

Assignment_2

by Joshua Beer

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Signals and
Digital
Communications

Digital Modulation Schemes

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1. Introduction

The aims and objectives of this assignment are as follows:

Carry out research into the following pulse code modulation areas; PAM and PCM techniques, aliasing and modulation schemes (e.g. ASK, FSK, PSK, QPSK and QAM 16).

These methods will be compared and contrasted and critically evaluated to find their strengths and weaknesses.

Carry out an experiment from the Feedback Instruments Ltd pack "Digital Communications" on pulse code modulation. This must include the experimental procedure, results and critical analysis as part of the report.

For this experiment you will investigation of sampling requirements, quantisation noise and aliasing will take place.

2. Research

(techopedia, 2018) States "Pulse code modulation (PCM) is a digital representation of an analogue signal that takes samples of the amplitude of the analogue signal at regular intervals. The sampled analogue data is changed to, and then represented by, binary data. PCM requires a very accurate clock. The number of samples per second, ranging from 8,000 to 192,000, is usually several times the maximum frequency of the analogue waveform in Hertz (Hz), or cycles per second, which ranges from 8 to 192 KHz."

The PCM is done in three different stages, these are; sampling, quantisation and coding. A diagram of this can be seen below in figure 1.

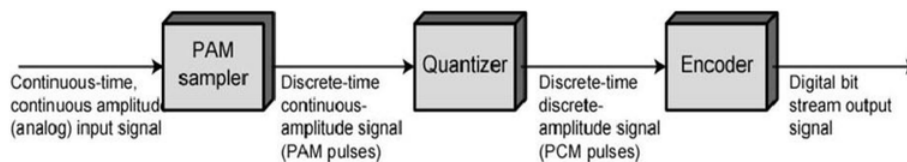


Figure 1 - PCM Sample, Quantisation and Coding (Elprocus, 2018)

In sampling a pulse amplitude modulation sampler is used to convert continuous sampling into discrete-time-continuous signal as shown above.

Sampling is taking a continuous signal and taking measurements of this signal at certain specific points. Depending upon how often the samples are taken will depend on how high the resolution of the signal will be, for example it would be wise to take samples more often to create a better understanding of the signal. If the samples were to be taken at too low of frequency compared to the original signal, the sample may be totally different from the original.

(Elprocus, 2018) States "the Sampling process generates a flat- top Pulse Amplitude Modulated (PAM) signal."

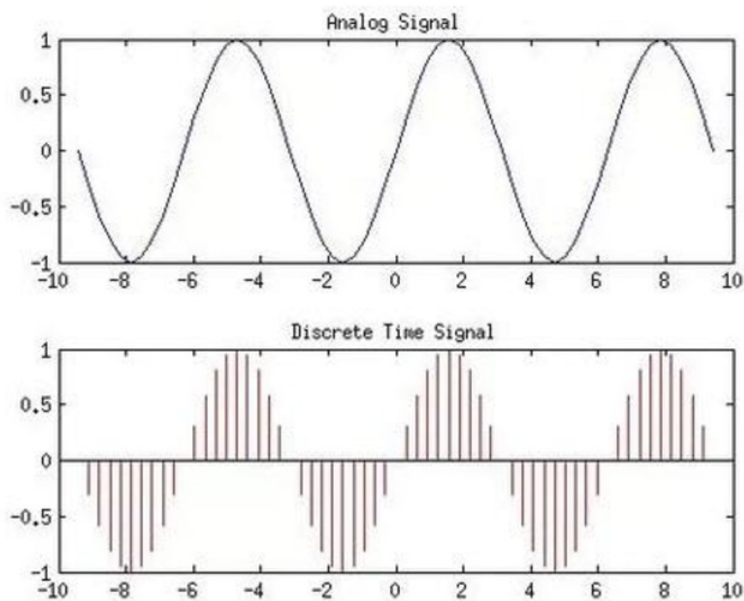


Figure 2 – Sampling (Elprocus, 2018)

The sample rate according to the Nyquist Theorem should be at least 2 times the upper cut-off frequency. Sampling frequency, $F_s \geq 2 \cdot f_{\max}$ to avoid aliasing effect.

The aliasing effect will be researched further later on.

Quantisation is the next part of PCM and means it is mapping input values from the analogue signal and placing them in smaller sets of countable signals, essentially quantisation is rounding the values of the analogue signal and digitising them. This creates a quantisation error.

Quantisation takes the samples from the signal and rounds them into specific fixed-set values. These are typically 8, 16 and 32 bit length values. As explained earlier, quantisation will produce errors, but the higher the length of bit used and therefore the more set values used, the lower the quantisation error.

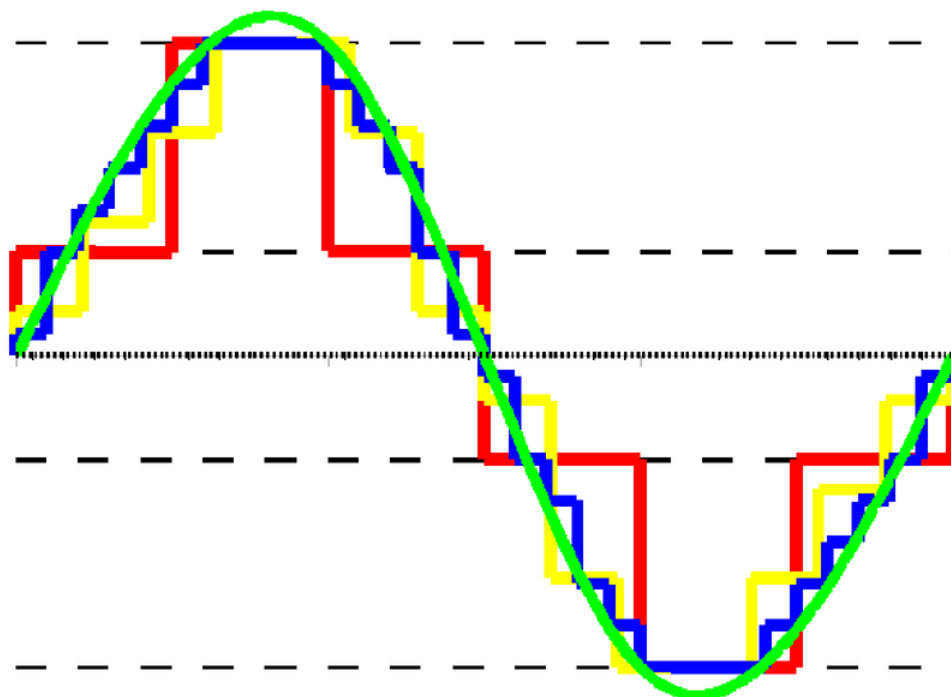


Figure 3 - Quantisation Example

Figure 3 shows the analogue signal (green) and 3 different sample resolutions, 2 bit (red), 3 bit (yellow) and 4 bit (blue).

This shows how quantisation is working and how more bits creates a higher resolution with less quantisation error.

Coding takes the quantisation signal and encodes the quantised samples.

Each quantised sample is encoded into an 8-bit code word by using A-law in the encoding process.

According to (Elprocus, 2018) Bit 1 is the most significant bit (MSB), it represents the polarity of the sample. "1" represents positive polarity and "0" represents negative polarity.

Bits 2, 3 and 4 will defines the location of sample value. These three bits together form linear curve for low level negative or positive samples.

Bits 5, 6, 7 and 8 are the least significant bits (LSB) it represents one of the segments quantised values. Each segment is divided into 16 quantum levels.

The coding takes the quantisation values and puts them into binary form that can be digitally transferred and read.

There are some advantages of PCM examples of which are given below:

- The PCM is convenient for long distance communication.
- It has a higher transmitter efficiency.
- It has a higher noise immunity.

There are disadvantages of PCM examples of which are given below:

- The PCM requires a large bandwidth compared to an analogue system.
- Encoding, decoding and quantizing circuit of PCM is very complex.

Below are some example applications of PCM:

- The PCM is used in the satellite transmission systems.
- It is used in space communication.
- The compact disc (CD) is a recent application of PCM.

Pulse amplitude modulation (PAM) is when the amplitude of each pulse is controlled by the amplitude of the modulation signal. This technique transmits the data by encoding in the amplitude a series of signal pulses.

(Elprocus, 2018) States "A PAM is generated from a pure sine wave modulating signal and a square wave generator which produces the carrier pulse and a PAM modulator circuit. A sine wave generator is used which is based on Wien Bridge Oscillator circuit. This can produce distortion less sine wave at the output. The circuit is designed such that the amplitude and the frequency of the oscillator can be adjusted using a potentiometer."

There are some advantages of PAM examples of which are given below

- It is the simple process for both modulation and demodulation.
- Transmitter and receiver circuits are simple and easy to construct.
- PAM can generate other pulse modulation signals and can carry the message at the same time.

