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WAVECREST Corporation

JITTER ANALYSIS OF CLOCK RECOVERY DEVICES AT 155.52 MBIT/S

Application Note No. 120

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Jitter Analysis of Clock Recovery Devices at 155.52Mbit/S

Application Note No. 120

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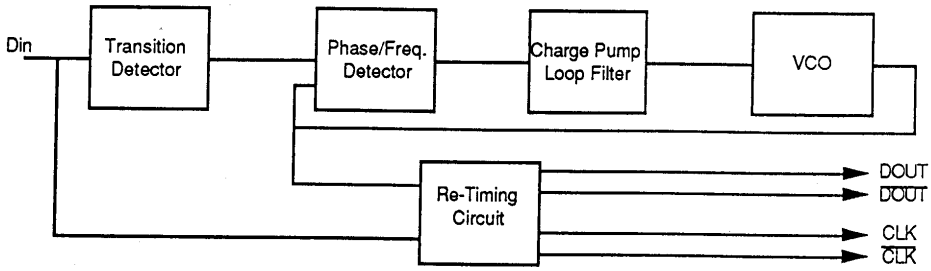
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Jitter Analysis of Clock Recovery Devices at 155.52 Mbit/S

Introduction

This application note discusses jitter analysis on "Clock Recovery Devices" such as the Texas Instruments TDC-1555. This analysis includes the characterization of these devices for developing specifications as well as the verification of specifications. Topics discussed are: jitter caused by various patterns, data-to-clock centering and jitter caused by long strings of Zero data.

In the process of collecting this jitter analysis data, various AC parametric parameters are also measured, such as, clock frequency/period and data-to-clock centering under changing pattern conditions.



BLOCK DIAGRAM OF TDC-1555

T
he speed, accuracy and low noise floor of the *Wavecrest* DTS 2070 Digital Time System (DTS), along with the "ARM on Nth event counters" and "Strobing Voltmeter," make it a valuable tool for taking large amounts of analytical data in a very short period of time, or, for production sampling of critical parameters. The data for each of the 1000 point histograms shown in this application note took less than 70ns to acquire and send to the host test system.

The TDC-1555 Device

The TDC-1555 referred to here recovers an embedded clock signal from a 155-52 Mbit/s STS-3/STM-1 serial data stream using a frequency/phase-lock loop. The device accepts pseudo-ECL (ECL signals referenced to 5V instead of GND) signals. The recovered clock and data outputs are pseudo-ECL compatible. The serial data inputs and recovered clock and data outputs are differential, thus providing maximum noise immunity.

This device normally operates from a 5V Vcc supply but can be tested in one of 3 ways. First, with the normal 5V Vcc, +3V Vterm and Vee at GND. Second, with the Vterm at GND, +2V for Vcc and -3V for Vee. And third, Vcc to GND, Vterm to -2V and Vee to -5V.

The DTS 2070 can support all three configurations using the equivalent termination. See Application Note No. 114, “Achieving ±30ps Accuracy in the ATE Environment.” That example uses split power supplies and a test board supplied by the IC manufacturer.

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All of the jitter and TPD/TR-TF/pulse width and Period measurements normally taken by a Digital Sampling Scope (DSO) can also be taken by the DTS 2070 with greater repeatability due to its patented ultra-linear calibration technique. Also, because the DTS is a true one-shot, input threshold, time measurement device, lower input noise and higher measurement throughput is possible. Currently, the DSOs on the market do not perform jitter analysis to the accuracy and resolution of the DTS. This is due to the lack of Arm on Nth event counters and low phase noise-time standard—which are available with the DTS 2070.

Testing the TDC-1555

This application note only discusses jitter analysis versus pattern of the TDC-1555 or similar devices. The tests performed here require a generator capable of a 2^{n-1} pseudo-random bit stream (PRBS) as called out by CCITT rec. 0.151, or equivalent, and setting specific data cells.

The HP8110A pulse generator is the driving source for the tests in this application note. The DTS 2070 utilizes a PC computer and printer for remote control and hard copy. The following major test categories can be found in the section indicated below:

Section	Categories
1.	Jitter analysis of simple 1/0 pattern as reference.
2.	Jitter analysis of PRBS 2 E-7 pattern.
3.	Jitter analysis of 30 zero pattern.

Within each section the following *test groups* were performed:

1. Jitter histogram of period, frequency, and TPD.
2. Synchronous jitter analysis.
3. Asynchronous jitter analysis.

Within each of the above *test groups* the following *measurements* were made:

1. Oscilloscope measurement of both channels.
2. Analysis of the DATA OUT channel (channel 1).
3. Analysis of the CLOCK OUT channel (channel 2).
4. Analysis of high DATA to CLOCK jitter (tpd+ +).
5. Analysis of low DATA to CLOCK jitter (tpd- +).

Analysis of the DATA OUT and CLOCK OUT channels as well as both DATA to CLOCK paths include the following graphs:

1. Jitter analysis of asynchronous anomalies.
2. Spectrum histogram of asynchronous variations.
3. Frequency versus count analysis of synchronous anomalies.
4. Period versus count analysis of synchronous anomalies.
5. TPD versus count analysis of synchronous anomalies.

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Jitter Testing Setup

Figure 1 shows the setup used for all of the tests performed: Jitter versus simple 1/0 pattern, PRBS 2^{E-7} pattern and the 30 zero pattern.

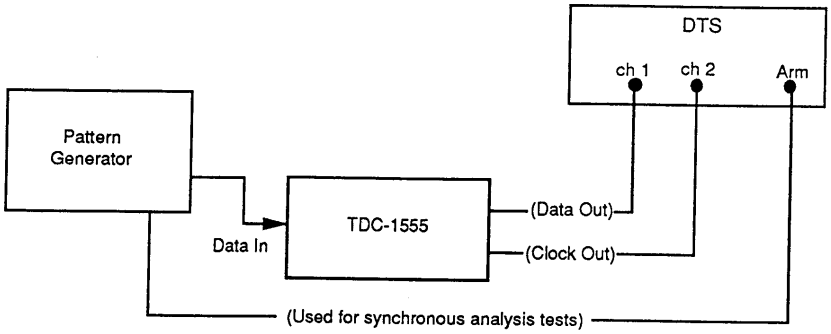


FIGURE 1

Figure 2 shows the basic pattern output from the TDC-1555 to the DTS. The random data output is followed by the clock edge.

- All patterns are 200 addresses long.
- Channel 1 is connected to pin 18, DATA out.
- Channel 2 is connected to pin 21, CLOCK out.

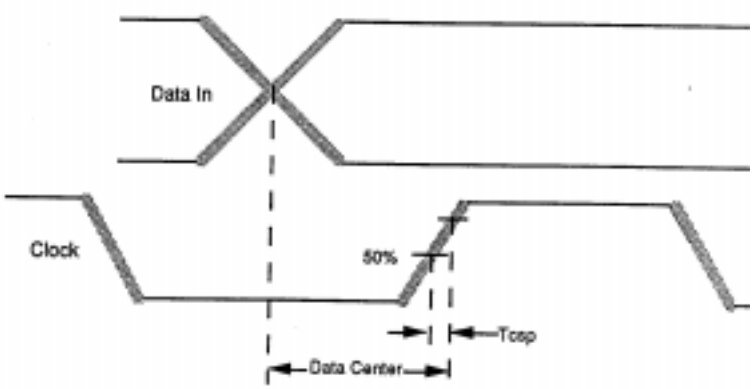


FIGURE 2

- Input data rate for the TDC-1555 is 155.52 Mb/S.
- The DTS is set up for TPD++ for high data to clock.
- The DTS is set up for TPD-+ for low data to clock.
- Reference voltages are all at the 50% points.

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Jitter Testing Versus "Eye" Pattern (Clock Centering in Data Stream)

Construction of the traditional eye pattern requires taking two measurements with the DTS. The DTS is set up as shown in Figure 1 with "start first enable mode" selected. This enables the DTS to measure the first clock after the random data event selected. No special triggering is required. Clocks not associated with the data event are ignored.

Next, a TPD++ and TPD-+ histogram is taken, adding the TPD delta shift to the maximum jitter measured to derive the "eye" pattern versus clock jitter for both positive and negative going edges. See Figure 3.

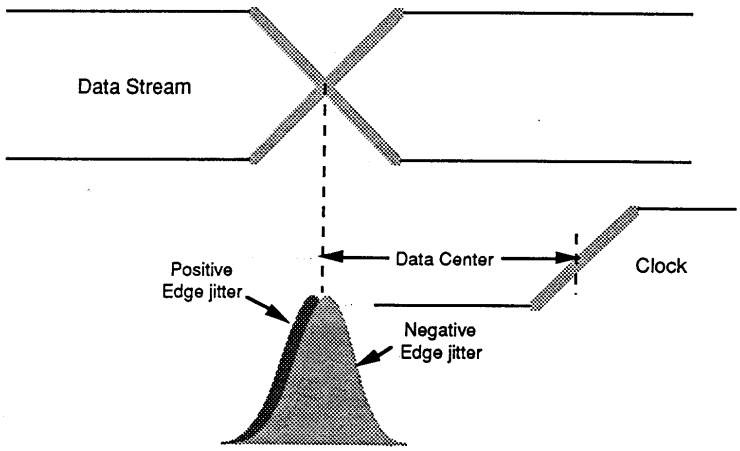


FIGURE 3

Spectrum Analysis Function Description

The DTS, when measuring time using its time measurement unit, acts like a one-shot time domain spectrum analyzer for all signals crossing the input reference voltage threshold (see Figure 1-1-2). When the user auto arms and does a measurement burst of some number of time measurements, say 1000, the DTS measures the function specified by the user occurring on the channel(s) and displays the results as multiple jitter histograms. See Figure 3-1-2 in Section 3 for an example of several jitter distributions occurring on the same channel during the time the DTS executes a burst of measurements. (in auto arm mode, the DTS takes measurements asynchronous with respect to the device under test.)

The legend at the bottom of the graph indicates the average of all of the data displayed, the rms jitter, or one standard deviation of the data displayed, the ± peak jitter of the data displayed, the min: time measured and the max: time measured during the burst. If the data filters were used to isolate one of the histograms in Figure 3-1-2 then the legend at the bottom would only display the statistics for the filtered data as shown in the histogram in Figure 2-1-2 (see Virtual Instruments™ users manual).

The user can display all of the data taken by the DTS using the spectrum analyzer window. For example, pulse width, TT+, TT-, TPD++ TPD-- TPD+-, TPD-+ can be displayed this way, along with period and frequency.

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Jitter Analysis Description

The jitter analysis feature of the DTS (see Figure 1-1-4) uses the Arm on Nth event or Arm on count feature of the arming circuitry to start a measurement at a count within a pulse stream and stop the measurement at another point within the same pulse stream. (See Application Note No. 115, “Arming the DTS 2070” for details on how to use this feature.)

For example, take a perfect square wave clock pulse with only 10ps rms jitter on the period caused by electron noise only. The jitter on one period measures 10ps. Over a double or triple period, it still measures 10ps rms jitter. Over many hundreds of periods it still measures 10ps rms jitter. Because this occurrence is only true in very low phase noise oscillators and seldom the case with PLLs used in noisy digital environments, the user must have tools to analyze and define phase jitter from synchronous and asynchronous sources.

The Virtual Instruments™ jitter analysis window enables the user to scan a range of periods, or other functions, to measure the jitter over the specified count delta and view the results graphically. Figure 1-2-4 shows the range of 250 periods measured and the rms jitter measured at each period. For example, the user selected from 1 period to 250 periods to measure the jitter. The burst count was set at 100 measurements and the GO button pressed. These results are shown in Figure 1-2-4.

The jitter analysis mode is best used asynchronously versus synchronously. Asynchronous jitter analysis uncovers phase modulation periods and deviations running at rates other than the clock of the PLL. Whereas synchronous jitter analysis shows any jitter anomalies relating to a specific pattern or clock multiple of the PLL. The legend at the bottom of the graph shows the average rms jitter displayed, the ± range and the min and max jitter measured.

Function Analysis Description

The function analysis window enables the user to view the measured value of the signal on either or both channels with respect to its cycle count starting from an arming point supplied by the pulse generator, ATE system or circuit under test. Figures 1-2-2 and 1-2-3 demonstrate some of the information available using this window.

For example, function analysis is used to measure PLL frequency or period settling time from the point where the change was initiated (see Figures 2-2-2 and 2-2-3). The stair step display shows the time for that pulse cycle in the figures presented. In Figure 2-2-2, the HP 811 0A data generator was programmed to generate a 77.7 MHz RZ clock pattern with 30 zeros which repeated every 200 pulses. In Figure 2-2-3, the VCO rings for as much as 3 MHz and the first two pulses deviate before the generator pattern repeats. Consequently, the function analysis window helps the user view any synchronous jitter pattern that may exist and also view the cycle-to-cycle measurements within the pattern.

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Function analysis can also display measurements as a function of time when the proper option is selected (see the Virtual Instruments™ users manual). Also, the user may want to view the derivative of each consecutive measurement with respect to the last measurement. Selecting derivative in the option/function analysis window allows this, and at the bottom of the graph are the function and jitter statistics for the displayed data.

The function analysis window can be used in the auto arm mode as well as in the external arm mode. In auto arm mode, the data represents overall measurement variations or peak-to-peak measurements. While in external arm mode, the data displayed shows cycle dependent anomalies with respect to the external arm point.

One of the main benefits of the DTS Virtual Instruments™ is the viewing capability. The user can view any of the measurement functions using this window. For example, period and frequency can be viewed in this mode. Plus, pulse width, rise/fall times and the delay between channels, such as data to clock, can also be viewed for these pattern dependent anomalies.

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Jitter Analysis of Clock Recovery Devices at 155.52 Mbit/S
(Section 1)

Jitter Versus Simple 1/0 Pattern

The following histograms show the test results of a 2E7-1 PRBS pattern. For both cases, the TPD-+ and ++ were close to each other at 3.43ns and rms jitters ranged from 6.0 to 18.1ps with mostly Gaussian distributions. The DTS was set to take a 1000 point spectrum histogram, 100 point jitter analysis and 10 point function analysis data per count. See each graph in this section for information as to the particular DTS setup.

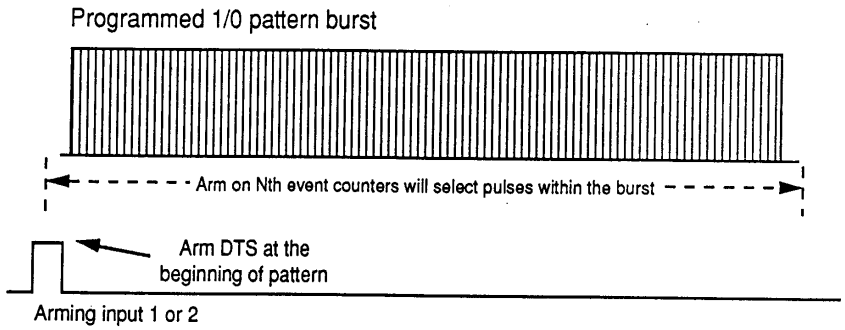


Figure 1-0-0

Each of the pictures in this section represent a baseline for the following two sections. For example, in Section 2, a string of 30 zeros are imbedded within the pattern to determine what effect no data has on the stability of the PLL within the device. Also, in Section 3, a PRBS pattern is generated to look for similar anomalies.

