

# S.Dedoncker PSDE 5014 Ass 2 FINAL

*by* Scott Dedoncker

---

|                |                                                                                |                 |       |
|----------------|--------------------------------------------------------------------------------|-----------------|-------|
| FILE           | 12968_SCOTT_DEDONCKER_S.DEDONCKER_PSDE_5014_ASS_2_FINAL_152851_1347830958.DOCX |                 |       |
| TIME SUBMITTED | 25-APR-2018 09:52PM (UTC+0100)                                                 | WORD COUNT      | 3141  |
| SUBMISSION ID  | 87478652                                                                       | CHARACTER COUNT | 21773 |

# HND Electrical & Electronic Engineering

## PSDE 5014: Signals & Digital Communications



### Assignment 2

### Digital Modulation Schemes

---

Scott Dedoncker

Valero Energy Electrical Apprentice

Date of Submission: 25/04/18

Word Count: 3079

---

## Contents

|                                                |    |
|------------------------------------------------|----|
| 1. Introduction .....                          | 2  |
| 2. Research into PCM Techniques.....           | 3  |
| 2.1. What is Pulse Code Modulation? .....      | 3  |
| 2.2. What is Pulse Amplitude Modulation? ..... | 4  |
| 2.3. Aliasing .....                            | 5  |
| 2.4. Modulation Schemes.....                   | 7  |
| 3. Experimental Methods .....                  | 9  |
| 4. Testing and Results .....                   | 10 |
| 5. Conclusions.....                            | 21 |
| 6. Appendices .....                            | 22 |

|                                                                     |    |
|---------------------------------------------------------------------|----|
| Figure 1 - PCM Example (Tutorials Point, 2018) .....                | 3  |
| Figure 2 - PCM Parameter Flow Diagram (Tutorials Point, 2018) ..... | 3  |
| Figure 3 - Sampled frequency = $2f$ (On My Phd, 2018) .....         | 5  |
| Figure 4 - Sampled Frequency = $1.5f$ (On My Phd, 2018) .....       | 5  |
| Figure 5 - Sampled Frequency = $0.8f$ (On My Phd, 2018) .....       | 6  |
| Figure 6 - ASK Modulation (E-Question Answers, 2018).....           | 7  |
| Figure 7 - FSK Modulation (E-Question Answers, 2018) .....          | 8  |
| Figure 8 - PSK Modulation (E-Question Answers, 2018) .....          | 8  |
| Figure 9 - Feedback Loop Rig.....                                   | 9  |
| Figure 10 - Feedback Loop Rig with Oscilloscope .....               | 9  |
| Figure 11 - 4v Peak to Peak .....                                   | 10 |
| Figure 12 - 8-bit ADC .....                                         | 11 |
| Figure 13 - 4-bit ADC .....                                         | 11 |
| Figure 14 - 4-bit Starting Frequency .....                          | 12 |
| Figure 15 - 4-Bit 1v P/P .....                                      | 12 |
| Figure 16 - 4-Bit 3v P/P .....                                      | 13 |
| Figure 17 - 4-Bit 5v P/P .....                                      | 13 |
| Figure 18 - 4-Bit 6v P/P .....                                      | 14 |
| Figure 19 - 8-Bit Starting Frequency .....                          | 15 |
| Figure 20 - 8-Bit 0.71v P/P.....                                    | 15 |
| Figure 21 - 8-Bit 1.45v P/P .....                                   | 16 |
| Figure 22 - 8-Bit 2.2v P/P .....                                    | 16 |
| Figure 23 - 8-Bit 3.9v P/P .....                                    | 17 |
| Figure 24 - 100Hz.....                                              | 18 |
| Figure 25 - 1kHz.....                                               | 18 |
| Figure 26 - 2.5 kHz.....                                            | 19 |
| Figure 27 - Sample Limit of 5K input to 5K output.....              | 19 |
| Figure 28 - 5.5K frequency lock lost.....                           | 20 |

## 1. Introduction

Modulation schemes are used in the engineering sector for various applications. They are used to transfer analogue signals over channels such as baseband channels by modulating them as a two level pulse wave signal. There is the option of using different pulse modulation schemes to allow the conversion of analogue signals to digital signals. This assignment will delve into the different methods of analogue to digital conversion using frequency modulation, and pulse code modulation.

This assignment will be split into two sections; research and experimental methods. The research should cover the following areas:

- PAM and PCM techniques
- Aliasing
- Various Modulation Schemes

The experiment conducted post research will involve carrying out a practical using the Feedback Instruments Ltd Pack "Digital Communications".

## 2. Research into PCM Techniques

### 2.1. What is Pulse Code Modulation?

Frequency modulation is the process of taking a carrier signal frequency and altering its parameters, whether that be a single parameter or multiple parameters in conjunction to the core message signals. A message signal is for example a signal being transmitted on a carrier frequency for the purpose of communicating with the receiver over a long distance. This carrier signal is sent at a very high frequency but has no data sent in it, only the message signal upon it. One method of performing this modulation is the digital technique called pulse code modulation.

Pulse code modulation is the process of taking a signal and using pulse modulation to convert analog information transmitted on that frequency into a digital value, or binary sequence number composed of 0's or 1's. A very simple example of PCM conversion from a sine wave frequency to a binary-scaled output can be seen below in figure 1.

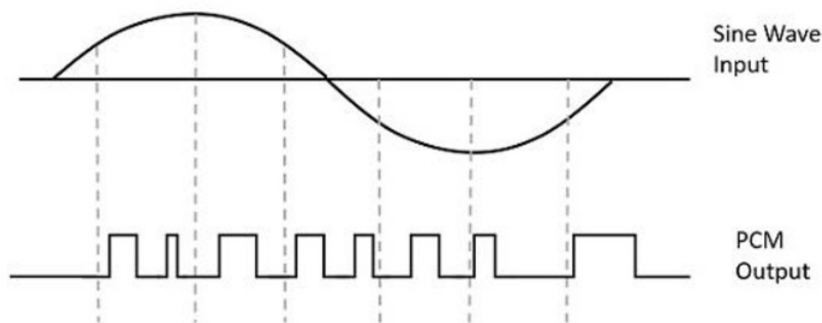


Figure 1 - PCM Example (Tutorials Point, 2018)

There are three basic parameters that need to be adhered to when a pulse code modulated circuit is transmitting. These are the sampling, quantizing and encoding processes and are all carried out in the analog to digital conversion section. Once the signal has been transmitted and reaches the receiver it then goes through the regeneration, decoding and reconstruction processes. A block diagram shown in figure 2 shows how this process is carried out.

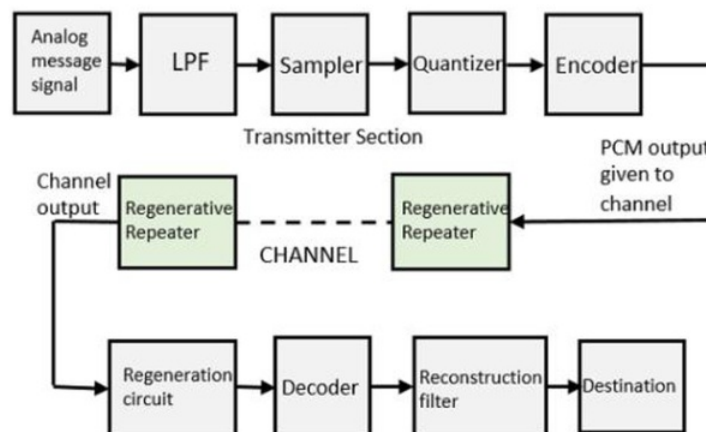


Figure 2 - PCM Parameter Flow Diagram (Tutorials Point, 2018)

