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Department of Electrical, Electronic and Computer Engineering

Stochastic Communication Systems ESC 320

Experiment 1

Source Encoding

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FORM A

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Abstract – A practical experiment studying the use of Delta Modulation for source encoding in voice communication.

Index terms - Delta Modulation, Source Encoding,

I. Introduction

This experiment is to explore how a digital bit stream can transmit an analog signal. For the purpose of this experiment we will explore the simple encoding method known as delta modulation. Delta modulation is a simple differential encoding technique that simply quantizes a signal as bigger than or smaller than the previous sampling instant; "1" representing bigger and "0" smaller. This signal is simply decoded by integrating (adding up) the bit string.

II. Theory

Delta modulation can be seen as a one-bit differential pulse code modulation (DPCM) [1], since it has only two levels. Since the code word is only one bit it doesn't require framing or synchronization making it very easy to implement. In a delta modulator we use I first order predictor in the form of the sample delayed by T_s the sampling interval. This is compared to the input to determine the next bit.

$m_q|k| \quad m_q|k \quad 1| \; | \; d_q|k|$

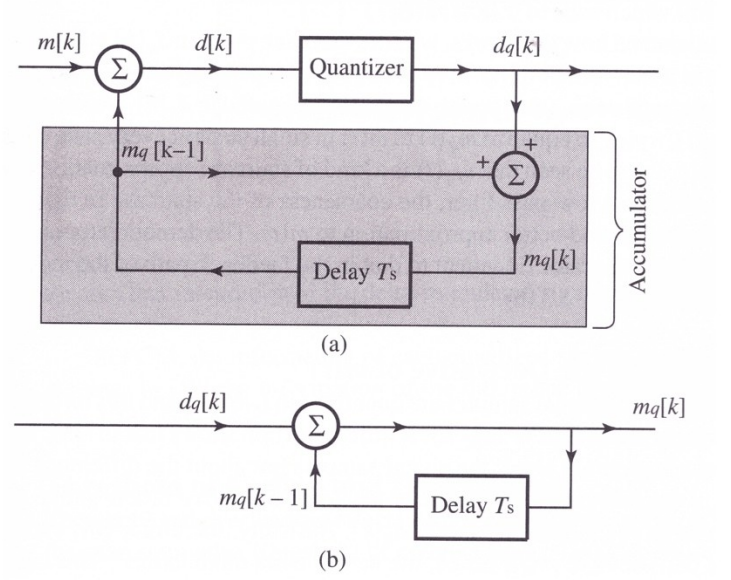


Fig. 1 Delta modulator [1]

The demodulation occurs by summing the terms. The demodulator is esentually a accumulator or integrator. This produces a step like output. The nature of this distortion in the signal is referred to as granular noise. This can be suppressed using a low pass filter, passing the desired operational band and suppressing the higher order noise created by quantization.

$$m_q[k] \quad \sum_{m=0}^{k} d_q[k]$$

To physically realize a delta modulator the predictor is estimated using a RC circuit integrator, a D type flip-flop is used as the memory device and a comparator to compare the predictor to the new sample, thus achieving quantization.

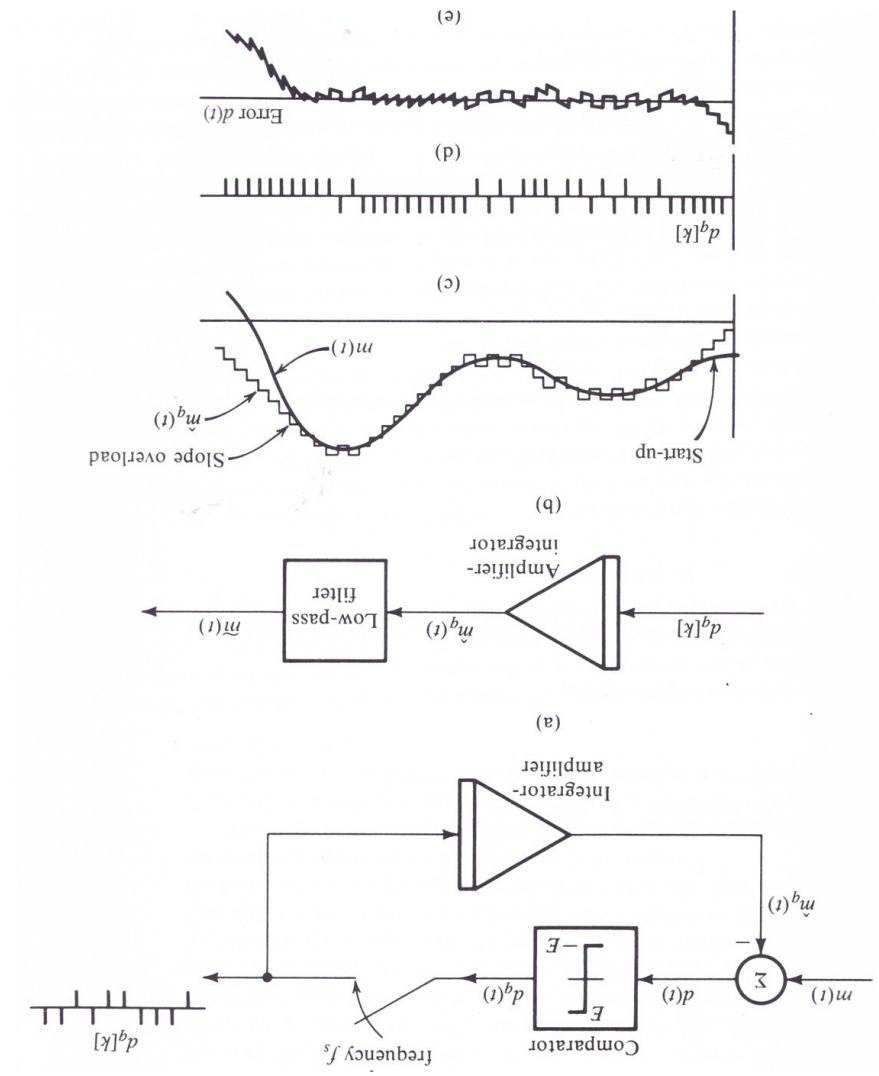


Fig. 2 Delta modulator physical implementation [1]