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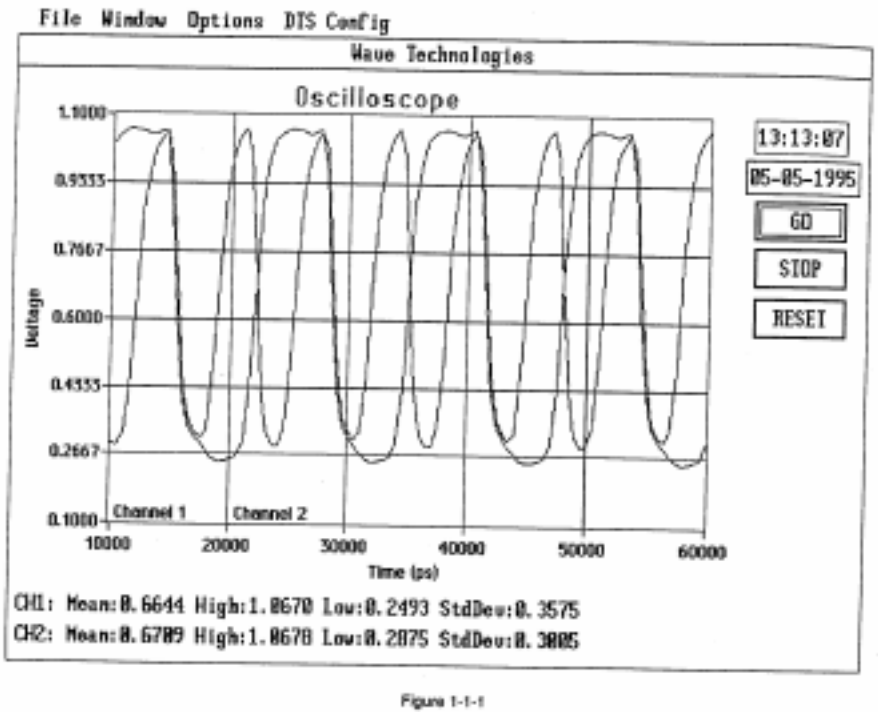


Figure 1-1-1

This is a strobing voltmeter picture of the data and clock output pins of the device under test (see Figure 1). Channel one has the alternating one/zero data information on it, while Channel 2 has the separated clock signal. The legend at the bottom of the picture has the VOH and VOL levels for each channel and the time in picoseconds.

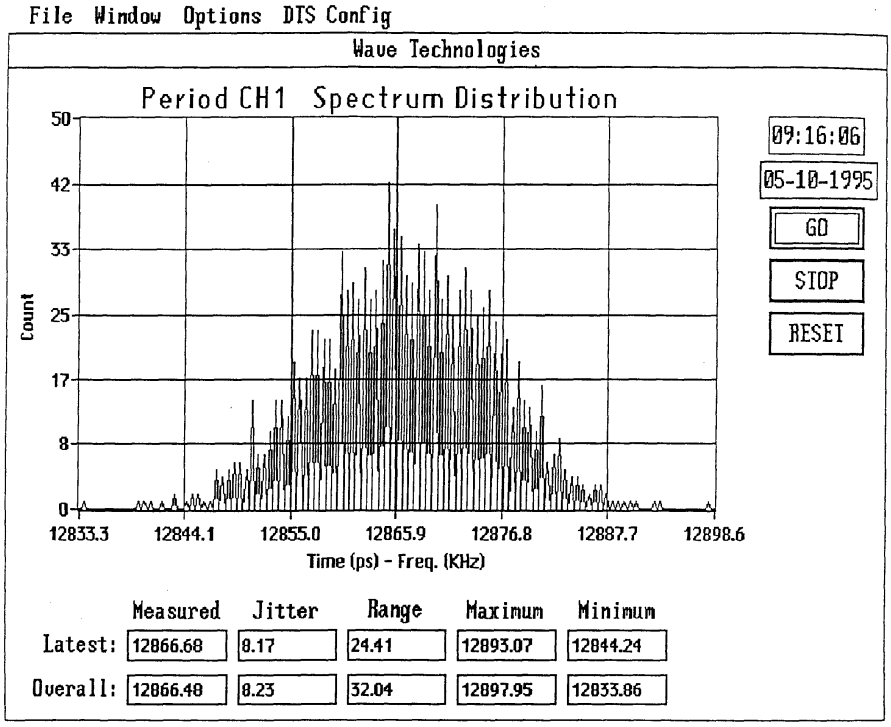


Figure 1-1-2

This is a period spectrum distribution picture of the data output on channel 1. The legend at the bottom of the picture gives statistics for the displayed distribution. “Measured” is the center of the distribution, “Jitter” is the rms value of the jitter or 1 sigma of the distribution, “Range” is the “Peak” jitter and “Maximum” and “Minimum” are the peak-to-peak measurements made during the burst.

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The legend is split into two parts. The first line indicates the “Latest” data displayed on the screen and the “Overall” line is the accumulated statistics for all of the screens the user executes. Each time the user presses the GO button on the screen, the DTS processes a full screen of data for the display.

As shown in Figure 1-1 -2, the distribution is mostly Gaussian. A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1-sigma or jitter value.

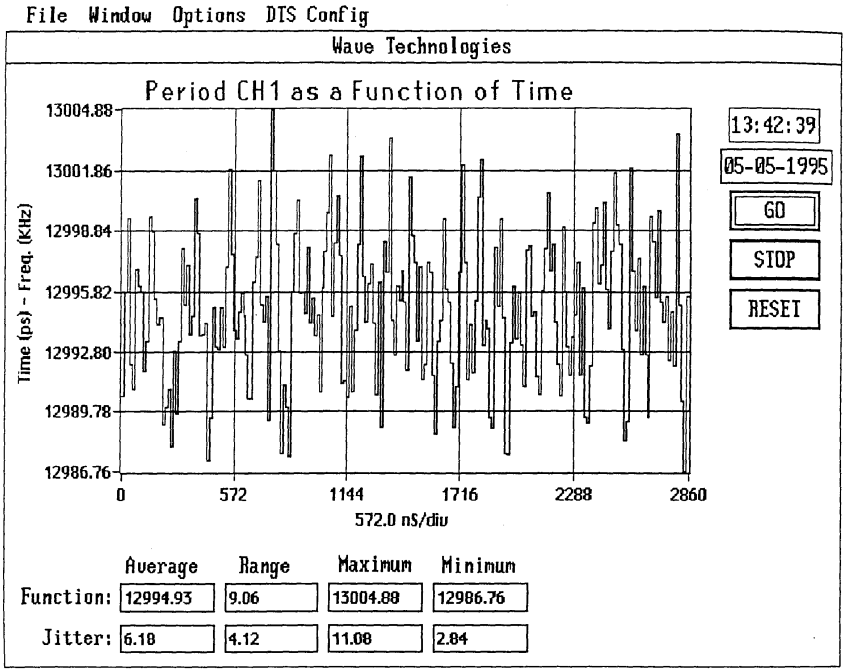


Figure 1-1-3

This displays period data as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the period at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each period in the picture. The function versus time or count analysis shows synchronous jitter anomalies during the pattern.

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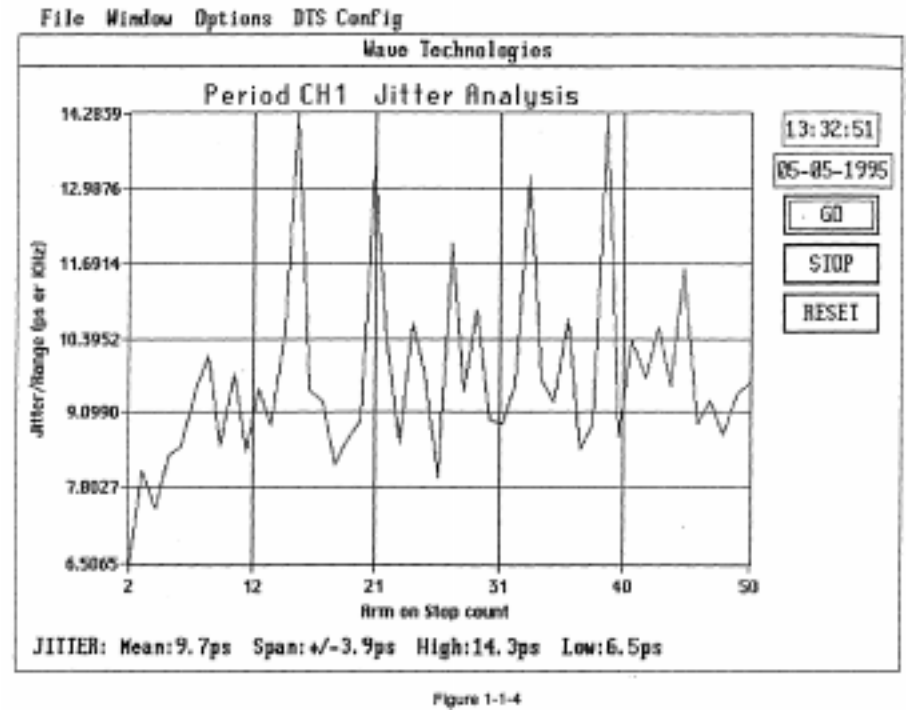


Figure 1-1-4

The jitter analysis picture of the data shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 1-1-3.

If the user wants to see the synchronous jitter measured at each cycle instead, the arming inputs would be used, as shown in Figure 1-1-3. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

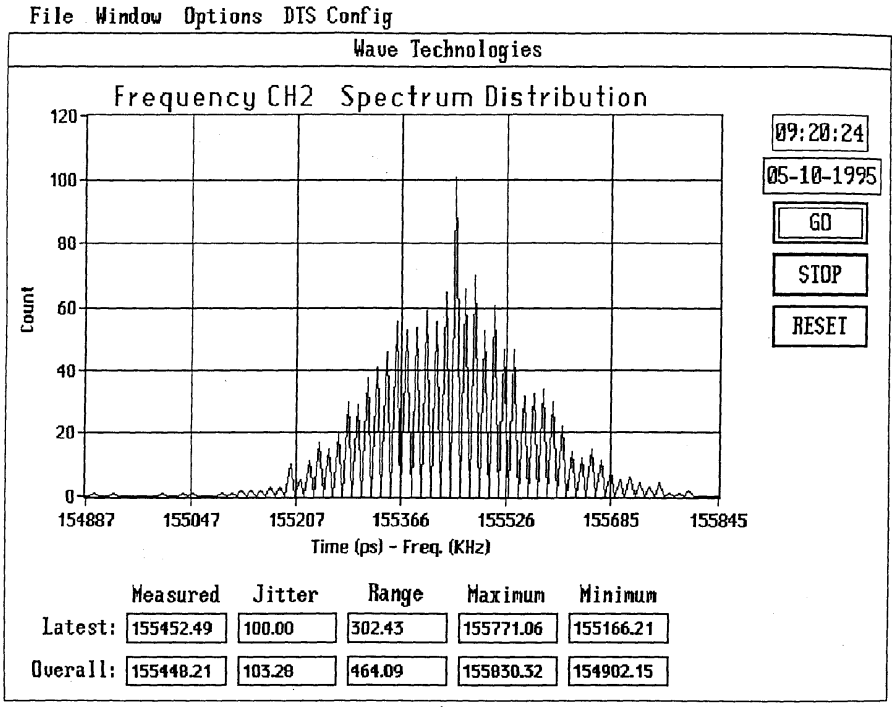


Figure 1-2-1

This is a frequency spectrum distribution picture of the clock output on channel 2. The legend at the bottom of the picture gives the statistics for the displayed distribution. "Measured" is the center of the distribution, "Jitter" is the rms value of the jitter or 1 sigma of the distribution, "Range" is the "Peak" jitter and "Maximum" and "Minimum" are the peak-to-peak measurements made during the burst.

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The legend is split into two parts. The first line indicates the “Latest” data displayed on the screen and the “Overall” line is the accumulated statistics for all screens the user executes. Each time the user presses the GO button on the screen, the DTS processes a full screen of data for the display. The data in this legend is displayed in kiloHertz.

As shown in Figure 1-2-1, the distribution is mostly Gaussian A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1 sigma or jitter value. Notice that the center frequency is 155.45MHz, but the distribution is not centered within the screen. The cause for this can be seen in Figure 1-2-2.

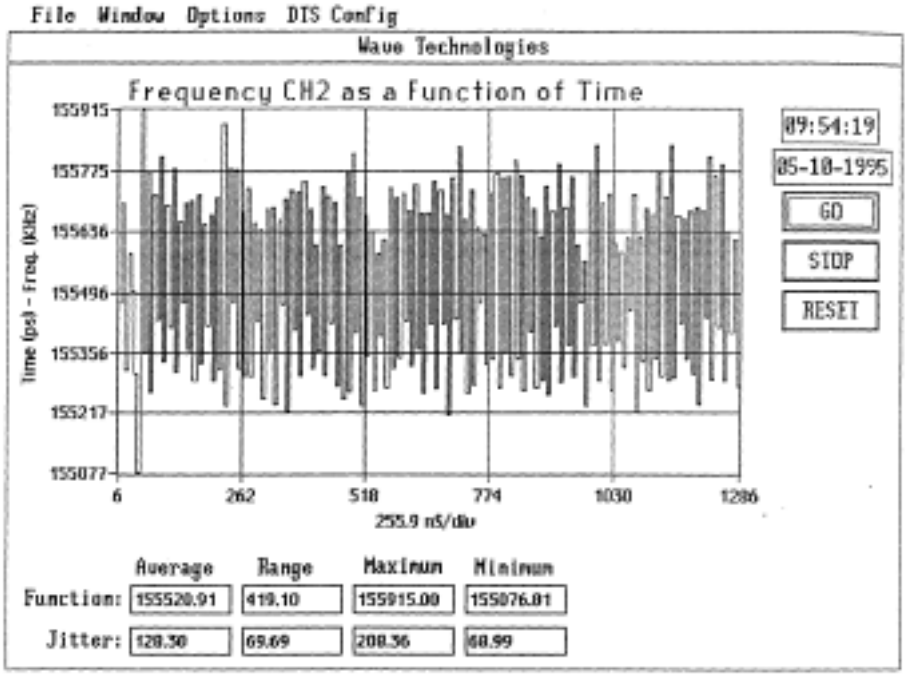


Figure 1-2-2

This is a frequency display of the clock as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1 -0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the frequency at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements while the “Jitter” legend indicates the peak-to-peak jitter measured at each frequency in the picture. The function versus time or count analysis is shows *synchronous* jitter anomalies usually caused by pattern dependencies.

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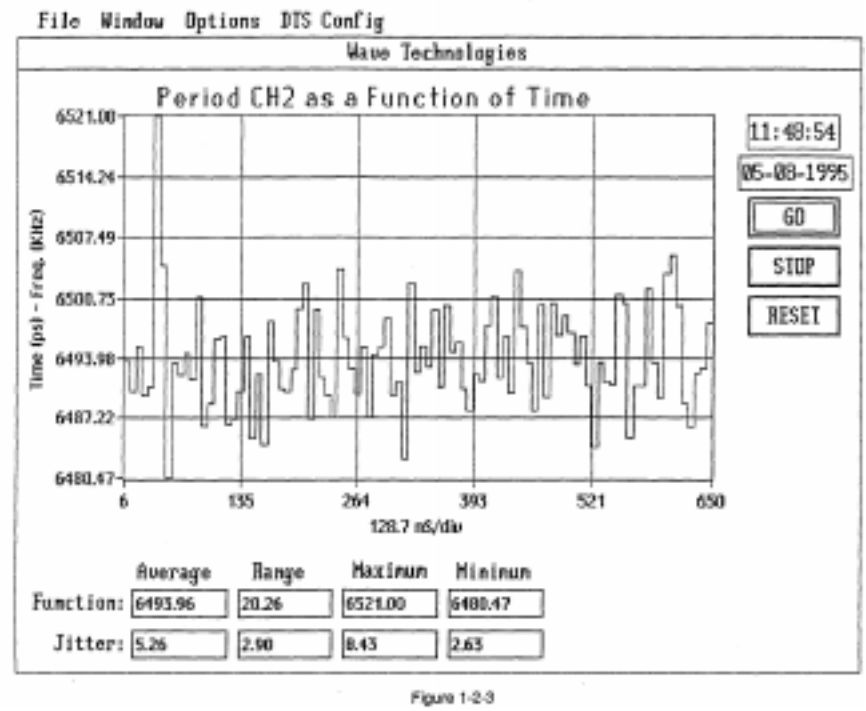


Figure 1-2-3

This figure shows the clock period instead of the frequency shown in Figure 1-2-2. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the frequency at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements while the “Jitter” legend indicates the peak-to-peak jitter measured at each period in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies usually caused by pattern dependencies.

