HIGH RESOLUTION DIGITAL DATA TRANSITION ANALYSIS AND TESTING

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ABSTRACT

The need for margin analysis in high density digital data storage systems is established. A review of margin analysis techniques is presented. This review includes a discussion of time interval analysis and a series of instruments which have evolved as a means of performing this analysis. Emphasis is given to a high resolution (1 nanosecond) statistically oriented embodiment of such an instrument.

INTRODUCTION

As recording densities of digital data storage systems have increased, so has the need for margin analysis. The bit error rate of such systems continues to be an important figure of merit but conveys no insight as to system margin.

Margin is that quality which allows the repetitive manufacture of a given product design and insures the reliable long life operation of any given system. A casual review of the literature reveals an ongoing affirmation of the need for margin analysis (1), (3), (4), (5).

Errors are caused by a variety of system imperfections, several of which are listed in Table 1. While each of these causes may be dealt with separately, it is desireable to view their cumulative effect upon margin.

Table 1 Causes of Error

1. Media Imperfections
2. Intersymbol Interference (Peak Shift)
3. Interchannel Crosstalk (Track to Track)
4. Drive Speed Variations (Jitter)
5. System Noise

MARGIN ANALYSIS TECHNIQUES

The traditional means of assessing system performance such as signal to noise, flutter and eye pattern measurements (1), (2), (4), have given way to the techniques of window sliding (3), (5) and transition distribution analysis (1), (2), (4), (5).

Figure 1 illustrates an eye pattern from a high density tape system. This technique does reveal the cumulative effect of all error causes and is simple, however it is subjective and rather inaccurate. (See illustrations at end of text.)

Window sliding is described in detail by Mackintosh in references (4) and (5). This technique has gained wide acceptance in the disk drive industry and may be used to generate the type of distribution data discussed later in this paper. While window sliding may even be built into the system under test, it has the disadvantage of failing to test the system decoder or data separator in its intended mode of operation.

Transition distribution analysis has been discussed as early as 1976 by Lerma (1) who was responsible for its introduction as a means of margin analysis in the manufacture of high density spaceborne recorders at Odetics Inc. The technique gained acceptance not only within the engineering community at Odetics, but was soon included as a partial basis of acceptance testing on several aerospace recorder programs. The technique is advocated by others in the industry (3), (5) and has evolved to the sophisticated instrument which is the subject of this paper.

Figure 2 is a sample histogram obtained from an early adaption of an Odetics Transistion Density Analyzer.

This histogram reveals the variance from ideal of a delay modulated random data pattern recorded at about 15,000 bits per inch on magnetic tape. In the absence of any interference the histogram would consist of three narrow peaks. The peaks would occur at intervals of 1, 1.5, and 2 times the width of one bit.

A typical data decoder can tolerate shifts from the ideal transition location of ± 25% of a bit. Thus the point midway between peaks should be devoid of any transitions. The TDA histogram allows for rapid evaluation of the margin associated with this requirement.

TIME INTERVAL ANALYSIS

The fundamental concept of time interval analysis is to measure the time between two successive transitions in a data stream over a period of many transitions, store the individual results, and display the cumulative results at the end of the measurement period.

For a perfect square wave, the resultant display would be one vertical line, the height of which would equal the total number of transitions counted. The horizontal location would correspond to the time of one half the square wave period.

In the presence of noise the square wave transitions will occur earlier and later than the nominal half period. The ability to detect these variant transitions is determined by the resolution of the interval analysis technique.

Although square wave transitions all occur at the same nominal interval length, typical data formats used in magnetic recording include several expected transition intervals. Thus provisions must be made for the storage of many individual sets or bins of analysis results.

Finally, for an analysis to be statistically accurate, a large number of intervals must be measured. This requires that each individual bin be capable of storing a large number.

These basic requirements dictate the equivalent of a large number of “very narrow, but tall, storage bins.” Each measured interval is classified in terms of length and added to the contents of the bin representing that length.