There are some disadvantages of PAM examples of which are given below

- Bandwidth should be large for transmission PAM modulation.
- Noise will be great.
- Pulse amplitude signal varies so power required for transmission will be more.

Below are some example applications of PAM:

- It is used in Ethernet communication.
- It is used in many micro-controllers for generating the control signals.
- It is used in Photo-biology.
- It is used as an electronic driver for LED lighting.

Aliasing was touched on above, but to further explain it; figure 4 below will be used.

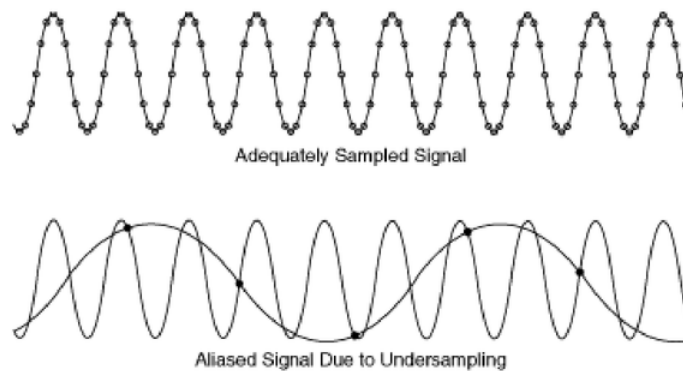


Figure 4 – Aliasing (National Instruments, 2018)

Figure 4 shows aliasing as the original signal is under sampled. This can be seen as the original signal above is at a much higher frequency than the sampled frequency below. This is because the aliased signal is under sampled.

(National Instruments, 2018) States "Signals with frequency components above the Nyquist frequency appear aliased between DC and the Nyquist frequency. In an aliased signal, frequency components actually above the Nyquist frequency appear as frequency components below the Nyquist frequency."

ASK is made by changing the amplitude of the carrier signal to reflect amplitude levels in the digital signal. The line encoding will determine the values of the analogue waveform to reflect the digital signal being carried, this is done by a digital high signal of 1 not affecting the signal whereas a low signal of 0 would make the signal zero.

The bandwidth B of ASK is proportional to the signal rate S .

$$B = (1+d)S$$

" d " is due to modulation and filtering, lies between 0 and 1.

FSK is made by the digital data stream changing the frequency of the carrier signal, f_c . The line encoding can determine the values of the analog waveform, this is done by a "1" representing $f_1 = f_c + \Delta f$, and a "0" representing $f_2 = f_c - \Delta f$.

The bandwidth of FSK is shown as: if the difference between the two frequencies (f_1 and f_2) is $2\Delta f$, then the required BW B will be:

$$B = (1+d) \times S + 2\Delta f$$

FSK can be coherent or non-coherent, this means that coherent will switch from one signal to the other on the same phase shift whereas the non-coherent will not be on the same phase shift.

Multi-level FSK is possible, similar to ASK, FSK can use multiple bits per signal. This means that when receiving the frequency there needs to be a provision to separate these frequencies and represent a different frequency each.

The bandwidth for FSK can be higher

$$B = (1+d) \times S + (L-1)/2 \Delta f = L \times S$$

PSK is made by varying the phase shift of the carrier signal to represent digital data, the bandwidth requirement, B is:

$$B = (1+d) \times S$$

PSK is much better and stronger than ASK as it isn't vulnerable to noise which changes the amplitude of the signal and thus affect ASK more.

Quadrature phase shift keying (QPSK) is used because instead of using 0 and 1 to transfer data like normal shift keys, it can carry 4 bits of data at once 00, 01, 10 and 11.

This is because it varies in terms of phase and not frequency, thus allows 4 stages at 45, 135, 225 and 315 degrees.

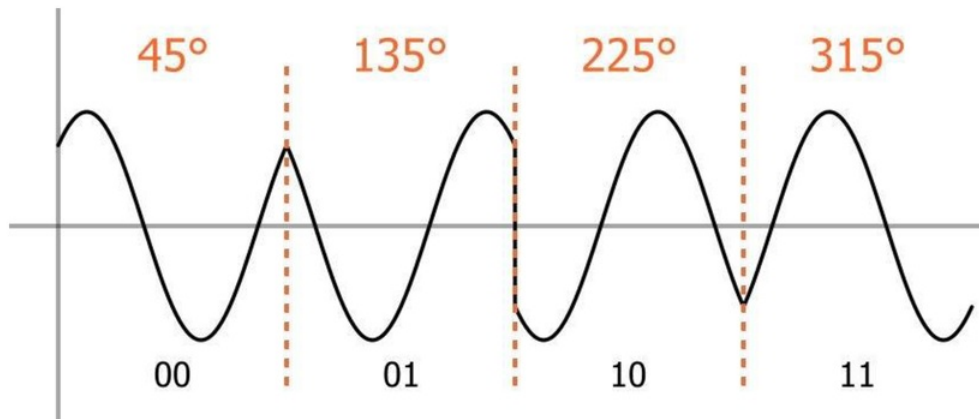


Figure 5 - QPSK (Allaboutcircuits, 2018)

(Allaboutcircuits, 2018) States "There's another reason why it makes sense to choose 45° , 135° , 225° , and 315° : they are easily generated using I/Q modulation techniques because summing I and Q signals that are either inverted or non-inverted results in these four phase shifts."

Advantages of QPSK are that it takes up half the bandwidth frequency of others as it carries twice as much data in the same space.

3. Experimental method

The next part of the assignment is to practically test with the use of pulse code modulation and the limits of the in-built ADC.

The practical will test and therefore investigate the sampling requirements, quantisation noise and aliasing.

Investigate the limits of the in-built ADC.

Specification of ADC: Sample rate = 10,000 samples/second and Range = 5Vp-p

- Effect of changing the number of bits of the ADC
 - Set the ADC to 8 bit.
 - Set the input frequency to 100Hz @ 4V p-p and observe the output.
 - Set the ADC to 4 bit and again observe the output.
 - Screenshot and comment on results

- Effect of changing the input amplitude for 8 bit and 4 bit ADC's with frequency held constant
 - Set the ADC to 4 bit.
 - Set the input frequency to 100Hz @0V and observe the output.
 - Slowly increase the amplitude to 6Vp-p and observe the output.
 - Record the values at which a new quantisation level is needed
 - Determine the resolution of the ADC and compare to calculated value
 - Set the ADC to 8 bit and repeat.

- Effect of changing the frequency of the input with amplitude held constant.
 - Set the ADC to 8 bit.
 - Set the input frequency to 100Hz @ 4V p-p.
 - Add measurements on PicoScope to show blue and red channel frequencies.
 - Increase the frequency in decades (100Hz, 1KHz etc) by clicking the range buttons on the function generator and observe the output at each.
 - Record and comment on any significant changes.
 - Set the function generator to 4KHz.
 - Use the dial to increase the frequency in 200Hz steps to 6KHz, then in 500Hz steps to 10KHz.
 - Observe the waveforms and comment on any significant changes.

Figure 6 - Practical Procedure

Figure 6 shows the practical procedure which will be used to carry out the tests used for the next part of the assignment.

It sets out the specification of the ADC which is:

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

The first part of the procedure is to test the effect of changing the number of bits in the ADC. This will change the numbers of bits used from 4 to 8 bits.

The first part of the practical will need ADC to work with 8 bits; the research can be referred to for how increasing or decreasing bits will affect the ADC.

Once the 8 bit set up is working along with the specification mentioned in figure 6 the test will be carried out and the results taken.

The next part of the procedure asks for the ADC to be changed to operate with 4 bits, again as above abiding by the same specification mentioned in the procedure.

Once this has been completed the test results will again be taken for analysis in the next part of the assignment.

The next part of the procedure asks that the signals amplitude is changed; this part will keep the frequency at a constant of 100Hz and increase the peak to peak voltage from 0-6V p-p.

The practical test will be done and results taken for analysis.

The next part of the procedure asks for the changing the signal frequency, this will have a starting frequency of 100 Hz and an amplitude of 4V p-p, then gradually increasing the frequency to 1 KHz.

All test results will be recorded using screenshots and the results analysed.

The final part of the procedure asks for the function generator to be set up for 4 KHz and then increasing the frequency in 200 Hz steps until it reaches 6 KHz.

Once this has been achieved the frequency will be increased by 500 Hz steps until 10 KHz is reached.

All test results will be recorded using screenshots and the results analysed.

4. Testing and Analysis of Results

The first part of the procedure asked to test the effect of changing the number of bits in the ADC. This part of the practical was to set the ADC up to the requirements as per the assignment brief with 8 bits being used.

