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by Matthew Davies

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- ① RESEARCH WAS OK, BUT TRY TO FOCUS ON WHAT IS RELEVANT TO THE ASSIGNMENT BRIEF. THIS WILL MAKE CONCLUSIONS MUCH EASIER TO WRITE.
- ② BOTH EXPERIMENTS WERE COMPLETED TO GIVE AN OVERVIEW OF BOTH TOPICS.
- ③ RESULTS COULD HAVE BEEN BETTER ANALYSED, ESPECIALLY FOR FM WHERE A COMPARISON OF THEORY/PRACTICE WAS NEEDED.
- ④ SOME GOOD CONCLUSIONS WERE MADE.
- ⑤ SOME DIAGRAMS WOULD HAVE BEEN BETTER IN THE APPENDIX.

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1. Executive Summary

During this assignment, research was carried out into signals and modulation techniques used in the real world to create digital information which is user friendly on computerised systems and micro controllers. The research task provided sufficient knowledge prior to carrying out the experiment tasks, where this knowledge could be applied to create assumptions and comparisons between practical results and theoretical ideas.

*THIS SHOULD COVER IT WELL ABOUT AND ALLOW
THE READER TO UNDERSTAND EVERYTHING IN SUMMARY
WITHOUT READING THE FULL REPORT*

2. Research into analogue and digital communication systems and techniques

Modulation is a process used in signal communications to alter the amplitude or frequency of a carrier wave depending on the intensity of the signal. In this research, both areas of modulation will be covered.

Amplitude Modulation

This is an analogue modulation method for transmitting information over radio, where the high frequency carrier wave amplitude is changed in accordance with the signal intensity. This was created by Landell de Moura and Reginald Fessenden in the 20th century when they were carrying out experiments using radiotelephones. From here, the amplitude modulation (AM) method was established and introduced to electronic communications. (electronicsnotes, 2022)

By modulating the signal onto a higher frequency carrier wave, it allows smaller antennas to be used, the available bandwidth can be used more efficiently, and it is flexible enough to carry different data types. (National Instruments, 2022)

This gets used on a range of applications; however, it is now used a lot less than it once was in previous years. It is used in broadcast transmissions for long, medium, and short-wave bands. It can be demodulated simply using a radio receiver, which is inexpensive and easy to manufacture. It is also used in airborne applications where Very High Frequencies (VHF) transmission is used. There are advantages to using AM, these are that it is easy to implement, a cheap receiver can be used, and the demodulation can be done using a simple circuit with few components. The downfalls are that it is inefficient in power usage, it requires a high bandwidth equivalent to the highest audio frequency, and it can create a noticeable amount of noise in its output signal. (byjus, 2022)

Frequency Modulation

This too is considered an analogue form of modulation, as the baseband signal is analogue. This type of modulation is when the frequency of the modulated wave is altered depending on its input (baseband) signal. It isn't as easily done as AM; however, it does offer some clear advantages over AM. It is widely used and very appropriate for VHF FM broadcasting where the frequencies are 30MHz and above. it provides interference free broadcasting, which is the main reason behind it being used for audio/radio broadcasting. Figure 1 – FM shows how the frequency modulated signal changes depending on the amplitude of the incoming signal. The amount that the frequency modulated signal increases and decreases in frequency is known

as the deviation. The deviation is measured in kHz. To generate frequency modulated signals, a few different methods can be used. A varactor diode oscillator is a common method. This is when a varactor diode is used in a tuned oscillator circuit, as seen in Figure 2 - Varactor Diode Oscillator. The diode is used in reverse bias, so that junction capacitance is created. The modulating voltage is in series with varactor diode, therefore the diode bias will vary, as will the junction capacitance which results in the oscillator frequency to change with it. (teamques10, 2015)

THE WORD COUNT IS BETTER USED TO LOOK AT FM AT SYSTEM LEVEL, RATHER THAN COMPONENT.

Phase locked loop (PLL) is also a frequently used method for modulation. It is a negative feedback system containing 3 major components: multiplier, loop filter and a voltage-controlled oscillator (VCO). A PLL is used to track the phase and frequency of the carrier on an incoming FM signal. The unit of measurement in the feedback loop is phase Φ . The aim is to get the error signal from the feedback loop to 0, so that both angles of incoming signal and modulated signal are the same. Once these are synchronised, the PLL locks to the phase angle of the incoming signal. (Sasmita, 2020)

TOO DEEP ASAN.

From research, the advantages and disadvantages of Frequency Modulation can be concluded as:

Advantages	Disadvantages
Resilience to noise	Poor spectral efficiency compared to other modulation techniques
Efficient RF amplifiers can be used with FM signals	Requires more complicated demodulator
Modulation can be applied at low power stages	Sidebands extend to infinity

Table 1 - FM advantages and disadvantages

WHAT ARE THE FUNDAMENTALS OF FM.
 ① f_c CHANGES WITH AMPLITUDE OF f_m
 ② WHY IS RATE OF CHANGE IMPORTANT
 ③ WHAT IS MODULATION INDEX AND HOW DOES THAT RELATE TO Bessel VALUES.

Analogue to Digital Converters (ADC's)

Analogue to digital converters, or ADC's as they are commonly known as, convert an analogue input signal to a binary code for use in the digital world. Analogue signals come from a range of sources which are continuously varying, such as sound, temperature, movement etc. In an ADC, these signals would be converted into a binary value of either 0 or 1, which will be discrete in time and value. ADC's play a major part in microcontrollers being able to store information efficiently, as the digital signals will be compressed information. (elprocus, 2020)

The main features of an ADC are the resolution and sample rate. The resolution refers to the accuracy of the analogue to digital conversion, which depends on the ADC bit number. The higher the bit number, the greater the accuracy of the digital signal compared to the analogue input signal. To calculate the resolution of an ADC, the following equation must be used:

$$\text{Step Size} = V_{\text{ref}}/N$$

Equation 1

Where:

Step Size = resolution of each level (V)

Vref = Voltage reference (input range)

N = Level size of ADC

Where:

$$N = 2^n$$

Equation 2

Where:

n = No. of bits

This proves how the number of bits on the ADC directly affects the resolution and accuracy of the ADC. An example would be a 12-bit ADC, with a voltage range of 5V. This would equate to a step size of 1.22mV, meaning that the digital side of the ADC will detect input voltage changes on an accuracy of 1.22mV. Decreasing the bit number would increase the step size, resulting in larger step size and lower accuracy. Figure 3 - ADC Resolution shows how the bit number will provide a smoother and more accurate digital output on an ADC. (Gudino, 2018)

The sampling rate is a value which determines the samples per second that the ADC takes. This can be in either S/s or Hz. The higher the number of samples the ADC takes per second, the greater the frequencies it can handle. The equation to determine sampling rate is:

$$f_s = 1/T$$

Equation 3

Where:

F_s = sample rate

T = period of sampling

An image illustrating sampling rate can be seen in Figure 4 - ADC Sampling Rate.

PAM & PCM Techniques

Pulse-amplitude modulation (PAM) is a cross between digital, analogue and pulse modulation. PAM uses amplitude shift keying to apply digital modulation to an analogue signal (ASK). This amplitude-modulated analogue signal is then utilised to modulate a pulse train, which is then transmitted across a channel. The signal and data are recovered at the receiver end by sampling the signal at the pulse rate. The demodulation of the recovered amplitude-modulated analogue signal yields digital data. (cadence system analysis, 2020)

Pulse code modulation (PCM) is the simplest technique for coding waveforms from analogue into digital. This is an extension of Pulse Amplitude Modulation (PAM), where a sampled signal is represented by a train of pulses, each of which corresponds to the signal's amplitude at the corresponding sampling time. Each analogue sample value is quantized into a discrete value before being represented as a digital code word. The most common analogue-to-digital conversion technique is pulse code modulation, which is outlined in the ITU-T G.711 specification. The encoder (ADC) and the decoder are the two primary components of a conversion system (DAC). (TechnologyUK, 2020)

Synchronous Digital Hierarchy (SDH)

This is a multiplex technology which allows data streams of low bit rates to be combined with high-rate data streams. Due to the network being synchronous, the low bit rates and individual bit streams can be extracted or embedded into the high-rate data streams with ease. On a synchronously timed network, SDH combines 'n' signals with bit rates of 'b' to generate data streams with bit rates of $n \times b$. In contrast to PDH, the separate transmission lines have little clock inconsistencies. The synchronous mode of operation allows low-order multiplex

systems, such as telephone system communication lines, to be introduced in higher hierarchy levels and then deleted via add and drop. SDH recognises several hierarchies such as STM-1, STM-4, STM-16, or STM-64 (155 MBits, 622 MBits, 2,488 MBits, 9,953 MBits) and more in line with the levels described by the standard. (NFON, 2022)

A diagram must be.

3. Experimental method for Experiment 1

A carrier of 455kHz is used in this experiment, which has an amplitude of 375mV and is frequency modulated by a 10kHz square-wave signal of a 2V amplitude. The modulator has a frequency modulation transfer characteristic of 20kHz p/volt and from these known values, the following can be calculated.

Calculations

Maximum Frequency Deviation and Modulation Index

$$\Delta f = \text{modulator transfer characteristic} \times \text{message amplitude}$$

Equation 4

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

Equation 5 – Maximum Frequency Deviation

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

Equation 6 - Modulation Index

Amplitude Values

From the above values, the coefficients can be taken from the Bessel table, which allows the amplitude values for each frequency to be calculate.

J0	J1	J2	J3	J4	J5	J6	J7
0.4	0.07	0.36	0.43	0.28	0.13	0.05	0.02

Table 2 - Bessel Coefficients

The following calculation is used for calculating the amplitude values expected to see on the spectrum analyser for the various frequencies. Where $E_c = 375\text{mV}$.

$$\text{Amplitude} = E_c \times J$$

Equation 7

Using this equation, the expected values of amplitude for the varying frequencies can be seen in the table on the following page.

Frequency (kHz)	Amplitude (mV)
455	150
445 & 465	26.25
435 & 475	135
425 & 485	161.25
415 & 495	105
405 & 505	48.75
395 & 515	18.75
385 & 525	7.5

Table 3

Using these values, a spectrum analysis for the calculated figures can be seen in appendix 2 as Figure 5 - Calculated Spectrum, where the expected amplitude for each bandwidth is shown. Due to the modulation index, the Bessel table shows that this experiment will have 8 sidebands, but 15 will be plotted as the sidebands occur at $f_c + f_m = 525\text{kHz}$ and $f_c - f_m = 385\text{kHz}$. This means the bandwidth will be $525 - 385 = 140\text{kHz}$ and with a 10kHz modulated message, there will be 15 sidebands.

The experimental setup can be seen in Figure 6 - Experiment 1 Setup, where it shows how the different modules are connected to each other to produce the readings required to compare the theory and calculations to the real-world values from this experiment.

4. Testing, results, and analysis for Experiment 1

As stated in the research, “the frequency of the modulated wave is altered depending on its input (baseband) signal.” Therefore, the expectation for this experiment is for the frequency of the FM wave to vary depending on the input signal amplitude input signal, whilst the FM wave amplitude stays constant and the same as the carrier amplitude of 375mV. The results shown for amplitudes of 2V, 4V and 6V input amplitudes in appendix 2 show that as the input voltage amplitude increases, so does the frequency of the FM wave. The table below shows the results.

Input Amplitude (V)	FM Wave Frequency (kHz)
2	350.5
4	418.4
6	519.5

Table 4 - FM frequencies

Figure 10 - Experiment Spectrum Analysis shows the spectrum analysis from the experiment. Measurements can be taken off this analysis to compare to the calculated values as seen in Figure 5 - Calculated Spectrum. The comparison table is below.

