

PAM AND TIME DIVISION MULTIPLEXING

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PAM AND TIME DIVISION MULTIPLEXING

ACHIEVEMENTS: *channel selection from a multi-channel PAM/TDM signal.*

PREREQUISITES: *completion of the experiment entitled **The sampling theorem**.*

PREPARATION

In the experiment entitled *The sampling theorem* you saw that a band limited message can be converted to a train of pulses, which are samples of the message taken periodically in time, and then reconstituted from these samples.

The train of samples is a form of a pulse amplitude modulated - PAM - signal. If these pulses were converted to digital numbers, then the train of numbers so generated would be called a pulse code modulated signal - PCM. PCM signals are examined in *Communication Systems Modelling with TMS, Volume D1 - Fundamental digital experiments*.

In this PAM experiment several messages have been sampled, and their samples interlaced to form a composite, or *time division multiplexed* (TDM), signal (PAM/TDM). You will extract the samples belonging to individual channels, and then reconstruct their messages.

at the transmitter

Consider the conditions at a transmitter, where two messages are to be sampled and combined into a two-channel PAM/TDM signal.

If two such messages were sampled, at the same rate but at slightly different times, then the two trains of samples could be added without mutual interaction. This is illustrated in Figure 1.

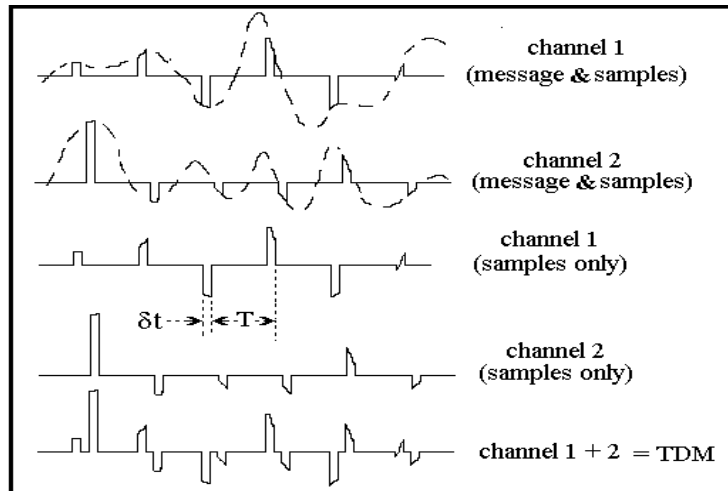


Figure 1: composition of a 2-channel PAM/TDM

The width of these samples is δt , and the time between samples is T . The sampling thus occurs at the rate $(1/T)$ Hz.

Figure 1 is illustrative only. To save cluttering of the diagram, there are fewer samples than necessary to meet the requirements of the sampling theorem.

This is a two-channel time division multiplexed, or PAM/TDM, signal.

One sample from each channel is contained in a *frame*, and this is of length T seconds.

In principle, for a given frame width T , any number of channels could be interleaved into a frame, provided the sample width δt was small enough.

at the receiver

Provided the timing information was available - a knowledge of the *frame period* T and the sampling width δt - then it is conceptually easy to see how the samples from one or the other channel could be separated from the PAM/TDM signal.

An arrangement for doing this is called a de-multiplexer. An example is illustrated in Figure 2.

