COLOR GRADING AND THE STATISTICAL DATABASE

Color Grading is the most powerful display mode in the CSA 803. Not only does it add another dimension to the display, sample density, but with a 512 by 256 array of 16-bit counters, it allows the accumulation of an on-board statistical database.

Color Grading

The CSA 803 provides four waveform acquisition modes: Normal, Variable Persistence, Infinite Persistence, and Color Grading. In the Normal acquisition mode waveform points are displayed as they are acquired, with no storage on the screen. In the Variable Persistence mode the user can define the length of time waveform samples will be stored on the screen — from 200 ms to 20 sec.

The Infinite Persistence and Color Graded modes are similar, in that acquired waveform samples are added to the display and held there until the trace is cleared or a waveform setting is changed. There are, however, two major differences in these two display modes:

In the Infinite Persistence mode, waveform samples are added to the display as they are acquired. In the Color Graded mode, waveform samples are added according to a user-defined Refresh Rate (see sidebar).

And, instead of the "flat" two-dimensional display available with Infinite Persistence, Color Grading adds a third dimension — sample density (Figure 1).

Sample density is represented by the color assigned to each waveform point in the display. Colors are assigned according to the number of times each point on a waveform is acquired relative to the number of times all other waveform points *in the same graticule* are acquired. The CSA 803 keeps track of the number of times each waveform point is sampled with an on-board Statistical Data Base. An array of 16-bit software counters (16-bit words) is used to count the number of times each waveform point is "hit". Since the CSA 803 is a sequential sampling tool (one sample per trigger event), each time the waveform is sampled, one counter will be incremented.

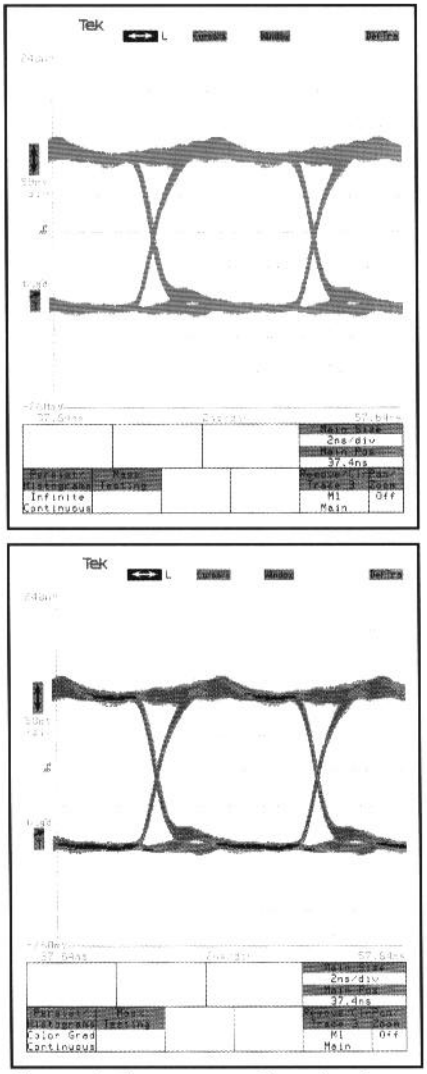

Figure 1. The top waveform has been acquired with the CSA 803's Infinite Persistence mode. The bottom trace is the same input signal acquired with Color Grading. The Color Graded display provides an instant qualitative view of the acquired data.

When a single graticule is displayed, a 512 by 256 array of 16-bit counters is used to count waveform samples. Since there are 512 by 512 pixels in the display, each of the 256 vertical levels in the counters will be mapped to two adjacent vertical pixels. This increases the visual resolution of the display.

When you select the Dual Axis or Windowing modes, two graticules will be displayed. Each graticule will contain 512 by 256 pixels. And now, *two* 512 by 128 arrays of 16-bit software counters (one for each graticule) will keep track of the sample density for the two graticules. Again, each vertical level in the counters will be mapped to two adjacent vertical pixels.

The Statistical Database

While the color graded display provides a convenient "third dimension" to the acquired data, that's only a small part of the underlying power of the Statistical Data Base. The Statistical Data Base is also available for histogram and mask analysis and can be transferred over the GPIB or RS-232-C to an external computer for data logging or further analysis. And since the acquired data is stored in this on-board data base, you can make several measurements on the same data, rather than reacquiring data for each new measurement.

