

PSDE5014 A2 Digital Modulation Schemes

by Emyr Dyer

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HND Electrical & Electronic Engineering

Digital Modulation Schemes

PSDE5014 – Signals and Digital Comms

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1 RESEARCH

1.1 PAM AND PCM

Pulse-Amplitude Modulation or PAM is the process of encoding information as an amplitude of a signal at regular intervals as is shown in **Error! Reference source not found.1**. Demodulation of a PAM signal is the reversal of the process by Sampling (measuring) the amplitude at a set period (J.S.Chitode, 2009).

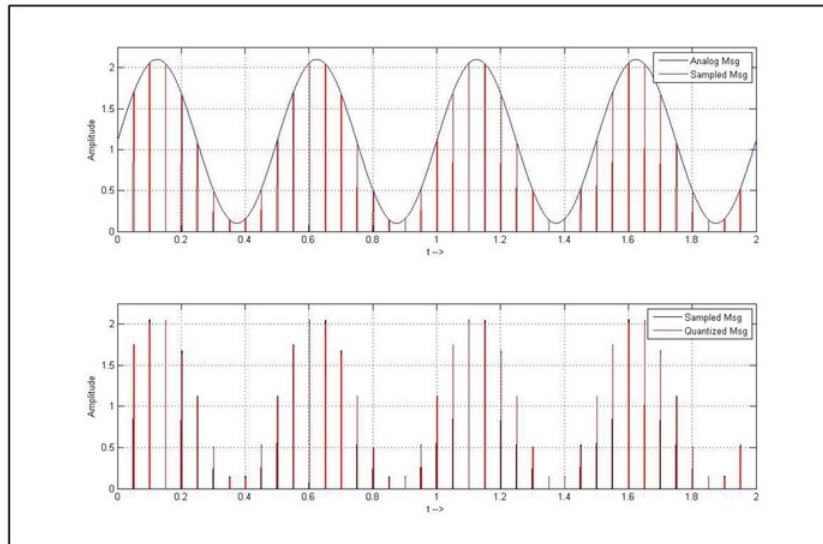


Figure 1.1: MATLAB representation of PAM

In Sampling, the analogue signal is measured every T_s seconds, and the sampling rate is defined as $f_s = 1/T_s$.

In PAM there are three types of sampling methods which are;

- 'Ideal' - when specific instant (point) is sampled,
- 'Natural' – when a short pulse of varying amplitude is sampled,
- 'Flat Top' – which is short pulse, but the amplitude is fixed during the sampling.

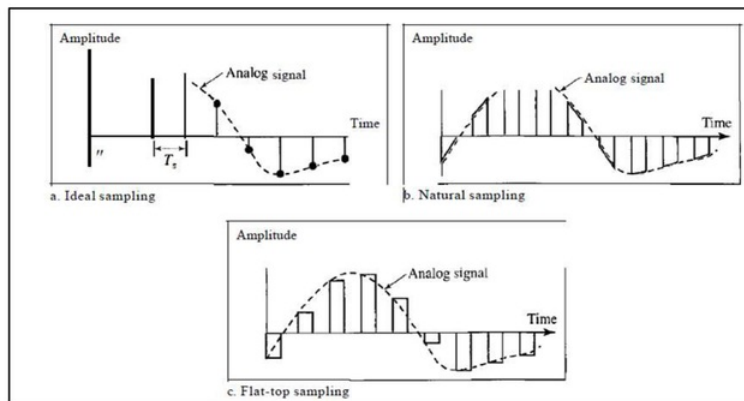


Figure 1.2: Sampling Types

Pulse-Code Modulation or PCM takes PAM a step further by digitally representing an analogue signal by sampling, quantizing, and then encoding (Bill Waggener, 1995).

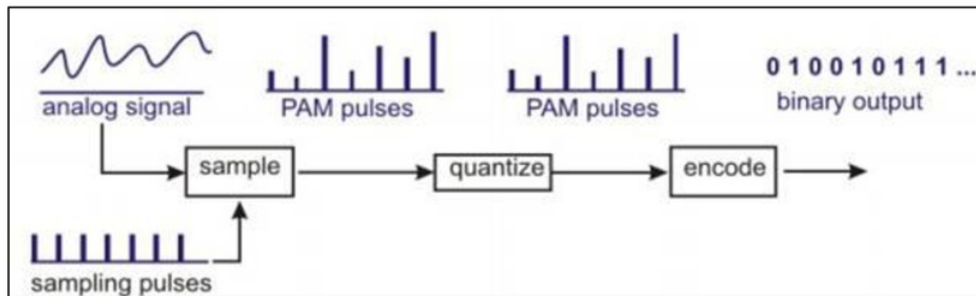


Figure 1.3: Quantization Process

During the sampling process, the magnitude of the analogue signal is sampled at regular uniform intervals (frequency). The sampled magnitudes are then converted into binary values in **Error! Reference source not found.**, there are equally distributed steps. There will be times where the analog signal is not quite as close to the quantization level, so the point is simply set to the nearest, the difference being called the 'quantizing error'.

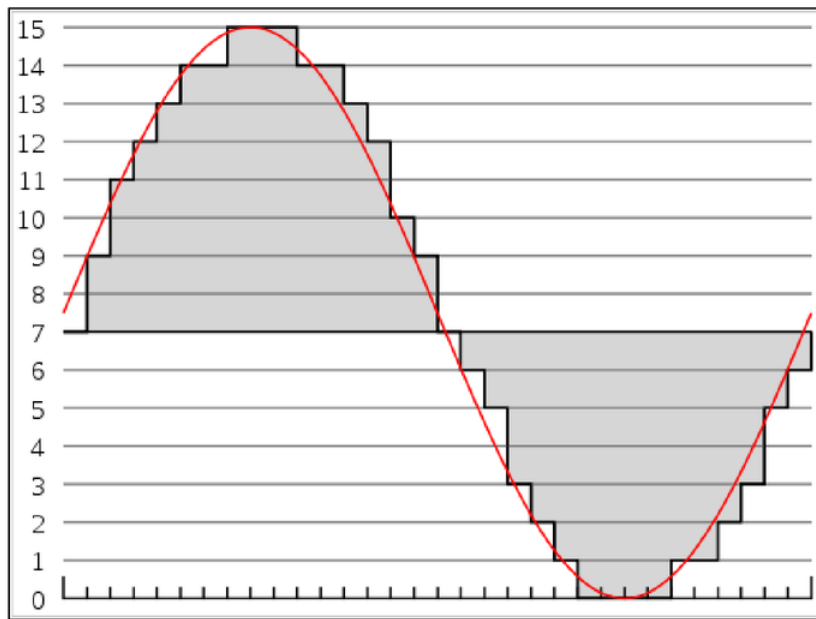


Figure 1.4: Quantizing and Analogue Signal

1.2 ALIASING

The term Aliasing refers to the appearance of a misinterpreted sound signal, which is the result of a low sampling rate that insufficiently samples the whole of the original higher frequency signal.