Such bins may be constructed using semiconducter random access memories. Available RAMs suit the requirements of “a large number of tall bins.’ To make the bins “narrow” requires a high frequency timer capable of resolving interval variations to the desired accuracy.

With time interval data stored in such a memory a microprocessor may be used to “paint” the measurement results on a display in a variety of useful formats.

Figure 3 is a simplified block diagram of a time interval analyzer which provides the features just discussed.

EXAMPLES

The following figures illustrate several different display formats available on the TIA 150 analyzer manufactured by Kode Inc. In each case the results of a system with little or no margin are contrasted with a different system which is operating with margin.

The figures on the left are from a 5 MBPS floppy disk drive which was improperly adjusted and was exhibiting a high error rate.

The contrasting figures derive from a 10 MBPS rigid disk operating within specification. Both drives were recording a random data pattern using MFM (delay modulation) encoding.

in Figure 4A the TIA is operating with a 2 nanosecond time base. Thus each bin is 2 nsec in width and the 5 MBPS data is resolved to 100 bins per bit, or 1%. The solid, left hand, cursor (vertical line) in Figure 4A is at 200 nsec while the broken, right hand cursor is at 400 nsec. The short and long transitions should be centered about these two points respectively, but as seen, bit shift has occurred depriving the drive of adequate margin. The numerical readout at the bottom of the display indicates the total number of transition intervals displayed between the two cursors. In this case nearly the entire sample of 10,000 is included.

Figure 4B, taken with 1 nanosecond resolution reveals a healthier system as evidenced by the relatively narrow peaks of the three data intervals. The cursors may be positioned to aid in the quantitative assessment of the analysis. In this figure the numerical display at the bottom is indicating the mean value of the transitions within the cursors. For the data rate of just over 10 MBPS, 191 nsec is centered properly and is one indication of proper margin.

Figure 5 is a sample of a segment display. In this mode the solid white bar seen at the bottom is adjusted to represent the “window” or segment of bins over which the decoding circuits will operate properly. Typically, this window is one-half bit in length. The display is an overlay of the transition distributions at each of the intervals. This mode simplifies the assessment of margin and is helpful in dealing with formats having a larger number of transition intervals.

The figure on the left shows the transitions occupy the entire window, hence no margin, while the 10 MBPS data is much better.

Figure 6 illustrates a second type of segment display, where in essence, the display of Figure 5 has been folded about the center of the window. In other words, it is a plot of all transition interval variances, both plus and minus versus the magnitude of the variance. The resultant curve is quite useful in understanding system performance. A thorough discussion of this curve and its value is provided by Katz and Campbell (3).

Pattern sensitivities show up as a flattening of the top of the curve while signal to noise effects the slope of the steep portion of the curve. The intrinsic error rate of the system is revealed by this curve at the point of intersection with the window boundry. Although an accurate reading of intrinsic error rate is not possible from the display, the data contained in the analyzer memory could be curve fit by an external computer.

As in the previous examples, the 5 MBPS data is without adequate margin while the 10 MBPS data is good.

ANALYSIS INSTRUMENTS

Time interval analysis has been a useful tool in the development of spaceborne tape recorders at Odetics Inc., for nearly the last decade. While Odetics included the analysis capability in their special test equipment, an affiliate, Kode Inc., has developed two instruments which are commercially available.

The TIA 100, shown in Figure 7, offers resolution to 10 nanoseconds and serves the analysis needs up to 5 MBPS depending upon resolution requirements.

The high resolution TIA 150 is shown in Figure 8. This instrument was used as the source of analysis examples presented earlier. The principal features of the TIA 150 are listed in Table 2.