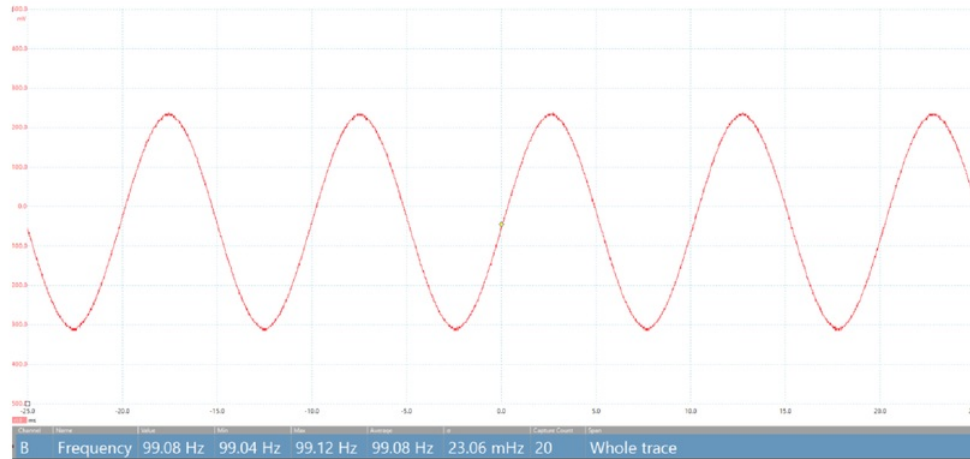


Figure 7 - 8 bit 100 Hz

Figure 7 shows setting the frequency up to 100 Hz.

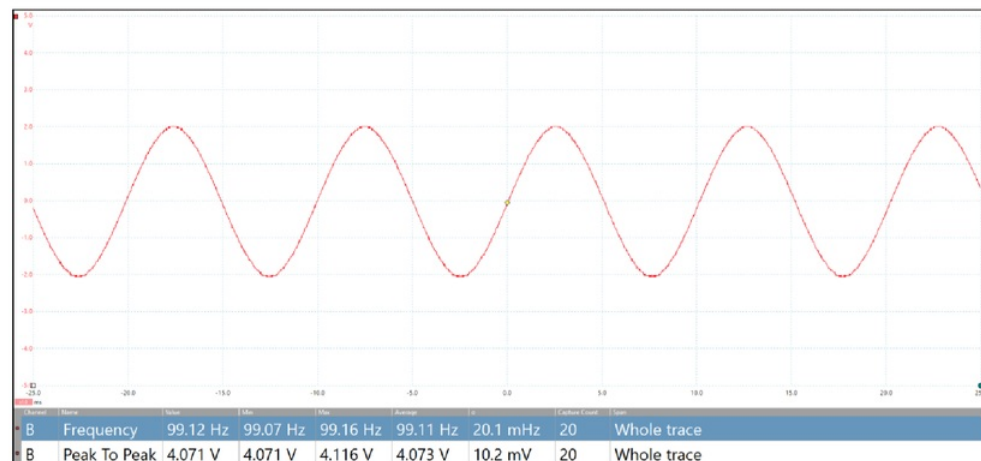


Figure 8 - 8 bit 4 V p-p

Figure 8 shows setting the V p-p to 4 V p-p.

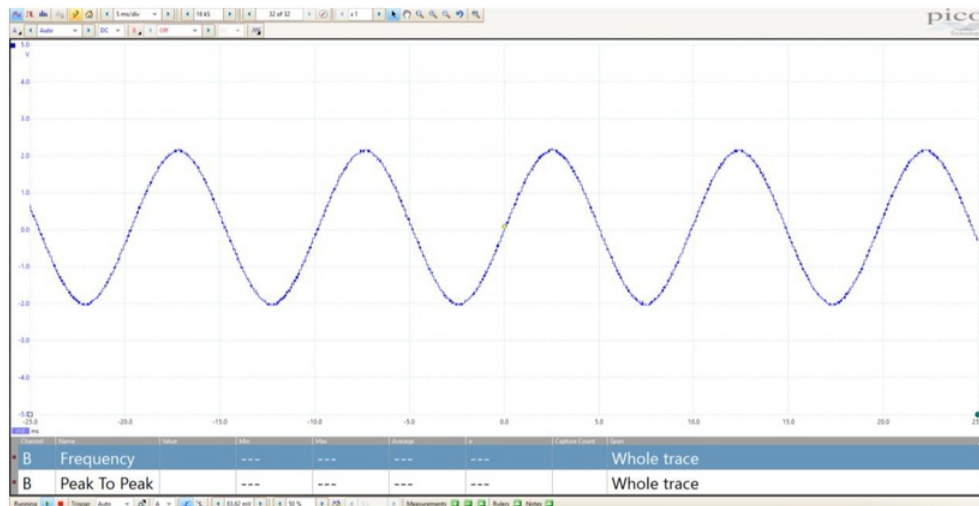


Figure 9 - 8 bit Setup Screenshot (8 bits)

Figure 9 shows the experiment has now been set up as per procedure and 8 bits resolution for the ADC is switched on the board. This is giving a smooth signal curve as 8 bits is a good resolution.

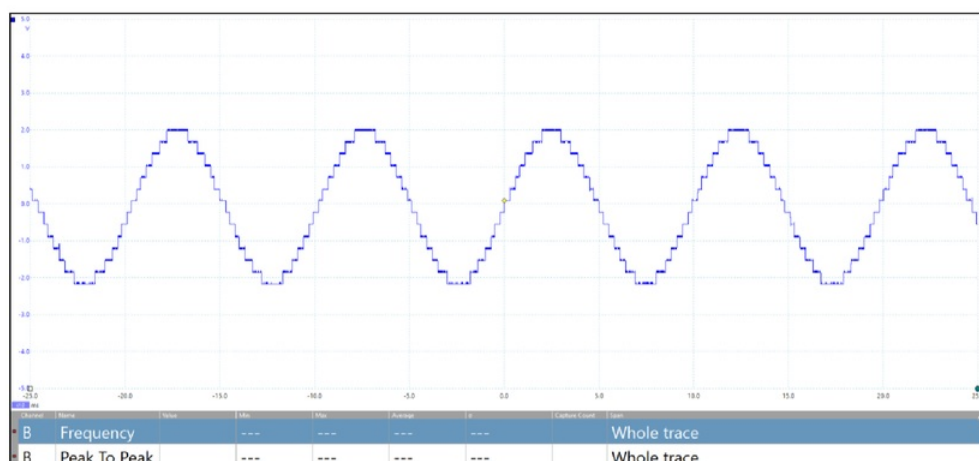


Figure 10 - 8 bit Setup Screenshot (4 bits)

By swapping from 8 to 4 bits as pre procedure the difference in the signal resolution can clearly be seen. It is far less smooth and has poorer resolution; this is down to the quantisation effect explained in the research.

The next part of the procedure asked to test the effect of changing the V p-p from 0 – 6 V. This part of the practical was to set the ADC up to the requirements as per the assignment brief with 4 bits being used. The difference from the specification set out in the procedure is that 500 mV is the lowest amplitude the machine would generate and therefore this can be considered to be 0 V.

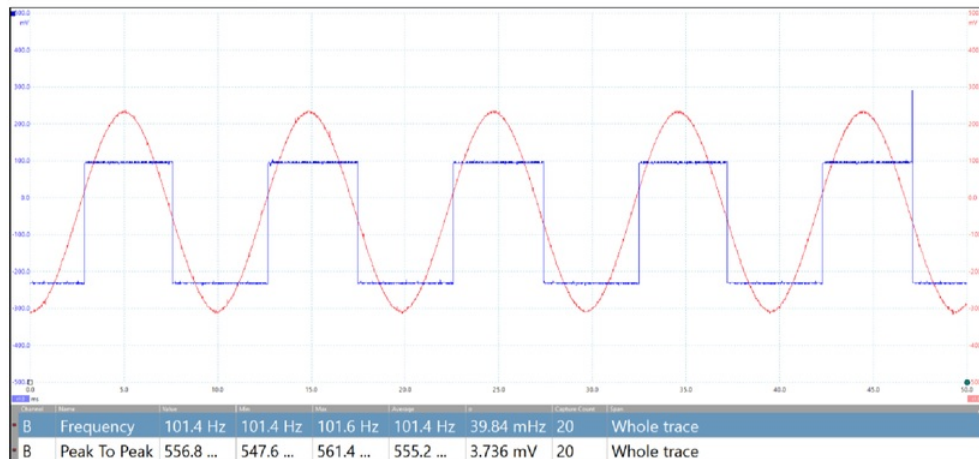


Figure 11 - 4 bit 0 V p-p

Figure 11 shows 0 V p-p and the sampling is poor.

