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Fibre Channel Jitter Compliance Measurements Using the *WAVECREST* SIA-3000™

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Fibre Channel Jitter Compliance Measurements Using *WAVECREST's* SIA-3000™

Application Note 143

INTRODUCTION

This application note will describe how to perform Fibre Channel jitter compliance measurements on Storage Area Network (SAN) systems and components using ***WAVECREST's*** SIA-3000 Signal Integrity Analyzer, PM50 Pattern Generator and *Virtual Instrument Signal Integrity*™ (*VISI*) software. This note will also describe a variety of setups used to perform jitter compliance measurements using data only from the device under test (DUT). The measurement techniques in this application note can be easily transferred to other protocols such as Gibabit Ethernet, SONET and Infiniband™ where systems or components may be tested with a repeating pattern such as CRPAT, CJTPAT or PRBS. Four different examples of jitter compliance testing are included to illustrate the flexibility of ***WAVECREST***'s signal integrity measurement instrumentation. A brief review of the data acquisition method for calculating jitter using the SIA-3000 is also included. Two comprehensive documents describing jitter measurement methods including a summary of jitter values at the various compliance points are: **Fibre Channel – Methodologies for Jitter Specification (MJS)** and **Fibre Channel – Physical Interfaces (FC-PI)**. These documents can be downloaded off the Internet at www.t11.org.

INSTRUMENTATION

Testing SAN systems for jitter compliance can be difficult because traditional techniques and instruments, such as oscilloscopes, do not provide jitter values at a specified bit error rate (BER) or separate out the various jitter components. Furthermore, oscilloscopes require a bit clock or trigger and, typically, these signals are not available on these systems. With ***WAVECREST's*** SIA-3000, PM50 and dataCOM software, users can perform jitter compliance measurements on only the data without a bit clock or trigger. The PM50 produces a pattern marker from a repeating pattern that is then used as an arming signal for the SIA-3000. In essence, the pattern marker provides a reference point for time interval measurements. The PM50 matches up to a unique, 40-bit portion of the data. For example, the unique 40-bit portion of a pattern, such as CRPAT, would be the start-of-frame (SOF). An arm signal will be generated after the SOF and a time interval measurement will be made from the next data edge, after the arm signal, to an edge *n* unit intervals away. Algorithms de-convolve the data to provide quantitative information on random, deterministic and periodic jitter and this is described in detail at the end of this application note. The PM50 can also be used in the Edge Count mode where the user inputs the number of positive edges of the pattern and a pattern marker is output every time the pattern repeats. With the A45/A25 oscilloscope option, the SIA-3000 can also make voltage measurements such as eye masks and rise/fall times.

STORAGE AREA NETWORK APPLICATIONS

The tremendous increase of data traffic has fueled the need for higher speed networking components and systems. As a result, ensuring signal integrity of network systems and components by testing against industry standards has never been more important.

Fibre Channel (FC) is a protocol used to transfer data between components that make up storage area networks such as RAID (Redundant Array of Inexpensive Disks) systems, JBODs (Just a Bunch of Disks), workstations and servers. Figure 1 shows a typical SAN. Test example numbers indicate the locations where jitter measurement test setups, using the FC Test Set, were performed. These test examples and setups are detailed below.

