A PCM DATA DETECTION SYSTEM FOR LONG-PLAY MODE VCRs

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Abstract

This paper describes how to achieve accurate data detection from deteriorated eye patterns. In our data detection system two threshold levels are employed, and either is selected, to read deteriorated data in the amplitude direction; and three different timing methods are used for reading deteriorated data in the time-domain direction. This has enabled us to develop a digital recording system for use with a VTR (Video Tape Recorder) operating in the long-play EP mode.

1. Introduction

The first PCM processor developed for use with a VTR (Video Tape Recorder) appeared in 1977 as the first piece of digital equipment for consumers [Ref. 1]. Subsequently, several different digital audio processing systems were proposed [2], but the next year, 1978, standards were established by EIAJ [3]. Since then, PCM processors have gained wide popularity among consumers.

When the standards mentioned above were made official in 1978, however, they were based on VTRs capable of operating only in the SP (Standard-Play) mode, since VTRs equipped with the long-playing EP mode had not yet appeared. As a result, when a digital recording was made by a PCM processor on a VTR operating in the EP mode, it was nearly impossible to play it back with high stability, because a recording made in the EP mode was much more prone to data deterioration than one made in the SP mode.

We observed these deteriorated PCM playback signals and extrapolated the factors related to the occurrence of errors. Based on our findings, we successfully developed a new data detection system that has the ability to obtain accurate data from deteriorated signal waveforms.

By incorporating this new system into a PCM processor, it is now possible to play back a PCM recording made in the EP mode with the same stability and with the same low error rate as one made in the SP mode.

This paper discusses the details of the new data detection system, compares the error rates of a conventional PCM processor and a new processor incorporating the new detection system, and presents our observations based on the results.

2. Playback waveshapes of PCM signals

First, we recorded a PCM signal on a VTR and observed the waveform of its playback. Fig. 1 shows the waveform of a signal from a tape played back on a VTR running in the SP mode, while Fig. 2 shows the waveform of a signal from a tape played back in the EP mode.

In the EP mode, a tape runs three times slower than in the SP mode, and the track pitch is correspondingly narrower. As a result, a PCM digital recording made in the EP mode is much more susceptible to jitter and crosstalk, which leads to a deteriorated C/N (Carrier-to-Noise Ratio) [4]. A digital signal with higher frequency tends to be more deteriorated, as seen in the deteriorated eye pattern in Fig. 2.

Fig. 1 Eye patterns from VTR A running in SP mode

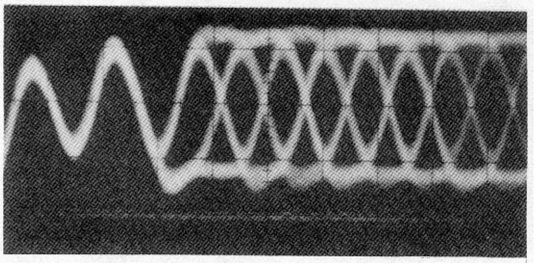


Fig. 2 Eye patterns from VTR A running in EP mode

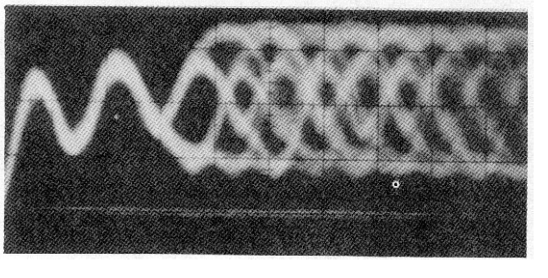
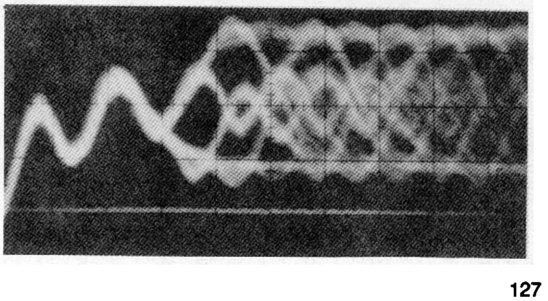


Fig. 3 Most deteriorated eye patterns



Moreover, many of the VTRs on the market with EP mode capabilities have a built-in means of compensating for picture deterioration. The unique non-linear pre-emphasis and de-emphasis applied to recording and playback in the EP mode is an example. When a PCM recording made on one VTR is played back on another, data can deteriorate so much that it is impossible to distinguish "open eyes" in the eye patterns (Fig. 3).