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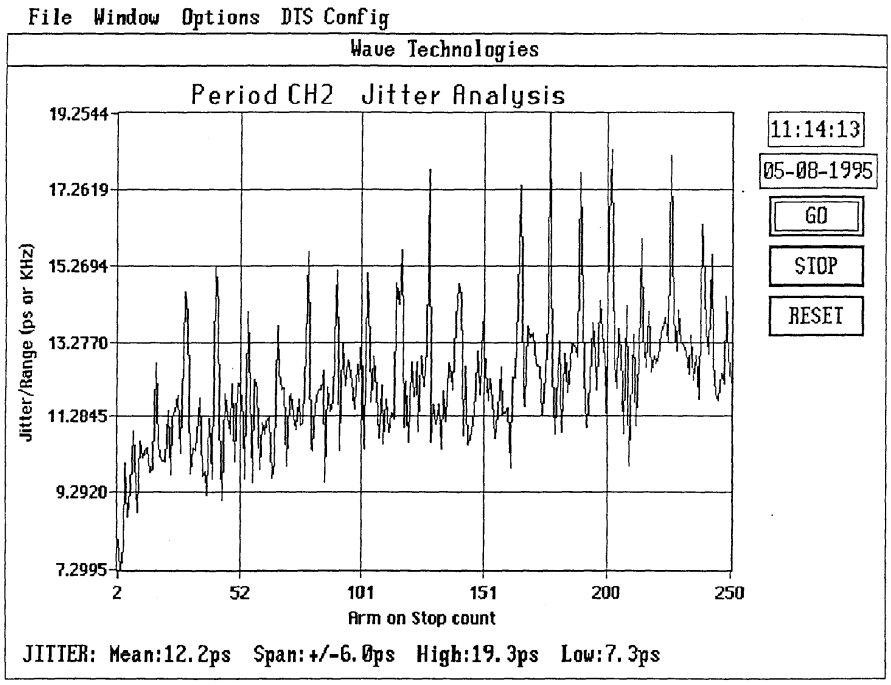


Figure 1-2-4

This is a picture of the asynchronous jitter of the clock output from 2 to 250 pulses. The jitter analysis picture shows the low frequency content of a device's output signal. The user usually nuns this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 1-2-3.

If the user wants to see the synchronous jitter measured at each cycle instead, the arming inputs would be used, as shown in Figure 1-2-3. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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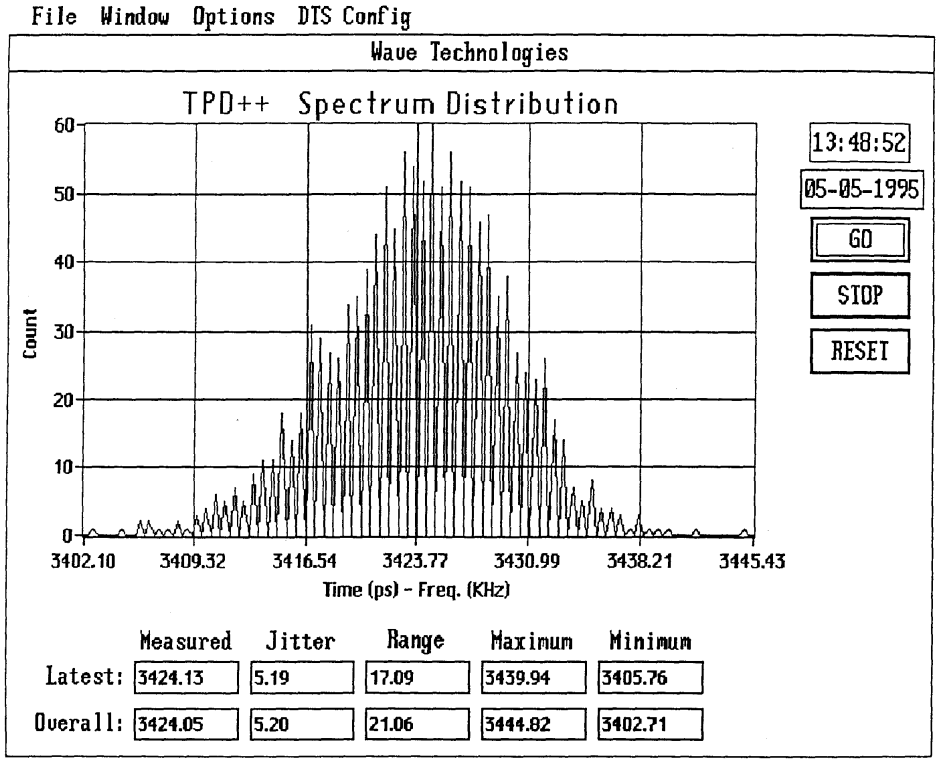


Figure 1-B-1

This is a TPD++ spectrum distribution picture of the high data going to positive clock output on channels 1 and 2. The measured value of 3.42ns is the center of the distribution and represents the delay from data to clock. The distribution in Figure 1-B-1 shows how that delay varies over the executed pattern—which in this case, is a simple one/zero alternating data pattern.

As shown in Figure 1-B-1, the distribution is mostly Gaussian. A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1-sigma or jitter value.

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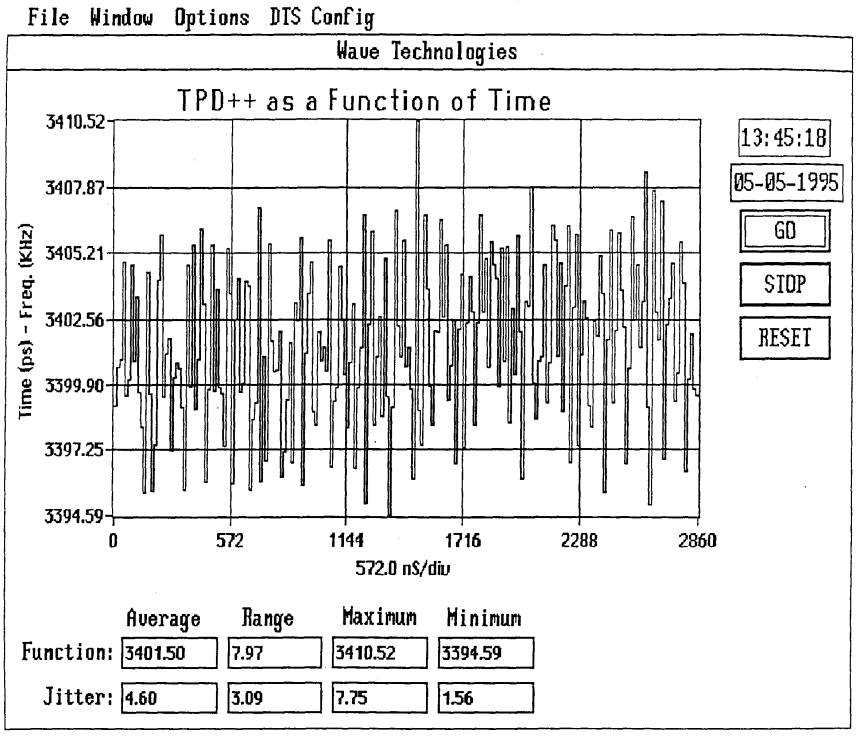


Figure 1-B-2

This is a cycle-to-cycle display of the data to clock delay as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1 -0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the delay at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each delay in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies that occur over the course of an execution pattern.

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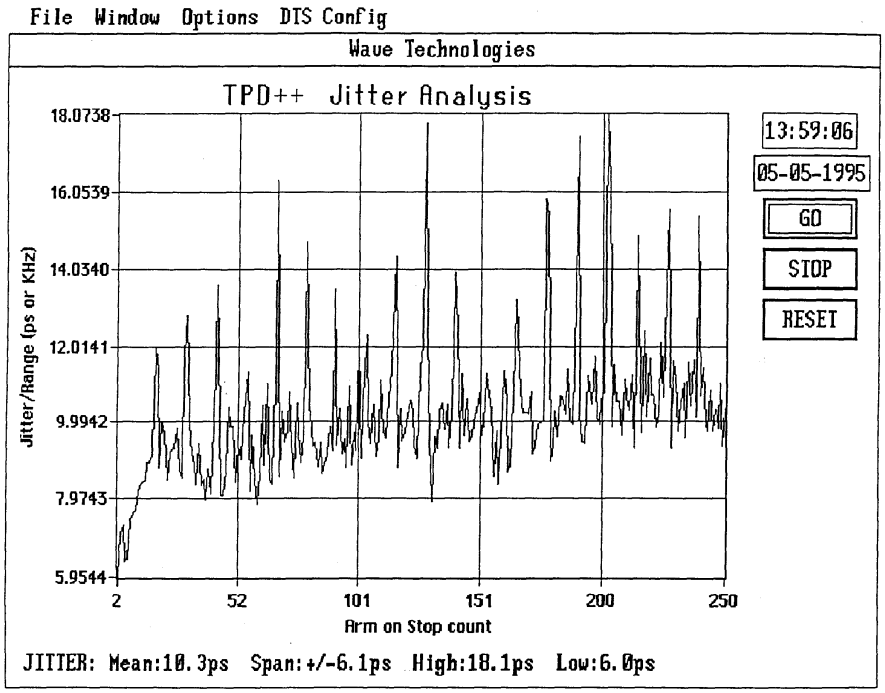


Figure 1-B-3

This is a jitter analysis picture of the delay between the high data to positive clock. As shown in Figure 1-B-3, the jitter spikes upward every 12.5 cycles, indicating a cyclical problem that could be caused by something within the chip occurring at a 12.4 MHz rate.

The jitter analysis picture shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 1-B-2.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure I-B-2. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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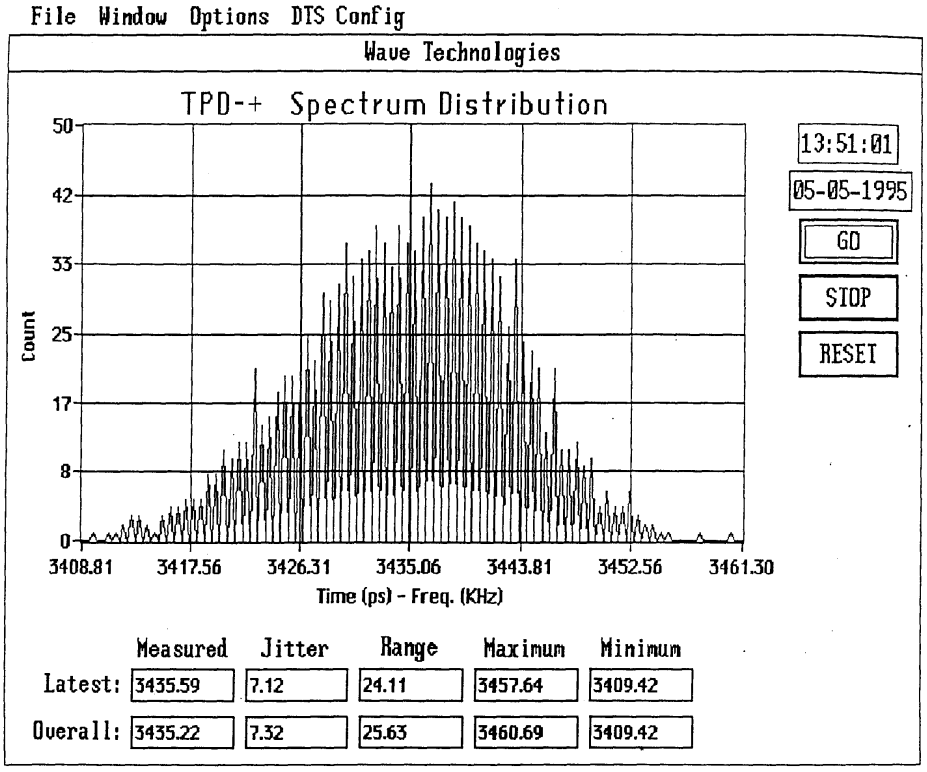


Figure 1-B-4

This is a TPD-+ spectrum distribution picture of the low data going to positive clock outputs on channels 1 and 2. The measured value of 3.43ns is the center of the distribution and represents the delay from data to clock. The distribution in Figure 1-B-4 shows how that delay varies over the pattern being executed—which in this case, is a simple one/zero alternating data pattern.

As shown in Figure 1-6-4, the distribution is mostly Gaussian. A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1 sigma or jitter value.

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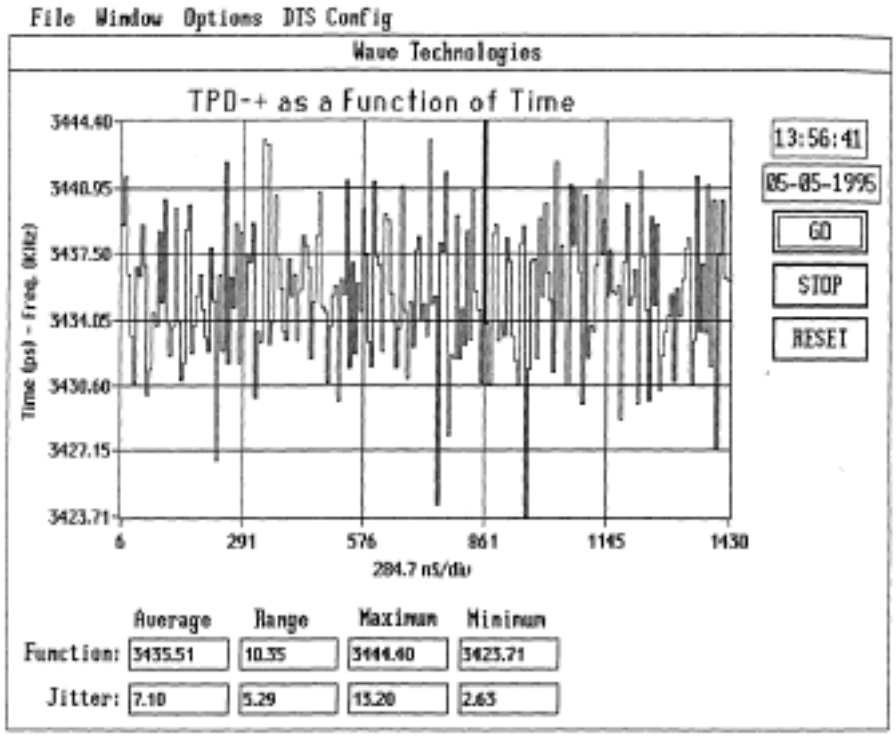


Figure 1-B-5

This is a cycle-to-cycle display of the low data to clock delay as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the delay at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements while the “Jitter” legend indicates the peak-to-peak jitter measured at each delay in the picture. The function versus time, or count analysis, shows *synchronous* jitter anomalies that occur over the course of an execution pattern.

