

1708179

by Thomas Wood

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TIME SUBMITTED	03-APR-2020 01:24PM (UTC+0100)	WORD COUNT	4533
SUBMISSION ID	123489095	CHARACTER COUNT	22945

Course: HND Electrical and Electronic Engineering

Module: SGEE5005 Signals and Digital Comms

Assignment: Signals and Modulation

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University number: 1708179

Date submitted: 03/04/2020

Word count: 2632 (Excluding Tables and Figures)

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1. Executive Summary

This report was produced in order to gain and share theoretical and practical understanding of signals and digital communications.

The research within this report draws attention to modulation techniques (frequency and amplitude). Furthermore, the development of digital communication is investigated, and each stages relevancy to the overall process is explained.

Having carried out the research underlined practical experiments were then carried out, this was undergone to provide some practical results that can be compared to the theories developed within the research section of the report.

The experiments undergone analyse frequency modulation and also underlines the importance of the selection of an ADC for a certain input frequency and amplitude.

*Too
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sections*

2. Research into analogue and digital communication systems and techniques

2.1 An evaluation of amplitude and frequency modulation techniques

Modulation is the process of preparing a signal for transmission, the reason for this is that it is “necessary to shift the baseband frequencies to a frequency range more suitable for transmission” (Kristensen, 2005). Kristensen explains that some signals are not suitable for transmission and therefore must be converted to a more suitable signal without losing the original signal.

Two different forms of modulation are Amplitude Modulation (AM) and Frequency Modulation (FM), these two abbreviations are well known within radio. The two techniques are relatively self-explanatory, within AM the modulation signal determines the amplitude of the carrier signal whereas within FM the modulation signal determines the frequency of the carrier signal. This is better illustrated within Figure 1.

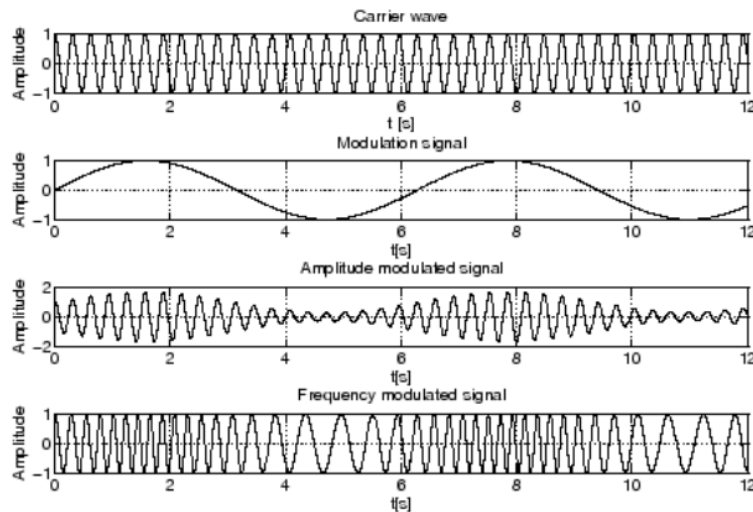


Figure 1 - Modulation (Kristensen, 2005)

2.2 An evaluation of the development of digital communication techniques such as:

2.2.1 Analogue to digital convertors (ADCs)

ADC is an acronym given to the circuits that carry out the process of converting analogue signals into digital data (Binary) known as analogue to digital converters; there are several different ways that this can be carried out with flash ADC being the most common. The analogue data that is received by the ADC is continuous in real time and the digital data (Binary) is discrete in time. ADC has become a crucial process and the accuracy of the conversions are becoming far greater. ADC is crucial as advanced microcontrollers nowadays work with digital logic, digital data is also easy to store and recall upon within the future. ADC's allow for sensors that do not have the capabilities to work digitally to be continually used within the ever growing digital world. As mentioned earlier although the accuracy of ADC's is growing the conversions are not exactly the same as the real world data. The effect of the ADC's resolution can be seen within Figure 2. It can be seen as the resolution is increased the emulation of the original signal is far greater.

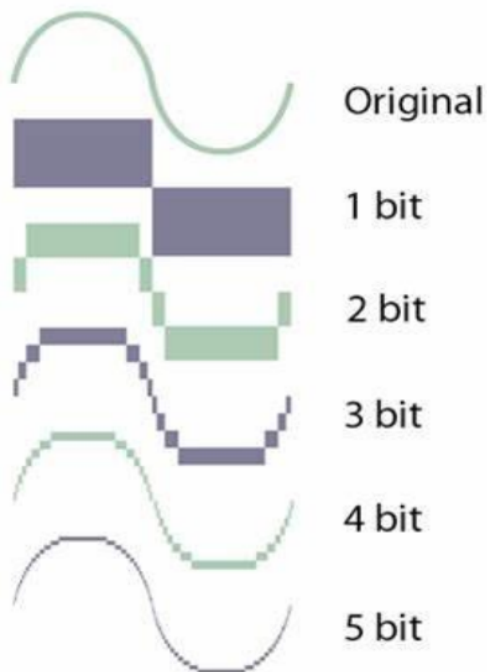


Figure 2 - Effect of resolution of ADC (Studies, n.d.)

The most commonly used type of ADC is the flash ADC, these are the most common ADC's as they are the fastest form of ADC. This is illustrated within a figure taken from Rowe's article (Figure 3).

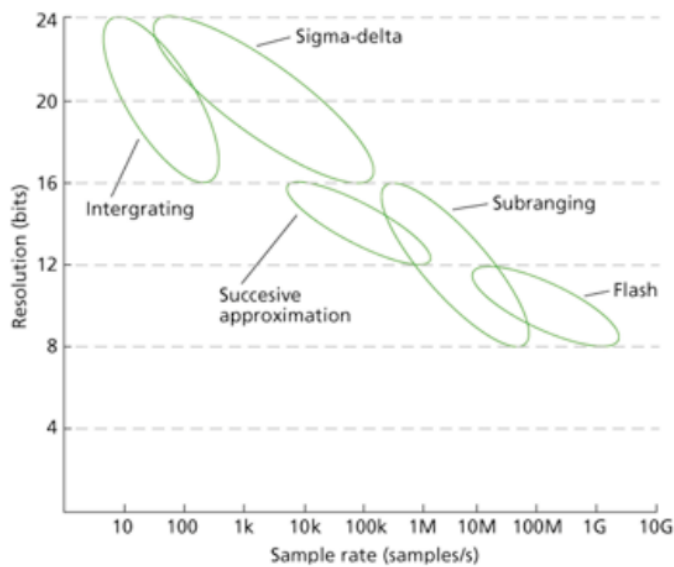


Figure 3 – “A graph of resolution versus sample rate and shows where the ADC types fit on the graph.” (Rowe, 2002)

Flash ADC's are commonly used within test equipment; the simplest form of flash ADC resolves analogue voltage into 8 bit words. “Parallel flash converters use a bank of comparators that compare the input voltage to a set of reference voltages across a resistor network.” (Rowe, 2002) As Rowe explains the voltage continues through the comparators until there is no more potential, these comparators then if triggered change their state to a logic 1. All these comparator states are then utilised to produce an 8-bit word which in turn is converted to a 3-bit binary weighted code that represents the voltage signal into the ADC. The circuit of a flash ADC can be seen within Figure 4.

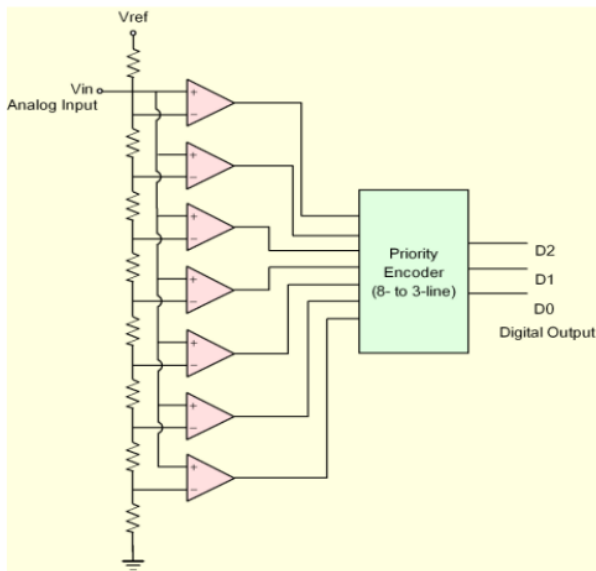


Figure 4 - Flash ADC circuit (Anon., n.d.)

2.2.2 PAM and PCM techniques

Pulse-amplitude modulation (PAM) and Pulse code modulation (PCM) are forms of modulation that allow for conversion analogue to digital data and ultimately the transmission of this digital data. The techniques are both ways of assigning integer values to a signal which can in turn be quantized and then encoded for transmission. Although similar the techniques have their distinctive differences.

Both techniques, in simple terms, convert a wave signal into a digital signal by determining values at set intervals and then plotting these almost like a bar chart, these are known as pulses. The original wave form can be depicted by the height of these pulses within PAM. This is illustrated within Figure 5.

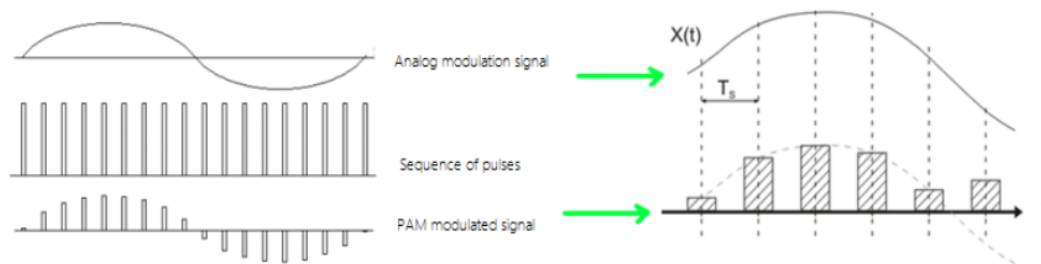


Figure 5 - PAM Example (BehindTheSciences, 2016)

As earlier explained the PAM technique sees the signal being coded through the use of the amplitude of the signal, therefore the higher the pulse the higher the value of the signal. “Pulse code modulation is an extension of Pulse Amplitude Modulation (PAM)” (TechnologyUK, n.d.), this is true as PCM works upon the same theory that the amplitude effects the size of the pulse produced however PCM also quantizes each of these pulses into a digital bit word, this can be seen within Figure 6. Therefore, it can be deemed that PCM is the overall process of digitally transmitting analogue data whereas PAM is only the sampling step of the signal.

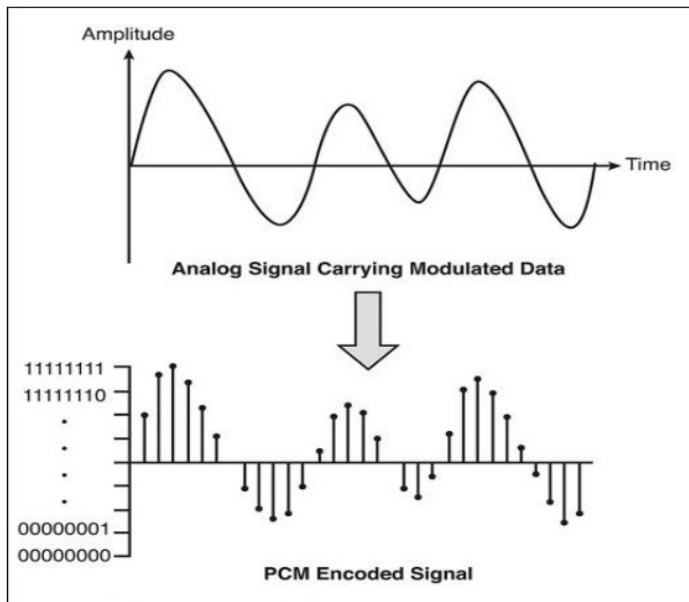


Figure 6 - PCM Example (Admin, 2015)

Once the digital signals are transmitted a demodulator is then utilised to recreate the pulses which can be better used to emulate the signal that was modulated and transmitted between digital systems.

2.2.3 Modulation schemes

There are two main types of modulation schemes, these being Quadrature phase shift keying (QPSK) and Quadrature amplitude modulation (QAM).

QPSK is a digital modulation technique that reduces the discrepancies of modulation caused from noise. This is done by increasing the amount of states available on the modulation from 2 (0 and 1) to 4 (00, 01, 10 and 11). The phase shift values of these states are ; 45° , 135° , 225° and 315° (Figure 7). This is achieved by modulating the carrier wave through shifting the phase as a pose to the frequency. "The carrier can experience numerous phase changes. Then multiplying the received signal by a sine wave of equal frequency will demodulate the phase shifts into voltage levels that are independent of frequency." (Teschler, 2017)

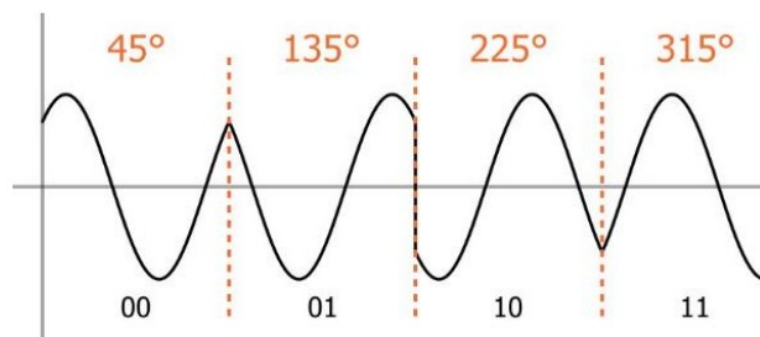


Figure 7 - QPSK modulated signal (Keim, 2016)

QAM is a modulation technique which utilises two carrier waves. These waves are known as in-phase and quadrature. These waves are 90° out of phase, these waves are then combined after modulation. This technique modulates both the amplitude and phase modulation. QAM is commonly known as QAM 16, this name is derived from the use of an IQ diagram, an IQ diagram typically has 16 points (4-bits) hence the name; QAM 16. The amount of points can be increased all the way to 1024. By increasing the amount of “points on the constellation, it is possible to transmit more bits per symbol. However the points are closer together and they are therefore more susceptible to noise and data errors.” (Anon., n.d.).

