VIDEO CASSETTE RECORDING.
OF
STANDARD PCM DATA

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ABSTRACT:

Standard video cassette recorders (VCR's) are relatively inexpensive, small, and capable of recording large quantities of data for hours. The problem with using VCR's to record pulse code modulated (PCM) digital data is that glitches are recorded in the serial data stream coincident with the video sync pulses. This problem can be solved by formating the PCM data stream and synchronizing the video sync pulses to the PCM data.

INTRODUCTION:

A reliable instrumentation recorder is required when recording and playing back high frequency IRIG Standard Pulse Code Modulated (PCM) serial data. The conventional instrumentation recorder used in this application has the following characteristics:

a. As data frequencies increase, tape speed will also increase.
   As tape speed increases, available record time decreases.
b. The standard tape recorder cannot reliably record PCM data at bit rates much greater than 1 to 2 MHz per track.
c. Tape recorders are relatively expensive. Also, an average reel of tape will cost over $100.
d. Size and weight of these recorders are relatively large.
e. Power consumption is relatively high.

Table I lists several comparisons of conventional instrumentation recorders to a VCR recording system. The comparisons are not meant to be inclusive but rather offer a simplistic generalization to dramatize the features of a VCR when used to record PCM data.

TABLE I
PCM RECORDING TECHNIQUE COMPARISONS

Technique	Freq. (MHz)	Max Record Time (Min.)	Volume (cu ft)	Weight (1bs)	Power (Watts)	Cost ($)
Wide Band:						
Portable	2	15	4.1	120	500	50K
Lab Model	2	15	31.3	950	3000	80K
HDDR	105	15	61.5	1000	1900	170K
Commercial VCR	4	120	0.5	10	35	500
Military VCR	4	120	0.3	9	20	12K
PC24 Formatter*			.2	1	10	lK

(* Required when recording PCM data on the VCR)

As shown in Table I, the VCR records high frequency PCM data for up to two hours on a cassette available from any retail outlet. When compared to Wide Band recorders, the commercial VCR is 83% smaller; 91% lighter; it's record time is 8 times longer; it consumes 91% less power; is 97% less costly. The potential of a VCR can be visualized when an accounting is made of tests where the test object imposes critical restrictions on the test equipment in the areas of size, weight, power, long record times, and restricted budgets. For the test engineer that requires one PCM channel and one channel for recording IRIG timing, the VCR recorder offers impressive advantages over conventional recorders.

VIDEO CASSETTE RECORDERS

Video cassette recorders (VCR's) are different from conventional instrumentation recorders in four main aspects. First, typical instrumentation recorders have from 14 to 42 channels with side tracks used for recording audio and time code. VCR's, generally, can record only two channels at a time; one channel for audio and one for video.

Second, with conventional recorders, the read/write heads are stationary. Data is recorded in several continuous tracks that run parallel to the motion of the tape. VCR's use a helical-scan technique. Here, the tape is guided at an angle around the surface of a rotating drum in which the video heads are mounted (see Figure 1). The heads cross the tape at a gradual angle from edge to edge. Space is left near each edge to record audio and timing signals on regular longitudinal tracks (see Figure 2). The path taken by the video heads slants across the tape to form part of a helix.

