PWM AND PPM

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ACHIEVEMENTS: *generation and demodulation of pulse width modulated (PWM) and pulse position modulated (PPM) signals.*

PREREQUISITES: *completion of the experiment entitled* ***The sampling theorem*** *(Volume A1). It would be an advantage if the experiment entitled* ***Sampling with SAMPLE & HOLD*** *(Volume D1) has also been completed.*

ADVANCED MODULES: *INTEGRATE & DUMP*

PREPARATION

general philosophy

It has been shown that an analog message can be converted to a pulse amplitude modulated (PAM) signal, and the message recovered from it, with tolerable distortion, by simple lowpass filtering.

For example, see a suitable Text book, or the experiment entitled *Sampling with SAMPLE & HOLD*.

Suppose a train of rectangular pulses exists, of fixed width, and at the same pulse rate as a PAM signal.

- if the *width* of each of these rectangular pulses is varied according to the amplitude of each of the corresponding PAM pulses, then the new signal is said to be pulse *width* modulated - PWM (sometimes called pulse duration modulation - PDM).
- if the *position* of each of these rectangular pulses is varied according to the amplitude of each of the corresponding PAM pulses, then the new signal is said to be pulse *position* modulated - PPM

Conceptually there should be no problem with the generation of these signals, and in practice there is not. No mathematics is required to see this. In principle they may be generated exactly; and in practice, almost so.

why bother ?

If one already has a PAM signal, why bother to convert it to PWM or PPM, transmit it, then convert back to PAM before finally demodulating it ?

This is a rhetorical question. See Tutorial Question Q1.

generation

The INTEGRATE & DUMP module can be used to generate both PPM and PWM signals.

As in other experiments, there is no need to know *how* this is done. What we investigate is that it *is* done.

The same module has sub-systems which perform DIGITAL DELAY and INTEGRATE-AND-HOLD operations. Both of these are used in the demodulators to be examined. These two sub-systems were examined in the Chapter entitled *Digital utility sub-systems* in this Volume.

demodulation

Demodulation might present a problem ? As for generation, it is conceptually easy to see how each of them might be converted back, after transmission, to PAM signals. And it has been shown how the message may be recovered (reconstructed) from a PAM signal - by interpolation with a LPF. This was investigated in the experiment entitled *Sampling with SAMPLE & HOLD* (in Volume D1).

EXPERIMENT

important: throughout the work to follow:

1) detailed step-by-step instructions are *not* given in this experiment. It is left to you to plan a course of action to achieve the required results.
2) use a fixed clock frequency of 8.333 kHz.
3) make sufficient measurements to enable you to answer all the Tutorial Questions.

PWM (or PDM)

A pulse width modulator is incorporated within the INTEGRATE & DUMP module.

All it needs as input is a TTL clock and an analog message.

T1 *obtain an INTEGRATE & DUMP module. Before inserting it into the TIMS frame, set the on-board switches thus:*

a) select PWM1 with the rotary switch SW1 to position 7 or 8
b) select I&H 2 with the switch SW2 to position 2
c) select the short integrator time constant - set J1 open
d) the toggles of SW3 both to the RIGHT (required later for the DIGITAL DELAY sub-system)

T2 *insert the module into the TIMS frame. Patch an 8.333 kHz TTL clock to the CLK input, and a DC signal from the VARIABLE DC module to the I&D 1 input socket.*

T3 *synchronize the oscilloscope via its ext. trig. facility to the 8.333 kHz clock.*

T4 *observe the clock signal on CH1-A, and the output from I&D 1 socket on CH2-A.* ***note****: although the socket is labelled 'I&D1' the actual operation performed is determined by the on-board switch SW1; the 'I&D1' labelling refers to 'the output from the INTEGRATE & DUMP module sub-system #1'.*

You will see two trains of TTL pulses. That on CH2-A is the modulator output.