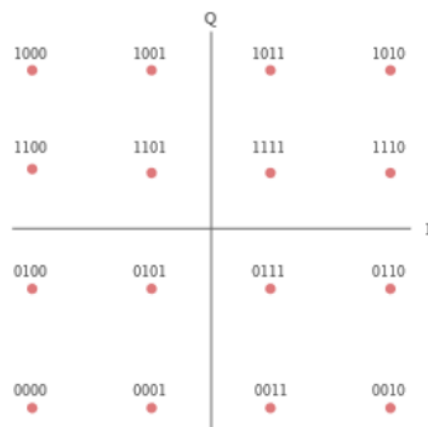


Figure 8 - QAM In-phase/Quadrature Diagram

2.2.4 Plesiosynchronous and synchronous digital hierarchy

PDH (Plesiosynchronous Digital Hierarchy) and SDH (Synchronous Digital Hierarchy) are forms of hierarchy used for the transmission of huge amounts of data over digital transport equipment. PDH works through the use of many multiplexers, these multiplexers all have the same bit rate inputs but are derived from different clocks from different oscillators. Therefore, these clocks are not perfectly synchronised which leads to the underlying factor of PDH which is the fact that it operates with networks that are nearly synchronised.

SDH is the newest hierarchy that has been developed in order to take over from PDH, the main difference is that SDH has a common clock upon its multiplexers which therefore means that the network is synchronised, this point is proven by what the admin from Fibre optic network has said; “SDH system is designed to replace PDH system for transporting large quantities of telephone calls and data traffic over the same fibre without synchronization problems” (Admin, 2015).

Although this PDH is still often used instead of SDH if there is not a great need for the transmission of large amounts of data, this is due to the cost of PDH being lower than SDH therefore excessive use of SDH is not financially beneficial.

Both transmission techniques utilise multiplexers these multiplexers allow for large amounts of signals to be inputted combined and then put onto a single output line, this process is almost like

packetizing the signals and therefore reducing the traffic and allowing signals to be transmitted faster. This process is illustrated within Figure 9, it can be seen that each original signal is transmitted at 64Kbps, however as the signals work their way through the transmission process (through each multiplexer) the transmission speed increases until eventually one large piece of data is transmitted at 565Mbps. The transmission system seen within Figure 9 is emulated on a PDH system, an SDH system has the capability to transmit more data at a faster rate than the PDH system.

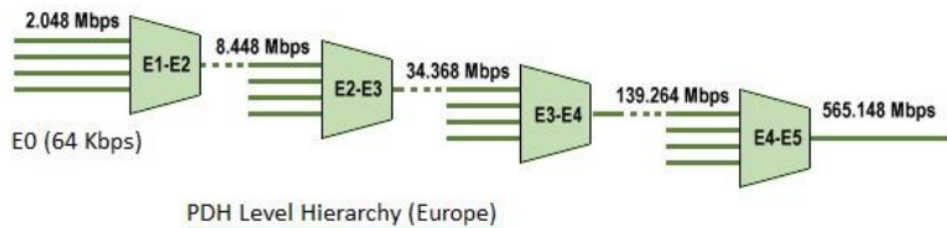


Figure 9 - Layout of PDH transmission (Anon., n.d.)

Figure 10 shows another defining factor that makes SDH a better form of transmission than PDH is the fact that after the signals have been transmitted PDH requires an array of de-multiplexers in order to separate the individual signals. This process is not required within SDH.

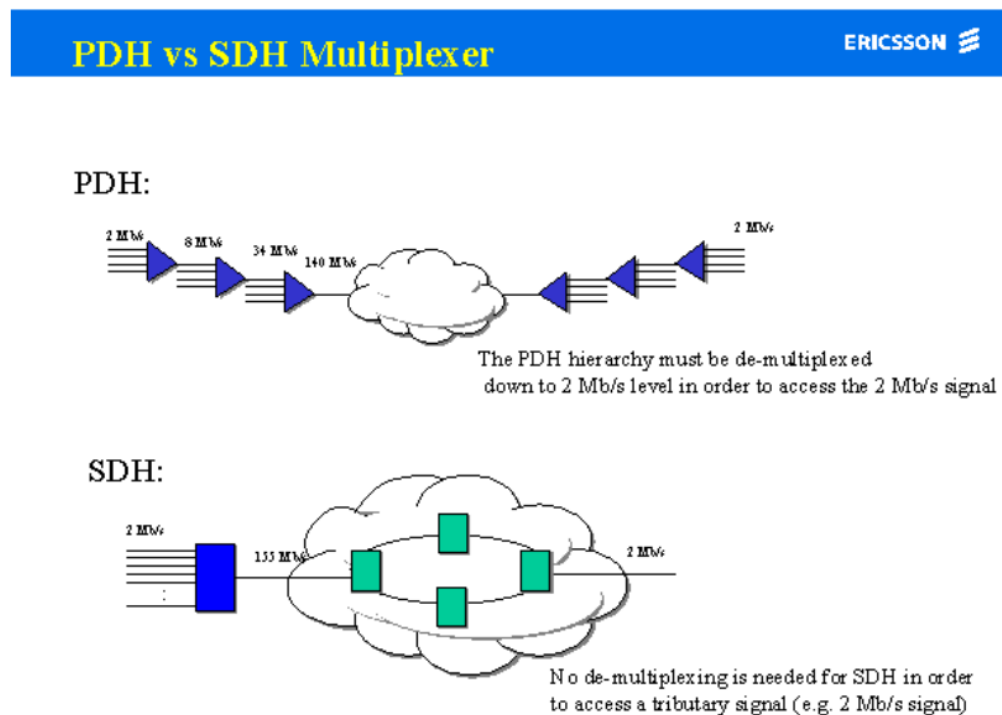


Figure 10 - PDH v SDH (Anon., n.d.)

3. Experimental method & Testing, results and analysis

Two separate experiments have been carried out, therefore this section has been split in two;

3.1 Experiment 1

"A 455kHz carrier has an amplitude of 375mV and is frequency modulated by a 10 kHz square-wave signal of amplitude 2V. If the modulator has an FM transfer characteristic of 20kHz per volt"
(Assignment Brief)

From analysing the brief, the values below were calculated (full calculation method can be seen within Appendix B);

Frequency Deviation (δf_c) = 40 KHz

Modulation Index (β) = 4

The values that were calculated allowed for the side frequencies to be displayed through the use of the relevant Bessel Table, the spectrum of the wave was then produced (Figure 11).

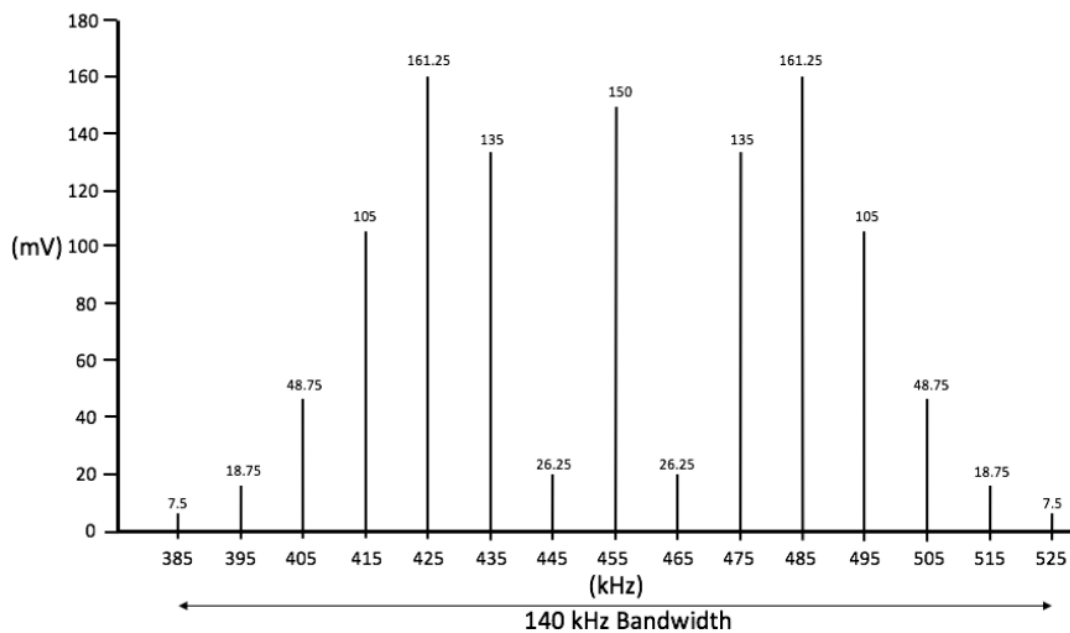


Figure 11 - Calculated Side Frequencies

In order to test this theory a practical experiment will be carried out which will allow for comparison between theoretical values and practical values.

The set-up of the equipment for experiment 1 can be seen within Figure 12,

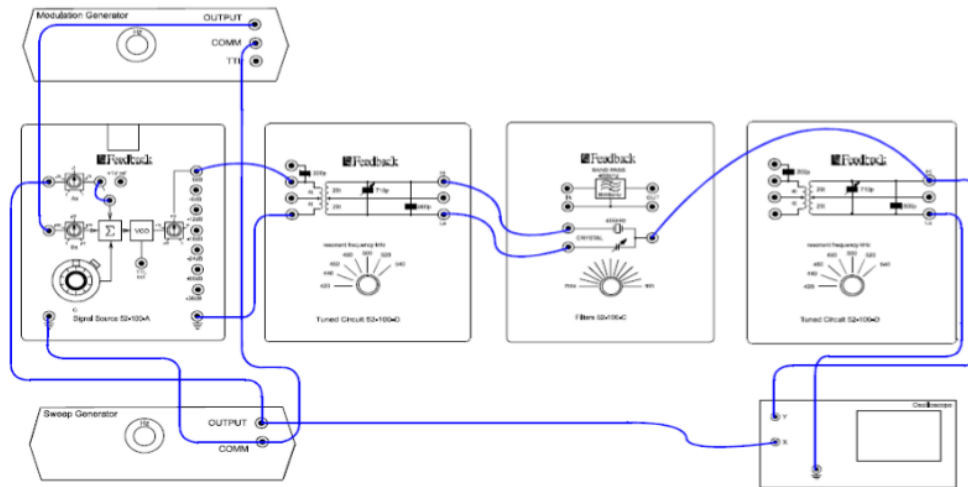


Figure 12 - Experiment 1 Set-up

3.1.1 Setting up a FM (Frequency Modulated) Signal

This part of the experiment produces a frequency modulated signal, in order for this to be possible the equipment within Figure 12 has been set up. To begin with the frequency control has been set to 455 KHz and modulation generator to 1Hz at 6V Peak to Peak (p-p). The amplitude of the modulation generator was then reduced in 1V steps.

Following this the modulation generator was set back to 6V p-p, and the frequency was then increased in accordance with the scale upon the generator (1Hz, 10Hz, 100Hz....).

The findings of this experiment are detailed below;

It was found that as the frequency of the modulation generator was increased that the frequency of the modulated signal also increased this is evident as the signal is a FM signal and therefore has a direct relationship with the frequency of the input signal.

It was found that as the amplitude was changed the modulated signals amplitude would also decrease however the frequency would not be effected, this is expected as the FM signal itself is not directly affected by the amplitude.

The carrier wave and modulated signal used within this experiment can be seen within Figure 13 & Figure 14.

