



WAVECREST Corporation

EXAMINING CLOCK SIGNALS AND MEASURING JITTER
WITH THE *WAVECREST* DTS 2075™ AND
VIRTUAL INSTRUMENTS™ - DATA COM SOFTWARE

Application Note No. 127

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Examining Clock Signals and Measuring Jitter with the *WAVECREST* DTS 2075™ and *Virtual Instruments*™

Application Note 127

Introduction

The purpose of this paper is to present a general-purpose procedure that can be used to start a characterization or debug session of an unknown signal. This procedure will detail the setup for *Virtual Instruments*™ (VI) (Patent pending) software with an approach that a new operator of the DTS 2075™ (DTS) can use to discover what significant data exists in a signal, thus narrowing the scope of ongoing characterization.

Step 1. Finding the Signal.

Assuming the user has an idea of the device's pins or test setup's probe points, the first step in using the instrument is to use VI's **Oscilloscope** tool to view a figure of the waveform in question. This figure is an important first step because it will reveal the presence of a measurable signal as well as the quality of the signal the DTS will measure. The figure reveals the presence of any reflections or ringing that can cause false measurements. It will tell the user if the signal is continuous or if there are gaps in the waveform. The need for an external arm will show up as an incoherent figure if the waveform is not continuous and clock-like. The Oscilloscope figure will reveal if there is significant, observable jitter. Finally, in the case of a two channel skew measurement, it will reveal the phase relationship between edges and give clues to the user for determining which enable mode should be used to perform a TPD measurement.

Setting Up the Oscilloscope Tool

The DTS has a strobing voltmeter circuit that is used to capture waveforms, much like a sampling oscilloscope. This circuit needs three pieces of information:

- 1) The user must select the trigger source that will be used to create a time zero reference point for the display. There are four choices available, Channel 1, Channel 2, Arm 1 and Arm 2. In the case of a continuous waveform, it is often easiest to use the signal being measured as the trigger source. In other words, if the signal in question is connected to Channel 2, use Channel 2 as the trigger source. Just as in a sampling oscilloscope, the signal used as a trigger will affect the quality of the acquired waveform. If there is a lot of jitter on the signal, the accumulation of this jitter will distort the edges farthest from T_0 . In

this case, using another signal on Arm 1 or Arm 2 can fix this problem. In the case of a skew measurement on a clock to data pins, use the channel that is connected to the clock as a trigger. In the case of a signal that has pseudo-random data on it, using the external arming inputs enabled from a signal that marks the start of pattern is the best way to observe the waveform.

- 2) The start time must be specified. This value has a minimum of 20ns. This is equivalent to the trigger hold-off on a sampling scope. The start time can range between 20ns and 300µs.
- 3) The stop time must be set. This defines the length of the capture. It can range between 20ns and 300µs. The combination of the start and stop time defines the amount of capture time displayed.
- 4) The increment must be set. This is the step size used for the strobing voltmeter. It can be as small as 10ps. The maximum number of steps in a capture is 16K, so that the (stop time - start time) / Increment <16K.
- 5) Select the channel(s) to be measured and select the channel to be plotted.
- 6) Perform a pulse find by clicking the **Pulse Find** button on the top tool bar.
- 7) Hit the **GO** button on the top tool bar and the waveform will be displayed.

Figure 1 shows an Oscilloscope plot.

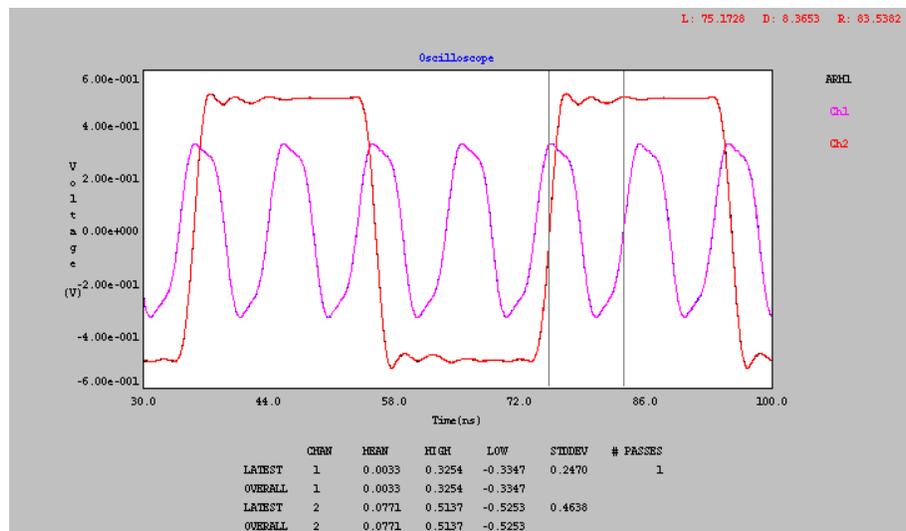


Figure 1 - Oscilloscope Example

For an unknown signal, start with a coarse resolution and larger start/stop time delta and dial these in to points of interest that should include a capture of one period. Observe the rise and fall time of the signal paying particular attention to see if there are any reflections at the 50% point in the waveform. *If there is a reflection you must adjust the start and stop comparator levels using USER Levels in subsequent tools to avoid including it in any jitter measurements.*