Frequencies (kHz)	Calculated (mV)	Measured (mV)
385	7.5	8
395	18.75	25
405	48.75	20
415	105	120
425	161.25	170
435	135	95
445	26.25	25
455	150	52
465	26.25	25
475	135	95
485	161.25	170
495	105	120
505	48.75	20
515	18.75	25
525	7.5	8

Table 5 - Sideband Comparison

The comparison table, and by looking at both Figure 5 - Calculated Spectrum and Figure 10 - Experiment Spectrum Analysis it can be seen that the experiment proved the theory to be mostly correct, as the amplitude of the sidebands are nearly the same on both calculated and measured graphs. There were discrepancies between the amplitudes, however the trend of the spectrum analysis mostly followed the same as that on the calculated graph. The expectation of the FM wave frequency increasing as the input amplitude increases was also proven to be true from the testing carried out.

THE TABLES COULD GO IN THE APPENDIX,
THE GRAPHS HERE. (FIGS 5 & 10)

5. Experimental method for experiment 2

The purpose of this experiment was to test how the quality and accuracy of an ADC conversion can be changed depending on the number of bits used in the converter. The ADC used had a sample rate of 10,000samples/second with an input voltage range of 5V. 3 tests were carried out on the ADC, these were: changing the bit number, changing the input amplitude, and changing the input frequency.

The setup of this experiment can be seen in Figure 13 - Experiment 2 Setup.

Changing bit number

This experiment was to set the ADC to 4-bit with an input frequency of 100Hz and a 4V p-p amplitude. The output was recorded on the picoscope and then repeated the test with an 8-bit ADC. Screenshots were taken and results recorded.

Changing the input amplitude

The ADC was set to 4-bit, with the input at 100Hz @ 0V. The output was recorded, and the input amplitude was increased slowly to 6V. The output was recorded, as well as the values where new quantisation level is required. The ADC resolution can be determined and compared to the theoretical calculation. The ADC was then changed to 8-bit and the test was repeated.

Changing the input frequency

The final test was to set the ADC to 8-bit, with an initial input frequency of 100Hz @ 4V, then the frequency was increased in decades until it reached 1MHz. The results were taken at each decade. Then the function generator was set to 4kHz, and increased in 200Hz increments until 6kHz, then it was increased in 1kHz steps until 10kHz. The results were recorded at each significant change to the waveform.

6. Testing, results, and analysis for experiment 2

According to the values provided on the specification of the ADC, the following calculations can be carried out.

$$\text{Quantisation Level} = \frac{\text{Input Voltage}}{\text{No. of Levels}}$$

Equation 8 - Quantisation Equation

$$4 \text{ Bit Quantisation} = \frac{5V}{16} = 0.3125$$

Equation 9 - 4-Bit Quantisation

$$8 \text{ Bit Quantisation} = \frac{5V}{256} = 0.0195$$

Equation 10 - 8-Bit Quantisation

Changing bit number

The results can be seen in Figure 11 - 8 Bit 100Hz @ 4V and Figure 12 - 4 Bit 100Hz @ 4V. The 4-Bit ADC proves that the quantisation level calculation was correct, as the step size should equate to 312.5mV. The PicoScope graph proves this to be an accurate calculation as a 4V amplitude divided by a 312.5mV step size equals 12.8 steps, which is true on the graph as there are 13 steps on the graph. The 8-Bit proves how the ADC is more accurate as the bit number increases, as the output of the ADC is much smoother and accurate on the 8-Bit experiment. This is due to its lower quantisation level, resulting in a much lower step size too (19.5mV).

Changing the input amplitude

Figure 14 - 4-Bit 100Hz @ 0V to Figure 17 - 4-Bit 100Hz @ 6V shows the output of the 4-Bit ADC as the input amplitude is increased in 2V increments from 0V to 6V. As the input voltage was altered, the quantisation level changed on the ADC. The change in these levels can be seen in the table below.

Input Voltage	4-Bit	6-Bit
6	0.375	0.0234
4	0.25	0.0156
2	0.125	0.0078
0	0	0

Table 6 - Quantisation Levels

As calculated at the start of this experiment, for the rated input range of the ADC (5V), the quantisation levels were 0.3125 for the 4-Bit and 0.0195 for the 8-Bit. As can be seen in Table 6 - Quantisation Levels, Figure 17 - 4-Bit 100Hz @ 6V and Figure 21 - 8-Bit 100Hz @ 6V, the quantisation level goes above the maximum rating due to the input voltage range exceeding the 5V range, resulting in the ADC not providing any readings above the 5V range. This was common for both 4 and 8-Bit ADCs.

Changing the input frequency *FAL TOO HIGH, 10KHz IS FINE*

The results from testing of the 8-Bit ADC @ 100Hz and increasing the input frequency in decades up to 1MHz can be seen in Appendix 3 between Figure 22 - 8-Bit 100Hz @ 4V and Figure 26 - 8-Bit 1MHz @ 4V. The Nyquist theorem states that the ADC sampling rate must be greater than twice the input frequency in the analogue signal. This is required to obtain critical sampling. The sampling rate was 10,000 samples/second for this ADC. Therefore, the theory suggests that to achieve minimal sampling, the frequency should be no greater than 5kHz to get sufficient sampling. The results show this to be true, as the ADC output waveform in Figure 22 - 8-Bit 100Hz @ 4V has a high number of samples taken, and then as the frequency is increased in decades, the number of samples decreases drastically. The waveform is still acceptable in Figure 23 - 8-Bit 1kHz @ 4V, however from 10kHz onwards, the ADC sample rate isn't fast enough to cope with the high frequency of the input signal.

The significant changes in results from the final task can be seen in Appendix 3 between Figure 27 - 8-Bit 4.2kHz @ 4V and Figure 34 - 8-Bit 10kHz @ 4V. This test again proves that the sampling rate is too low to cope with frequencies from 4.8kHz onwards. None of the ADC outputs are accurate enough in this task to represent the input signal accurately, however in Figure 27 - 8-Bit 4.2kHz @ 4V, Figure 28 - 8-Bit 4.8kHz @ 4V, and Figure 29 - 8-Bit 5.6kHz @ 4V it can be seen that the samples are being taken and are following the same pattern as the input frequency, but only showing 1 change in state as the amplitude rises and decreases. From 6kHz onwards, the resolution was too high to provide any sort of ADC signal which is representative of the analogue input signal.

A TABLE OF RESULTS WOULD HAVE CLEARLY SHOWN THIS.

<i>f_{in}</i>	<i>f_{out}</i>
1kHz	1kHz
2	2
4	4
5	4.8
10	3

7. Conclusions and recommendations

The aim of this assignment was to carry out 2 experiments: frequency modulation (FM) and Analogue to Digital Conversion (ADC). Both experiments were carried out using educational equipment for testing and proving the theory obtained from the research task was correct when put into practice. Overall, this aim was achieved with a general level of success, whilst obtaining some discrepancies in practice at the same time. The research task covered 5 topic areas, with 2 of these topics being put into practice (FM and ADC).

The FM experiment proved how the frequency output from the modulator increases as the input amplitude is increased. This expectation was stated in the research task and was proven correct from the results shown in Appendix 2, where the frequency of the FM waves increased as the input amplitude increased from 2V, to 4V and to 6V. The expected side frequencies were calculated and plotted in Figure 5 - Calculated Spectrum, which allowed the side frequencies from the PicoScope to be compared to the calculated values based on theory. Calculated and measured side frequencies compared well to each other in general, however there were discrepancies which will be expected. These could've been down to the sensitive equipment which was used for the testing.

THIS WASN'T PART OF THE EXPERIMENT.

The ADC experiment outlined how increasing the number of bits can provide more accurate conversions. This was proven in the first test carried out where the input frequency and amplitude remained constant, and the ADC bit number was 4 initially, and then increased to 8. This proved how the resolution was better on the 8-bit as the output signal closely matched the input signal due to its very low resolution/step size. The second test proved how the input amplitude affected the ADC output signal. The input range of the ADC was 5V, and the theory suggests that the input amplitude should be 5V to obtain the best response. This test proved this was true, as when the amplitude was dropped to 4V and 2V, the samples being taken decreased, and the ADC output wasn't as accurate any longer to the input signal. At 6V, it showed the ADC output would cut off at 5V and draw a flat line until the sine wave decreased again to drop the amplitude below 5V. This can be seen in Figure 21 - 8-Bit 100Hz @ 6V. The Nyquist theory states that the sampling rate is most effective when the rated ADC sampling rate of 10,000samples/second is at least twice as great as the input frequency. This was proven to be true as the best results obtained in this test were at the lowest input frequencies of 4kHz and below. Anything above 4kHz provided a very poor sample.

A recommendation for this assignment would be to use equipment which isn't as sensitive as the one used for these tasks. This would provide increased confidence when making comparisons between experiment results and theory.