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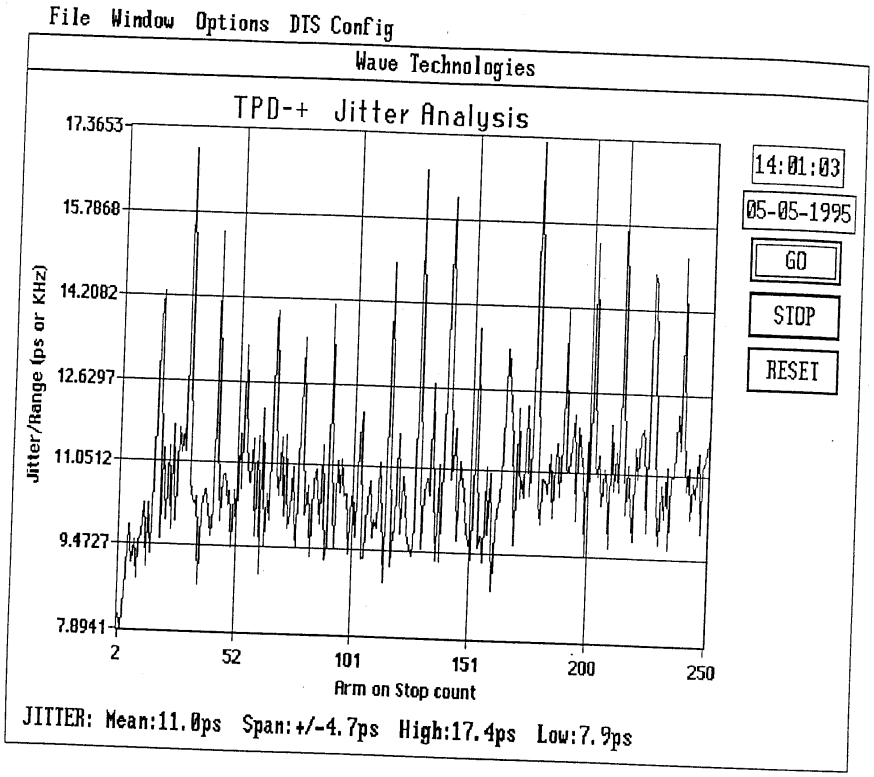


Figure 1-B-6

This is a jitter analysis display of the delay between the high data to positive clock. As shown in Figure 1-B-3, the jitter spikes upward every 12.5 cycles, indicating a cyclical problem that could be caused by something within the chip occurring at a 12.4MHz rate.

The jitter analysis picture shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 1-B-2.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 1-B-2. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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Jitter Analysis of Clock Recovery Devices at 155.52 Mbit/S
(Section 2)

Jitter Versus String of 30 Zeros

A string of 30 zeros is imbedded within a simple one/zero pattern. The DTS is externally armed at the beginning of this pattern as shown in Figure 2-0-0. The arming pulse can be provided to either arming input on the DTS. The figures in this section can be compared with the ones in Section 1 to show the effects on synchronous and asynchronous jitter, both random and cycle to cycle.

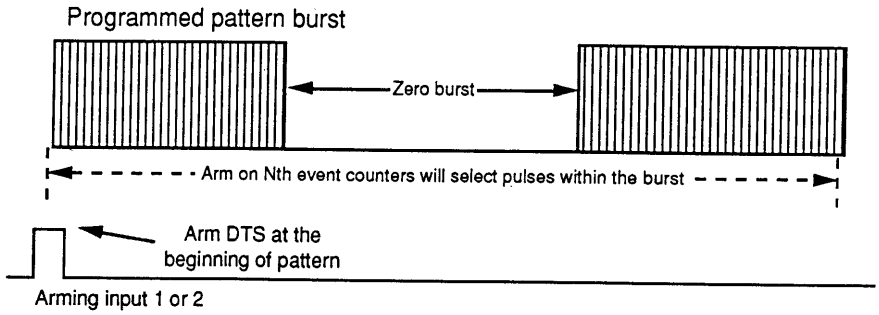


Figure 2-0-0

In this example, the zeros start at 10 pulses into the pattern. The DTS is enabled to measure each pulse parameter in the pattern. This tells how well the VCO held lock to check the filter loop circuit. As can be seen in the following figures, the data center TPD and jitter moved, as might be expected.

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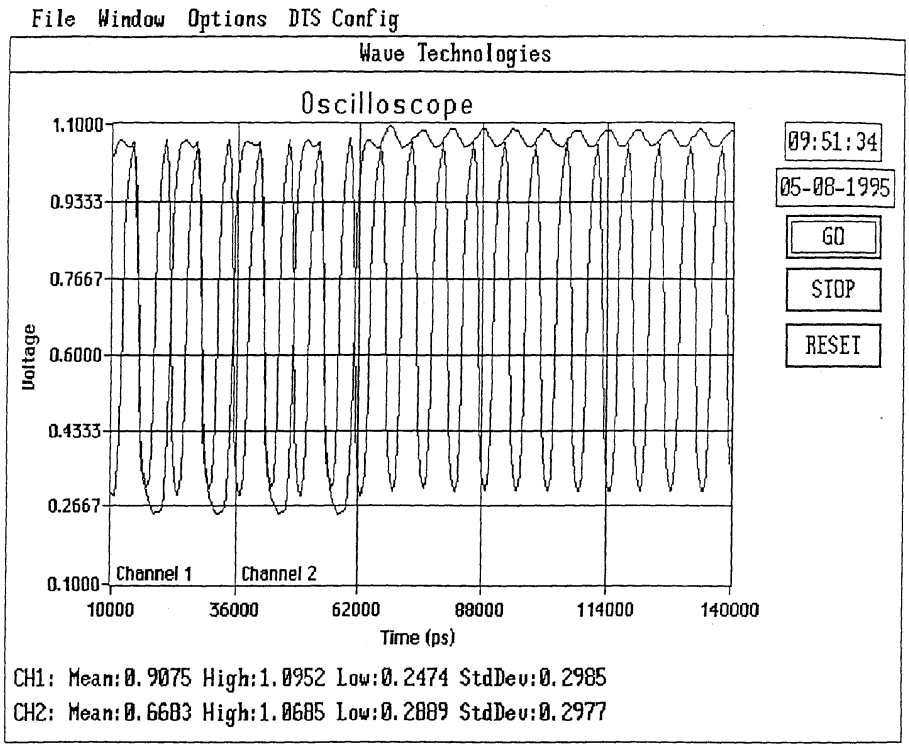


Figure 2-1-1

This is a strobing voltmeter display of the data and clock output pins of the device under test (see Figure 1). Channel 1 has the string of 30 zeros imbedded within the data information, while Channel 2 has the separated clock signal. The legend at the bottom of the picture has the VOH and VOL levels for each channel and the time in picoseconds.

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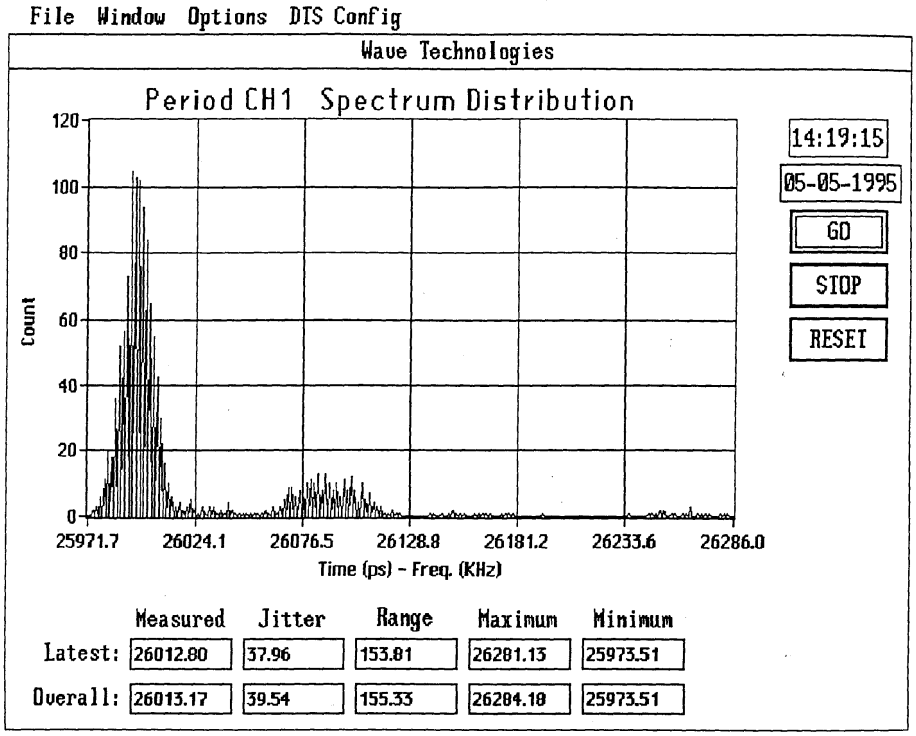


Figure 2-1-2

This is a period spectrum distribution picture of the data output on channel 1. The legend at the bottom of the picture gives the statistics for the displayed distribution. “Measured” is the center of the distribution, “Jitter” is the rms value of the jitter or 1-sigma of the distribution, “Range” is the “Peak” jitter and “Maximum” and “Minimum” are the peak-to-peak measurements made during the burst.

The legend is split into two parts. The first line indicates the “Latest” data displayed on the screen. The “Overall” line is the accumulated statistics for all screens the user executes. Each time the user presses the GO button on the screen, the DTS processes a full screen of data for the display.

As shown in Figure 2-1-2, the distribution is not Gaussian but is bimodal with flyers extending out 100ps. To avoid the 30 zero gap, the filters on the DTS were set to 26ns ± 5ns. This enables the user to zoom in on the area of interest.

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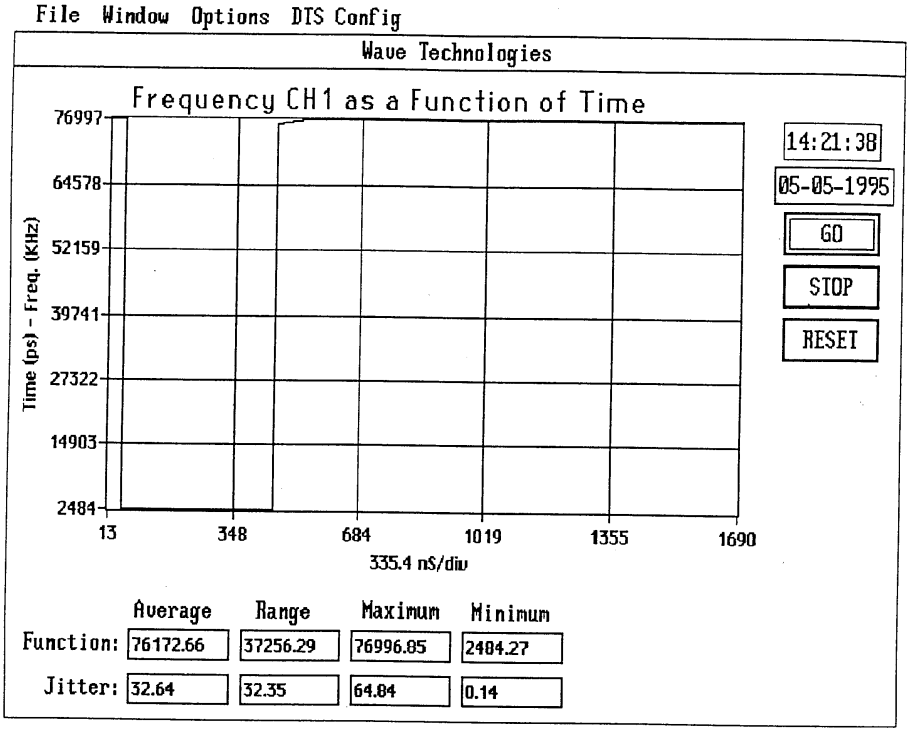


Figure 2-1-3

This is a display of frequency data as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 2-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the frequency at the various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each frequency in the picture. Values are expressed in kHz. Notice the string of 30 zeros shows up as a frequency of 2.48MHz while the remainder of the pattern is at 76.99MHz. The function versus time or count analysis shows *synchronous* jitter anomalies during the pattern.

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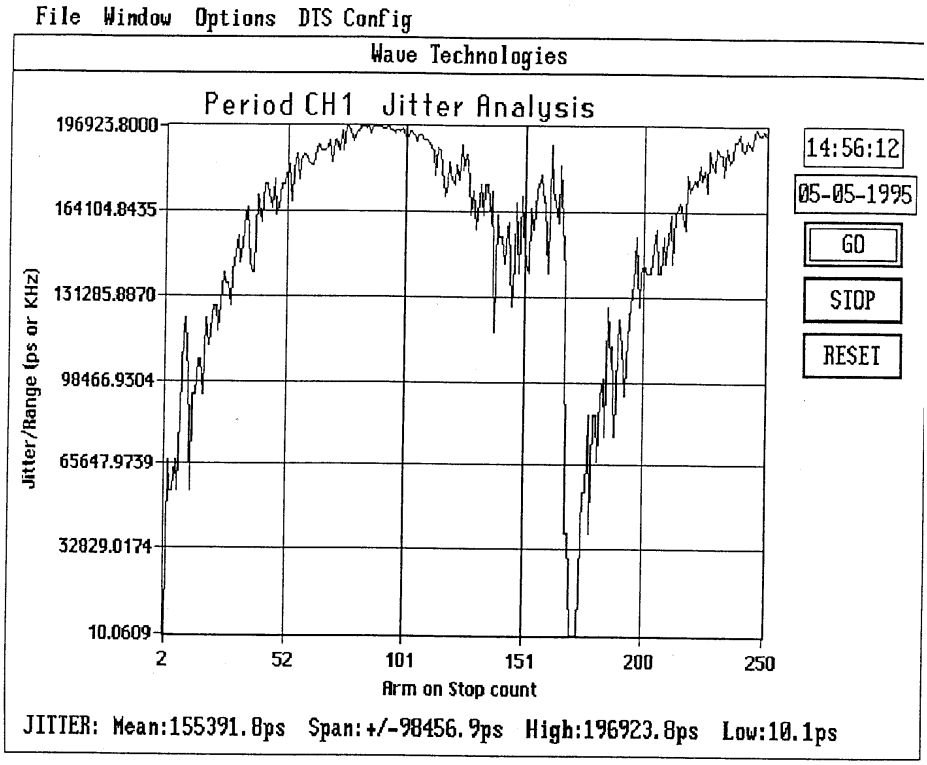


Figure 2-1-4

The jitter analysis picture of the data shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 2-1-3.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 2-1-3. Notice the profound difference between this picture and Figure 1-1-4. This graph shows the low frequency deviation effect of the 30 zeros and their period of repetition. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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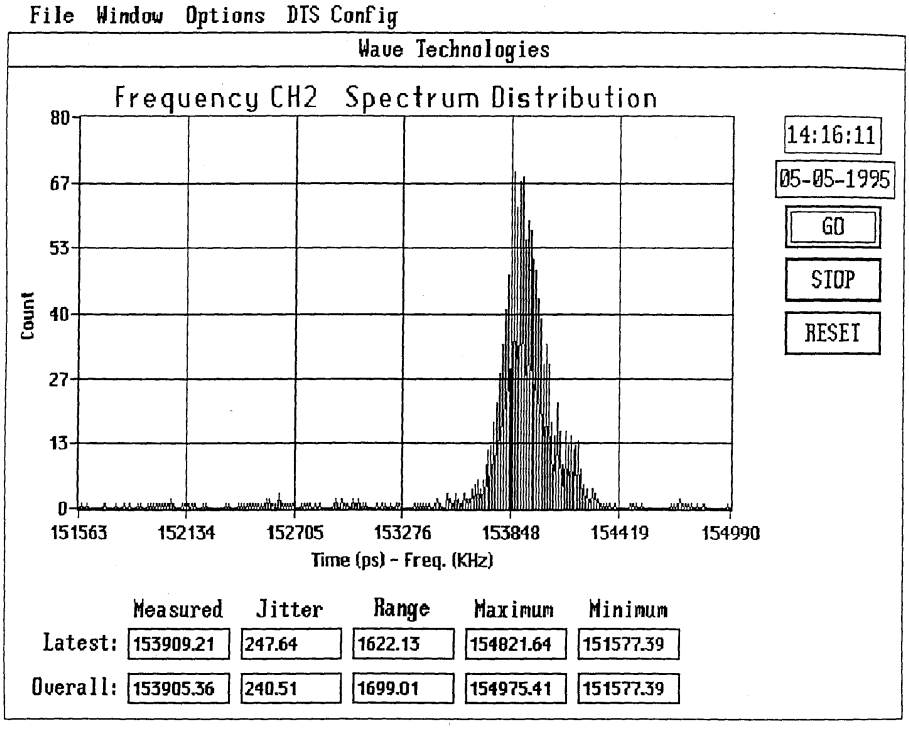


Figure 2-2-1

This is a frequency spectrum distribution picture of the clock output on channel 2. The legend at the bottom of the picture gives the statistics for the displayed distribution. “Measured” is the center of the distribution, “Jitter” is the rms value of the jitter or 1 sigma of the distribution, “Range” is the “Peak” jitter and “Maximum” and “Minimum” are the peak-to-peak measurements made during the burst.

