *"Once the tributaries are synchronously multiplexed, they can be transmitted to the remote locations using electrical, optical fiber, or any other means or media."* (Chen, 1996) This is done by the single clock pulse which sends the information across.

3. FM Experimental method, results and analysis

To carry out the FM experiment, the 52-100-A signal source was connected to the 52-200-Q power supply module. The PicoScope was set up to measure the source from the function generator on Channel A, and Channel B was set up to measure the output from the board.

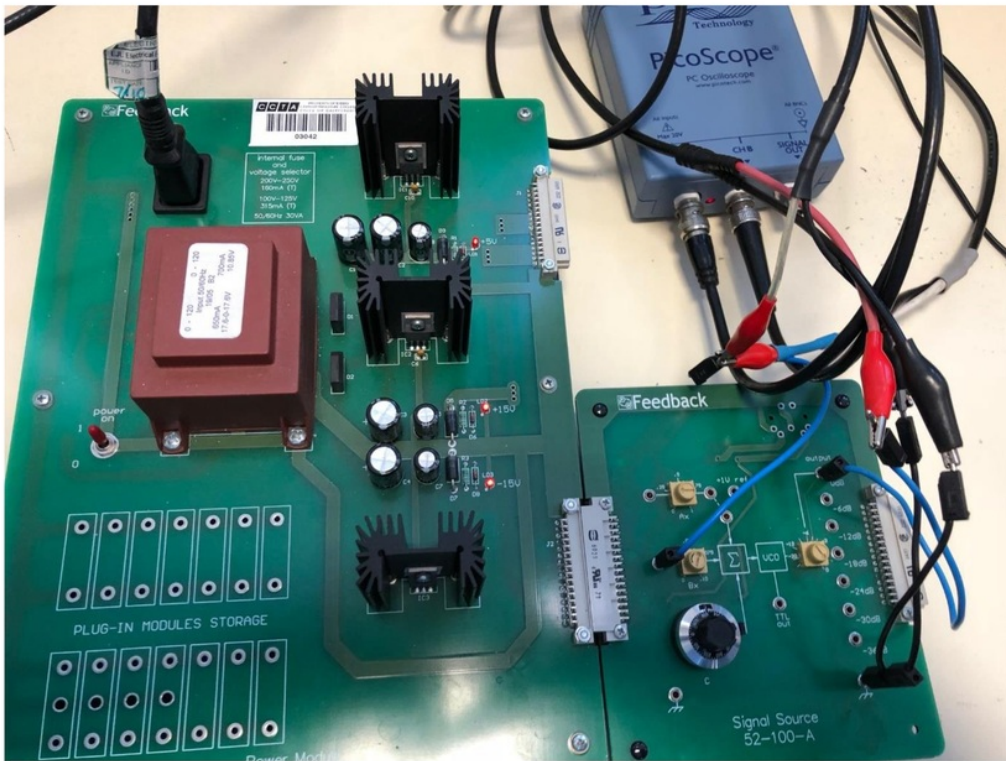


Figure 17: Signal Source, Power Supply and PicoScope

Figure 17: Signal Source, Power Supply and PicoScope7 shows the set up and adjustment dials for the attenuator, frequency and sensitivity control. The PicoScope is connected to the PC via USB and

Figure 18: 1kHz square wave

feeds information to the software.

When powered up, the function generator was set to generate a 1kHz square wave shown in figure 18. This is done to allow the individual frequency changes to become visible at this frequency during the set-up.

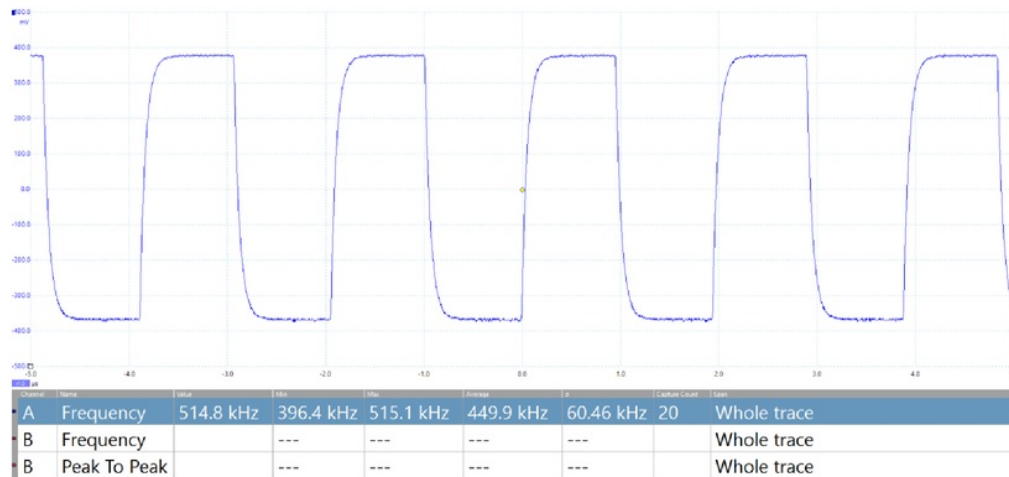
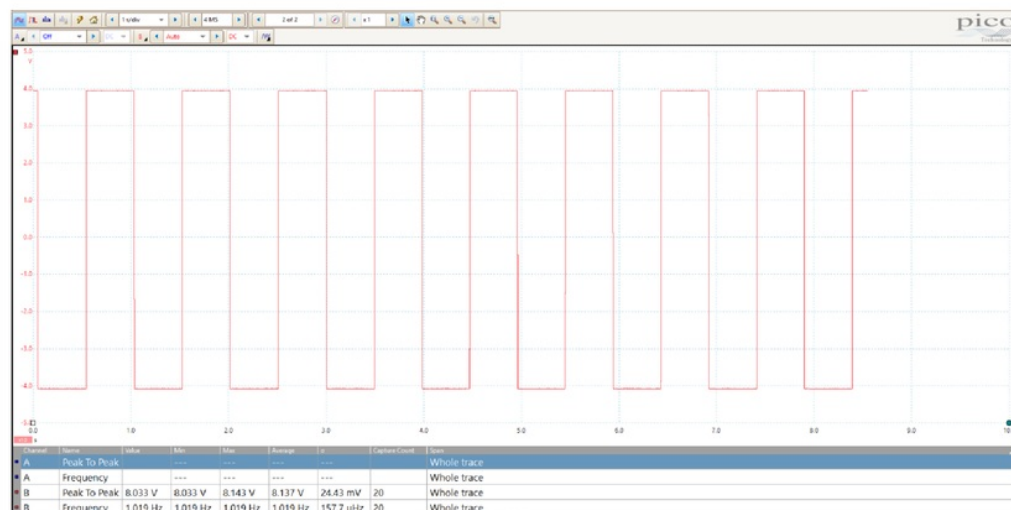


Figure 19: 6V p-p approx. 455kHz

The signal source was set to attenuate to 0dB with sensitivity control to maximum. Channel A frequency was set to 455kHz. The modulation generator was set to 1kHz with 6V peak-to-peak.

Figure 19 shows the set up at as close to 455kHz as possible for 6V peak-to-peak. The frequency on Channel A is varying between 514 and 396kHz.



The amplitude of the modulation generator was then reduced in 1V steps to observe the change in carrier frequency deviation, producing the following set of results.