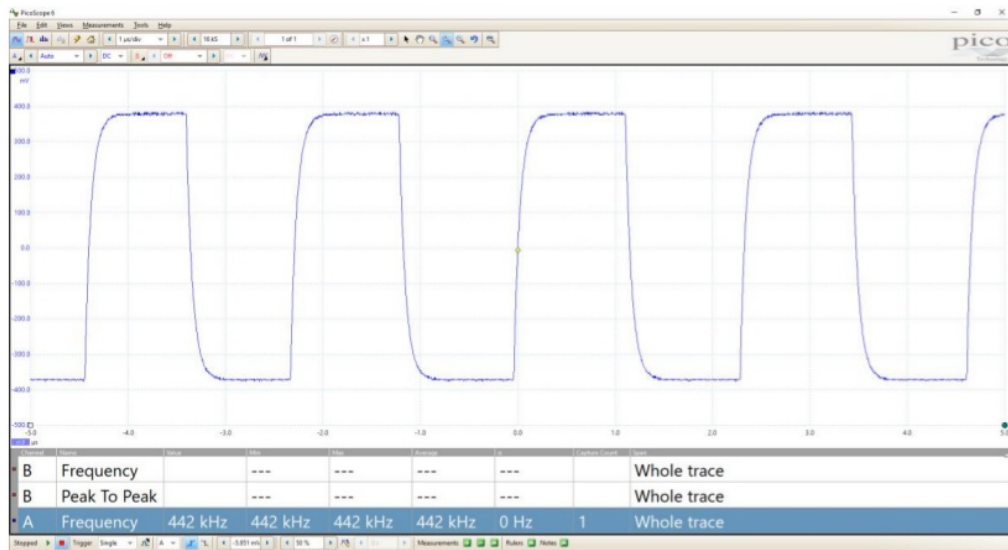


Figure 13 – Manual Frequency Signal (carrier wave)

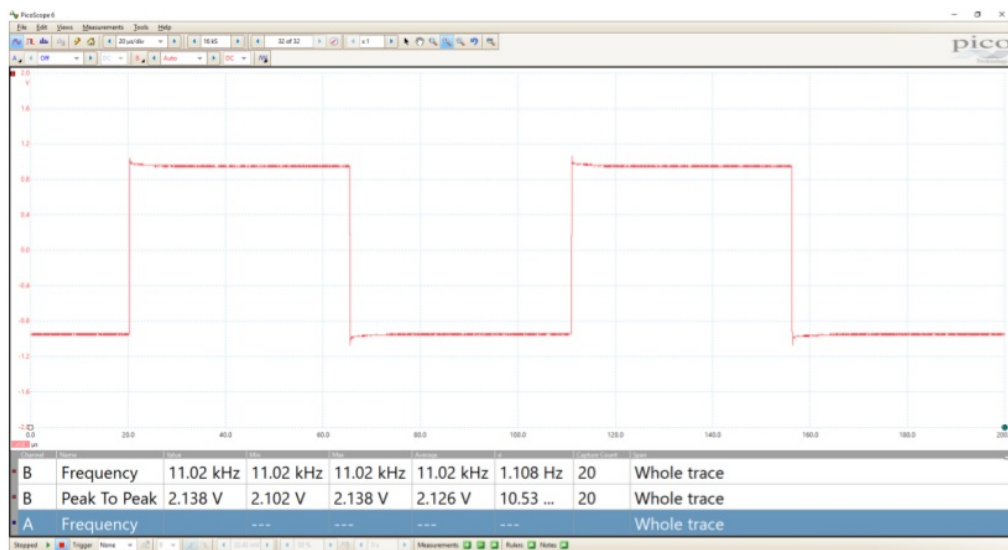


Figure 14 – Modulated Signal

3.1.2 Displaying of Side Frequencies

The second part of this experiment will produce the side frequencies of the modulated signal. This is achieved by setting the output of the modulation generator to 20 KHz at 2V p-p and changing the picoscope into spectrum mode.

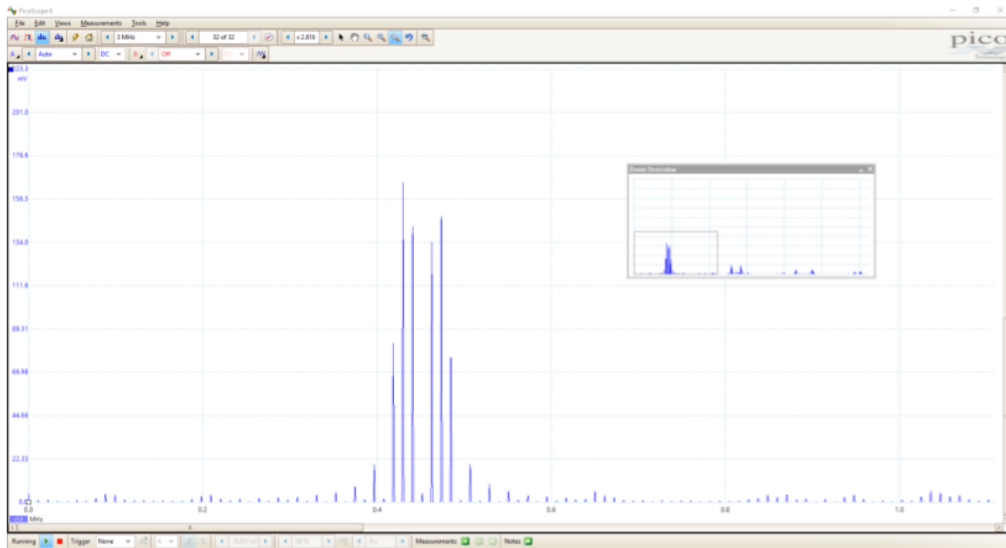


Figure 15 - Side-frequencies

The side frequencies produced from the experiment can be seen within Figure 15. The side frequencies at around 450 kHz have been concentrated upon. With regard to the side frequencies calculated (Figure 11) it can be seen that predominantly the spectrums are very similar, however there are some obvious differences. One very clear difference is the centre frequency; it can be seen within Figure 15 that at 0.455MHz (455 kHz) the frequency is displayed at around 5mV, however it can be seen that the calculated value for this frequency is 150mV. Other than this there are only minor discrepancies that can be expected, the general shape of the spectrum is also the same as the shape of the calculated spectrum. The bandwidth of Figure 15 (190 kHz) has also been found to be larger than the calculated value (140 kHz).

A results table comparing the

*practical results with the
calculated would have been
good here.*

3.2 Experiment 2

The second practical experiment that has been carried out concentrated upon ADC's. Within the experiment several theoretical theories were investigated. These were;

- Difference in quality of ADC conversion between 4-bit and 8-bit converters.
- The importance of the input signals amplitude matching the input range of an ADC.
- The relationship between the input signal frequency and the sampling rate of the ADC.

The set-up of the equipment for experiment 2 can be seen within Figure 16,

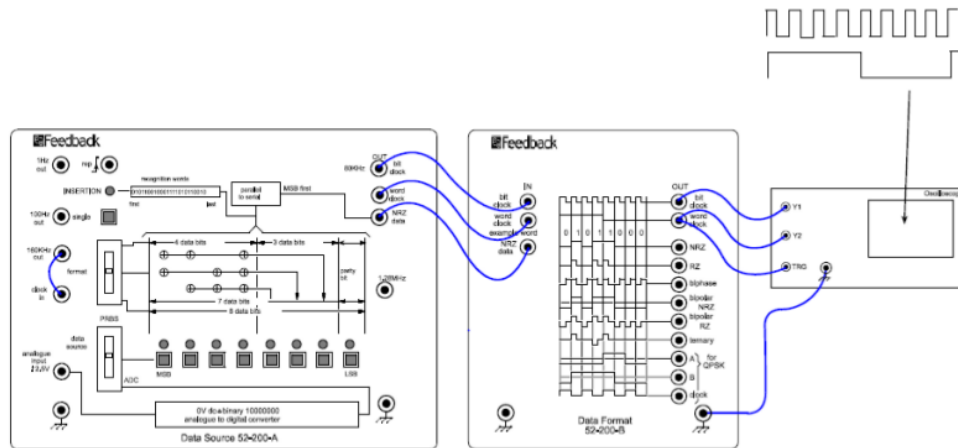


Figure 16 - Experiment 2 set-up

The ADC that is being used within the experiment has an amplitude range of 5 Vp-p and a sample rate of 10,000 samples/second.

3.2.1 Effect of changing the number of bits of the ADC

In order to investigate the effect of the amount of bits used on the conversion quality the ADC was first set to 8-bits, the input frequency was then set to 100Hz @ 4 Vp-p, the conversion was then observed on the oscilloscope. This process was then repeated with the ADC set to 4-bits.

The findings of this experiment can be seen within Figure 17 & Figure 18;

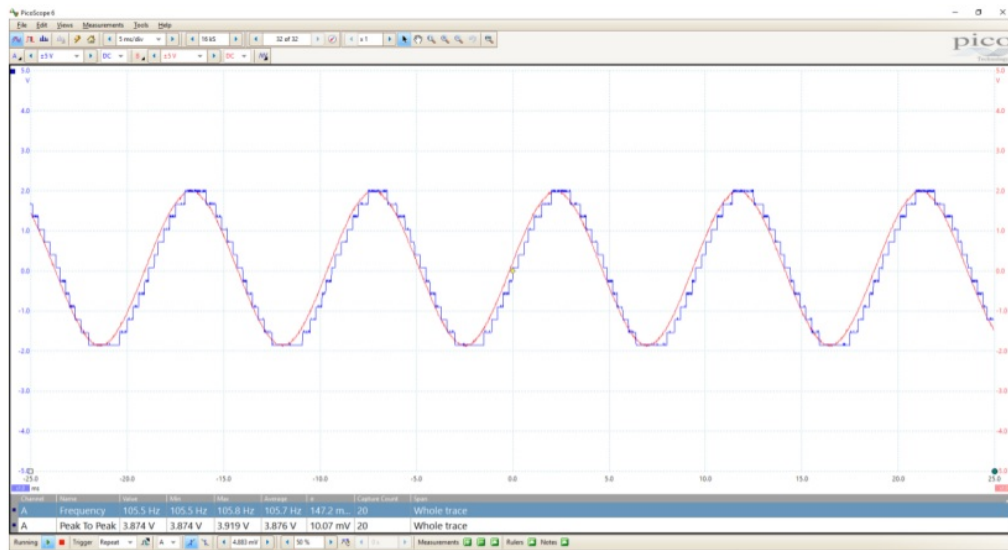


Figure 17 – 4-bit Conversion (input of 100Hz @ 4V p-p)

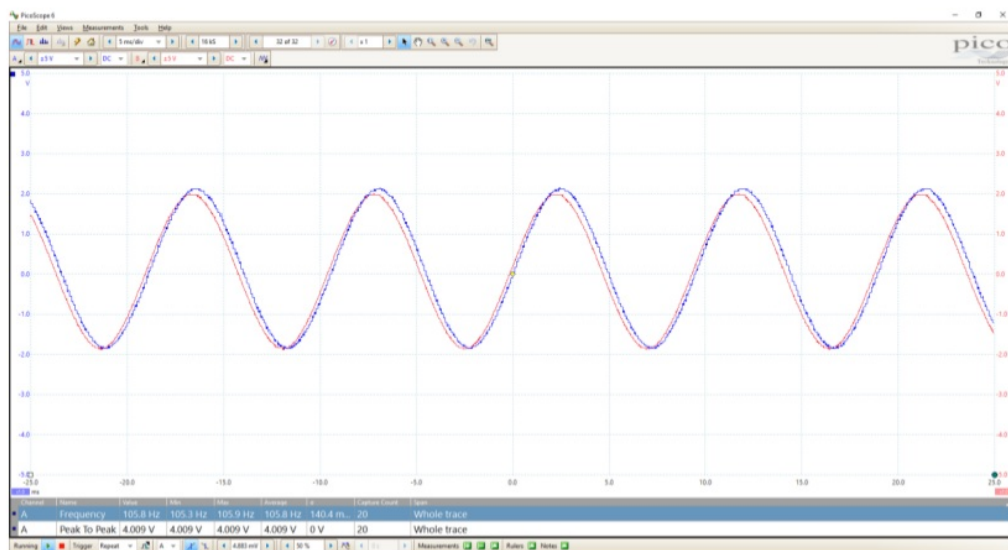


Figure 18 - 8-bit Conversion (input of 100Hz @ 4V p-p)

The findings within Figure 17 & Figure 18 clearly illustrate that the accuracy of the conversion is heavily increased as the amount of bits of the ADC is increased, this is clear as the 8-bit conversion better represents the original waveform. It is clear to see within the conversions that there is a slight delay between the two waveforms, this represents the conversion time of the ADC.

3.2.2 Effect of changing the input amplitude

In order to investigate the effect of altering the input amplitude into an ADC first of all the ADC was set to 4-bits, the input was then set to 100Hz @0 Vp-p, the amplitude was then increased in 2 Vp-p steps; up to 6 Vp-p. The ADC was then set to 8-bits and the above process was repeated.

