MCMASTER UNIVERSITY

ENG PHYS 2E04

Design Project

Prakhar Garg

3/24/2014

Prakhar Garg
1204351
Gargp2

Lab Partner: Zecharaya Hiller
1141596
hilleryz

Prakhar Garg
1204351
Gargp2

Lab Partner: Zecharaya Hiller
1141596
hilleryz

Abstract

This project is very important, as it teaches us an important technique on how to connect our analog world to our digital computers. In this project, the method used in order to do this was a sigma delta analog to digital converter which took a 2 volt peak to peak sine wave input and would produce a zero to five volt digital output. From this project the importance of these devices could clearly be seen.

Introduction

A sigma delta adc is composed of a few key elements which act together in order to take an analog input and give out a digital output which can then be understood by a computer. The main parts are the difference, integrator, comparator, and the latch.

Difference accepts the original analog input together with the output of the circuit which gets converted back to an analog signal along the feed-back loop. The differentiator then outputs a wave which is directly proportional to the rate of change of the difference of the input waves.

Integrator comes after the differentiator and outputs the integral of the voltage wave which it receives.

Comparator is the component of the circuit which takes an analog signal as input and converts the signal into highs and lows which allow for a digital output. The comparator is given a reference voltage which it compares against the input voltage, and depending on if the input voltage is above or below the reference voltage it will output either high or low.

Latch is a logic chip which acts as the memory for the circuit. The latch converts the high and low signals from the comparator into a binary signal which runs in sync with the clock.

A digital to analog converter composed of resistors is then necessary along the feed-back loop in order to send the digital output back through the analog to digital converter. Sigma delta analog to digital converters have a practical application in many modern electronic components. These include switched mode power supplies, converters, as well as many other components.

Methods

Parts Used	Details and Reason for Part
Capacitor	Two 1 micro Farad capacitors required. They had the same purpose as one was for the low-pass filter and one for the integrator which is a form of low-pass filter.
Resistor	There were seven resistors required in our circuit. The values of the resistors include 1,2,5,6, and 15 kilo Ohm resistors. The purpose of the resistors was to control the voltages at different points of the circuit, and the correct resistor value was then used depending on the required voltage.
Op-Amp	Two Op-Amps were used in the circuit, one for the differentiator and one for the comparator.
Logic Gates	4 not gates and 3 and gates were required in order to build the flip flop latch which was used as our 1-bit memory.
Voltage Sources	A five volt DC source was necessary in order to power each of the necessary op-amps. A n AC source was used to produce the input voltage of 2 Vpp.
Clock	A clock was necessary in order for the latch to function.
Oscilloscope	Four channel oscilloscopes were constantly used. These were used so that the output at any point along the circuit was constantly being monitored to ensure that our circuit was performing as desired. They were also used to monitor any changes that would ensue as a result of any frequencies being changed.