According to Nyquist's Theorem (Nyquist Rate), the sampling frequency must be more than double that of the highest frequency of the original signal to ensure a sufficient number of sampling points, thus preventing an Aliased signal, that is providing that the original signal is a sine-wave.

To satisfy the Sampling Theorem, an Anti-Aliasing filter may be used to restrict the bandwidth of the signal so that the frequency may be adequately sampled (Smith, 2003).

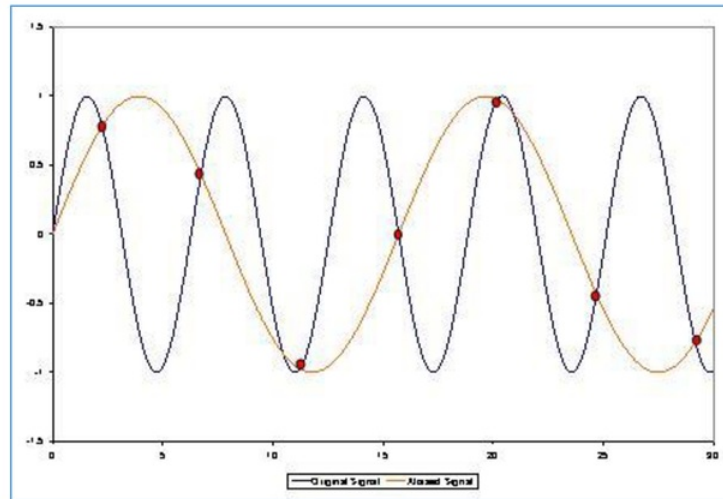


Figure 1.5: Aliased Signal

1.3 MODULATION SCHEMES

1.3.1 ASK

Amplitude Shift Keying Modulation (ASK) is the digital signal is modulated into an analogue carrier signal, so that an amplitude of the output analogue signal represents a binary 1 or 0. In this method of modulation, the frequency remains constant.

ASK modulation can be represented by the following equations;

$$\text{Binary 1 - } s(t) = A_2 \times \cos(2 \times \pi \times f_c \times t)$$

$$\text{Binary 0 - } s(t) = A_1 \times \cos(2 \times \pi \times f_c \times t)$$

The benefits of ASK are that digital signals can be sent through fibre optic cabling, and that there is a simple design regarding the receiver.

Disadvantages include poor power efficiency, and noise interference can result in a corruption of the binary 0 state (Xiong, 2006).

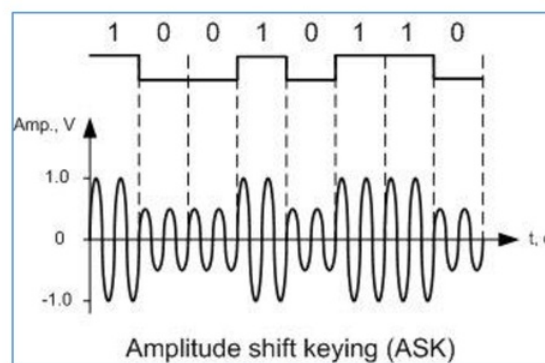


Figure 1.6: ASK

1.3.2 FSK

In Frequency Shift Keying (FSK), the binary states are represented by variation in frequency of the input signal, so in this case amplitude is inconsequential.

FSK modulation can be represented as;

$$\text{Binary 1 - } s(t) = A \times \cos(2 \times \pi \times f_1 \times t)$$

$$\text{Binary 0 - } s(t) = A \times \cos(2 \times \pi \times f_2 \times t)$$

The benefit of FSK is that voltage spikes or interference noise can be ignored (high Signal-to-Noise ratio). The significant disadvantage however is that a greater bandwidth is required than ASK (Xiong, 2006).

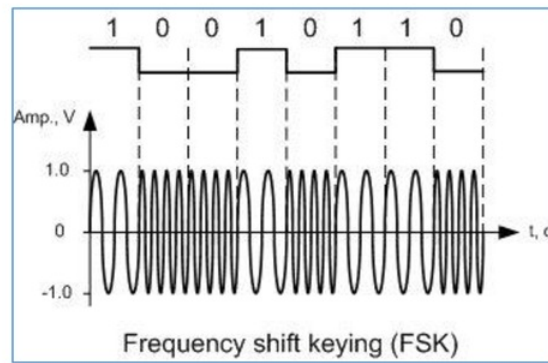


Figure 1.7: FSK

1.3.3 BPSK

With Binary Phase Shift Keying (BPSK), the phase of the analogue signal is manipulated (180° difference) to represent binary 1 and 0.

The following equations represent the binary states in PSK;

$$\text{Binary 1 - } s(t) = A \times \cos(2 \times \pi \times f_c \times t)$$

$$\text{Binary 0 - } s(t) = A \times \cos(2 \times \pi \times f_2 \times t + \pi)$$

The significant benefit of BPSK is that the same frequency range as ASK can be occupied, but with less interference errors than ASK due to the shifting of Signal Phase. The disadvantage is that the detection of binary states is estimated and requires very complex algorithms to detect and decode the binary data (Xiong, 2006).