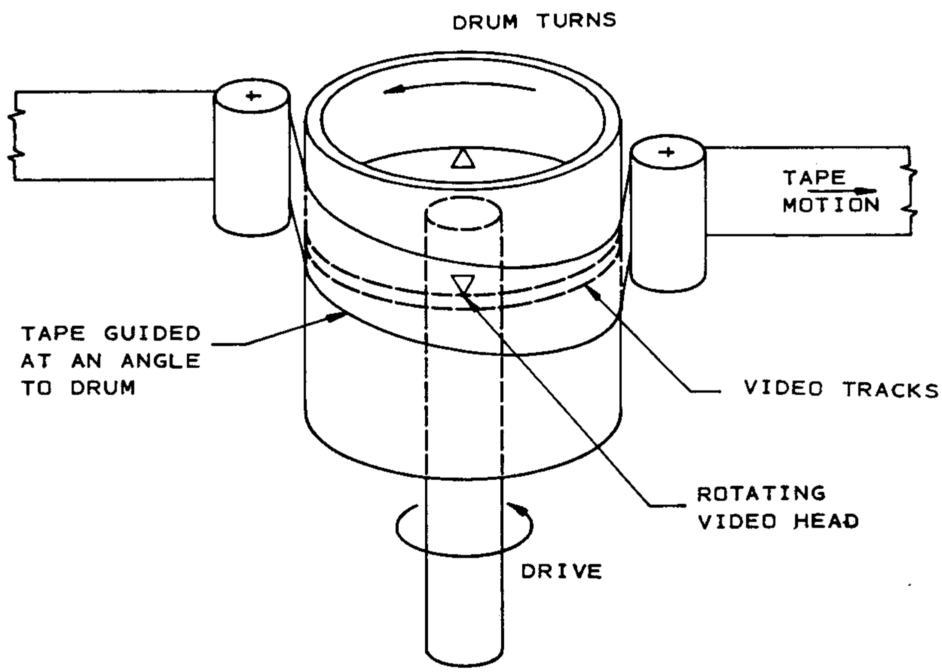

Figure 1: HELICAL SCAN SYSTEM

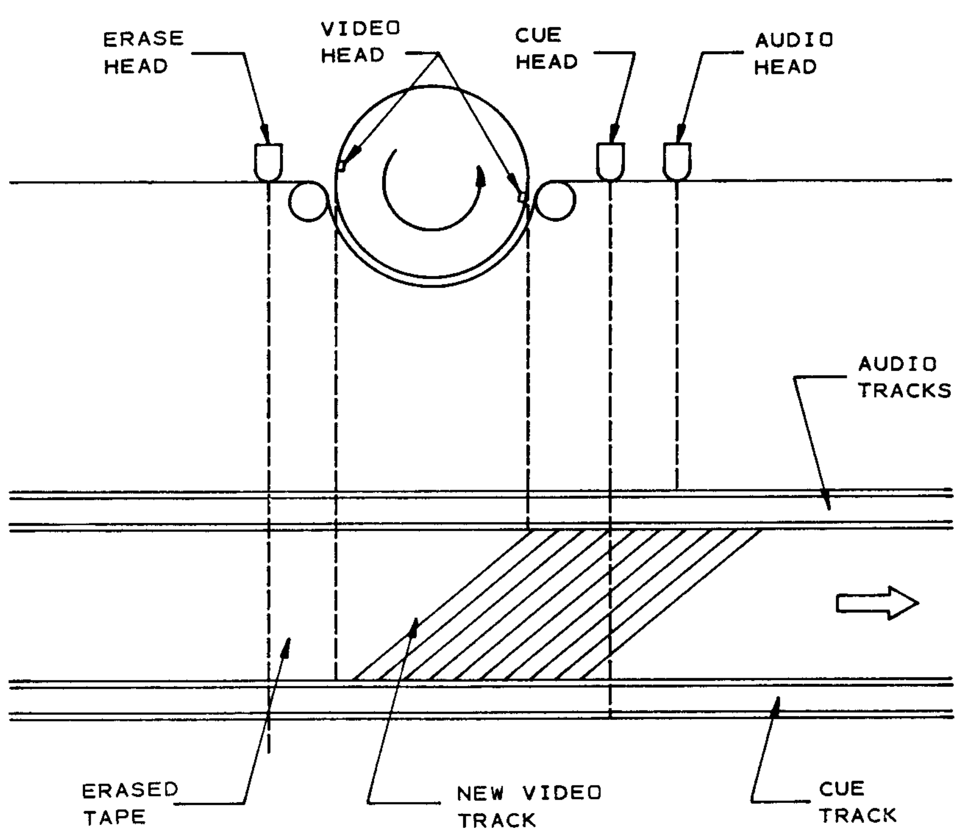

Figure 2: TRACK AND HEAD POSITIONS

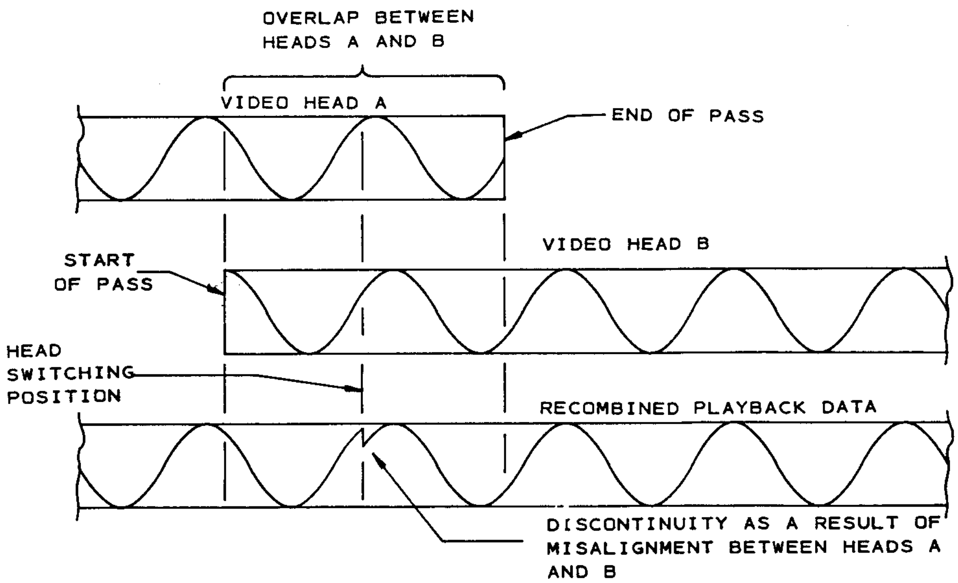

Figure 3: OVERLAP AND VIDEO HEAD SWITCHING

The third distinction is that during the read and write process, the heads switch from one to the next as they rotate on the drum. In most helical-scan machines, head rotation is arranged so that a single swipe of a head past the tape takes 1/60 sec. There is also an overlap period during which the same information is recorded by the video head just leaving the tape and the head that is just beginning to make its pass (see Figure 3). The overlap exists in playback as well. Electronic switching is used to effect a changeover from one video head to the next so that a continuous signal is produced. However, if the heads are not perfectly aligned, the result of misalignment can be the insertion of gaps or discontinuities in the PCM data as it is either written to or read from the tape as shown in Figure 3.

A fourth aspect different is that a VCR requires video synchronizing pulses. Unlike a conventional recorder, both horizontal and vertical video timing pulses are required to maintain proper rotation of the heads. These pulses are multiplexed into the data stream and generate gaps in the data. Standard PCM data must be continuous with no gaps or the PCM decoder tends to get lost and may have a hard time finding sync-lock.

PCM FORMATTER; GENERAL DESCRIPTION

For a VCR to reliably record PCM data, something must be done to eliminate the effect caused by both the switching of the heads and the multiplexing in of the video sync pulses. To accomplish this result, there are two tasks: first, create buffer zones that are insensitive to the switching of the heads and the sync pulses and, second, generate appropriate timing pulses that will provide adequate control for the rotating VCR drum.

The system outlined in Figure 4 offers all the features required to record and playback PCM data. The system may be implemented using any VHS or BETA formated recorder. No modifications are required of the VCR. The system does not require the PCM data from the PCM Encoder to conform to any rigid format that ties the frame or word boundaries of the PCM data to the synchronization of the video sync pulses. The only link between the VCR and the PCM data from the Encoder is between the Encoder's output data clock and the video sync pulses. This may be accomplished using phase lock circuitry. In this system, the Encoder system clock is supplied by the PCM Formatter to provide a simpler and more stable link.