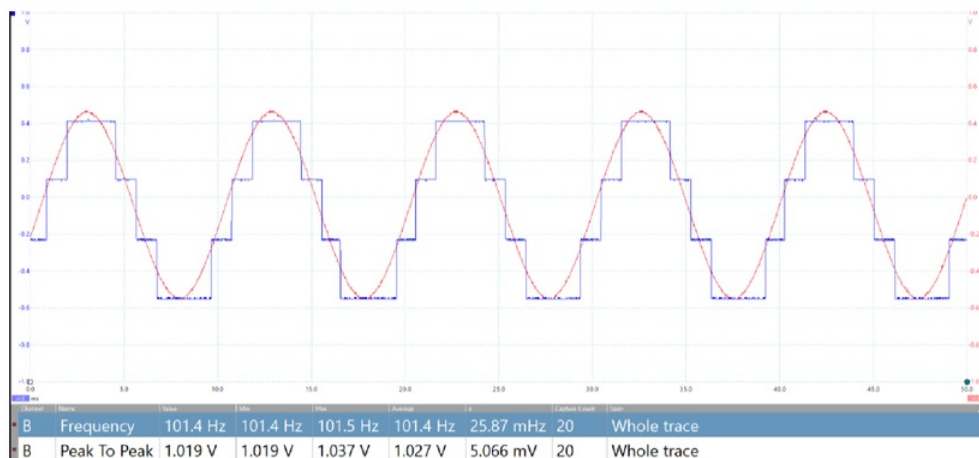


Figure 12 - 4 bit 1 V p-p

Figure 11 shows 1 V p-p and the sampling is still poor but has been made slightly better.

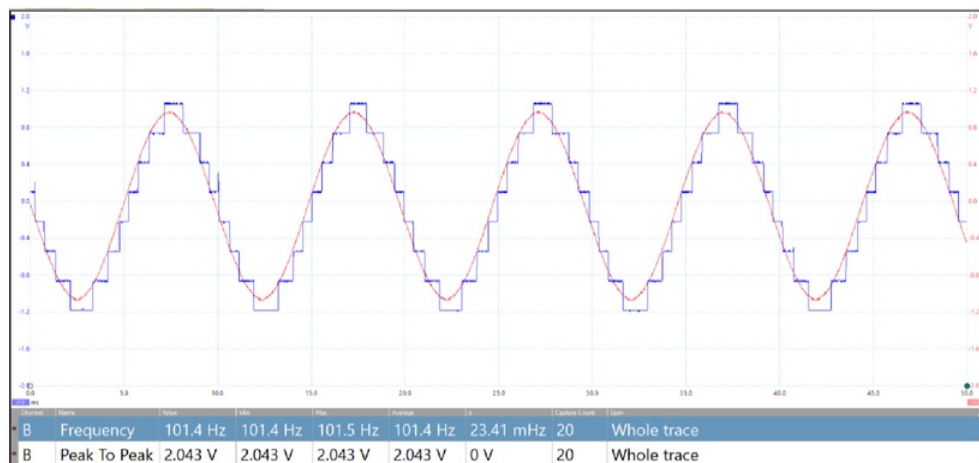


Figure 13 - 4 bit 2 V p-p

Figure 13 shows 2 V p-p and the sampling is improving and getting better.

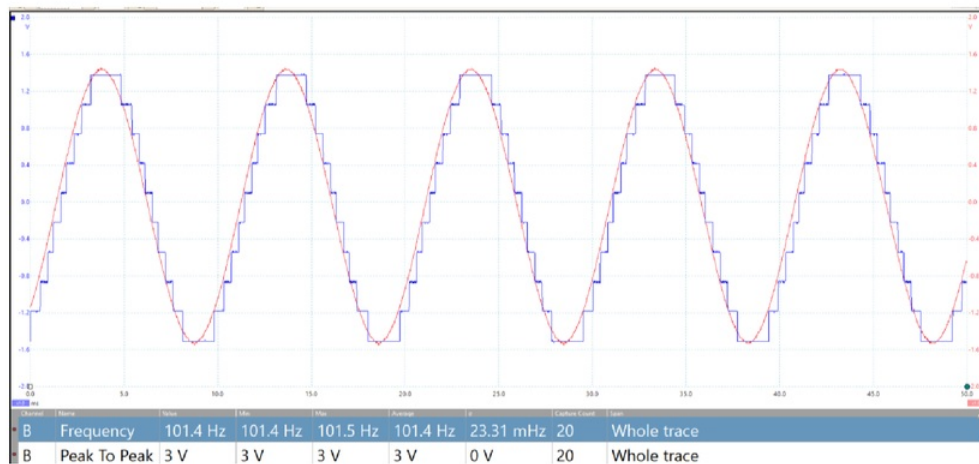


Figure 14 - 4 bit 3 V p-p

Figure 14 shows 3 V p-p and the sampling is improving and getting better still.

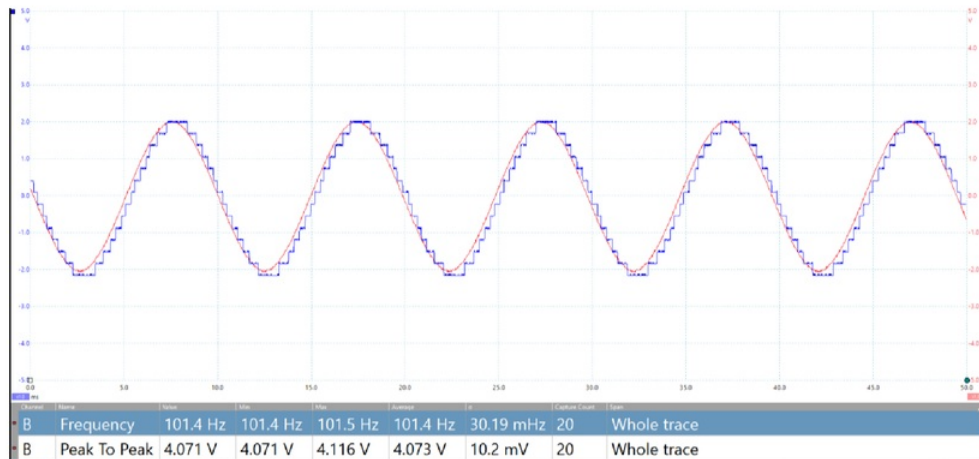


Figure 15 – 4 bit 4 V p-p

Figure 15 shows 4 V p-p and the sampling has vastly improved and the signal is beginning to smooth out but flat top PAM is starting to occur and be a problem.

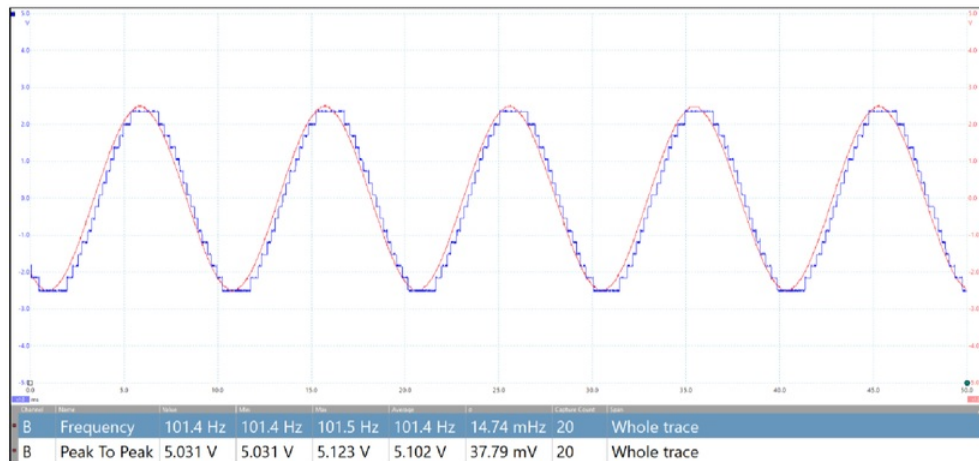


Figure 16 - 4 bit 5 V p-p

Figure 16 shows 5 V p-p and the sampling has improved again as the signal is beginning to smooth out even more but flat top PAM is becoming more of an issue.