8. Citation List

Works Cited

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9. Appendices

Appendix 1 – Research

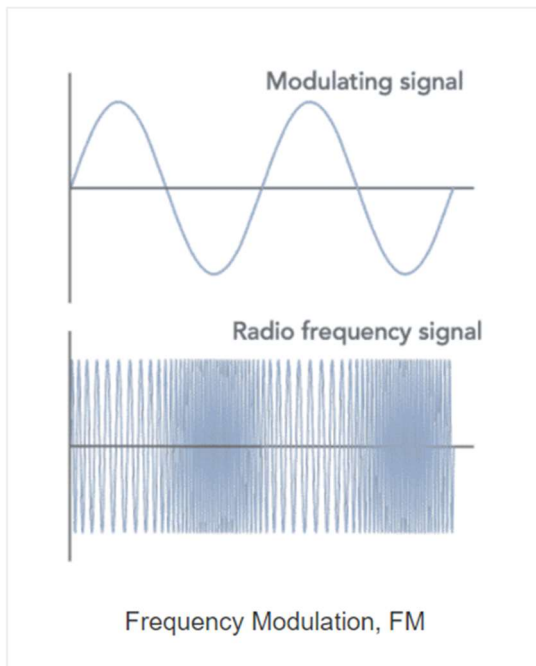


Figure 1 – FM

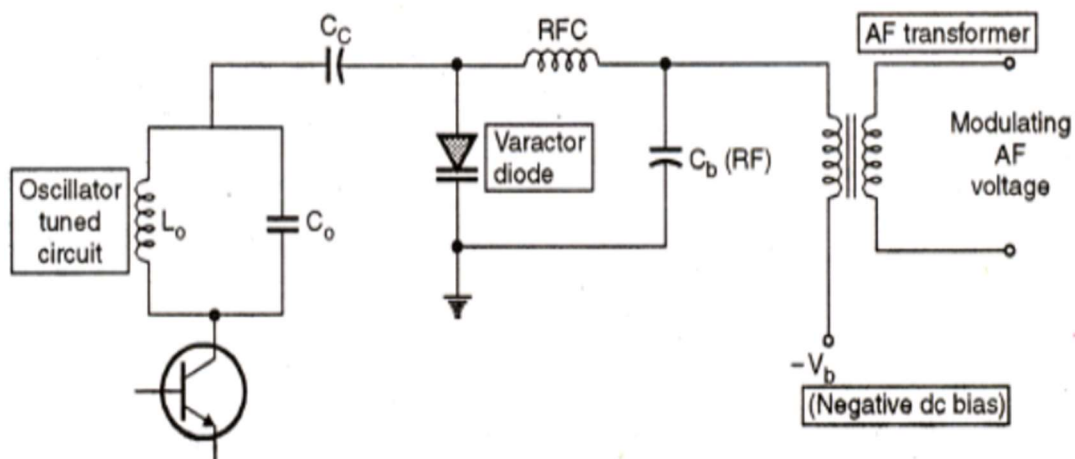


Figure 2 - Varactor Diode Oscillator

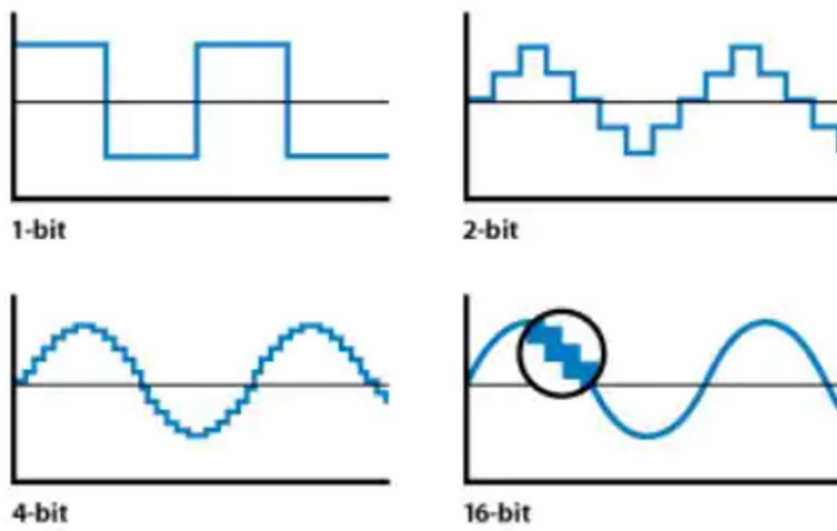


Figure 3 - ADC Resolution

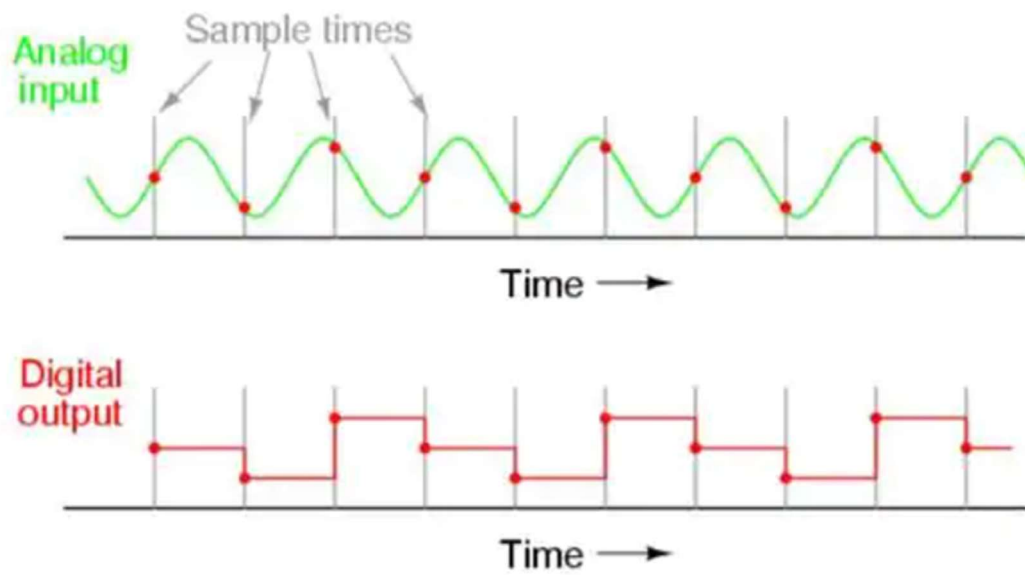


Figure 4 - ADC Sampling Rate

Appendix 2 – Frequency Modulation

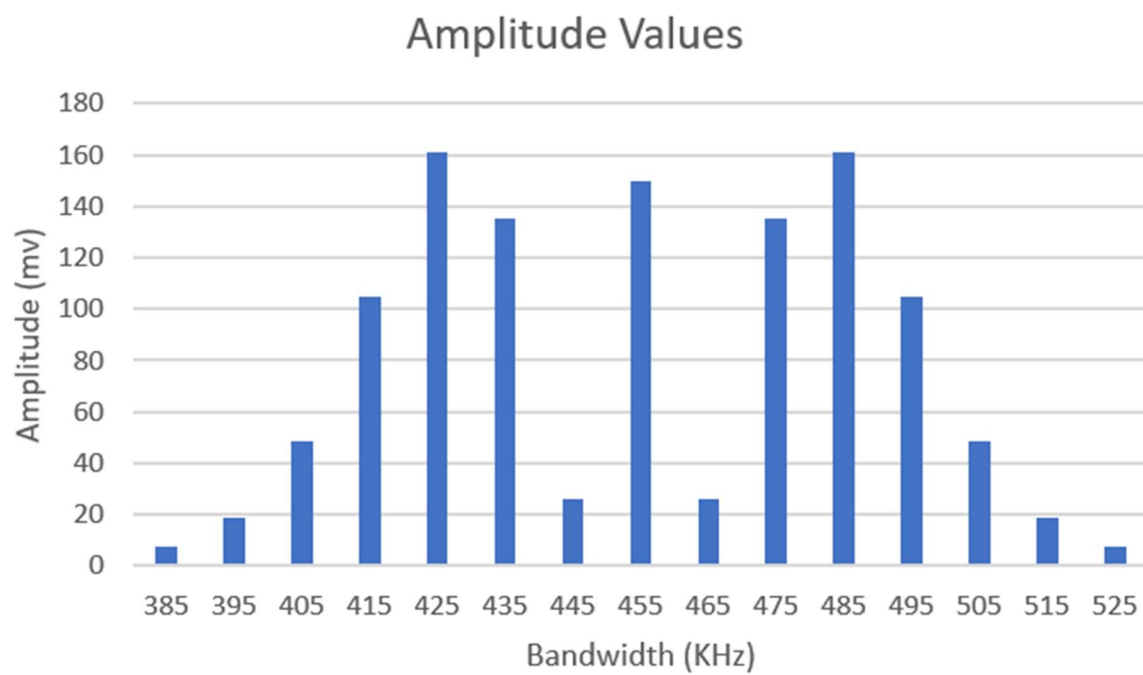


Figure 5 - Calculated Spectrum

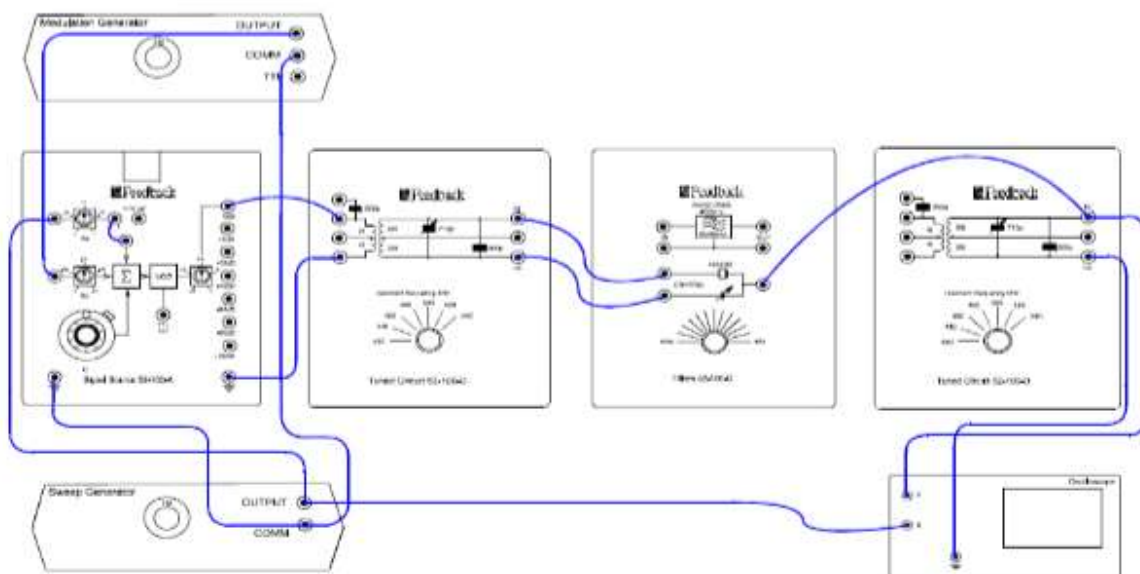


Figure 6 - Experiment 1 Setup



Figure 7 - 2V peak to peak

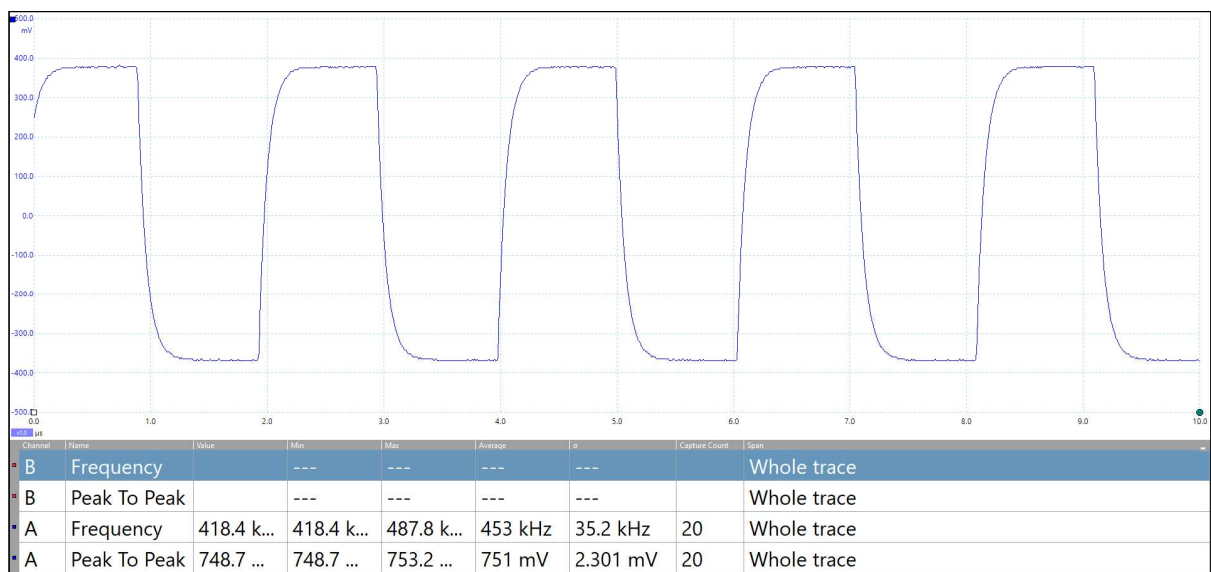


Figure 8 - 4V peak to peak

