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"A MARGIN ANALYSER

FOR DISK AND TAPE DRIVES"

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A MARGIN ANALYSER FOR DISK AND TAPE DRIVES

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Abstract - *The use of a margin analyser in disk and tape drives is discussed, and several different types are described. The results from one simple type of margin analyser are presented.*

INTRODUCTION

The common method of data recovery in a moving magnetic memory is to (a) accurately identify the recorded flux transitions, (b) generate a read clock, or 'data windows', based on the average position of these transitions, and then (c) use the position of the data transitions within the windows to reconstruct the recorded information. Figure 1 shows how, for MFM code, all '1' transitions occur nominally in the centre of the ones window, while any '0' transitions occur in the centre of the zeros window. These transitions could actually be anywhere within the window and still be interpretted correctly, but any transition which fell outside its correct window would cause a data error. In practice, transitions can indeed vary from their ideal position within the window due to such factors as intersymbol interference ('peak shift'), overwrite modulation, off-track interference, PLL jitter, write error, group delay variation, logic delay variation, zero-crossover error and differentiator error. After these components of error have been subtracted from the available window width, that portion remaining is further degraded by any perturbations with a gaussian distribution (chiefly due to white noise). The reduction due to this can be calculated from the desired error-rate [1][2][3], and any window then remaining is the margin of the system.
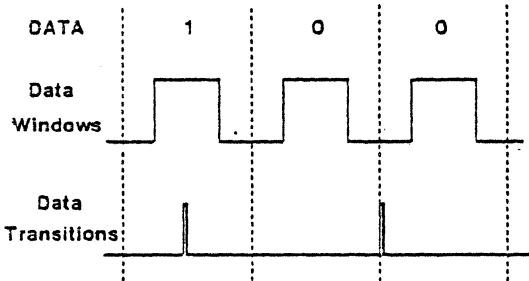

Fig. 1   Ideal location of data transitions within windows

A passive approach to margin analysis. which merely monitors signals in the drive, can not only guarantee normal operation of the machine, but can also be used to more quickly give an accurate indication of how margin is being lost to the various components. In the simple method, shown in fig.2, the ends of the window are monitored for any transition occurring therein. An 'early window' is generated from the first edge of the data window, and the number of data transitions occurring within it over a period of time is counted. The back end of the window is similarly monitored by means of a 'late window', generated by the data transition, which looks for the falling edge of the data window occurring in it. If the early and late windows are adjusted from one run to another, a picture can be built up of the distribution of the transitions within the window, assuming this has not changed from run to run.
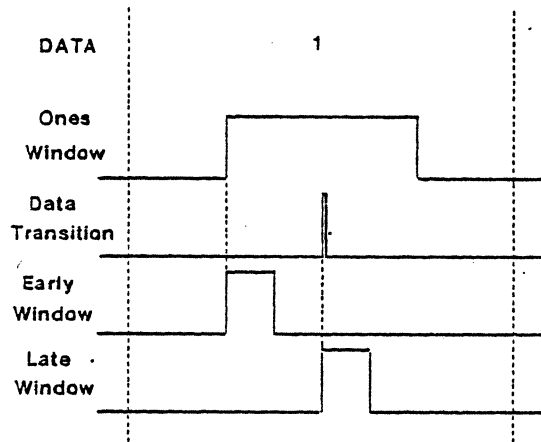

Fig. 2   Generation of early and late windows

MARGIN MEASUREMENT TECHNIQUES

The common way to determine the margin of a particular machine is to either reduce the width of the window, or deliberately offset the transitions within the window, until the desired error-rate occurs. Both of these methods have the disadvantage that you may well be altering the operation of the drive in ways other than that intended; for example, the PLL may have been designed for optimum performance only with symmetrical windows. Nevertheless, one approach based on the latter method has proved most useful. A computer is used to monitor the error-rate and continually adjust the offsetting of the data transitions , by means of a D to A converter on the control voltage of a monostable, until the desired error-rate is achieved. This can be a lengthy process, however, unless a degraded error-rate is used, but testing in this fashion, for expediency, is only suggested after suitable correlation checks have been made between margin at the normal(or desired) error-rate and margin at the degraded one.
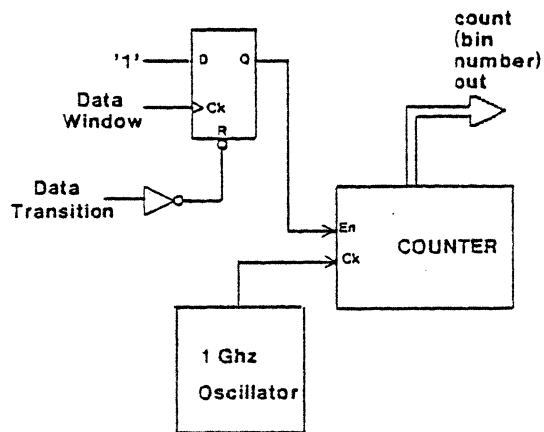
Fig. 3   Margin analyser using high-frequency oscillator