Prakhar Garg
1204351
Gargp2

Lab Partner: Zecharaya Hiller
1141596
hilleryz

Results

Circuit

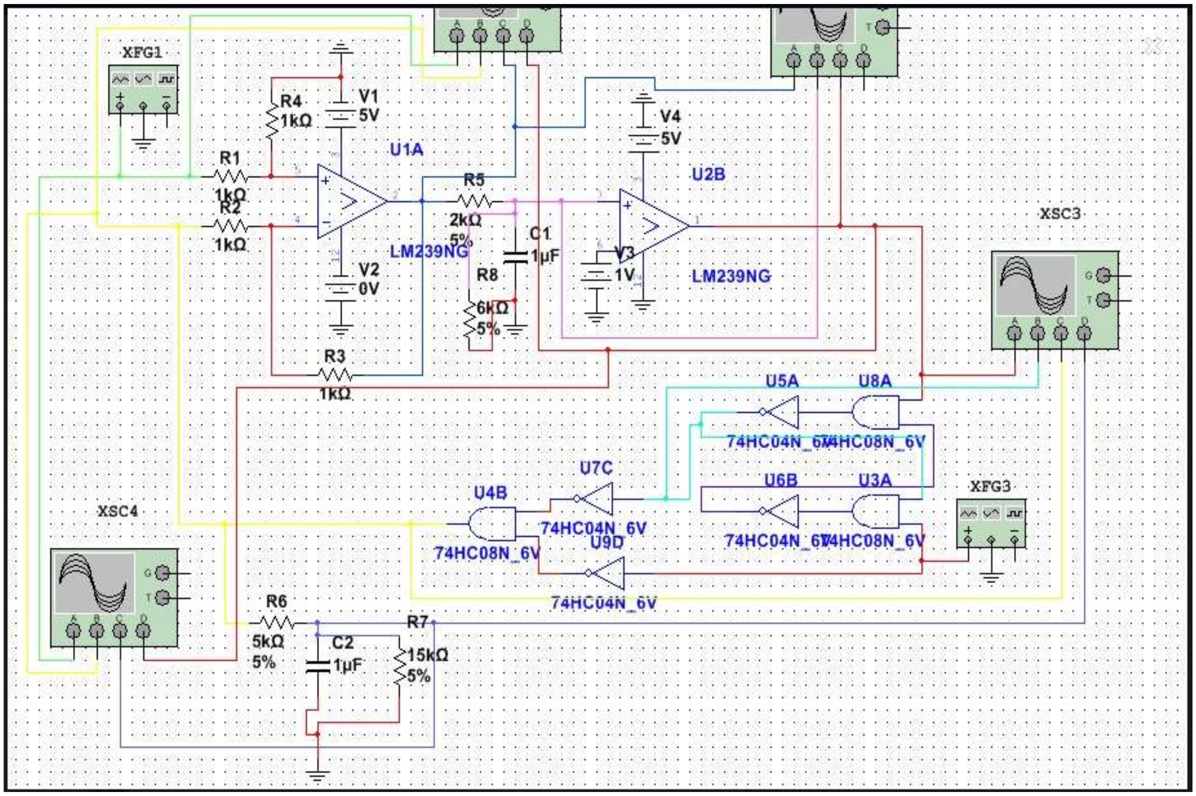

Figure 1: The ADC circuit

Prakhar Garg
1204351
Gargp2

Lab Partner: Zecharaya Hiller
1141596