The original analog signal is sent through a low pass filter where any high frequency components greater than the highest possible frequency are removed to avoid any possibility of aliasing. Then the sampler is used to collect instantaneous data sample of the signal so that it can be reconstructed at the other end. This sampling rate must be greater than two times the highest possible frequency in order to avoid aliasing. The signal is then quantised to compress it for transmission. The encoder digitises the signal by quantifying each part of the signal as a binary value. This is the analog to digital conversion process and also minimises the amount of bandwidth used for transmitting the signal. The regenerative repeaters then boost the signal strength and accommodate for any loss of signal due to distance or interference. Once the transmitted signal arrives at the receiver it is sent to the decoder. This decoder simply decodes the pulse coded waveform in order to derive the originally generated signal. This is the digital to analog conversion part. The reconstruction filter is a second low pass filter that is used to derive the final parts of the original signal before it is sent to its destination for amplification through speakers or other forms. (Tutorials Point, 2018)

## 2.2. What is Pulse Amplitude Modulation?

Whereas pulse code modulation concentrates on the conversion of analog to digital signals for transmission and vice versa, pulse amplitude modulation uses techniques of varying amplitudes for signal transmission. Specifically, this method is a type of single modulation that varies the amplitude of voltage, or power levels in pulses in a regularly timed sequence. These are in the form of either electrical or electromagnetic pulses. It is possible for this type of modulation to be used with analog pulsing signals, however the pulse count for transmission can be infinite. This method of modulation is more commonly used in digital signal transmission.

With pulse amplitude frequency modulation, the modulator samples the original signal at regular intervals in proportion to the signal's original magnitude. The sampled signals (pulses) can then be sent to the receiver either through a single channel, or modulated onto a carrier wave. PAM can be categorised into either

- Single polarity modulation. All pulses are positive at all times
- Double polarity modulation. Pulses are both positive and negative

(Technopedia, 2018)

### 2.3. Aliasing

Before aliasing can be investigated it is important to understand the following characteristics of signals:

- A continuous signal can be sampled at any certain frequency
- It is possible to represent this frequency in a frequency domain

Aliasing is a side effect of sampling a frequency signal at less than double the highest frequency contained in that transmitted signal. This phenomenon shows the sampled signal or frequency as being different to the original transmitted frequency. An example of this can be seen below. The original transmitted signal can be seen as plotted in yellow on the graph, with the sampled signal plotted in blue. When the sampled signal  $f_s$  is equal to  $2f$  (2 x the signal frequency), it is clear from figure 3 that the signal frequencies are the same. However, when the sampled frequency  $f_s$  is less than  $2f$ , the sampled frequency looks very different to the original signal as shown in figures 4 and 5.

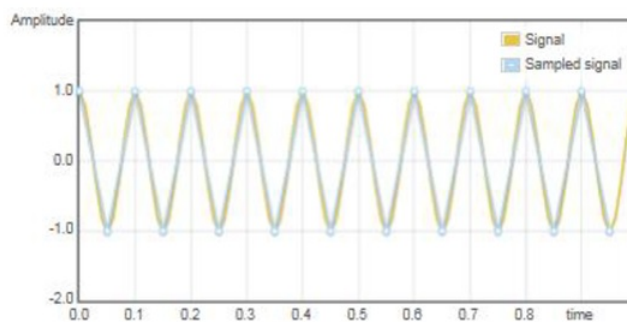


Figure 3 - Sampled frequency =  $2f$  (On My Phd, 2018)

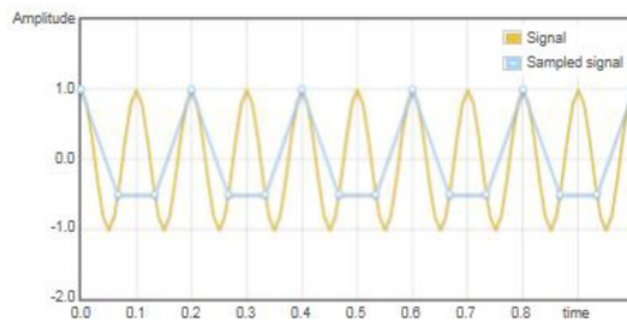


Figure 4 - Sampled Frequency =  $1.5f$  (On My Phd, 2018)

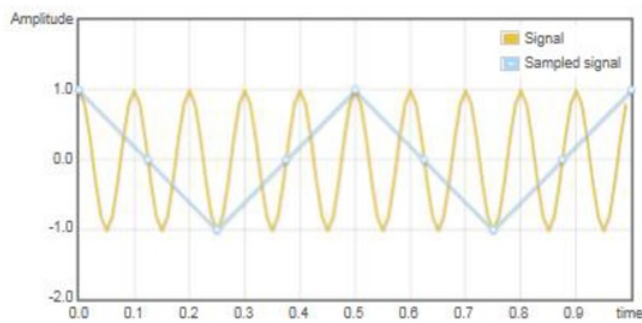


Figure 5 - Sampled Frequency =  $0.8f$  (On My Phd, 2018)

This shows that if the sampled frequency from the original signal is too low, it can give a fake depiction of what the original frequency was. This is aliasing and is a similar effect to how car wheels begin to spin at such a speed that they appear to be spinning backwards and more slowly in the opposite direction, also known as the “wagon-wheel” effect. Aliasing can be a harmful effect on frequency sampling as once the aliased signal has been sampled you can never recover the true original frequency.

(On My Phd, 2018)

## 2.4. Modulation Schemes

Modulation is a process of combining an audio signal with an oscillated carrier wave signal in order to transmit it over a distance. During modulation certain aspects of the carrier wave are adjusted in order to allow the audio signal to ride on it. Once the signal has been received by the receiver on the opposite end it begins the process of demodulation. This is where the carrier frequency is broken down and the original audio signal sent on it is extracted for amplification and emitted through various speaker forms on the receiver end.

There are numerous ways in which frequency modulation can occur. When talking in regards to digital modulation there are three basic types of digital modulation that can be observed. Digital modulation uses a more discrete process when the original signal is being amplified prior to being transmitted instead of analogue where the amplitude, frequency and phase of the carrier frequency are constantly fluctuated and adjusted.

The first method of digital modulation is ASK, also known as Amplitude shift key modulation. When concerning this type of modulation the signal that is amplified for transmission is modulated as an on/off signal. For an example see figure 6. The modulated signal presents the information being transmitted when the signal is equal to 1, and the information not being present on the carrier signal when the modulated signal is 0. This is what is referred to as using a digital high/low data transmission. This type of signal modulation is most commonly found in infrared and fibre optic cabling applications.

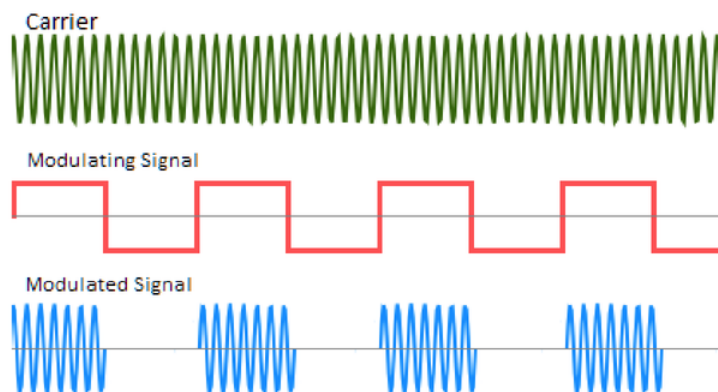


Figure 6 - ASK Modulation (E-Question Answers, 2018)

The Second main type of digital modulation is FSK, also known as frequency shift key modulation. This is the process of taking at least two varying frequencies and transmitting them as the modulated frequency. These signals are once again modulated using the digital high/low data transmission techniques. This is visible in figure 7 as the modulated signal becomes tighter on a digital 0, and wider on a digital 1. This type of digital modulation is most commonly found in internet hubs.