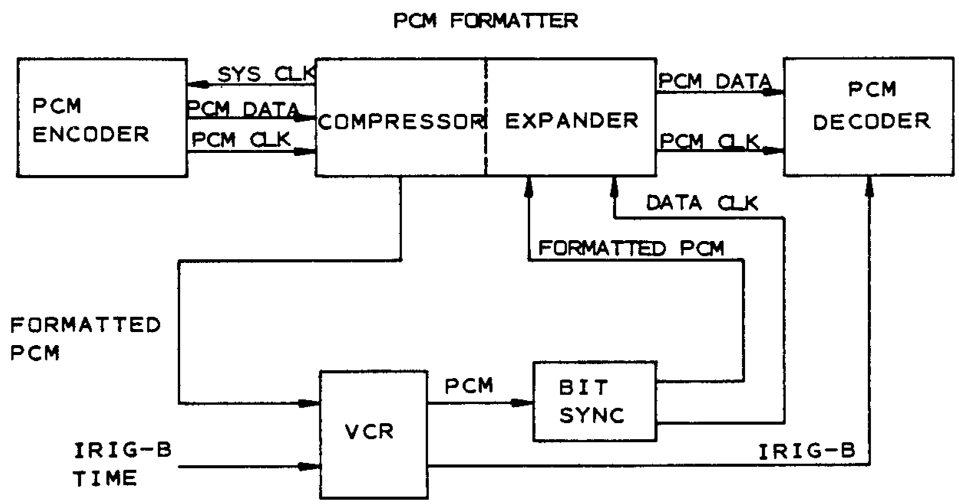

Figure 4: VCR/PCM RECORDING SYSTEM

BUFFER ZONES

Buffer zones are periods of time where filler data and video sync pulses are inserted in the PCM stream. The purpose of the filler data is to provide a period of time in which the switching of the heads may occur without affecting valid PCM data. To generate the extra time required by buffer zones, the frequency of the PCM data is increased. This compresses the data and allows it to be transmitted in short bursts of time. As shown in Figure 5, with the data now in short bursts, extra space or buffer zones are created in the data stream. Video sync pulses may now be added causing the heads to switch during these periods without affecting the PCM data.

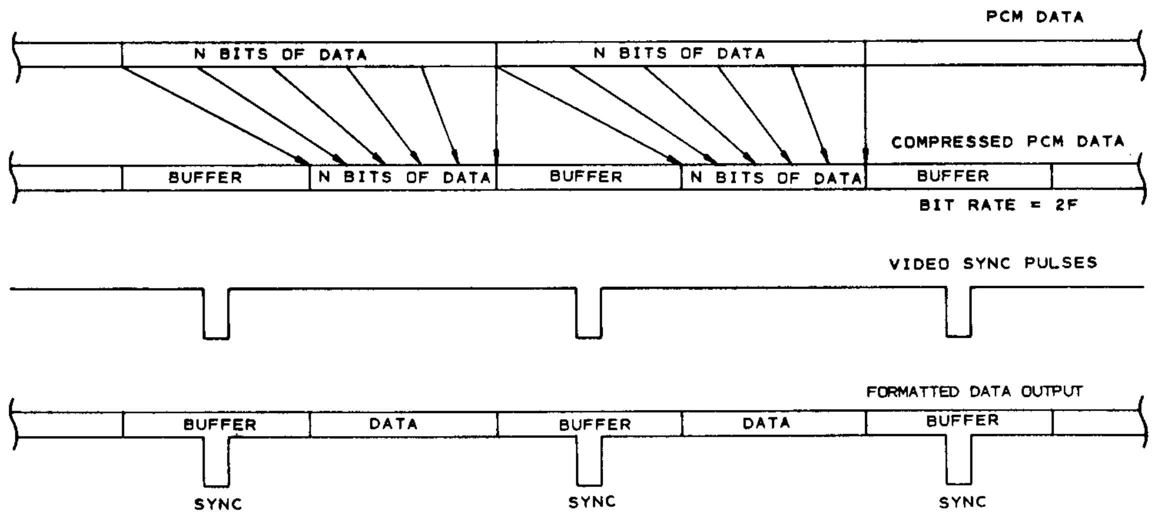

Figure 5: COMPRESSED DATA

VCR TIMING

Table II lists timing characteristics of the standard video signal. Basically, the standard video signal is composed of Vertical Sync pulses having a frequency of 60 Hz, and Horizontal Sync pulses having a frequency of approximately 15.7 KHz. The PCM Formatter generates timing pulses that are similar to standard timing but differ where necessary to be more compatible with PCM data.