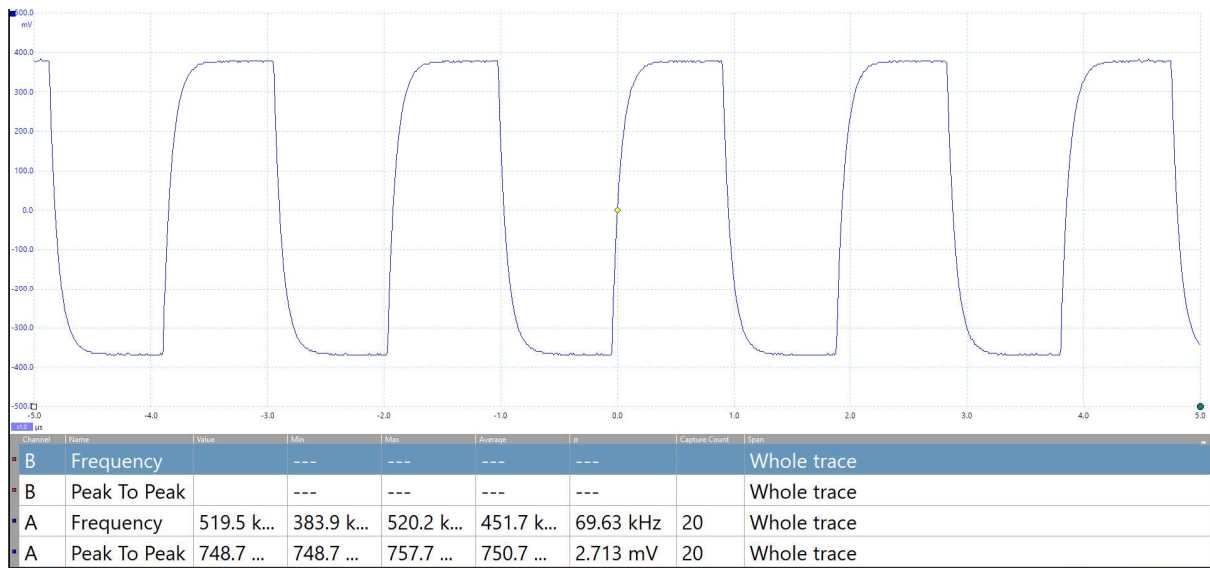


Figure 9 - 6V peak to peak



Figure 10 - Experiment Spectrum Analysis

Appendix 3 – ADC

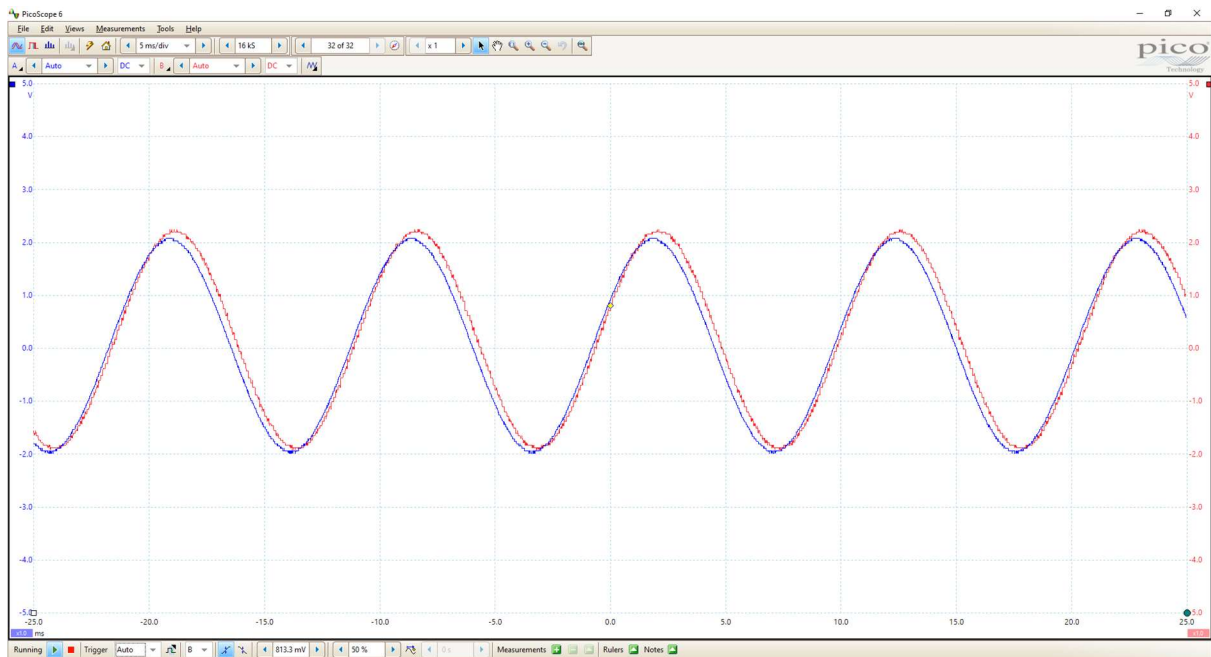


Figure 11 - 8 Bit 100Hz @ 4V

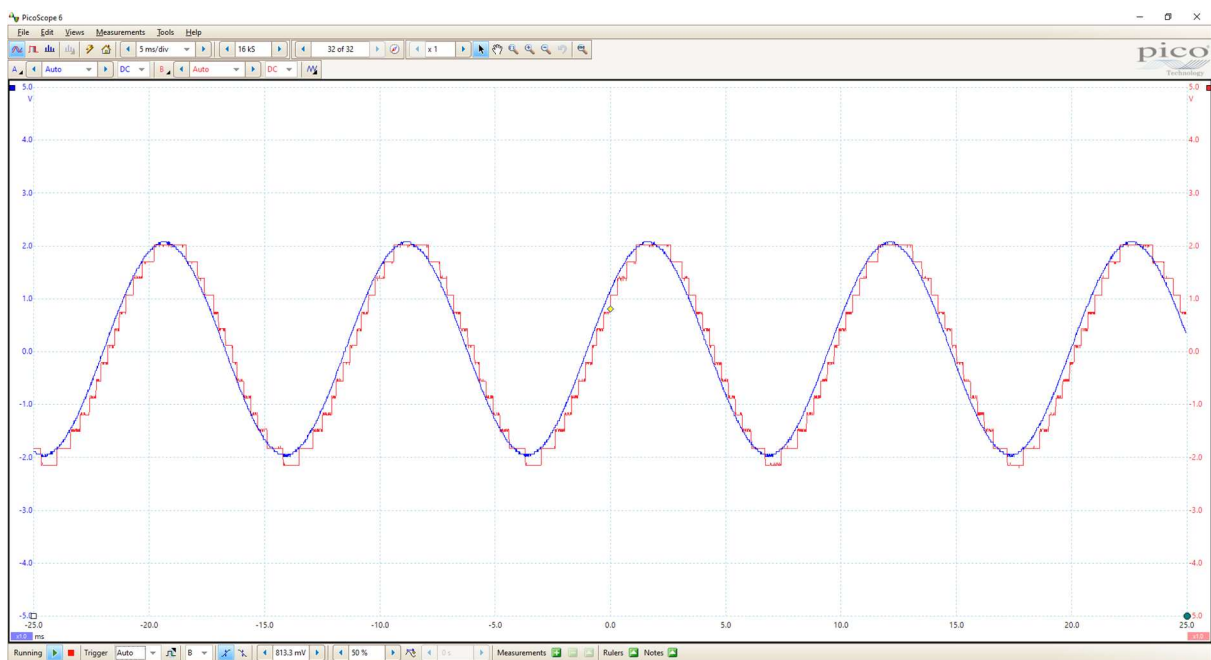


Figure 12 - 4 Bit 100Hz @ 4V

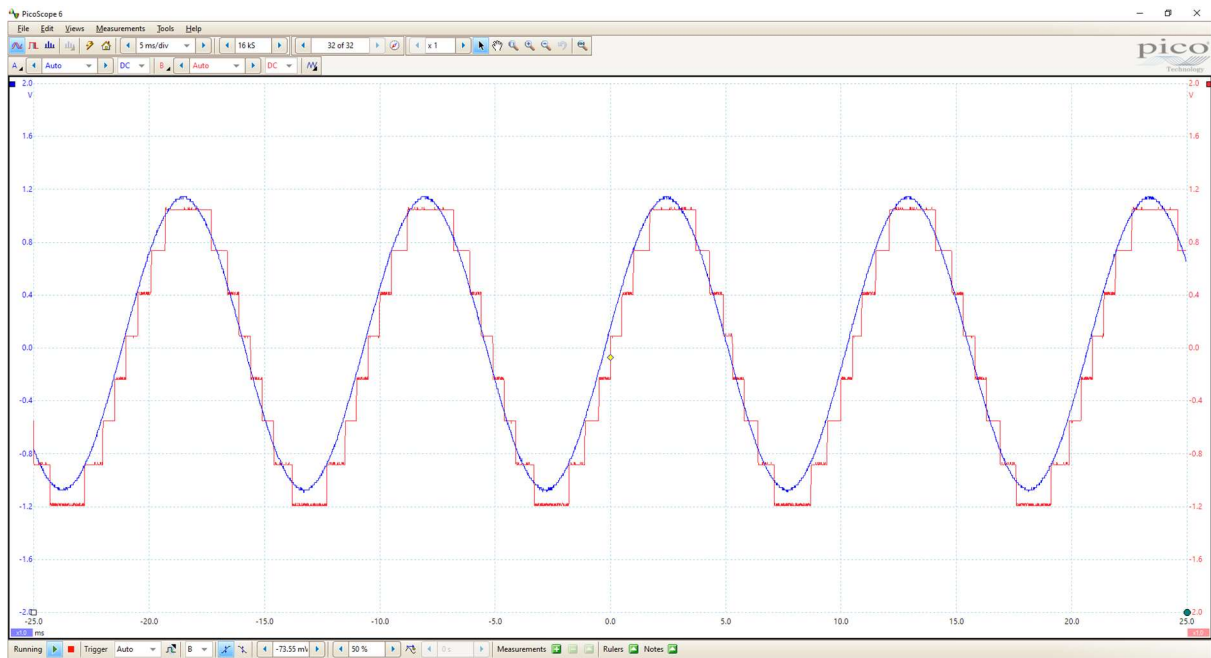


Figure 15 - 4-Bit 100Hz @ 2V

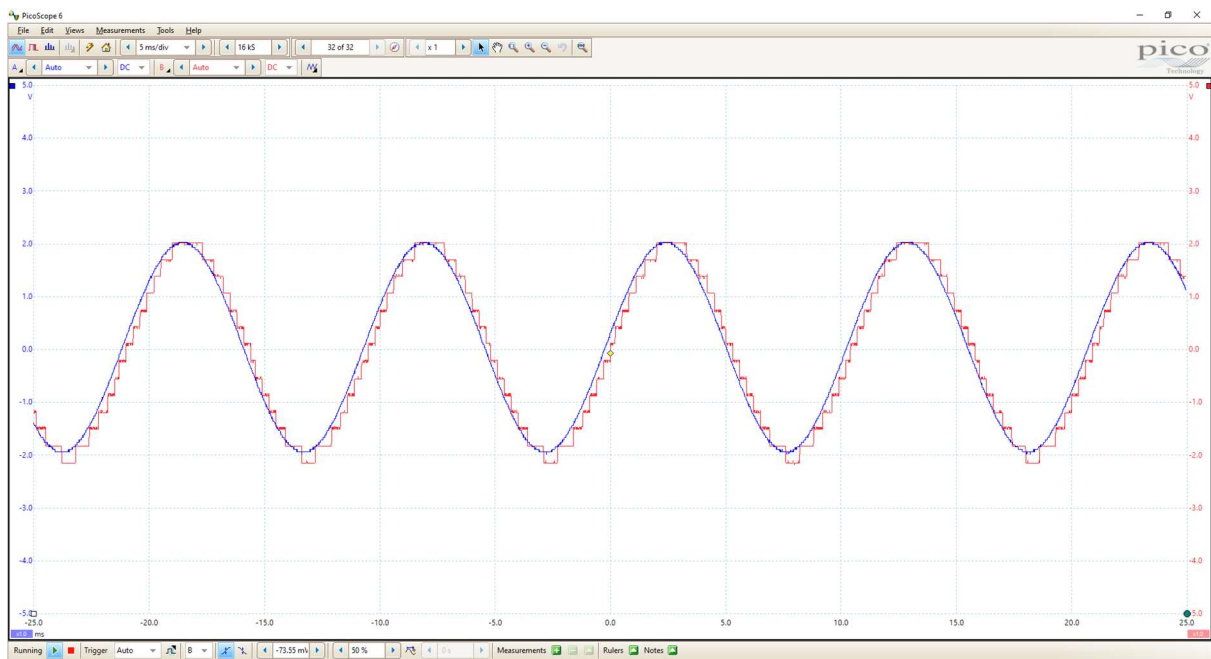


Figure 16 - 4-Bit 100Hz @ 4V

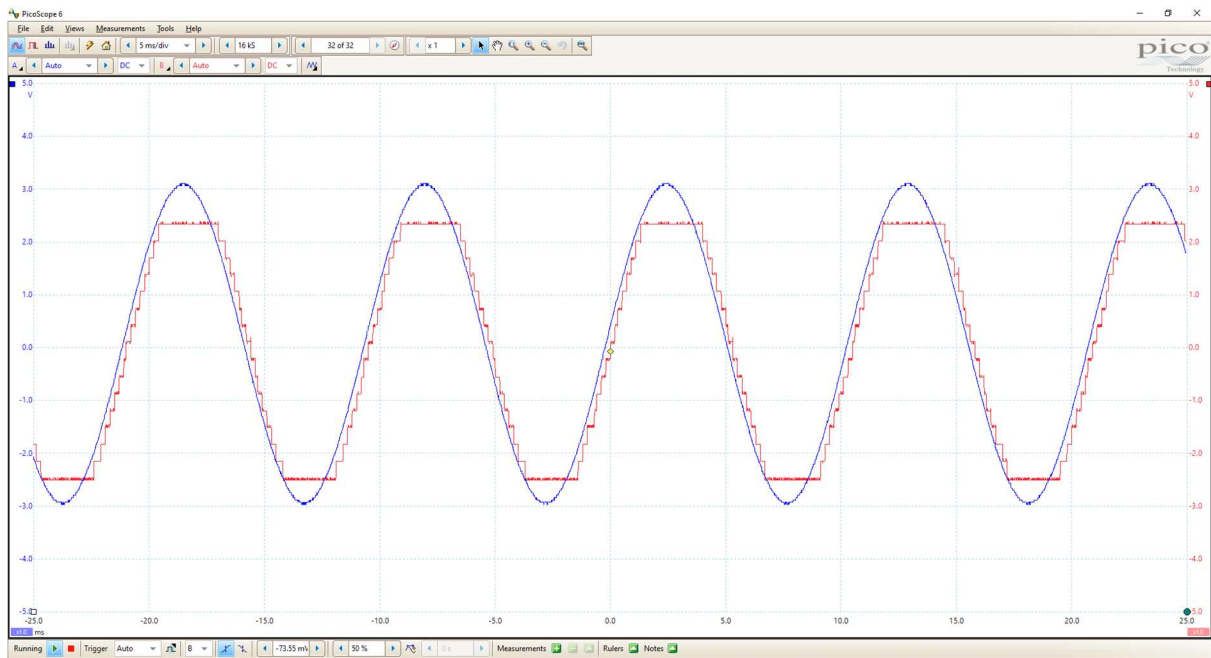


Figure 17 - 4-Bit 100Hz @ 6V

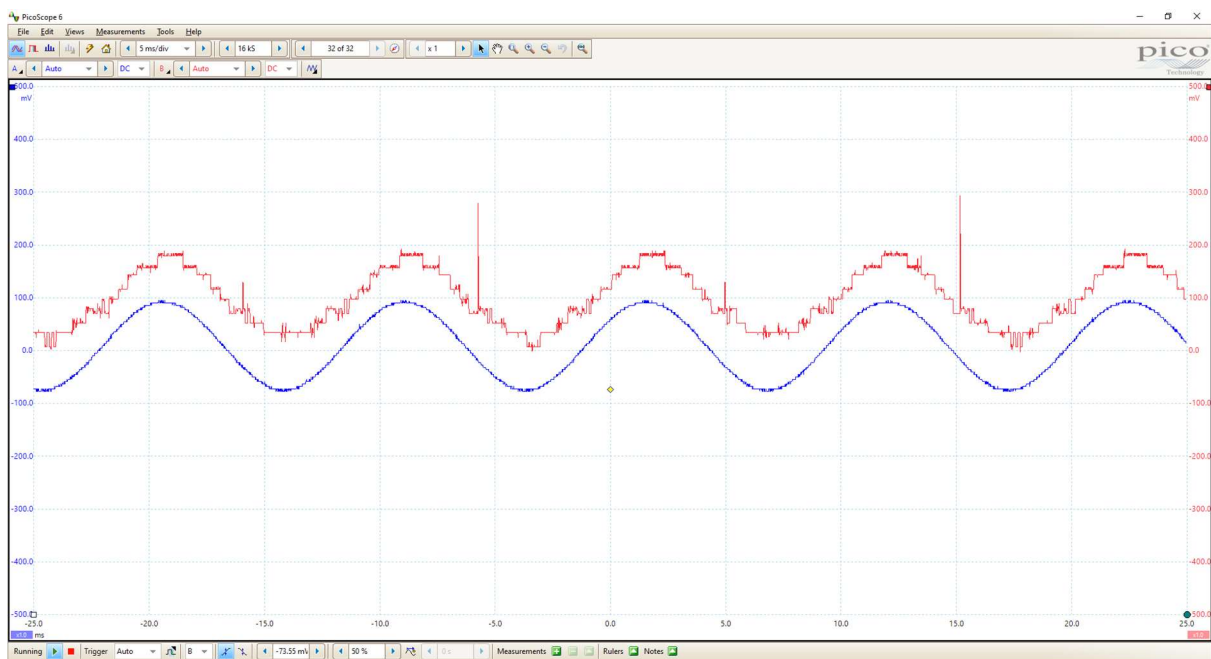


Figure 18 - 8-Bit 100Hz @ 0V

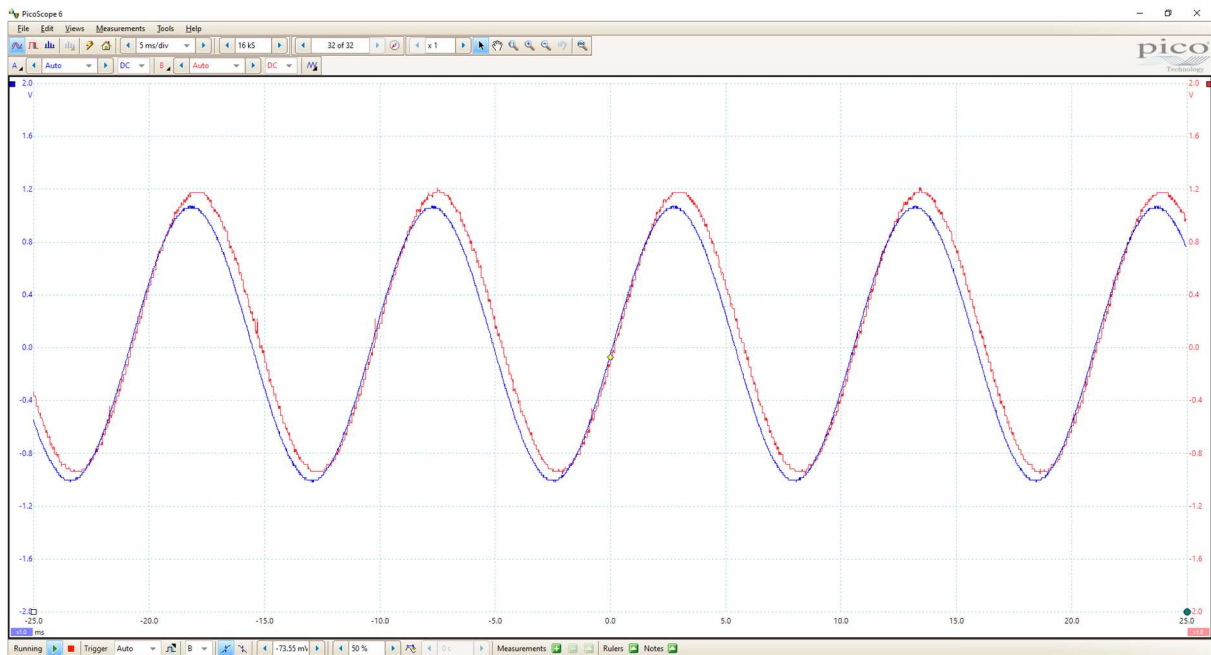


Figure 19 - 8-Bit 100Hz @ 2V

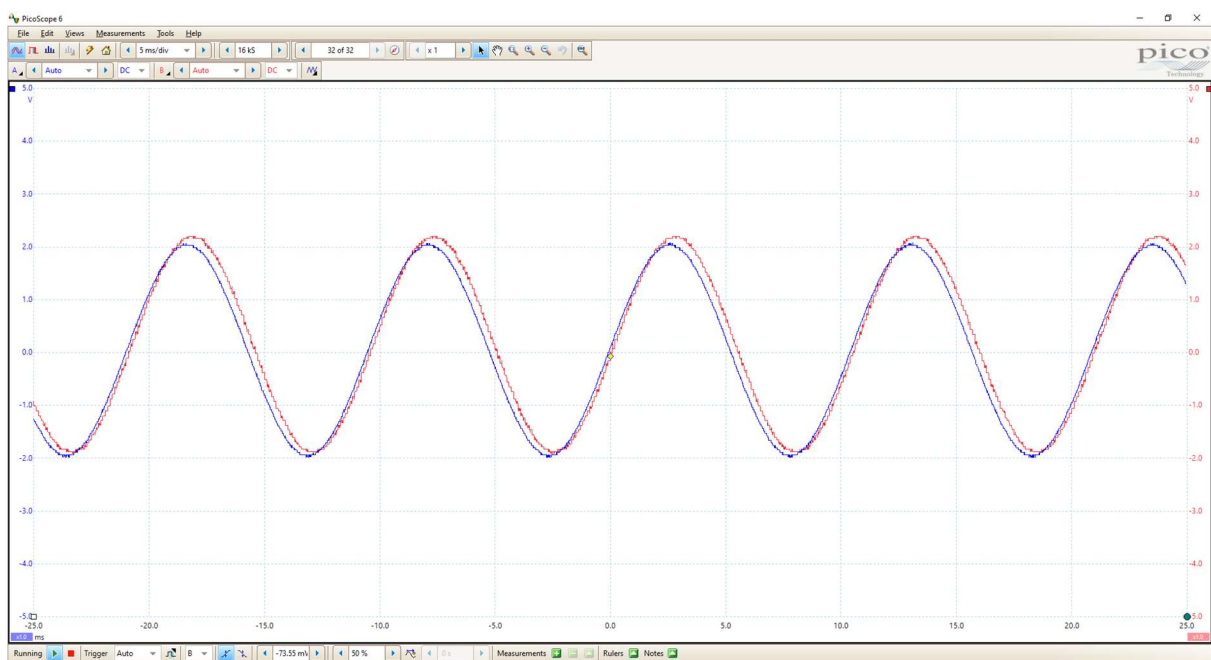


Figure 20 - 8-Bit 100Hz @ 4V