Step 2. Measuring the Edge to Edge Jitter

Once the signal has been seen and the proper comparator start and stop levels chosen, the jitter can be measured. The basic tool for measuring jitter is the Spectrum tool. Using the Windows pull-down, select Spectrum. Within the Spectrum tool window, select the DTS pull-down and choose Function Dialog. This is the dialog box which controls the measurement function, enable, comparator levels and sample size settings the DTS uses to create a Spectrum plot.

In this example, we have discovered that we are measuring a continuous clock on Channel 1. We will take a Spectrum plot asynchronously, which means using auto arm. The Spectrum tool DTS/Function Dialog settings are as follows:

Function - PER
Channel - CH 1
Sample Size - 1000
Pulse Find % - 50%-50%
Arming - Arm on Stop
Start Arming Event - 1
Stop Arming Event - 2

These conditions will set up the DTS to make a Period measurement (rising edge to next rising edge) on Channel 1. Take this measurement 10000 times, using the 50% voltage point of the waveform for the comparator trip cycles. It will measure the period of adjacent edges (Defined by Start and Stop Arming Events).

Next, select the Options pull-down, Options Dialog menu in the Spectrum window. It is the user's choice what Graph Style is preferable. The Triangle display provides more resolution between histogram bins, while the Straight display is good for overlays. The plot below is taken using Straight-line mode. The Uppdate Mode most often used is Overlay. This mode allows the last pass to be overlaid on the total data set so that the user has an idea of the histogram stability.

The user needs to execute a PULSE FIND and hit the GO or the CYCLE button on the main tool bar. The result is a histogram plot of the signal on Channel 1 using the CYCLE execution shown in Figure 2.

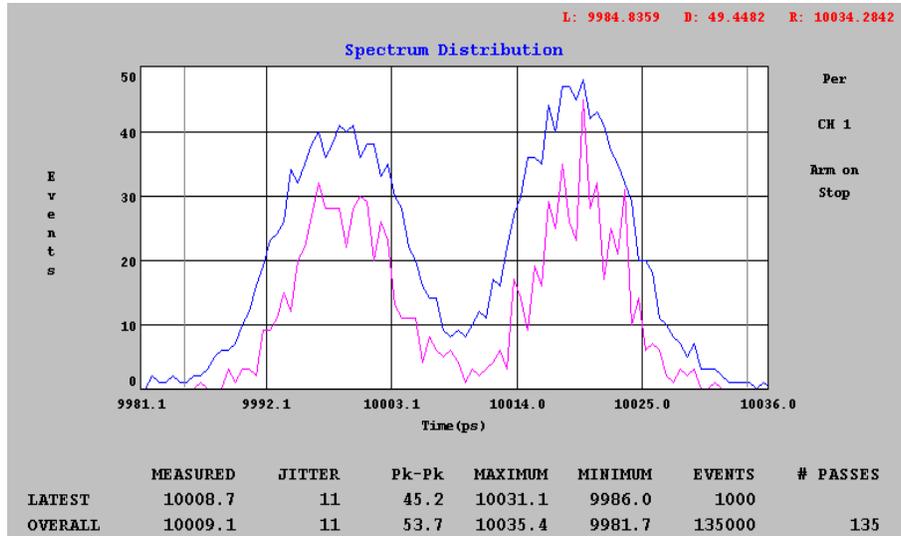


Figure 2 - Spectrum of Signal on Channel 1

The last pass is displayed on the LATEST line and in magenta (inside plot line) on the graph. The overall statistics are shown on the OVERALL line and displayed as the blue plot (outside plot).

The Measured value is the mean of the collected data. The Jitter is the one-sigma deviation from the mean that occurred in the measurement population. The Pk-Pk value is the maximum delta among samples in the database. In all plots, the data displayed at the bottom of the window refers to the plot that was last taken (Latest line) and the complete data set taken with the Cycle button (Overall line).

It is obvious that there is a bimodal distribution on this clock. There is more to learn from this signal than with just the Spectrum plot. Step 3 will show the reader how to set up the Jitter Analysis window to look for Jitter Modulation.

Step 3. Jitter Analysis, Discovering Jitter Modulation Frequencies

The final step in this process of discovery is to use the Jitter Analysis tool to find out what frequencies are most responsible for creating the histogram in Figure 2. The Jitter Analysis tool will plot Accumulated Jitter in the time domain and can plot an FFT spectrum of jitter versus clock event time.