A delta modulator has its payoff in its simplicity of implementation but at the cost that the signal needs to be sampled at a rate much higher than the Nyquist rate to produce usable fidelity.

To optimize the design of the delta modulator we need to take into account the threshold of the modulator that is the smallest variation in the input signal it can detect. Further overloading needs to be prevented, that is when the signal changes to rapidly for the delta modulator and the output does not follow the input closely. There are two factors that determine the threshold and weather overloading occurs, the input signal magnitude and the step size (sampling interval) of the modulator.

No overload occurs if :

$$|\dot{m}(t)| < \Delta f_s$$

Where Δ is the step size and f_s is the sampling frequency.

Considering all signals can be represented as harmonics of sinusoidal signals we conclude that:

$$A_{max} \approx \frac{E f_s}{\omega_\gamma}$$

Where ω_γ is the bandwidth of the signal type, commonly accepted as $2\pi \times 3kHz$

These limits can be improved by using Sigma-Delta modulation or adaptive Delta modulation.

Sigma-Delta modulation introduces pre-emphasizing of the signal by moving the integrator:

- Decreasing accumulation of quantization noise.
- Soothes the signal so overloading is less likely.
- The demodulator is simplified to a simple low pass filter.

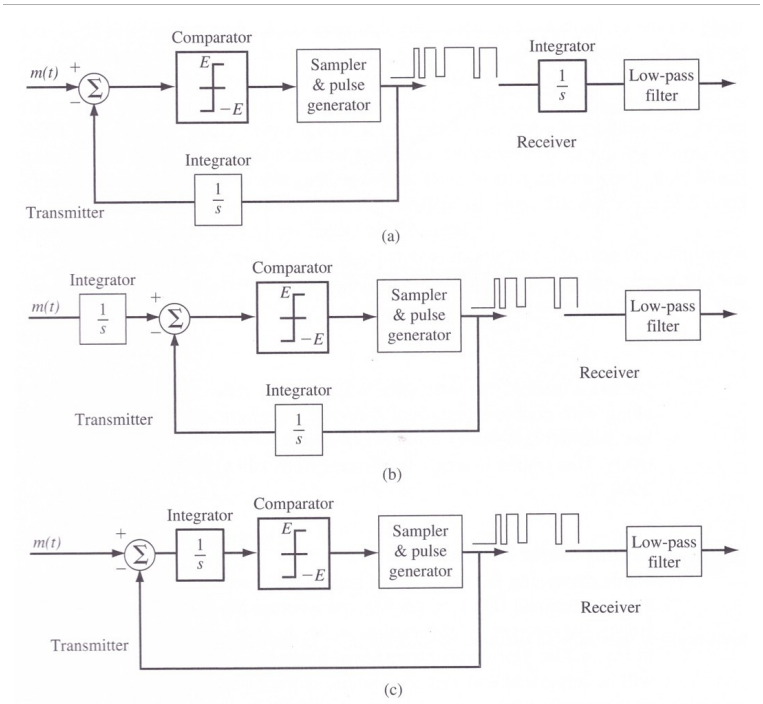


Fig. 3 Delta-Sigma Modulator [1]

Design

The design of this circuit has two elements that make it unique, the integrator and filter, all other elements are as shown in the study guid.

A. Integrator Calculation:

Calculate for f_m= 5kHz and f_D= 20kHz

S_{eff} = 1.57

$T_D/RC=0.127$ where $T_D= 1/f_D$

$\therefore$ RC= $2.924x10^{-4} \approx 0.3x10^{-3}$

Choose

R=1k
C=0.3uF

Or

R=2.7K
C=0.1uF=100nF

B. Filter Calculation:

A second order low pass filter is designed for 3kHz for a voice signal. Using the well known sullen key configuration.

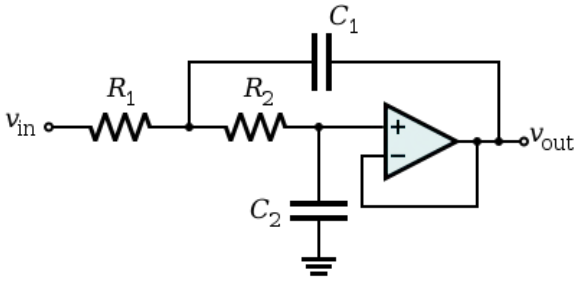


Fig. 4 Sullen Key low pass filter

$$\omega_0 \quad 2\pi f_0 \quad \frac{1}{\sqrt{R1R2C1C2}}$$

Choose $C2 \quad C1 \quad 10uf$

$$2\times\pi\times3000 \quad \frac{1}{\sqrt{R1\times R2\times 10^{-6}\times 10^{-6}}}$$

$$R1\times R2 \quad \frac{\left(\frac{1}{2\times\pi\times3000}\right)^2}{10^{-12}} \quad 2.8k\Omega$$

$$R1 \quad R2 \quad 1.4k\Omega$$

III. Simulation

Analyse the Delta-PCM modulator in Appendix 1. Use MATLAB to generate and plot all the waveforms at the critical points in Figure 6.33-3 below

