

ADAPTIVE DELTA MODULATION

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ADAPTIVE DELTA MODULATION

ACHIEVEMENTS: introduction to a variation of the basic delta modulator, which adjusts the step size according to the slope of the signal being sampled

PREREQUISITES: completion of the experiments entitled *Delta modulation* and *Delta demodulation* in this Volume.

ADVANCED MODULES: DELTA MODULATION UTILITIES; DELTA DEMOD UTILITIES; WIDEBAND TRUE RMS METER optional.

PREPARATION

background

It is assumed that you have been introduced to the principles of adaptive delta modulation in your course work.

TIMS adaptive delta modulator

The basic delta modulator was studied in the experiment entitled *Delta modulation*. It is implemented by the arrangement shown in block diagram form in Figure 1.

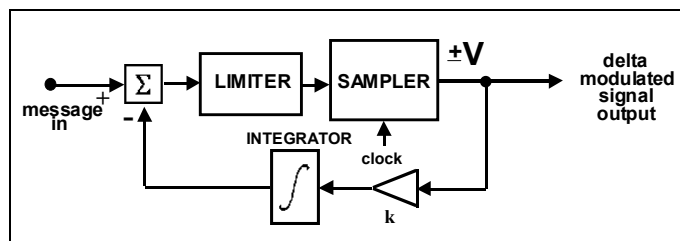


Figure 1: basic delta modulator

You will remember that with this modulator there was a conflict when determining the step size.

A large step size was required when sampling those parts of the input waveform of steep slope. But a large step size worsened the granularity of the sampled signal when the waveform being sampled was 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 2.

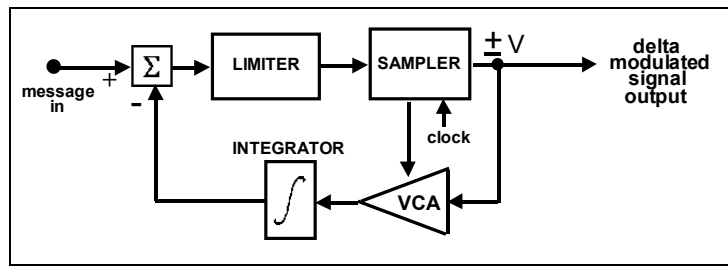


Figure 2: an adaptive delta modulator

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. This was observed in an earlier experiment.

Slope overload is indicated by a succession of output pulses of the same sign.

The TMS 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.

Much work has been done by researchers in this area, and sophisticated algorithms have been developed which offer significant improvements over the simple system to be examined in this experiment.

the voltage controlled amplifier - VCA

The VCA can be modelled with a MULTIPLIER. This is shown in Figure 3.

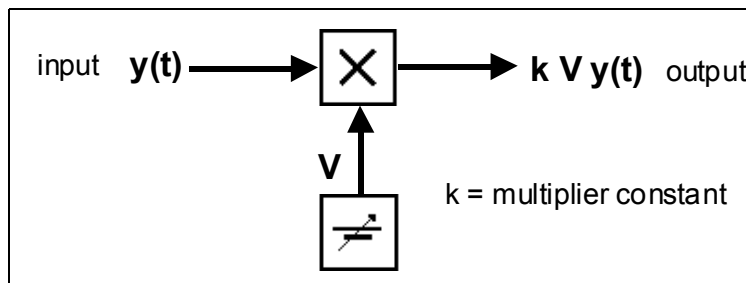


Figure 3: the voltage controlled amplifier

The control in Figure 3 is shown as a DC voltage. This may be set to any value in the range $\pm V_{\max}$. Beyond V_{\max} the MULTIPLIER will overload. However, the control voltage need not be DC, but can be time varying. Under these conditions the arrangement is more likely to be called a modulator.

You have met the MULTIPLIER constant, 'k', in earlier experiments of Part I, where it was defined and measured.

EXPERIMENT

The block diagram of Figure 1 was modelled in the experiment entitled *Delta modulation*. Refer to that experiment for details.

The adaptive delta modulator of Figure 2 differs only by the addition of a voltage controlled amplifier (VCA), modelled, as described above, with a MULTIPLIER.

the adaptive control voltage

The DELTA MODULATION UTILITIES module has a socket labelled ADAPTIVE OUTPUT. The signal from this socket is at a level of either +2 or +4 volts. The lower output is what might be 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 level¹. Three or more consecutive samples of the same level indicates slope overload.

When including the VCA in the feedback path you must ensure that at no time will either of the inputs to the MULTIPLIER exceed its safe (ie, linear) operating range (say ± 5 volts absolute maximum).

VCA calibration

Before setting up the delta modulator, it is wise to familiarise yourself with the operation of the VCA.

T1 set up a VCA according to the block diagram of Figure 3. Use the VARIABLE DC module as a control signal, and a sinewave as input. Connect each via a BUFFER amplifier so that the values of $V_{max/x}$ and $V_{max/y}$ can be determined. These are the overload levels for each of the inputs. They are likely to be similar. Select DC coupling with the front panel switch of the MULTIPLIER.

T2 measure the VCA gain for a control voltage of +2 volt. This is the 'normal' output from the ADAPTIVE CONTROL of the DELTA MODULATOR UTILITIES module.

Your measurements should have shown that the MULTIPLIER can accept inputs considerably in excess of the TMS ANALOG REFERENCE LEVEL before overload sets in.