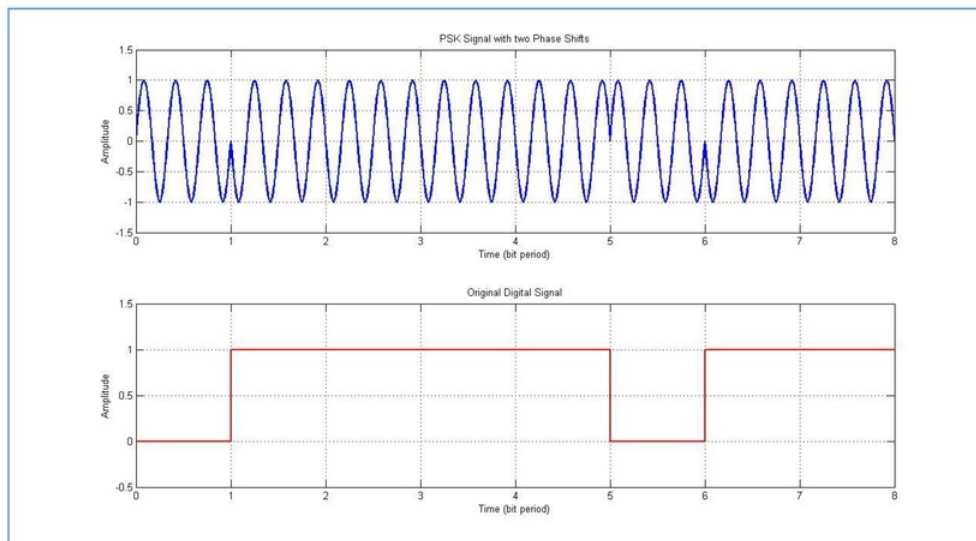
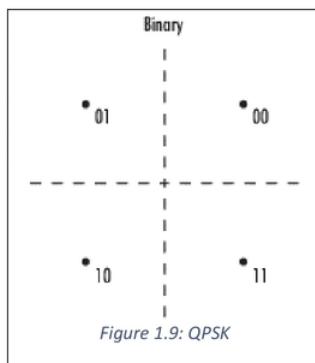


Figure 1.8: BPSK

1.3.4 QPSK

In a similar manner to BPSK, Quadrature Phase Shift Keying (QPSK), represents binary states using shifts in phase, however instead of one binary digit being represented, it is two (00,01,11,10). To represent the four binary values, the whole of a 360° phase is divided up into 45° , 135° , 225° and 315° .

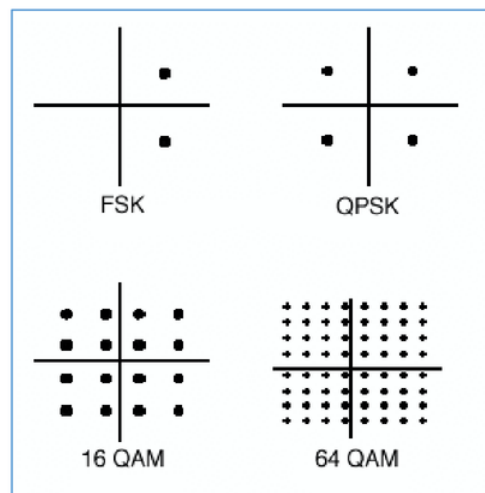
This method of modulating is much more effective than BPSK, as more bits of data can be transmitted due to the additional identified which effectively increases the bandwidth efficiency (Xiong, 2006).



Bits	Phase Shift
00	45°
01	135°
11	225°
10	315°

1.3.5 QAM 8+

Simply called Quadrature Amplitude Modulation (QAM), this means of modulation is typically used in radio transmission applications and exists in 8, 16, 32, 64, 128 and 256 variations which increase data rates with added constellation points on the quadrature. If the energy of the transmission is not increased, then the constellation points on the quadrature are packed more densely, increasing the bit rate higher than is desired. When deploying QAM method, it vital to consider the trade-off between the amount of data to be transmitted, and the potential error resulting from the modulation. In the UK uses QAM 16 and 64 are used for terrestrial television transmission of data (Xiong, 2006).



2 EXPERIMENTAL METHOD

2.1 SETUP

The Goal of this experiment is to practically demonstrate the limitations of Analogue to Digital Conversion by observing the resulting signal output depending on the input amplitude, frequency, and quantization bits.

The voltage range was set at 5V peak to peak, with a sampling rate for this experiment was fixed at 10,000 samples per second.

As shown in Figure 2.1, the Data Source was linked to the Data Receiver, and a Low Pass Filter was linked to the Data Receiver. An Picoscope (Oscilloscope) was linked to both the Data Source and Receiver to observe both the input and output signals, and a Function Generator was linked to the Data Source.

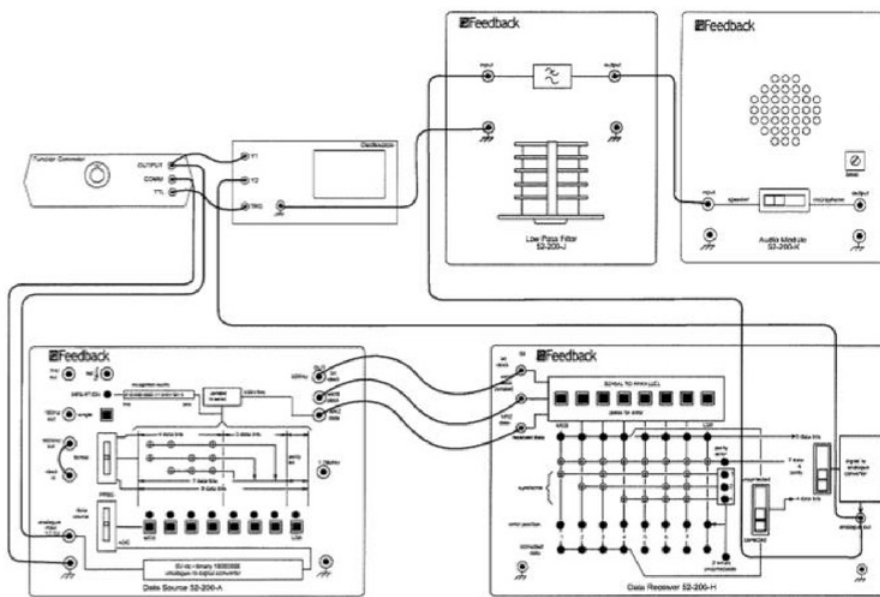


Figure 2.1: Experiment Setup

2.2 1ST TEST (QUANTIZATION)

The first test entailed changing the quantization for the source signal with a fixed frequency of 100Hz and 4.2V peak to peak amplitude. Starting at 8-bits, readings were recorded before setting to a lower 4-bit size and recording readings again. The expected result would be a better-defined sine wave when set to a higher bitrate.