All previous instruments required you to acquire new data for each new measurement. Noise and jitter measurements, for example, could not be made on the same waveform data. Waveforms points were acquired over a long period of time (from minutes to hours) to satisfy statistical criteria. If errors occurred during measurements, the acquisition had to begin all over again.

Display Updating

The CSA 803 periodically updates histogram results, mask counts, and the Color Graded display to show you the progress of a measurement or acquisition. You can select a screen refresh rate from 5 seconds to 3 minutes (see sidebar). At the selected interval, the color graded display and histograms will be updated to show new results, so you can see, early in the process, whether you are getting the measurement you desire. Without this capability, you can't see the results of a measurement until the entire acquisition is complete. After acquiring data for several minutes or even hours, it's pretty frustrating to find that the measurement wasn't set up exactly as you expected, forcing you to start the process over again.

Starting Color Grading

Color grading is turned on by simply touching the *Color Grading* selector in the *Persist/Histogram* pop-up menu.

Controlling Color Graded Acquisition

In some applications the user may wish to set well-defined limits on the acquisition so that repetitive tests are all performed exactly the same. The CSA 803 allows the user to define the conditions under which waveform acquisition will cease while in the Color Graded mode. These include: setting a limit to the number of waveforms acquired, *Set N Waveforms*; or setting a pixel-hits overflow condition called *Max Contrast*. In addition, waveform acquisition may be stopped at any time by simply pressing the **Run/Stop** button on the front panel.

Note that if the user changes acquisition methods or parameters while the CSA 803 is in the process of acquiring data, the screen will be cleared and waveform acquisition will begin anew.

Specifying a Waveform Count

The user may specify the maximum number of waveforms to be acquired by pressing the *Persist/Histogram* selection of the *Display Modes* major menu, and then choosing *Stop N Waveforms*. Using the Control Knobs, the user can dial-in the desired number of waveforms to be acquired. Upon reaching this number, acquisition will stop. Histograms or mask testing may be performed at any time during the acquisition process and will be updated with the acquisition until the specified limit is reached. The measurement results and the acquired waveform data can also be transferred to external storage via the GPIB or RS-232-C interfaces.

Setting the Max Contrast Overflow Condition

The **Max Contrast** function in the *Persist/Histogram* menu allows you to stop color grading when a specified number of overflow conditions occur in the statistical database. An overflow condition occurs when one of the 16-bit counters has reached its maximum count of 65,535 and the current waveform sample would cause it to "wrap around" to zero (by being incremented). Remember that one of the 16-bit counters is normally incremented for every waveform point that is acquired. However, once a counter reaches its maximum count, it stays there — it does not "wrap around" to zero.

The *Set N Max Contrast* function specifies the number of overflow conditions that may occur before waveform acquisition is stopped. This "stop acquisition condition" could be satisfied due to one overflow occurring in *"N"* counters, or *"N"* overflows occurring in one counter, or any combination thereof. The *Set N Max Contrast* function does not initiate "stop acquisition condition". This is done by *Stop on Max Contrast*, which clears the waveform display and begins new waveform data acquisition.

When the specified number of counter overflows occur, the acquisition is automatically stopped. The **Stop** indicator light, next to the **Run/Stop** button tells you that the acquisition is complete. You can restart the acquisition by pressing **Run/Stop** again, and the instrument will start acquiring new data without clearing the current waveform data. If you press *Stop on Max Contrast* again, the waveform data is cleared, and a new acquisition starts as before. You can also interrupt an acquisition started with *Stop on Max Contrast* by pressing the **Run/Stop** button.

Choosing "N" for Max Contrast

In most measurement situations, you'll want to acquire data into the statistical data base without overflowing any of the 16-bit counters, because overflowing a counter causes truncation of the data in the data base. This implies an "N" of 1 for Max Contrast.

If, however, you are interested in waveform details of very low statistical probability, such as metastability states, etc., you may actually want to allow some of the data base counters to overflow, since you're not interested in the highly stable parts of the waveform display, but in the low-probability events. In these cases, you may want to set "N" to a larger number to acquire more of the low probability data.