Using a conventional PCM processor, we detected the signals that presented the patterns shown in Figs. 2 and 3, and found out that, with some VTRs, their block error rates reached over 10 percent, rates too high for the processor to accurately correct.

In an effort to establish a relationship between the patterns of the data and the occurrence of errors, we found that more than 90 percent of errors happened at transitions when the data changed from one state to the other.

We also discovered that there were two causes to the errors that compounded each other. One was that due to the deterioration in the amplitude direction, data could not be accurately detected by the slice level set at the center of an eye pattern. The other was that due to the deterioration in the time-domain direction, accurate data could not be extracted by the clocks set at the center of each bit cell.

3. New data detection system

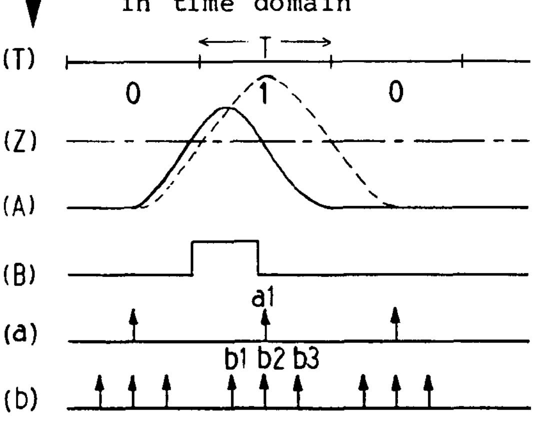
The most distinctive feature of our new data detection system is that it determines the next method of detection depending on the state of the data detected immediately before, in order to facilitate the detection of data right after states have reversed. Based on our discovery, we built the system from two circuits: one that is effective for deteriorated data in the amplitude direction, and another that is effective for deteriorated data in the time-domain direction. Below are the details of this new detection system.

3.1 Data detection effective for deterioration in the time-domain direction

Referring to Fig. 4, "T" is a 1-bit word of the data.

Normally, data is extracted at the center of a bit, (a), that is, at position T/2. But with our new detection system, the data is extracted at three points, (b1), (b2) and (b3) in (b) of Fig. 4. Moreover, those three points are set within the range of ±T/4 from the center of each bit cell so that the data immediately before and after will not be erroneously detected. When the state of any one of the three points is different from the others, the correct data is obtained by the following algorithm:

Fig. 4 Data detection from deteriorated signal in time domain



"If the state of any of the three sets of data is different from the state of the data immediately before, then the different state is deemed correct."

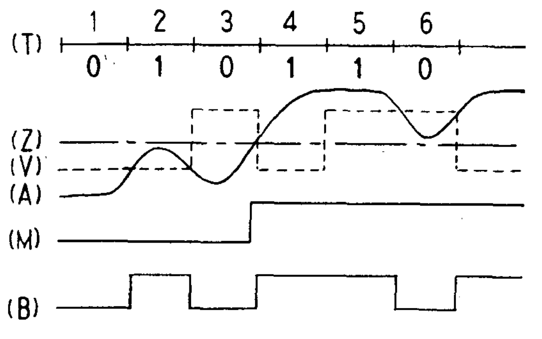
Therefore, if the data immediately before is "0," and the state of any one of the three sets of data is "1," then "1" is deemed as the correct data.

In (A) in Fig. 4, which represents the waveform of a played-back signal, the dotted line shows that the states of the bits are "0," "1," and "0," respectively. The solid line in the same figure represents the waveform of a deteriorated signal. When this signal is sliced by a slice level (Z) and waveshaped, we have a signal with waveform (B). Since the signal (B) is deteriorated in the time-domain direction, the right data ("1") will not result when the signal is extracted by a clock at the center of the bit cell (a1).

Suppose, then, the data is extracted by the clocks shown in (b). The correct data "1" will not be extracted by clocks (b2) and (b3), but it will by clock (b1). Because the previous data is "0," the present data "1" can be deemed as correct.

3.2 Data detection effective for deterioration in the amplitude direction

Fig. 5 Data detection from deteriorated signal in amplitude



Referring to Fig. 5, the played-back waveform of a deteriorated signal is shown as (A). As you can see, the deterioration in the amplitude direction is excessive for the 2nd and 6th sets of data; their amplitudes do not reach the slice level (Z) as they should. The signal, sliced by level (Z), is shown in (M). As you can see, the correct states for the 2nd ("1") and the 6th ("0") sets were not obtained.

Therefore, in our data detection system, two slice levels are set up, one above and the other below the center of the eye pattern, so that either is automatically chosen, bit by bit. The algorithm of its operation is that if the data immediately before is "1," then the upper slice level is chosen to facilitate the detection of the next "0" when it comes; and, conversely, if that data is "0," then the lower slice level is chosen to facilitate the detection of the next "1." For instance, when the signal has a waveform (A) in Fig. 5, the slice level for each bit changes (shown as V), which results in the detection of correct data (shown as B).