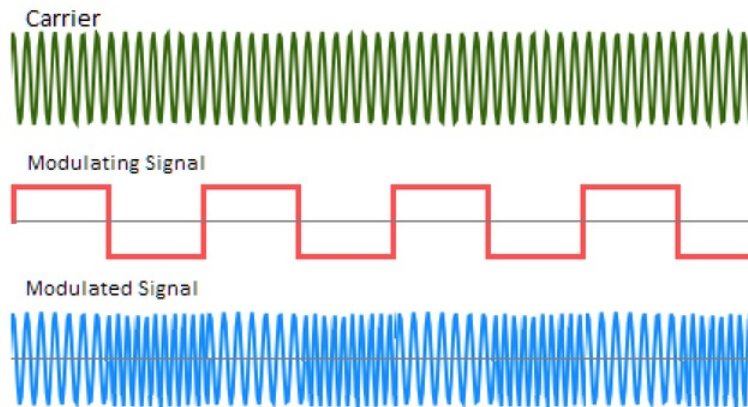


Figure 7 - FSK Modulation (E-Question Answers, 2018)

The third type of digital frequency modulation is PSK, also known as phase shift key modulation. This type of digital modulation uses an instantaneous phase working in conjunction with an instantaneous amplitude in order to successfully transmit a signal on a carrier frequency. This type of modulation once again uses digital high/low data transmission to transmit in 2bit information. This is most commonly phone in satellite communication. Examples of this modulation can be seen in the figure below. There is a different format of PSK where the 2bit information can be sent in 4 different quadrants. This special type of PSK is what's known as QPSK, or quadrature phase shift key modulation. As many as 1024 different states can be represented by this modulation technique.

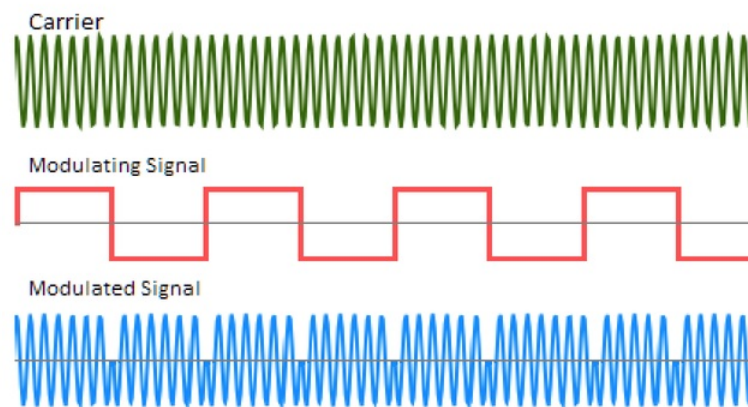


Figure 8 - PSK Modulation (E-Question Answers, 2018)

(E-Question Answers, 2018)

### 3. Experimental Methods

Like explained in the research section of this assignment, pulse code modulation is the process of taking binary numbers and converting them to electromagnetic pulses so that a digital frequency can be transmitted and subsequently formed through a digital channel.

An experiment was too be carried out where a feedback loop rig would be connected and powered to simulate a sinusoidal sine wave input frequency and pulse code modulation occurring at the receiving end. Various tests would then be performed on it by adjusting the bit ratio of the frequency, the peak to peak voltage, the input voltage. A schematic of the loop feedback rig can be seen below along with a photo of the final setup.

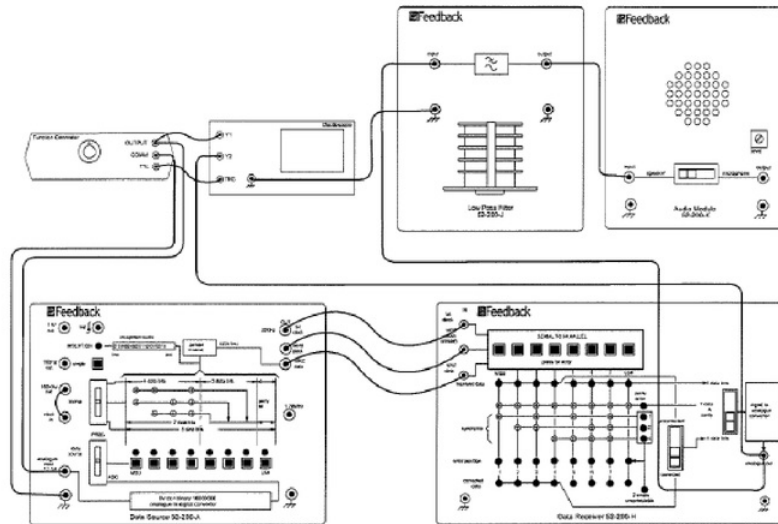


Figure 9 - Feedback Loop Rig

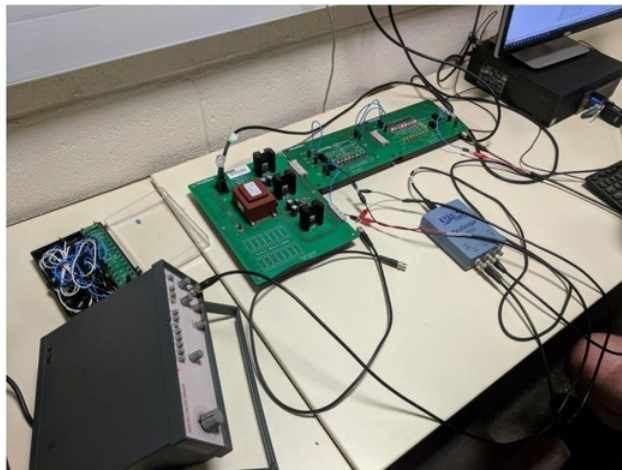


Figure 10 - Feedback Loop Rig with Oscilloscope

## 4. Testing and Results

Before the initial tests could be carried out the format switch on the data source module needed to be set to 8 bits and the data source switch to the lowest setting. This was so the circuit could receive and interpret an analogue signal and use the quantiser to convert each amplitude of the signal to the correct (or nearest) 8-bit binary value. The sampling rate for this circuit would be 10,000 samples per second and each binary piece of data would take up 0.1 milliseconds on the time scale. This would equal 5v peak to peak.

The data receiver would also need to be setup. Both switches on the module would need to be switched to their up positions. This is so the receiver could receive 8-bit data and interpret it into the original signal. The low pass filter module would need to have a cut off frequency of 5 kHz.

The function generator was now set to produce a sine wave frequency output of 4v peak to peak at around 100 Hz. This can be seen in the figure below.

