EYE DIAGRAM AS AN DIAGNOSTIC TOOL FOR BER ANALYSIS IN HIGH SPEED SERIAL LINKS- A REVIEW

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ABSTRACT

Eye diagram is a visual representation tool for analyzing the digital signals propagating in High speed links. As high speed digital signals exceed many gigabits per second speeds, eye diagrams provide the means to quickly and accurately measure signal excellence and system performance. This paper is a review of measurement of various parameters which indicate the degradation of a signal as it propagates through a high speed serial link. This may be due to clock jitter or poor synchronization of the phase-locking circuitry that extracts timing data from the received signal in a transmission system (wireline or optical).

KEYWORDS: *Eye diagram, histogram, High speed link, jitter, Inter symbol interference.*

I. INTRODUCTION

Digital signalling is the transmission of baseband data over a cabled connection. This data is usually modulated or coded according to the telecommunication protocol set as a standard for the intended interface. The type of baseband coding (commonly called Line Coding) chosen for a standard best optimizes performance, given the electrical characteristics of the data and the transport medium. Legacy high−speed digital standards including USB 1.1/2.0 use a form of non−return to zero (NRZ) for the data coding where a high (positive) pulse represents a logic one and a low (negative) pulse a logic zero. By controlling the data format (i.e., bit stuffing, etc) to make the number of ones and zeros equal, NRZ waveforms can be DC balanced and limit the DC content in the signal. This allows the signal to be capacitively (or AC) coupled and also provides common mode voltages or DC power to be combined with the signal on the same cable

1.1. Definition

It is an experimental tool for the evaluation of the combined effects of channel noise and intersymbol interference on the performance of a baseband pulse-transmission system. It is the synchronised superposition of all possible realisations of the signal of interest viewed within a particular signalling interval. Eye diagram, is an oscilloscope display in which a digital data signal from a receiver is repetitively sampled and applied to the vertical input, while the data rate is used to trigger the horizontal sweep. Figure 1shows the eye diagram of a digital signal.

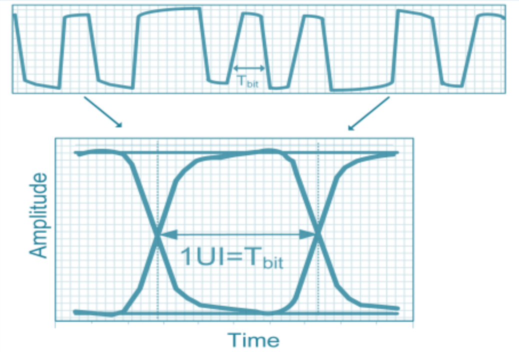

Figure 1. Typical High Speed Digital Signal with Eye Diagram

II. MEASUREMENTS OF DIFFERENT LEVELS OF EYE DIAGRAM

2.1.Histogram

The measurements in an eye diagram are based on the concept of histogram for all the measuring points like eye height, eye amplitude, eye width etc. Figure 2 is a Histogram which is a graphical representation of the statistics of eye diagram.

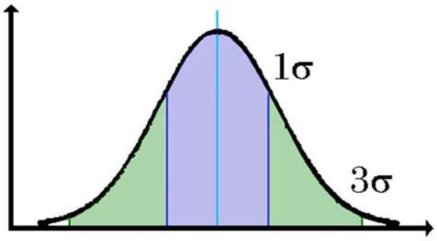

Figure 2: Histogram

- Mean is the sum of data values divided by the number of values
- Standard Deviation, two sigma, is ±1 σ, ±34 percent (or 68 percent) of mean
- Standard Deviation, six sigma, is ±3 σ, ±49.85 percent (or 99.7 percent) of mean [1]

2.2. Amplitude Definitions of Eye Patterns

1) **One Level:** The one level in an eye pattern is defined in Figure below. The one levels of the time/pulse waveform in the graphic on the right are highlighted by the arrows. The one level is calculated as the mean value of the top histogram distribution The actual computed value of the one level comes from the histogram(shown to the left of the figure) mean value of all the data samples captured inside the middle 20 percent of the eye period.

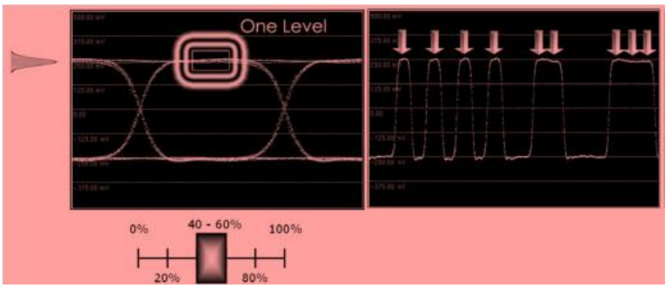

Figure 3: One Level representation

2) **Zero Level:** As shown in Figure below, the actual computed value of the zero level comes from the histogram mean value of the data captured inside the middle 20 percent of the eye period.