2.3 2ND TEST (AMPLITUDE)

In this test, the ADC was fixed at 4-bits with a fixed frequency of 100Hz. The Function Generator was set as low as possible before ramping up the signal to the maximum amplitude, all the while recording the readings from the Picoscope. The expected result would be a poorly defined sine wave

at lower amplitude with fewer quantization stepping, improving with increased signal amplitude, until the maximum amplitude was reached, the signal would 'flatten' out.

2.4 3RD TEST (FREQUENCY)

The final test entailed setting the ADC to 8-bits with a fixed source signal amplitude. The frequency was set to 100Hz, increasing to 6KHz and then to 10KHz, all the while recording the resulting output waveforms according to input signal frequency. The expected result was that at lower frequency there would be minimal difference between input and output, but at increasing frequencies, the distortion between input and output would increase.

3 TESTING AND RESULTS

3.1 1ST TEST (QUANTIZATION)

Starting at 8-bits, the following Sine Wave was recorded. Set amplitude was 4.2V peak-to-peak at 100Hz.

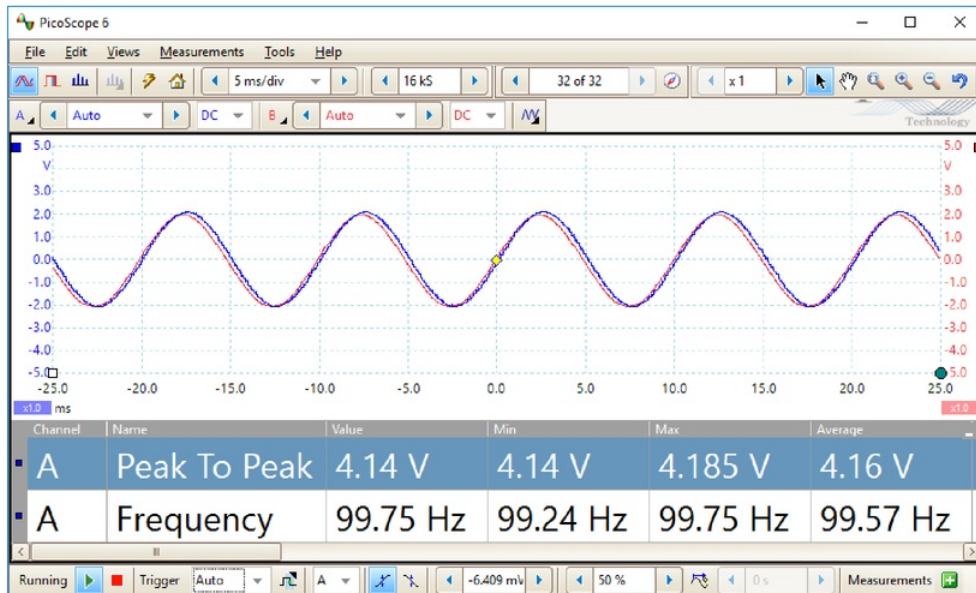


Figure 3.1: 8-bits at 4.2V peak-to-peak at 100Hz

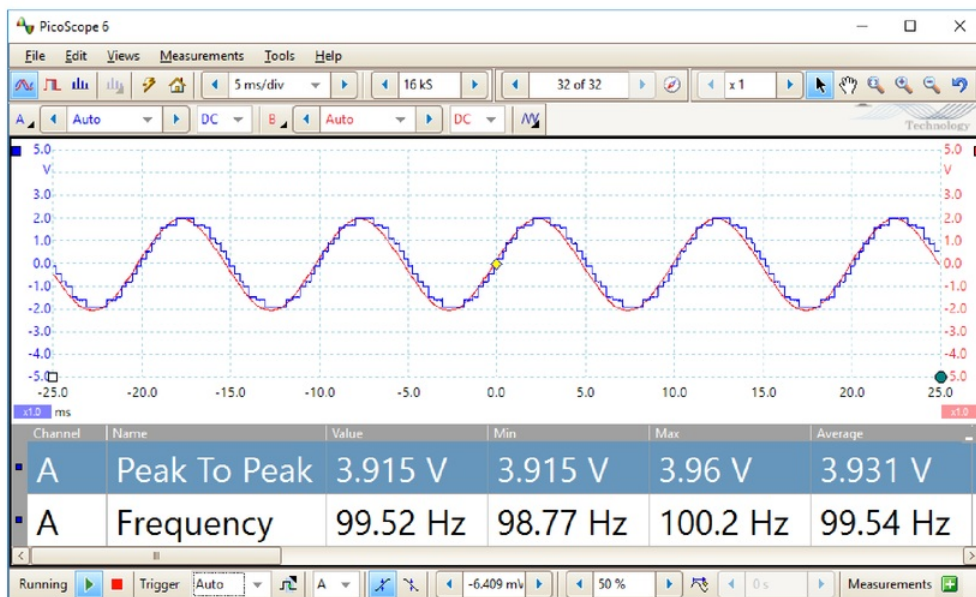


Figure 3.2: 4-bits at 4.2V peak-to-peak at 100Hz

The expected result happened with increased stepping resulting from the reduced quantization. This is verified with the following calculations;

$$\frac{5}{2^4} = 312.5V \text{ resolution for 4-bit}$$

$$\frac{5}{2^8} = 19.5mV \text{ for 8-bit}$$

So, with increasing quantization, the resolution increases in sensitivity, meaning a more accurate output waveform was produced.

3.2 2ND TEST (AMPLITUDE)

The Function Generator was set as low as it could be tuned for amplitude, and the frequency was fixed at 100Hz with the ADC set to 4-bit.