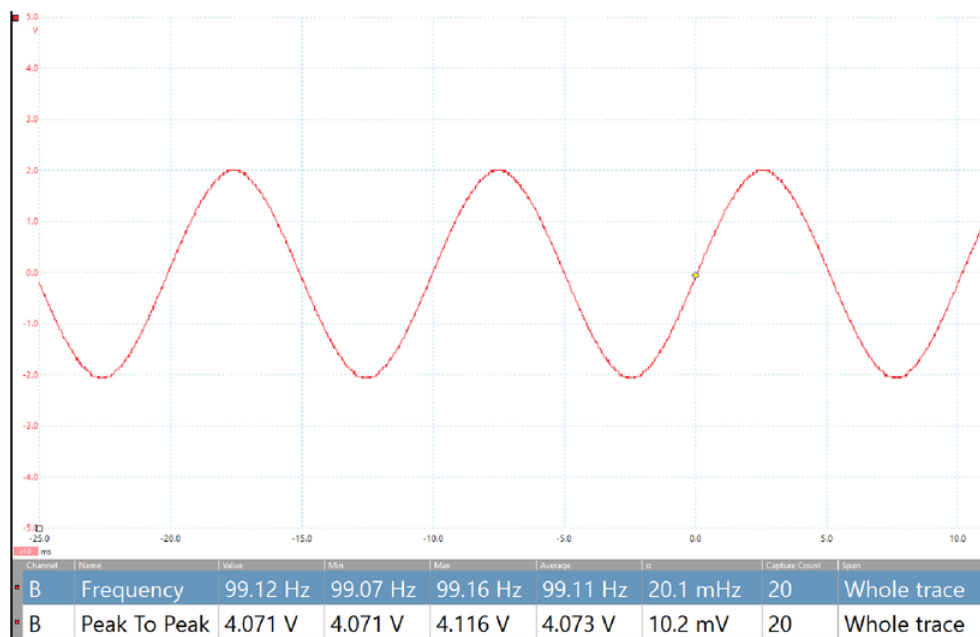


Figure 11 - 4v Peak to Peak

The ADC was then switched first to 8-bit and then 4-bit output. These are the replicated bit rate waveforms reconstructed from the receiver end of the system. These waveforms are compared with the original sine wave in the figures below. It can be seen from figure 12 that the 8-bit waveform is an appropriate replication of the original signal, with the step differences due to the bite rate being minuet. The 4-bit waveform shown in figure 13 shows a more staggered representation of the original signal, while still holding the general shape of the original sine waveform. Both of these conversions keep the sine wave on a 4 v peak to peak.

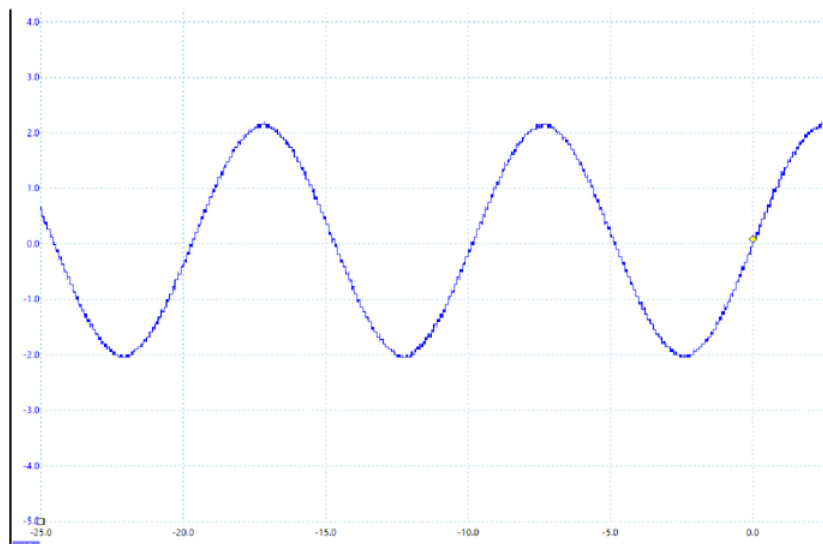


Figure 12 - 8-bit ADC

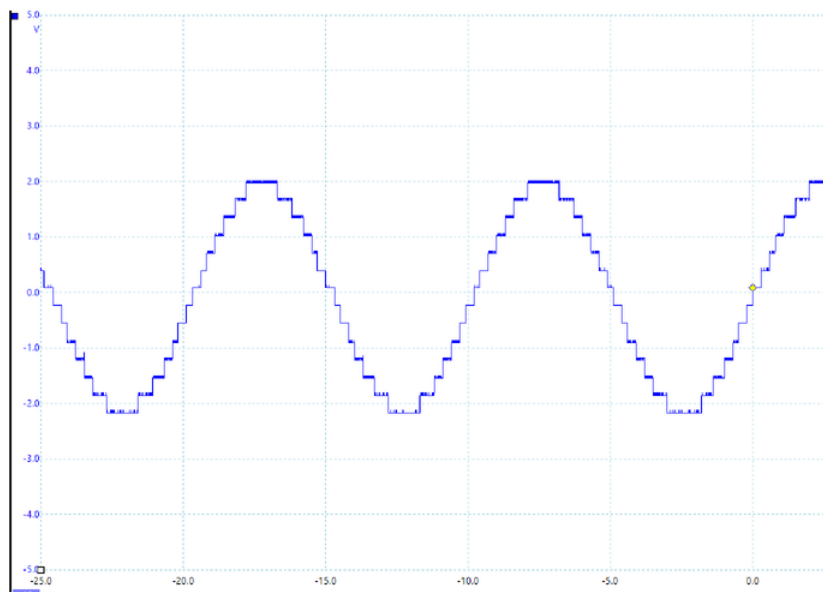


Figure 13 - 4-bit ADC

The next step of the experiment was to set the input frequency to 100 Hz at 0v and slowly increase the output up to 6v peak to peak. This was first to be done with the ADC set to 4 bits. The lowest measureable voltage that could be achieved while sustaining an input on the oscilloscope was 500mv peak to peak, so this would be used as a measurement for 0v. The frequency was also tuned to 101.4 Hz. This can be seen in figure 14. The following figure then demonstrate how the response changed as the voltage increased from 0v peak to peak, to 6v peak to peak.

