



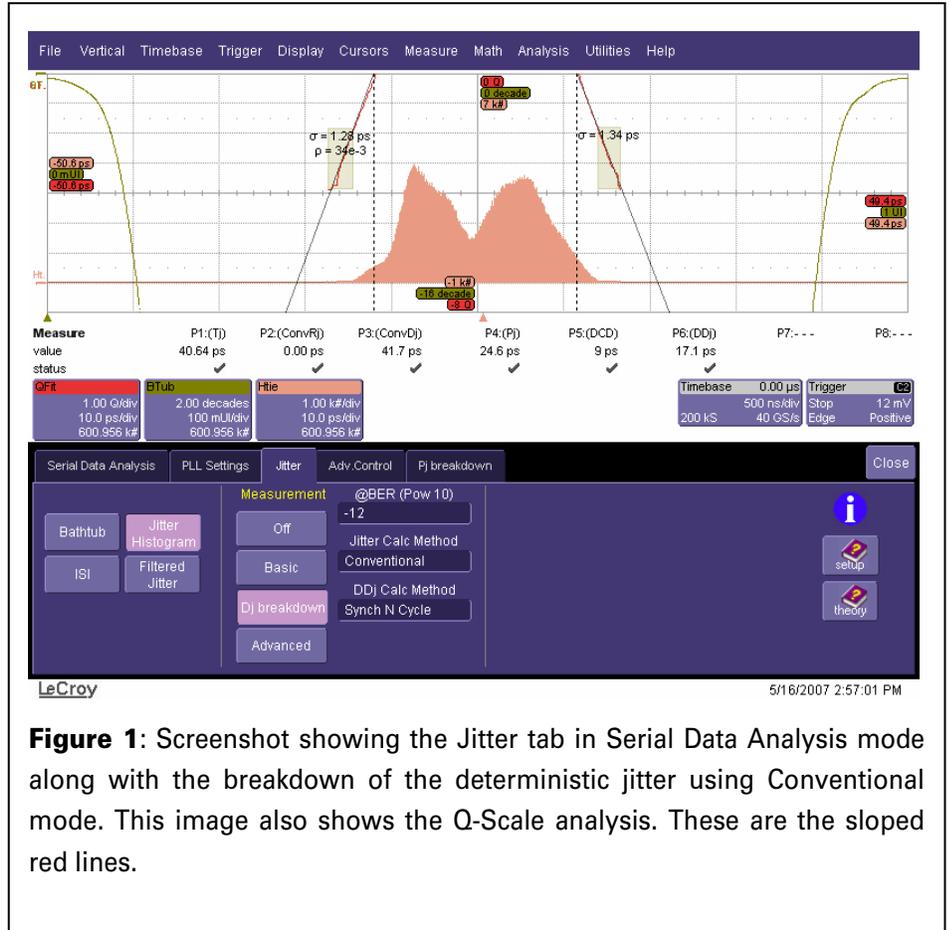
## UNDERSTANDING THE CHOICES FOR JITTER CALCULATION METHOD

The LeCroy Serial Data Analyzers give users a choice of three different methods for calculating the jitter in their signals. This application brief describes the methodology used to determine the jitter components for each method, and when each method should be used.

To measure jitter in Serial Data Analyzer mode, the user calls up the Serial Data Analysis configuration screen by either selecting the Analysis menu option called Serial Data or by pressing the Serial Data button. The resulting screen contains option buttons on the left hand side; choosing the Jitter button brings up the Jitter tab. The user can then choose one of the three jitter calculation methods, as shown in figure 1: **Conventional**, **Effective**, or **MJSQ**. After a method is selected, the scope calculates the jitter using all data accumulated, and places the results in the Measure Table. The results for total jitter (Tj), random jitter (Rj), and deterministic jitter (Dj) are placed in the Value row of the table in parameters P1, P2 and P3, respectively. With each additional trigger, the values are updated to include the data from the most recent sweep as well as from all sweeps since the measurement system was last reset.

### Calculation of Tj

Each of these methods calculates Tj in the exact same way: using LeCroy's patent-pending "Normalized Q-Scale method". This method employs a statistical analysis of the Time Interval Error (TIE) measurements taken by the oscilloscope, and results in random and deterministic jitter values which are



**Figure 1:** Screenshot showing the Jitter tab in Serial Data Analysis mode along with the breakdown of the deterministic jitter using Conventional mode. This image also shows the Q-Scale analysis. These are the sloped red lines.

summed using the MSJQ methodology (see below). The oscilloscope displays the result of the Q-scale analysis; these are also shown in figure 1. The slope of the Q-scale curves and their separation at 0 (the top of the grid) determine the values for Rj and Dj.

Note that Rj is often better described as "remaining" jitter, since the term "random" is often (and not correctly) used to refer to sources of jitter that are unknown rather than not deterministic.