The user should select the Jitter Analysis pull-down from the top tool bar. From the DTTS pull-down, select Function Dialog and set the conditions like those of the Spectrum tool except for one item, **Sample Size**. The Jitter Analysis tool will take the number of measurements specified by the sample size at each step between a start and stop count and reducing the sample size will speed up the measurement. Normally the sample size for Jitter Analysis can start with 100.

Next, the user must select the Options pull-down from the Jitter Analysis tool. Inside the Options Dialog, the first thing that should be tested is the accumulated jitter in the time domain. The purpose of this test is to try to find the lowest frequency of jitter modulation: the point where one full cycle of jitter modulation begins to repeat, or stabilizes. The approach here is to set the following:

Analyze - Jitter (1-sigma)
 Low Stop Count - 2
 High Stop Count - 5000

(This number is a guess, so is in some ways arbitrary and relates to the figure the user wishes to acquire. It should be high enough to reasonably capture events but not too high since there is a time penalty as more events are captured.)

Increment Event By - 1
 X Axis - Event
 Method - Remote

The resulting plot of accumulated jitter is shown in Figure 3.



Figure 3 - Accumulated Jitter

The plot in Figure 3 shows a jitter function that has a response frequency relating to the PLL response. This plot displays the 1-sigma time deviations in the statistics of each measurement population as the stop count in the measurement increases from 2 to 5002. Note that the jitter is always positive and increases from a minimum to maximum value with the maximum accumulated mean jitter found at a stop count of approximately 200. The Jitter is accumulating from 12.8ps, which is the edge to edge 1-sigma value seen in Figure 2, up to approximately 58ps where it stabilizes and oscillates slightly. The user should experiment with the High Stop Count and Increment settings to acquire the best view of the accumulated jitter.

The display in the Jitter Analysis references the actual plot in Figure 3. The MEAN jitter is the average value of the plot. The Pk-Pk is the difference between the Minimum 1-sigma jitter at 6.134ps and the Maximum jitter at 1196.461ps

If there is a need to identify the deterministic frequency components of this Jitter plot, the user should select Fast Fourier - 1 clock or Fast Fourier - n clock in the Analyze selection box. This will pull out the frequencies which are causing the largest amount of peak jitter. When Fast Fourier is selected, a second dialog window is presented asking the user to select an FFT Window. As a general rule, selecting the Kaiser window with a Padding of 16 and an Alpha of 6 or 8 provides good results.

An FFT normalized to one clock is shown in Figure 4. This is the effect of the Jitter modulation on a single clock period.

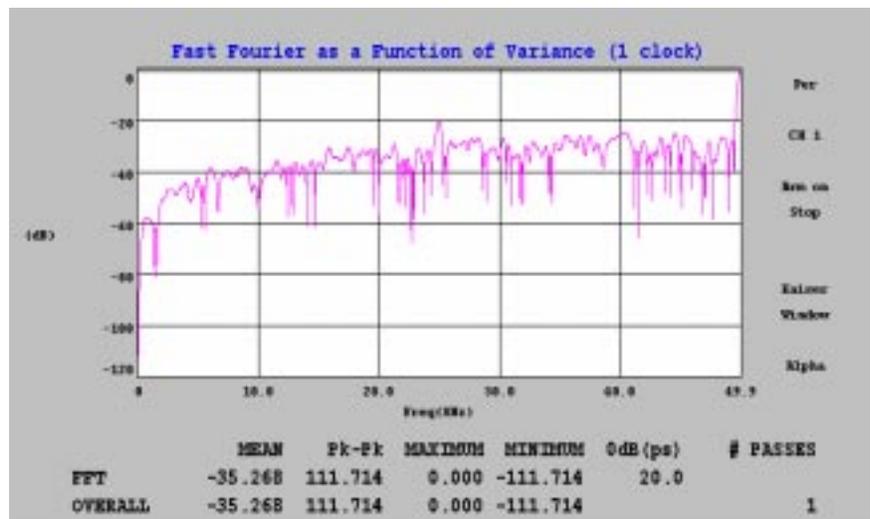


Figure 4 - Full Spectrum FFT Normalized to a Single Clock Period

This plot shows two main frequency components. The first, at 50MHz, is the high frequency modulation seen in the bimodal histogram plot in Figure 2. This is producing 20ps of *peak* jitter (40ps of the 60ps peak to peak jitter) seen in the Spectrum plot. Note the presence of a second modulation at 25MHz. This is 20dB down from 20ps so is only providing 2ps of peak jitter on a single clock period.

