EXPERIMENT 3: DELTA MODULATION & DEMODULATION, ADAPTIVE DELTA MODULATION & DEMODULATION

Objective:

Introduction to basic delta modulation and demodulation, and adaptive delta modulation as a variation of the basic delta modulation.

Equipment:

- Multiplier Module
- Delta Modulation Utilities Module
- Delta Demod Utilities Module
- Variable DC Module
- Adder Module
- Buffer Amplifier Module
- Tunable LPF Module
- Oscilloscope

General Information:

**Basic Delta Modulation:**

*Delta modulation* is a simplified PCM. The output of a delta modulator is a bit stream of samples, at a relatively high rate the value of each bit being determined according as to whether the input message sample amplitude has increased or decreased relative to the previous sample. It is an example of *differential pulse code modulation (DPCM).*

The operation of a delta modulator is to periodically sample the input message, to make a comparison of the current sample with that preceding it, and to output a single bit which indicates the sign of the difference between the two samples. This in principle would require a sample-and-hold type circuit. **Figure 3.1** illustrates the basic system in block diagram form.

![Figure 3.1 Basic Delta Modulator](image-url)
The system is in the form of a feedback loop. It is a continuous time to discrete time converter. In fact, it is a form of analog to digital converter. The sampler block is clocked. The output from the sampler is a bipolar signal, in the block diagram being either \( \pm V \) volts. This is the delta modulated signal, the waveform of which is shown in Figure 3.2. It is fed back, in a feedback loop, via an integrator, to a summer. The integrator output is a sawtooth-like waveform as shown in Figure 3.2.

![Figure 3.2 Integrator Output Superimposed on The Message with The Delta Modulated Signal below](image)

The sawtooth waveform is subtracted from the message and the difference – an error signal – is the signal appearing at the summer output. An amplifier is shown in the feedback loop. This controls the loop gain and the size of the ‘teeth’ of the sawtooth waveform. The signal from the integrator, which is a sawtooth approximation to the message, is adjusted with the amplifier to match it as closely as possible.

The binary waveform illustrated in Figure 3.2 is the signal transmitted. This is the delta modulated signal. The integral of the binary waveform is the sawtooth approximation to the message. Lowpass filtering of the sawtooth (from the demodulator) gives a better approximation to the message. But there will be accompanying noise and distortion, products of the approximation process at the modulator.

The unwanted products of the modulation process, observed at the receiver, are of two kinds. These are due to ‘slope overload’ and ‘granularity’.

**Slope overload** occurs when the sawtooth approximation cannot keep up with the rate-of-change of the input signal in the ranges of greatest slope. The step size is reasonable for those sections of the sampled waveform of small slope, but the approximation is poor elsewhere. This is ‘slope overload’, due to too small a step and is illustrated in Figure 3.3.
To reduce the possibility of slope overload the step size can be increased (for the same sampling rate). This is illustrated in Figure 3.4. The sawtooth is better able to match the message in the regions of steep slope.

An alternative method of slope overload reduction is to increase the sampling rate. This is illustrated in Figure 3.5, where the rate has been increased by a factor of 2.4 times, but the step is the same size as in Figure 3.3.

Referring to Figure 3.3, the sawtooth follows the message being sampled quite well in the regions of small slope. To reduce the slope overload the step size is increased as shown in Figure 3.4, and this time, the match over the regions of small slope has been degraded. The degradation shows up, at the demodulator, as increased quantizing noise, or ‘granularity’.
Adaptive Delta Modulation:

There is a conflict between the requirements for minimization of slope overload and the granular noise. The one requires an increased step size, the other a reduced step size. There is a way to overcome this problem which adjusts the step size according to the slope of the signal being sampled. This is a variation of the basic delta modulation and is called the adaptive delta modulation.

A large step size is required when sampling those parts of the input waveform of steep slope. But a large step size worsens the granularity of the sampled signal when the waveform being sampled is changing slowly. A small step size is preferred in regions where the message has a small slope. This suggests the need for a controllable step size – the control being sensitive to the slope of the sampled signal. This can be implemented by an arrangement such as is illustrated in Figure 3.6.

![Figure 3.6 Adaptive Delta Modulator Block Diagram](image)

The gain of the amplifier is adjusted in response to a control voltage from the sampler, which signals the onset of slope overload. The step size is proportional to the amplifier gain. Slope overload is indicated by a succession of output pulses of the same sign. The sampler monitors the delta modulated signal, and signals when there is no change of polarity over 3 or more successive samples. The actual Adaptive Control signal is +2 volt under ‘normal’ conditions, and rises to +4 volt when slope overload is detected. The gain of the amplifier, and hence the step size, is made proportional to this control voltage. Provided the slope overload was only moderate the approximation will ‘catch up’ with the wave being sampled. The gain will then return to normal until the sampler again falls behind.

The Voltage Controlled Amplifier - VCA can be modeled with a multiplier. This is shown in Figure 3.7. The control in this figure is shown as a DC voltage. This may be set to any value in the range ±V_{max}. Beyond V_{max}, the multiplier will overload.

![Figure 3.7 The Voltage Controlled Amplifier](image)
In the TIMS, the DELTA MODULATION UTILITIES module has a socket labeled ADAPTIVE OUTPUT. The signal from this socket is at a level of either +2 or +4 volts. The lower output is called the ‘normal level’. If at any time the delta modulated signal contains three or more consecutive samples of the same size then this signal goes to the higher (+4 volt) level. Three or more consecutive samples of the same level indicates slope overload. When including the VCA in the feedback path, it must be ensured that at no time will either of the inputs to the MULTIPLIER exceed its safe (ie, linear) operating range (±5 volts absolute maximum).

**Basic Delta Demodulation:**

The principle of the demodulator is shown in block diagram in Figure 3.8. It performs the reverse of the process implemented at the modulator.

![Demodulator Block Diagram For Delta Modulation](image)

The sampler, which is clocked at the same rate as the one at the modulator, outputs a bi-polar signal (±V volts). The integrator generates a saw tooth-like waveform from this. This is an approximation to the original message.

The saw tooth waveform contains information at the message frequency, plus unwanted frequency components (quantizing noise). The unwanted components which are beyond the bandwidth of the original baseband message are removed by a lowpass filter. Those unwanted components which remain are perceived as noise and distortion. Unlike ideal sampling of an analog signal, and ideal reconstruction with a lowpass filter, the reconstruction of the message from a delta modulator is not perfect.

The TIMS DELTA DEMOD UTILITIES module is used for demodulation (the receiver). It contains a sampler and an integrator. The sampler uses a clock stolen from the modulator (the transmitter). The sampler accepts TTL signals as input, but gives an analog output for further processing (e.g., lowpass filtering).

**Procedure:**

1. Build the circuit shown as a block diagram in Figure 3.1. Use 100 kHz TTL as the CLK for the required modules. Use a 2 kHz sine wave as the message signal. Cross connect (1st input from system, 1st output to 2nd input, 2nd output to system) the amplifier for strongly controllable amplifying.
2. You should get a view as shown in Figure 3.2 in two display steps. Observe and sketch on a scope sheet.
3. Change the step size and the sampling rate of the delta modulated output one by one. Observe and draw the resulting waveforms and write the modifications you did to get these waveforms for each case.

4. Demodulate the Delta Modulated signal obtained in step 1. Sketch the resulting waveform with respect to its digital data.

5. Build the adaptive delta modulation circuit shown in Figure 3.6. Repeat step 2 for this configuration.

6. Demodulate this Adaptive Delta Modulated signal. Sketch the resulting waveform with respect to its digital data.