T5 *vary the amplitude of the DC message, and demonstrate that the signal on CH2-A is indeed a PWM signal. Note and record the properties of this modulator.*

You are now going to use a periodic message. Obviously (?) some thought must be given to the message frequency. For example, what should be its relationship to the clock frequency ? Be aware of this when making your observations. But remember this is the *modulator*, and you have only an oscilloscope. Unwanted effects may not show up in the time domain (or until *demodulation* is attempted - see later).

T6 *use an AUDIO OSCILLATOR for the message. Use the two BUFFER AMPLIFIERS in cascade to set two amplitudes* V_1 *and* V_2*; one for what you would define as 'high' depth of modulation* [1]*, the other for 'low'. You can then change between these two later without need for constant re-measurement (see Figure 1 below). Determine amplitude limits for the message at the modulator input (I&D 1).*

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[1] before the modulated edge runs into an adjacent pulse. Make sure you record how *you* have defined the 'depth of modulation'.

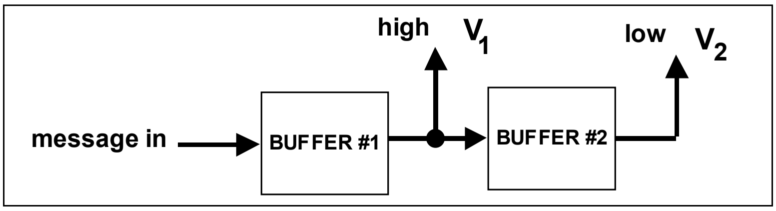

Figure 1: setting up for high and low depths of modulation

T7 *experiment with the oscilloscope trigger settings, the sweep speed, and the frequency of the AUDIO OSCILLATOR (a low frequency near a sub-multiple of the clock is a good start). With care, interesting, stable displays can be obtained, showing clearly the maximum degree of modulation allowed.*

T8 *is it possible to detect any limitations to the message frequency by looking at the PWM signal in the time domain ?*

demodulation

If the modulator performance seemed to be independent of message frequency, your experience should probably warn you that there *will* be limitations on the message frequency when attempting to demodulate.

Likewise, the bandwidth of the reconstruction filter will play a part. As a first step, set the filter bandwidth no wider than say *80% of half the clock frequency* [2].

warning: it can be shown that the spectrum of PWM has components ('sidebands') around the clock frequency more like FM than AM. As the depth of modulation increases these increase in amplitude and *spread out*. Depending upon the ratio of clock frequency ('carrier ω') and message frequency ('μ') they will eventually fall within the reconstruction filter`s passband. This is aliasing distortion. It can thus increase with depth of modulation. Be aware of this phenomenon during your investigations below.

T9 *try message reconstruction by lowpass filtering of the PWM signal. Use a TUNEABLE LPF module. Test at low and hight depths of modulation. Record your findings (for comparison with later measurements).*

You should have observed that this simple demodulator gave increased distortion with increased depth of modulation.

The preferred method of demodulation is first to convert the PWM signal to PAM, and then reconstruct with a lowpass filter. Conversion to PAM can be effected with an integrate-and-hold function.

Unlike PWM, PAM does *not* exhibit multiple sidebands around the clock frequency. Thus (aliasing) distortion is *not* going to increase with depth of modulation.

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[2] what is the basis of this suggestion ?

T10 *perform an integrate and hold operation on the PWM signal. Use the* INTEGRATE-&-HOLD *sub-system*[3] *in the INTEGRATE & DUMP module (at the I&D 2 sockets; you have already set the I&H 2 function with the on-board rotary switch SW2 and J1. Confirm the conversion to PAM.*

Experiment ! it is important to experiment with message frequency and oscilloscope adjustments to obtain useful, stable displays, which reveal important system relationships and phenomena.

T11 *reconstruct the message by lowpass filtering of the PAM signal. Show that now the distortion does not increase as the depth of modulation is increased as it did in Task T9.*

T12 *determine the allowable frequency range of the message. It might be necessary to use a two-tone message - say a variable AUDIO OSCILLATOR and the fixed 2.083 kHz* MESSAGE *available from the MASTER SIGNALS module. See Tutorial Question Q3.*

PPM

One method of generation of PPM is to start with PWM, and then convert this to PPM. Before reading on consider how this might be done with available TIMS modules, and especially with the facilities of the INTEGRATE & DUMP module.