Notably, when the peak-to-peak signal voltage is kept constant, the deviation in frequency does not change. Figures 20-28 show the results obtained.

P-P Voltage	Freq min	Freq max
6	396.4	515.4
5	371.4	538.4
4	389.1	521.9
3	405.9	506
2	423.1	489.6
1	435	472

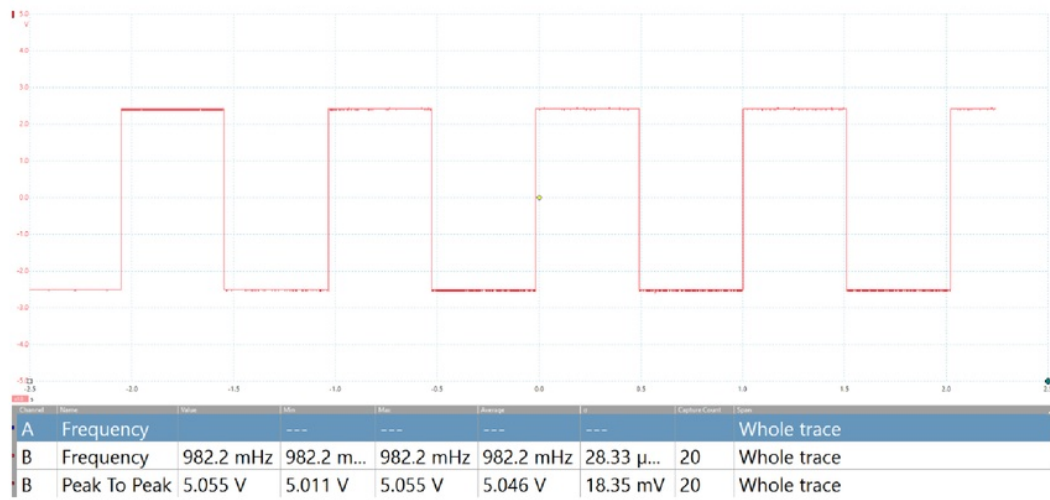


Figure 20: 5Vp-p modulation generator set up

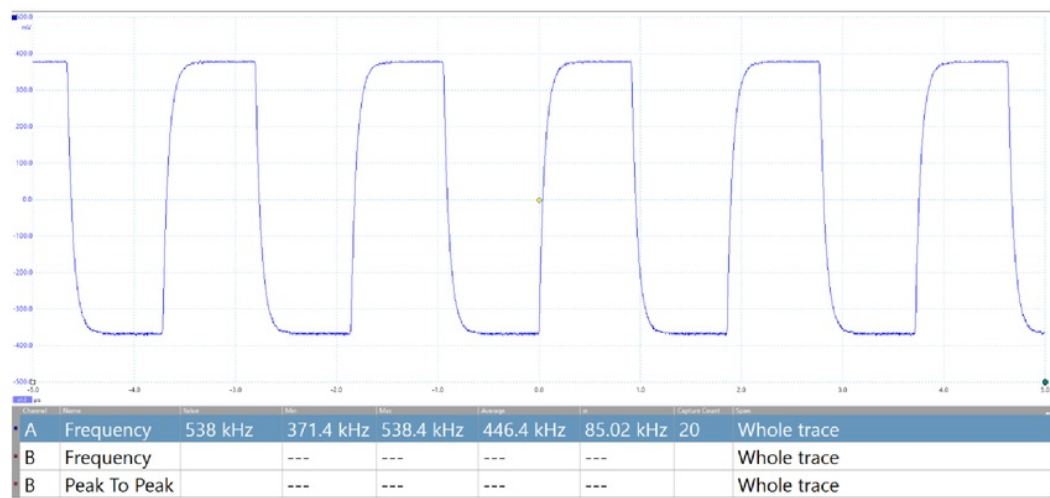


Figure 21: 5Vp-p freq



Figure 22: 4Vp-p modulation generator

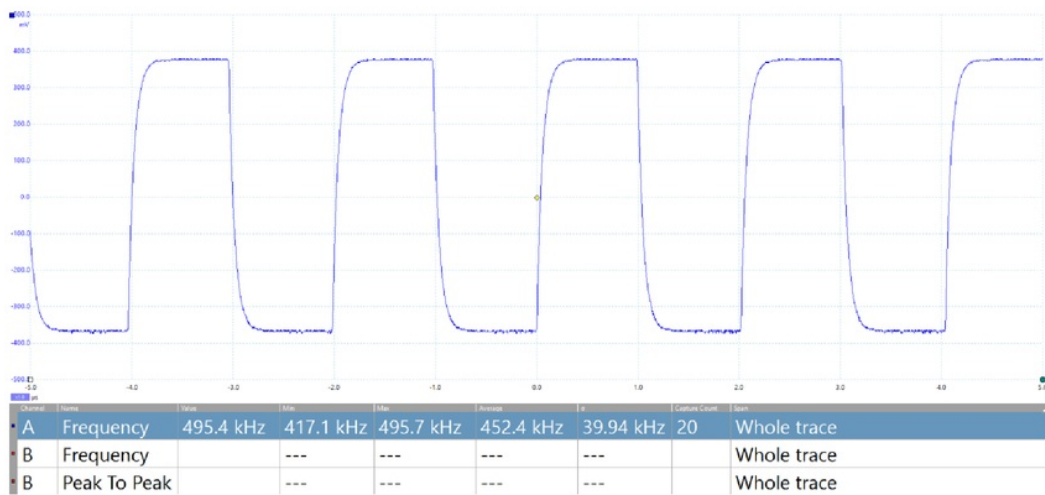


Figure 23: 4Vp-p freq



Figure 24: 3Vp-p modulation generator

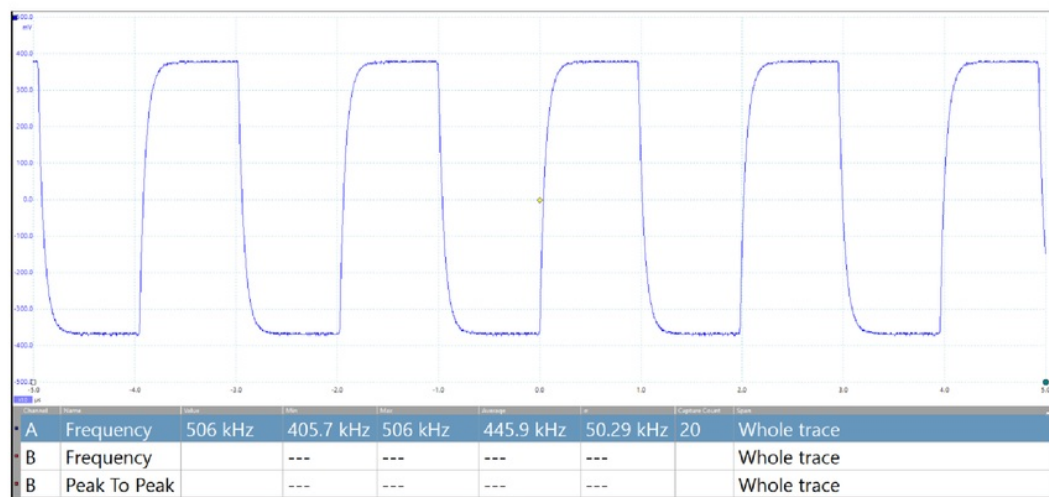


Figure 25: 3Vp-p freq

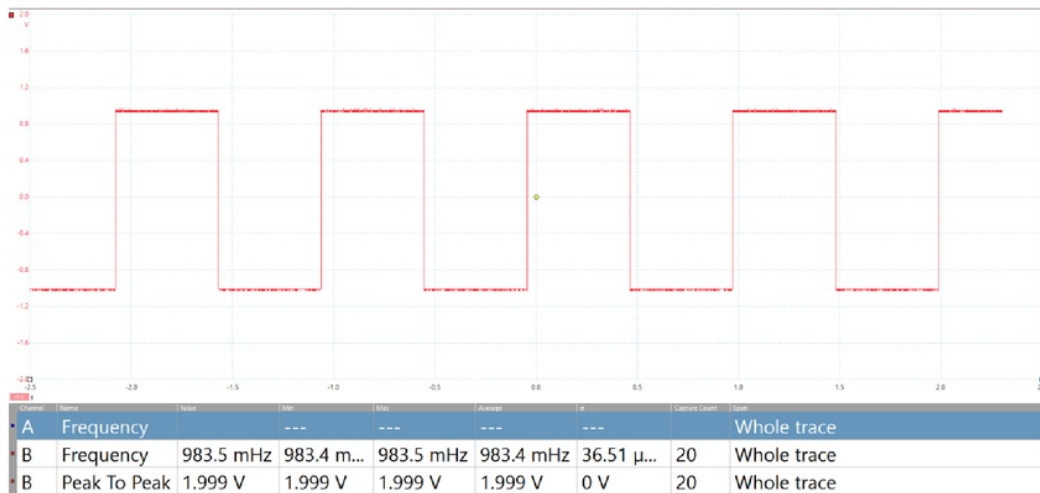


Figure 26: 2Vp-p modulation generator

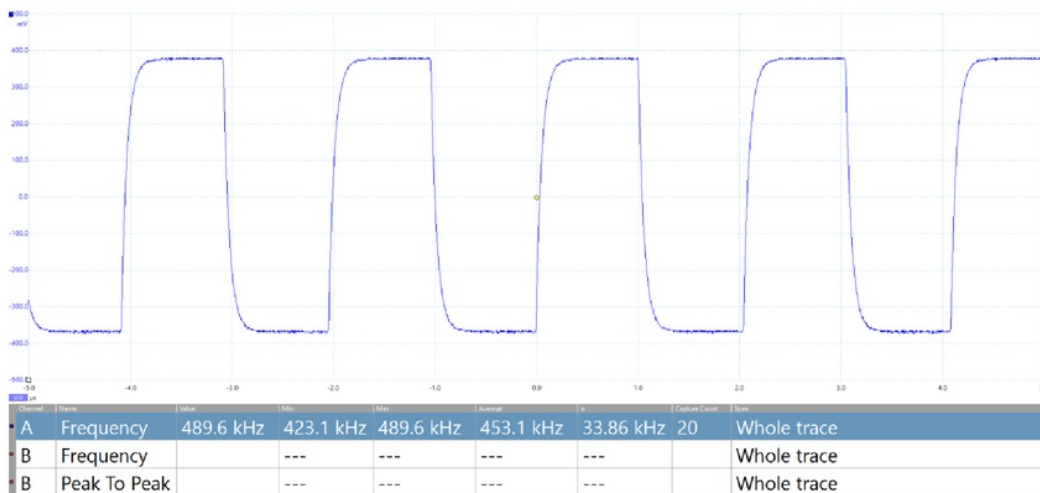


Figure 27: 2Vp-p freq

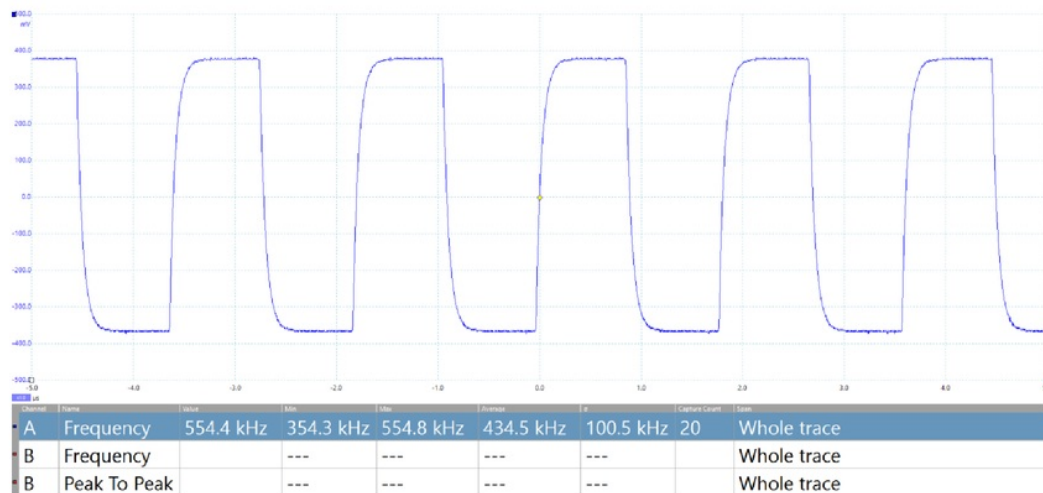


Figure 28: 1Vp-p freq

Calculations

With the experiment set up, values could then be calculated for the maximum frequency deviation and modulation index. The sidebands are found as follows:

$$f_c - f_s = 455k - 10k = 445kHz \text{ and } f_c + f_s = 455kHz + 10kHz = 465kHz$$

So at 2V peak-to-peak, there is 20kHz per volt with this FM characteristic. This means the frequency deviation is 40kHz.

Modulation index is equal to the change in carrier frequency (40kHz) divided by the message frequency (10kHz): $\beta = \frac{\Delta f_c}{f_s} \rightarrow \frac{40kHz}{10kHz} = 4$

To calculate the frequency deviation, the carrier frequency is taken away from the maximum frequency. The equation can thus be rearranged to find the maximum frequency:

$$40kHz = f_{max} - f_c \rightarrow f_{max} = 40kHz + 455kHz = 495kHz$$

Using the Bessel function table, the values for the frequency spectrum can also be determined in conjunction with the modulation index. So at $\beta = 4$:

$$J_0 = 0.4, J_1 = 0.07, J_2 = 0.36, J_3 = 0.43, J_4 = 0.28, J_5 = 0.13, J_6 = 0.05, J_7 = 0.02.$$

$$J_0 = 0.4 \times 375V = 0.15V$$

$$J_1 = 0.07 \times 375V = 0.02625V$$

$$J_2 = 0.36 \times 375V = 0.135V$$

$$J_3 = 0.43 \times 375V = 0.16125V$$

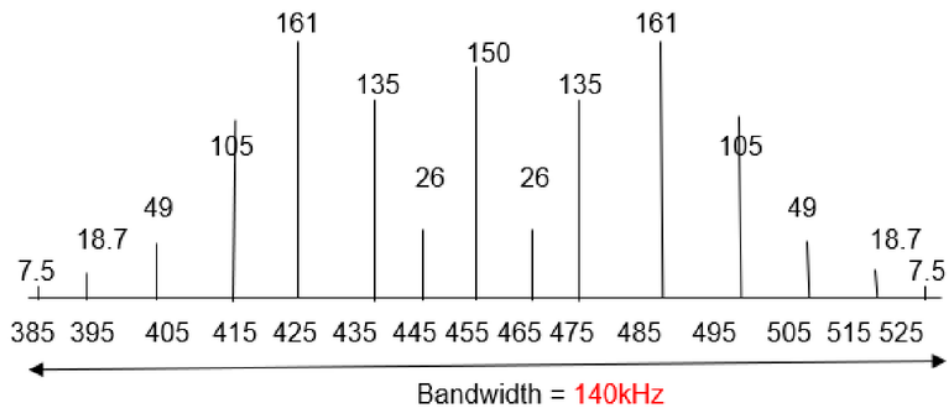
$$J_4 = 0.28 \times 375V = 0.105V$$

$$J_5 = 0.13 \times 375V = 0.04875V$$

$$J_6 = 0.05 \times 375V = 0.01875V$$

$$J_7 = 0.02 \times 375V = 7.5 \times 10^{-3}V$$

Bandwidth $525kHz - 385kHz = 140kHz$ The Frequency spectrum diagram can be seen below, with the peaks labelled in millivolts.



With the spectrum values calculated, the practical set up could now be adjusted to obtain the same frequency spectrum for comparison. This was done with 2V peak-to-peak and 20kHz modulation generation to obtain the frequency spectrum, shown in figures 29 and 30.

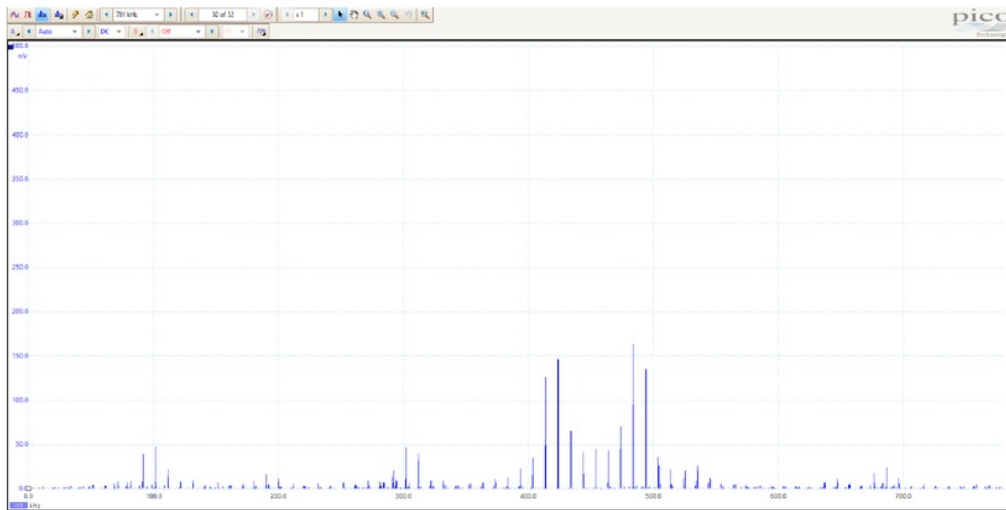


Figure 30: Frequency spectrum

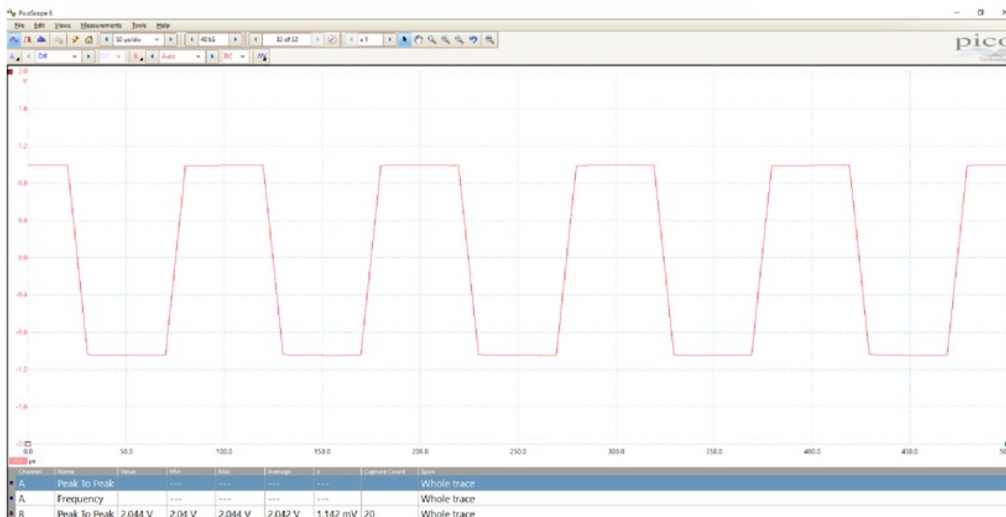


Figure 29: 2V peak-to-peak 10kHz

After obtaining the frequency spectrum, the values can be compared to the calculated spectrum and the pattern observed. J0 is at 45mV, J1 then drops to 40mV and rises to 70mV for J2. The next peak is the highest at 165mV for J3, then drops slightly to 135mV and then the last 4 noticeable peaks get progressively smaller.

Looking at the table, the frequency spectrum follows the same pattern for both the practical and the calculated, this trait is down to the modulation factor of 4. The peak voltages are slightly different, notably the centre peak voltage is much lower for the practical experiment. This is down to differences in the settings of the equipment on the practical as the calculations are performed accurately using exact values. For the practical, this was not always the case as it was difficult to achieve exact frequencies.

	Voltage (mV)	
Peak	Calculated	Practical
J0	150	45
J1	26	40
J2	135	70
J3	161	165
J4	105	135
J5	49	35
J6	18.7	22
J7	7.5	20

4. ADC Experimental method, results and analysis

To carry out the ADC experiment, the Analogue to digital converter was hooked up to the data formatter and on to the picoscope. The picoscope observed the analogue sine wave input and the ADC output on separate channels for comparison.

The specification of this particular ADC is sample rate: 10,000 samples/second, and range: 5Vp-p.