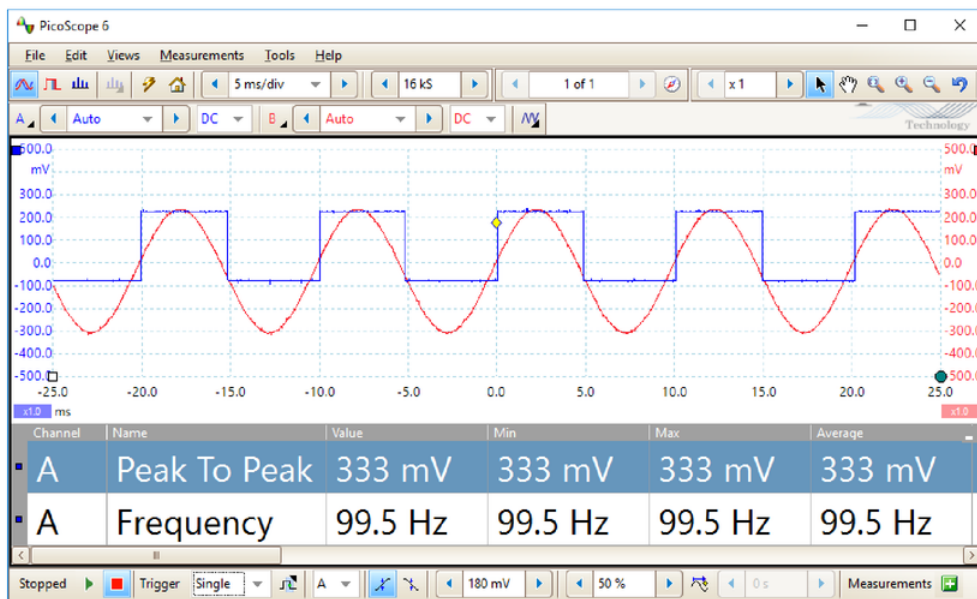


Figure 3.3: Lowest Amplitude at fixed 4-bit and 100Hz frequency

There are only two distinct quantization levels present due to the low amplitude source signal, resulting a significant quantization error where the curve is effectively lost.

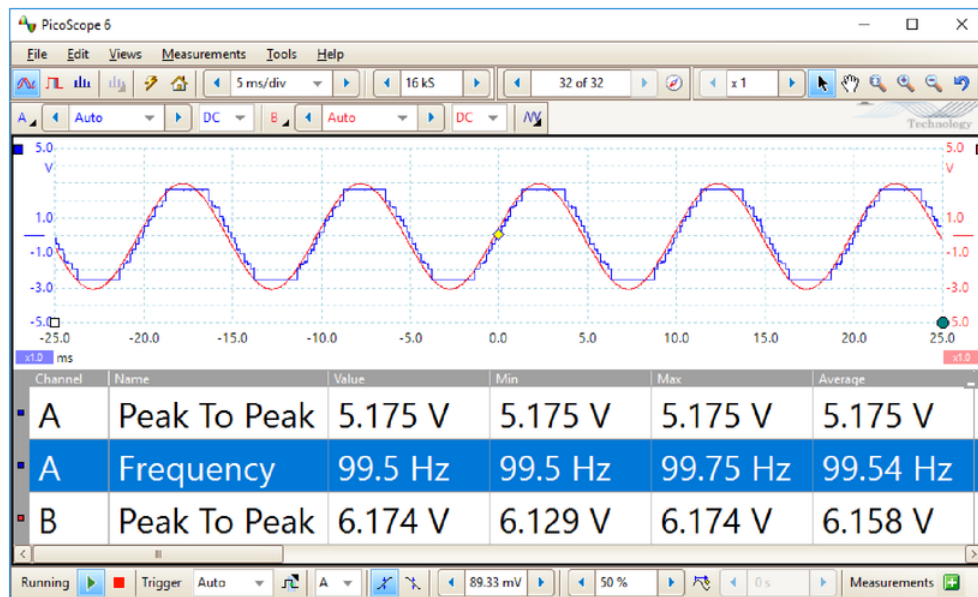


Figure 3.4: Amplitude increased to maximum

With the Amplitude increased to a little above the maximum 5V peak-to-peak, the resolution has greatly increased as the source signal is more measurable, however there is a 'flattening' at the top of the output signal where some of the original amplitude is lost.

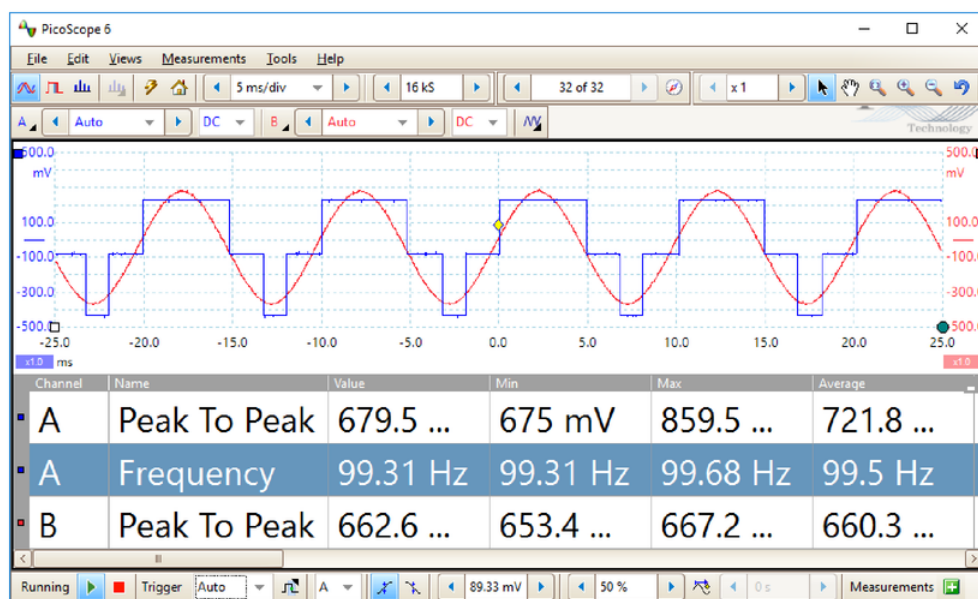


Figure 3.5: Amplitude at three quantization levels

With the amplitude of the source signal turned back down, to show three levels, a better representation is shown than of the original reading.