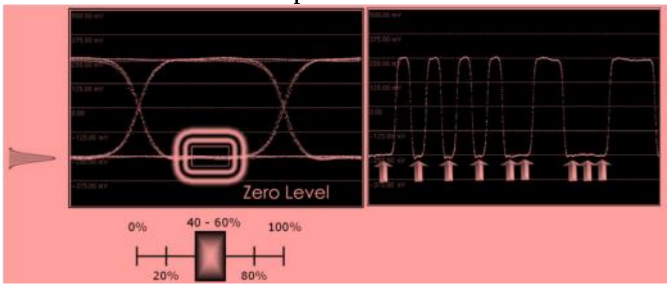

Figure 4: Zero Level representation

3) **Eye Amplitude, Eye Height:** The definitions for eye amplitude and eye height are shown in Figure below. Eye amplitude is the difference between the one and zero levels. The calculation values used are the mean values of the two histograms shown, measured during the middle 20 percent region of the eye crossings. The definition for eye height is derived from computing the difference between the inner 3 σ points on the inside of the histograms of the one and zero levels.[2]

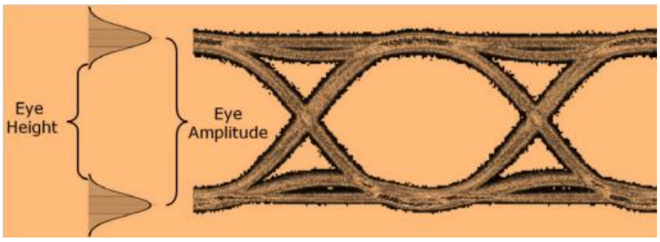

Figure 5: Eye Amplitude, Eye Height

The eye amplitude and eye height definitions are important amplitude terms since the data receiver logic circuits will ultimately determine whether the data bit is a "0" or "1," based on the eye amplitude. Any data bits scattered beyond the 3 σ points into the open eye will indicate a possible error in the detection, the BER is dependent on the eye height.

4) Eye Crossing Percentage: The eye crossing percentage is a measure of the amplitude of the crossing points relative to the one and zero level. It indicates the data pulse symmetry performance of the system. The crossing level is determined by taking the mean value of a thin vertical histogram window centered on the crossing point. The crossing percentage is then calculated using the following equation:

100 * [(crossing level – zero level)/ (one level – zero level)]

The figure 6 depicts the three rows of screen captures organized from top to bottom in terms of eye crossing percentage. In the top row, with a 75%, the time-pulse pattern for the "1" is longer in duration than the "0." The longer time for a "1" pushes the crossing point up. The pulse pattern shows that the "0" duration is also much shorter in time than the "1."

Eye crossing percentage is valuable for measuring amplitude distortions caused by differences in the one- and zero-level durations. It also reveals pulse symmetry problems for diagnosis. When the eye crossing symmetry value deviates from the perfect 50 percent point, the eye closes, which degrades BER.[1][2]

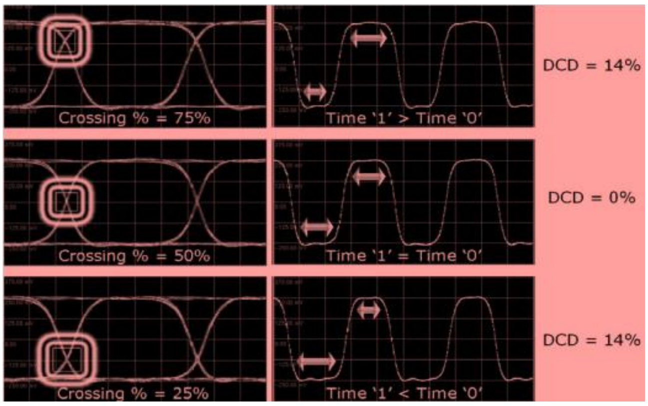

Figure 6: Eye Crossing

III. MEASUREMENTS ON HORIZONTAL AXIS

The horizontal time axis can be displayed as picoseconds or Unit Interval (UI). One data bit-width is interchangeable with one UI. The UI is also a convenient way to specify jitter performance in some standards and data sheets. The advantage of using UI instead of actual time on the horizontal scale is therefore clear. It is a normalizing term, irrespective of the data rate, and therefore makes it easier to view eye-pattern measurements of different data rates.[3]