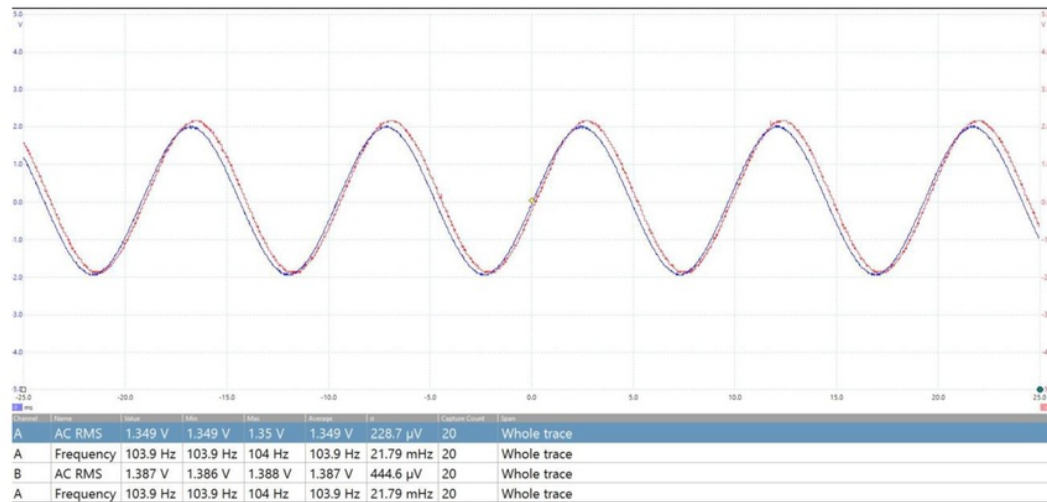


Figure 31: 8bit 100Hz at 4Vp-p

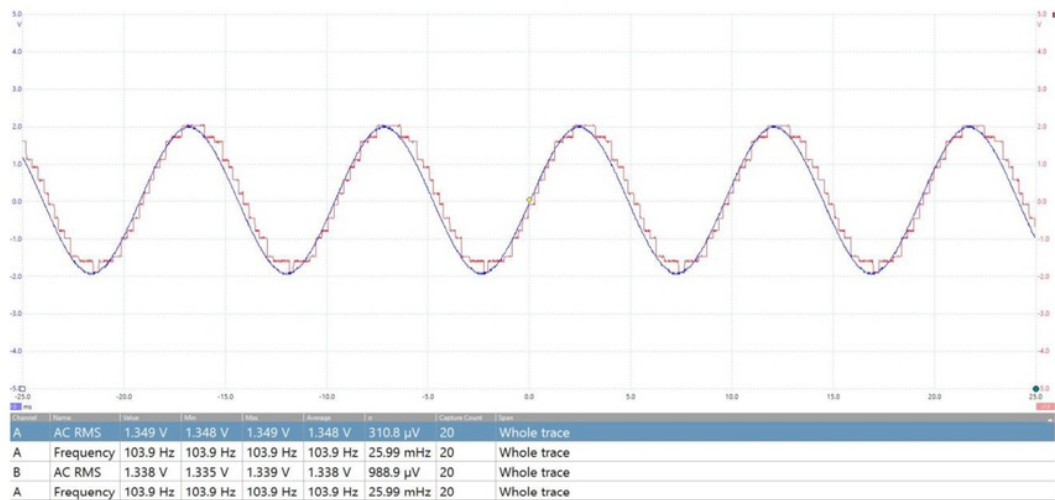


Figure 32: 4bit 100Hz at 4Vp-p

The first part of the experiment was to check the effect of changing the number of bits on the ADC. The ADC was set to 8bit and input frequency to 100Hz at 4Vp-p, the result is shown in figure 31. This is an almost identical representation of the input signal with the sample rate being clearly enough at 100Hz, at this point the ADC is sampling 100 times per wave cycle.

To see the effect, everything was kept constant apart from the bit setting of the ADC, which was reduced to 4, figure 32 displays this. The difference is noticeable as the output from the ADC is now clearly distinguishable from the original signal. There are fewer quantisation levels and there is a larger amount of quantisation error present. However, the output is still similar enough that it can be identified to be a representation of the original.

For the next test, the input frequency is kept at 100Hz and the ADC set to 4-bit. The input wave amplitude will be slowly increased from 0V.

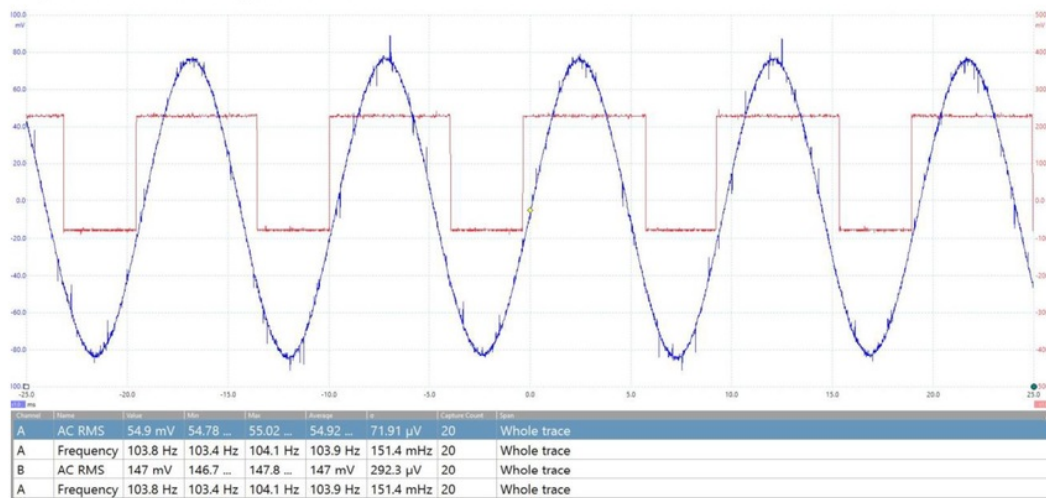


Figure 33: 4bit, 100Hz, 0V amplitude

The output at 0V amplitude can be seen in figure 33, at these small amplitudes, the size of the quantization jump is clear and shows how the original signal is being amplified as it jumps to the closest quantisation level at about 220mV, while the original signal peak amplitude is only 75mV.

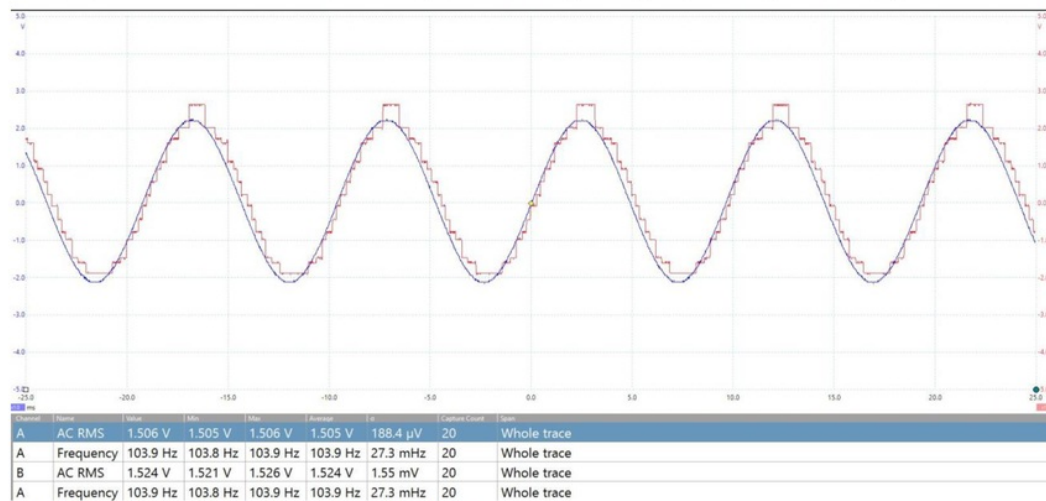


Figure 34: 4bit, 100Hz, 4Vp-p next quantisation level jump

Through calculating the resolution for the ADC $= \frac{10V}{2^4} = 0.625V$ per quantisation level and comparing to the results shown in figure 34 at the point where the next quantisation level has been reached. The quantisation level jump has increased by approximately 0.6V, this ties in with the value calculated.