The findings from the investigation can be seen within the figures below;

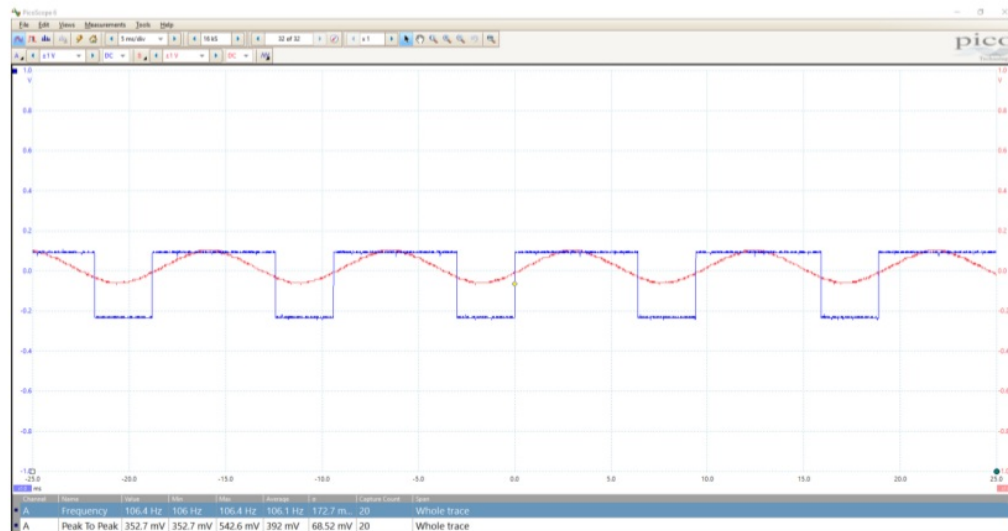


Figure 19 -4-bit 0V 100Hz

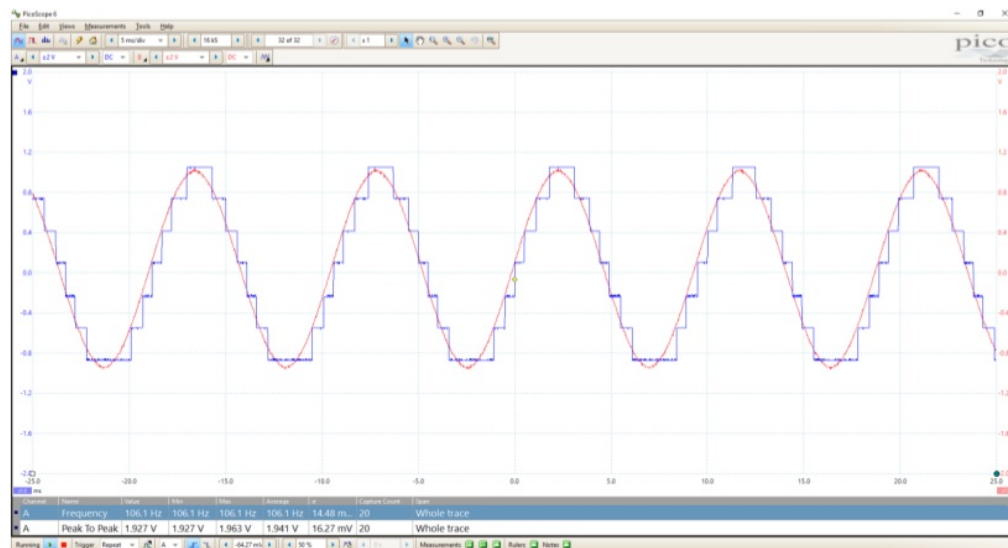


Figure 20 - 4-bit 2V 100Hz

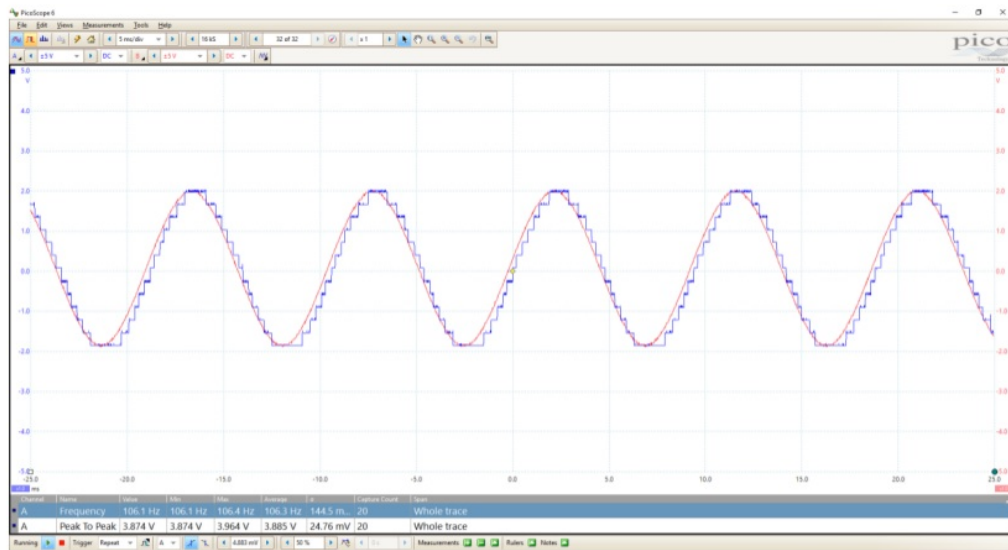


Figure 21 – 4-bit 4V 100Hz

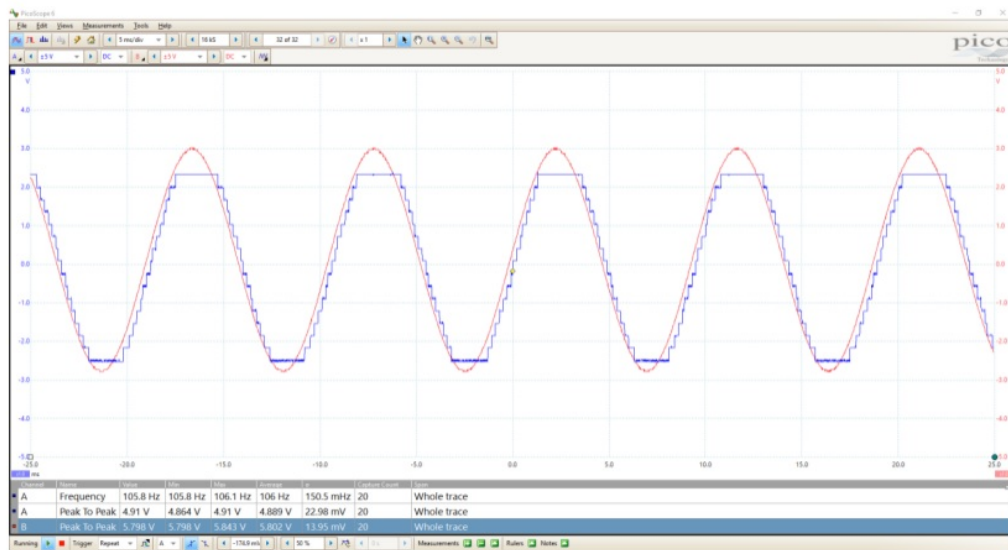


Figure 22 – 4-bit 6V 100Hz

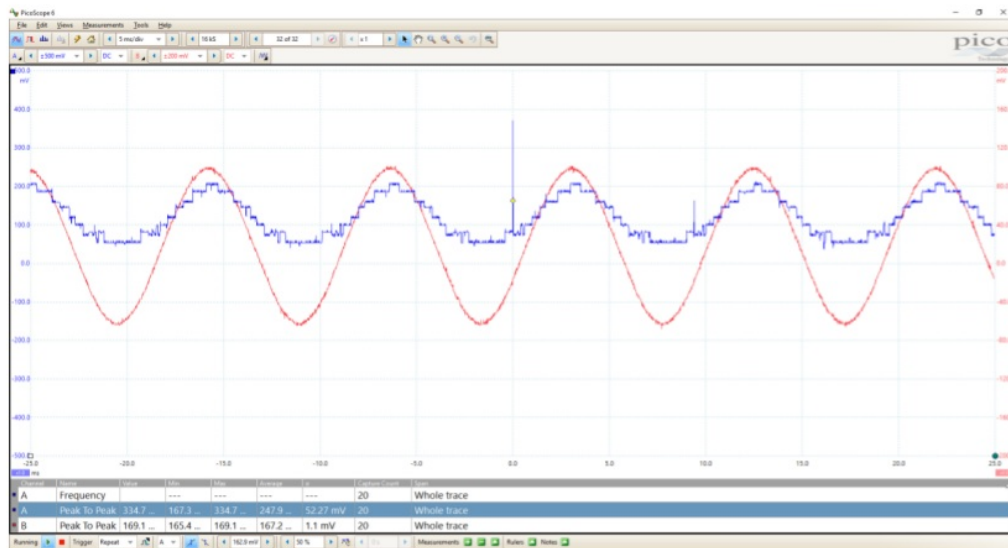


Figure 23 - 8-bit 0V 100Hz

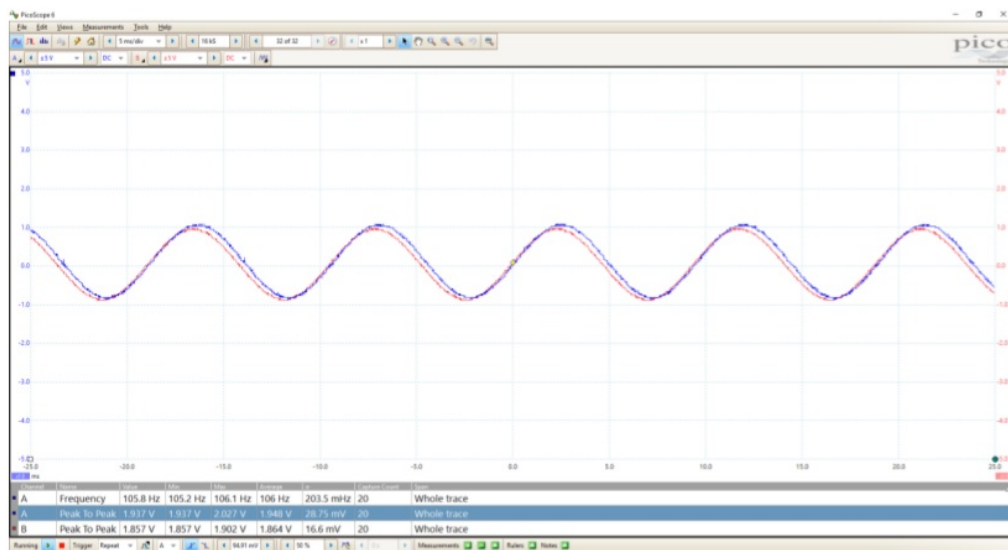


Figure 24 - 8-bit 2V 100Hz

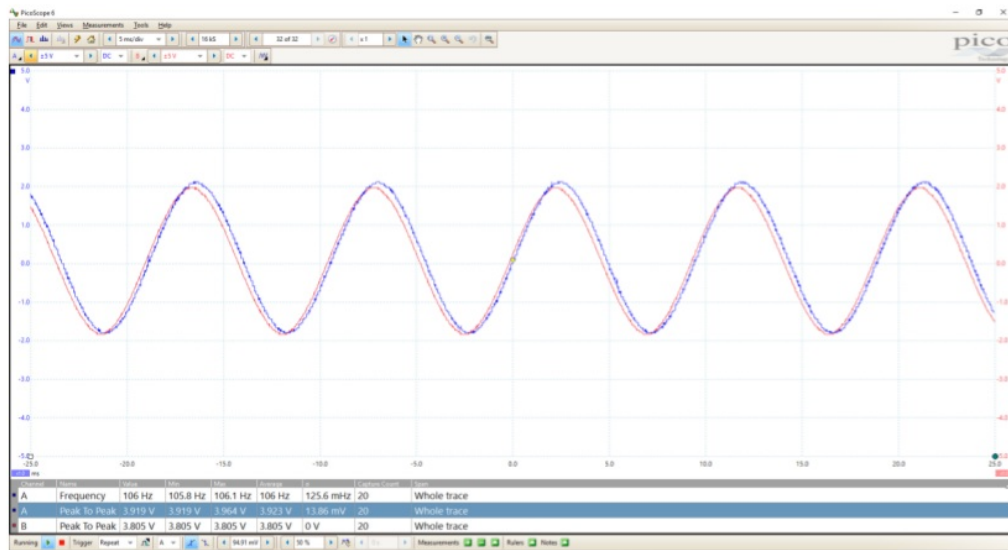


Figure 25 - 8-bit 4V 100Hz

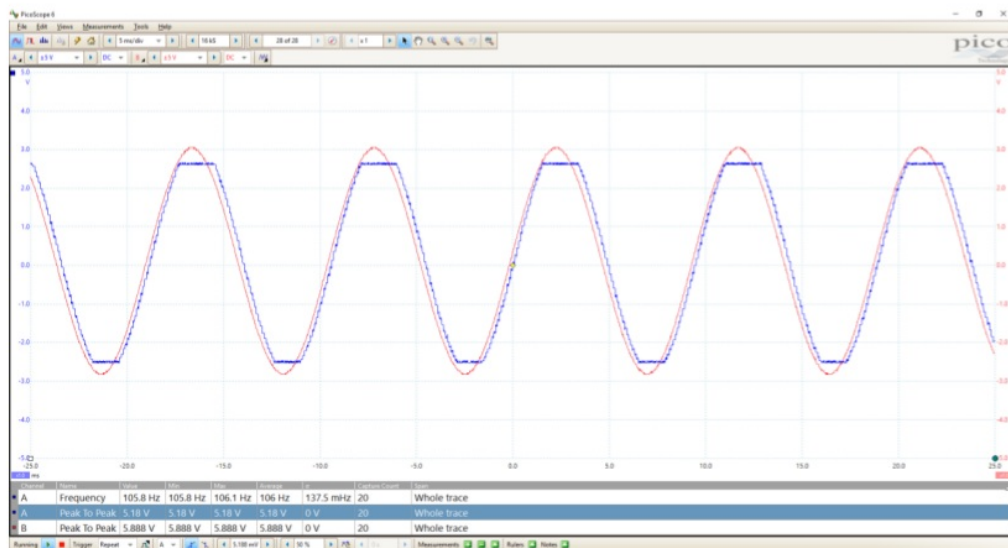


Figure 26 - 8-bit 6V 100Hz

The investigation findings clearly illustrate that as the amplitude is increased the accuracy of the ADC conversion of the signal increases (to a point). However, this theory is only true up to the input range of the ADC, the ADC used within this investigation has an input amplitude range of 5 Vp-p, it can be seen within Figure 22 & Figure 26 that the ADC cuts off the conversion at this input range therefore not accurately converting the true peak value of the signal. Similarly to the findings within 3.2.1 Effect of changing the number of bits of the ADC it can also be seen from the findings of this experiment that the 8-bit convertor produces a much more accurate conversion of the signal.

3.2.3 Effect of changing frequency

This investigation was carried out by first setting the ADC to 8-bits, the input frequency was then set to 100Hz @4 Vp-p, the frequency was then increased in decade increments.