User Defined Refresh Rate

Updating the color graded and histogram display takes about 2 seconds. During the update period, no new data is acquired and stored in the data base. Therefore, if the refresh rate is set for 5 seconds, the instrument spends 3 seconds acquiring data and 2 seconds refreshing the screen. Turning the refresh rate down to 18 seconds, for example, allows the instrument to spend 16 seconds acquiring data and 2 seconds updating the screen — a significant improvement in effective acquisition rate.

Obviously, slower refresh rates equate to faster data acquisition. However, you'll have to wait longer between updates to see the results of newly acquired data. You may want to use a faster refresh rate while you're setting up a measurement, and then set the refresh rate slower after you're confident that the acquisition is progressing properly. You can change the refresh rate at any time without fear of loosing data.

Note that the refresh rate affects only the display — you can get data from the instrument over the GPIB or RS-232-C at any time, independent of refresh rate. If you're using the instrument in an automated system where an operator will not be watching the screen, you'll probably want to use a slow update rate, since effective data acquisition rate will be higher and there is little need for screen updating.

Filling a Data Base Counter

So how long does it typically take to acquire enough data to overflow a data base counter? The 16-bit counters in the statistical data base can store up to 65,535 waveform samples. At full trigger rates, it takes about 2½ hours with a very stable signal (i.e., one that hits the same waveform points each time) to reach the maximum count in any counter. Signals with more jitter or noise or signals acquired at higher vertical sensitivities or faster sweep speeds will take longer to fill up the data base, since the waveform is not concentrated on a single line through the display.

Remember, however, that you don't have to fill up the data base to make measurements. You can get histograms and mask results at any time during the acquisition, and you can see intermediate results as the data base fills.

The Default Colors of the CSA 803

Five default colors are assigned to displayed traces as shown in Table 1. In Color Grading mode, these same colors are assigned to the color graded data as shown in Table 2. By using a limited color palette in Color Grading mode, waveform areas of greatest activity appear more dense, and are easier to distinguish. Users may also change any default color via the Color pop-up menu in the *Utility* major menu.

TABLE 1

Trace, Window, Background and Histogram Colors

Item	Color
Trace 1	Pale Yellow
Trace 2	Rose
Trace 3	Green
Trace 4	Purple
Window	Light Blue
Background	Grey *
Histogram	Red *

* These reserved colors are not available for any trace or window.

TABLE 2

Default Colors for Sample Density

(Listed in order of greatest sample density to least.)

Pale Yellow
Rose
Purple
Light Blue
Green

Color Graded Display Algorithms

Three algorithms are used to assign colors in the Color Grading mode. The color assigned to a pixel depends on how many waveform points it has registered (frequently referred to as the number of times a pixel has been "hit"). In the following algorithms, **Max** is the maximum number of hits in all the pixels. **Hit Density** is a range of hits.

Algorithm 1: Max >15

HIT DENSITY	DEFAULT COLOR	MAPS TO
[Max/2 + 1] to Max	Pale Yellow	Trace Color 1
[Max/4 + 1] to Max/2	Rose	Trace Color 2
[Max/8 + 1] to Max/4	Purple	Trace Color 4
[Max/16 + 1] to Max/8	Light Blue	Window Trace
1 to Max/16	Green	Trace Color 3

Algorithm 2: Max ≥6 and Max ≤15, sf=Scaling Factor=Fourth root of Max

HIT DENSITY	DEFAULT COLOR	MAPS TO
[Max/sf + 1] to Max	Pale Yellow	Trace Color 1
[Max/sf^2 + 1] to Max/sf	Rose	Trace Color 2
[Max/sf^3 + 1] to Max/sf^2	Purple	Trace Color 4
[Max/sf^4 + 1] to Max/sf^3	Light Blue	Window Trace
1 to Max/sf^4	Green	Trace Color 3

Algorithm 3: Max <6

HIT DENSITY	DEFAULT COLOR	MAPS TO
Max	Pale Yellow	Trace Color 1
Max −1	Rose	Trace Color 2
Max −2	Purple	Trace Color 4
Max −3	Light Blue	Window Trace
Max −4	Green	Trace Color 3

Note: for all points where Hit Density ≤0, no color is assigned. If Max is less than 5, not all colors will be represented on the display.