The disadvantage of the last method of margin analysis is the large number of runs that are needed to accumulate the distribution information, as well as the requirement that the distribution does not change from run to run (a susceptibility to line transients, for example, might fail this criterion). The obvious answer is to continually monitor all portions of the window so that the exact occurrence of every transition is recorded. This is simple in concept, but extremely difficult to put into practice in all but the slowest of machines, where 50ns bins may give sufficient resolution. Some possible techniques for accomplishing the parallel approach are as follows. In Fig.3, the distance from the start of the window to the occurrence of the data transition is measured by means of a 1 Ghz clock which is gated into a counter. A different approach is shown in Fig.4, where the leading edge of the window enables a linear ramp, which is then halted by the data transition. The voltage achieved thus represents the time of interest, and can be fed through a fast A to D converter for processing as before. In Fig.5, a third method, a tapped delay line is used to seek coincidence between the data transition and one of the delayed versions of the data window. A priority encoder can then be used to encode this to the binary number required.
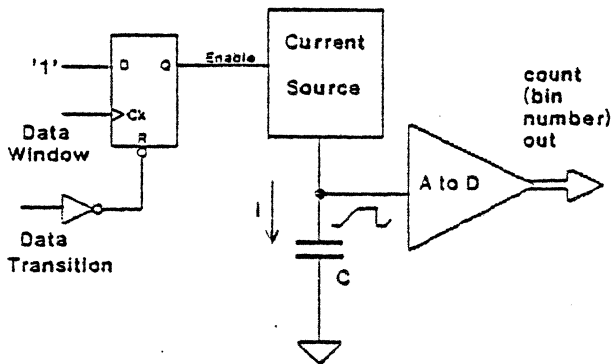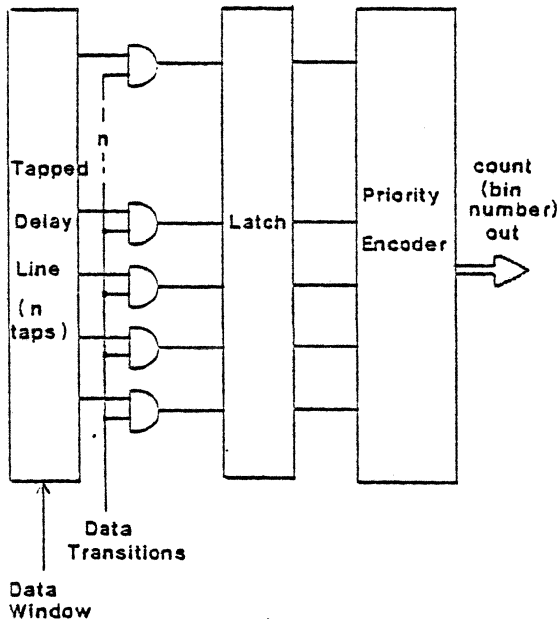
In each case, the number measured must then be unloaded , or acted upon, before the next measurement commences. This may be only 50ns away so, again, it is not a trivial problem - a commercial bench-top counter could not transfer the data in time, for example. Figure 6 shows how the data can be accumulated by using a hardware counter for each of the bins of interest. The appropriate one is incremented each time a measurement has been made. Once the run is complete, and the desired number of bits have been transferred, the count in each bin can then be printed, or the data can even be displayed directly as a histogram.
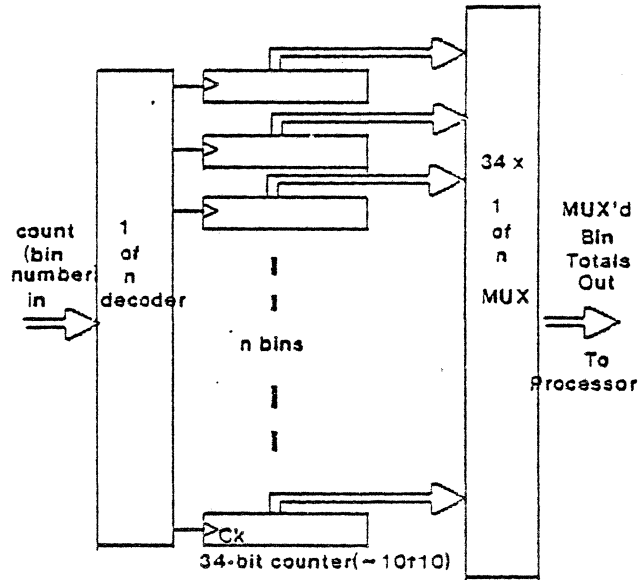