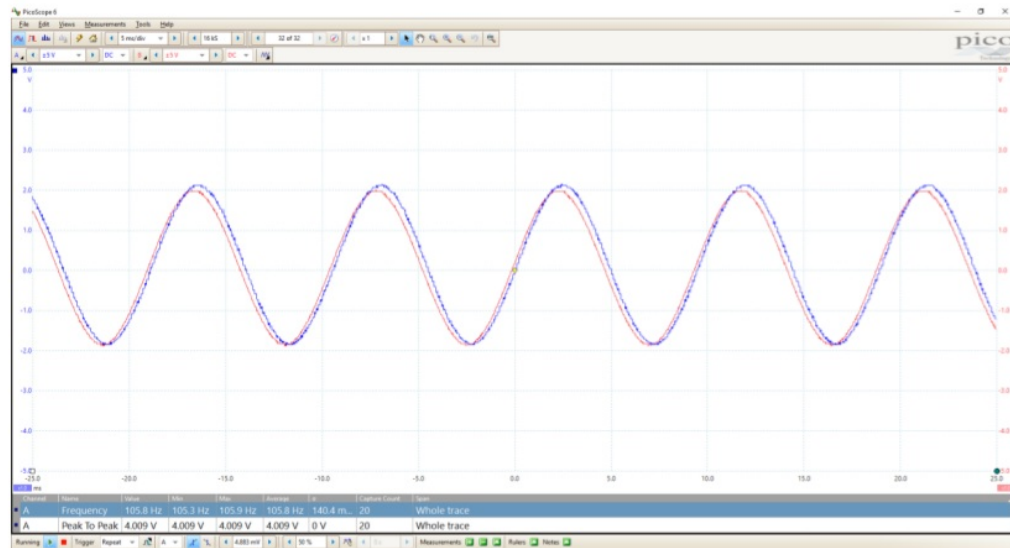


Figure 27 - 8-bit 4V 100Hz

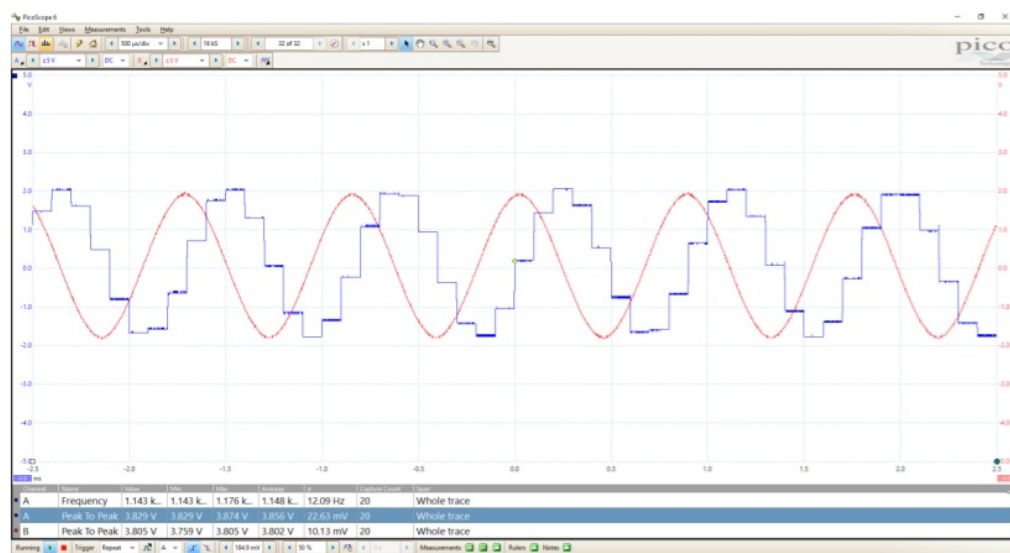


Figure 28 - 8-bit 4V 1 KHz

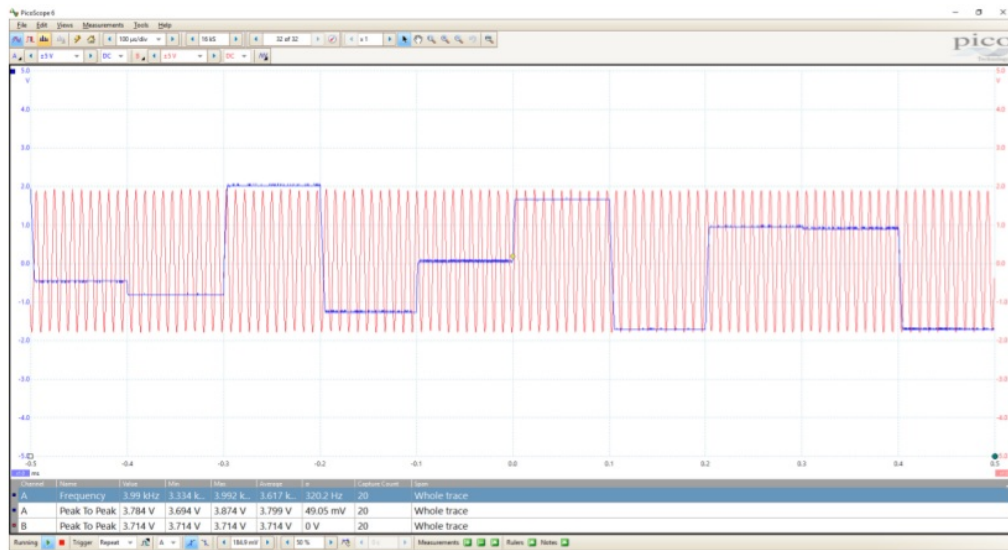


Figure 29 - 8-bit 4v 100KHz

The findings of this investigation within Figure 27, Figure 28 and Figure 29 clearly show that as the frequency is increased the accuracy of the conversion is decreased, this is because of the sample time of the ADC being exceeded this therefore means that the ADC basically cannot keep up with the high frequency signal and therefore cant convert the signal accurately.

The second part of the investigation sees the frequency set to 4 KHz, the frequency was then increased by 200Hz up to 6 KHz and from there onwards increased in 1 KHz steps up to 10 KHz.

The most appropriate points have been selected however all these set points can be seen within Appendix A.

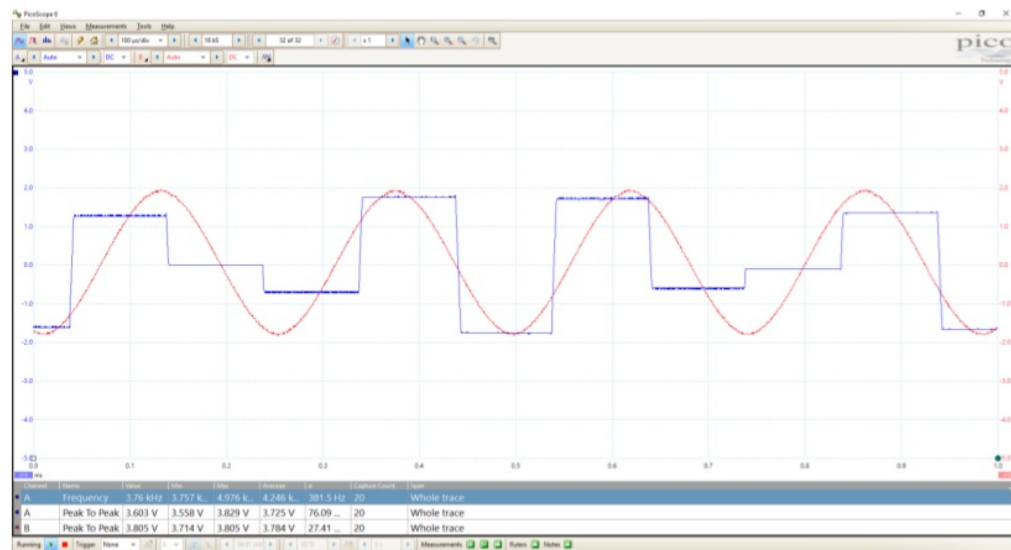


Figure 30 - 8-bit 4V 4 KHz

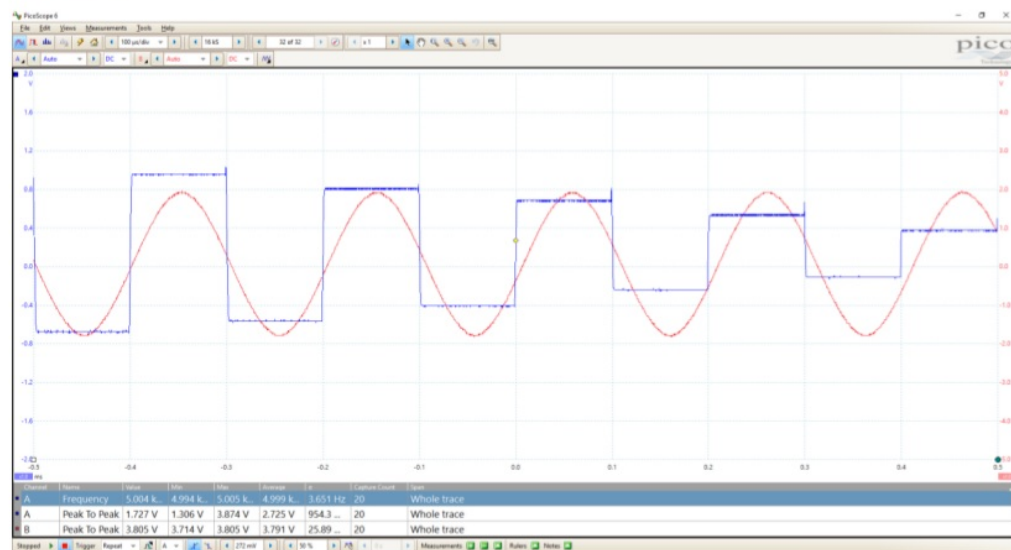


Figure 31 - 8-bit 4V 5 KHz

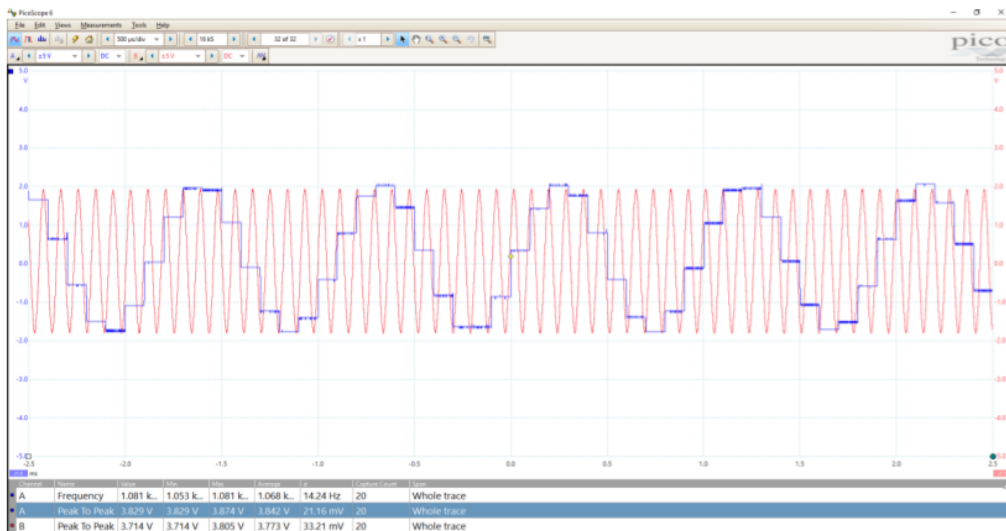


Figure 32 - 8-bit 4V 10 KHz

It can be seen from the findings that as the frequency is slowly increased the difference is very little between the responses, however a large increase also does not affect the response a great deal. This is because the ADC already cannot accurately emulate the signal at the original frequency value. Consequently the response therefore as seen within Figure 35 shows how the ADC would behave after its sample rate has been exceeded.

Results are confusing and don't demonstrate the Nyquist Criteria. A table of results showing input and output frequencies was needed.

4. Conclusions and recommendations

Within Research into analogue and digital communication systems and techniques several topics were researched, ultimately through this research it has allowed for a conclusive understanding to be gained. Through research it was concluded that modulation is a vital process within the transmission of signals, this is true as the signals are converted to a more appropriate signal for transmission without actually losing the original signal after transmission is complete.

Another topic that was covered within the research is the actual structure of the transmission process of a signal, as a result of this research it can be concluded that the process of transmitting an analogue signal digitally is far more complex than people may think, however, although complex, modern technology and theories has allowed for the process to work very quickly. This can be concluded with SDH taking over PDH, the new technology that is taking over the old technology is allowing for more data to be transmitted quicker, and also the reading time for the receiving device is being reduced.

Within the Analogue to digital convertors (ADCs) section of the research, a theory on the effect of the resolution of an ADC and the accuracy of the converted signal was drawn. It was deemed that the higher the resolution of the ADC (the more bit capacities of the ADC), the more accurate the conversion of the analogue signal to a digital signal. This theory was confirmed within 3.2.1 Effect of changing the number of bits of the ADC, through analysing the difference between a 4-bit conversion and an 8-bit conversion of the same input signal. It was clear to see that the 8-bit conversion was far more accurate than the 4-bit conversion.

Through research and practical investigations, it can be concluded that the selection of ADC within a system is important, this is evident as the ADC must be able to cope with the input signal it is converting. For example, within 3.2.2 Effect of changing the input amplitude, Figure 22 and Figure 26 clearly show that when the input signal to the ADC is not suitable to the ADC's specification the converted signal will not be accurate. This can be seen as the converted signal cuts off the peak of the input signal as the ADC only has a peak to peak voltage range of 5V. This conclusion is only further enhanced within 3.2.3 Effect of changing frequency as it can be concluded that increasing the input frequency above the ADC's capability also causes the converted signal to become inaccurate.