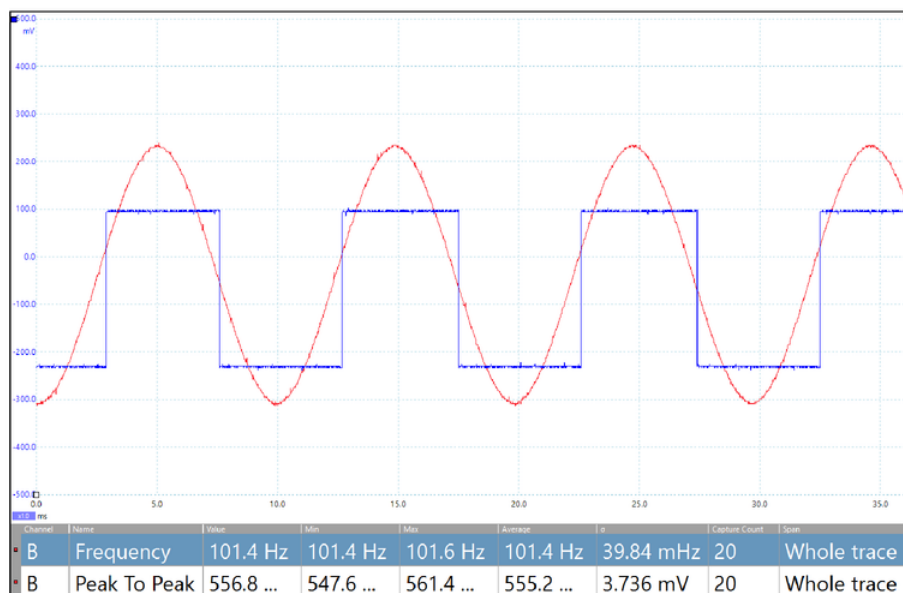


Figure 14 – 4-bit Starting Frequency

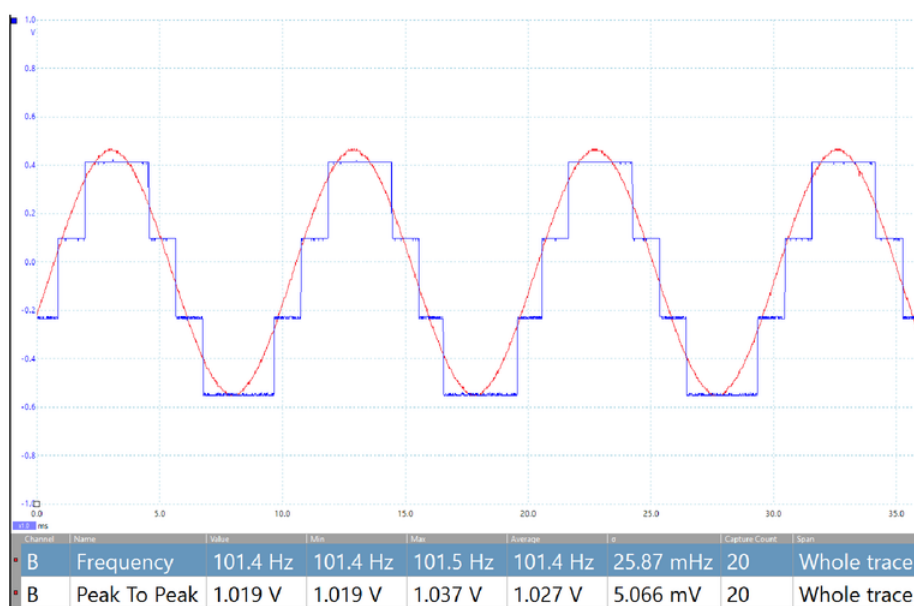


Figure 15 - 4-Bit 1v P/P

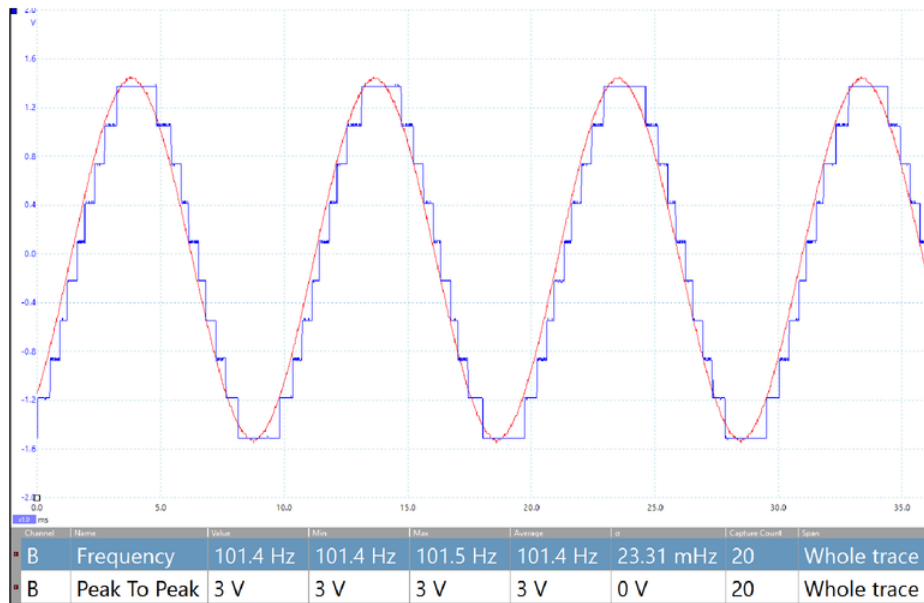


Figure 16 - 4-Bit 3v P/P

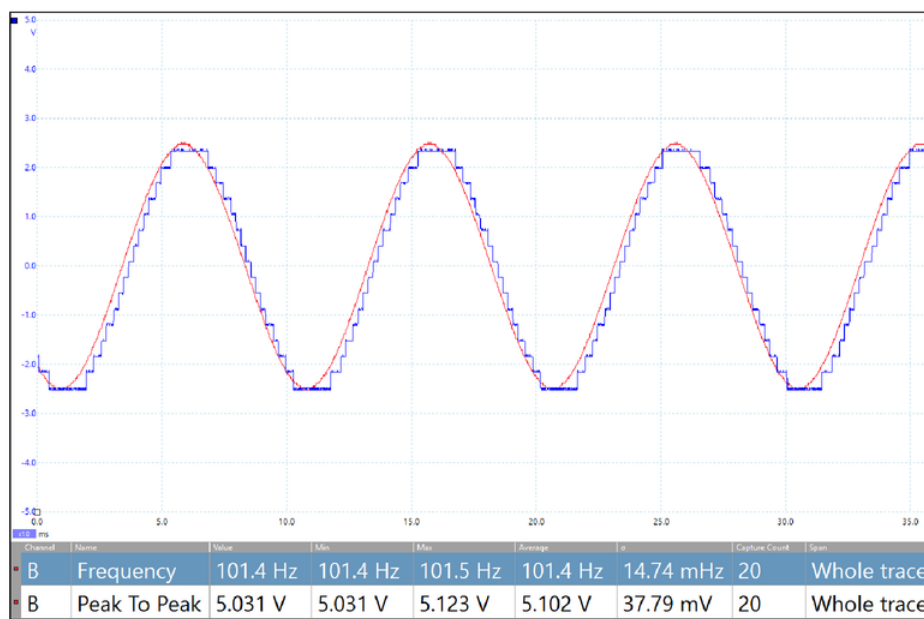


Figure 17 - 4-Bit 5v P/P

It can be seen that the closest replication to the initial frequency response is viewed at 5v. This is because this is the maximum range of what the load cell would be able to detect. Past this point and onto 6v and it is clear to see that at each peak of the sine frequency the replicated response begins to go flat in comparison to the measured response of the initial sine wave. This shows how the pulse modulated response can only be detected in range between 0 and 5v.

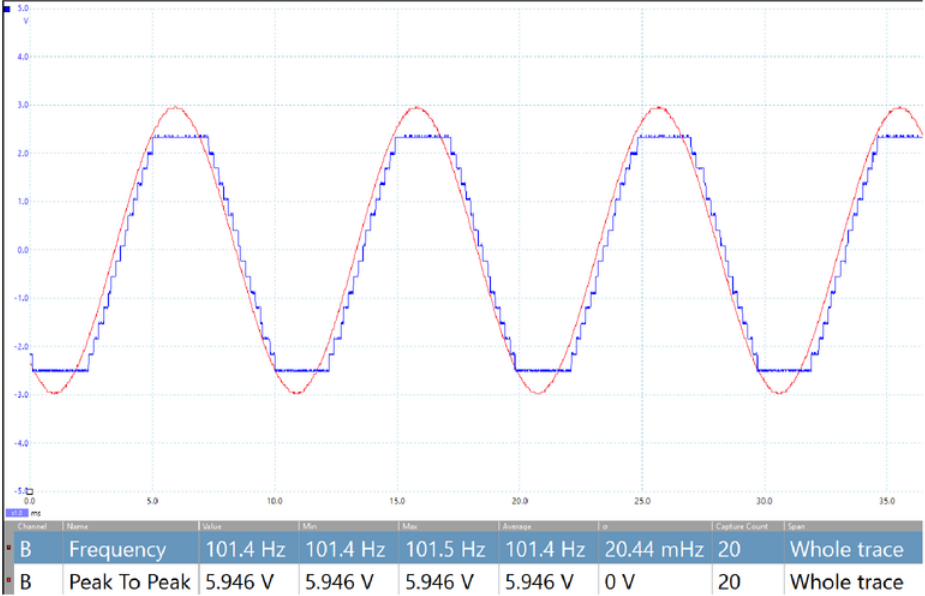


Figure 18 - 4-Bit 6v P/P

Now the ADC was switched to measure 8-bit pulse modulated responses. In theory this would give a smoother and more accurate replicated sine wave compared to this initial response than the 4-bit ADC did. The initial response for this circuit was measured at 0.5v peak to peak and the frequency was once again 101.4 Hz. The voltage was then increased in steps of 1v peak to peak and the differences in sine waves were recorded. These can be seen in the following screenshots.