It is important to understand that value of Tj is a function of "bit error ratio". Bit error ratio is abbreviated

"BER", but do not confuse this with bit error rate! For each jitter calculation method, users can select the BER value for the jitter measurement. The value  $1 \times 10^{-12}$  is the default value used; enter a different exponent if a different value is preferred.

### Tj Breakdown Algorithms

The jitter calculation methods differ in how they breakdown the Tj result into Dj and Rj. Note that there is no singular method of calculating Tj, Rj and Dj, and no shortage of literature on the topic of calculating jitter. For additional information, see the list of suggested readings at the end of this application brief.

The **MJSQ** method is part of the Fibre Channel specification. (MJSQ stands for “Methodologies for Jitter and Signal Quality Specification”.) This method has become a widely accepted for measuring jitter in serial data applications. In MJSQ,  $D_j$  is modeled as having a dual-Dirac shape, with two Gaussian functions that grow with the bit error ratio. (See the suggested readings for the details). Built-in to the MJSQ model are a set of assumptions as well as a methodology for estimating  $R_j$  and  $D_j$ . It is important to understand that the measurements reported by the oscilloscope are indeed estimates, since it is extremely difficult to acquire enough data to accurately and directly measure  $R_j$  and  $D_j$  at bit error ratios of interest to most customers.

MJSQ calculates  $T_j$  from  $R_j$  and  $D_j$  based on numerical fitting of the observed jitter distribution.  $R_j$  is determined by averaging the sigma values that were determined from the normalized Q-scale analysis, one for each of the two Gaussian distributions. In figure 2, the left and right distributions give sigma values of 1.28 ps and 1.34 ps, which average to the 1.31 ps value displayed in P2 in the Measure Table. The value for  $D_j$  can also be read out from the Q-Scale analysis; the separation of the Q-scale lines at  $Q=0$  (the top of the grid) give the  $D_j$  value. In figure 2, the result is 23.48 picoseconds, corresponding to about 2.35 divisions of separation.

Use MJSQ when needing to measure jitter using an industry-accepted method.

The **Effective** jitter method seeks to breakdown  $T_j$  through an analysis of the bathtub curve. This is the only way to determine  $R_j$  and  $D_j$  values when using other instru-

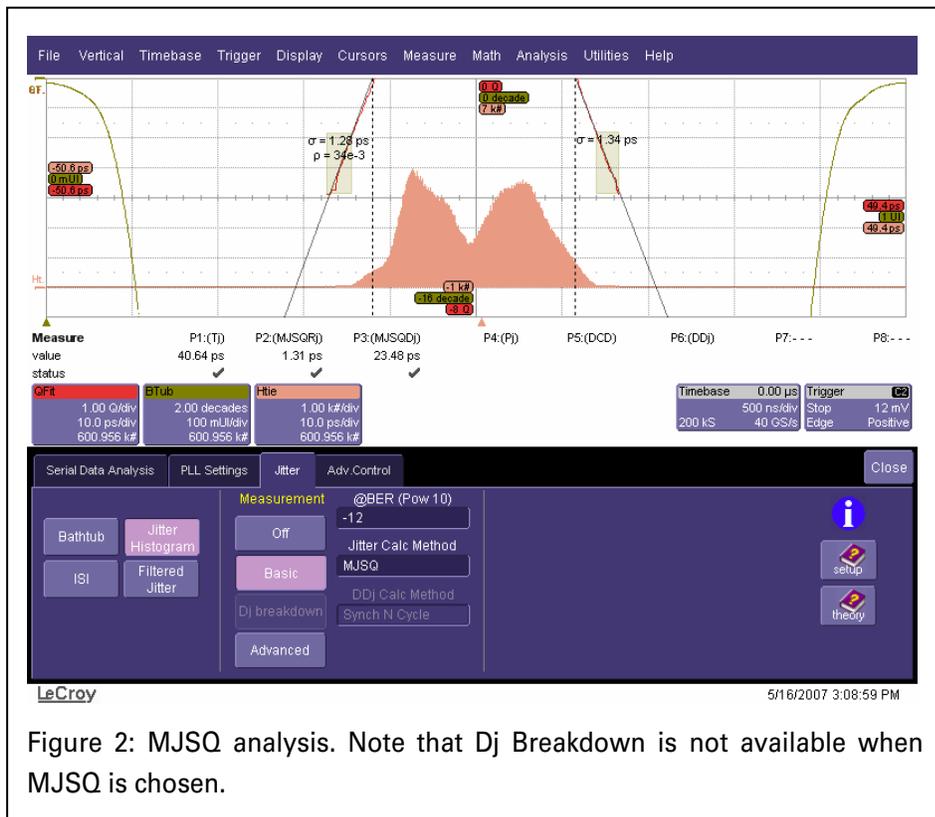


Figure 2: MJSQ analysis. Note that  $D_j$  Breakdown is not available when MJSQ is chosen.

ments like a bit error rate tester (BERT) that cannot analyze the actual waveforms. LeCroy’s implementation of this method plots the width of the total jitter curve at different values of BER. This forms a line with a slope and intercept that relate directly to  $R_j$  and  $D_j$  values. Note that this method often returns values of  $R_j$  and  $D_j$  that are similar to MJSQ.