TABLE II
STANDARD VIDEO vs FORMATTED PCM TIMING

		Video	PCM
Vertical Sync:			
	Pulse Width	190.5 usec	200.0 usec
	Period	16.66 msec (60.000 Hz)	16.64 msec (60.096 Hz)
Horizontal Sync:			
	Pulse Width	4.7 usec	5.0 usec
	Period	63.5 usec	65.0 usec
Horizontal Periods per Vertical Period		262.5 periods	256.0 periods

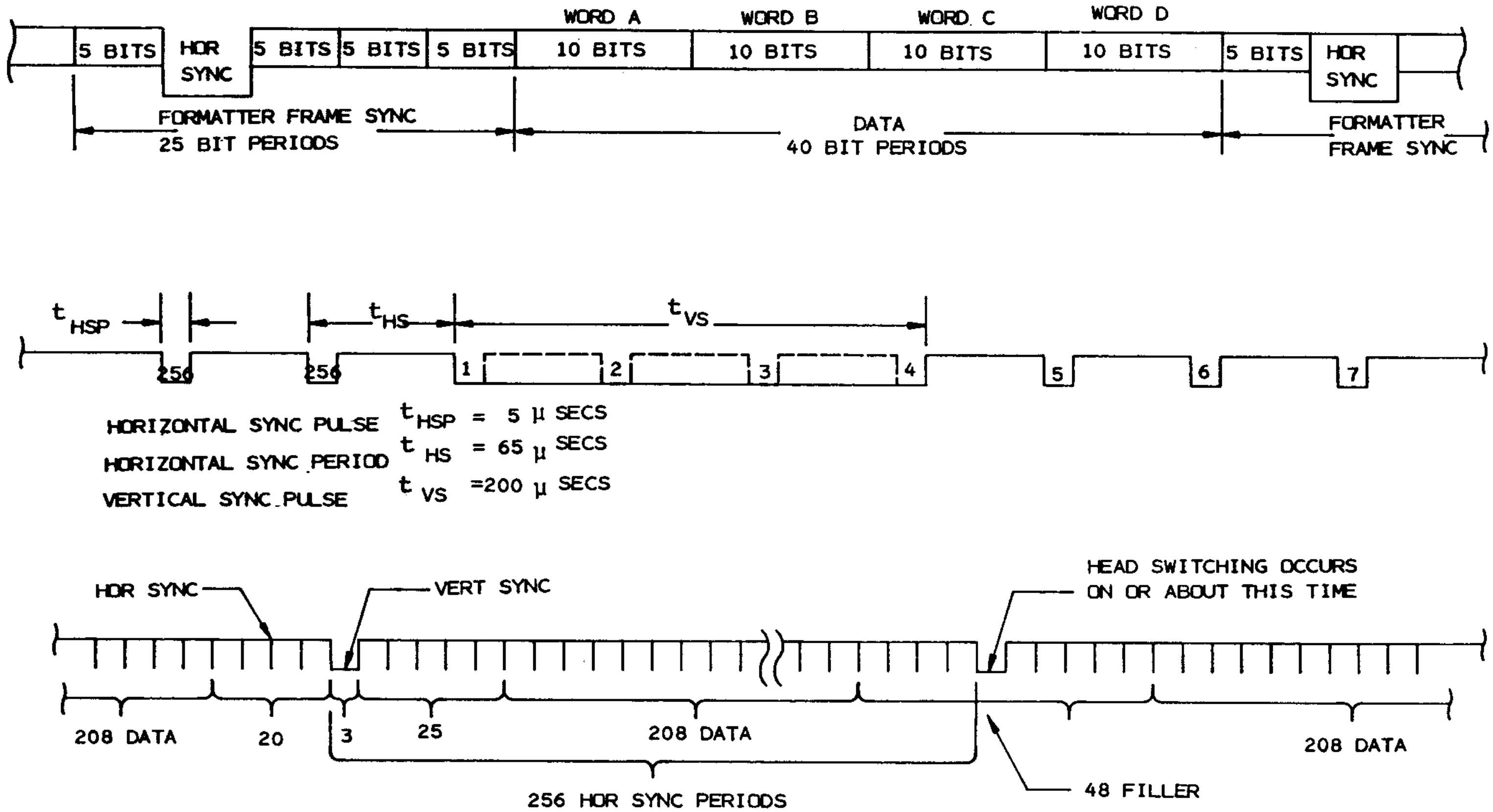

Figure 6: FORMATTED PCM DATA

As shown in Figure 6A, the Formatter generates 256 horizontal sync periods for every vertical sync period. Actual data is placed in 208 of these horizontal sync periods. The remaining 48 periods contain filler which act as a buffer zone for the vertical sync and head switching events. The relative timing of these synchronizing pulses is shown in Figure 6B. As shown, the first three horizontal sync periods occure during the vertical sync. With the buffer zone lasting 48 horizontal periods for a total of 2.9 milliseconds, the head switching event has plenty of room to move around in before it endangers the PCM data.

The Formatter takes 40 bits of PCM data and inserts them, in 10 bit word intervals, between horizontal sync pulses. Each horizontal sync pulse is actually part of a frame sync pattern used to identify horizontal periods containing PCM data. The frame sync code is used to locate the PCM data during playback and thus provide a means for the PCM data to be returned to its original format. Each frame sync code is 25 bits long or 5 bytes long where each byte contains 5 bits. (i.e. slightly more than a nibble.) In Figure 6C you can see how the 10 bit data words are placed relative to the horizontal sync pulse and the associated frame sync code.

FUNCTIONAL DESCRIPTION

The PCM Formatter actually contains two parts that may or may not be packaged together. The Compressor takes the original PCM data from an encoder and formats it for recording on a VCR. The Expander is used for playing the data back from the VCR and returns the PCM data to it to its original format.

COMPRESSOR

As was mentioned, the Compressor portion of the Formatter supplies the system clock for the PCM encoder. This is done so that the encoder and the Compressor are phase locked to the same clock. Other means are available, but this method seemed to be the simplest method of maintaining an accurate clock. In this application, the PCM data from the encoder has a frequency of 500K Bits/sec. The output of the Compressor is 1 M-Bit/sec. As shown in Figure 7, the PCM data is converted from serial data to 10 bit parallel data and temporarily stored until it can be output. The Compressor has three controllers each operating at a frequency of 4 MHz. The Input controller monitors the serial-to-parallel conversion process and writes the input data to memory. The Output controller reads data from memory and controls the parallel-to-serial conversion process of the output. The System controller acts as a bus switch. It tells the Input and Output controllers when to access the memory bus and inserts video sync pulses into the serial output.