The legend is split into two parts. The first line indicates the “Latest” data displayed on the screen. The “Overall” line is the accumulated statistics for all screens the user executes. Each time the user presses the GO button on the screen, the DTS processes a full screen of data for the display. The data in this legend is displayed in kHz.

As shown in Figure 2-2-1, the distribution is not Gaussian, but shows extensive flyers below center frequency. The cause for this can be seen in Figure 2-2-2.

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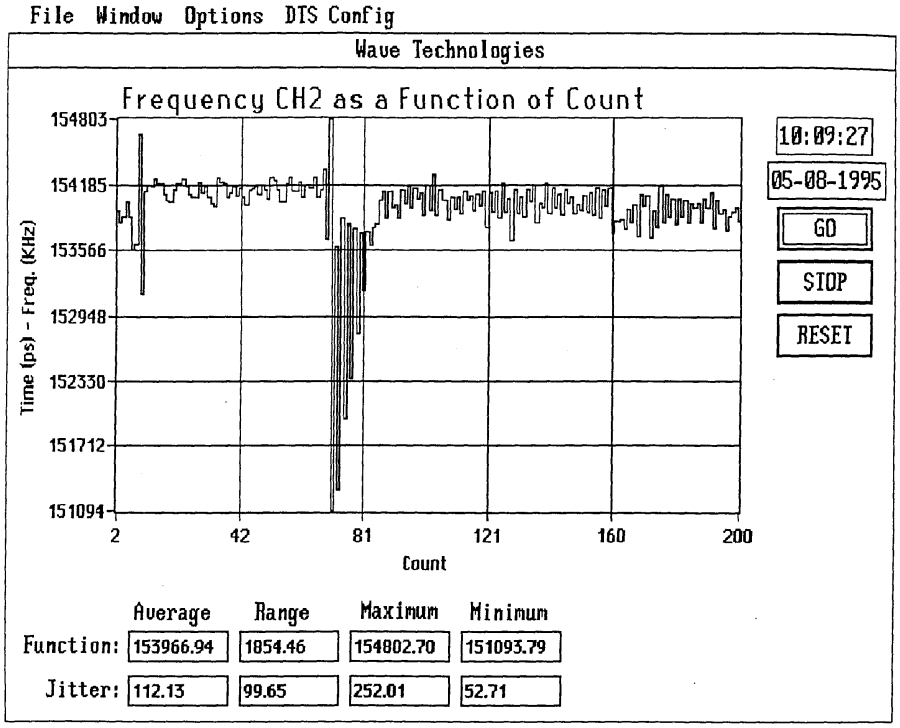


Figure 2-2-2

This is a frequency display of the clock as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see figure 2-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the frequency at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements while the “Jitter” legend indicates the peak-to-peak jitter measured at each frequency in the picture. Notice the VCO shifts in frequency when the 30 zeros start and stop. It takes about 20 periods for the VCO to settle out at the 154MHz rate—that's about 130ns. The function versus time or count analysis shows *Synchronous* jitter anomalies usually caused by pattern dependencies. Figure 2-2-3 shows an expanded view of the settling time.

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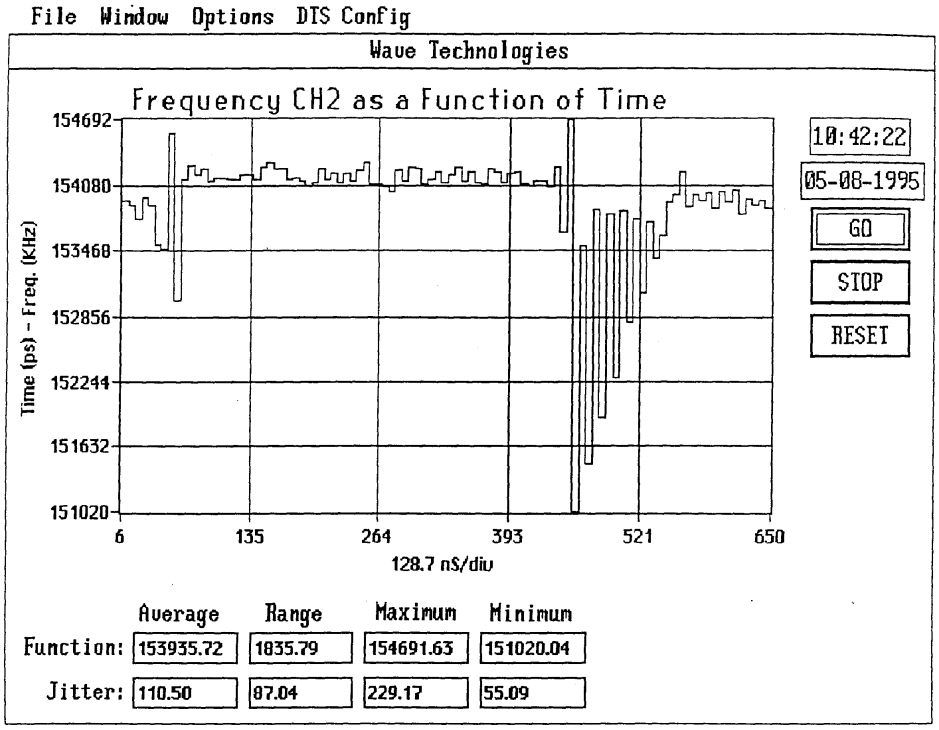


Figure 2-2-3

This figure shows an expanded view of the clock frequency settling time with time on the horizontal axis instead of count (see Figure 2-2-2). It shows how long the VCO takes to settle on the leading edge of the 30 zeros as well as the trailing edge of the zeros. This low frequency ringing of the VCO causes the flyers in Figure 2-2-1.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each frequency in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies usually caused by pattern dependencies.

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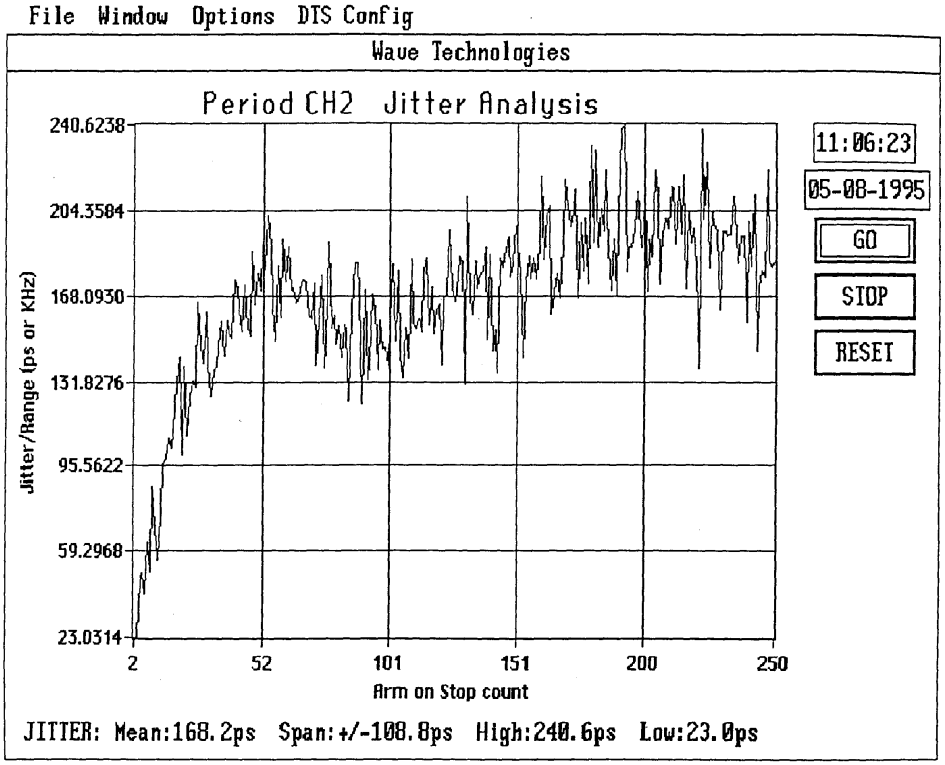


Figure 2-2-4

This is a picture of the asynchronous jitter of the clock output from 2 to 250 pulses. Notice the dramatic increase in jitter from Figure 1-2-4 over the same number of pulses.

The jitter analysis picture shows the low frequency content of a device's output signal. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 2-2-3.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 2-2-3. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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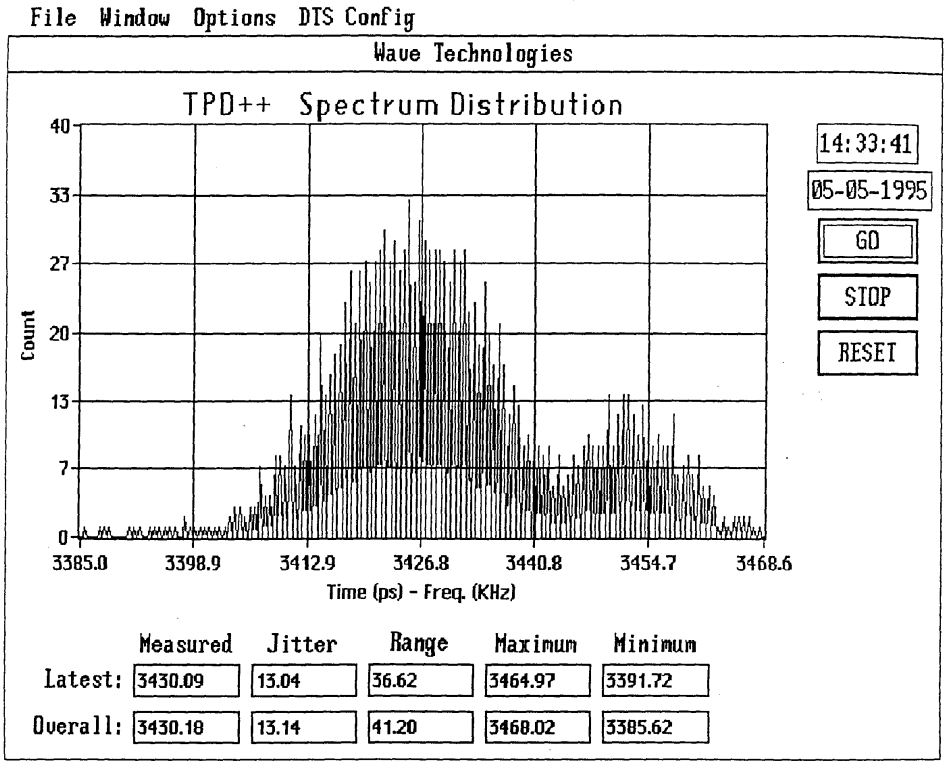


Figure 2-B-1

This is a TPD++ spectrum distribution picture of the high data going to positive clock output on channels 1 and 2.

The measured value of 3.42ns is the center of the distribution and represents the delay from data to clock. The distribution in Figure 2-B-1 shows how that delay varies over the executed pattern which in this case is a one/zero alternating data pattern with a string of 30 zeros. As shown in Figure 2-B-1, the distribution is not Gaussian, but is bimodal. The following figures show the cause of this bimodal distribution.

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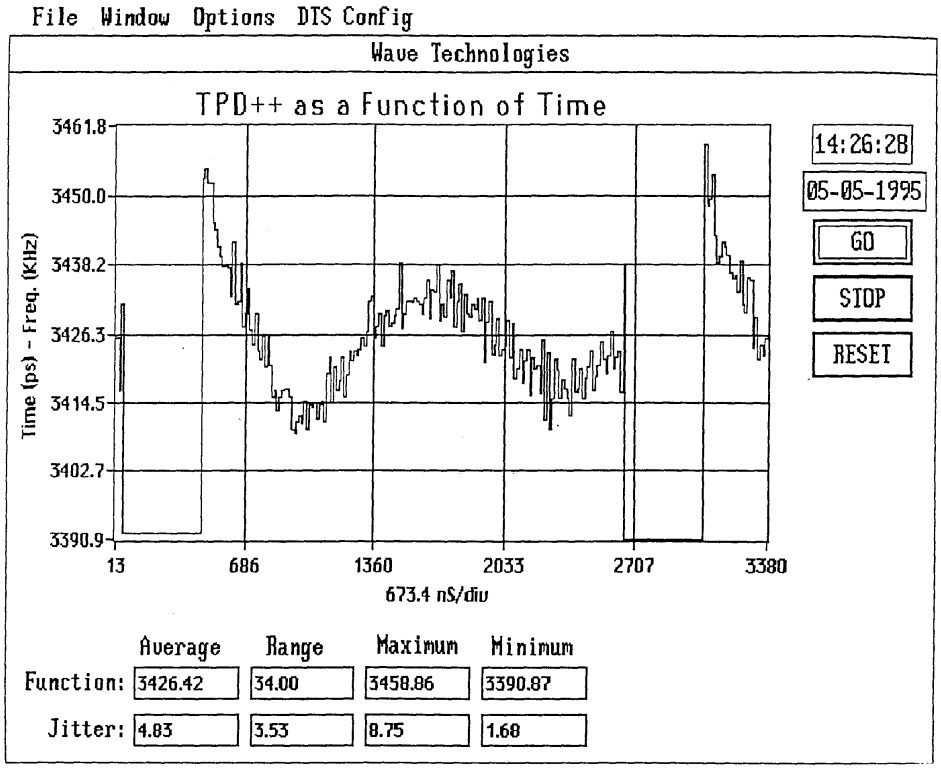


Figure 2-B-2

This is a cycle-to-cycle display of the data to clock delay as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 2-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the delay at various times from the beginning of the pattern as indicated on the horizontal axis.

Notice the step function and sinusoidal ringing pattern caused by the zero pattern input. The peak-to-peak jitter for this pattern is 68ps, while in Figure 1-B-2, the peak-to-peak jitter is 16ps. The "Function" legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements while the "Jitter" legend indicates the peak-to-peak jitter measured at each delay in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies that occur over the course of an execution pattern.

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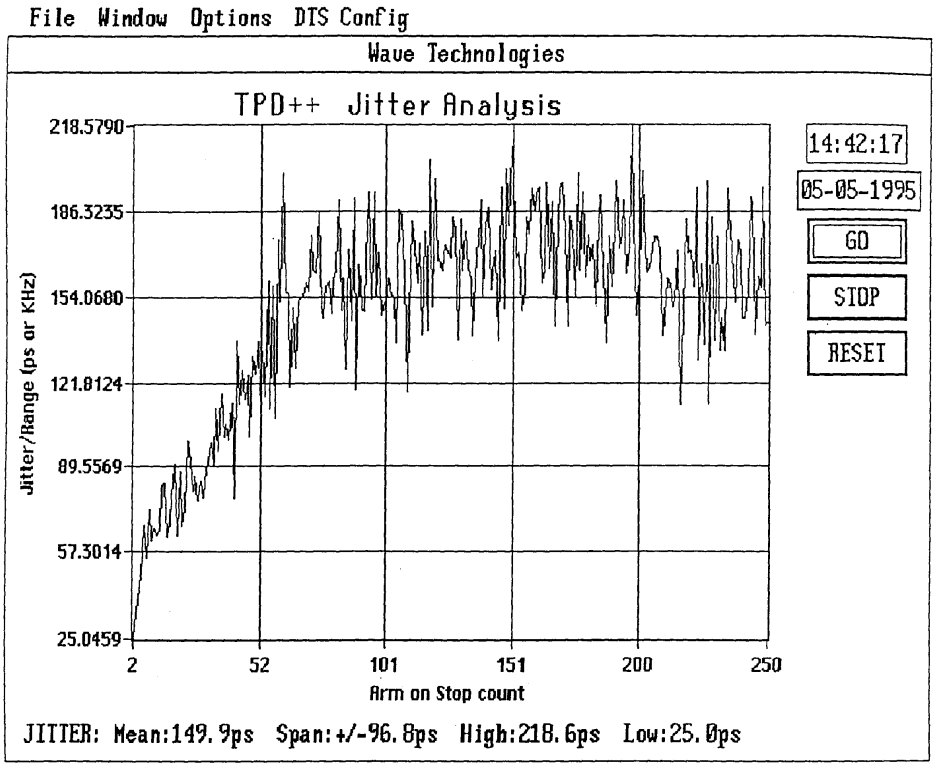


Figure 2-B-3

This is a jitter analysis picture of the delay between the high data to positive clock. It shows a similar increase in jitter buildup to Figure 2-2-4. Notice that the accumulative jitter buildup levels off at 218ps.