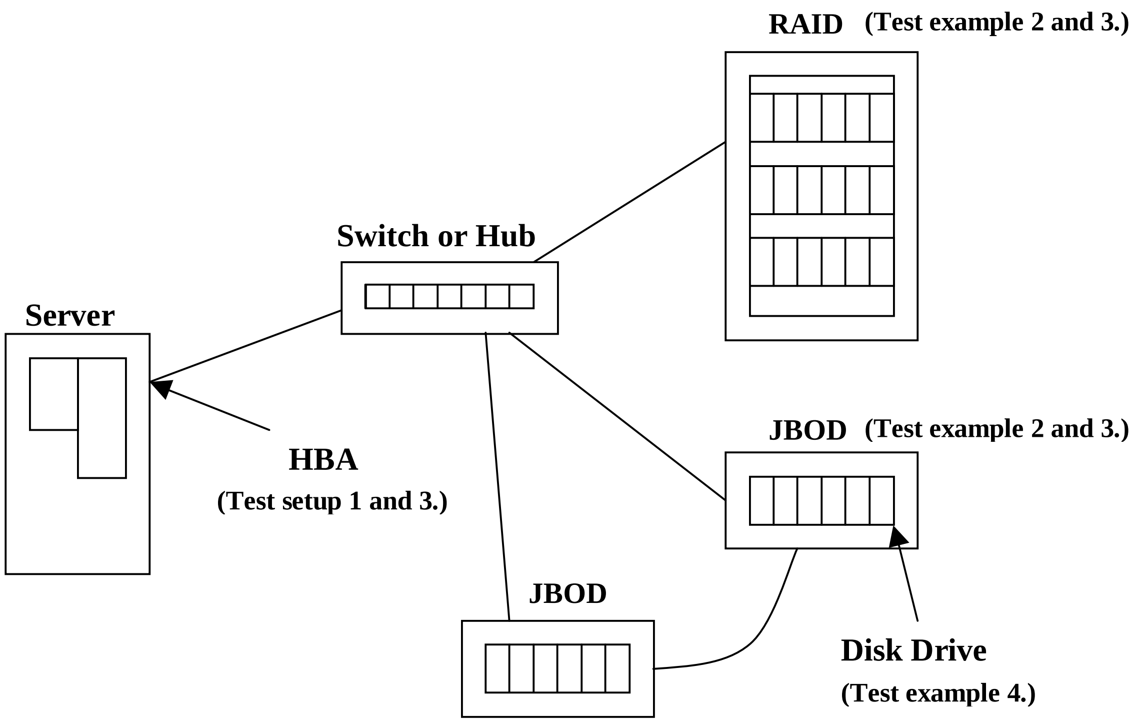


Figure 1 - Typical Storage Area Network

Test Example 1 - Testing a Fibre Channel Host Bus Adapter (HBA)

Figure 2 shows the instrument setup used to perform these measurements. A typical location for an HBA would be in a server for interfacing a PCI bus to an external Fibre Channel storage system. The setup is composed of an FC Host Bus Adapter, computer for controlling the HBA, SIA-3000™ with PM50 and dataCOM software.

The HBA is capable of generating compliant test patterns such as CRPAT, CJTPAT and SPAT as well as noncompliant IDLE patterns. The compliant patterns contain low frequency patterns, long and short runs of 0's and 1's and composite patterns as described in the MJS document. These patterns are used because they stress the clock data recovery unit in different ways. For example, the high and low transition density patterns are used to generate data dependent jitter.

The PM50 pattern marker provides a pattern marker or an arm signal, as described above, for the SIA-3000. The pattern mark is automatically placed in a low transition density region to insure repeatable and reliable data even in the presence of large amounts of jitter.

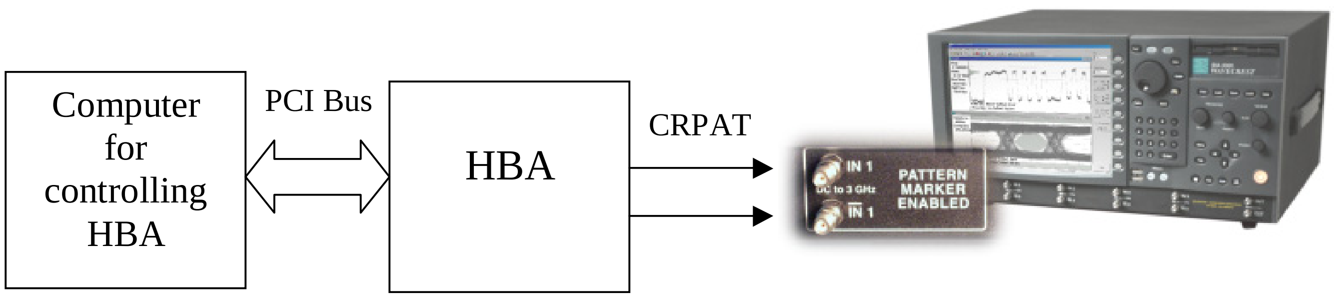


Figure 2 – HBA Measurement Setup

Using CRPAT as the serial data stream, the HBA was tested at 1.0625 Gb/s (1×) and 2.125 Gb/s (2×) data rates.

Figure 3 shows the FFT of the autocorrelation function, commonly referred to as the power spectral density. The data was acquired at the γ_T compliance point. The data shows that the system had a Total Jitter of 212.3 ps at 10^{-12} BER. De-convolving TJ, the individual components were 8.2 ps of Random Jitter (RJ rms) and 99.8 ps of Duty Cycle Distortion/Intersymbol Interference (DCD/ISI) and 12.5 ps of Periodic Jitter (PJ) with a peak at 13.7 MHz as determined from the FFT. The jitter output for the γ_T compliant point at 1× data rates from the FC-PI document is 254 ps for TJ and 122 ps for DJ. The HBA was compliant for TJ, DJ and RJ.