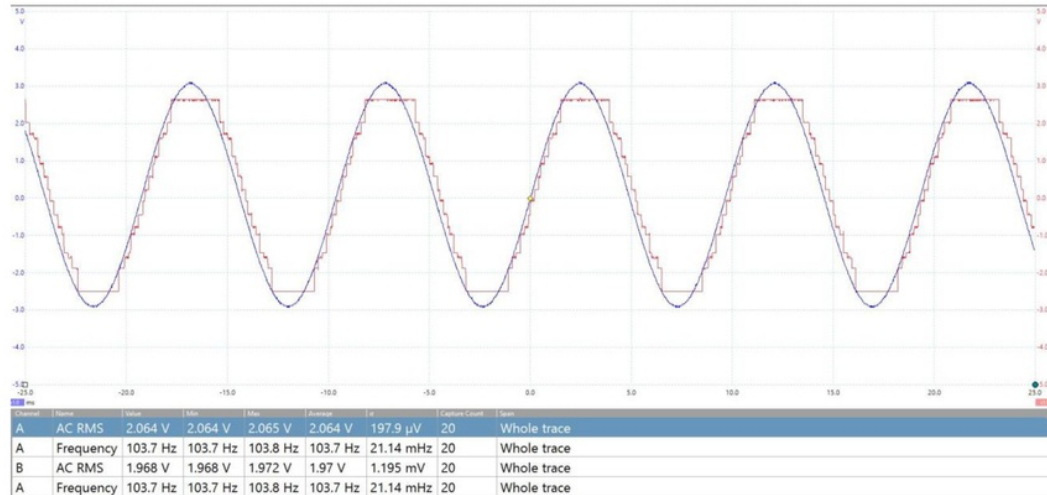


Figure 35: 6Vp-p clipping

In figure 35, the amplitude has been increased to 6Vp-p to the point where the ADC output is clipping, the peak-to-peak voltage of the output is 5V, this ties in with the range of the ADC and proves that it cannot output past this.

To do this for 8-bit resolution $= \frac{10V}{2^8} = 39mV$, the ADC will jump up 39mV to the next quantisation level. This was repeated for the ADC set to 8-bit with the amplitude set as close to zero as possible, shown in figure 36.

The separate quantization levels are visible at 0V for 8-bit, the jump seen at the top of the peak is just under 40mV, similar to the calculated value.

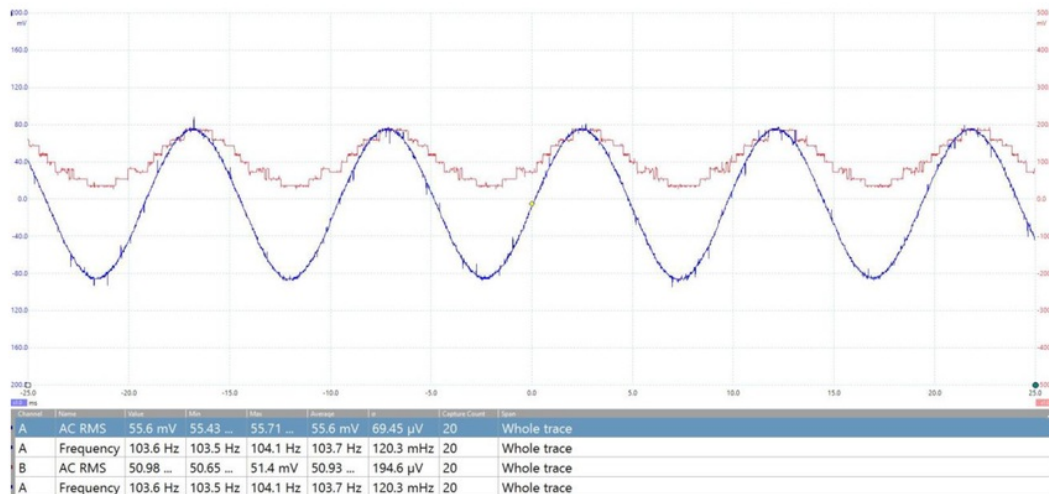


Figure 36: 8bit, 100Hz, 0V amplitude

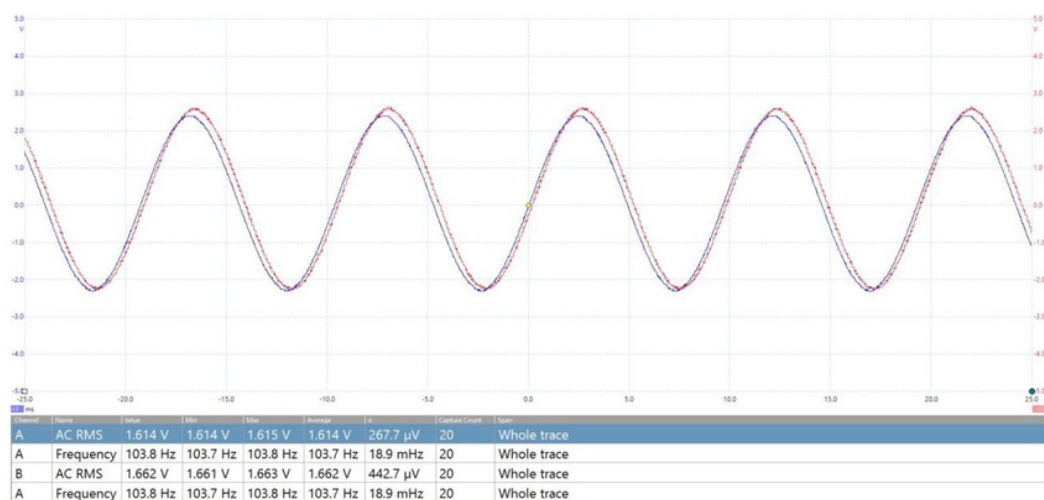


Figure 38: 8bit 5Vp-p no clipping

Figure 38 shows the maximum possible peak-to-peak voltage that the ADC can output before clipping, 5Vp-p. Once the amplitude is increased beyond this, it clips, as shown in figure 37 at 6Vp-p.

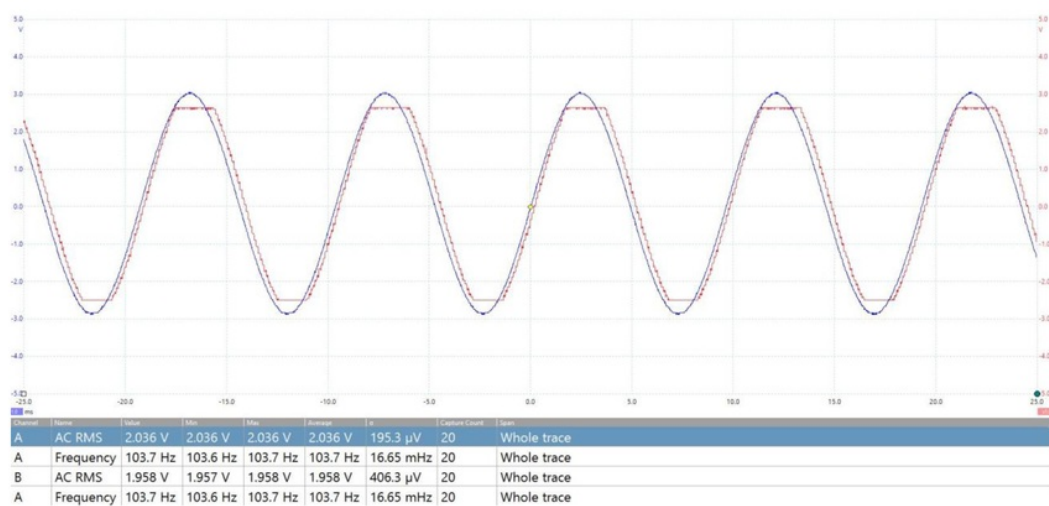


Figure 37: 8bit 6Vp-p

The next part of the experiment is to observe the effect of altering the input frequency, while amplitude stays at 4Vp-p. At 100Hz, the frequency remains the same for both the channel A and B. When increased to 1kHz, a slight phase shift becomes visible, as shown in figure 39.