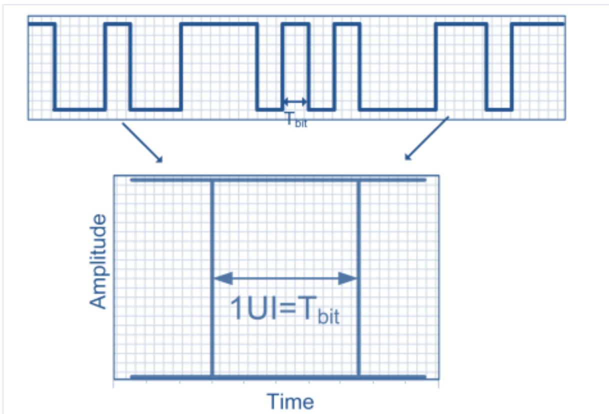

Figure 7: Horizontal Time Axis

3.1. Rise Time:

Rise time is a measure of the mean transition time of the data on the upward slope of an eye diagram. To measure the 20 to 80 percent rise time, two thin horizontal histogram slices are placed at the 20 percent level (to the left of the eye crossing) and at the 80 percent level (to the right of the eye crossing), as shown in Figure below. The rise time is then calculated using the following equation:

Rise Time = mean (80 percent time level) - mean (20 percent time level)

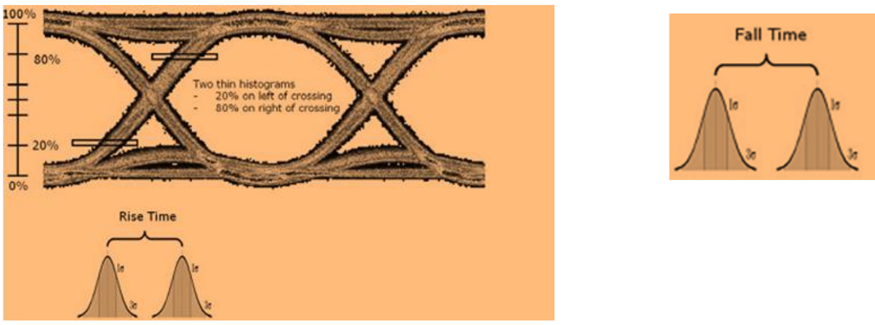

Figure 8: Rise Time, Fall Time

3.2.Fall Time :

Fall time is measured in a similar fashion as rise time, on the downward transition time of a data bit. The fall time is then calculated using the following equation:

Fall Time = mean (20 percent time level) - mean (80 percent time level)

3.3. Eye Width :

Eye width is a measure of the horizontal opening of an eye diagram. It is the effective distance between the inner two 3 σ points on the time histograms at the two crossing points. In this way, eye width is similar to eye height which is also measured between the 3 σ inner points.

IV. MEASURING THE SIGNAL IMPAIRMENT FACTORS

4.1.Jitter:

Jitter is the time deviation from the ideal timing of a data-bit event. It is one of the most important factor in high-speed digital data signals. To compute jitter, the time variances of the rising and falling edges of an eye diagram at the crossing point are captured. Fluctuations can be random and/or deterministic. The time histogram, shown below the eye pattern, is analyzed to determine the amount of jitter. The peak to peak jitter is calculated as the width of the total histogram. The RMS value of jitter is measured as the width between 3 σ points.

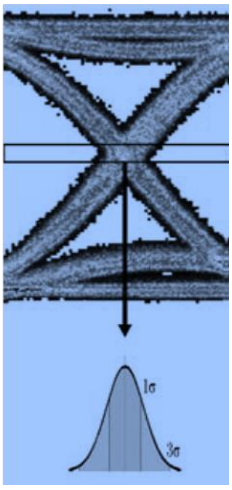

Figure 9: Histogram for Jitter Measurement

4.2. Signal-to-Noise Ratio (SNR) :

The SNR is defined as a ratio of the desired signal level to the level of background noise, plus any distortion. Higher SNR values are more desirable than lower SNR values To calculate SNR, eye pattern analyzer uses the following equation:

(one level – zero level)/(1s [one level] + 1s [zero level])

Figure 10 shows the eye diagram for signal with very poor SNR. In this case, the signal is obscured by the background noise.. On screen captures, it is noted that the one and zero levels are broadly distributed and largely buried in noise. In this situation, the standard deviation is large because many points are away from the mean and the eye height is very small. Because of this the receiver data detectors face problem in differentiating between 1 s and 0 s [4]