Table II
PRINCIPLE FEATURES OF TIA 150

*Resolution to 1 Nanosecond
*CRT Display of Results
*Variety of Triggering Modes
*Variety of Statistical Display Modes
*Variety of Statistical Readout Modes
*Menu Driven Keyboard Instrument Setup
*Printer and Plotter Interfaces
*IEEE 488 Interface
*200 or 1000 Bin Display
*1000 Bin Memory

CONCLUSIONS

Margin analysis, although always useful, has either been difficult to perform or subjective in its implementation. A family of test instruments which overcome these problems is now available to assist the engineer.

REFERENCES

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2. Petit, R.D. “A TRANSITION DENSITY ANALYZER,” Kode Inc., 2752 Walnut Avenue, Tustin, CA, 92680. Telephone: (714)730-6901.

3. Katz, E.R and Campbell, T.G., “EFFECT OF BITSHIFT DISTRIBUTION ON ERROR RATE IN MAGNETIC RECORDING,” IEEE Transactions on Magnetics, Vol. Mag-15, No. 3, pp 1050-1953, May 1979.

4. Mackintosh, N.D., “A MARGIN ANALYSER FOR DISK AND TAPE DRIVES,” IEEE Transactions on Magnetics, Vol. Mag-17, No. 6, pp 3349-3351, Nov. 1981

5. Mackintosh, N.D, “EVALUATION OF DISK DRIVES BY MARGIN ANALYSIS,” Century Data Systems, P.O. Box 3056, Anaheim, Ca., 92803.
Telephone: (714)999-2552