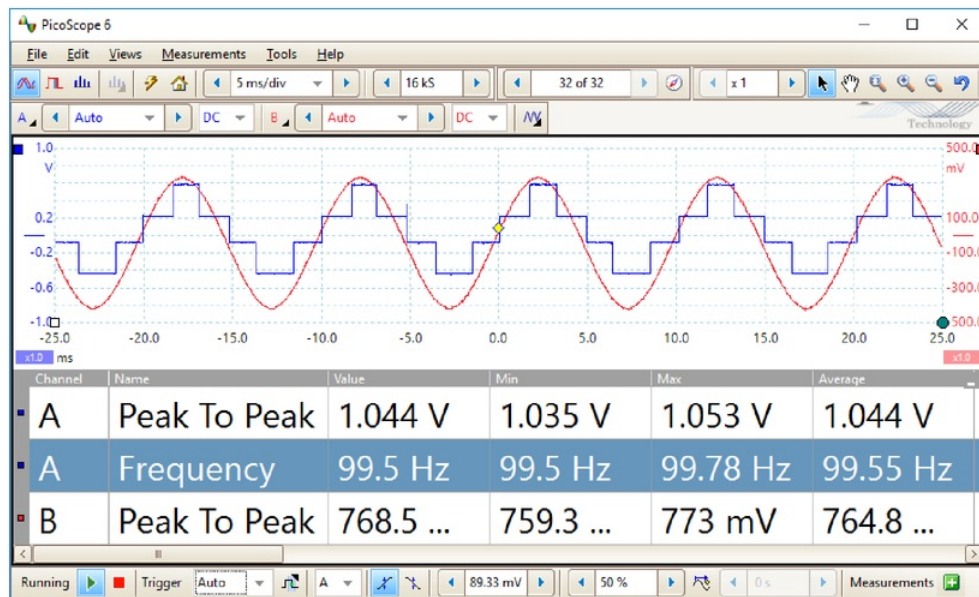


Figure 3.6: Four quantization levels

At 1V peak-to-peak, the quantization levels increase further, however the bottom of the source signal is lost due to poor resolution.

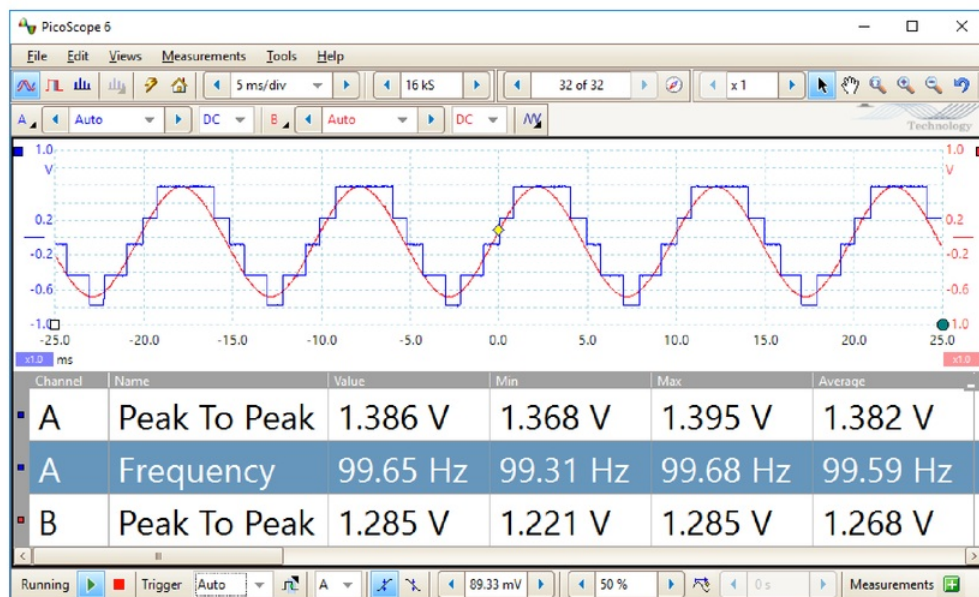


Figure 3.7: Five quantization levels

At 1.3V peak-to-peak, the resolution has improved, and the output is getting closer to the source.

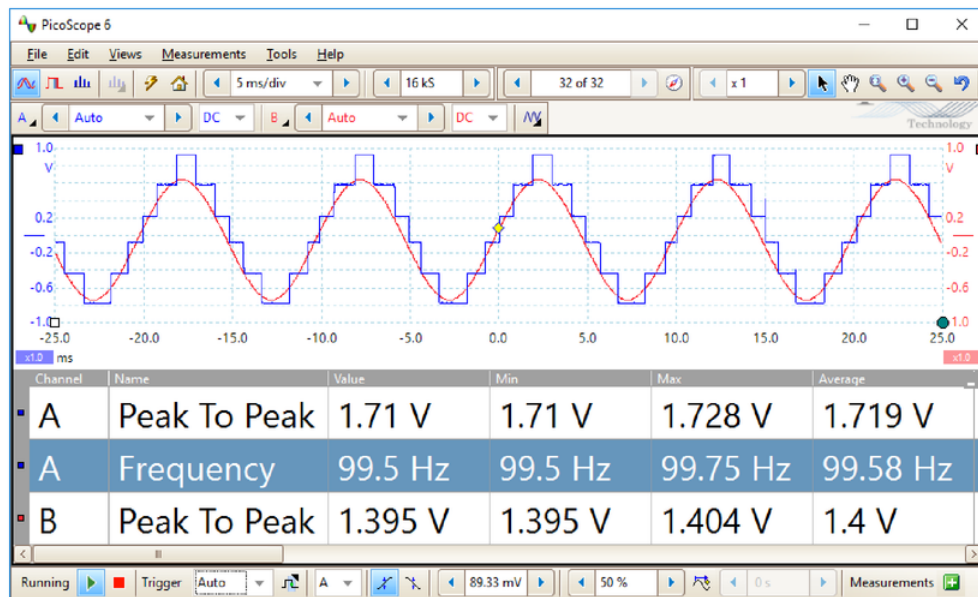


Figure 3.8: Six quantization levels

An inaccuracy occurs at 1.71V peak-to-peak with the ADC representation of the maximum amplitude being excessive, though it is likely that with better resolution, the excessive output peak would disappear.

Looking back at the results recorded, there was a distinct improvement in the output waveform as the amplitude of the source signal was increased. Knowing that the resolution of the ADC was set at 4-bit, the resolution was verified under these conditions as 312.5mV. By calculating with the resolution value, it should have been possible to calculate how close the resulting waveform was in amplitude.

$$\text{quantization steps} \times \text{resolution} = \text{output amplitude}$$

$$2 \times 312.5\text{mV} = 625\text{mV} \text{ compared to } 675\text{mV} \text{ measured}$$

$$3 \times 312.5\text{mV} = 937.5\text{V} \text{ compared to } 1.04\text{V} \text{ measured}$$

$$4 \times 312.5\text{mV} = 1.250\text{V} \text{ compared to } 1.386\text{V} \text{ measured}$$

$$5 \times 312.5\text{mV} = 1.563\text{V} \text{ compared to } 1.71\text{V} \text{ measured}$$

The results of these calculations show a level of inaccuracy in the Analogue to Digital Conversion; however, this could be down to noise interference or poor re-calibration of the test equipment.