Fig. 6 Accumulation of bin values

Fig. 4 Ramp-based margin analyser

Fig. 5 Margin analyser using tapped delay-line

USE OF MARGIN ANALYSIS

In its most efficient form, where the position of all transitions is accurately recorded, the margin analyser becomes one of the most useful tools available for data channel design and optimisation, troubleshooting and manufacture. By studying the distribution of transitions for various permutations of pattern, write prestress, radius, offtrack error, filtering, and even code, the effect of all parameters can be conveniently studied. As an example, increasing the delay in a delay-line differentiator will increase the peak-shift but may improve the signal-to-noise ratio. Use of the margin analyser will quickly determine the optimum value, for maximum margin.

In its very simple form, using a fixed early and late window, requiring at most 6 integrated circuits, a margin analyser could be built right into the drive itself. When transitions occur in the early or late windows, they could both inform the controller and perhaps flash an LED. This could be useful as an indication of sufficient margin at various stages of manufacture, and in the field could be used as an early warning of reduced margin if the controller interpretted it correctly.

An example of the results obtainable with even the simple type of margin analyser is shown in Fig.7, for an MFM all 1's pattern on one head at the inner radius, for a drive with a window of ±25ns. The data has been taken in 1ns increments, or 'bins'. Figure 8 shows the same conditions except the pattern has changed to a worst-case 1's peak-shift (110110...). The peak-shift is clearly evident, and is approximately 4ns. Figure 9 shows the same pattern, but using all eight heads at the inner radius. Figure 10 shows the same after implementing a modification to the data channel (a smaller delay in the differentiator), from which it can be seen that the margin has improved.

Probability Density

Probability Density

Transition location relative to centre of ones window
(ns)

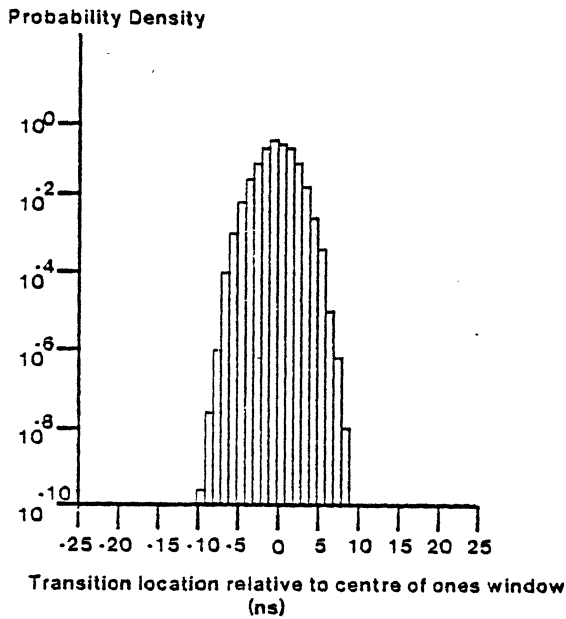Transition location relative to centre of ones window
(ns)

Fig. 7 Transition distribution for MFM all ones pattern on one head at the inner radius

Fig. 9 Transition distribution for MFM 110110.. pattern using all eight heads at the inner radius

Probability Density

Probability Density

Transition location relative to centre of ones window
(ns)