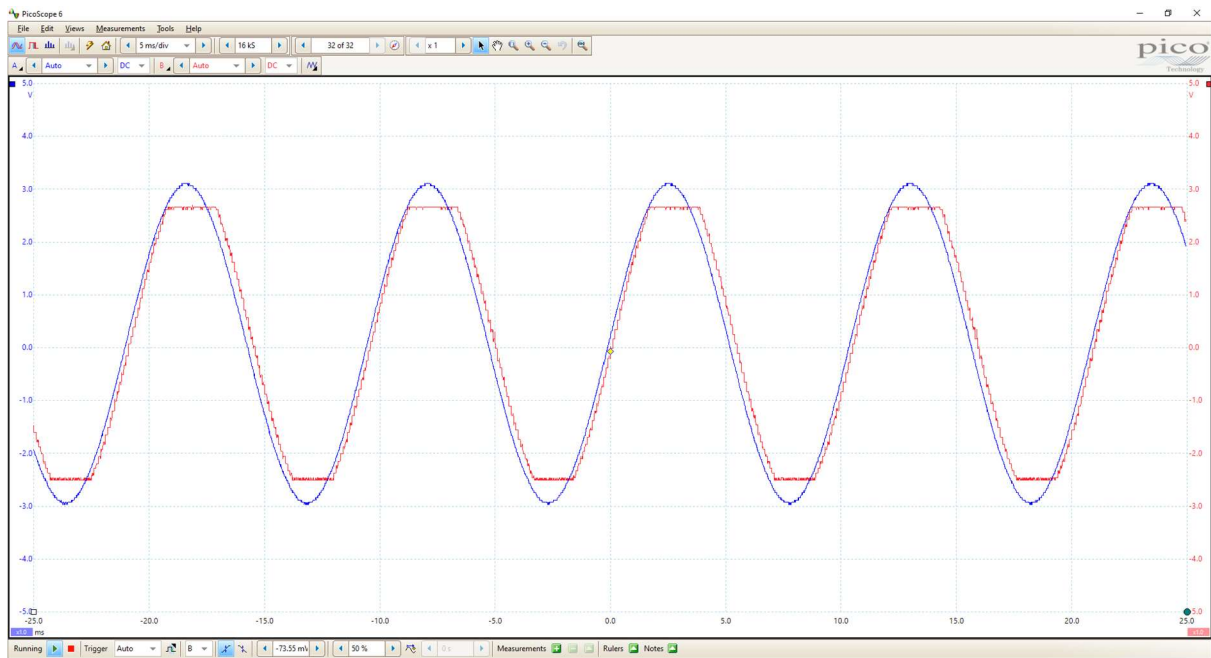


Figure 21 - 8-Bit 100Hz @ 6V

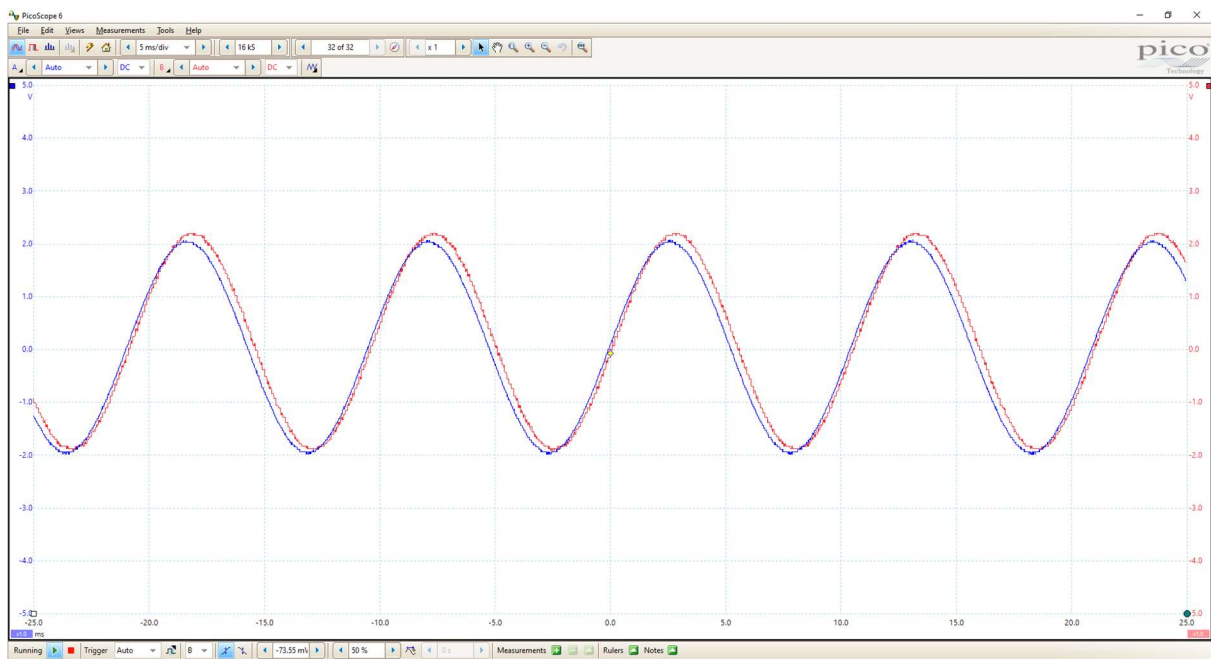


Figure 22 - 8-Bit 100Hz @ 4V

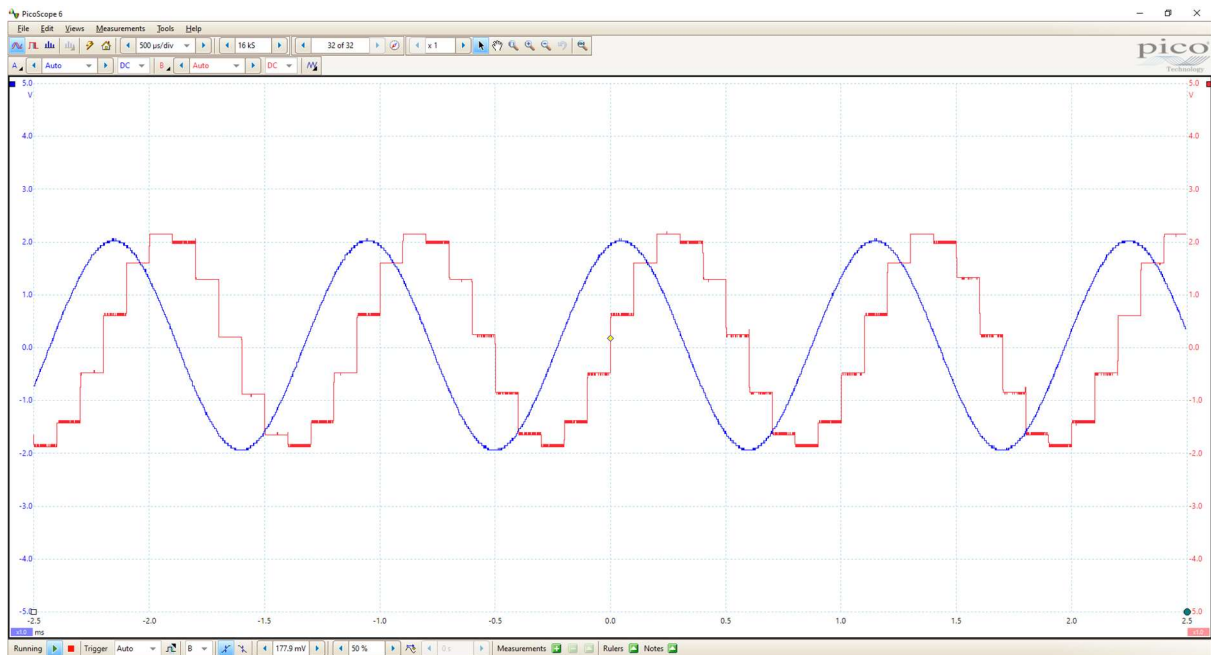


Figure 23 - 8-Bit 1kHz @ 4V

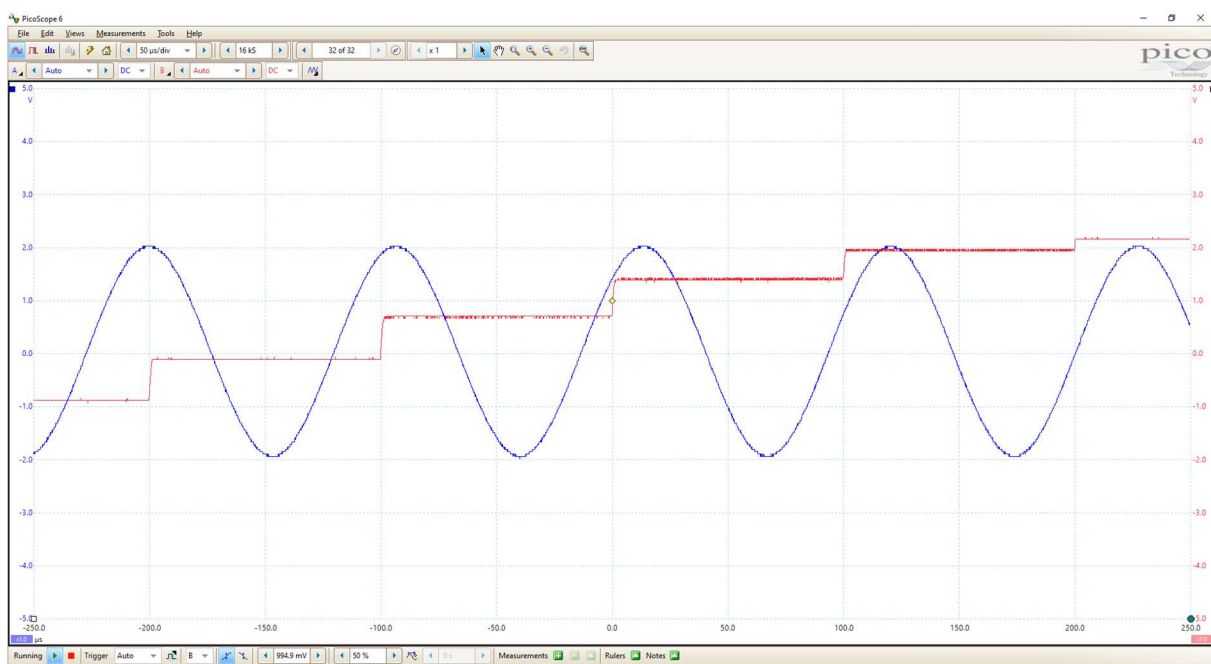


Figure 24 - 8-Bit 10kHz @ 4V

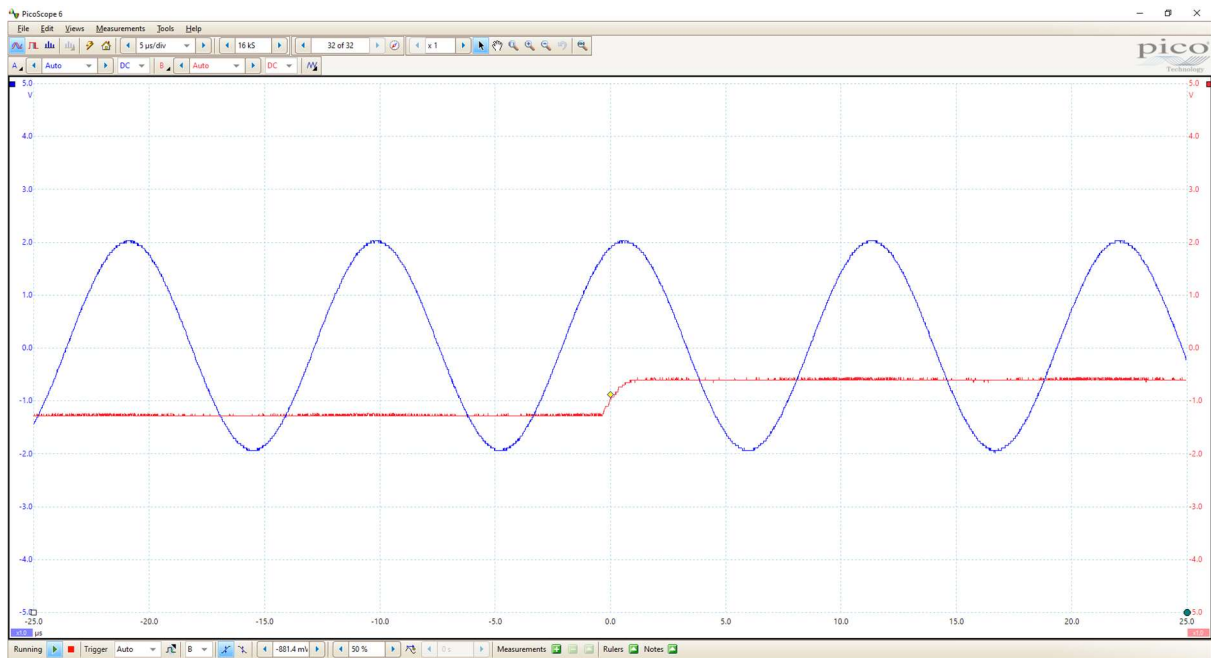


Figure 25 - 8-Bit 100kHz @ 4V

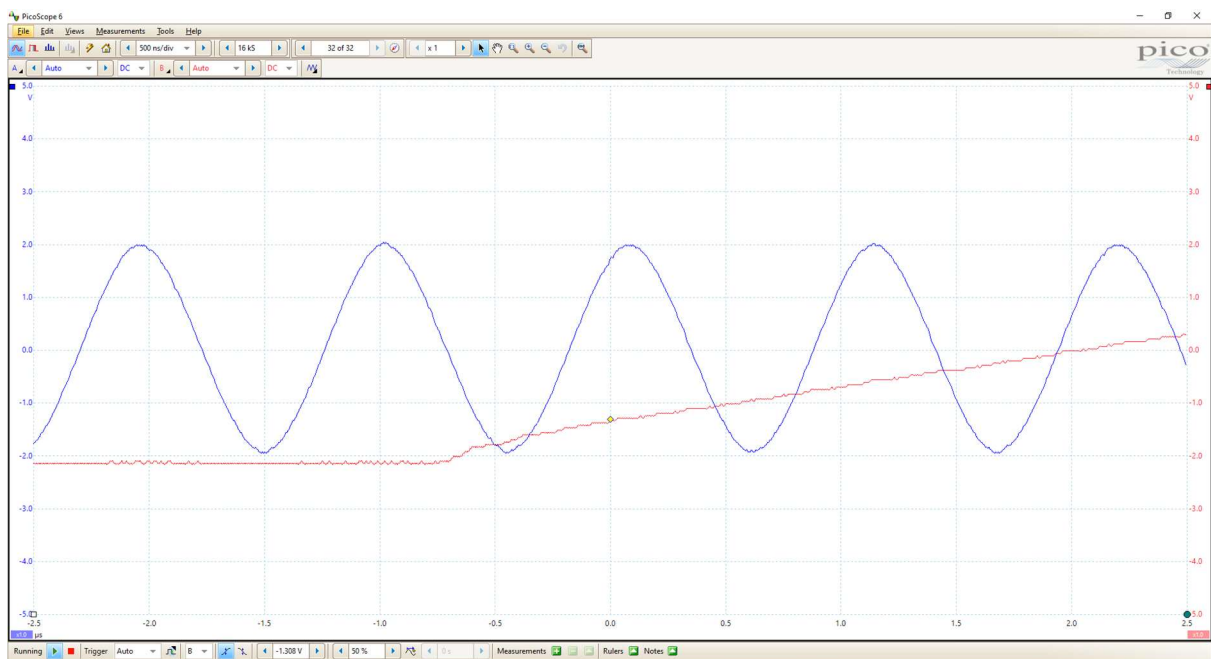


Figure 26 - 8-Bit 1MHz @ 4V

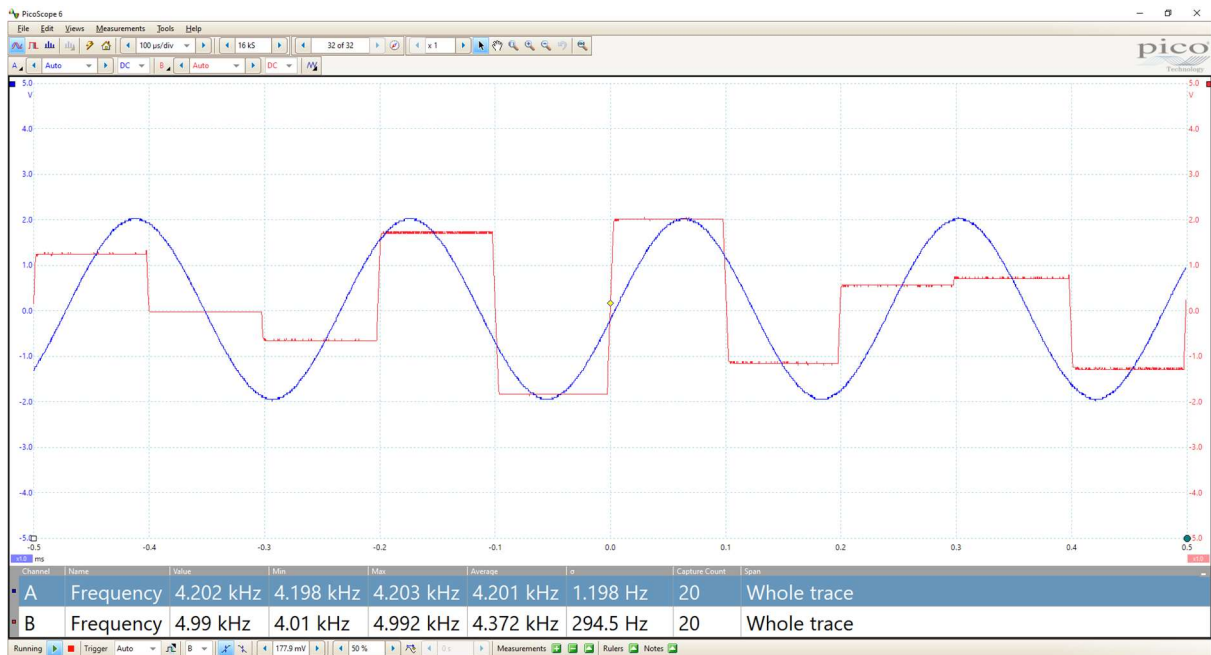


Figure 27 - 8-Bit 4.2kHz @ 4V

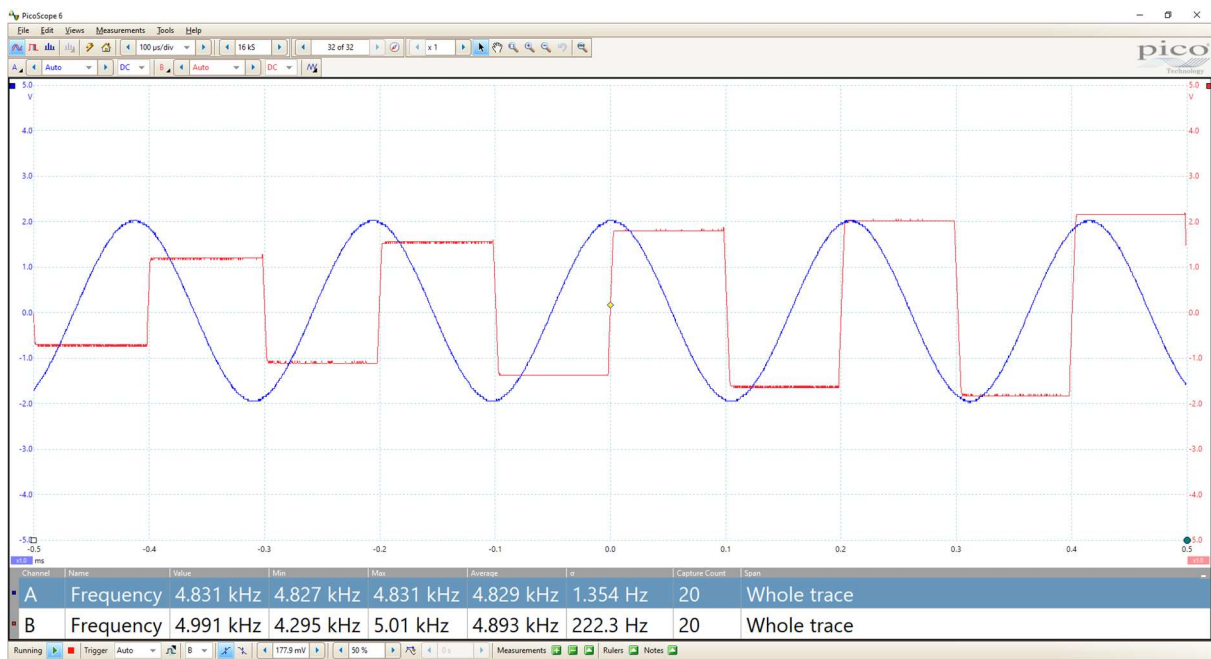


Figure 28 - 8-Bit 4.8kHz @ 4V

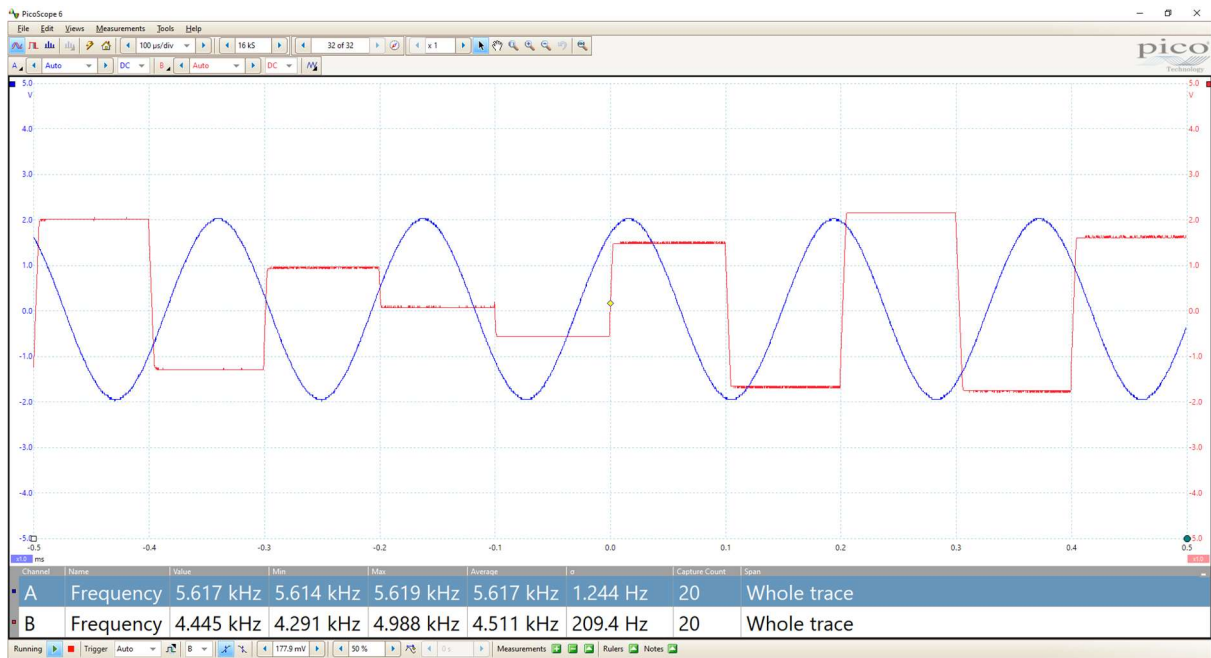


Figure 29 - 8-Bit 5.6kHz @ 4V

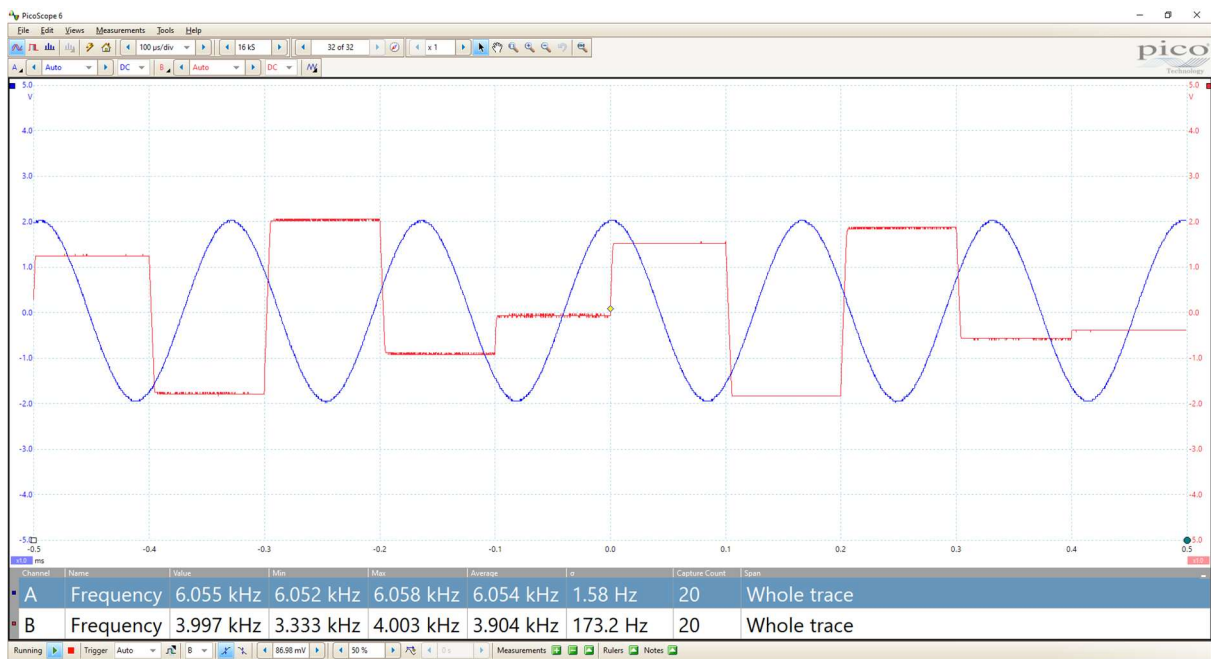