3.3 3RD TEST (FREQUENCY)

The source signal was fixed at 4V peak-to-peak with the ADC set to 8-bit for 256 quantization levels.

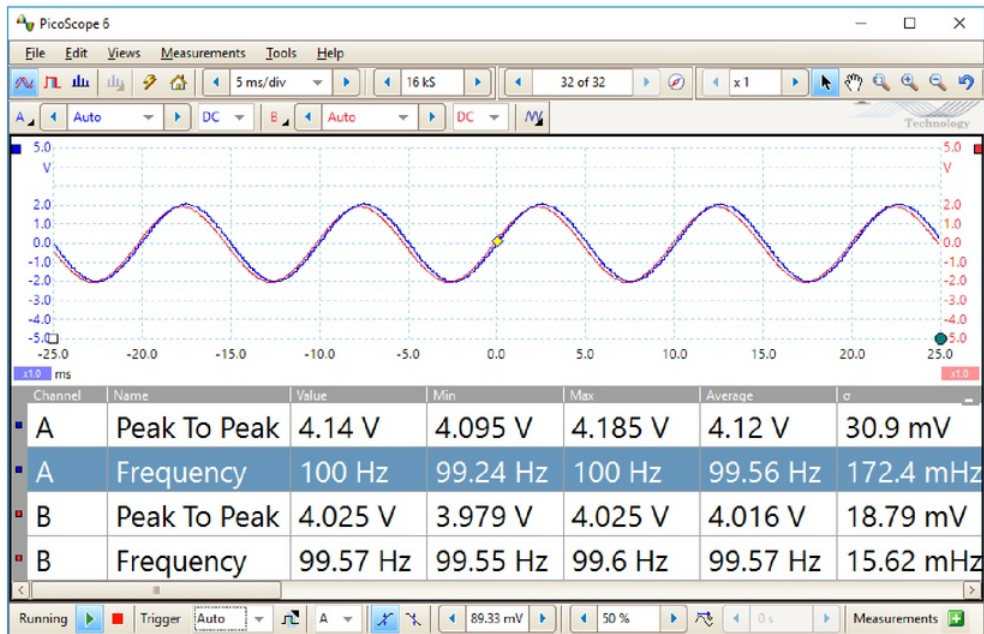


Figure 3.9: 100Hz

At 8-bit conversion at 100Hz, an accurate conversion of source analogue signal to digital has been achieved.

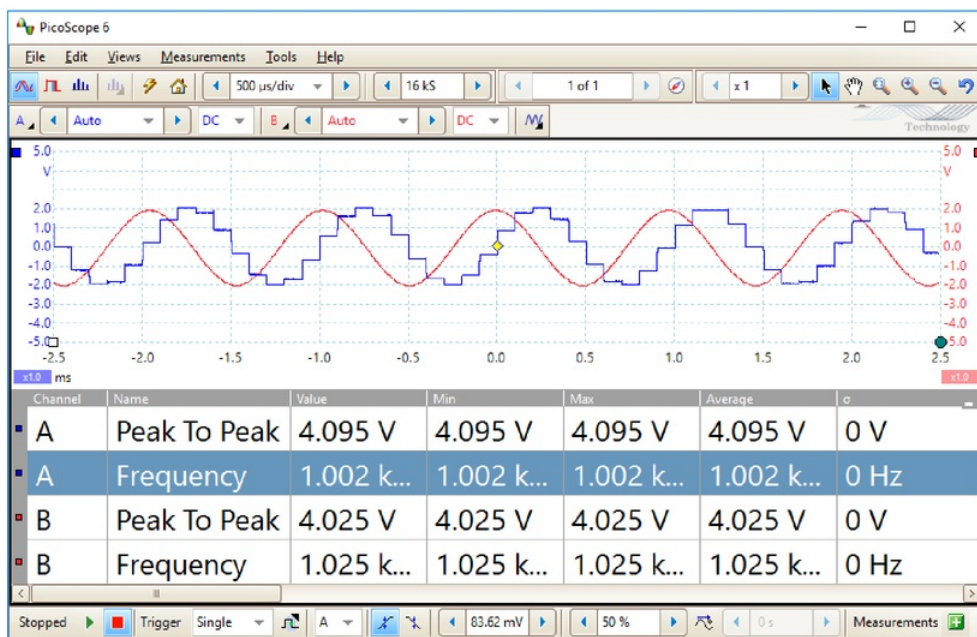


Figure 3.10: 1KHz

At 1KHz frequency, stepping occurs in the output waveform. This is a result of the higher frequency of sampling resulting in fewer amplitude points being sampled. This issue should exacerbate with increased frequency.

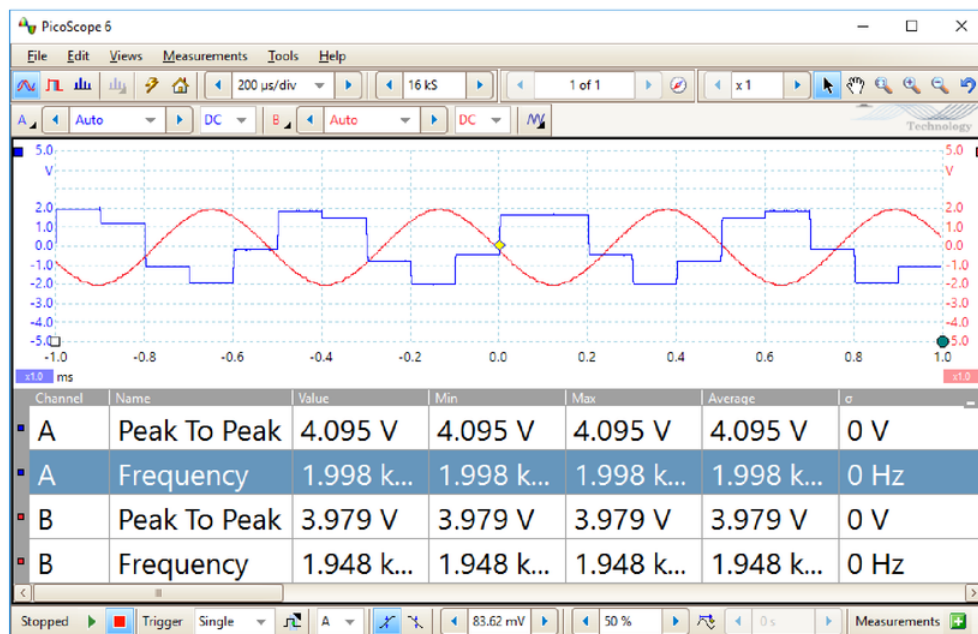


Figure 3.11: 2KHz

The sampling has deteriorated further as the higher frequency has yielded fewer samples taken. The frequency will now be pushed further.