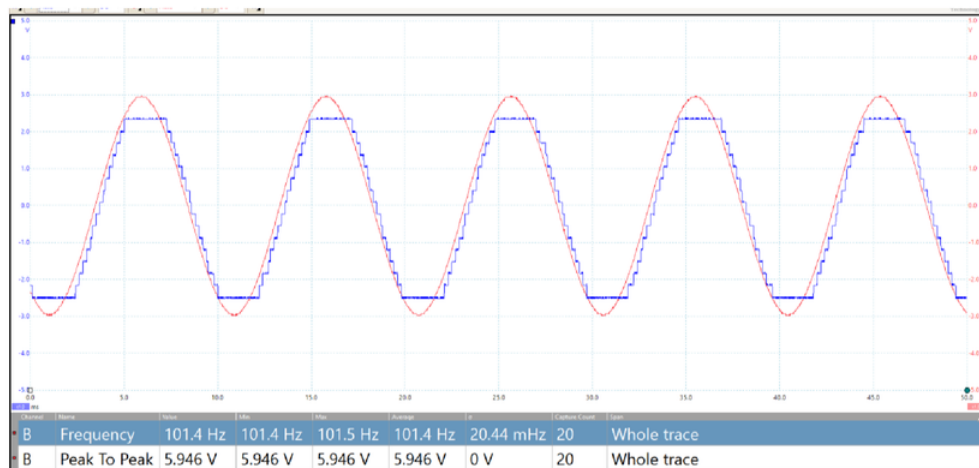


Figure 17 - 4 bit 6 V p-p

Figure 17 shows 6 V p-p and the sampling has improved again as the signal is beginning to smooth out even more but flat top PAM is now a major issue.

This shows that by increasing the V p-p the signal becomes smoother and better resolution but at some point during pulse amplitude modulation flat top PAM will occur and this will cut off the top portion of the signal.

The next part of the procedure asks for the increase in step numbers from 1 and view the change in voltage.

This is to find out at what level a new quantisation is needed.

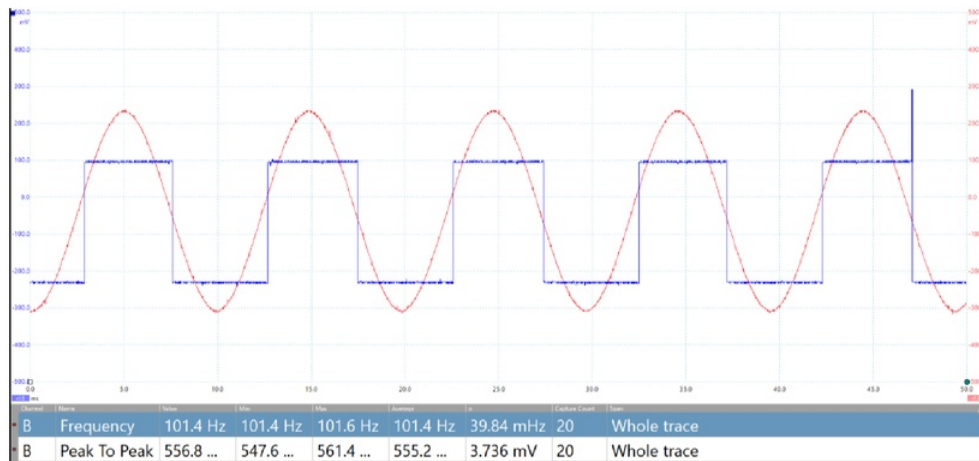


Figure 18 - 0.55 V P-P (1 step)

Figure 18 shows one step change and this occurs at 0.55 V p-p

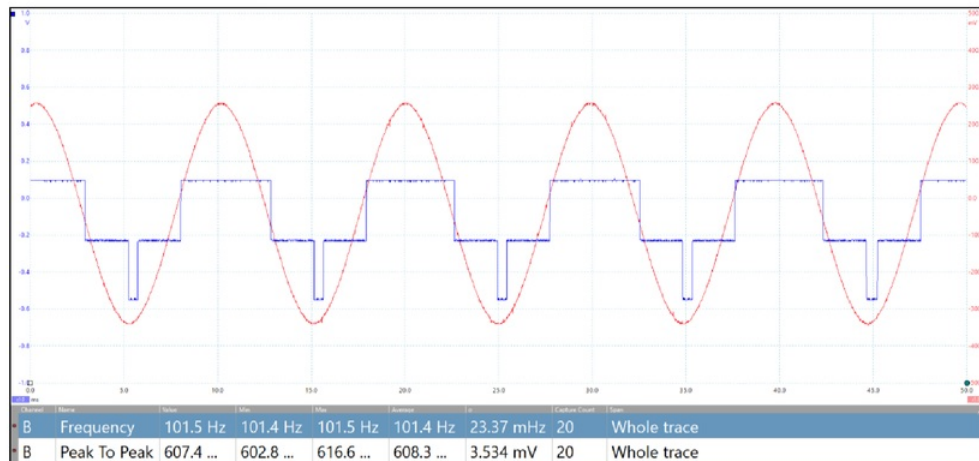


Figure 19 - 0.61 V P-P (2 step)

Figure 19 shows that by increasing the amplitude, a step change will occur. This step change took place at 0.61 V p-p.

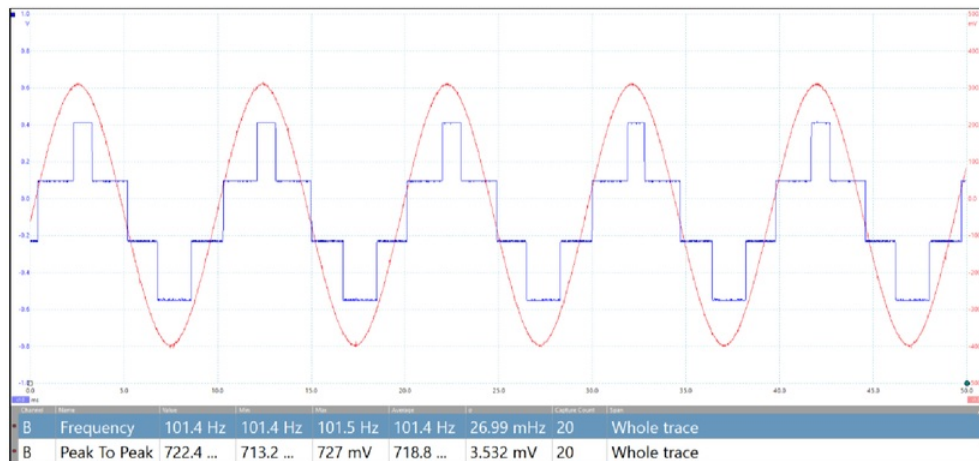


Figure 20 - 0.71 V P-P (3 step)

Figure 20 shows another step change and this occurs at 0.71 V p-p

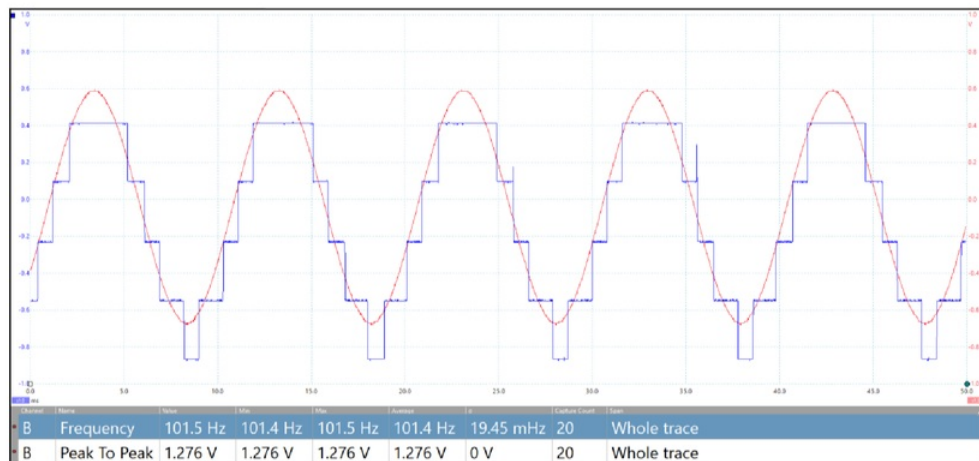


Figure 21 – 1.28 V P-P (4 step)

Figure 21 shows another step change and this occurs at 1.28 V p-p

The next figure will all have the step change value in the figure labels.