Within Experiment 1 a frequency modulated signal was first of all analysed through the use of calculations, as a result of the calculations carried out, the spectrum of the wave was plotted. This same signal was then analysed through the use of a practical investigation, the spectrum plotted from the calculations was then compared with the practical spectrum. It was concluded that although the centre frequency had a big discrepancy the spectrums were very similar and therefore underlines that the calculations are correct and can be used to predict a FM signal with a given carrier wave.

Ultimately this assignment has illustrated the importance of the correct selection of different processes and also physical components utilised within the transmission of both analogue and digital signals.

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Appendix A



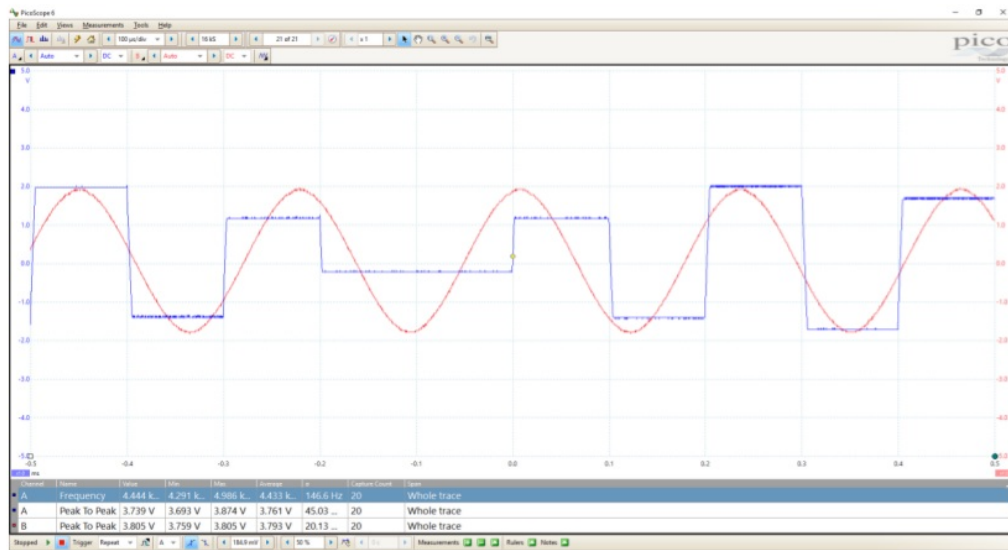


Figure 35 - 8-bit 4V 4.4 KHz

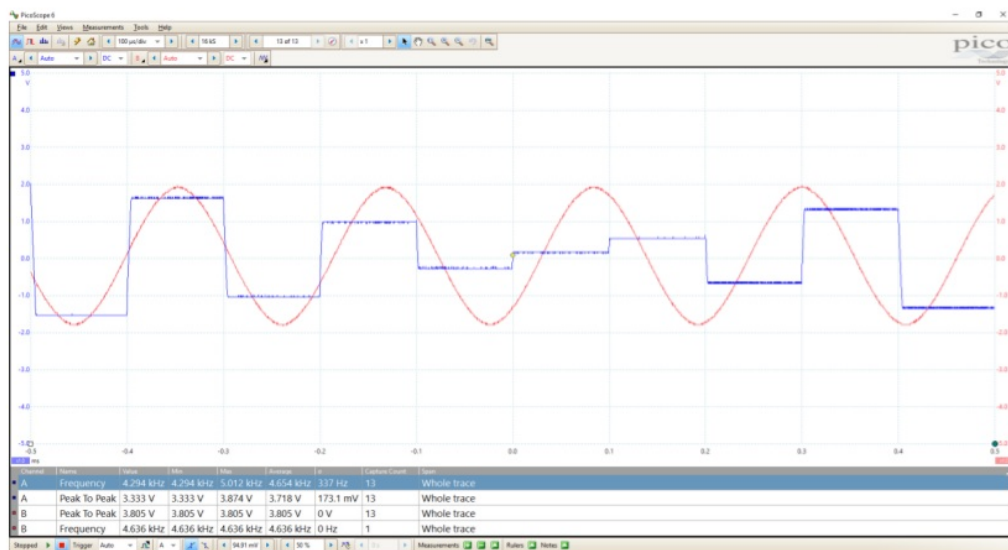


Figure 36 - 8-bit 4V 4.6 KHz

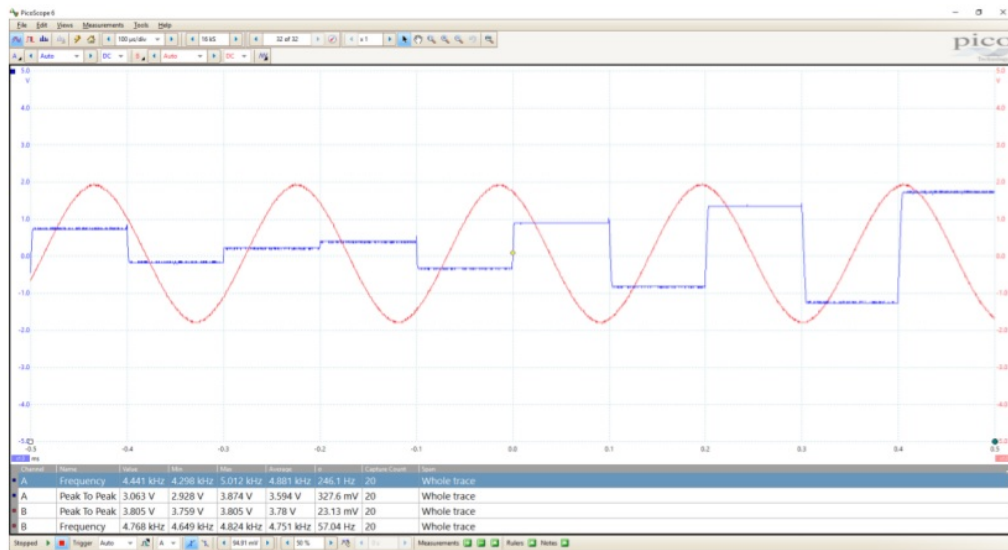


Figure 37 - 8-bit 4V 4.8 KHz

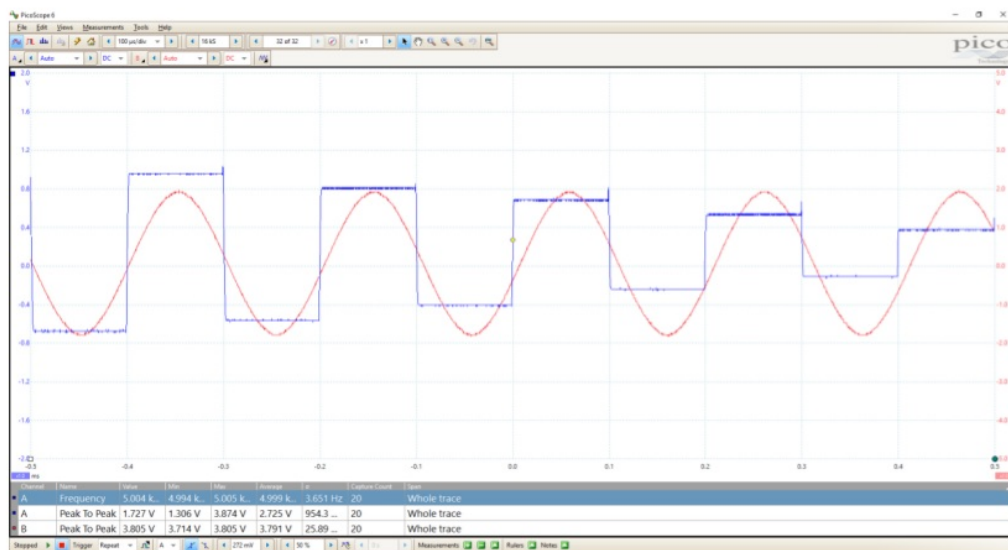


Figure 38 - 8-bit 4V 5 KHz

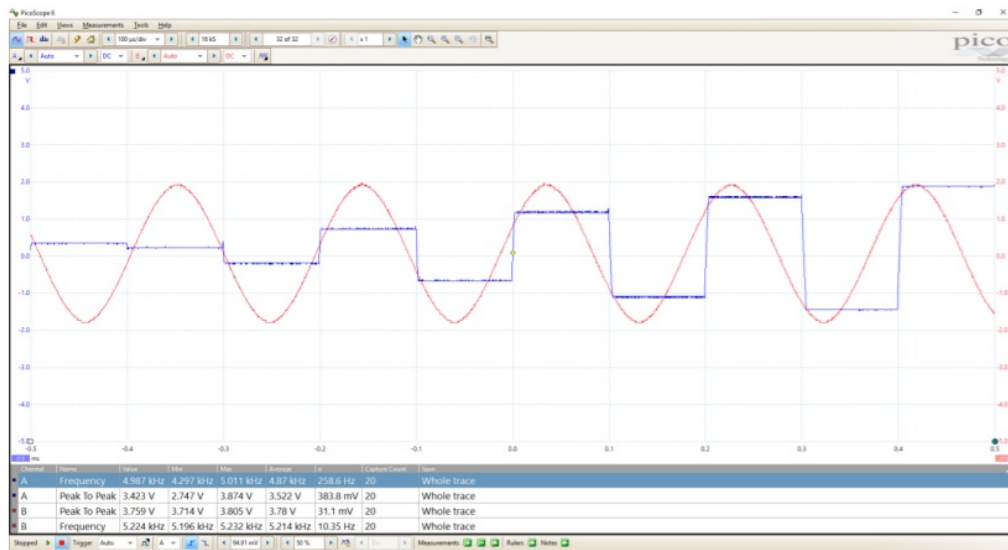


Figure 39 - 8-bit 4V 5.2 KHz

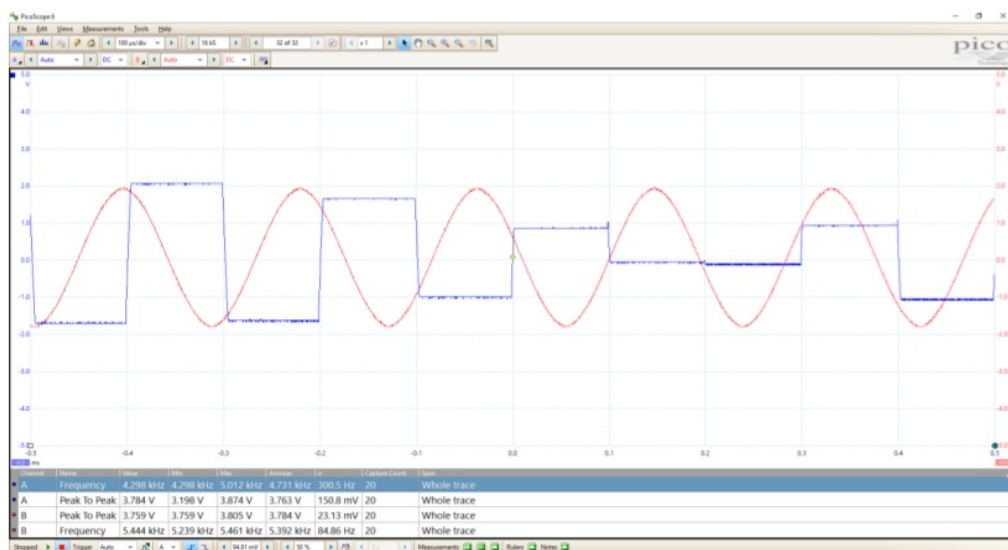


Figure 40 - 8-bit 4V 5.4 KHz

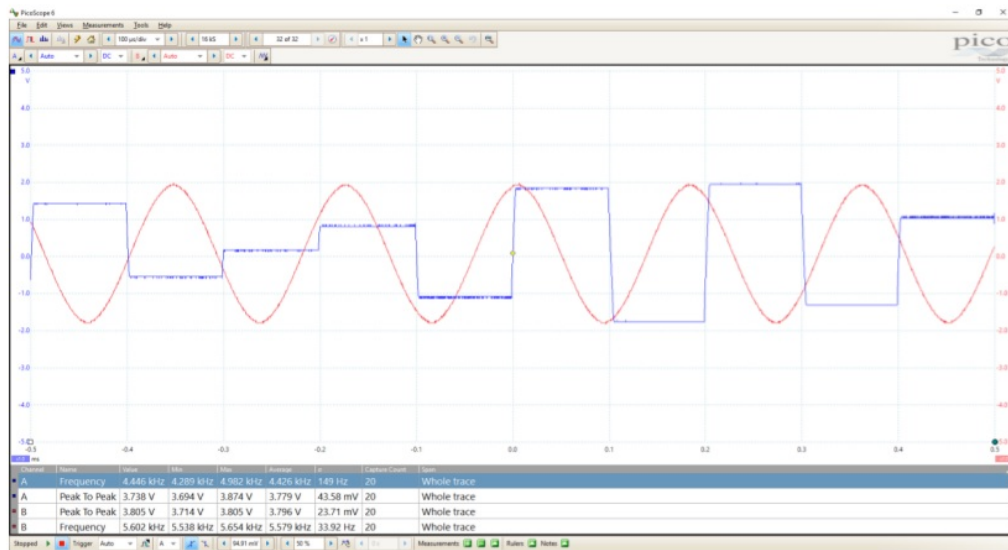


Figure 41 - 8-bit 4V 5.6 KHz

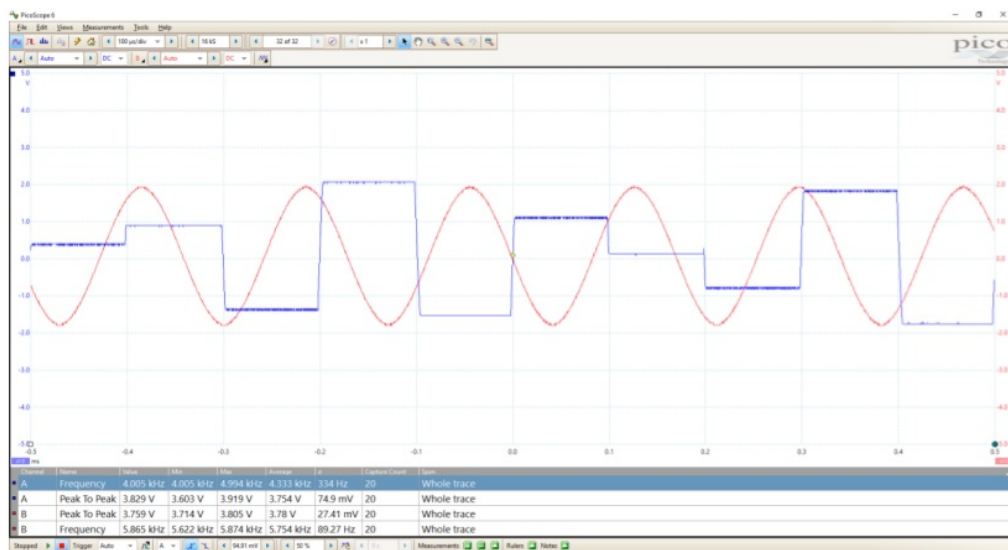


Figure 42 - 8-bit 4V 5.8 KHz

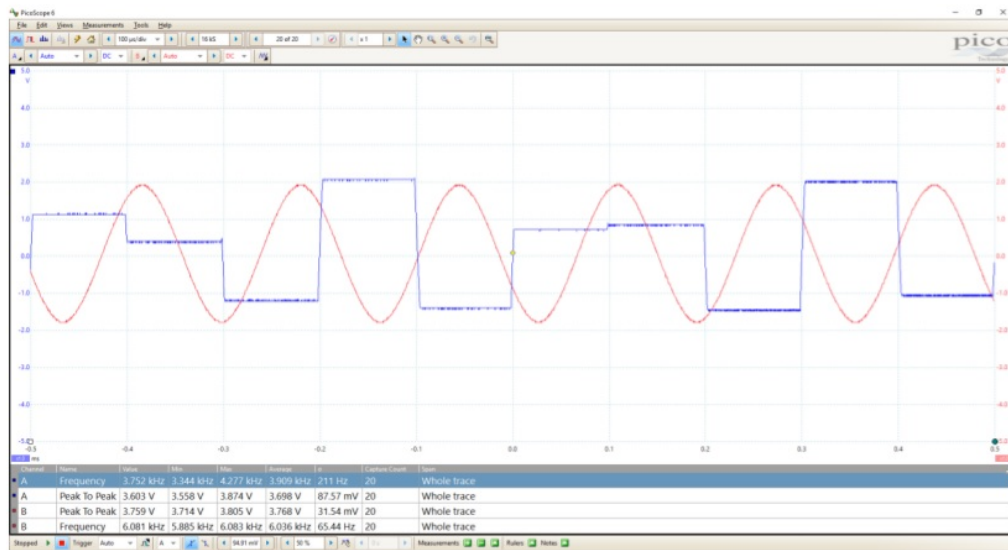


Figure 43 - 8-bit 4V 6 KHz

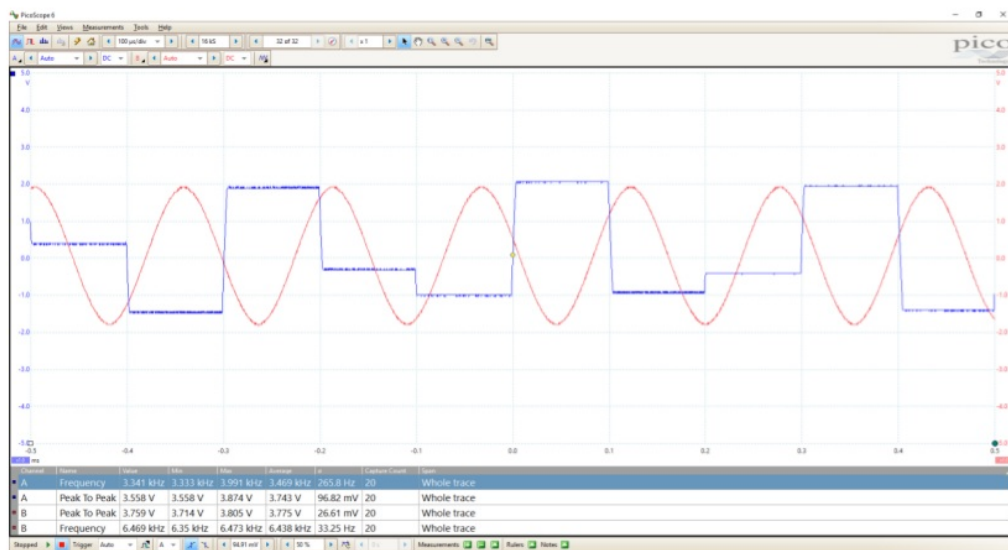


Figure 44 - 8-bit 4V 6.5 KHz

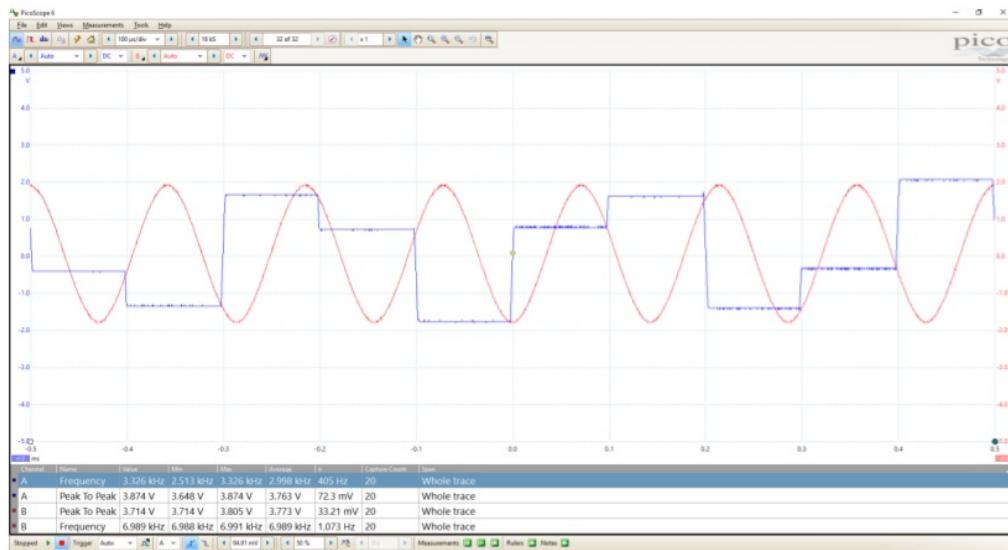


Figure 45 - 8-bit 4V 7 KHz

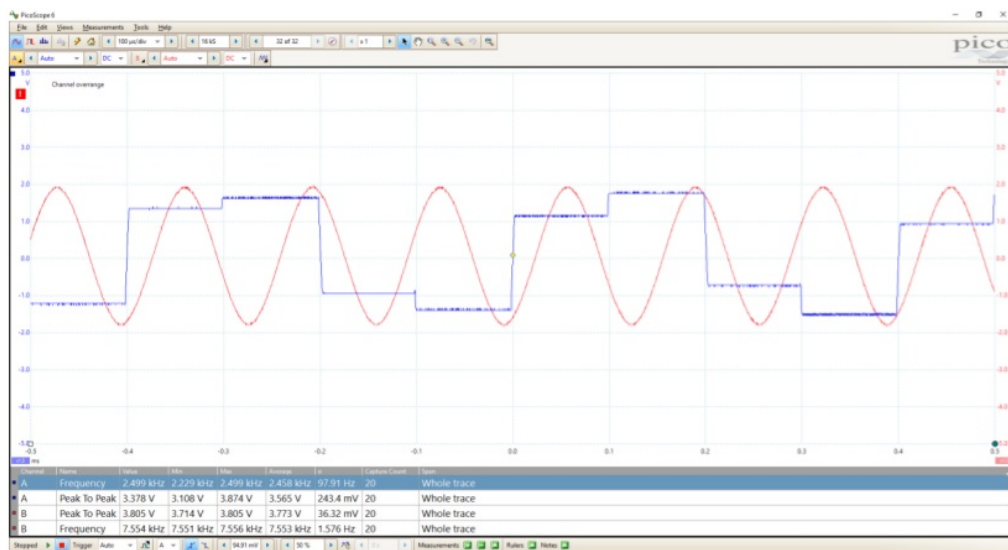


Figure 46 - 8-bit 4V 7.5 KHz

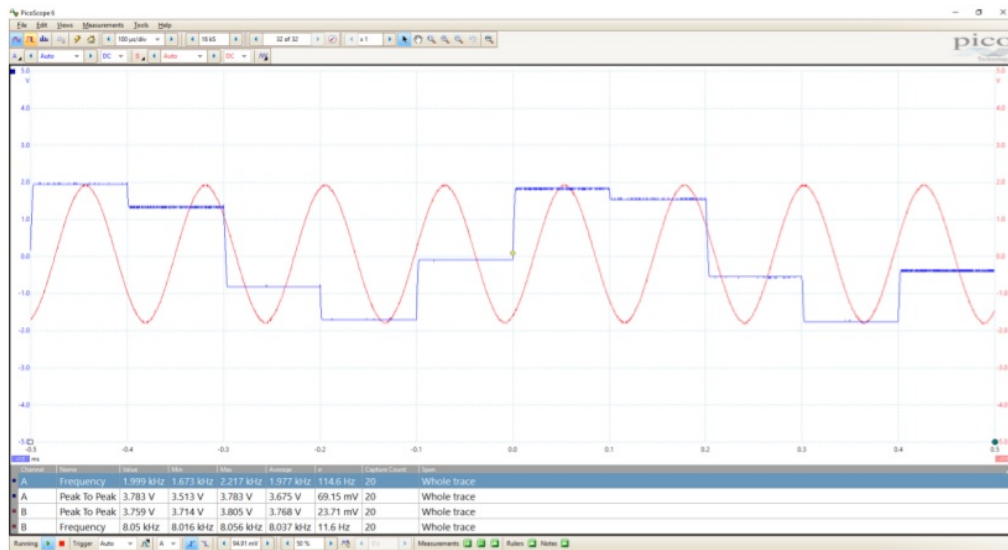


Figure 47 - 8-bit 4V 8 KHz