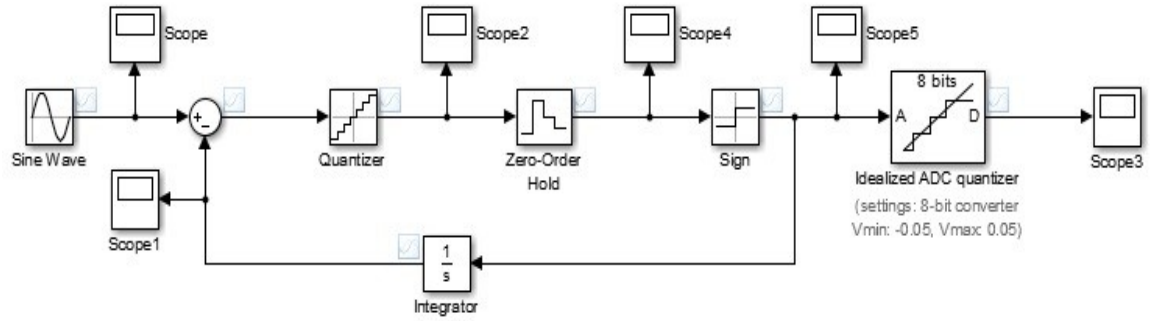


Fig. 5 Simulink model of Appendix 1

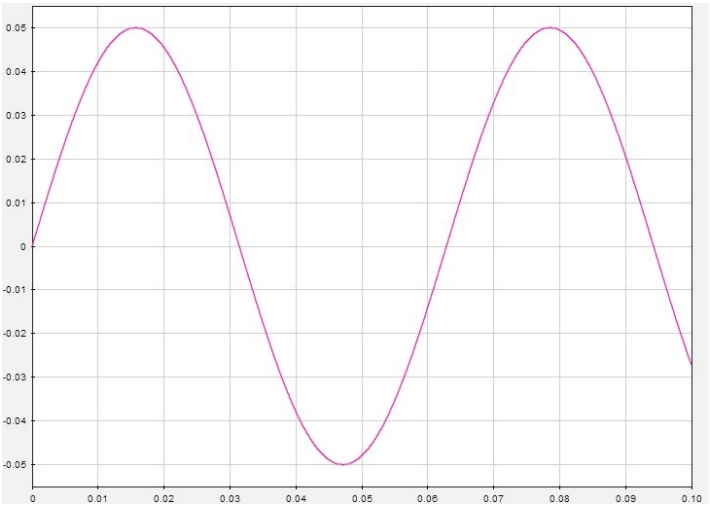


Fig. 6 Input sinusoidal signal with amp: 0.05 frequency: 100Hz

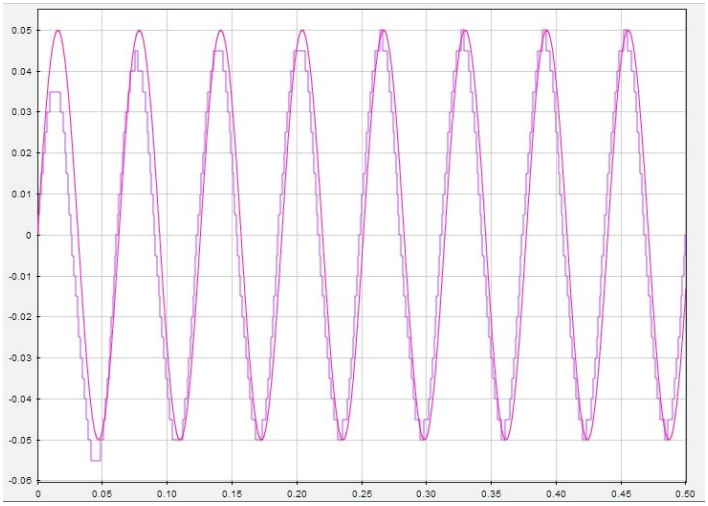


Fig. 7 Input signal compared with quantized signal

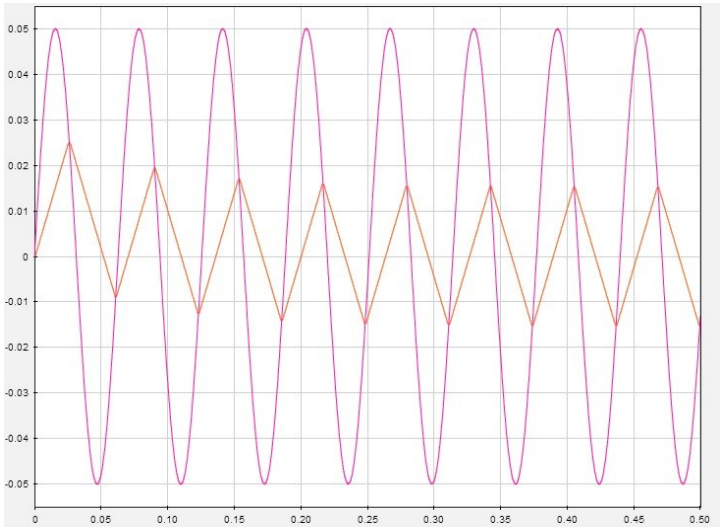