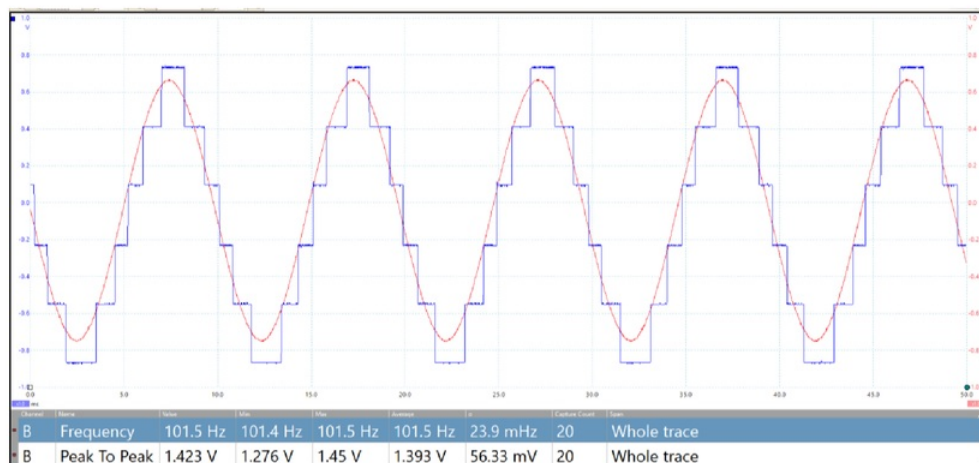


Figure 22 – 1.45 V P-P (5 step)

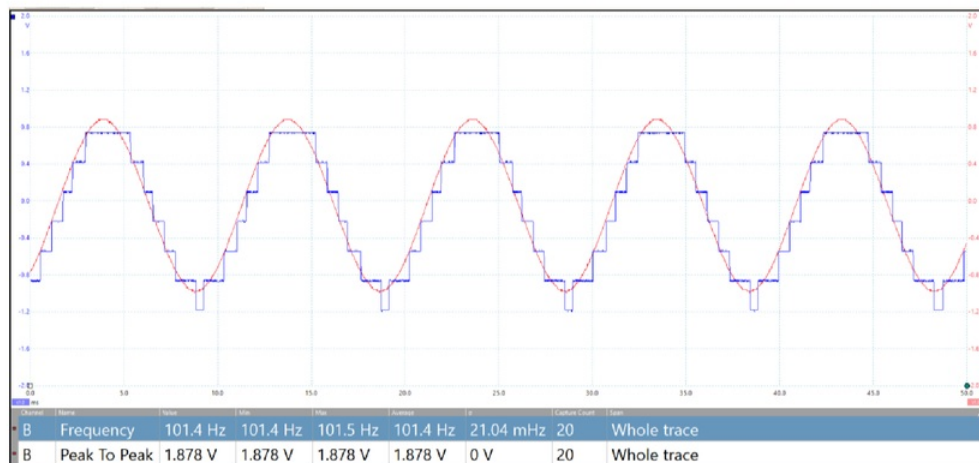


Figure 23 - 1.88 V P-P (6 step)

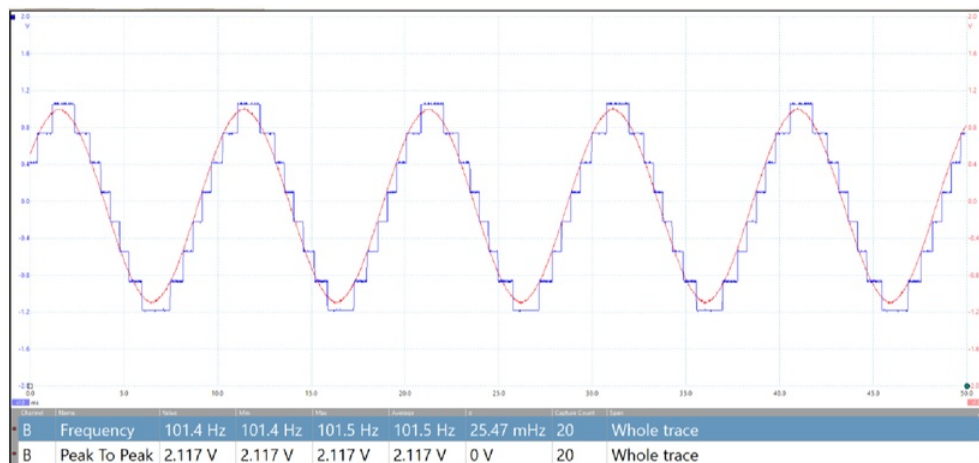


Figure 24 – 2.12 V P-P (7 step)

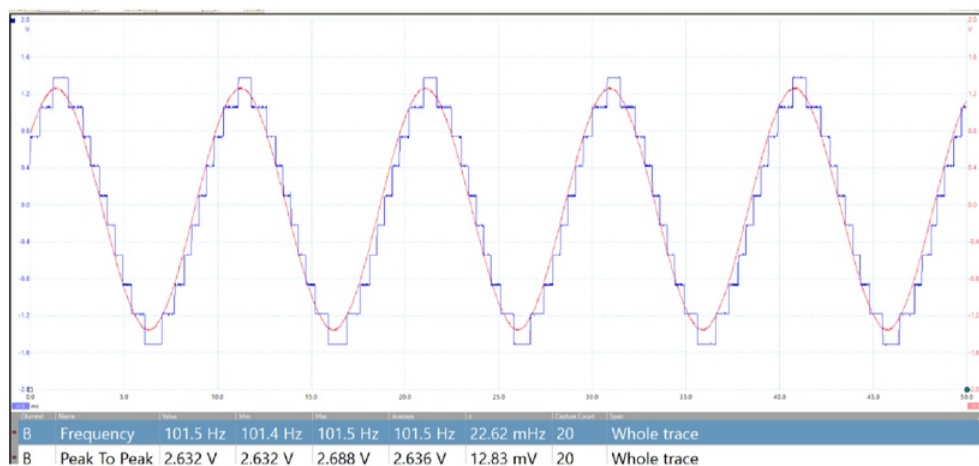


Figure 25 – 2.63 V P-P (8 step)

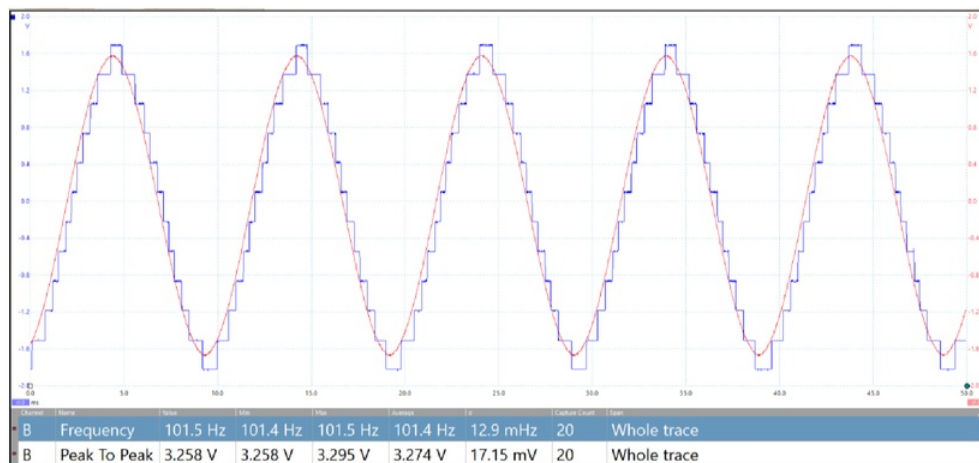


Figure 26 – 3.26 V P-P (9 step)

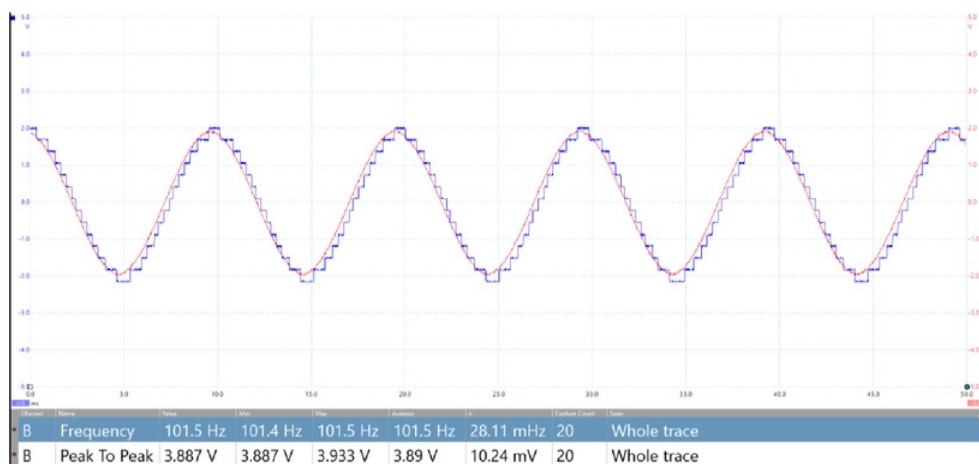


Figure 27 – 3.89 V P-P (10 step)

Figure 27 shows the maximum steps recorded as the signal is smoothed out and is at 10 steps with a 3.88 V p-p amplitude.

The screenshots above shows at what voltage quantisation for the next step occurs.

The resolution is calculated below for the 4 and 8 bit type.

$$4 \text{ bits} = 10/16 = 0.625$$

$$8 \text{ bits} = 10/256 = 0.039$$

For 4 bits the change or resolution should theoretically be every 0.625 volts and this is around what we see for our experiment as $6 \times 0.625 = 4.1 \text{ V}$ and our last step change was at 3.88 V.

The 8 bit experiment cannot be done as the resolution would be too small to accurately record any results.