Figure 30 - 8-Bit 6kHz @ 4V

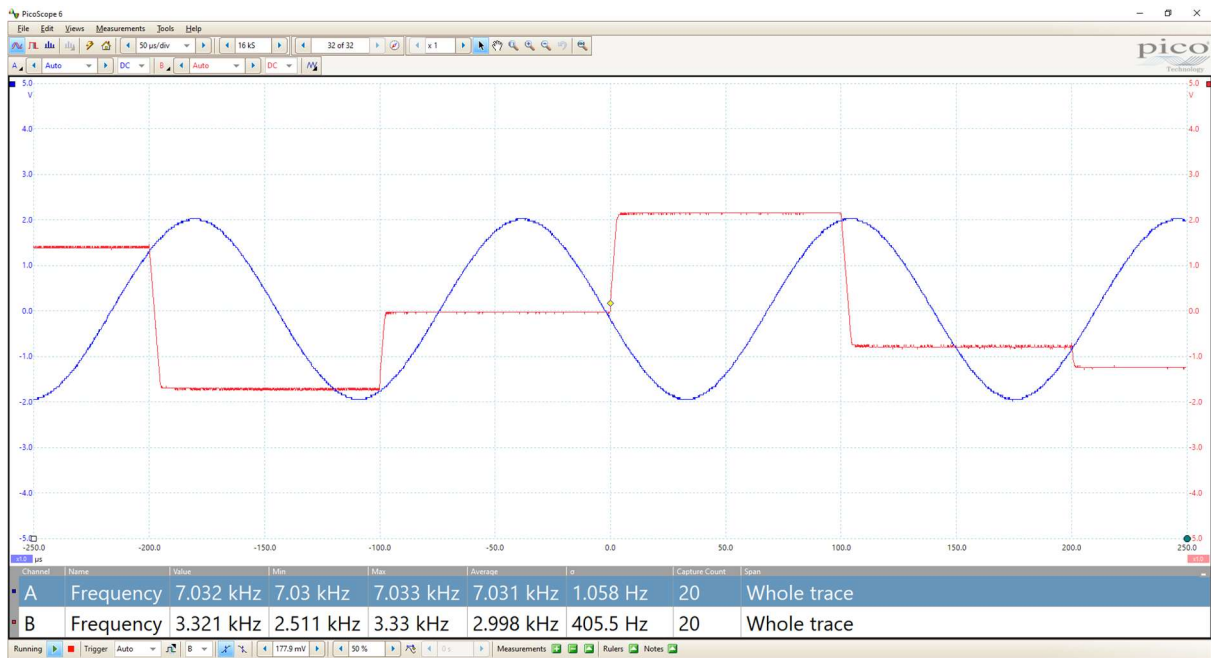


Figure 31 - 8-Bit 7kHz @ 4V

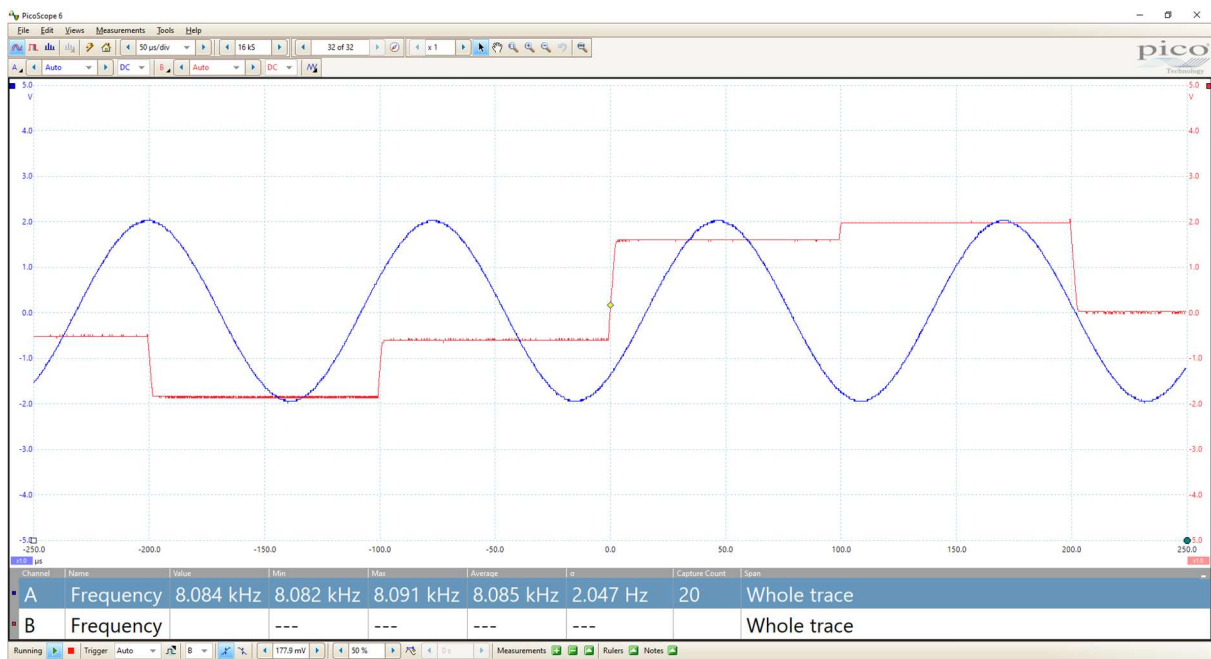


Figure 32 - 8-Bit 8kHz @ 4V

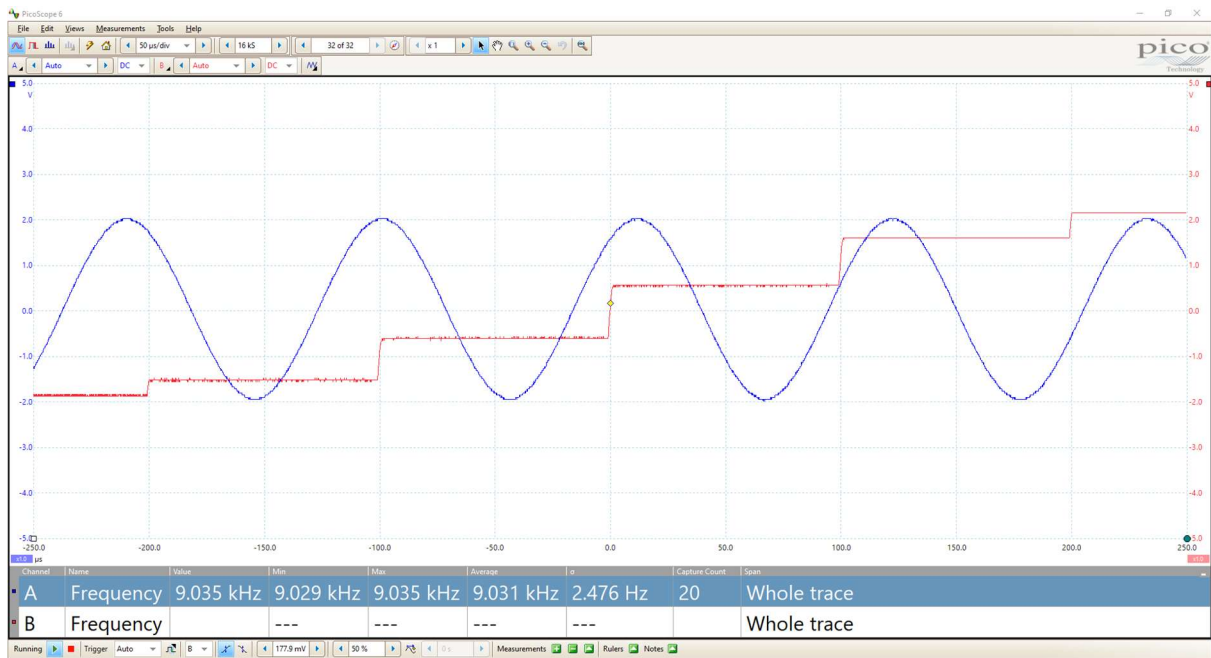


Figure 33 - 8-Bit 9kHz @ 4V

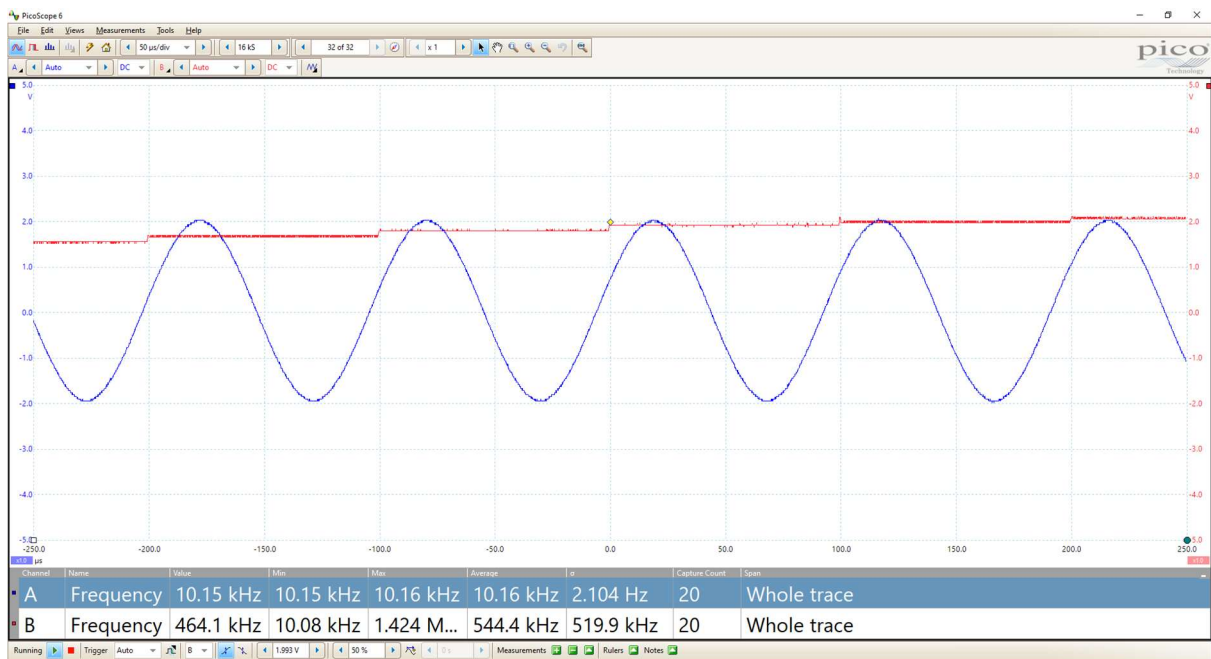


Figure 34 - 8-Bit 10kHz @ 4V

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: CSG-RUBIC

MATTHEW DAVIES

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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.

6

KNOWLEDGE AND UNDERSTANDING

 The knowledge and understanding of the subject demonstrated by this assignment was reasonably extensive. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a limited degree. You have demonstrated some critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes, however your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

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ANALYSIS

 Your analysis of the task was generally satisfactory, both in class and as shown in this assignment, however it did tend more towards

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

PRACTICAL APPLICATION AND DEP.

 Your application of practical skills for this task was generally good. You used the resources available appropriately when conducting both experiments and you used appropriate options for testing and evaluating the circuit performance. You managed to evaluate that the circuits functioned within the specification and achieved this by only asking for assistance when appropriate. Your results were comprehensive and allowed for a good conclusion to be attempted.

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SKILLS FOR PROFESSIONAL PRAC.

 In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was written in a professional and confident style, however you still need to be more efficient with your word count. The report was very well presented, with excellent diagrams in appropriate places, good sentence/paragraph

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structure and clear calculations. Word count was exceeded.