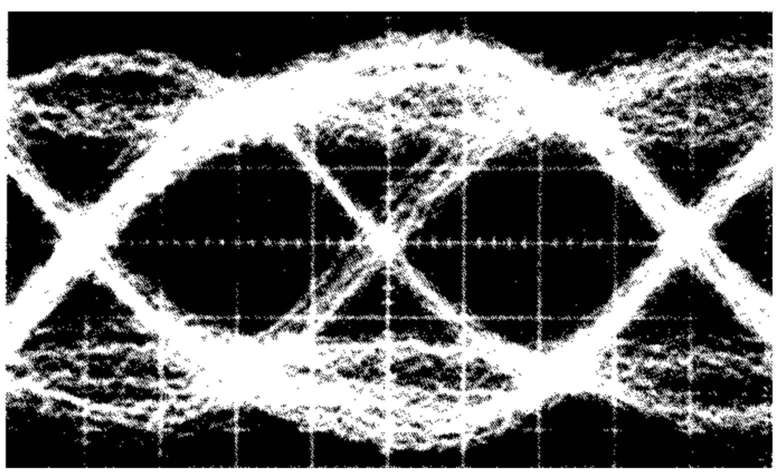


Figure 1. Eye Pattern

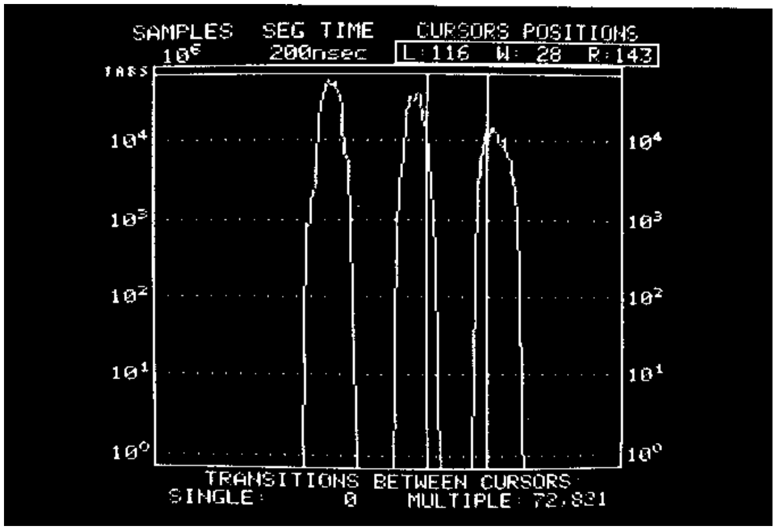