The jitter analysis picture shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 2-B-2.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 2-B-2. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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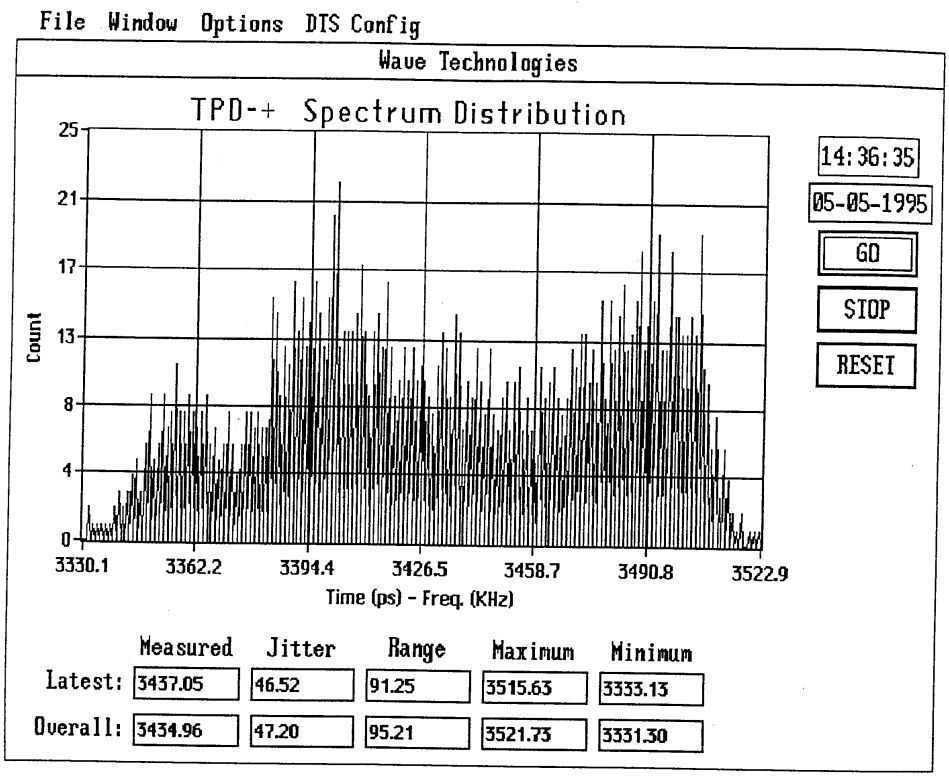


Figure 2-B-4

This is a TPD-+ spectrum distribution picture of the low data going to positive clock outputs on channels 1 and 2. Notice the tri-modal distribution in this picture and the equal amplitudes of the peaks at 3.394 and 3.490ns. This often indicates a sine-wave-imposed phase modulation causing edge jitter.

The measured value of 3.43ns is the center of the distribution and represents the mean delay from data to clock. The distribution in Figure 2-B-4 shows how the delay varies over the executed pattern — which in this case is a one/zero pattern with 30 zeros imbedded within the pattern.

As shown in Figure 2-B-4, the distribution is not Gaussian. A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1-sigma or jitter value.

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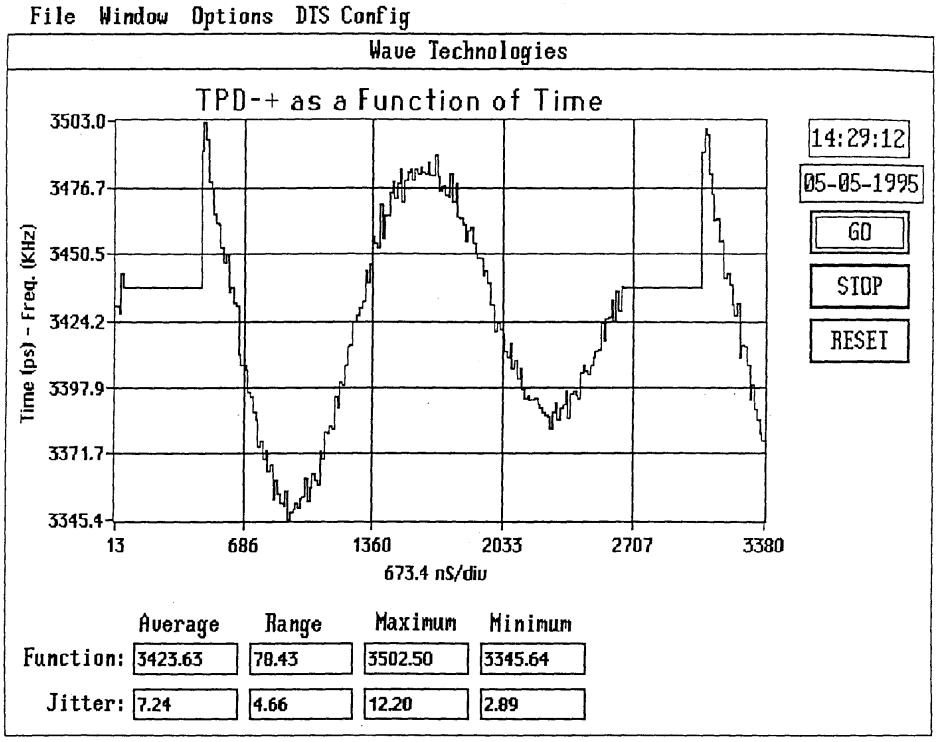


Figure 2-B-5

This is a cycle-to-cycle display of the low data to clock delay as a function of time. Notice the pronounced sinusoidal ring of the propagation delay between the low data and clock. Also notice that it is different than the high data to clock response found in Figure 2-B-2. The peak-to-peak jitter is 157ps, while it's 68ps with high data and 16ps in Figure 1-B-2.

The "Function" legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements while the "Jitter" legend indicates the peak-to-peak jitter measured at each delay in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies that occur over the course of an execution pattern.

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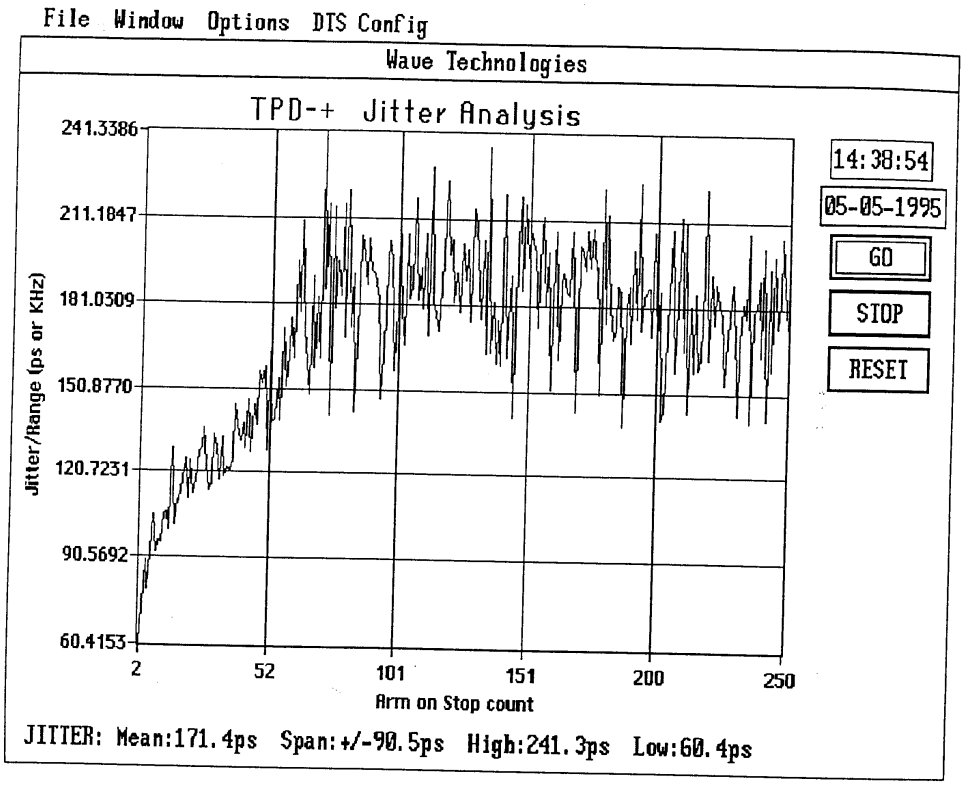


Figure 2-B-6

This is a jitter analysis picture of the delay between the low data to positive clock. As shown in this graph, the accumulated jitter effects are the same as in the last two jitter analysis pictures — no low frequency phase modulation causes pronounced jitter.

The jitter analysis picture shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 2-B-5.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 2-B-5. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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Jitter Analysis of Clock Recovery Devices at 155.52 Mbit/S
(Section 3)

Jitter Versus PRBS 2E-7 Pattern

The PRBS 2E-7 pattern repeats every 200 addresses. An arming pulse is generated by the signal source, as discussed in the other sections, and represents the beginning of the pattern. The leading edge of the arming signal must be at least 3ns before the first measured pulse. Compare the data in this section with those from other sections for differences caused by different signal inputs.

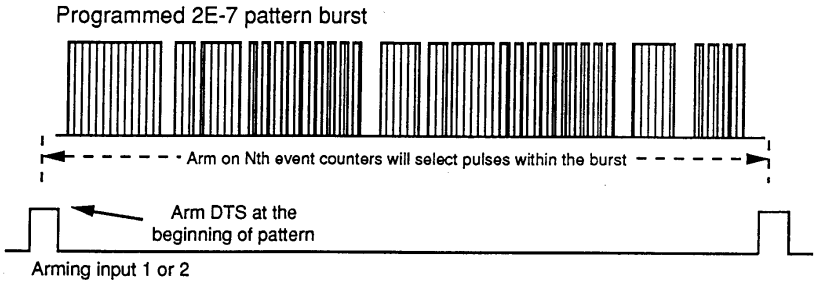


Figure 3-0-0

The Arm on Nth event counters enable the DTS to select pulses within the data stream for measurement by the DTS one-shot TIA. Because the counters and the arming technique occur prior to the measurement event, they cannot disturb the accuracy or jitter of the measurement.

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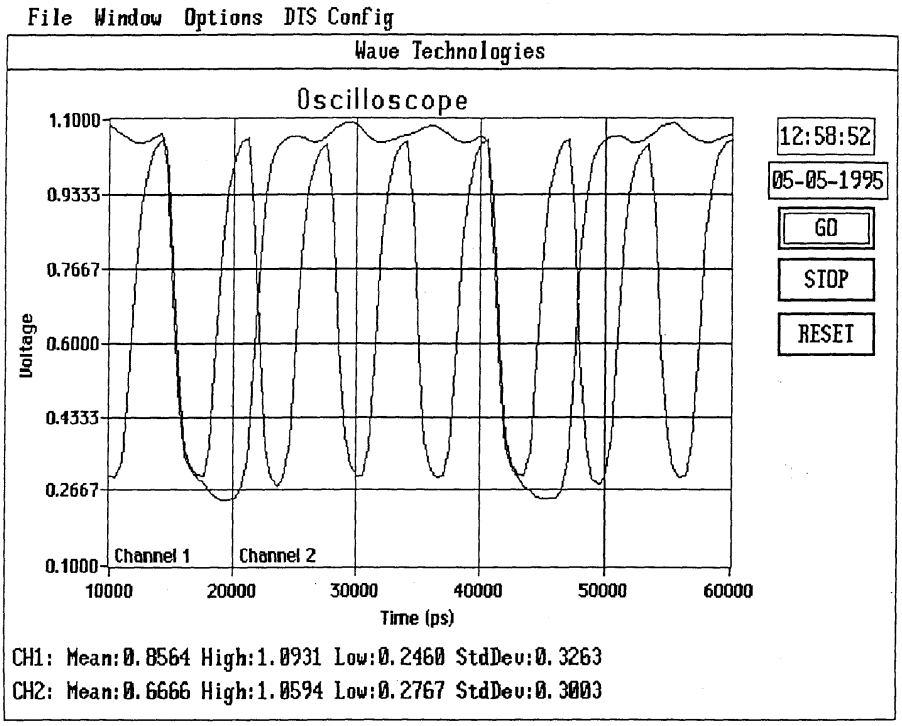


Figure 3-1-1

This is a strobing voltmeter picture of the data and clock output pins of the device under test (see Figure 1). Channel one has the PRBS 2E-7 data information on it, while channel 2 has the separated clock signal. The legend at the bottom of the picture has the VOH and VOL levels for each channel and the time in picoseconds.

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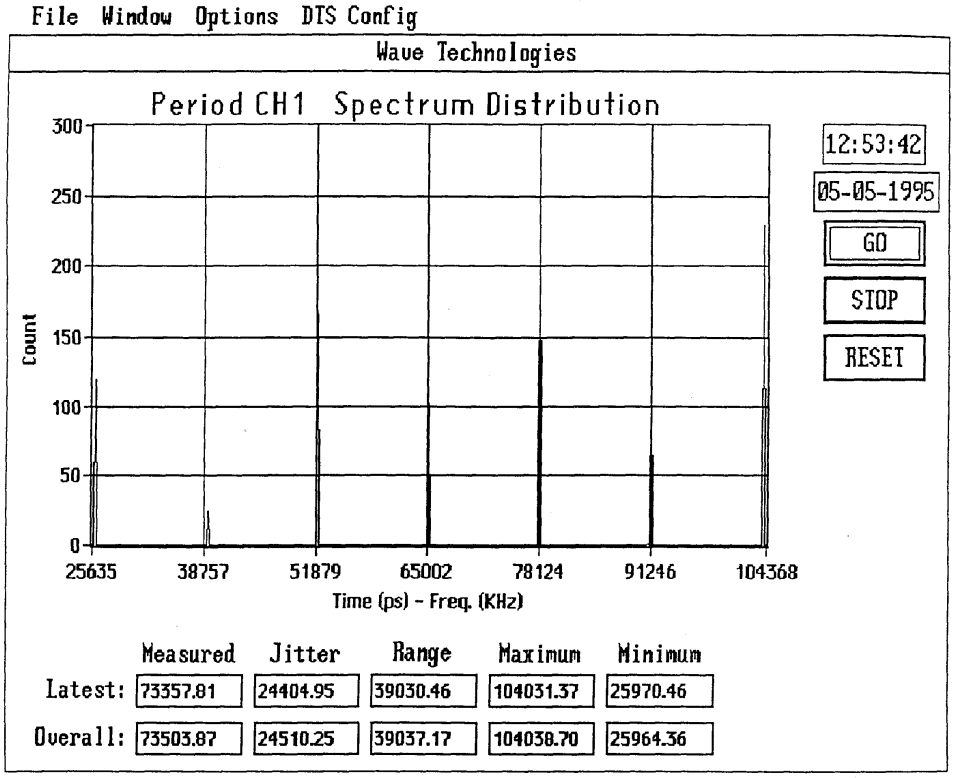


Figure 3-1-2

This is a period spectrum distribution picture of the data output on channel 1. The legend at the bottom of the picture gives the statistics for the displayed distribution. “Measured” is the center of the distribution, “Jitter” is the rms value of the jitter or 1-sigma of the distribution, “Range” is the “Peak” jitter and “Maximum” and “Minimum” are the peak-to-peak measurements made during the burst.

The legend is split into two parts. The first line indicates the “Latest” data displayed on the screen. The “Overall” line is the accumulated statistics for all screens the user executes. Each time the user presses the GO button on the screen, the DTS processes a full screen of data for the display.