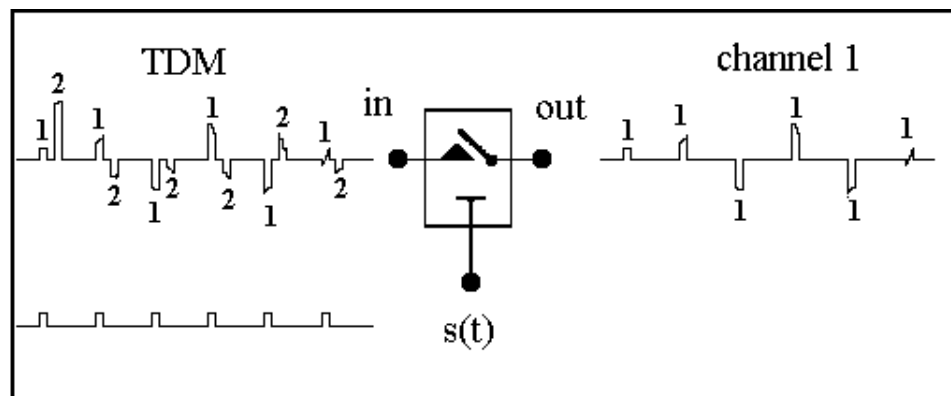


Figure 2: principle of the PAM/TDM demultiplexer

The switching function $s(t)$ has a period T . It is aligned under the samples from the desired channel. The switch is closed during the time the samples from the desired channel are at its input. Consequently, at the switch output appear only the samples of the desired channel. From these the message can be reconstructed.

EXPERIMENT

At the TRUNKS PANEL is a PAM/TDM signal.

T1 use your oscilloscope to find and display the TDM signal at TRUNKS.

clock acquisition

To recover individual channels it is necessary to have a copy of the sampling clock. In a commercial system this is generally derived from the PAM/TDM signal itself. In this experiment you will use the 'stolen carrier' technique already met in earlier experiments.

The PAM/TDM signal at TRUNKS is based on a sampling rate supplied by the 8.333 kHz TTL sample clock at the MASTER SIGNALS module. You have a copy of this signal, and it will be your stolen carrier.

The PAM/TDM signal contains no explicit information to indicate the start of a frame. Channel identification is of course vital in a commercial system, but you can dispense with it for this experiment.

a single-channel demultiplexer model

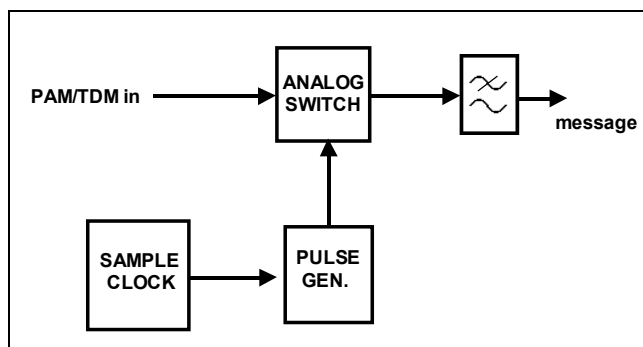


Figure 3: PAM/TDM demultiplexer block diagram

You are required to model a demultiplexer for this PAM/TDM signal, based on the ideas illustrated in Figure 2. You will need a TWIN PULSE GENERATOR and a DUAL ANALOG SWITCH.

T2 patch up a PAM/TDM demultiplexer using the scheme suggested in Figure 3. Only one switch of the DUAL ANALOG SWITCH will be required. Use the DELAYED PULSE OUTPUT from the TWIN PULSE GENERATOR (set the on-board MODE switch to TWIN). Your model may look like that of Figure 4 below.