Figure 2. TDA Histogram

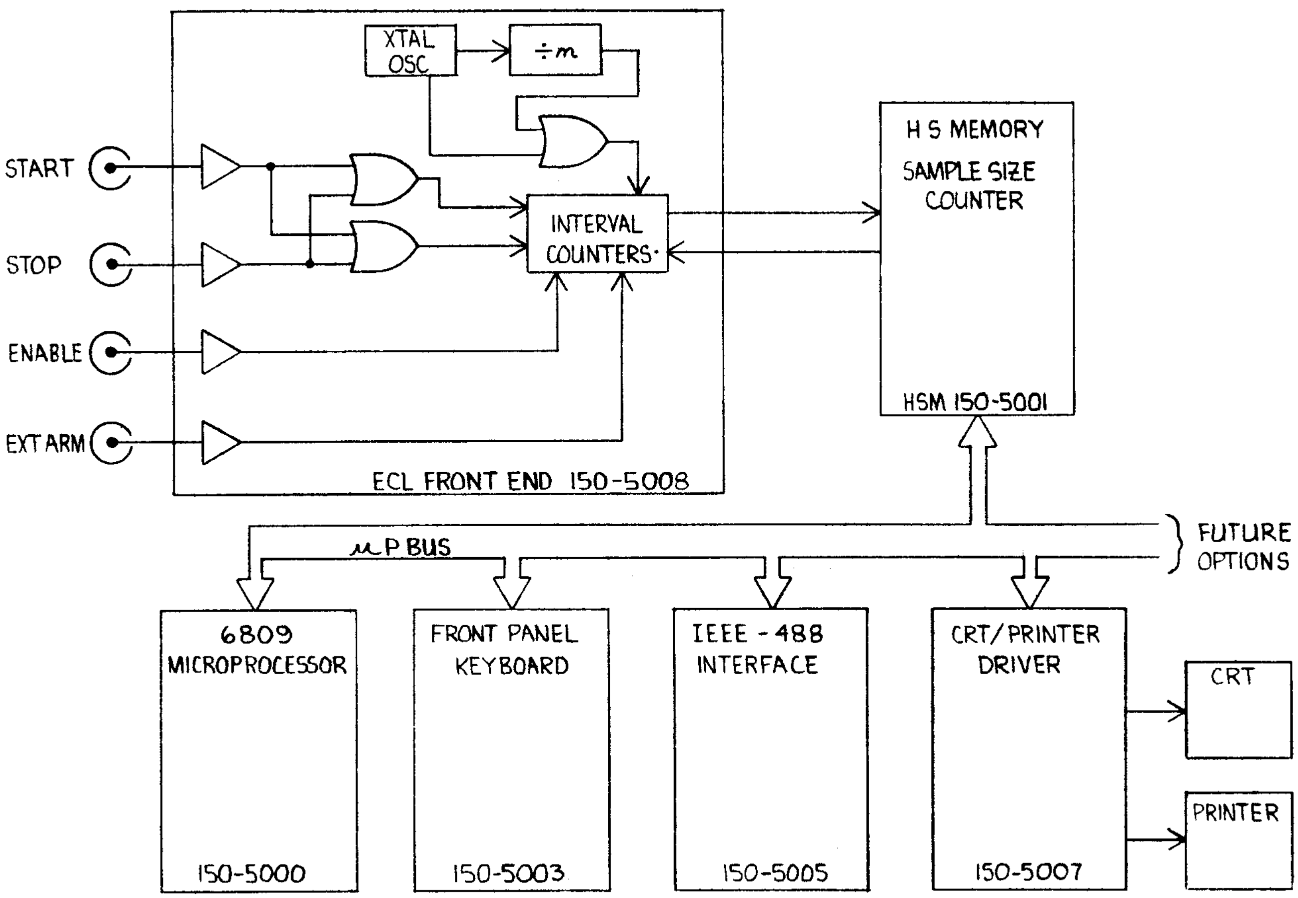
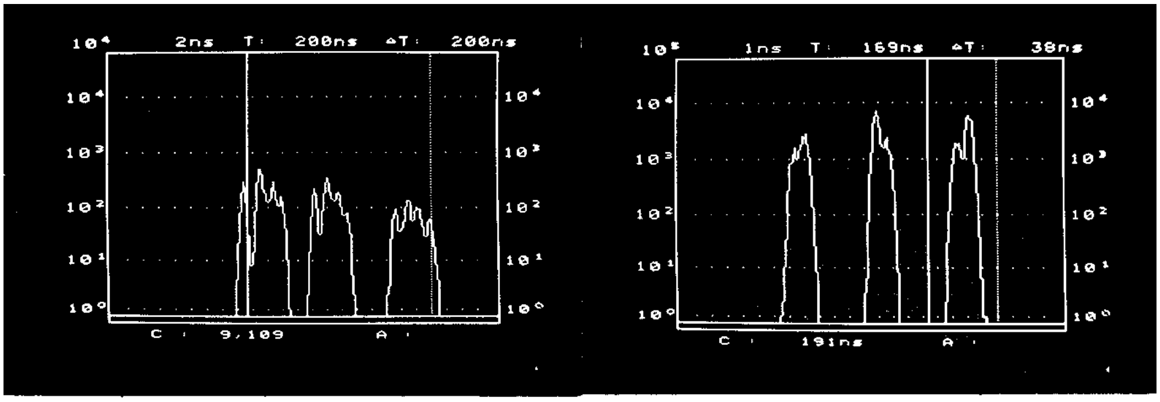