Transition location relative to centre of ones window
(ns)
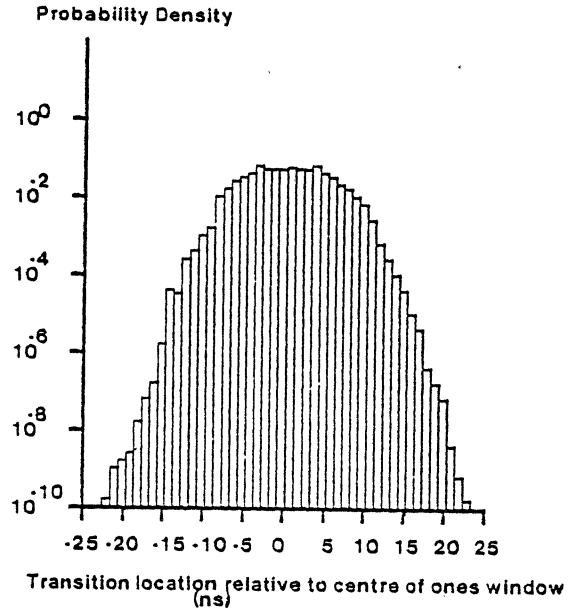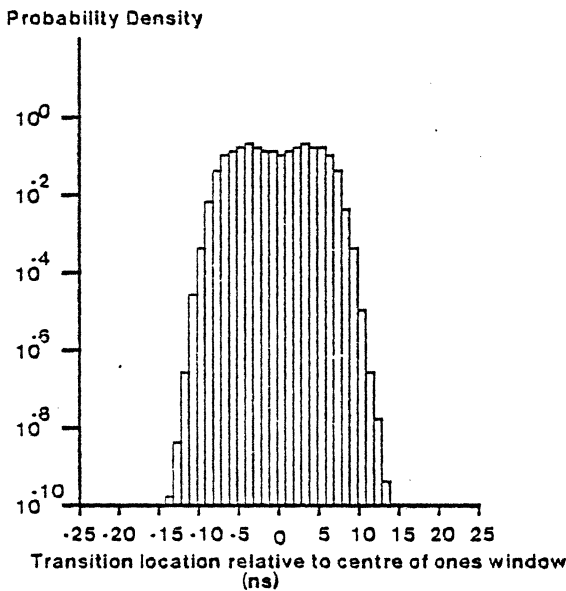
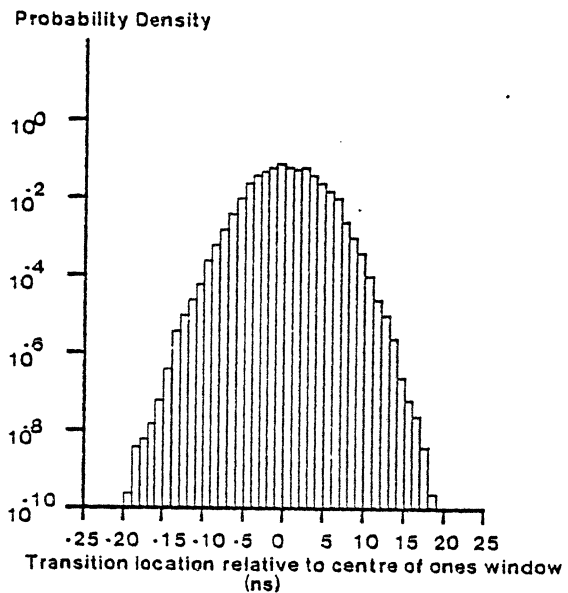Fig. 8 Transition distribution for MFM 110110.. pattern on one head at the inner radius

Fig. 10 Transition distribution for MFM 110110.. pattern using all eight heads at the inner radius after a modification to the data channel

CONCLUSIONS

Even a simple type of margin analyser can give very useful information about the operation of a disk or tape drive, while one of the more elaborate types described here can be one of the most useful tools available to both the drive designer and manufacturer.

REFERENCES

[1] G. F. Hughes and R. K. Schmidt , "On Noise in Digital Recording", IEEE Transactions on Magnetics , Vol. MAG-12 , No.6 , pp 752-754 , November 1976.

[2] Y. Ichiyama , "Theoretical Analysis of Bit Error Rate Considering Intertrack Crosstalk in Digital Magnetic Recording Equipment" , IEEE Transactions on Magnetics , Vol. MAG-15 , No. 1, pp 899-906 , January 1979.

[3] E. R. Katz and T. G. Campbell , "Effect of Bitshift Distribution on Error Rate in Magnetic Recording" , IEEE Transactions on Magnetics , Vol. MAG-15 , No.3, pp 1050-1053 , May 1979.