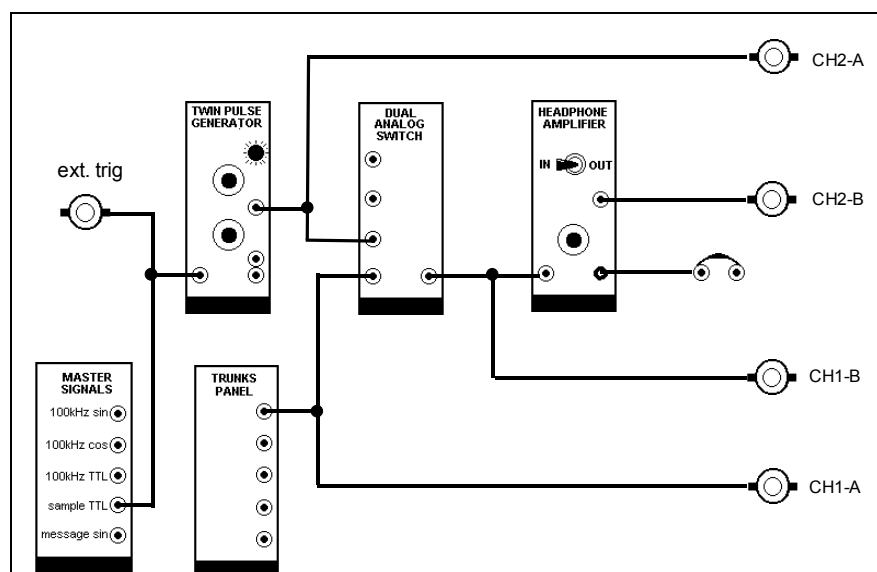


Figure 4: TDM demultiplexer

T3 switch the oscilloscope to CH1-A and CH2-A, with triggering from the sample clock. Set the gains of the oscilloscope channels to 1 volt/cm. Use the oscilloscope shift controls to place CH1 in the upper half of the screen, and CH2 in the lower half.

frame identification

A knowledge of the sampling frequency provides information about the frame width. This, together with intelligent setting of the oscilloscope sweep speed and triggering, and a little imagination, will enable you to determine how many pulses are in each frame, and then to obtain a stable display of two or three frames on the screen.

You cannot identify which samples represent which channel, since there is no specific marker pulse to indicate the start of a frame.

You will be able to identify which channels carry speech, and which tones. From their different appearances you can then arbitrarily nominate a particular channel as number 1.

de-multiplexing

T4 measure the frequency of the SAMPLE CLOCK. From this calculate the FRAME PERIOD. Then set the oscilloscope sweep speed and triggering so as to display, on CH1-A, two or three frames of the PAM/TDM signal across the screen.

T5 make a sketch of one frame of the TDM signal. Annotate the time and amplitude scales.

T6 set up the switching signal $s(t)$, which is the delayed pulse train from the TWIN PULSE GENERATOR. Whilst observing the display on CH2-A, adjust the pulse width to approximately the same as the width of the pulses in the PAM/TDM signal at TRUNKS.

T7 with the DELAY TIME CONTROL on the TWIN PULSE GENERATOR move the pulse left or right until it is located under the samples of your nominated channel 1.

T8 switch the oscilloscope display from CH1-A to CH1-B. This should change the display from the PAM/TDM signal, showing samples from all channels, to just those samples from the channel you have nominated as number 1.

T9 switch back and forth between CH1-A and CH1-B and make sure you appreciate the action of the DUAL ANALOG SWITCH.

T10 move the position of the pulse from the TWIN PULSE GENERATOR with the DELAY TIME CONTROL, and show how it is possible to select the samples of other channels.

Having shown that it is possible to isolate the samples of individual channels, it is now time to reconstruct the messages from individual channels.

Whilst using the oscilloscope switched to CH1-A and CH2-A as an aid in the selection of different channels, carry out the next two tasks.

T11 listen in the HEADPHONES to the reconstructed messages from each channel, and report results.

T12 vary the width of the pulse in $s(t)$, and its location in the vicinity of the pulses of a particular channel, and report results as observed at the LPF output.

TUTORIAL QUESTIONS

- Q1** what is the effect of (a) widening, (b) decreasing the width of the switching pulse in the PAM/TDM receiver ?
- Q2** if the sampling width δt of the channels at the PAM/TDM transmitter was reduced, more channels could be fitted into the same frame. Is there an upper limit to the number of channels which could be fitted into a PAM/TDM system made from an infinite supply of TMS modules ? Discuss.
- Q3** in practice there is often a 'guard band' interposed between the channel samples at the transmitter. This means that the maximum number of channels in a frame would be less than $(T/\delta t)$. Suggest some reasons for the guard band.
- Q4** what would you hear in the HEADPHONES if the PAM/TDM was connected direct to the HEADPHONE AMPLIFIER, with the 3 kHz LPF in series ? This could be done by placing a TTL high at the TTL CONTROL INPUT of the DUAL ANALOG SWITCH you have used in the DUAL ANALOG SWITCH module.
- Q5** draw a block diagram, using TMS modules, showing how to model a two-channel PAM/TDM signal.