hilleryz

Input

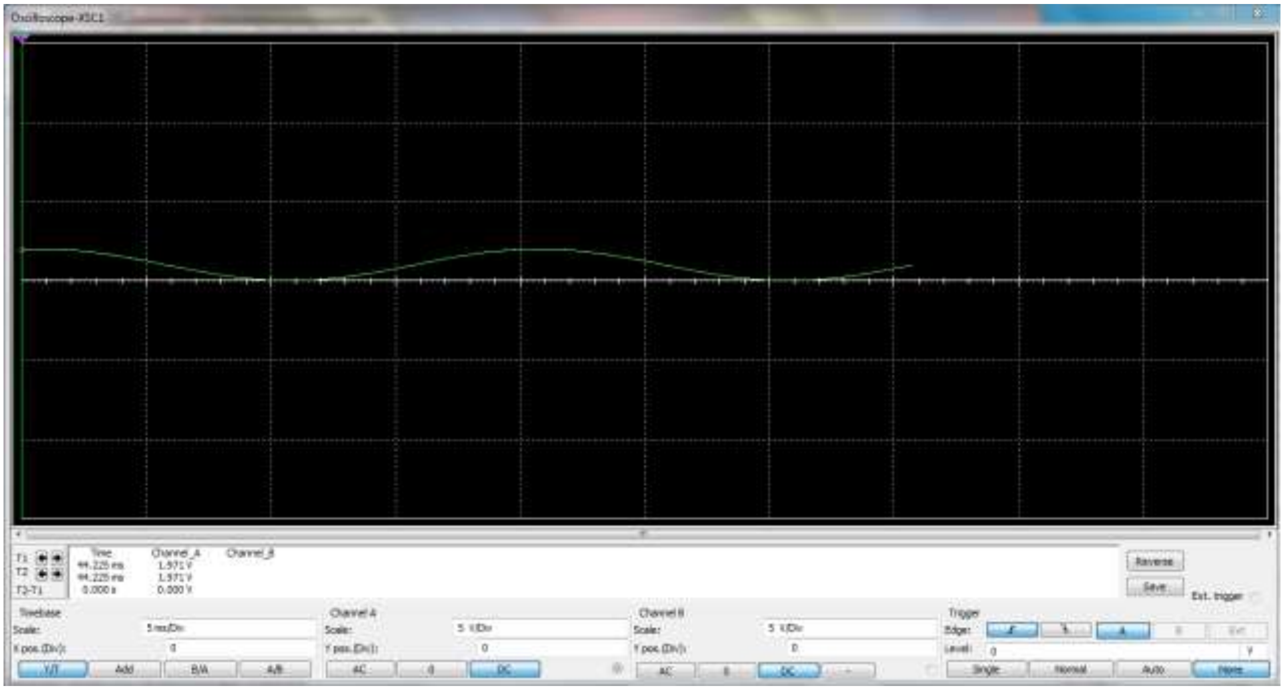

Figure 2: Sine wave input with p=p of 2V and an offset of 1V

Difference

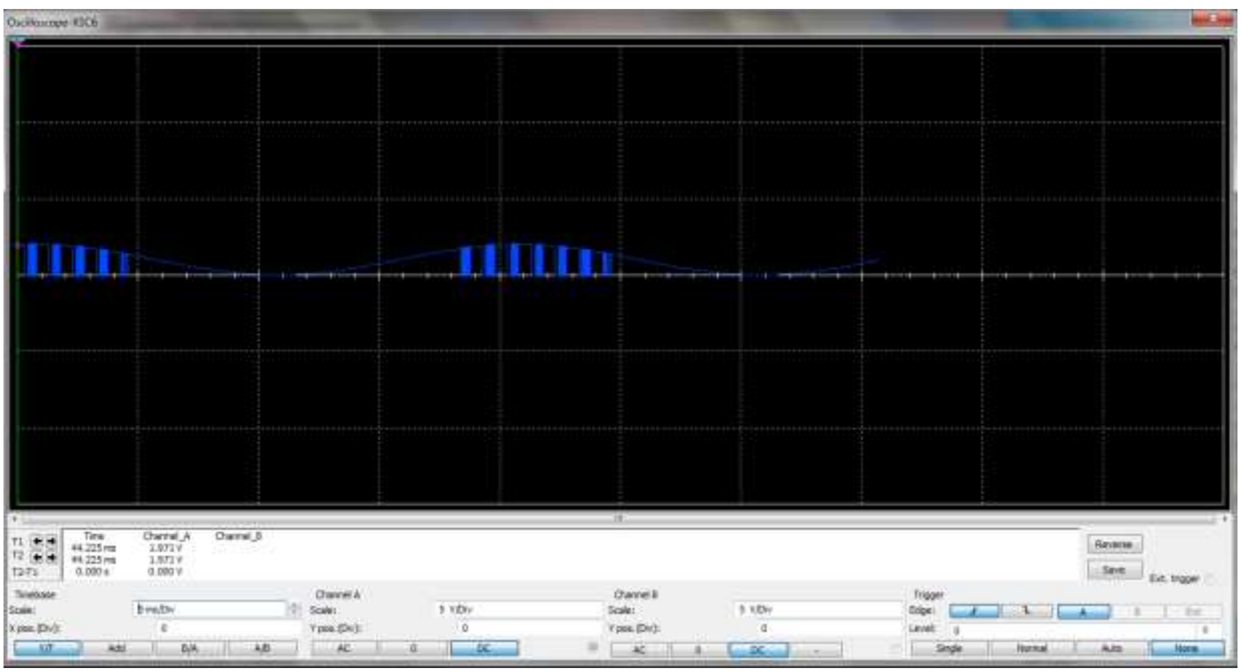

Figure 3: The difference between the input and feedback