Fig. 8 Input signal compared with Integrator

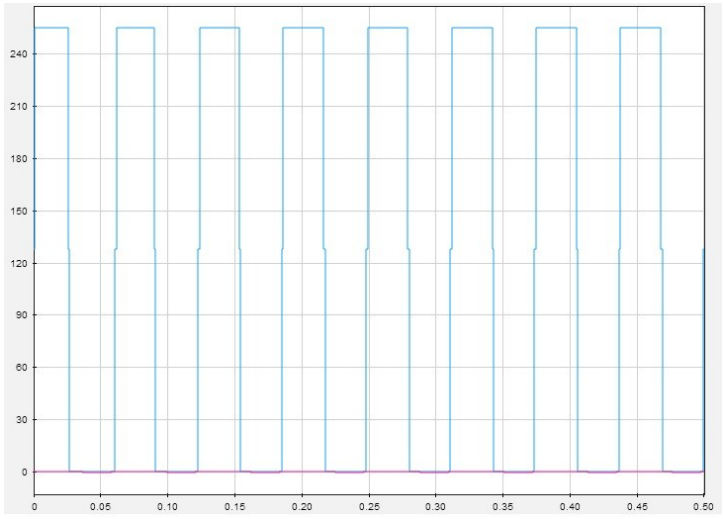


Fig. 9 Input signal compare with ADC converter

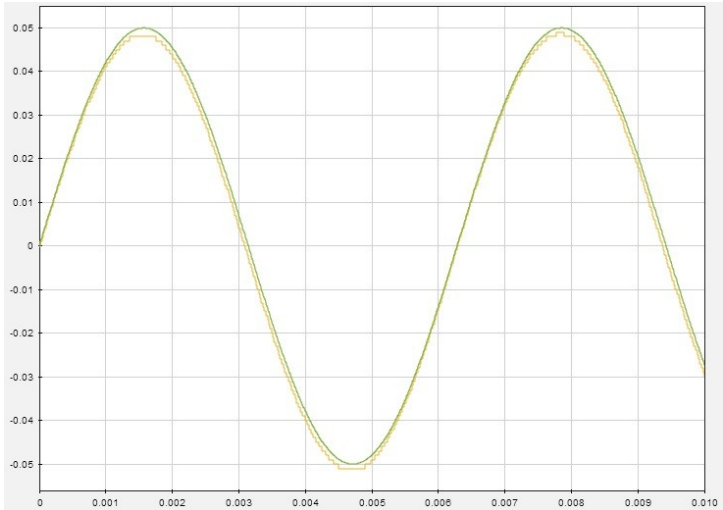


Fig. 10 Input signal (1kHz) compared with quantized signal

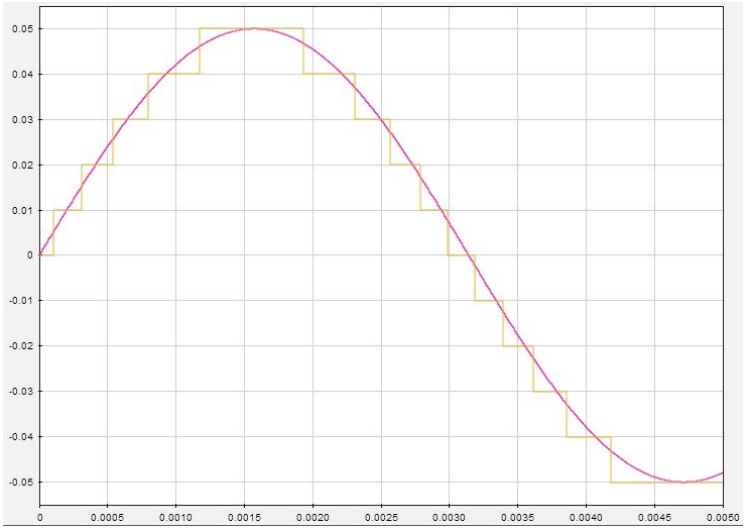


Fig. 11 Input signal (1kHz) compared with quantized signal (granular noise)