Note that the low frequency modulation is greater than 40dB down from 20ps so is not a significant factor on the edge placement of the clock. Normalizing the FFT to a single clock is most useful when analyzing clocks in a synchronous digital system. If the user wants to give equal weight to all frequency components, such as in a data communications application, the Fast Fourier - n clock selection may be more meaningful.

The way to read the FFT is to take the 0dB value, find a peak and see what its relationship in dB is to the 0dB level, i.e. 20dB down from the 0dB level is one tenth, 6dB is one half etc. The cursor software now displays the value it is pointing at as a time value. Note that the numbers in the plot aren't meaningful except for the 0dB value. The other numbers are referenced to the plot.

A different clock is shown in Figure 6. This clock contains high frequency noise but no significant low frequency component. The clock also has very low accumulated jitter.

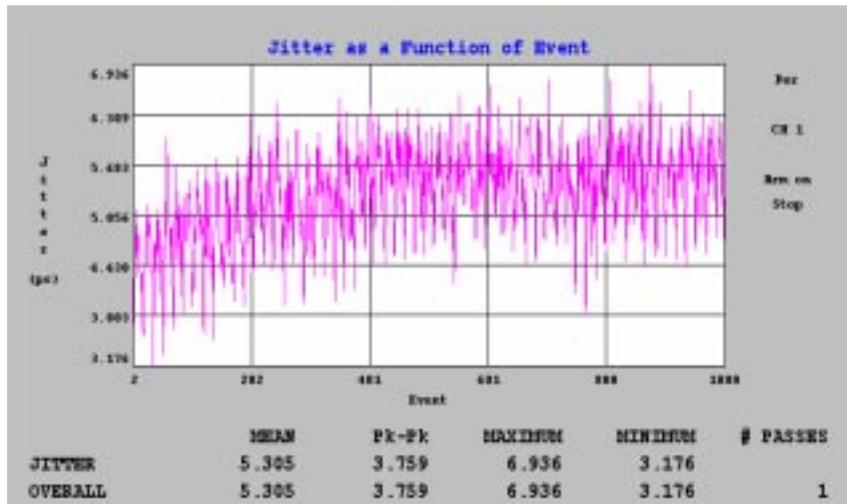


Figure 6 - Accumulated Jitter on 106MHz PLL

The jitter on the PLL is small and has a jitter accumulation up to count 202 with the jitter no longer increasing. This is the PLL response time: clock

fundamental (106MHz) divided by the count (202). Figure 7 shows us the FFT of this clock.

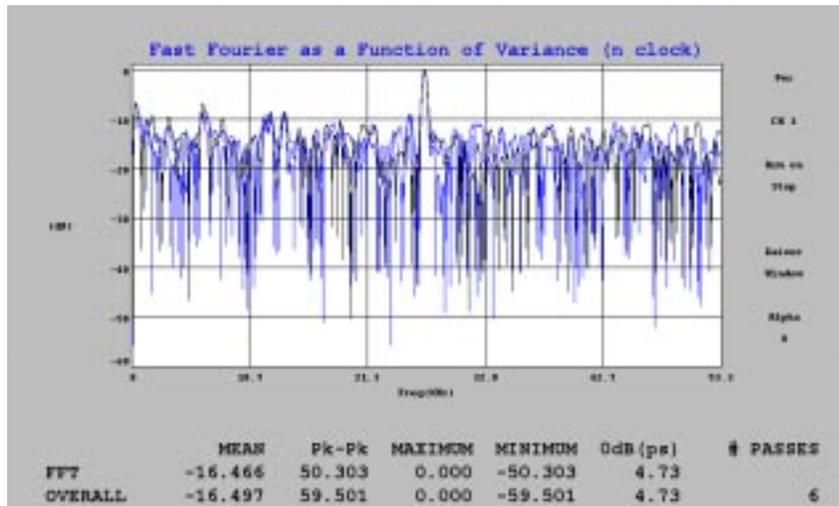


Figure 7 - FFT of 106 MHz Clock Normalized to N Clocks

The spike to note is the 26MHz peak in the center. This plot was taken with a stop count of 500 and an Increment of 1. The FFT window used was Triangular, which is also a common choice. The Peak deviation on the 106MHz clock as a function of its effect on a single clock period is 4.73ps, occurring at 26MHz. Overlay Screen mode was used to display the coherent spikes in the FFT

Summary

The three *Virtual Instruments*[™] tools required to extract the basic information about a clock and its jitter are Oscilloscope, Spectrum, and Jitter Analysis. With a little practice, the user can expand the search to include modifications of the Nyquist rate using the Jitter Analysis Increment. The user can look at the peak accumulated jitter stop count with the Spectrum tool by modifying the Stop Arming Event in the Function Dialog. The FFT measure cursors in Jitter Analysis also can provide useful information on the peak jitter, especially when the FFT is cycled to capture coherent frequency spikes.

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