Integral

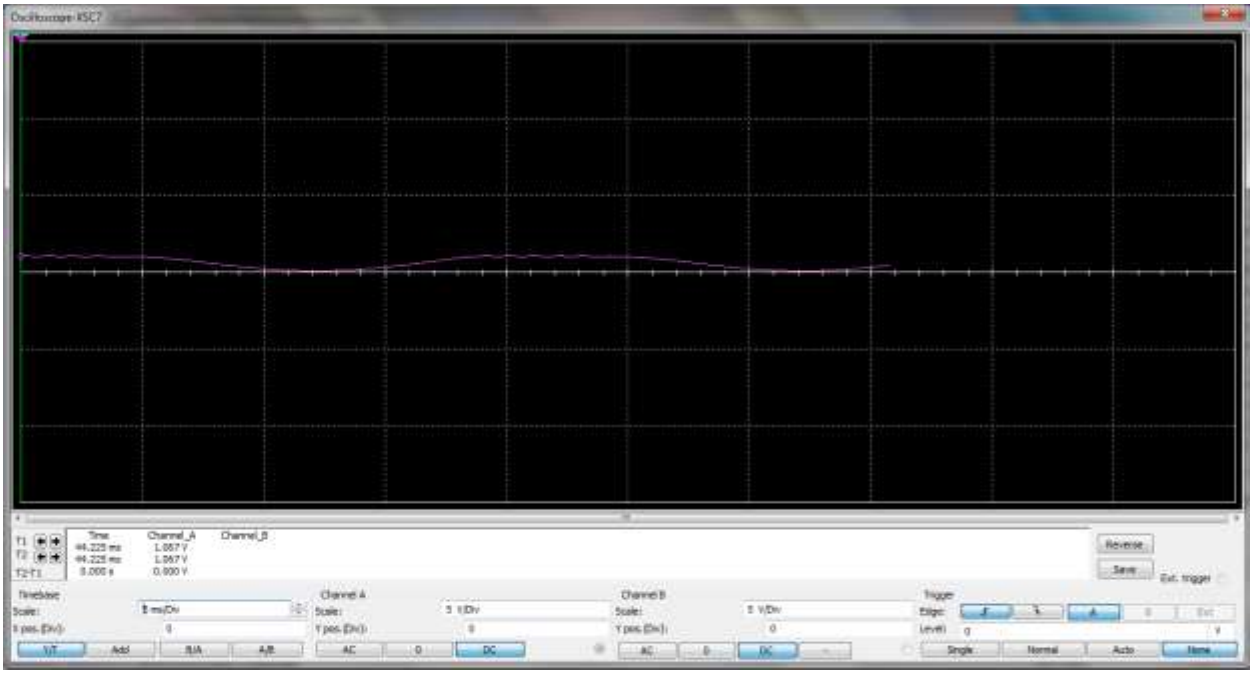

Figure 4: The integral of the difference

Comparator

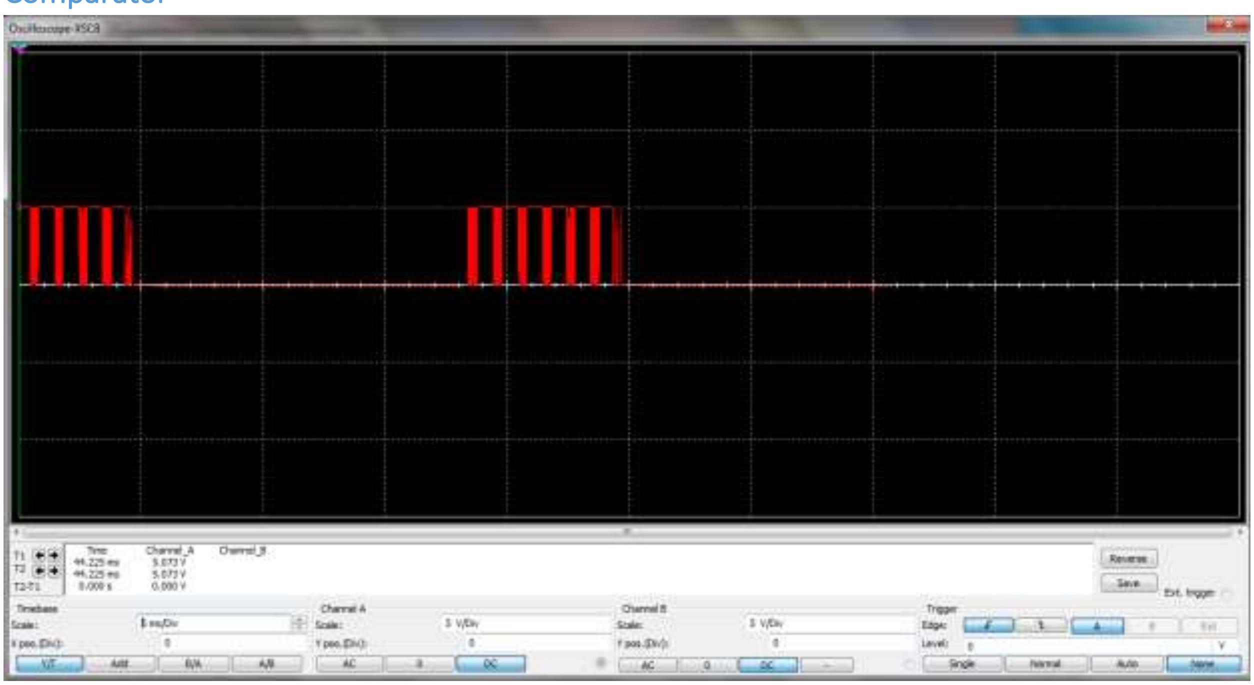

Figure 5: Comparator outputs a high or low signal based on the value of the integral