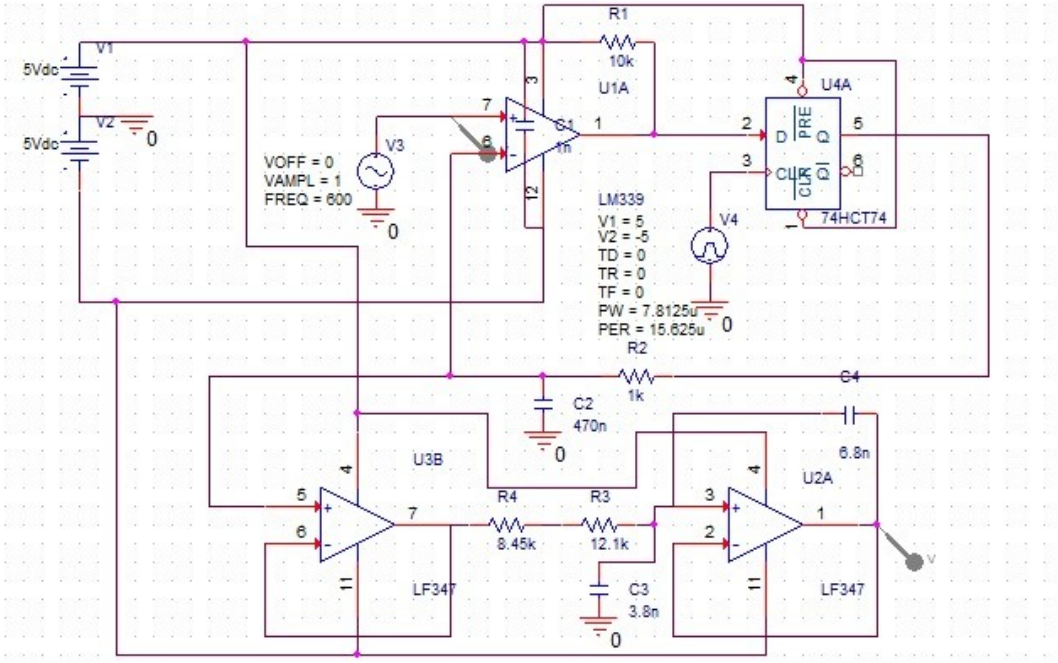


Fig. 12 Schematic diagram of circuit

IV. Results

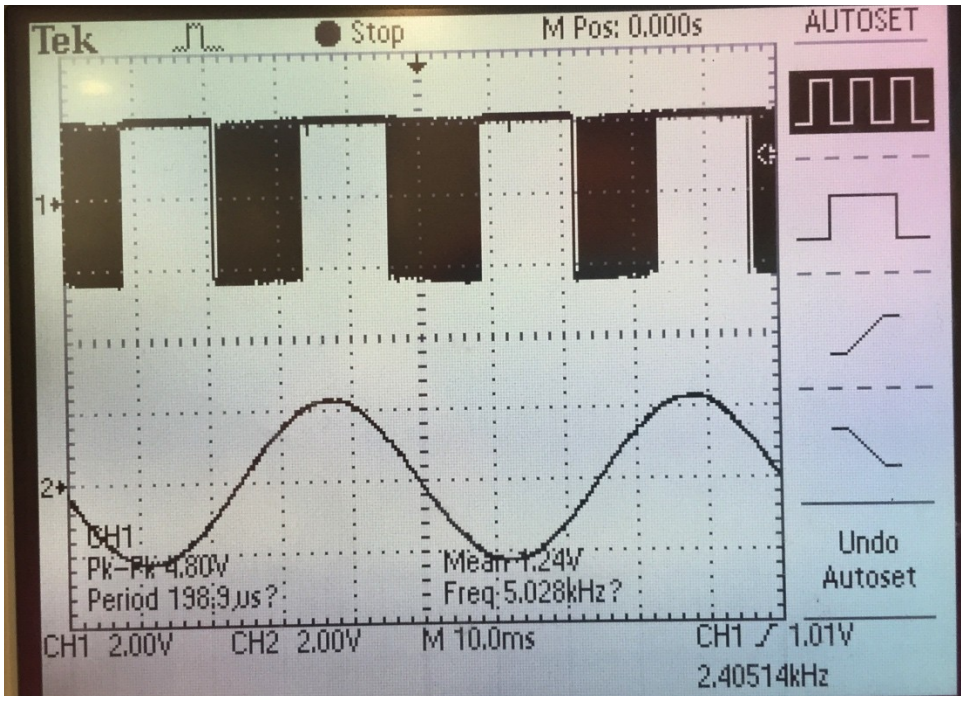


Fig. 13 Input signal and Bit stream

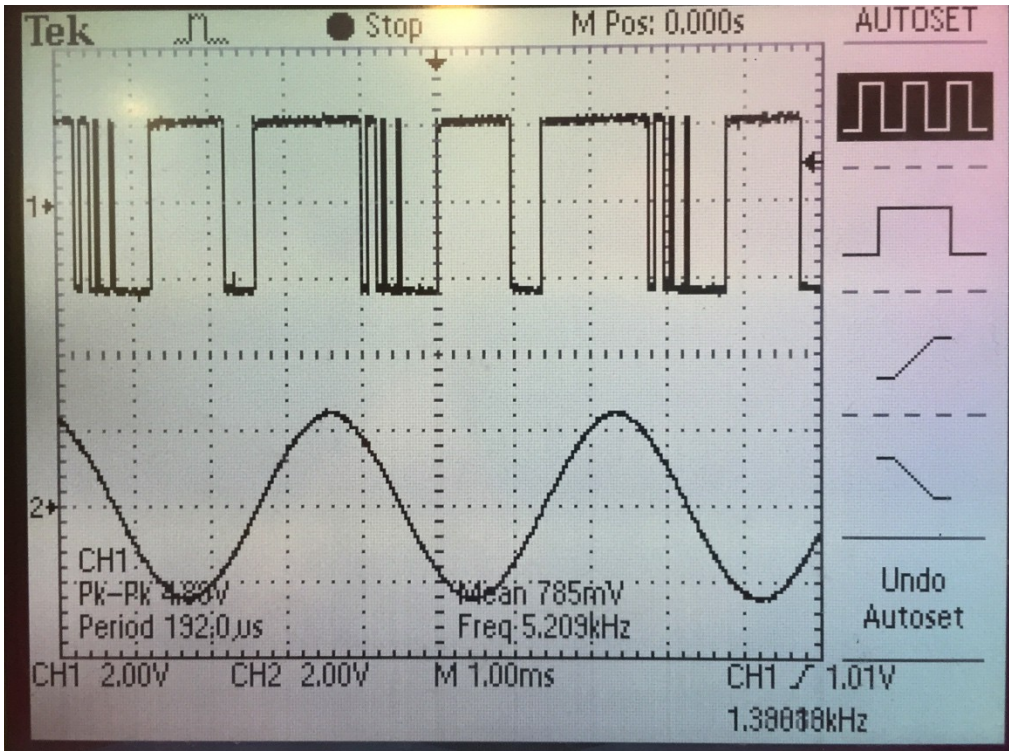


Fig. 14 Input signal of higher frequency and bit stream

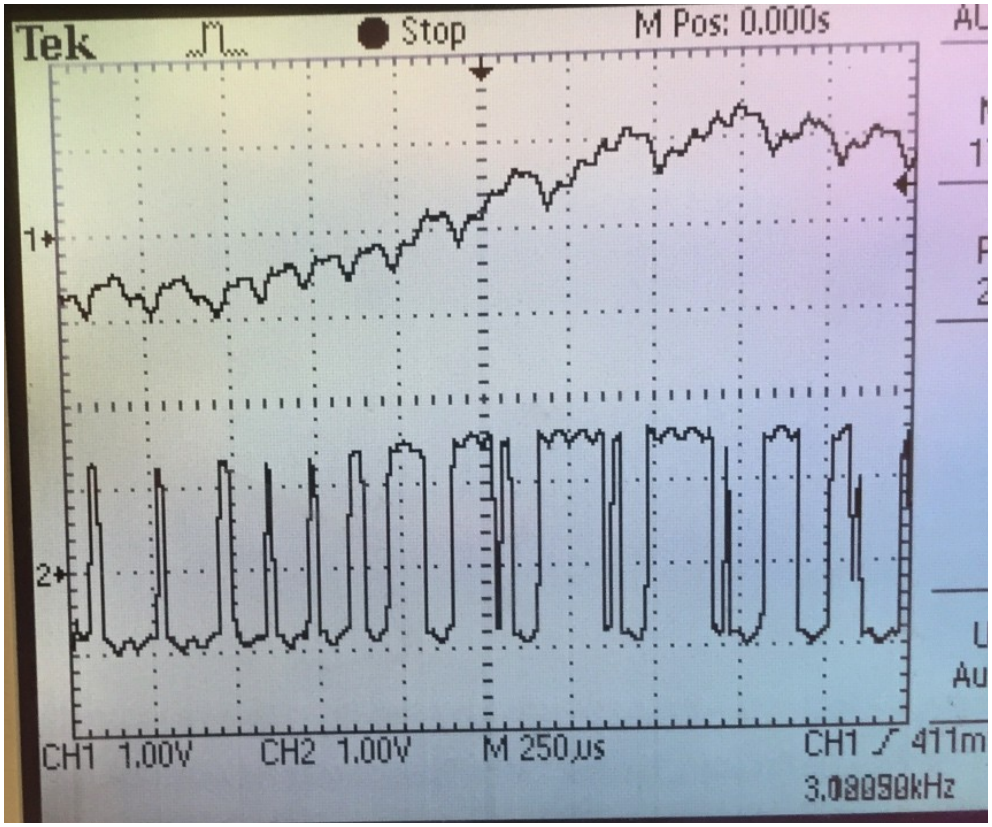


Fig. 15 Comparator and integrator output