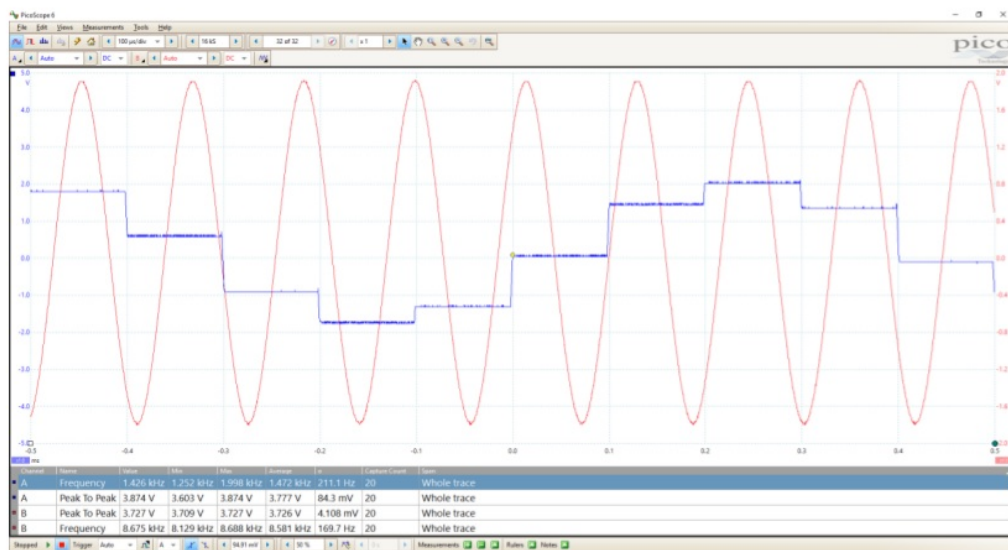


Figure 48 - 8-bit 4V 8.5 KHz

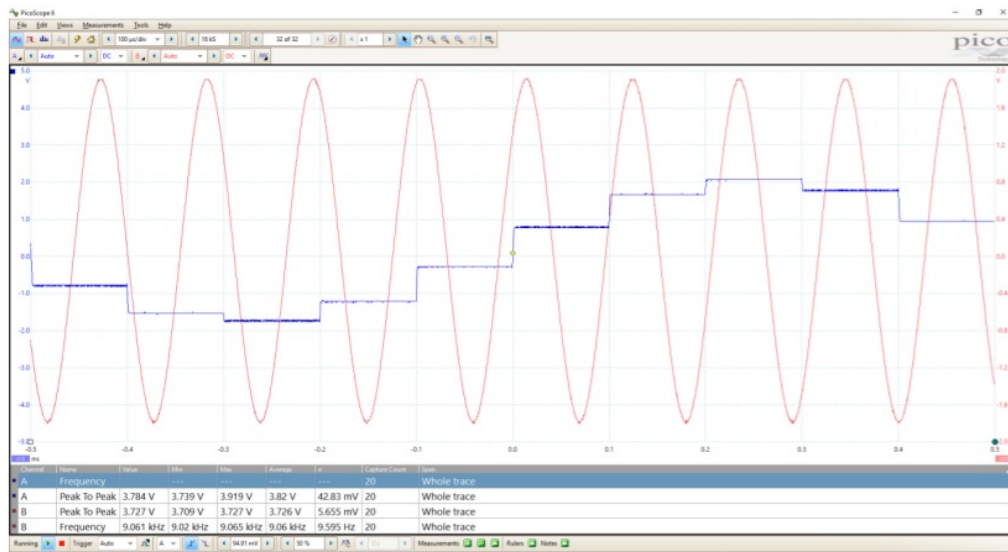


Figure 49 - 8-bit 4V 9 KHz

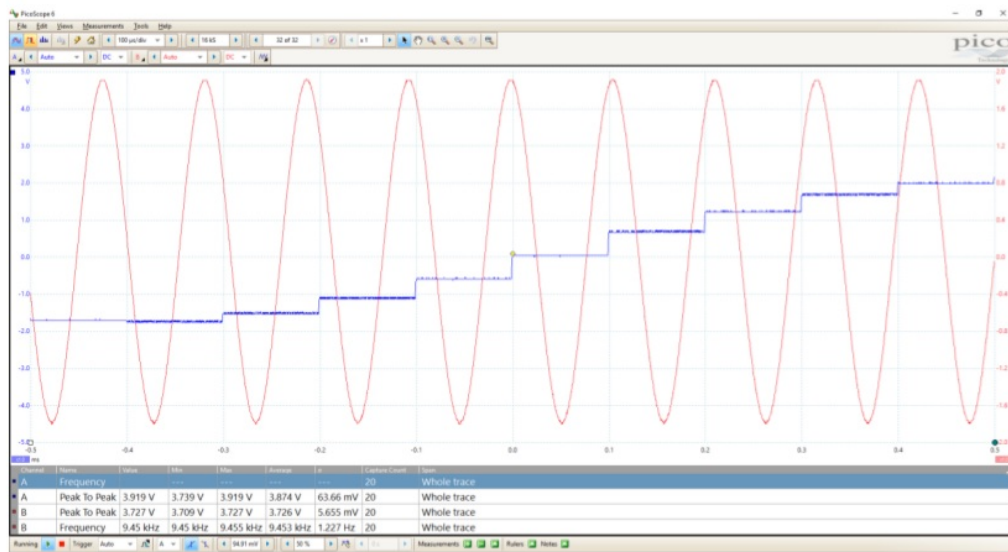


Figure 50 - 8-bit 4V 9.5 KHz

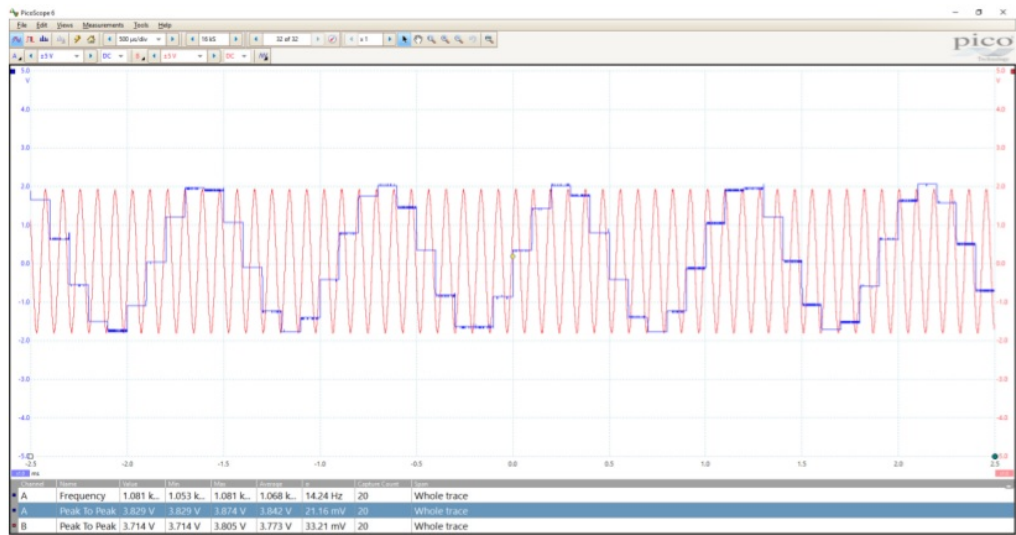


Figure 51 - 8-bit 4V 10 KHz

Appendix B

Calculations

- 455KHz Carrier at 375mV
- 10 KHz Modulator at 2V
- Modulator has a FM characteristic of 20KHz per volt

Frequency Deviation (δf_c) = Amplitude x FM Characteristic

Frequency Deviation (δf_c) = 2V x 20KHz

Frequency Deviation (δf_c) = 40 KHz

Modulation Index (β) = $\delta f_c / FM$

Modulation Index (β) = $\frac{40KHz}{10KHz}$

Modulation Index (β) = 4

Therefore, to find side frequencies use Bessel table of $\beta = 4$,

Bessel Tables										
β	J_0	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9
0.5	0.94	0.24	0.03							
1.0	0.77	0.44	0.11	0.02						
1.5	0.51	0.56	0.23	0.06	0.01					
2.0	0.22	0.58	0.35	0.13	0.03	0.01				
3.0	0.26	0.34	0.49	0.31	0.13	0.04	0.01			
4.0	0.40	0.07	0.36	0.43	0.28	0.13	0.05	0.02		
5.0	0.18	0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	0.01

Table 1 - Bessel Table

From Table 1,

$$J_n = E_c \times \beta(J_n)$$

$$J_0 = 375\text{mV} \times 0.4 = 150\text{mV}$$

$$J_1 = 375\text{mV} \times 0.07 = 26.25\text{mV}$$

$$J_2 = 375\text{mV} \times 0.36 = 135\text{mV}$$

$$J_3 = 375\text{mV} \times 0.43 = 161.25\text{mV}$$

$$J_4 = 375\text{mV} \times 0.28 = 105\text{mV}$$

$$J_5 = 375\text{mV} \times 0.13 = 48.75\text{mV}$$

$$J_6 = 375\text{mV} \times 0.05 = 18.75\text{mV}$$

$$J_7 = 375\text{mV} \times 0.02 = 7.5\text{mV}$$

The spectrum of the wave can now be displayed within, Figure 52;

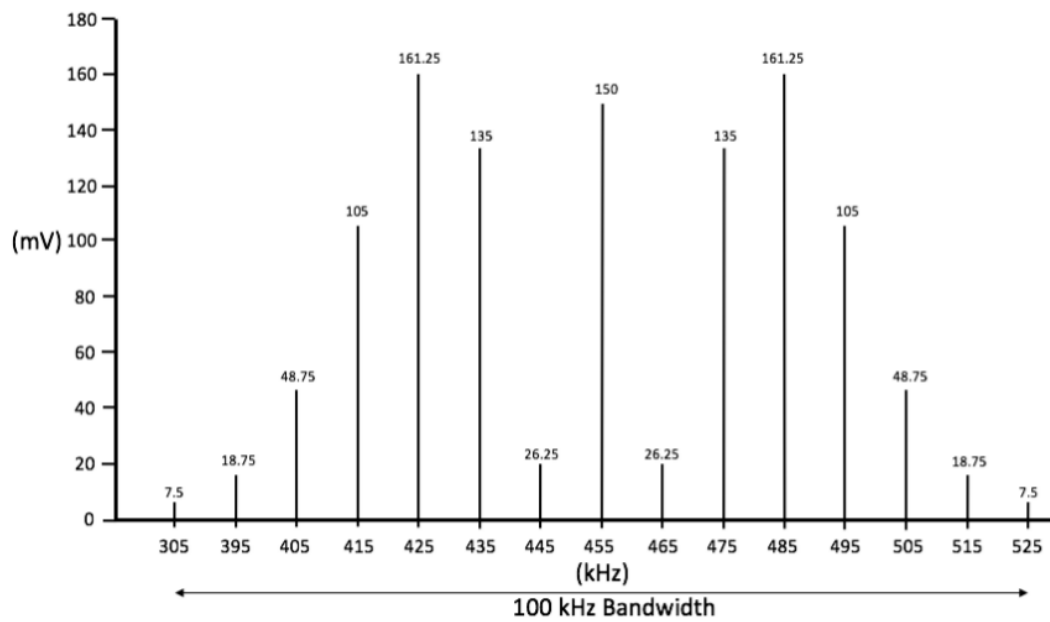
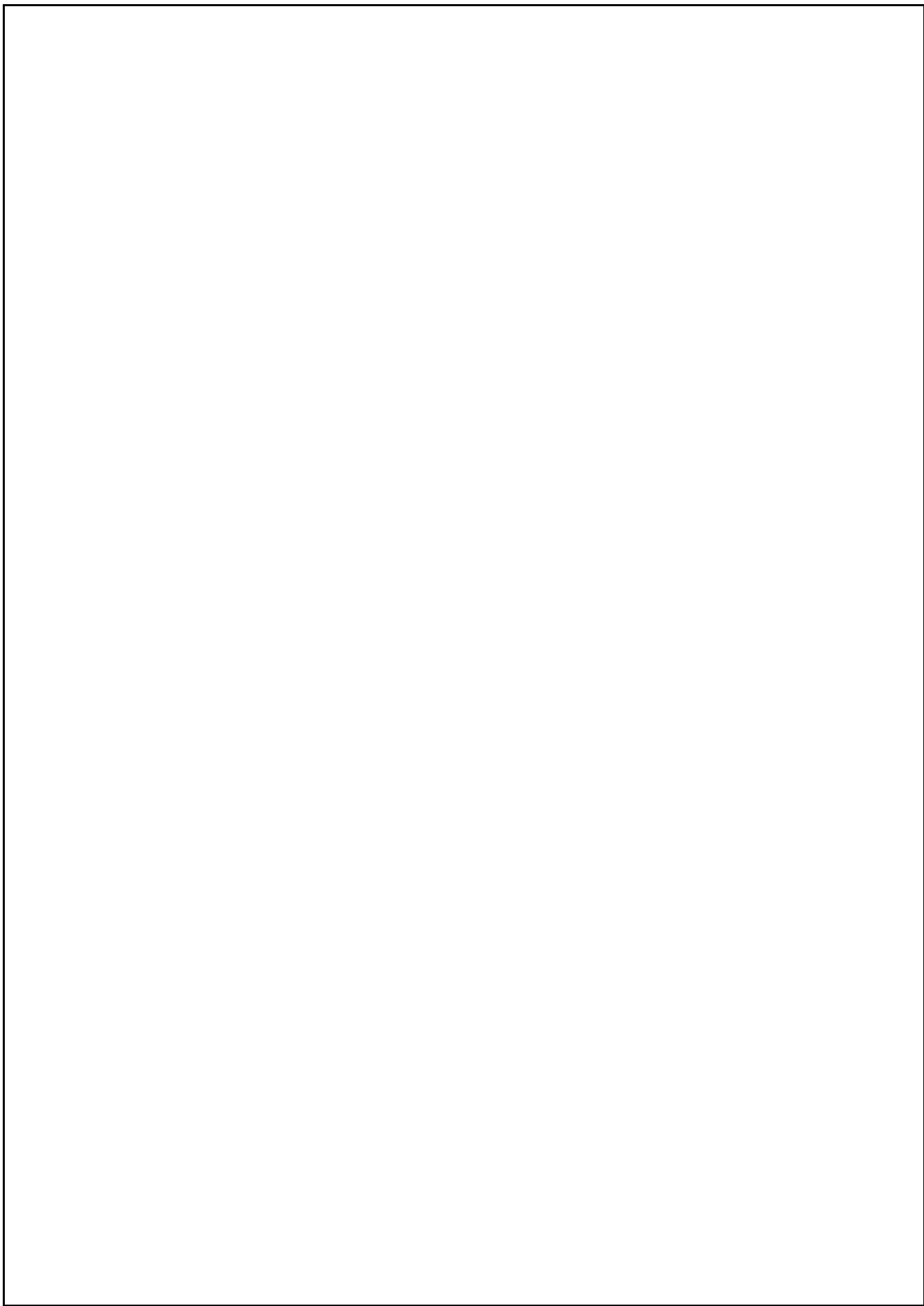


Figure 52 - Side Frequencies



FINAL GRADE

GENERAL COMMENTS

67/100

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

Text Comment. Too short, you need to cover all the sections

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

Text Comment. More research on the principles being investigated are needed

PAGE 13

PAGE 14

PAGE 15

PAGE 16

Text Comment. A results table comparing the practical results with the calculated would have been good here.

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

Text Comment. Results are confusing and don't demonstrate the Nyquist Criteria. A table of results showing input and output frequencies was needed.

PAGE 27

PAGE 28

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GRADING FORM: CSG-RUBIC

THOMAS WOOD

0

RESEARCH-INFORMED 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.

7/10

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was reasonably detailed and mainly accurate. There were very few gaps in your knowledge of the basic concepts and

19/30

your understanding of the higher level concepts was demonstrated to a limited degree - you could have explained in more detail how the circuit evolved. Further work – Your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

ANALYSIS



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 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.

22/30

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally satisfactory. You used the resources appropriately for testing and evaluating the circuit performance. Your results were adequate and allowed for a reasonable conclusion to be attempted. You should however have included more detailed results tables

12/20

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your

7/10

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.