Acquiring and Displaying Multiple Waveforms

When displaying more than one color graded waveform on the same graticule, it is possible to dilute the color grading of one of the waveforms. For example, if you display a highly repetitive clock signal on the same graticule as the eye diagram from a pseudo-random data stream, the color grading of the clock will dilute the color grading of the data stream (Figure 2a). This is because the algorithm used to assign colors is a function of the maximum number of pixel "hits" on any one pixel in the graticule.

By creating a second graticule, a separate time acquisition basis and statistical data base can be established for the data stream or the clock signal. As stated above, a 512 by 128 by 16-bit statistical data base will be assigned (automatically) to each graticule. The two waveforms will then be color-graded independently (Figure 2b).

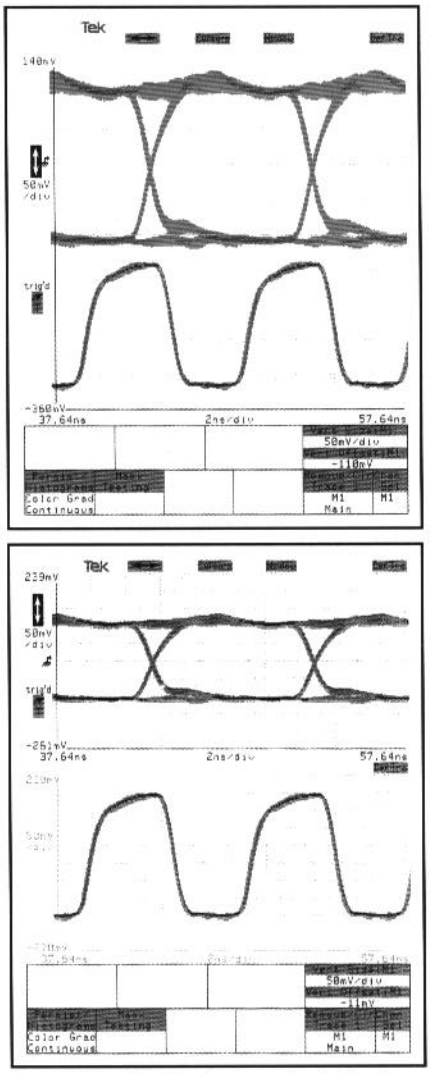

Figure 2. The color graded display of the clock signal in "a" (top) dilutes the color grading of the data's eye diagram, because the number of hits in each pixel is compared to the hits in all other pixels in the same graticule. When displayed on separate graticules, as in "b" (bottom) only those pixel hits in the same graticule are compared.

Windowed Waveforms

Any portion of an acquired waveform may also be viewed as a windowed waveform (Figure 3). Windowing allows users to distinguish the details of a display by sampling the selected portion of a waveform at a higher sweep speed. This is not simply a digital expansion of the main record, it is an actual reacquisition at higher resolution (sweep speed).

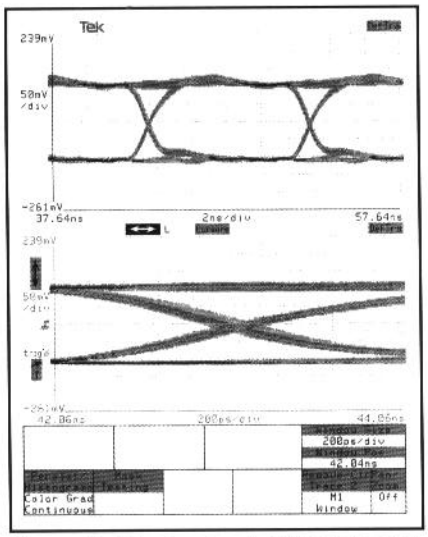

Figure 3. Windowing in Color Graded mode allows the user to see the quality of areas like transition zones.

Record Length

In Color Grading, as well as variable and infinite persistence, the longest allowable record length is 512 points. If the record length is longer than 512 points when any of these modes is selected, the record length is reduced to 512 points and a warning message is issued. You can't extend the record length beyond 512 points when any of these modes is selected. Normal display mode allows record lengths from 512 to 5120 points.