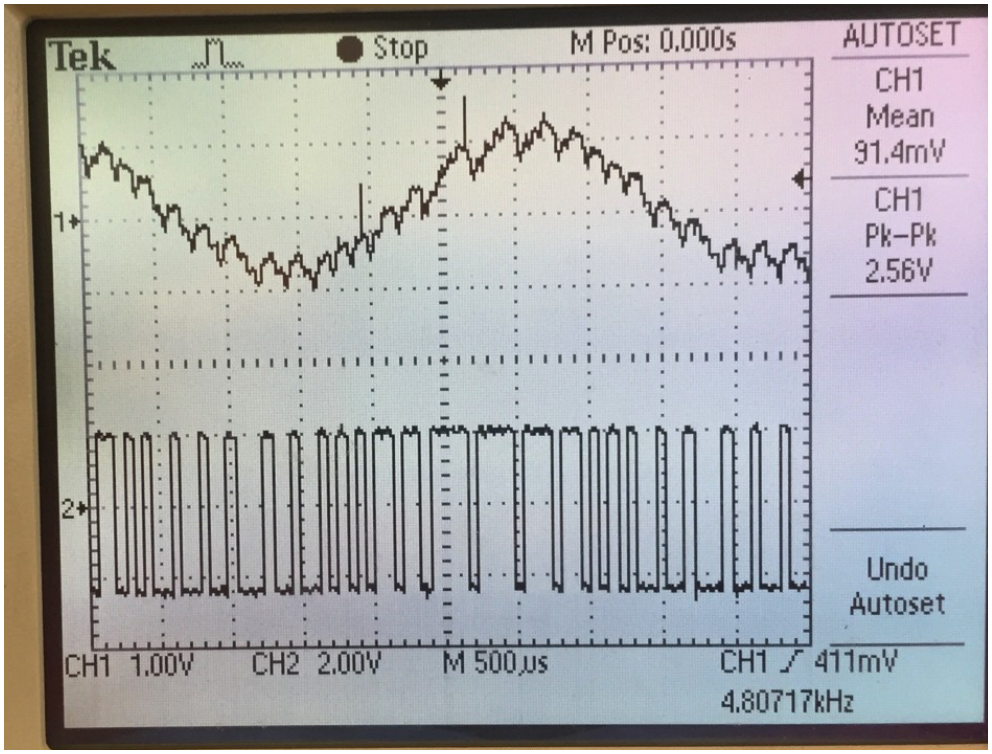


Fig. 16 Integrator output and bit stream

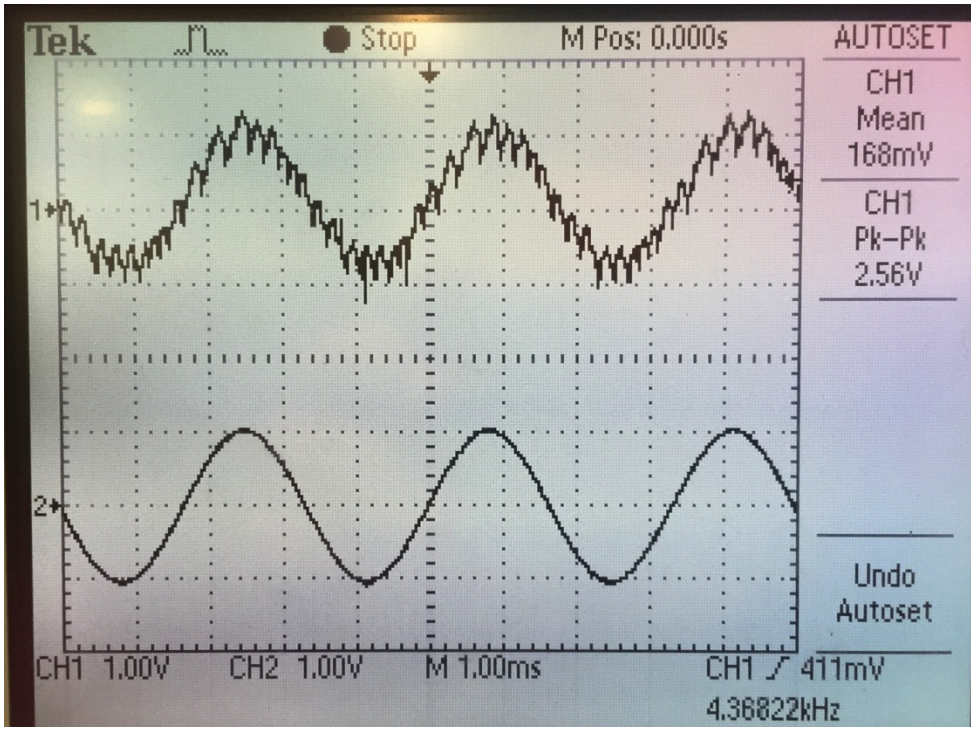


Fig. 17 Integrator output showing granular noise and original input

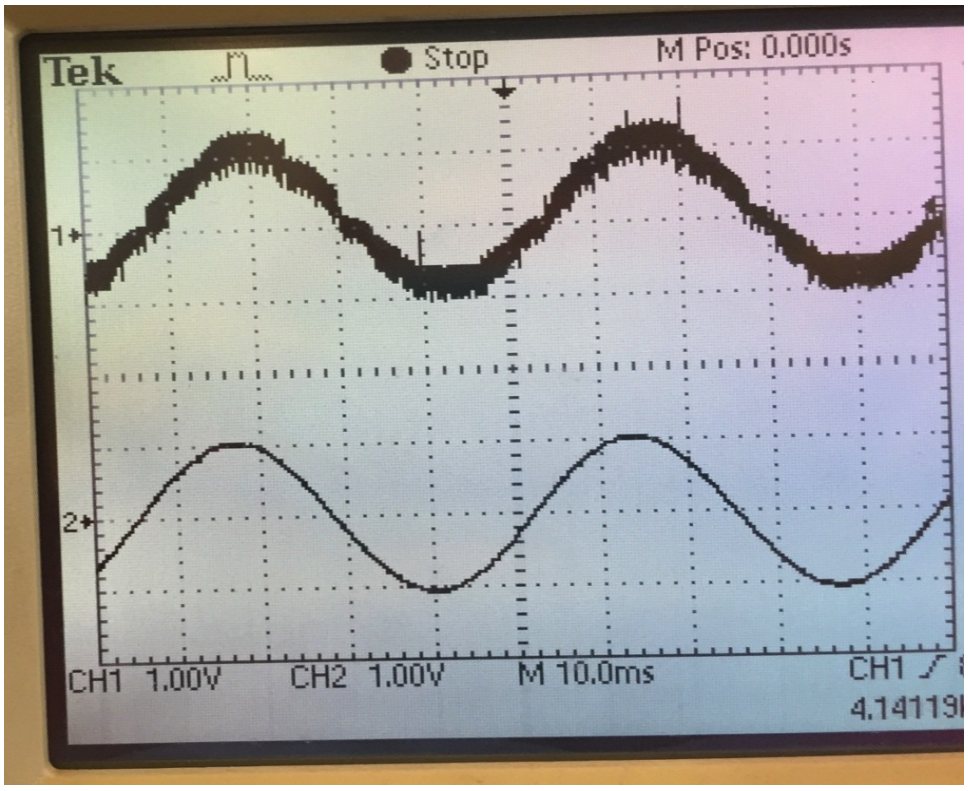


Fig. 18 Input signal and filtered output signal

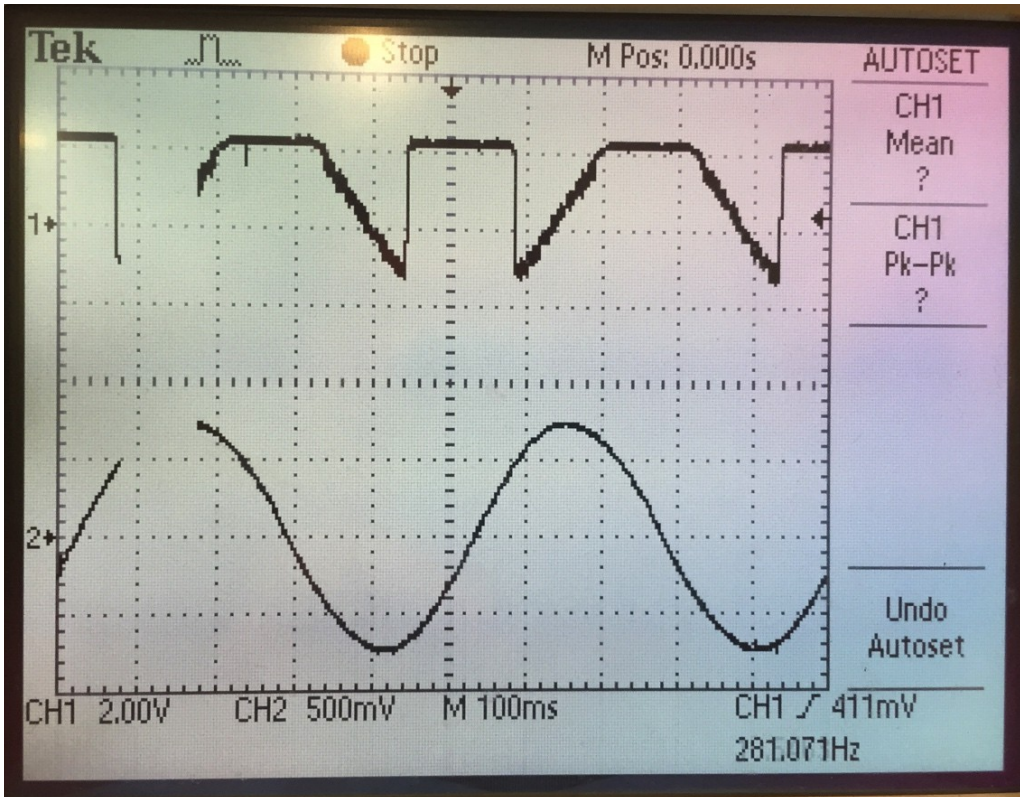


Fig. 19 A large amplitude input signal causes slope overload and saturation