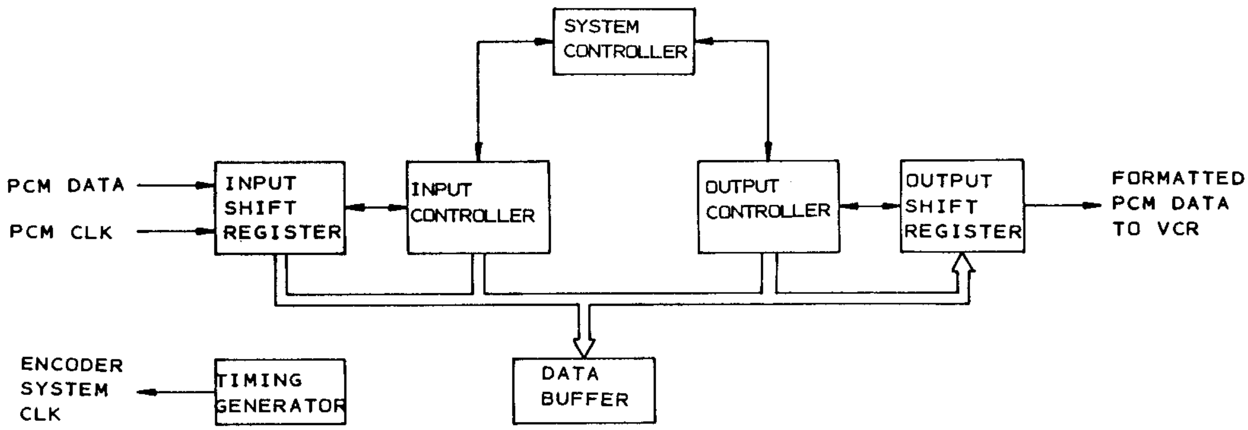

Figure 7: PCM FORMATTER (COMPRESSOR)

EXPANDER

When data is played back from the VCR, the formatting process is reversed. In the Compressor, the frequency of the PCM data was increased by a specific amount. In the Expander, the frequency is reduced by the same amount such that the buffer zones are removed and the data is returned to its original frequency. As shown in Figure 8, the Expander is almost identical in structure to the Compressor. The major difference being, the Expander watches for the frame sync codes of the horizontal sync periods containing PCM data. Unlike the common PCM decommutator which locks on to a periodic frame sync pattern, the Expander acts more like an RS232 interface and its associated start/stop bits. Once it recognizes the frame sync, the Expander reads 4 PCM data words and temporarily stores the data in a buffer. A submultiple of the original frequency is used to load a shift register from the buffer. Here the data is output in it's original serial format and is ready for decoding by a standard PCM decommutator.

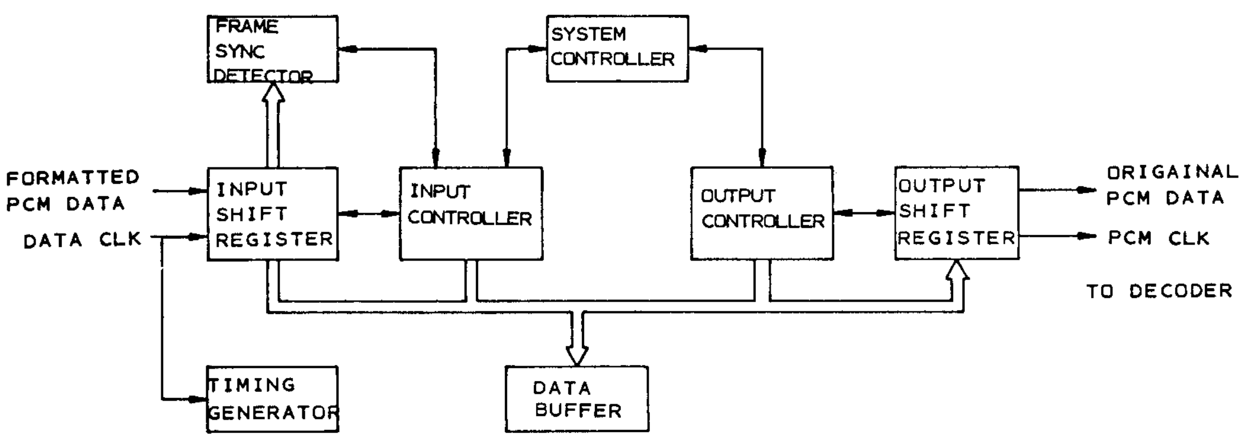

Figure 8: PCM FORMATTER (EXPANDER)

SUMMARY/CONCLUSION

Commercial grade, off-the-shelf video cassette recorders can successfully record PCM data. The associated costs are a small fraction of what they are for a contemporary PCM recorder. Higher frequency PCM data can be recorded successfully with an increase in available record time. This concept reduces the equipment size associated with standard PCM recording systems. The reduced size, weight, and power consumption of a VCR recording system makes possible the recording of data in portable and mobile applications previously not possible.