Histograms

The CSA 803 can display up to 8 waveforms. Each one of these traces can be paired with a vertical histogram or a horizontal histogram for statistical analysis of waveform parameters, such as risetime, fall-time, duty cycle, phase, jitter and noise. Only one type of histogram may be displayed with a trace at any time.

In high speed communications, histograms are most often used to quantify noise and jitter as shown in Figures 4a and 4b. For those who have to measure both, histograms and Color Grading can be an advantageous combination. (See the "Using Histograms For Jitter and Noise Measurements" Technical Brief for further details.)

To define a histogram, select either *Horizontal Histogram* or *Vertical Histogram* from the *Display Modes* major menu. A box will appear on the screen which establishes the limits of the histogram. By touching the *Vertical Limits* or *Horizontal Limits* selectors in the *Persist/Histogram* pop-up, you can then adjust the position and size of the histogram box with the Control Knobs.

Histogram statistics and acquisition information will be displayed and continuously updated at the refresh rate you've defined, at the bottom of the screen. The displayed information includes: **Mean; RMS Delta** (standard deviation); the percentage of waveform points that fall within one, two, and three standard deviations of the mean (**μ + 1sigma, μ + 2sigma, μ + 3sigma**); the number of waveforms acquired (**Wfms**); the **Top** and **Bottom**, **Left** and **Right** limits of the histogram box; and the number of waveform samples (**Hits**) that have fallen within the histogram area.

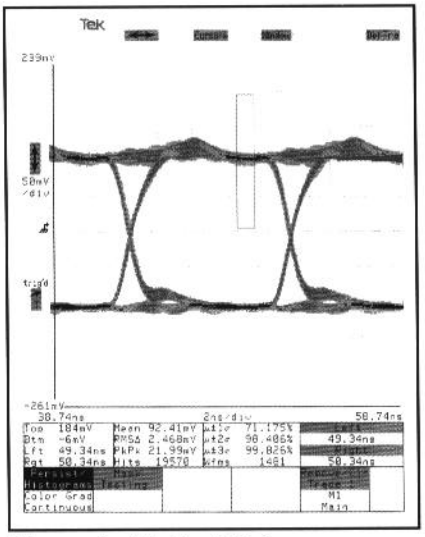

Figure 4a. Vertical histograms are powerful tools for making accurate noise measurements.

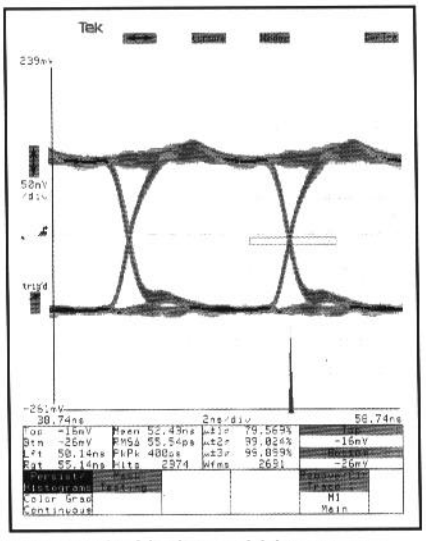

Figure 4b. Horizontal histograms are powerful tools for making accurate jitter measurements.

Mask Testing

The Mask Testing facility is a convenient tool for evaluating error rates and tolerances in digital communication signals. Normally used in conjunction with eye diagrams, this facility can also be applied to most other types of signals as well, such as TDR or pulse response signals . . . even constellation diagrams.

You can define up to 10 polygon shaped masks for each instrument setting, with up to 50 vertices available for each mask. Masks are defined through the front panel using an interactive editor or by downloading externally defined mask points via the GPIB or RS-232-C interfaces.

You can use tolerance masks to analyze one or more waveform traces. Single masks may be created for a test, or several masks may be placed next to or overlapping each other. Groups of masks may also be used to form complex figures, like concave shapes. The CSA 803 will automatically count the number of samples that fall into each polygon, display the individual counts for each polygon, the total number of waveforms acquired, and the total number of samples that fall in *all* of the masks. If there is any overlap between masks, the points falling within them are only counted once, so as not to corrupt the final total. (See the "Mask Testing" Technical Brief for complete details.)

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