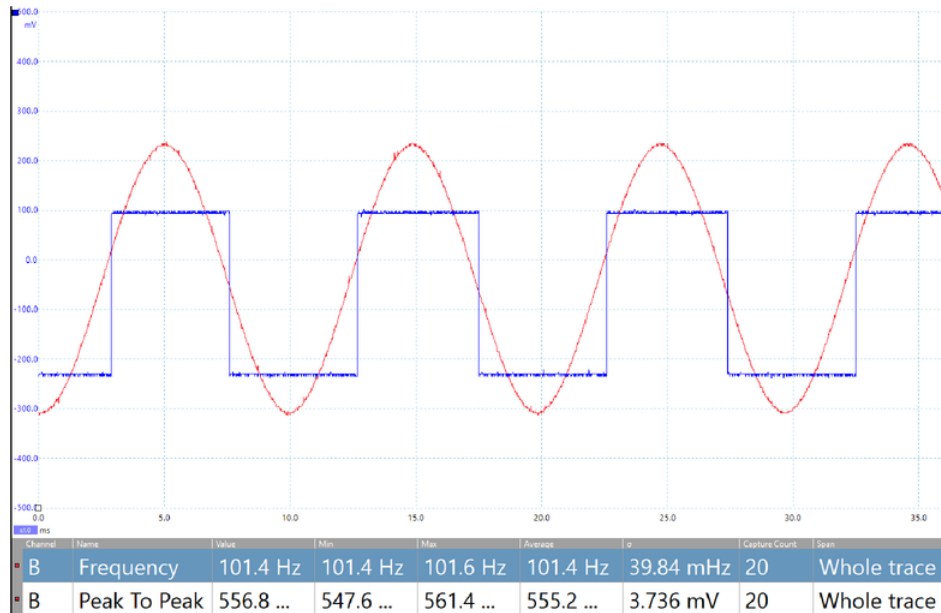


Figure 19 - 8-Bit Starting Frequency

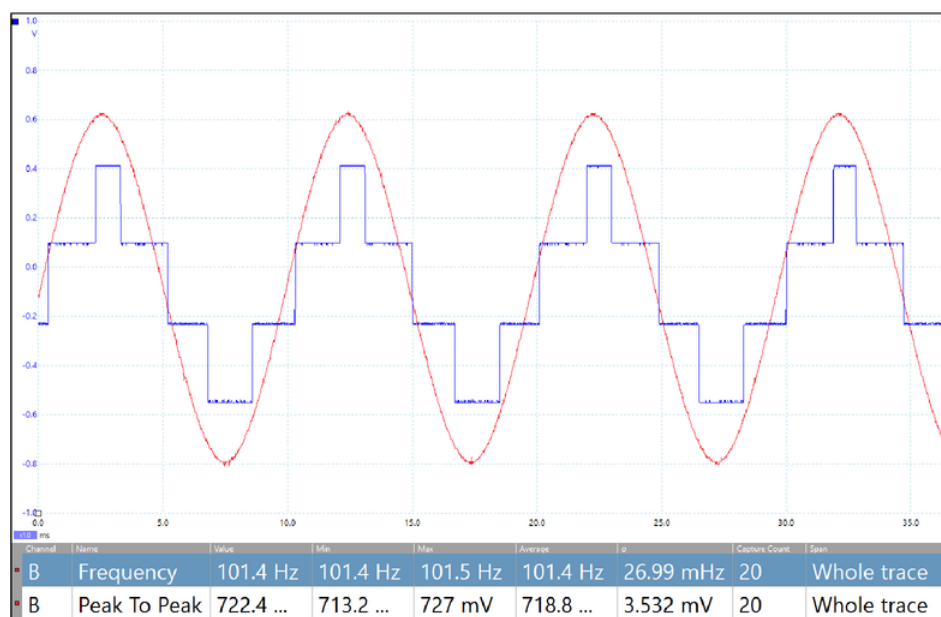


Figure 20 - 8-Bit 0.71v P/P

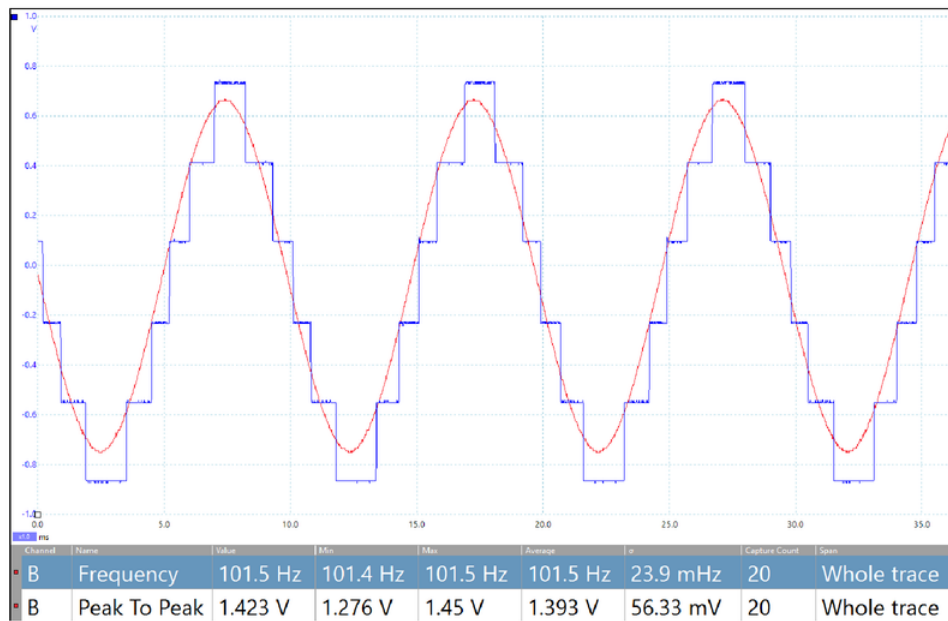


Figure 21 - 8-Bit 1.45v P/P

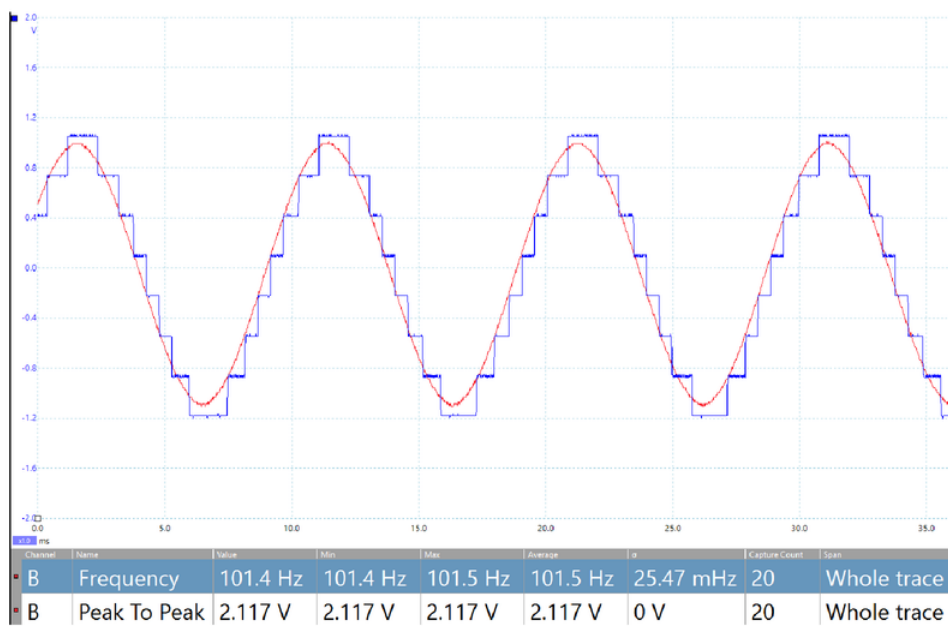


Figure 22 - 8-Bit 2.2v P/P

The best output that could be generated from 8 bits was at 3.9v. After this point the replicated response began to get too small for the resolution of the computer screen and therefore needed to be stopped.