3.3 Circuit configuration of the new data detection system

Fig. 6 Block diagram of the new data detection system

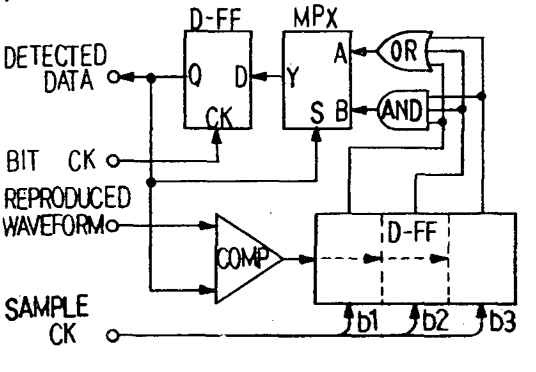


Fig. 6 shows the block diagram of a circuit capable of detecting the deteriorated signal in either the time-domain or amplitude direction, or both directions. By combining these two methods of detecting deteriorated data, we have improved the detection accuracy by a large degree.

4. Evaluation of results of error-rate measurements

By making a PCM recording and playing it back on four different VTRs equipped with the EP mode, we measured the error rates with both the new detection circuit and a conventional detection circuit. Fig. 7 shows the results. As is apparent from the chart, the new circuit reduced the error rate about ten- to one-hundredfold, in comparison with the conventional one.

We also measured the error rates when a PCM recording was made on one VTR and then played back on another. As shown in Fig. 8, the rates were worse than when recording and playback was done on the same VTR. Again, an approximately one-hundredfold decrease in the error rate was measured with the new detection circuit, when compared with the rates we obtained using the conventional detection circuit.

Fig. 7 EP mode error rate: Recording & playback on on same VTRs

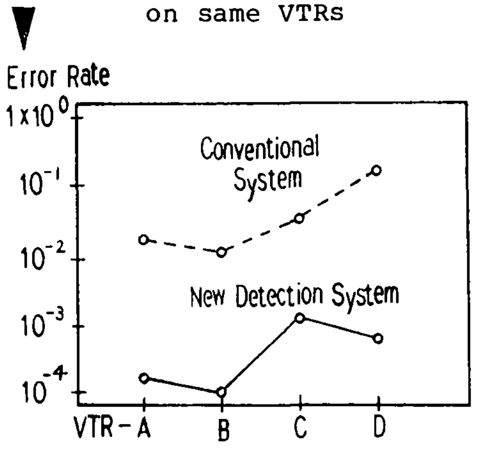
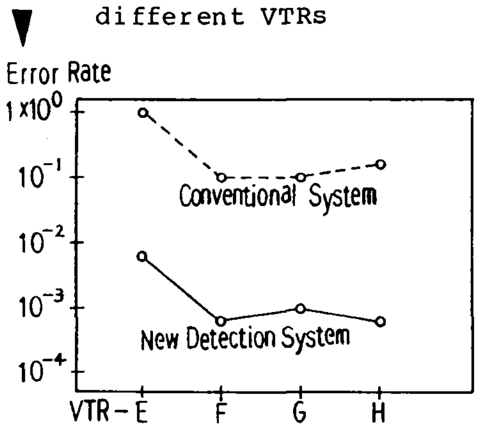


Fig. 8 EP mode error rate: Recording & playback on different VTRs



Whether a recording was made and played on the same VTR or made on one VTR and played on another, the error rates from the processor using our data detection system remained on the order of 10^{-3}, which were no worse than the rates we obtained from VTRs making a PCM recording in the SP mode.

5. Conclusion

We proved that by using the new detection system, we can successfully reduce the error rates of PCM recording on a VTR in the EP mode ten- to one-hundredfold, compared with a conventional detection system. In doing so, we improved the reliability of PCM recording on a VTR operated in its EP mode. This system can be applied just as well to the direct digital recording method as it is to the carrier frequency modulation method.

6. References

(1) A. Iga et al., "A Consumer PCM Audio Unit Connectable to Home-Use Video Tape Recorders" ASJ Conf. 3-2-9.

(2) N. Tomikawa et al., "A Prototype Rotary-Head PCM Recorder" IECE Japan EA 78-31.

(3) "Consumer PCM Encoder/Decoder" EIAJ Technical File "STC-007."

(4) "VTR Technology" Japan Broadcasting Corporation.