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Bit Error Ratio: What Is It? What Does It Mean?

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Bit Error Ratio (BER) is used to measure the performance of a communications link. This white paper discusses the conditions necessary to make useful BER measurements as well as the limitations of this metric.

Introduction

Bit error ratio (BER) is one of many statistical measures of a communications link or channel. BER is the ratio of the number of bits received in error to the total number of bits received over a given period of time. For example, a BER of 10^{-12} means that there is one bit in error for every trillion bits received.

Discussion

To measure the bit error ratio, enough bits must be issued and enough errors must occur to allow an accurate determination of the measurement statistics. There must be at least 30 errors to provide any reasonable confidence that the values for the mean and deviation are useful. From the previous example, a BER of 10^{-12} implies that one must wait until 30 trillion bits are issued. Even at 1 Gb/s, that amounts to 30,000 seconds, or about eight hours. Thirty events allow for calculation of useful statistical confidence intervals if and only if the distribution is normal.

Even after this long period, it can only be said that the error ratio is approximately 10^{-12} with a mediocre confidence level. The error ratio can become 10^{-13}, or even 10^{-11}, if one were to wait longer and gather more statistics.

Statistics

In the absence of any other information, bit errors are usually assumed to occur in a Gaussian or normal distribution. However, the errors might not be random at all, but could be related to system activity, power transients, cross talk from other sources, the data pattern itself, and many other non-random factors. Therefore, if the error distribution is not Gaussian, an even longer period of measurement is needed to validate the BER measurement. The error ratio is now vastly more complex to analyze because a burst of errors indicates non-random behavior. In this case, it is not a question of BER. The link is broken! A statistically valid BER measurement often takes more time than an engineer can afford to spend in getting this measurement.

Shortcuts

Engineers often assume the normal error ratio distribution to make intelligent estimates of the BER. They also try to predict the error ratio based on the eye opening or timing and amplitude margins of the signal. Given that the error ratio is random, that there is no deterministic source of errors, and that the margin can actually be measured, this assumption provides a result based on the communications theory that is commonly used and accepted. However, any receiver with receive equalization, or phase or frequency response distortion cannot be measured by observation of the eye pattern because it is invisible inside the design.

Bit error ratio testers (BERTs) assume a perfectly flat response for the receiver and derive the BER based upon all the assumptions mentioned earlier. They can be entirely too optimistic or pessimistic due to the many guesses about the receiver characteristic and the actual impairments that occur. As before, any non-random effects make the BER measurement useless.

What Can an Engineer Do?

BER is just one measure of link performance. Any link that issues errors sporadically or has error bursts is broken, and is not very useful. To evaluate a link, other important measures must be looked at besides BER:

- Transmit jitter: How much is random? How much is not random?
- Receiver input jitter tolerance: The higher the receiver input jitter tolerance, the greater is the link performance.
- Jitter transfer function: Does jitter decrease (good) or increase (bad)?
- Transmit shaping: Can the transmit be pre-distorted to improve the eye at the receiver based on knowledge of the losses in the link? (Also known as transmit equalization).
- Receive equalization: Does the receiver pull the signal from the noise by reducing the effects of the transmission link?
- True link BER: This is measured from the data source to the data sink.
- Run length: This is the number of zeros in a row before synchronization is lost.
- Performance with different patterns: Pseudorandom, stress, etc.

For examples of what is required, refer to the various transceiver Characterization Reports. These can be obtained from the Xilinx website at

http://www.xilinx.com/support/documentation/

Click the **Doc Type** tab, then click **Characterization Reports**.

Summary

Bit error ratio should not be used as the sole measure of link performance because it involves a stochastic process that is affected by many errors and is based on many assumptions. BER does not say much about link performance in the absence of other data. The bit error ratio test is only one test for comparing products and their specifications, and it must be examined in the context of all the factors and other tests that have been discussed in this white paper.

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
03/28/08	1.0	Initial Xilinx release. Based on a previously published *Tech Xclusive* article by the same author.

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