Prakhar Garg
1204351
Gargp2

Lab Partner: Zecharaya Hiller
1141596
hilleryz

Latch

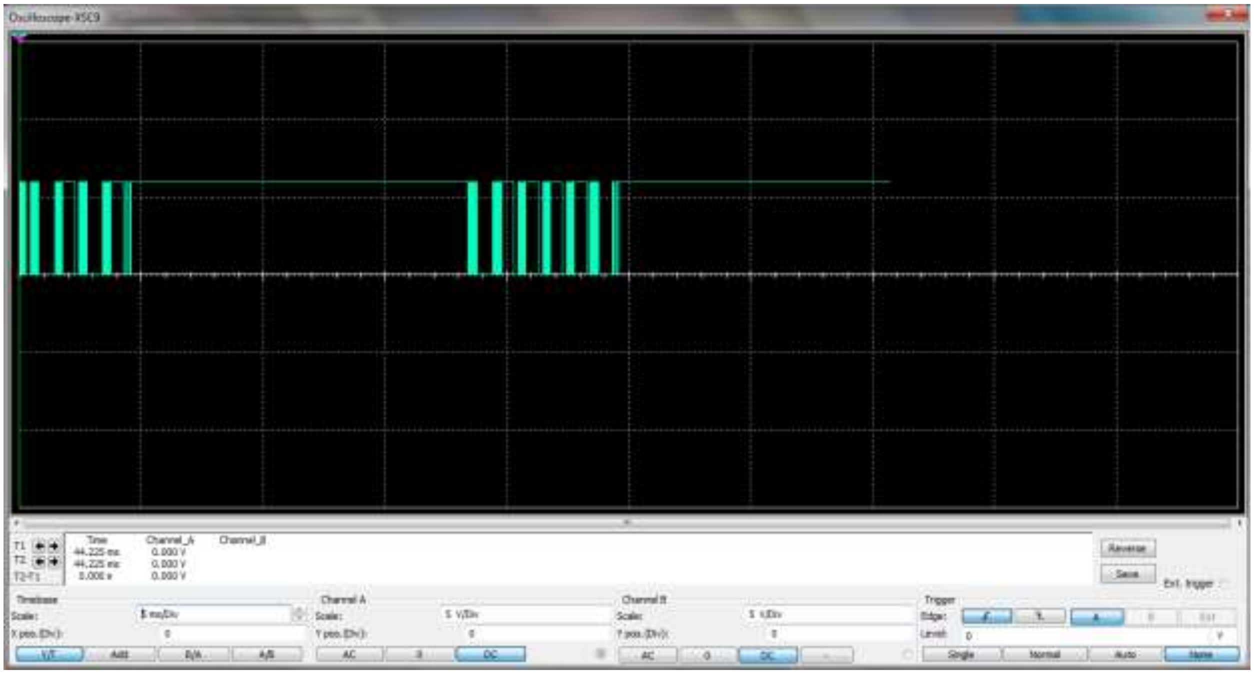

Figure 6: The digital signal after the latch

Output

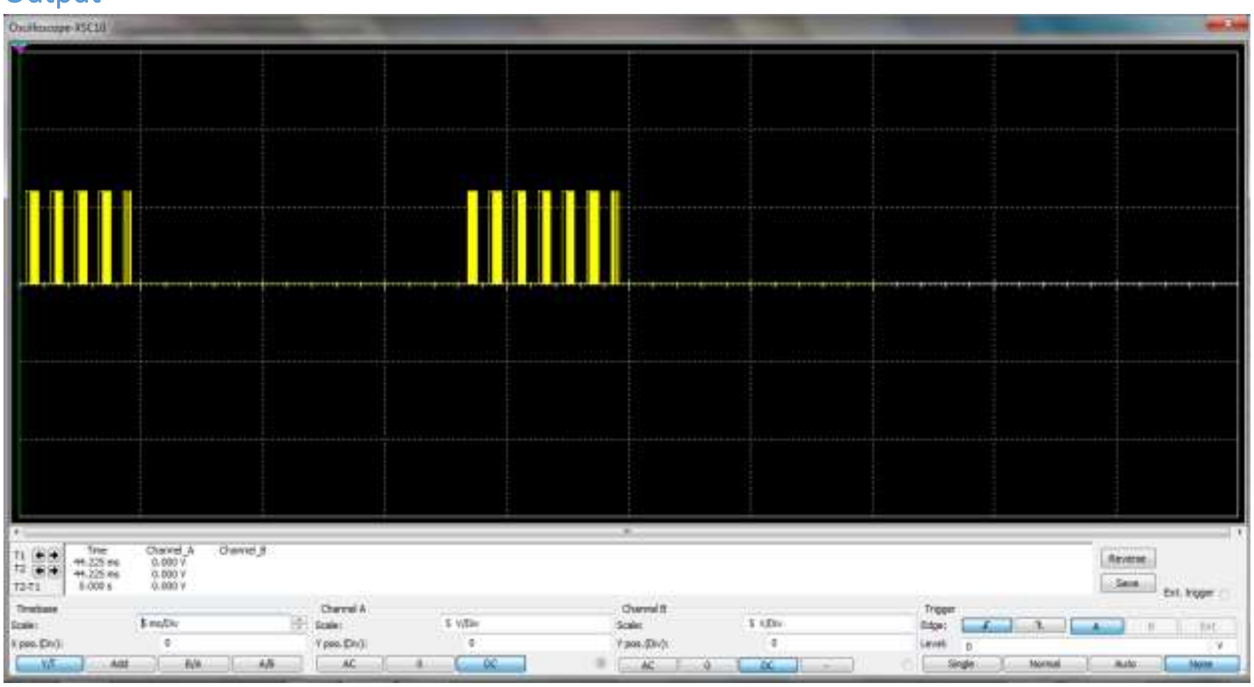

Figure 7: The final digital output

Reconstruction

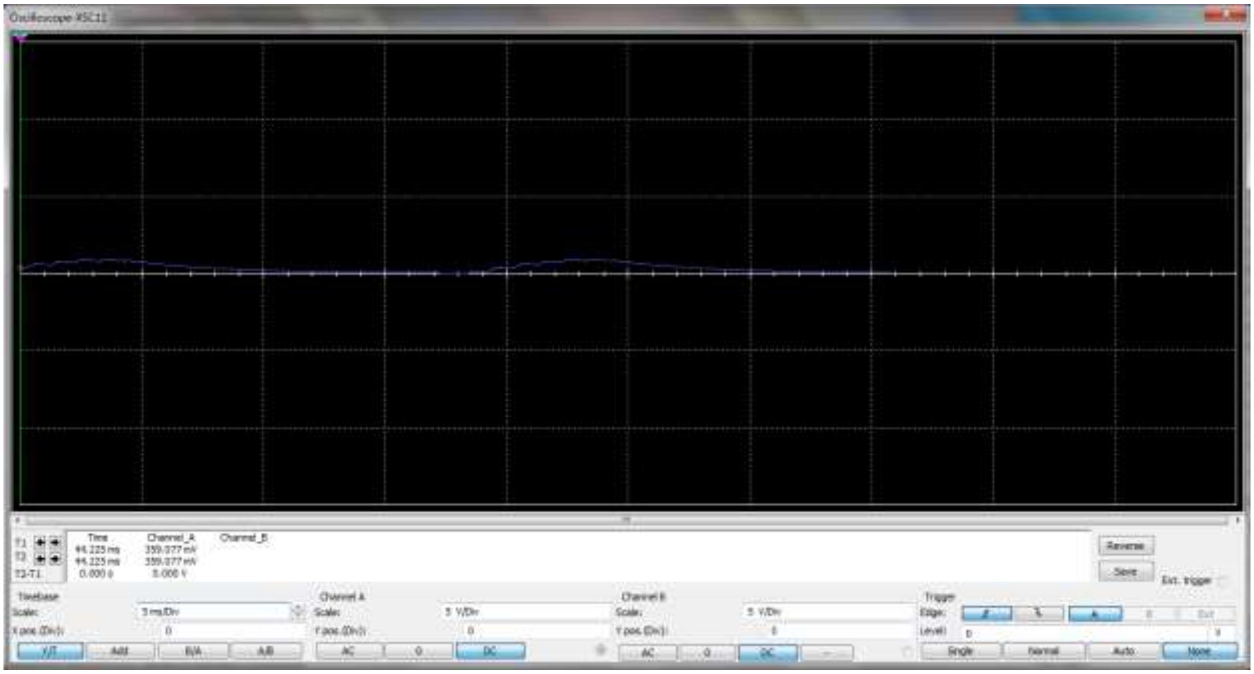

Figure 8: A reconstruction of the digital sine wave using a low pass filter

Discussion

The integrator that was built for our circuit had a capacitor with a value of 1 micro Farad, and a 2 kilo Ohm resistor. The time constant of our integrator equals 0.002.The values of the resistor and capacitor of our integrator were chosen so that the time constant of the integrator would be on the same scale as the period of the input signal. The input frequency was 50-100 Hz, which would give it a period of 1/f which equals 0.01-0.02. When a 10 kilo Ohm resistor was used so that our circuit would be designed with the time constant of the integrator equal to the period of the input voltage, the circuit would produce errors when trying to run. The cause for this error is most likely due to the theoretical error which is apparent in all of the circuit elements.

The clock frequency is what gives us the ability to fully convert our analog input into a digital output. The latch is synchronized with the clock so that whenever the clock transfers from low to high, it records from the comparator either a high or a low. Since the latch works together with the frequency of the clock, the higher the frequency of the clock is, the more precise the data will be as readings will be taken from the comparator more frequently. From experimenting with a range of different frequencies, it can be noticed that if the frequency of the clock drops to lower than double the input frequency, than the circuit does not function properly.