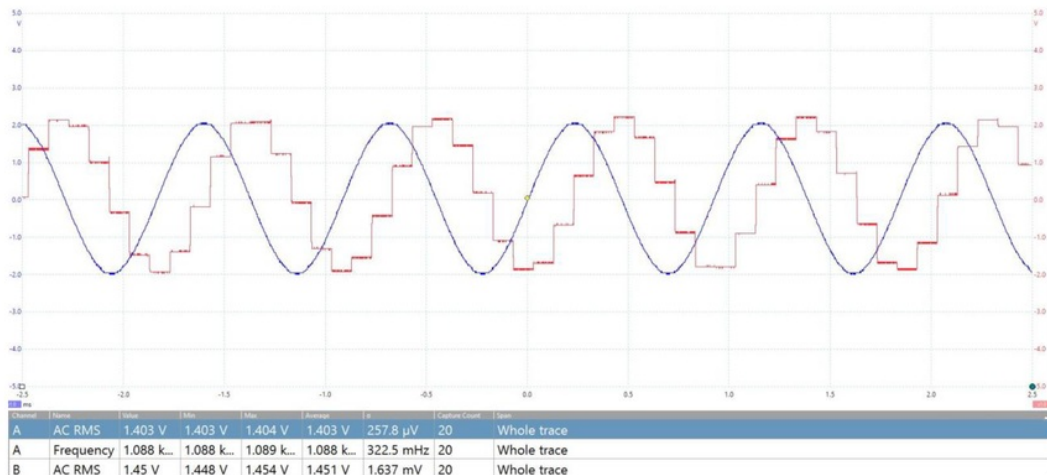


Figure 39: 1kHz

Furthermore, the next decade increase to 10kHz shows that aliasing has occurred, shown in figure 40.

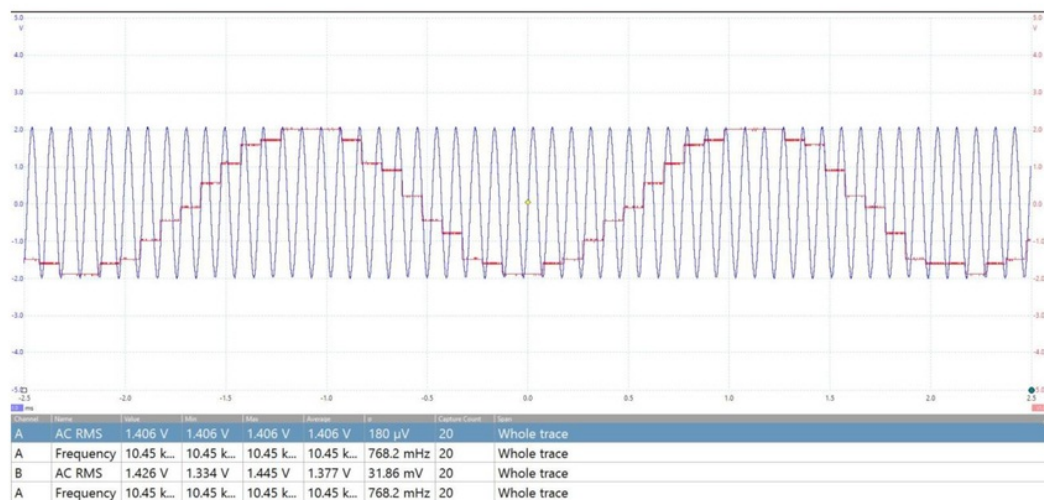


Figure 40: 10kHz alias

The input signal can be seen to be a much higher frequency at 10kHz where the output is a much lower alias signal. When comparing this to the ADC specification, it is stated that it samples at 10,000 times per second. As this is the frequency of the input signal, the ADC is sampling only once every wave form, hence an alias is seen being produced.

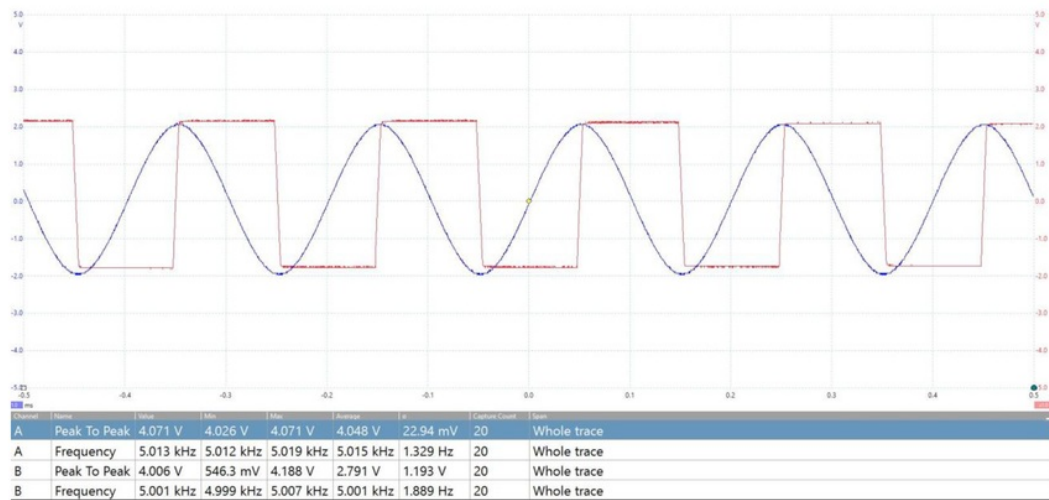


Figure 41: 5kHz

At 5kHz, the ADC is sampling twice every input wave cycle. As there is a positive and negative peak in each cycle, the ADC is sampling at the exact point of each peak. Figure 41 shows this, as just down to the sampling and frequency, both Channels are similar. This relates to the Nyquist theorem which states that the minimum sample rate must be twice that of the input wave frequency. If the sample frequency was any lower, the wave would not sample at these exact peaks of the input every cycle and the output would start to alias.