The last part of the practical experiment following the procedure was the change in frequency. A frequency of 100 Hz can be seen below.

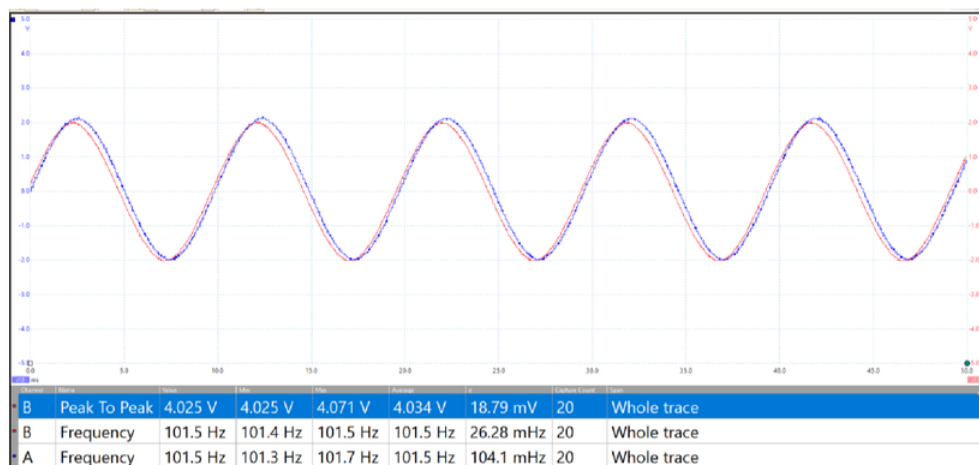


Figure 28 – Practical Test 100 Hz

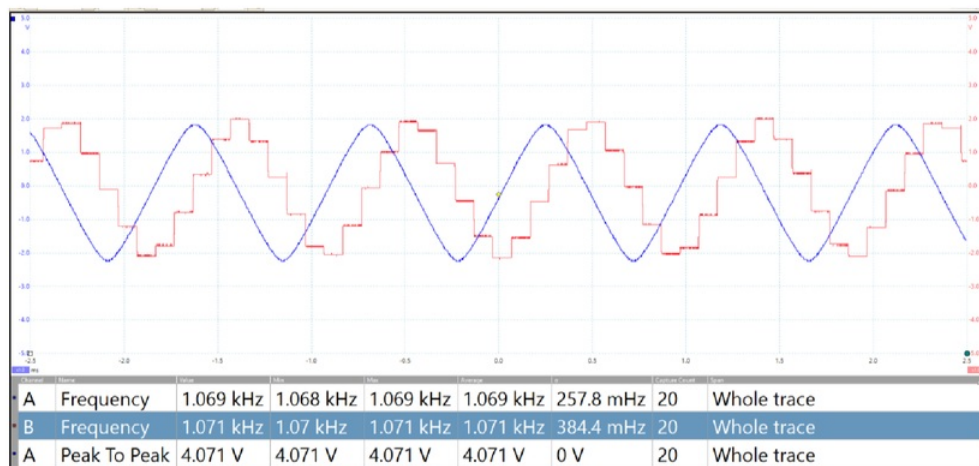


Figure 29 – Practical Test 1 KHz

By keeping the blue signal at 100 Hz and changing the red to 1 KHz the signal now changes as seen in figure 29. It shows that the steps have decreased making the signal less smooth.

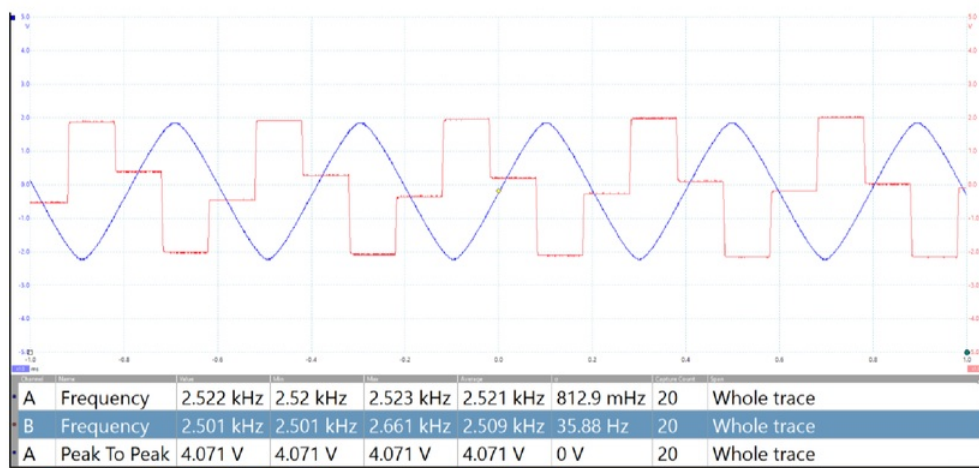


Figure 30 – Practical Test 12.5 KHz

Figure 30 shows the signal is now at 2.5 KHz and the signal has decreased further in resolution and bigger step changes are seen.

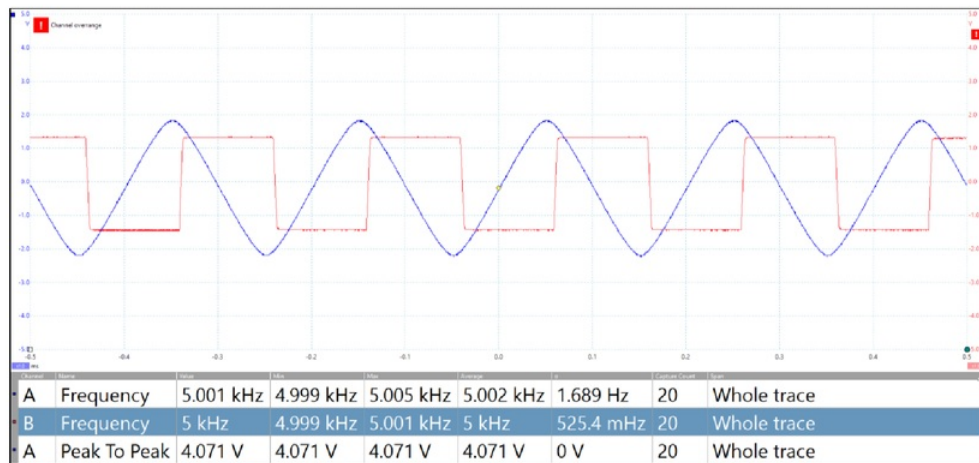


Figure 31 – Practical Test 5 KHz

Figure 31 above shows the frequency at 5 KHz with the channel over range warning showing in the top left hand corner, this means the sample limit is being reached.

The sample limit = 5K input = 5k output.

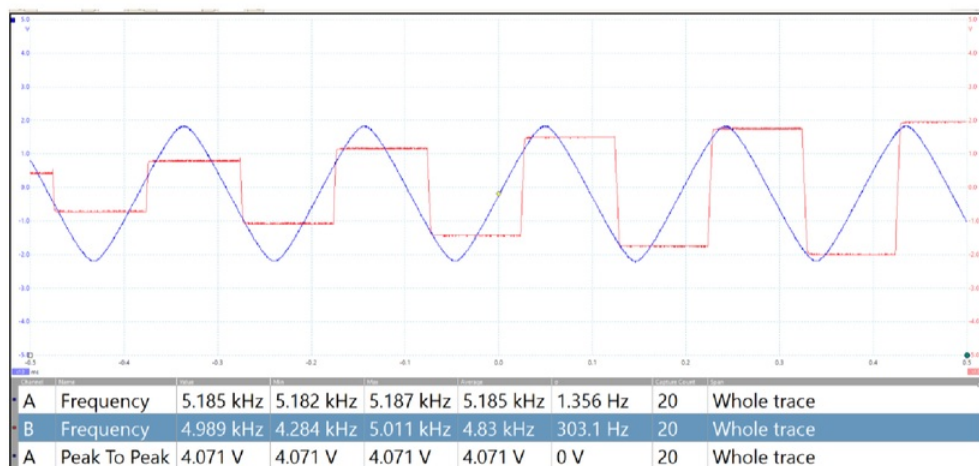


Figure 32 – Practical Test 5.1 KHz

Figure 32 shows that at 5.1KHz the frequency lock is lost.

This is showing aliasing of the signal.