FIGURE 3

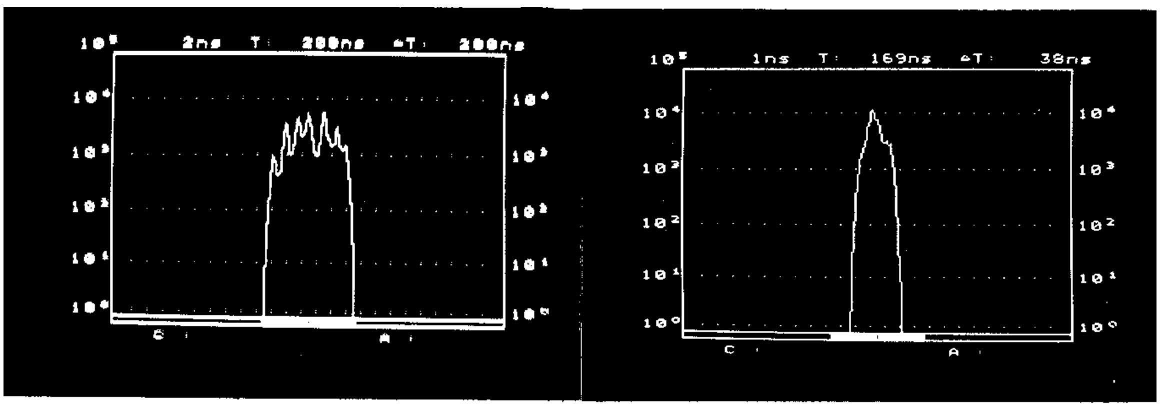
TIA 150 BLOCK DIAGRAM



A. 5 MBPS Data

B. 10 MBPS Data

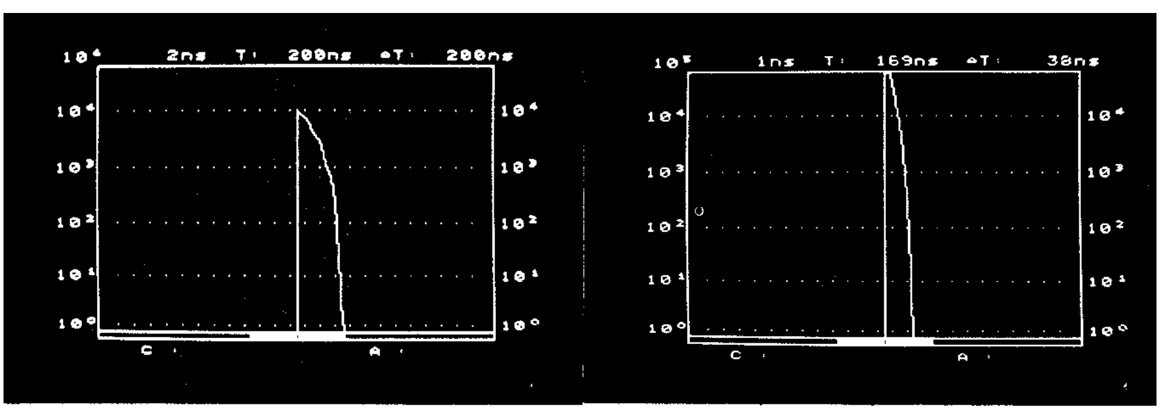
Figure 4. Linear Display



A. 5 MBPS Data

B. 10 MBPS Data

Figure 5. Segment Display



A. 5 MBPS Data

B. 10 MBPS Data

Figure 6. Probability Density Display

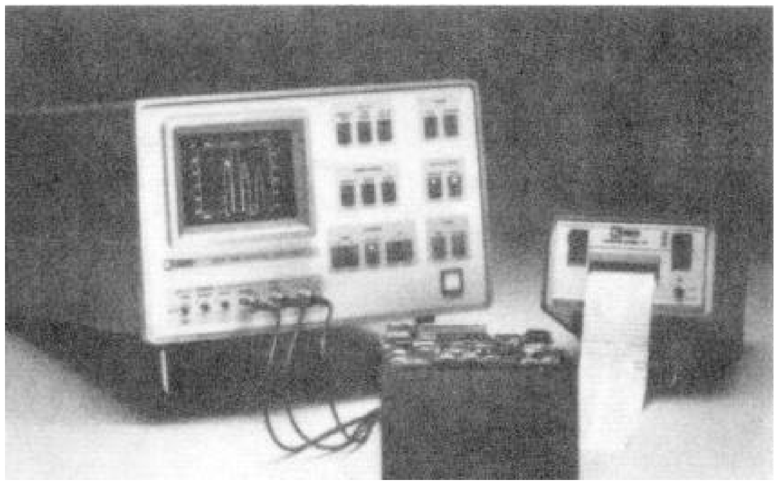


Figure 7. TIA 100

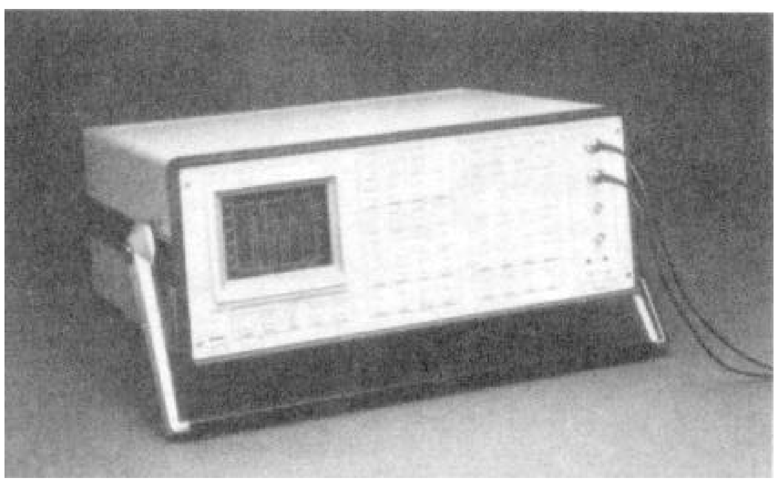


Figure 8. TIA 150