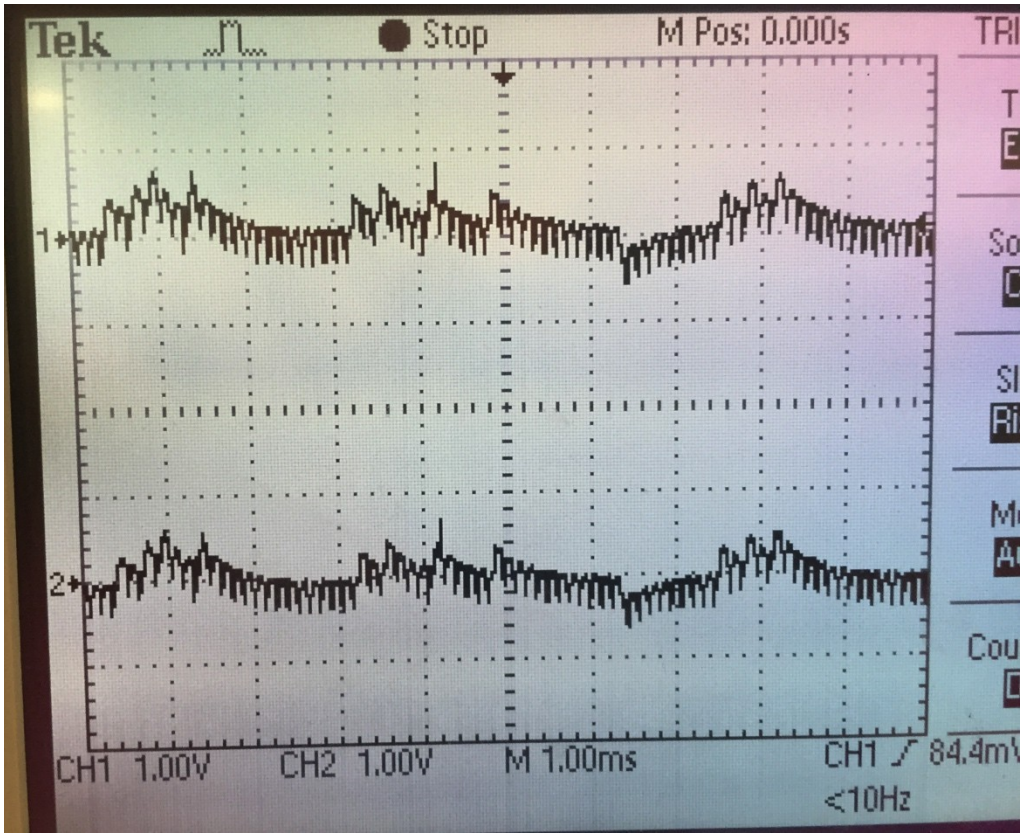


Fig. 20 Actual voice signal showing identical input and output waveforms

V. Discussion

The simulated and actual result compare well showing the design specifications have been met and the results are satisfactory.

VI. Conclusion

This experiment proves that the method of delta modulation is indeed an effective means of coding a voice signal to a digital form that can be suitably transmitted in a digital communications channel. Its simplicity makes it very practical but it is not ideally bandwidth efficient using much more than the minimum Nyquist bandwidth.

References

[1] B.P. Lathi and Z. Ding, Modern Digital and Analog Communication Systems, 4th ed., Oxford University Press, 2010