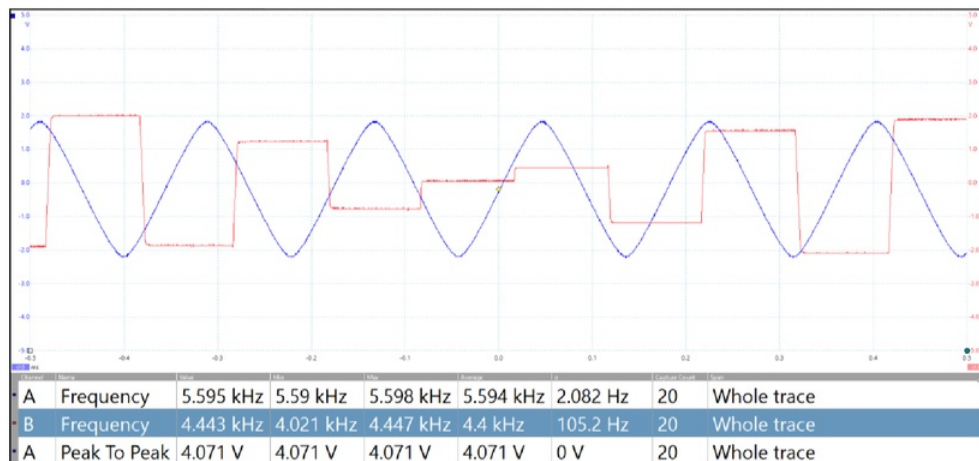


Figure 33 – Practical Test 5.5 KHz

Figure 33 shows that once the signal reaches 5.5 KHz the signal is deteriorating and this slight increase in frequency has become too much and the signal is now lost.

The function generator was now set to 4 KHz, the frequency was then increased to 10KHz.

This is shown in figures 34, 35 and 36 below.



Figure 34 - A at 10 KHz and B at 437 Hz

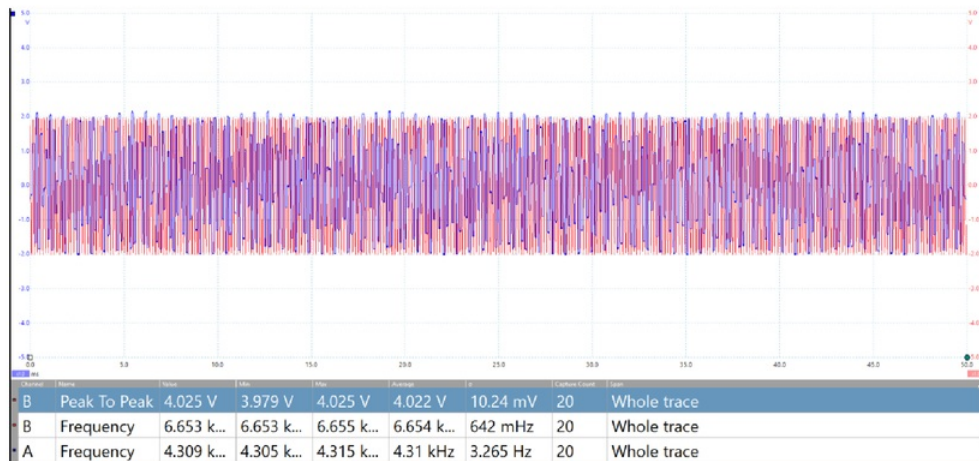


Figure 35 - A at 10 KHz and B at 4.3 KHz

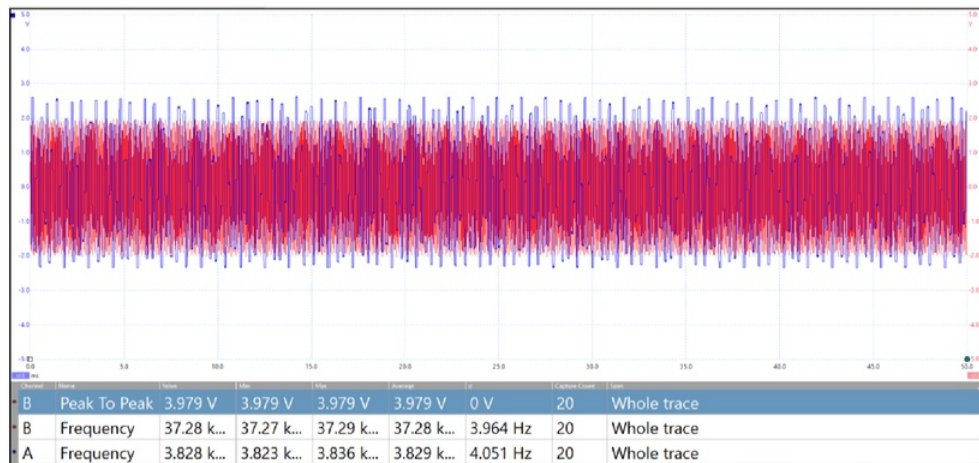


Figure 36 - A at 10 KHz and B at 37.3 KHz

The experiment has shown that changing the number of bits from 4 to 8 the signal will improve as the resolution is higher and also increasing the amplitude will increasing the resolution to a point until flat-top PAM occurs.

Increasing the frequency may cause the signal to deteriorate because of the aliasing effect, as proved above.

5. Conclusion

In order to draw conclusion, the aims and objectives of the assignment must be referred back to, to see if they were met successfully.

The aims and objectives of this assignment were are as follows:

Carry out research into the following pulse code modulation areas; PAM and PCM techniques, aliasing and modulation schemes (e.g. ASK, FSK, PSK, QPSK and QAM 16).

This was successful as all of these areas were researched and knowledge and understanding of these areas were gained and used for the practical testing.

These methods will be compared and contrasted and critically evaluated to find their strengths and weaknesses.

Their advantages and disadvantages were stated and compared to find out which areas were better; this helped when concluding the practical results.

Carry out an experiment from the Feedback Instruments Ltd pack "Digital Communications" on pulse code modulation. This must include the experimental procedure, results and critical analysis as part of the report.

The practical test was carried out, as per procedure and the results were kept and analysed for the assignment.

For this experiment you will investigation of sampling requirements, quantisation noise and aliasing will take place.

The practical results saw the effects of sampling, quantification and aliasing take place. These were commented on and mentioned in the results stage of the assignment.

In conclusion, this assignment has been successful as the practical test has shown to match the research done into PCM and PAM techniques.

6. Reference List and Bibliography

Bibliography

- Allaboutcircuits. (2018). *technical-articles/quadrature-phase-shift-keying-qpsk-modulation/*. Retrieved April 2018, from <https://www.allaboutcircuits.com:https://www.allaboutcircuits.com/technical-articles/quadrature-phase-shift-keying-qpsk-modulation/>
- Elprocus. (2018). *pulse-code-modulation-and-demodulation/*. Retrieved April 2018, from <https://www.elprocus.com:https://www.elprocus.com/pulse-code-modulation-and-demodulation/>
- National Instruments. (2018). *http://zone.ni.com/reference/en-XX/help/370051V-01/cvi/libref/analysisconcepts/aliasing/*. Retrieved April 2018, from <http://zone.ni.com/reference/en-XX/help/370051V-01/cvi/libref/analysisconcepts/aliasing/>: <http://zone.ni.com/reference/en-XX/help/370051V-01/cvi/libref/analysisconcepts/aliasing/>
- Northeastern Univiersity . (2012, 01 01). *FSK advantages, FSK disadvantages, Frequency shift keying*. Retrieved from Northeastern University : <http://www.rfwireless-world.com/Terminology/Advantages-and-Disadvantages-of-FSK.html>
- Rouse, M. (2011, 03 01). *Pulse amplitude modulation (PAM)*. Retrieved from WhatIs.com: <https://whatis.techtarget.com/definition/pulse-amplitude-modulation-PAM>
- techopedia. (2018). *definition/24128/pulse-code-modulation-pcm*. Retrieved April 2018, from <https://www.techopedia.com:https://www.techopedia.com/definition/24128/pulse-code-modulation-pcm>
- Tutorials Point. (2018, 01 01). *Amplitude Shift Keying* . Retrieved from Tutorials Point: https://www.tutorialspoint.com/digital_communication/digital_communication_amplitude_shift_keying.htm

Assignment_2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

65/100

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GRADING FORM: CSG-RUBIC

JOSHUA BEER

65

RESEARCH-INFORMED LITERATURE



There was evidence of further reading and research with the inclusion of a reference list and appropriate in text referencing. Your interpretation and understanding of the additional research was good. Your references were appropriate to the task and 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 good. The experiment worked and the explanation of how this was achieved had good detail. Your research 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 paraphrased more rather than direct quoting.

18

ANALYSIS



Your analysis of the task was generally satisfactory, both in class and as shown in this assignment. You have demonstrated some analytical skills and your approach to the task was logical. You carried out a short analysis and a short conclusion. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

12

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally very good. You used the resources available appropriately when conducting the experiment and you used appropriate options for testing and evaluating the circuit performance. Your results were comprehensive and allowed for a good conclusion to be attempted.

22

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was of an appropriate length, you could however be more efficient with your word

7

count. The report was well presented, with good diagrams in appropriate places, good sentence/paragraph structure and clear calculations.