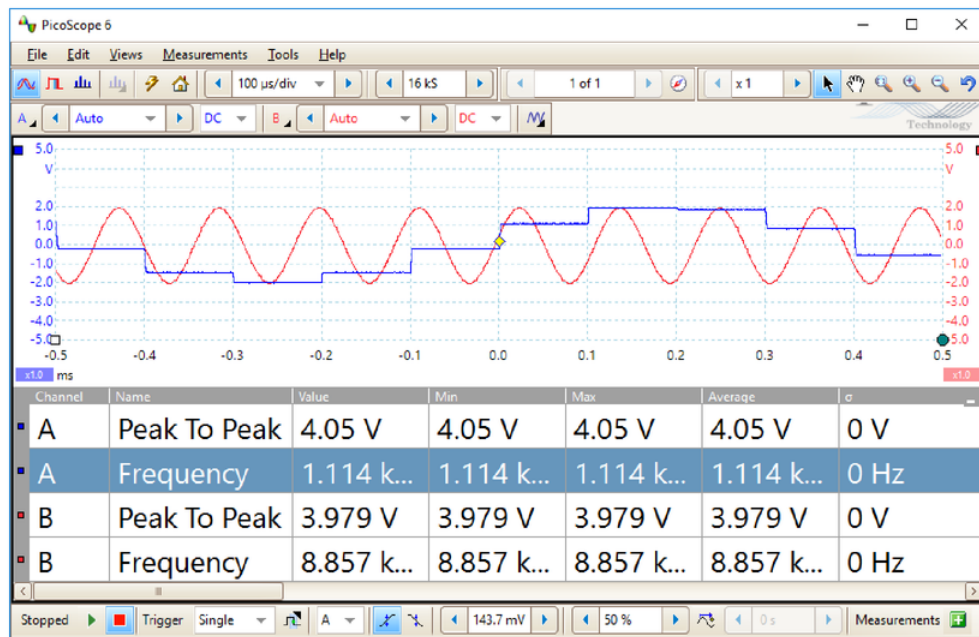


Figure 3.12: 8KHz and Aliasing

The expected Aliasing has occurred at 8KHz. With fewer samples taken, an alternative waveform has been produced from the lack of definitive points required for an accurate conversion.

4 CONCLUSIONS

From research and practical investigation, it has been shown that ASK and FSK has its limits, which is detrimental for transmission of large amounts of accurate data within a set time. Considering this, ASK and FSK certainly have their applications where accuracy is not a pressing requirement as the user may simply want an indication of binary state (on/off).

QAM shows a strong advantage due to its resistance to noise interference and data capacity, despite the complexity of algorithms required to demodulate the received signal from a transmission source.

The risks of using too high a frequency for a bit conversion rate is also evident from the observation of the Aliasing effect resulting from too few samples being taken over time.

An improvement to the investigation could be to either improve the sampling rate or bit conversion of the ADC, to produce a more accurate output waveform.

5 WORKS CITED

Bill Waggener, W. M. (1995). *Pulse Code Modulation Techniques*. Berlin: Springer Science & Business Media.

J.S.Chitode. (2009). *Principles Of Communication*. Shaniwar Peth: Technical Publications.

Smith, S. W. (2003). *Digital Signal Processing: A Practical Guide for Engineers and Scientists*. Oxford: Newnes.

Xiong, F. (2006). *Digital Modulation Techniques*. Michigan: The University of Michigan.

6 IMAGE SOURCES

Figure 1.1	https://uk.mathworks.com/matlabcentral/mlc-downloads/downloads/submissions/34610/versions/2/screenshot.jpg
Figure 1.2	http://2.bp.blogspot.com/-OSEcr3L6nGQ/Va3prlt15UI/AAAAAAAAAD0/ztdq39htnw0/s400/Picture1.jpg
Figure 1.3	http://2.bp.blogspot.com/-tvcxje52Jxc/Va3qZB5_dnl/AAAAAAAAAD8/Bxl4wtMJwRY/s400/Picture2.jpg
Figure 1.5	http://www.interfacebus.com/Aliasing.jpg
Figure 1.6	http://www.tmatlantic.com/upload/images/keying_ASK.jpg
Figure 1.7	http://www.tmatlantic.com/upload/images/keying_FSK.jpg
Figure 1.8	https://www.mathworks.com/matlabcentral/mlc-downloads/downloads/submissions/30582/versions/1/screenshot.jpg
Figure 1.9	https://www.mathworks.com/help/comm/ref/newbinarygray.png
Figure 1.10	https://questtel.com/img-qt/articles/qam-diagram.png

PSDE5014 A2 Digital Modulation Schemes

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

70/100

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GRADING FORM: CSG-RUBIC

EMYR DYER**70****RESEARCH-INFORMED LITERATURE**

There was evidence of further reading and research with the inclusion of a reference list and appropriate in text referencing. Your interpretation and understanding of the additional research was good. Your references were appropriate to the task and your reference list was of an appropriate length for this assignment.

6**KNOWLEDGE AND UNDERSTANDING**

The knowledge and understanding of the subject demonstrated by this assignment was generally very good. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was very good. Your research and explanation was particularly good and extended your knowledge well beyond that contained in the course notes.

23**ANALYSIS**

Your analysis of the task was brief and lacked a lot

of the required detail. You have demonstrated reasonable analytical skills and your approach to the task was logical. You carried out a reasonable evaluation of the results, but the conclusions were very brief.

10

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.

7