Now read on ....

There is already a modulated *position* on a PWM signal. This, as generated by the INTEGRATE & DUMP module, is the *rising* edge of the PWM signal (already examined above). This edge moves with respect to the falling edge, which is *fixed* in relation to the clock pulse. All that is then needed is to initiate the generation of a fixed-width pulse with this modulated rising edge.

The TWIN PULSE GENERATOR will do this. So will the DIGITAL DELAY sub-system in the INTEGRATE & DUMP module.

The DIGITAL DELAY sub-system is described briefly in the Chapter entitled *Digital utility sub-systems* (this Volume). By its name it is fairly obvious what it does, and closer investigation shows that it produces a fixed width pulse from each rising edge of a TTL input (the position of the pulse can be varied - delayed - but this is of no immediate interest).

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[3] this sub-system is examined in the Chapter entitled *Digital Utility sub-Systems* of this Volume.

generation method #1

T13 *convert your PWM signal to PPM using the* DIGITAL DELAY *sub-system in the INTEGRATE & DUMP module. Use a DC message. Display both the clock and the PPM signal, and confirm the modulation.*

T14 *determine all parameters of interest. Change to a periodic message. Check that the arrangement for a quick change from low to high depth of modulation (used previously for PWM) is still useful. Observe.*

generation method #2

T15 *convert your PWM signal to PPM using one pulse of a TWIN PULSE GENERATOR module. Use a DC message. Display both the clock and the PPM signal, and confirm the modulation. See Tutorial Question Q2.*

T16 *determine all parameters of interest. Change to a periodic message. Check that the arrangement for a quick change from low to high depth of modulation (used previously for PWM) is still useful. Observe.*

demodulation

T17 *how can the message be recovered from the PPM signal ? Try reconstruction with a lowpass filter (both low and high depths of modulation). Report results.*

Since this is an FM-like signal, why not try a phase locked loop (PLL) for demodulation ? This technique is described in the experiment entitled *FM and the PLL*, in Volume A2. A block diagram for such an arrangement is shown in Figure 2.

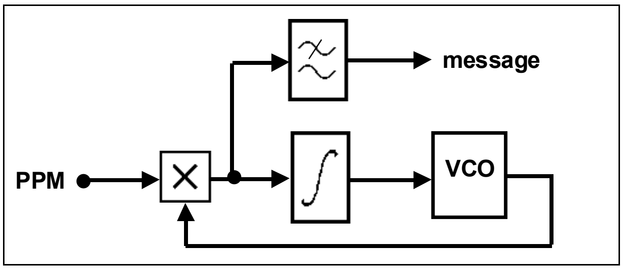

Figure 2: phase locked loop PPM demodulator

T18 *model the arrangement of Figure 2. The integrator can be the loop filter of the BIT CLOCK REGEN module. Ensure you do not overmodulate.*

Note that the PPM signal is a TTL signal, so it will be necessary to check that it is not overloading the MULTIPLIER. Perhaps a sufficient precaution would be to switch the MULTIPLIER to 'AC' mode. Otherwise it will need level shifting and scaling - use an ADDER and VARIABLE DC module.

A common method of demodulation in practice requires that the received PPM signal is first converted to PWM. See Tutorial Question Q2.

Another is lowpass filtering followed by integration. Why the integrator ?

TUTORIAL QUESTIONS

Q1 *why change PAM to PWM, then, after transmission, change it back again ? Indeed, why modulate ? In the answer to this question lie the reasons for most of communications engineering !*

Q2 *draw a block diagram illustrating a method of converting PPM to PWM.*

Q3 *explain the reasoning behind the suggestion to use a two-tone test signal when checking the allowable frequency range of the PWM system (Task T12).*

Q4 *for each of the modulators, explain how you decided when the output was 'fully modulated'.*

Q5 *why does the demodulator of Figure 2 show an INTEGRATOR and a LPF ?*