As shown in Figure 3-1-2, seven distinct distributions are caused by the data pattern. By using the DTS data filters, the user can zoom in on any one of the distributions shown to see if they are Gaussian or not.

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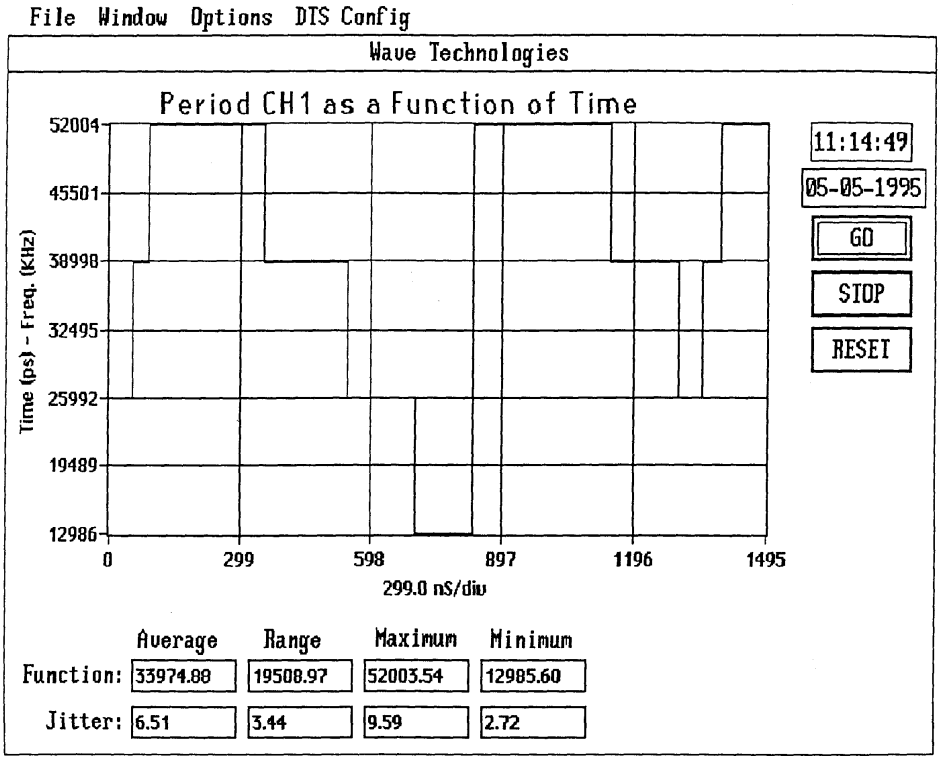


Figure 3-1-3

This is a display of period data as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse- by-pulse analysis by the DTS. The vertical axis indicates the period at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each period in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies during the pattern. Notice the effective period swing from 12.9 to 52ns. Each step indicates a pulse string at that period and represents the data separated from the input pattern.

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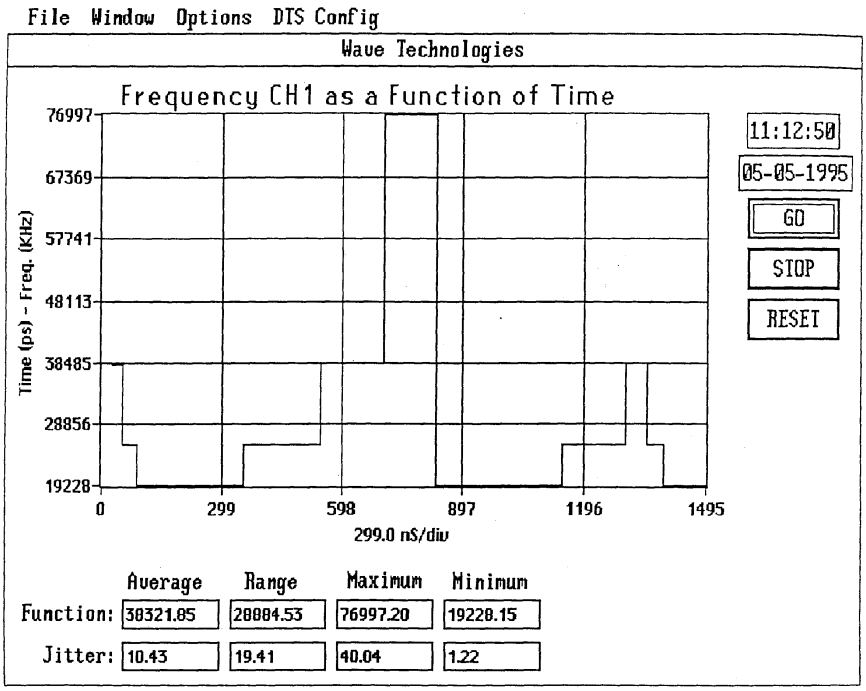


Figure 3-1-4

This is a display of frequency data as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the frequency at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each frequency in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies during the pattern. Notice the effective frequency swing from 19.2 to 77MHz. Each step indicates a pulse string at that frequency and represents the data separated from the input pattern.

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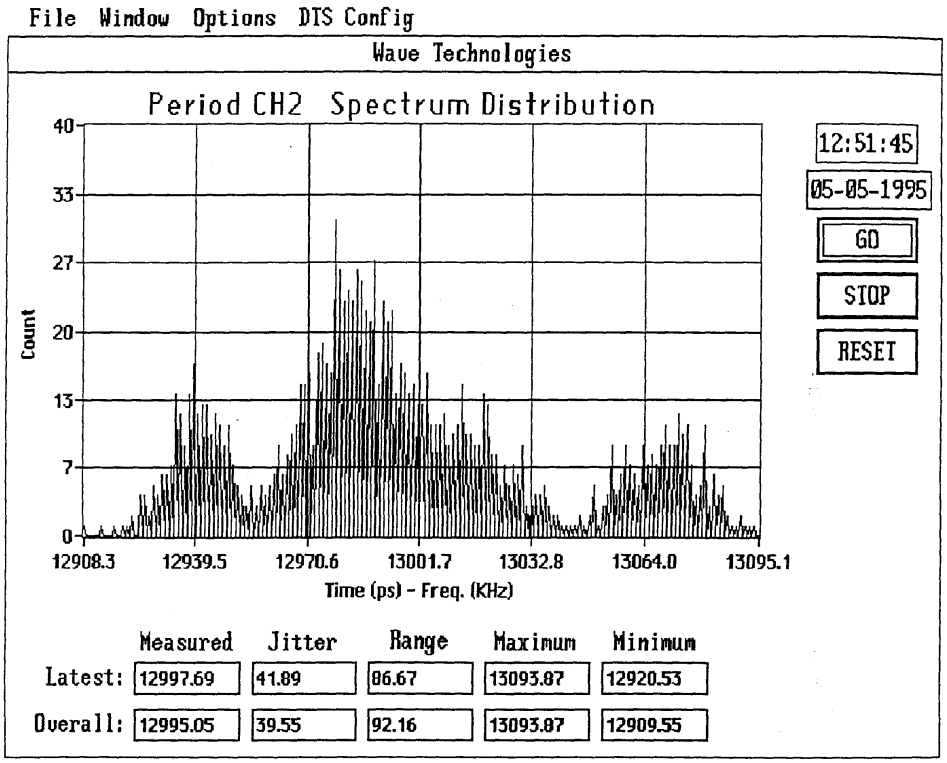


Figure 3-2-1

This is a period spectrum distribution picture of the clock output on channel 2. The legend at the bottom of the picture gives the statistics for the displayed distribution. “Measured” is the center of the distribution, “Jitter” is the rms value of the jitter or 1 sigma of the distribution, “Range” is the “Peak” jitter and “Maximum” and “Minimum” are the peak-to-peak measurements made during the burst.

The legend is split into two parts. The first line indicates the “Latest” data displayed on the screen. The “Overall” line is the accumulated statistics for all screens the user executes. Each time the user presses the GO button on the screen, the DTS processes a full screen of data for the display. The data in this legend is displayed in picoseconds. As shown in Figure 3-2-1, the distribution is not Gaussian, but is multi-modal. The cause for this can be seen in Figure 3-2-2.

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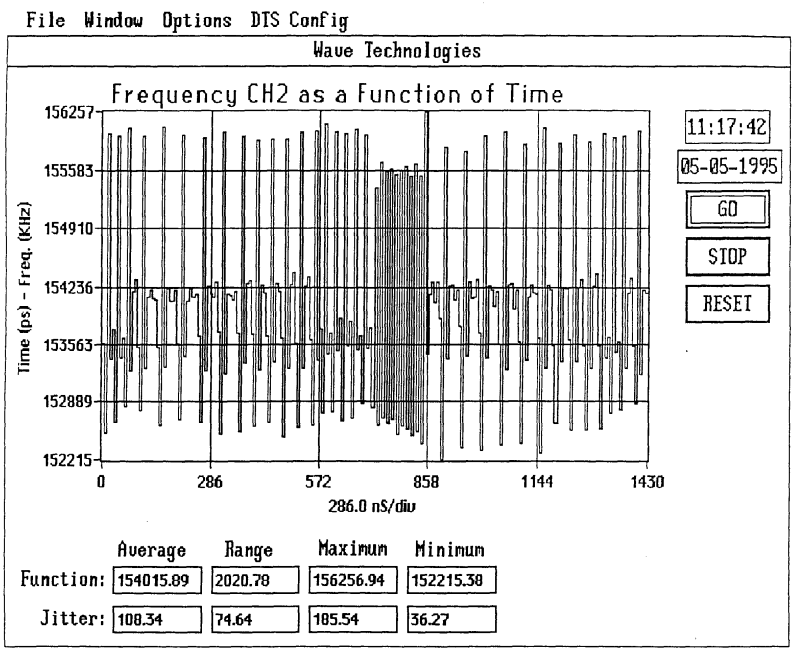


Figure 3-2-2

This is a frequency display of the clock as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the frequency at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each frequency in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies usually caused by pattern dependencies.

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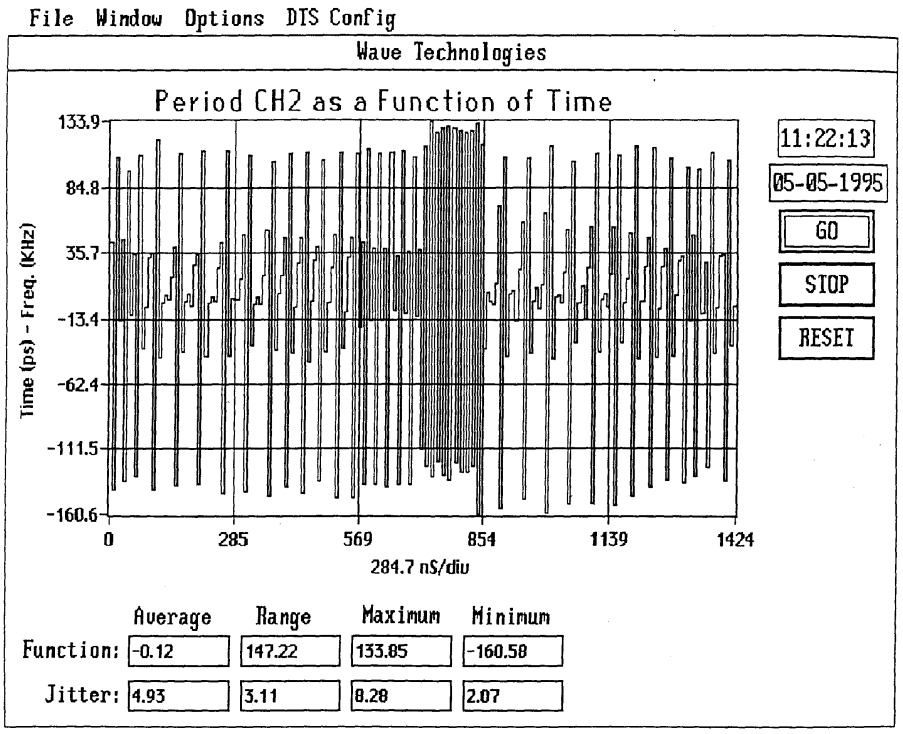


Figure 3-2-3

This figure shows the clock period instead of the frequency period shown in Figure 3-2-2. Also, in this view, the vertical axis indicates the derivative of each measurement with respect to the previous measurement. This option is selectable via the software.

The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 1-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the derivative at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each period in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies usually caused by pattern dependencies.

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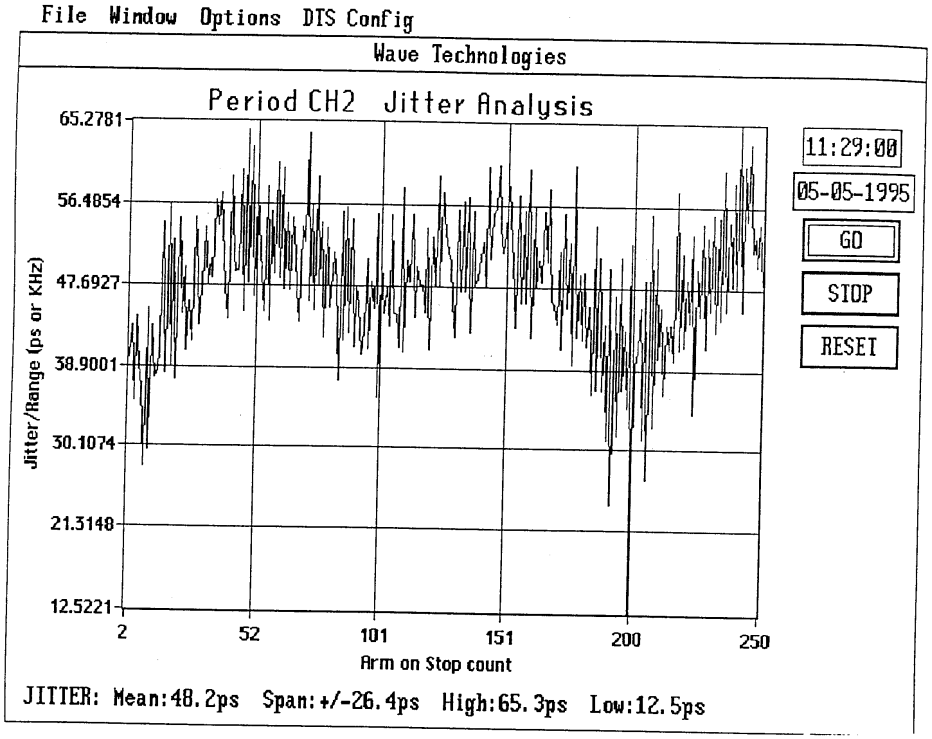


Figure 3-2-4

This is a picture of the asynchronous jitter of the clock output from 2 to 250 pulses. Notice a low frequency pattern that repeats every 100 cycles or 1.54MHz.