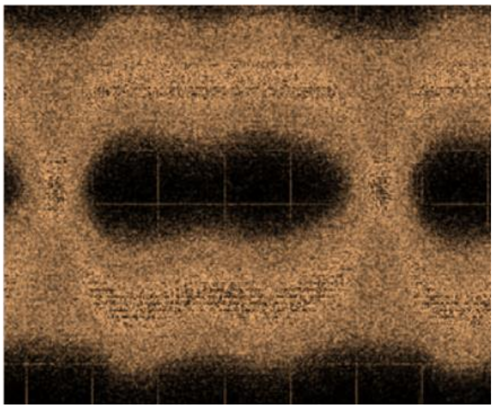

Figure 10: Signal to Noise Ratio representation

4.3.Duty Cycle Distortion (DCD)

DCD is a measure of the deviation in duty cycle from normal value and is usually caused by pulse-width deviations in the data pattern. It measures the time separation between the rising and falling edge at the 50 percent amplitude level of the eye diagram. To measure the DCD, the 50 percent level of the edges are calculated using the same histograms that are used in the rise-time and fall-time measurements (the center of the 20 to 80 percent measurement). The DCD is then calculated using the following equation:

DCD = 100 x time difference between rising and falling edges @ 50 percent level/ bit period

=100 x A/B (in the figure below)

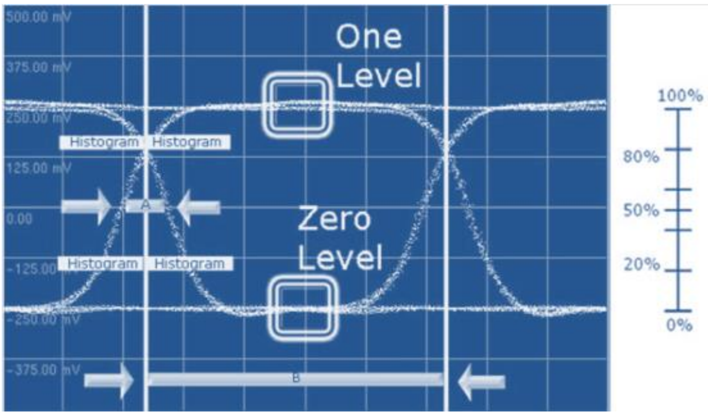

Figure 11: Duty Cycle Distortion

4.4 Skew in Differential Signals:

Differential signals offer superior noise immunity and overall improved signal integrity, which is highly desirable in the transmission and distribution of high-speed signals. Skew is the time difference between the bit patterns in channel 1 and channel 2 of differential pair. By considering each channel separately, if the two eye diagrams are overlaid the amount of skew can be measured display offers a quick at-a-glance assessment of the amount of skew which can be used for quickly isolating potential problems in differential pairs that impact signal integrity.[6]

4.5.Inter symbol interference:

Performance of high-speed electrical links is limited by conductor loss, dielectric dispersion, and reflections in the board, package, and connector. These nonidealities result in significant ISI. The presence of ISI in the system introduces errors in the decision device at the receiver out .

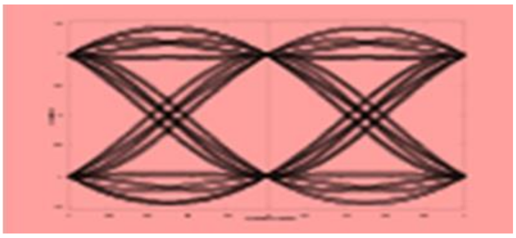

Figure 12: The eye diagram of a binary PSK system

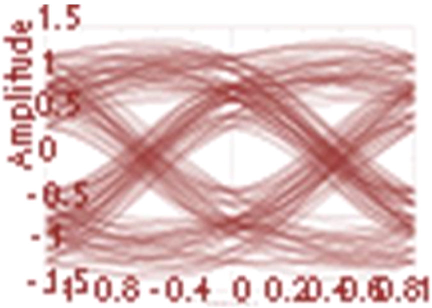

Figure 13: The eye diagram of the same system with multipath effects added

The effects of ISI are shown in the image which is an eye pattern of a system when operating over a multipath channel. The effects of receiving delayed and distorted versions of the signal can be seen in the loss of definition of the signal transitions. It also reduces both the noise margin and the window in which the signal can be sampled, which shows that the performance of the system will be worse and will have a greater bit error rate.[3][5]

V. Conclusion

Eye diagrams provide instant visual data that engineers can use to check the signal integrity of a design and uncovered problems early in the design process. Used in conjunction with other measurements such as bit-error rate, an eye diagram can help a designer predict performance and identify possible sources of problems. With the help of this paper can measure various parameters which indicate the degradation of a signal as it propagates through a high speed serial link.

VI. Future Work

This concept of EYE diagram can be used to calculate BER in signal propagating in various high speed serial link technologies.

Ex: PCIe, SATA, USB etc.

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