Use the effective method to compare the results from your LeCroy Serial Data Analyzer to other instruments that use the Effective method, such as bit error rate testers.

The **Conventional** method seeks to find the most accurate value of deterministic jitter by performing an intensive analysis of the waveform. This LeCroy algorithm determines the periodic jitter, duty cycle

distortion and data-dependent jitter. When the **Dj Breakdown** button is selected, the measurement table will display the contribution to the total jitter due to each of these components. Figure 1 shows the serial data analyzer configured for conventional mode with  $D_j$  breakdown turned on. In this mode of operation, the values for  $P_j$ , DCD and  $DD_j$  are placed into parameters P4 through P6 of the measurement table.

The Conventional method gives additional insight into sources of periodic and data dependent jitter. A breakdown of the periodic jitter is given in the  $P_j$  Breakdown tab shown in figure 3. Analyze the data in this tab for evidence of periodic aggressors in your system that will cause edges to shift in a periodic fashion.

The data-dependent jitter is determined through an analysis of either the Synchronous N Cycle Plot or of the ISI (inter-symbol interference). Use the ISI method if your data pattern is not repeating. The jitter that remains when removing the deterministic jitter from the total jitter is the  $R_j$ .

Use the Conventional method when you want the most accurate and direct measurements of the deterministic jitter at a specific BER.

**Additional reading:**

Fibre Channel MJSQ document:  
<http://www.t11.org/ftp/t11/pub/fc/mjsq/04-101v5.pdf>

A Comparison of Methods for Estimating Total Jitter Concerning Precision, Accuracy and Robustness  
[http://www.lecroy.com/tm/Library/WhitePapers/PDF/LeCroy\\_Jitter\\_Methods\\_DesignCon2007.pdf](http://www.lecroy.com/tm/Library/WhitePapers/PDF/LeCroy_Jitter_Methods_DesignCon2007.pdf)

6 Tales of  $R_j$  and  $D_j$   
[http://www.lecroy.com/tm/Library/WhitePapers/PDF/WP\\_TechBrief\\_Rj\\_and\\_Dj.pdf](http://www.lecroy.com/tm/Library/WhitePapers/PDF/WP_TechBrief_Rj_and_Dj.pdf)

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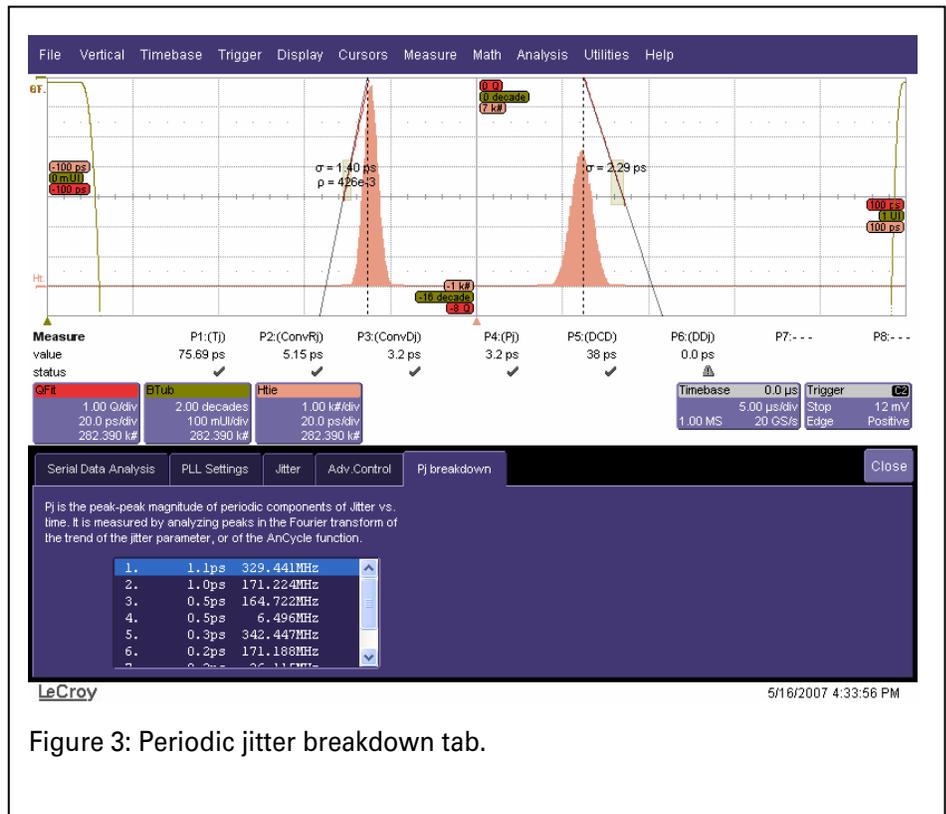


Figure 3: Periodic jitter breakdown tab.