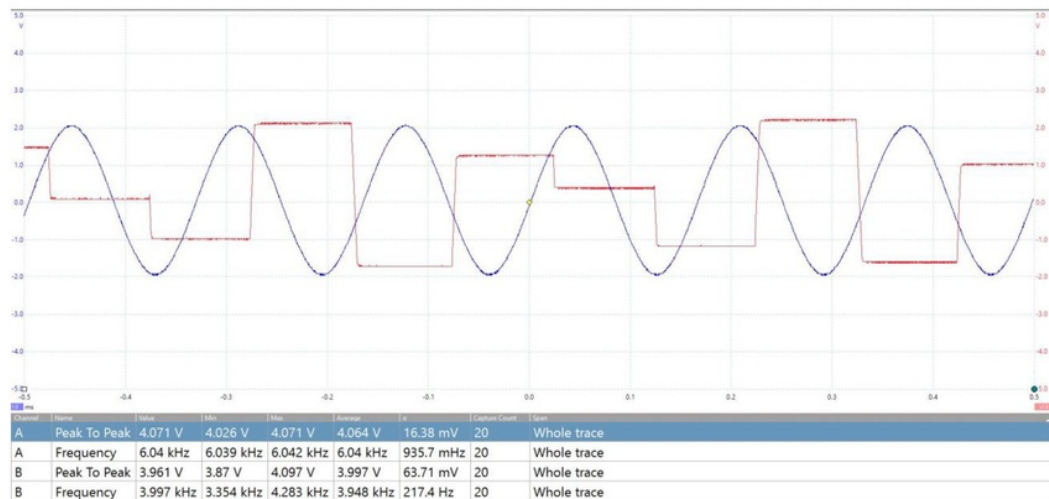


Figure 42: 6kHz, aliasing has started

Figure 42 shows how aliasing has started at 6kHz input frequency, the output frequency is almost half the input and the waveform looks totally different.

5. Conclusions and Recommendations

FM

Through carrying out the FM experiment and performing research and calculations based on theory, it became evident that the results tied in with the theoretical predictions.

Investigating the effect that increasing the peak-to-peak voltage on the modulation generator had on the resulting wave frequency proved that the amplitude of the modulation generator determined the frequency. A larger peak-to-peak voltage indicated a larger deviation between the two frequencies and vice-versa. As this was reduced from 6V to 1V, the distance reduced.

P-P Voltage	Freq min	Freq max	Difference
6	396.4	515.4	119
5	371.4	538.4	167
4	389.1	521.9	132
3	405.9	506	101
2	423.1	489.6	66
1	435	472	37

The modulation factor was worked out to be 4, this means that every volt increase, the deviation increases by 20kHz each side, so a total of 40kHz, this is roughly the increase when looking at the table above. The difference in practice could be down to slight inaccuracies in the instruments/equipment and parallax error.

When comparing the frequency spectrum tables taken from the practical and calculated from the Bessel function table, similarities can be seen.

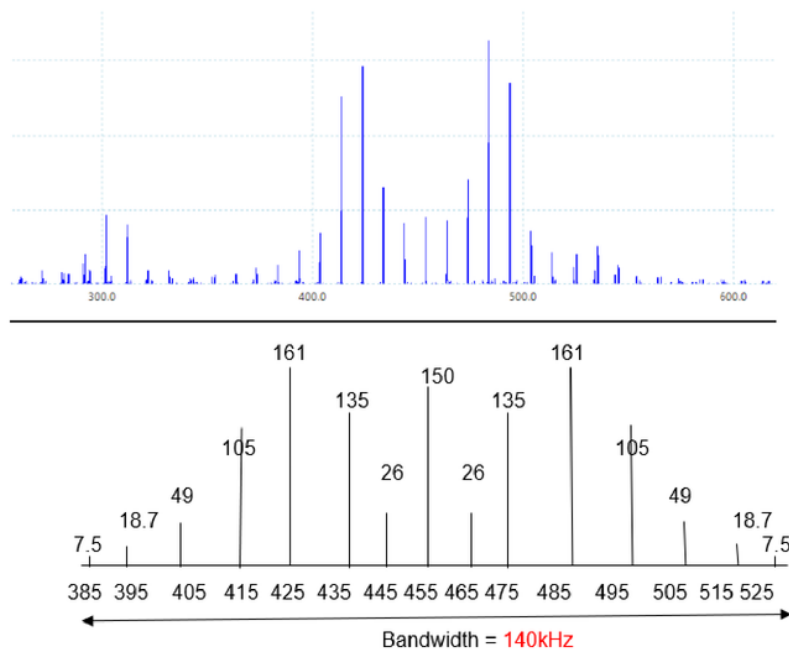


Figure 43: Spectrum comparison

The pattern of the frequency spectrum taken from the practical is similar to that calculated, with peaks being roughly the same magnitude and in the correct locations, all separated by 5kHz. This proves that this FM characteristic provides the centre frequencies and 7 pairs of sidebands. The outer most sidebands begin to drop sharply in amplitude, correlating to the researched Bessel order graph where the earlier pairs of sidebands become more prominent and further ones gain strength progressively while the carrier drops.

Overall, the results show correlation between theory and practice, slight differences are present, but it is still clear that the Bessel function table is an accurate way of deducing the sideband amplitudes for frequency modulation.

ADC

For the analogue to digital converter experiment, the results show that not meeting the sampling frequency required by the Nyquist theorem will produce aliasing. The limit of similarity before aliasing between input and output can be seen in figure 41 as the ADC is sampling on the peak of every wave cycle and the negative peak once each. This is at 5kHz and the sample frequency is 10kHz, double the frequency, this is the minimum Nyquist limit. Increasing the input frequency above this causes aliasing evident in figure 42, where the output frequency is almost half that of the input and the wave looks very different. Matching the sample frequency with the input at 10kHz shows a form of aliasing where the input is being sampled once a cycle and forms a completely different wave.

Investigating the effect of resolution and quantisation levels provided results which matched that of the calculated values. The point at which a new quantisation level is needed can be seen and the gap per level is approximately 0.6V in figure 35, matching that of the calculated value for 4bit. This is also the case with the 39mV quantisation level calculated for the 8bit resolution.

Exceeding the range of the ADC (in this case 5V peak-to-peak) produces a clipped output, this can be seen when the input is raised to 6Vp-p.

Overall the results of the practical match the theory and calculations very closely, proving that the Nyquist criterion is valid and not meeting it has a profound effect on the output. The quality of the conversion drops greatly as the resolution decreases as it means there are fewer quantisation levels and the signal jumps a further distance to meet this level, distorting it further.

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PSDE5014SGEE5005 Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: ASSIGNMENT RUBRIC 2018

DANIEL INCE

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ENGAGEMENT WITH LITERATURE

 There was very good evidence of further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was good and demonstrated a very good underlying appreciation of the subject. 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.

7

KNOWLEDGE AND UNDERSTANDING

 The knowledge and understanding of the subject demonstrated by this assignment was generally very good. There were 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 competent critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes.

22

COGNITIVE AND INTELLECTUAL

 Your analysis of the task was generally very good, both in class and as shown in this assignment. You have demonstrated sound critical analysis skills and your approach to the task was logical. You carried out a detailed evaluation of the results and included

20

a good conclusion relating the practical results to researched theory. The conclusions demonstrated very good cognitive skills and the ability to interpret quantitative and qualitative data without error.

PRACTICAL APPLICATION



Your application of practical skills for this task was generally very good. You used the resources appropriately when carrying out the experiment and you used appropriate options for testing and evaluating the circuit performance. You managed to setup an effective circuit that functioned within the specification and achieved this by only asking for assistance when appropriate thus demonstrating some advanced problem solving skills. Your results were comprehensive and allowed for a detailed conclusion to be attempted.

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TRANSFERABLE SKILLS FOR LIFE



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, with excellent diagrams in appropriate places, good sentence/paragraph structure and clear calculations.

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