¹ more details in the *TIMS Advanced Modules User Manual*.

Likewise, the INTEGRATOR input can, under some conditions, be subject to quite large input signals; but it is robust and can also handle input amplitudes well in excess of the TIMS ANALOG REFERENCE LEVEL.

You will notice that, except for the presence of the MULTIPLIER in the feedback loop, the modulator is the same as that studied in the experiment entitled *Delta modulation*. You should use the same setting up procedure as in that experiment, with the adaptive control inhibited. This is done by connecting +2 volt in place of the ADAPTIVE CONTROL voltage to the MULTIPLIER.

manual control

*T3 model the block diagram of Figure 1. This is not the adaptive modulator. Refer to the experiment entitled **Delta modulation** for details. The amplifier in the feedback loop is modelled with two BUFFER amplifiers in cascade.*

T4 observe the two inputs to the SUMMER. Adjust the feedback gain so that the sawtooth shows some evidence of (ie, moderate) slope overload.

T5 observe the control voltage from the ADAPTIVE CONTROL output socket. It will be alternating between V_1 (no slope overload) and V_2 volt (following the onset of, and coincident with, the slope overload). Record the value of V_1 (about 2 volt).

T6 insert the VCA between the SAMPLER and the BUFFER AMPLIFIER. Set the control voltage to the VCA to V_1 volts, obtained from the VARIABLE DC supply.

T7 observe the two inputs to the SUMMER. These should be exactly the same as observed during Task T4. The slope overload should, therefor, be apparent as before.

stability

There are now three amplifiers in the feedback loop. At the best of times this could be a cause for concern - the stability of the whole system could be compromised. Refer to the Appendix to this experiment for further comment.

adaptive control

The VCA is now set up in the feedback loop, but is currently in a passive mode.

You are now ready to implement adaptive control of the loop gain by replacing the fixed control voltage V_1 with the adaptive control voltage from the modulator.

What you will want to observe is the reduction of the length of the period of the slope overload.

T8 while watching the length of the slope overload portion of the sawtooth waveform from the INTEGRATOR, replace the DC voltage from the VARIABLE DC supply to the VCA with the ADAPTIVE CONTROL voltage from the modulator.

T9 replace the DC control voltage with the ADAPTIVE CONTROL from the SAMPLER. Notice that the slope overload remains as for the conditions of the previous Task when the control voltage was +4 volt, but that the granularity at the extrema of the message has **not** been worsened.

To change between adaptive and non-adaptive operation move the patch cord from the ADAPTIVE CONTROL output socket of the SAMPLER to the preset (V_1) output of the VARIABLE DC module.

T10 spend some time examining the waveforms at the various interfaces. As necessary, replace the ADAPTIVE CONTROL voltage with the manual (DC voltage) control. Don't forget to monitor the ADAPTIVE CONTROL voltage itself. In other words, make sure you make enough observations to appreciate what is happening.

T11 use a 'complex message', as described in the experiment entitled **Delta modulation**, and compare results (by visual inspection of the INTEGRATOR output waveform) with and without the adaptive feedback operating.

You should now be reasonably confident, from your observations at the modulator (transmitter), that the adaptive feedback control will improve the performance of the system as observed at the demodulator (receiver).

Thus it might be agreed that the object of the experiment has been achieved.

For positive verification, however, it is necessary to build a demodulator and make some further observations.

demodulation

It is essential that you have already completed the experiment entitled *Delta demodulation*. This introduced methods of noise and distortion measurement, which are required now.

You should now model a delta demodulator, as described in the experiment entitled *Delta demodulation*.

Whilst absolute measurement of signal to noise-plus-distortion ratio (SNDR) measurements are of interest, of greater interest in the present situation is to observe the change to the demodulated waveform which happens when the adaptive feedback is introduced. This is a qualitative measurement but nonetheless very instructive.

The setting up procedure at the demodulator will be somewhat similar to that used at the modulator.

Of interest will be a measurement to resolve the question: *is it necessary to make the demodulator adaptive in the same manner as at the modulator? Is there a penalty for not doing so?*

T12 set up a demodulator. Use a complex message. Observe recovered waveforms under various conditions.

TUTORIAL QUESTIONS

Q1 make a positive statement about how your observations at the modulator confirmed that the ADAPTIVE CONTROL 'improved' the performance of the modulator.

APPENDIX

loop stability

You are working with a feedback loop. At the best of times these can run into instability if the loop gain is too high. Some of this instability can be caused by unplanned for phase changes round the loop.

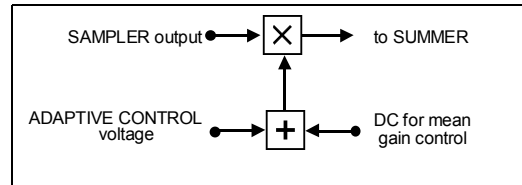


Figure 4: gain modification using VCA

The presence of two BUFFER amplifiers in cascade does not help the situation. These were placed there in the non-adaptive modulator as a convenient method of changing the loop gain.

Now there is an extra source of phase change introduced by the VCA, and also a new source of gain adjustment. If it turns out that the gain provided by the two BUFFER amplifiers is near unity it might be prudent to remove them.

Small gain adjustment could be introduced by the scheme illustrated in Figure 4. This scheme has not been included in any of the Tasks. If you elect to use it, then modify the instructions accordingly.