The jitter analysis picture shows the low frequency content of a device's output signal. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 3-2-3.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 3-2-3. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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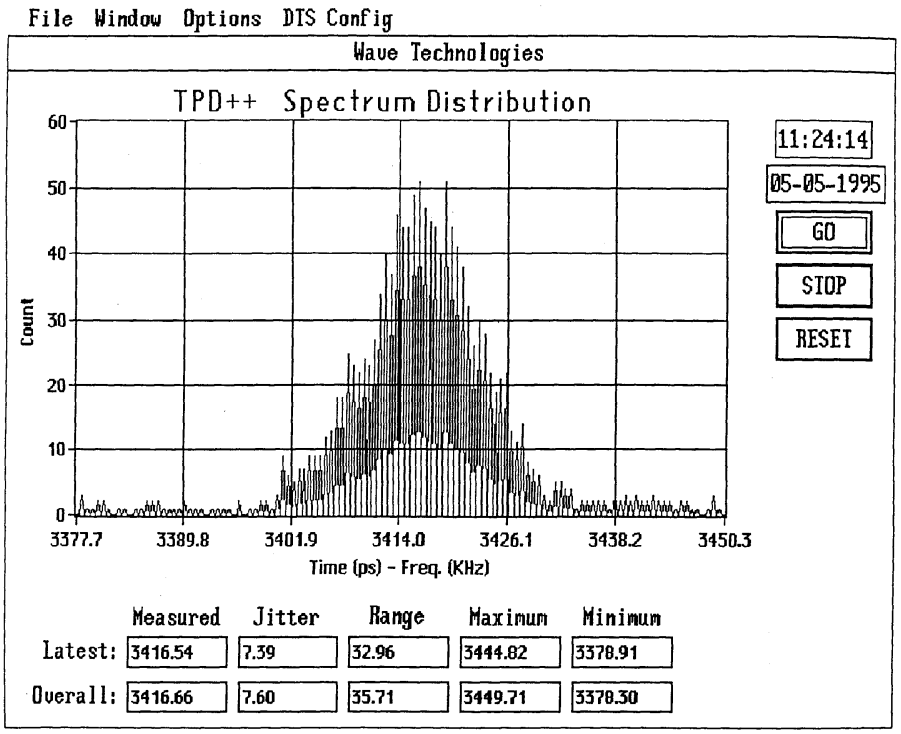


Figure 3-B-1

This is a TPD++ spectrum distribution picture of the high data going to positive clock output on channels 1 and 2. Notice the flyers extending above and below the main distribution. Figure 3-B-2 shows where they are generated in the pattern

The measured value of 3.414ns is the center of the distribution and represents the delay from data to clock. The distribution in Figure 3-B-1 shows how the delay varies over the executed pattern— which in this case is a PRBS 2^{E-7} data pattern.

As shown in Figure 3-B-1, the distribution is not Gaussian. A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1-sigma or jitter value. In this case, it is not.

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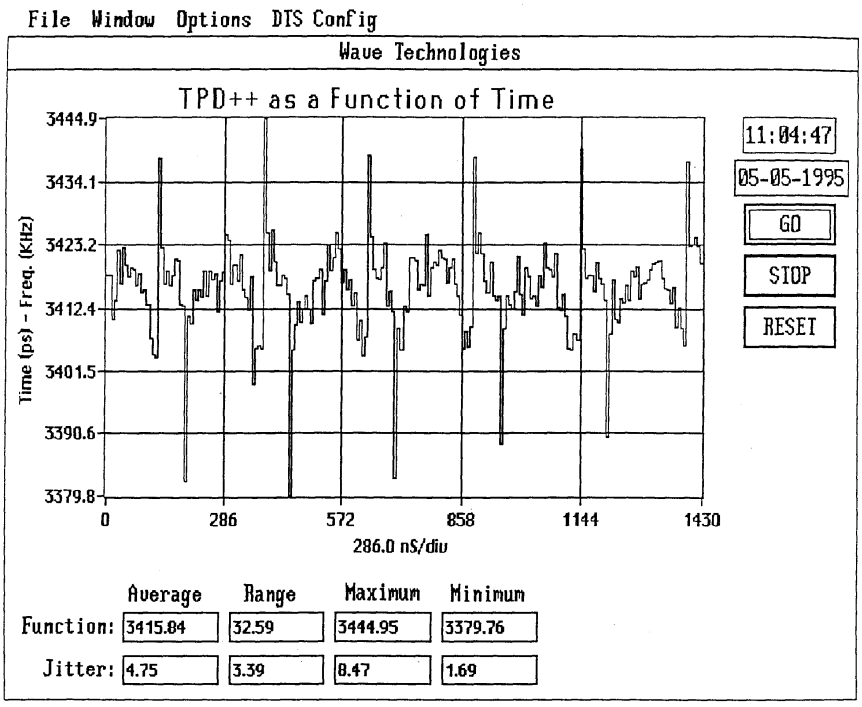


Figure 3-B-2

This is a cycle-to-cycle display of the data to clock delay as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 3-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the delay at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each delay in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies that occur over the course of an execution pattern. Notice the alternate TPD jumps during the pattern. This causes the flyers in Figure 3-B-1.

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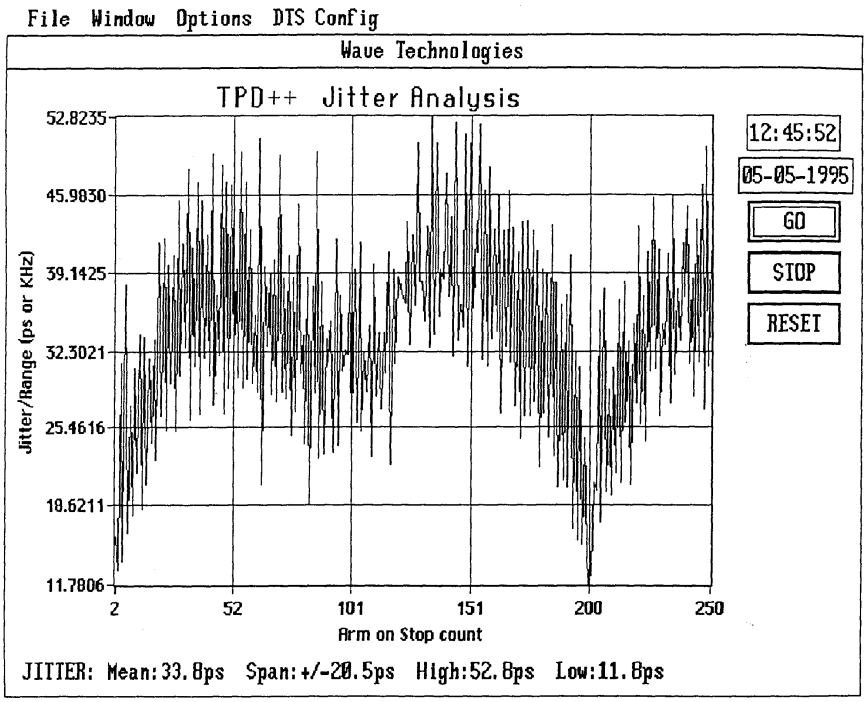


Figure 3-B-3

This is a jitter analysis picture of the delay between the high data to positive clock. As shown in Figure 3-B-3, the jitter indicates a repetitive pattern every 100 and 200 pulses.

The jitter analysis picture shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 3-B-2.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 3-B-2. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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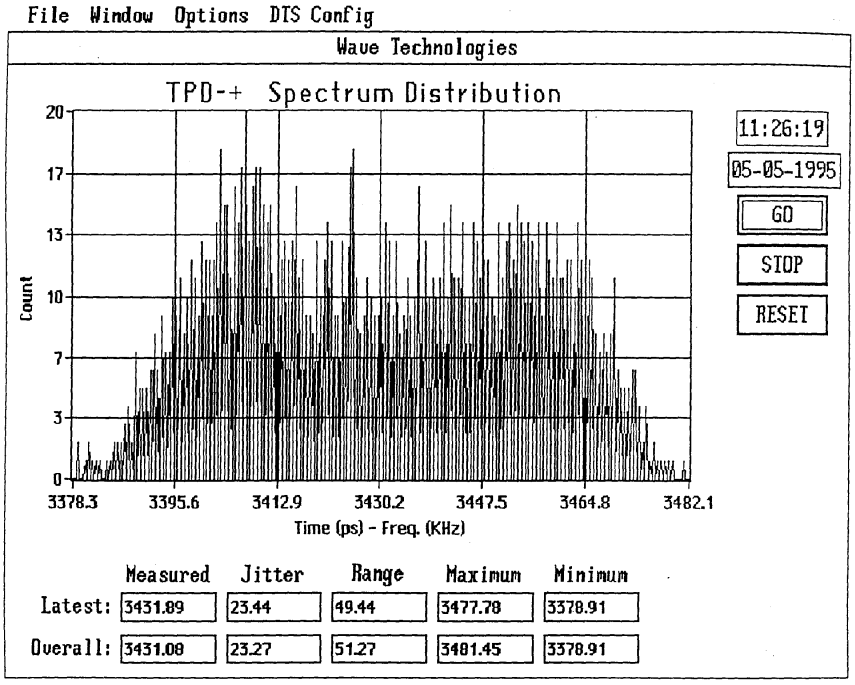


Figure 3-B-4

This is a TPD-+ spectrum distribution picture of the low data going to positive clock outputs on channels 1 and 2. Figure 3-B-5 shows why the distribution in this figure is bimodal at 3.40 and 3.45ns.

The measured value of 3.43ns is the center of the distribution and represents the delay from data to clock. The distribution in Figure 3-B-4 shows how the delay varies over the executed pattern — which in this case is a PRBS 2^{E-7} data pattern.

As shown in Figure 3-B-4, the distribution is not Gaussian, but is bimodal in nature. A good rule of thumb to use when determining whether a distribution is Gaussian or not, is if the range value of the distribution is three times the 1-sigma or jitter value.

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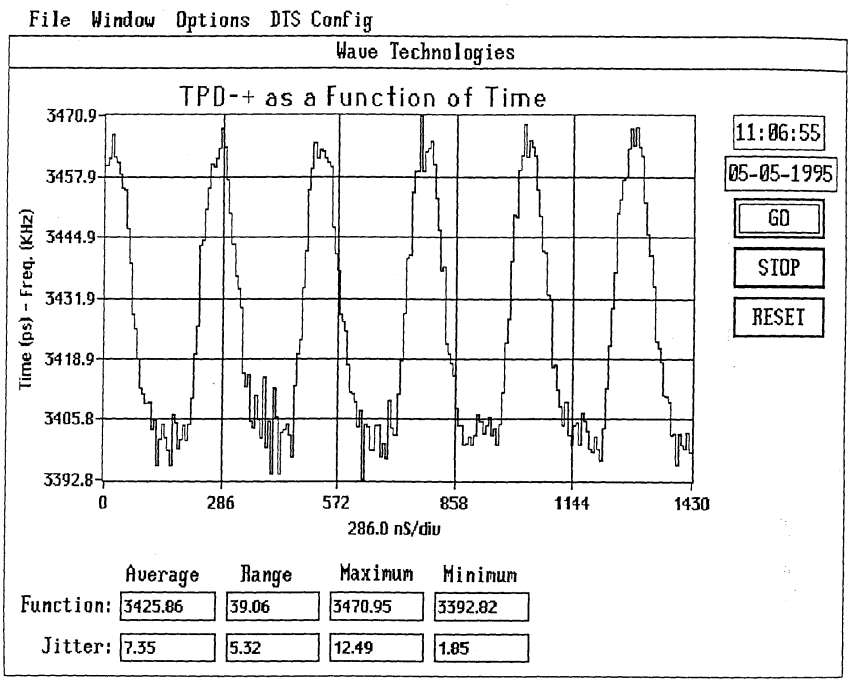


Figure 3-B-5

This is a cycle-to-cycle display of the low data to clock delay as a function of time. The left side of the picture is the beginning of the analysis and coincides with the strobe marker on the arming input to the DTS (see Figure 3-0-0 for the placement of the edge with respect to the pattern input to the DUT). The right side of the picture represents the end of the pulse-by-pulse analysis by the DTS. The vertical axis indicates the delay at various times from the beginning of the pattern as indicated on the horizontal axis.

The “Function” legend at the bottom of the picture indicates the peak-to-peak statistics for the pictured measurements, while the “Jitter” legend indicates the peak-to-peak jitter measured at each delay in the picture. The function versus time or count analysis shows *synchronous* jitter anomalies that occur over the course of an execution pattern. Notice the cyclical nature of the distribution of the TPDs as a function of the pattern, and how that correlates with the histogram in Figure 3-B-4.

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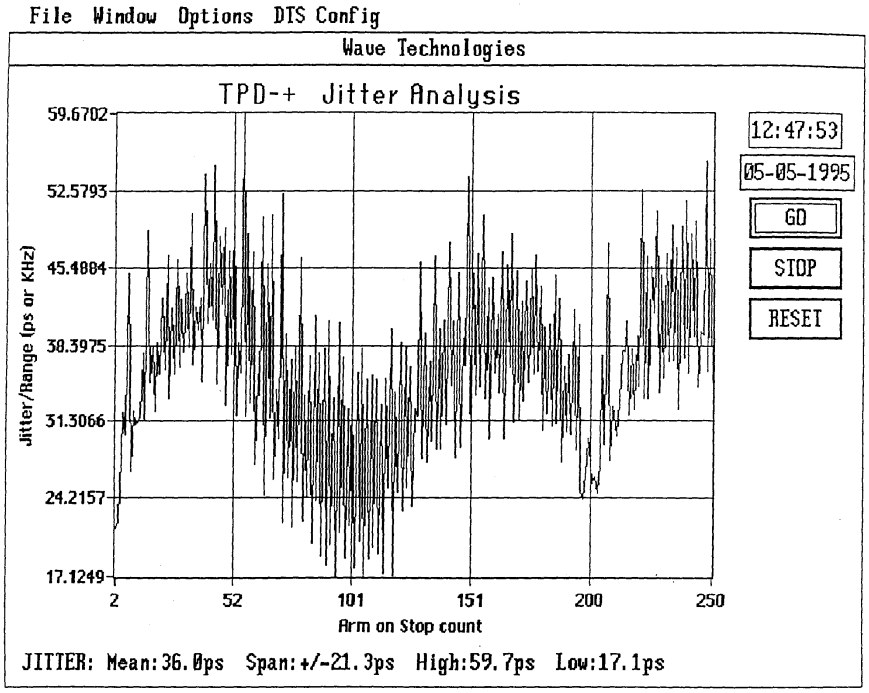


Figure 3-B-6

This is a jitter analysis picture of the delay between the low data to positive clock. As shown in Figure 3-B-6, the jitter is very similar to that in Figure 3-B-3 for the high data to clock.

The jitter analysis picture shows the low frequency content of a device's output. The user usually runs this tool in the asynchronous mode by using auto arm instead of one of the arming inputs used in Figure 3-B-5.

If the user wants to see the synchronous jitter at each cycle measured instead, the arming inputs would be used, as shown in Figure 3-B-5. The legend at the bottom of the picture indicates the overall statistics for the displayed jitter.

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Jitter Analysis of Clock Recovery Devices at 155-52 Mbit/S
(Section 4)

Conclusions

The test data given proves that the DTS 2070 is a fast and accurate tool for characterization of devices like the TDC-1555 clock recovery data separator. Jitter for the TDC-1555 fell within its published specifications as shown by the data.

Valuable settling time and instantaneous cycle-to-cycle pattern data allows the designer to accurately assess company products under dynamic conditions — without relying on only pass/fail data as provided by go-nogo BERT box testing. The settling time and data enable true jitter margin testing. Therefore, the IC manufacturer can accurately provide their customers with conclusive jitter specifications.

The noise floor of the DTS 2070 is low enough so jitter data can be read directly. Histogram data can then be taken up to 1000 times faster than with some Digital Sampling Scopes. Because the DTS uses high bandwidth input comparators instead of DSO sampling head, special smoothing algorithms are not required to enhance the data.

Because rms jitter assumes a Gaussian distribution, it is important to verify that jitter distributions are not bimodal in nature. If histogram distributions are not desired, the TPDs can be measured in the single-shot mode with little change in accuracy.

About the DTS 2070

The DTS 2070 is a precise, high-speed time measurement instrument designed for use in automated lab and production environments where large amounts of accurate and repeatable data are required.

Because of the patented calibration technique used in the DTS design, the linearity and repeatability of all timing measurements can be guaranteed to tight tolerances. Calibration is based on a built-in standard with 0.1 femtoseconds of accuracy in 10.0 nanoseconds.

The single-shot speed of the DTS enables it to take many measurements in a burst, to verify jitter distributions or to simply verify good continuity on contacts in a production environment.

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References

Texas Instruments TDC-1555Mbit/s Clock Recovery Device Specifications and Test Board.

WAVECREST Applications Note No. 112, “Jitter Testing of Clock Recovery Devices for High Speed Telecom and SONET Applications.”

WAVECREST Applications Note No. 115, “Arming the DTS 2070.”

WAVECREST Applications Note No. 114, “Achieving ±30ps Accuracy in the ATE Environment.”

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