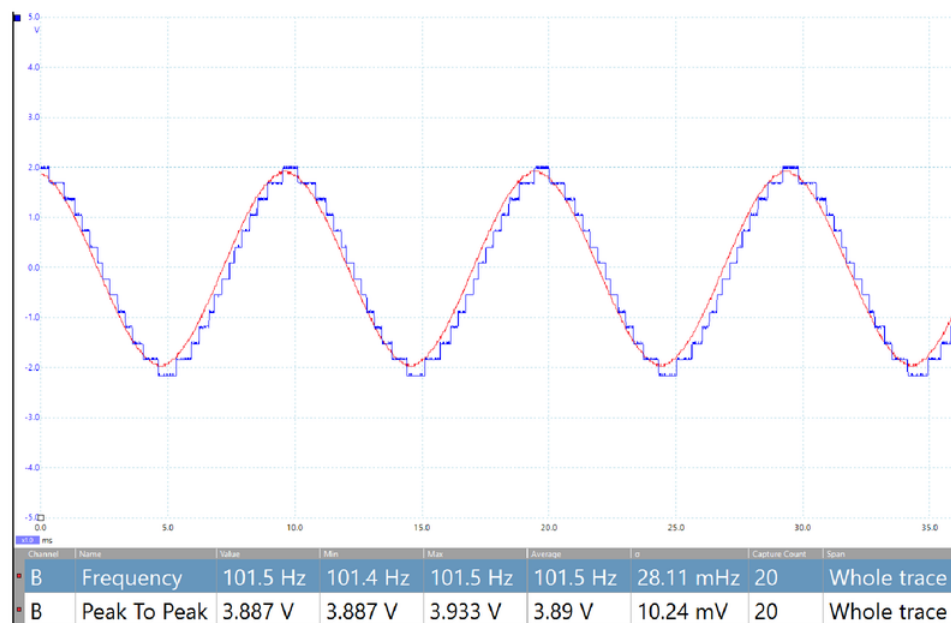


Figure 23 - 8-Bit 3.9v P/P

The next step of the experiment was to assess the change in response comparison when the amplitude is held constant. The ADC was set to 8-bits and the input frequency set to 100 Hz at 4v peak to peak. The frequency would then be increased in decades using the range button and the outputs would be observed. As the frequency would increase the signal lock between the two responses should begin to deteriorate and eventually lost all together. The first figure shows that at 100 Hz frequency both signals are almost identical with only slight lag in the system.

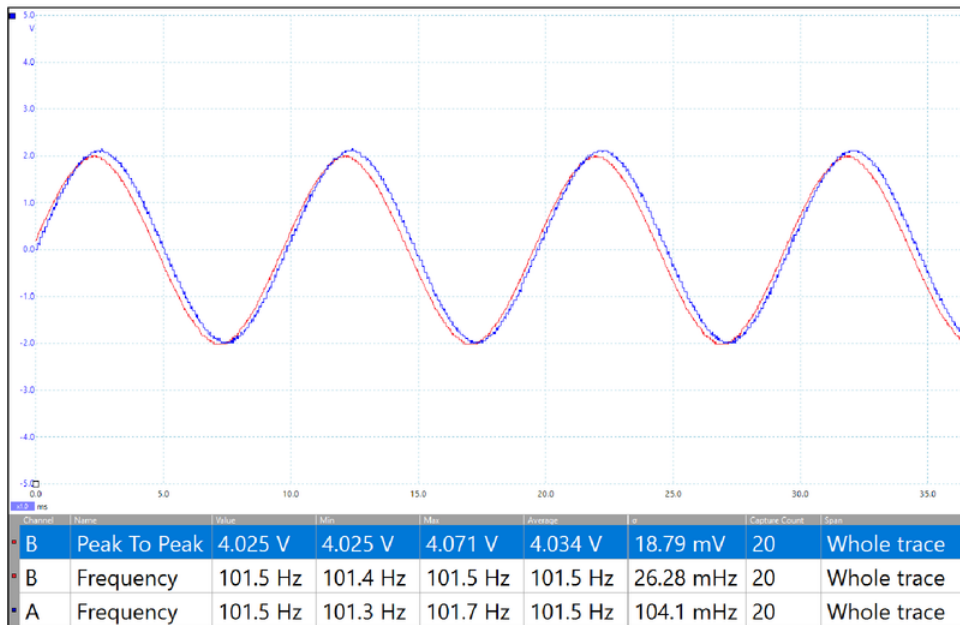


Figure 24 - 100Hz

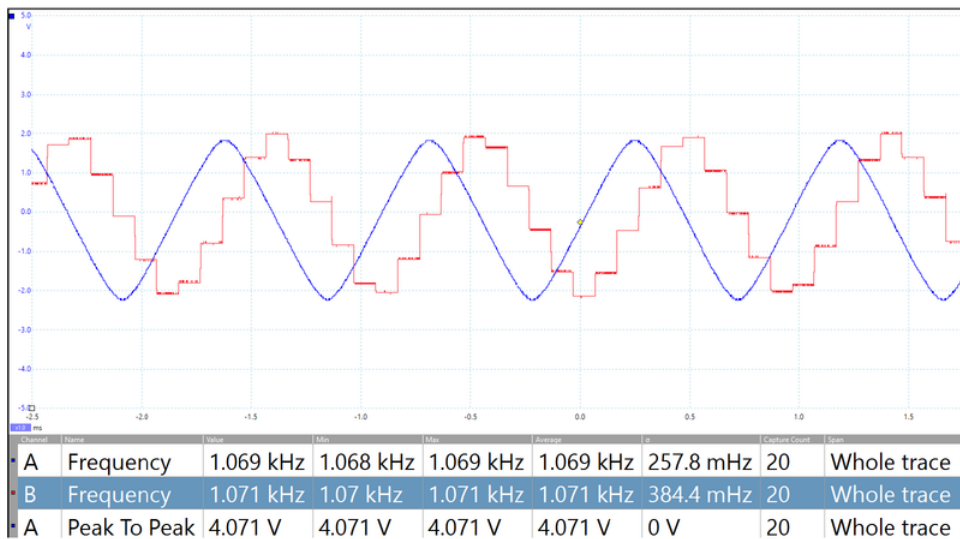


Figure 25 - 1kHz

It is clear from figures 26 and 27 that as the frequency is increased to 2.5kHz and then a 5k input to a 5k output respectively, the replicated frequency becomes and more unstable and unrecognisable compared to the original. Its steps becoming more jagged and uneven as the bit rate decreases.