Adjusting the value of the capacitor gives the ability to greatly adjust the cut-off frequency. The cut-off frequency of a low-pass filter equals 1/(2 pi RC). When the frequency is low, the capacitor has some reactance which then forces the current to go through the resistor. When the frequency is high, the amount of reactance which the capacitor has is greatly reduced, and therefore acts as a short circuit allowing the current to not go through the resistor.

When deciding what parts to use, it was first agreed that the most influential part of our decision was to choose parts which would allow our circuit to function to the best of its ability. When there were different parts which were able to be used, the relative tolerance of the part along with its price factored into our choice of which part to use. In order to be able to understand the functionality of the parts, data sheets for each part were downloaded off of the newark website so any necessary information could be accessed.

The simulated circuit meets the design requirements which we were assigned. For these requirements to be made, separated the circuit into its different components so that the complete process could be simplified. After many time and testing was spent on building each component, more time and testing was devoted to the circuit so that the finished product met the expected requirements. In order to further improve our circuit, the next steps would be to have more thorough calculations for the values of all of our parts, as only rough calculations and a lot of trial and error were used in order to get the results. With more accurate values, our circuit would be able to be a much more precise analog to digital converter.

Many four channel oscilloscopes were used to carefully monitor each part of the circuit, so that the process of our circuit could always be watched. We decided to use only oscilloscopes to monitor the results of our circuit as that was the simplest option, since we have already learnt how to operate them as well as knowing how to use many of the different functions which it offers.

Our design could be used in practical application in modern electronic components. These include switched mode power supplies, converters, as well as other components. In order for our design to be implemented, it wold have to be able to meet a lot more of different design criteria. Other criteria which may be necessary to meet include having specific packaging instructions, as well as a specified range for the bandwidth. It may also be required for the converter to have higher resolution, as our design only implements a 1-bit memory.

Conclusion

In conclusion, the design project allowed us to design our own circuit which could be potentially be implemented and useful for many every day applications. Through constantly monitoring results from every junction along our circuit, we were able to see exactly how the transformation took place. Through breaking up the circuit into many parts we were able to see how a large circuit simplifies into smaller parts which we were able to use our built of knowledge to calculate the results of each part individually and then combine them all into our final circuit.