 By Howard Johnson, PhD

Random and deterministic jitter

MANY CLOCK-RECOVERY CIRCUITS produce a repetitive, predictable jitter. This effect is particularly noticeable in cheesy clock-multiplier circuits and poorly equalized data-recovery units. The name for the predictable component of jitter in these circuits is *deterministic jitter*. The remaining components of jitter constitute *random jitter*. You can usually presume that deterministic- and random-jitter components are not correlated.

To measure the deterministic jitter on a clock (or data) waveform, you must trigger your oscilloscope at a rate commensurate with the source of the deterministic jitter. For example, in an 8B10B-coded data waveform transmitting a repetitive 10-bit test pattern, a trigger frequency of one-tenth the data baud rate taken directly from the data source would be appropriate. For another example, in a clock-multiplier circuit, the input reference-clock frequency would be appropriate.

You must set the scope to average its measured results. The averaging nulls all the random jitter, leaving you with a clean picture of a repetitive (though slightly distorted) time-domain waveform. The deterministic jitter is the difference in time, for each particular transition in the repetitive sequence, between the *actual* time at which the transition occurs and the ideal time, in a perfect system, at which the transition *should* occur.

Deterministic jitter comes from many sources, including duty-cycle distortion (DCD), intersymbol interference (ISI), and word-synchronized distortion due to imperfections within a data serializer. (For example, bit 3 of each data word always appears early.)

DETERMINISTIC COMPONENTS OF JITTER HAVE A LOWER RATIO OF PEAK VALUE TO STANDARD DEVIATION THAN DO THE RANDOM COMPONENTS.

From the collection of measured time differences, you can find the average value and then the variance (square of the standard deviation) of the measured values. This process gives you one piece of information: the variance of the deterministic jitter.

Next, use the histogram feature on your oscilloscope or time-interval-analysis instrument to measure the variance of *overall* jitter (including both deterministic and random jitter). The variance of the random jitter equals the variance of the total jitter minus the variance of the deterministic jitter.

The point of separating jitter into random and deterministic components is that the deterministic components have a lower ratio of peak value to standard deviation than do the random components. Measured only according to the standard deviation, a certain amount of deterministic jitter doesn't hurt your system nearly as much as a similar quantity of random jitter.

Good specifications for clock jitter provide separate budgets for the worst-case peak amount of deterministic jitter, plus an allotment for the standard deviation of random jitter.

For any kind of random jitter, the ratio of peak value to standard deviation depends on the bit-error rate (BER) at which the system must operate. **Table 1** indicates the ratio of peak to standard deviation for Gaussian random jitter, assuming various BER values. The presumption is that the magnitude of the Gaussian noise will not on average exceed the stated peak value more often than once every 1/BER bits. The peak-to-peak jitter ratio is twice the number in the second column of the **table.**□

TABLE 1—GAUSSIAN-WAVEFORM PROBABILITIES

BER	Ratio of peak deviation to standard deviation
1×10^{-4}	3.891
1×10^{-5}	4.417
1×10^{-6}	4.892
1×10^{-7}	5.327
1×10^{-8}	5.731
1×10^{-9}	6.109
1×10^{-10}	6.467
1×10^{-11}	6.807
1×10^{-12}	7.131
1×10^{-13}	7.441
1×10^{-14}	7.739

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