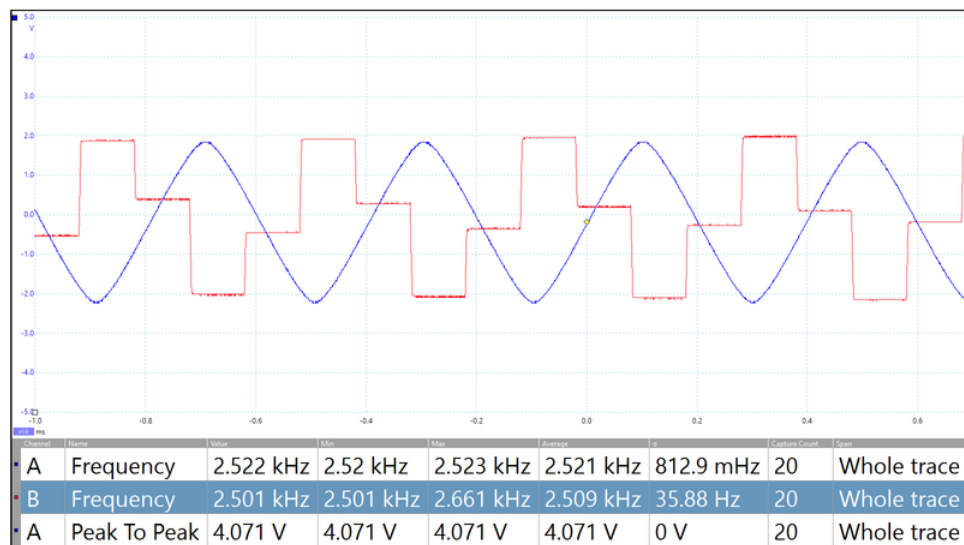


Figure 26 - 2.5 kHz

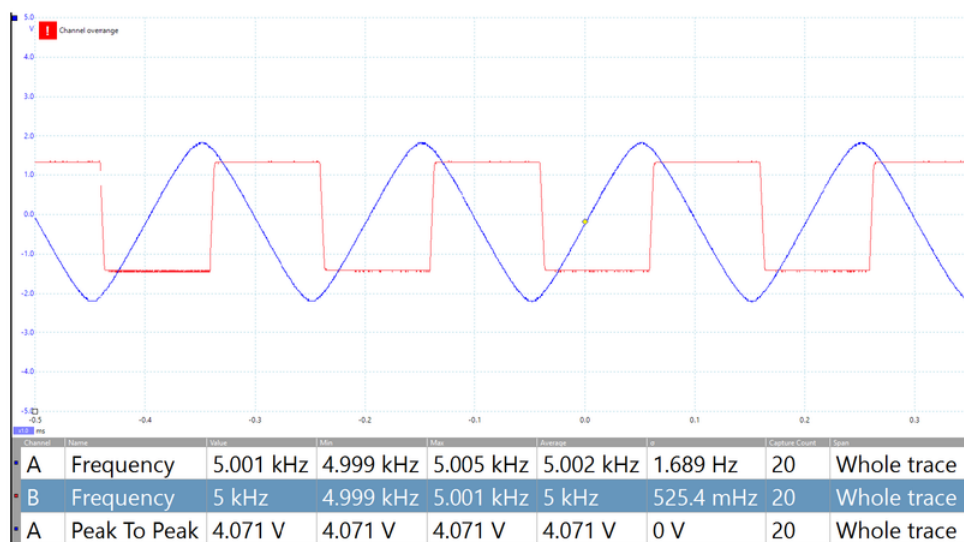


Figure 27 - Sample Limit of 5K input to 5K output

Once the 5k cap is passed it is clear that the replicated frequency is completely indistinguishable when comparing it to the original sine wave signal. This is due to frequency lock being lost due to the frequency increasing beyond the 5kHz threshold.

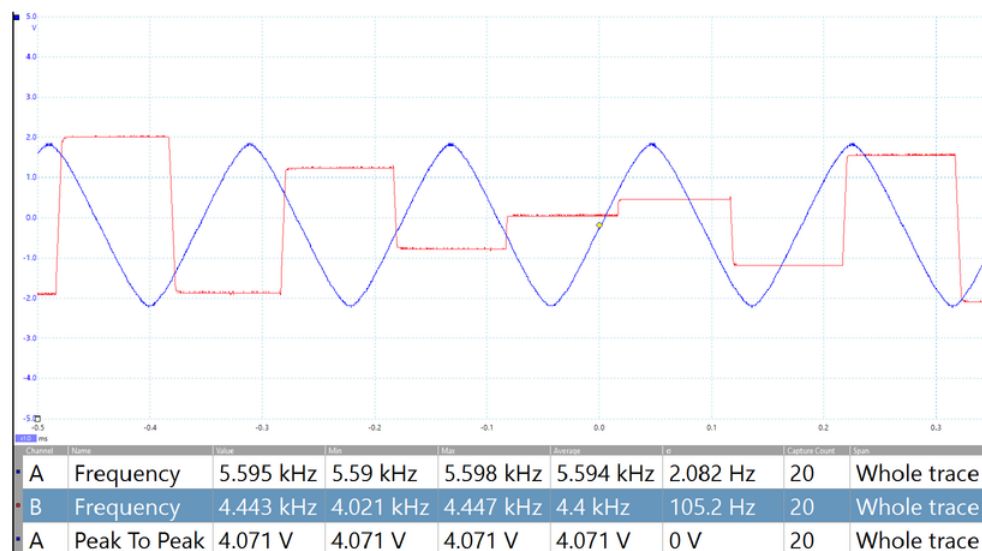


Figure 28 - 5.5K frequency lock lost

## 5. Conclusions

This assignment had the objective of performing research in various methods of digital modulation. Specifically this assignment was designed to look into analogue to digital conversion, or ADC, and pulse code modulation, or PCM.

For the research section of this assignment the main sections that were covered were:

- Pulse amplitude modulation techniques and their applications
- Pulse code modulation techniques and their applications
- What aliasing is and how it can cause problems for frequency modulation
- Various digital modulation schemes including amplitude, frequency and phase shift key modulation, as well as the less used QPSK modulation

All these areas in the first section of the report were covered in good detail and reported showing a clear understanding of how each task links together. There was a clear understanding of the difference between pulse amplitude and pulse code modulation and how each variation of modulation works. There is also a good foundation knowledge on aliasing and what problems it can cause in frequency sampling. The various digital modulation schemes were separated and explained in full as well as showing how some of them relate to each other.

For the experimental method of this assignment the modulation experiment that was carried out showed a clear link between the research and practical application.

## 6. Appendices

### Works Cited

Bill Waggener, W. M. (1995). *Pulse Code Modulation Techniques*. (illustrated, Ed.) Springer Science & Buisness.

E-Question Answers. (2018, 04 02). *Analog & Digital Modulation*. From E-Question Answers: <http://www.equestionanswers.com/notes/modulation-analog-digital.php>

On My Phd. (2018, 04 02). *Aliasing*. From On My Phd: <http://www.onmyphd.com/?p=aliasing>

Technopedia. (2018, 04 02). *Pulse Amplitude Modulation*. From Technopedia: <https://www.techopedia.com/definition/25118/pulse-amplitude-modulation-pam>

Tutorials Point. (2018, 04 02). *Pulse Code Modulation*. From [https://www.tutorialspoint.com/digital\\_communication/digital\\_communication\\_pulse\\_code\\_modulation.htm](https://www.tutorialspoint.com/digital_communication/digital_communication_pulse_code_modulation.htm)

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

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

PAGE 18

PAGE 19

PAGE 20

PAGE 21

## GRADING FORM: CSG-RUBIC

**SCOTT DEDONCKER****68****RESEARCH-INFORMED LITERATURE**

There was 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

**6****KNOWLEDGE AND UNDERSTANDING**

The knowledge and understanding of the subject demonstrated by this assignment was generally acceptable. The explanation of the experiment 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 in much more detail.

**19****ANALYSIS**

Your explanation of the experiment was good, however the conclusions lacked some detail. You

**11**

could have evaluated the results in more detail and specified whether they concurred with theory suggesting reasons for any discrepancies. You have however demonstrated good analytical skills and your approach to the task was logical. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

#### **PRACTICAL APPLICATION AND DEP.**



Your application of practical skills for this task were generally OK, you used the resources appropriately when carrying out the experiment and you used appropriate options for testing and evaluating the circuit performance - albeit to a limited fashion. Testing generally lacked a lot of the required detail however and you should have included a comprehensive set of results for each stage.

**24**

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

**8**