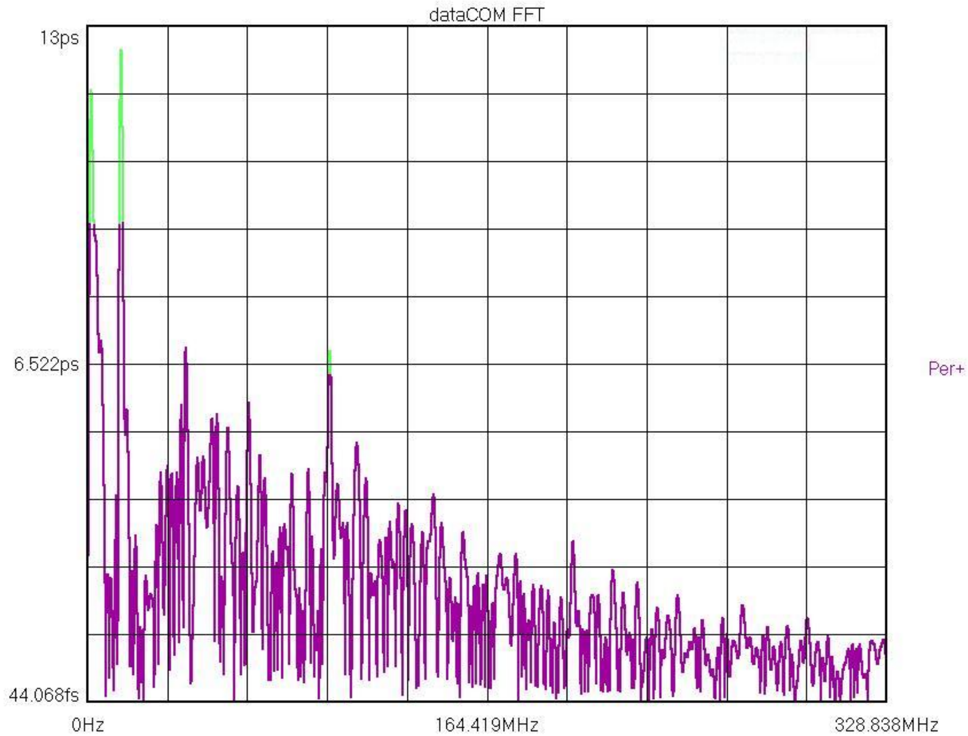


Figure 3

Test Example 2 - Testing a Fibre Channel Disk Array

Figure 4 shows the setup used to measure jitter on a disk array. In this setup, a pattern generator is used to generate a compliant test pattern, such as CRPAT. The data pattern can be routed either through the RAID controller board to the mid-plane and out to the measurement equipment or the data pattern can be sent between two locations of a disk drive.

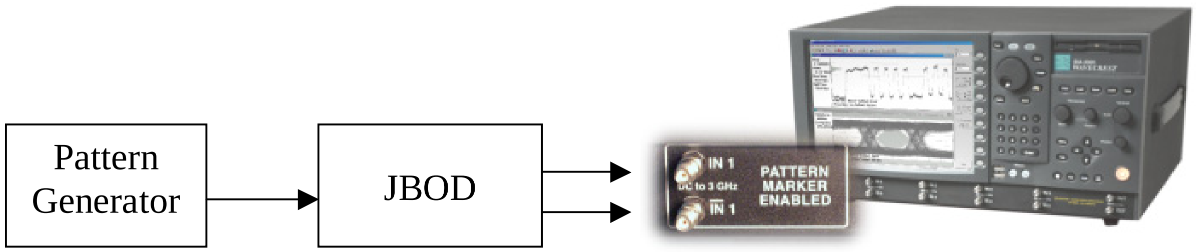


Figure 4

Results obtained from various locations between disk drives in the JBOD at 1× data rates are:

Tabel 1 - Jitter Output values from FC-PI

	1.0625 Gb/s			
Test points	**DJ**	**TJ**		
β_T	104 ps	216 ps		
Test Results				
Disk 0 to Disk 1				
DCD+ISI	**PJ**	**DJ**	**RJ**	**TJ**
44.4 ps	10 ps	54.4 ps	12.1 ps	209 ps
Disk 0 to Disk 14				
DCD+ISI	**PJ**	**DJ**	**RJ**	**TJ**
66.8 ps	5.3 ps	72.1 ps	5.9 ps	147 ps
Disk 0 to JBOD				
DCD+ISI	**PJ**	**DJ**	**RJ**	**TJ**
46.3 ps	7.9 ps	54.2 ps	10.2 ps	183 ps

The measured values in Table 1 are all below the jitter output specification values as specified in FC-PI at the 1× data rates. The trace length between Disk 0 and 1 was much less compared to the trace length between Disk 0 to 14 and, as a result, the later DCD+ISI value was 50% higher but still below the allowable limits. The SIA-3000™ with PM50 card was also useful in characterizing earlier designs. Early board designs were characterized and had contained spectral components from crosstalk and EMI. The source(s) were easily identified and eliminated.

Test Example 3 - Testing a Single Mode Gigabit Interface Converter (GBIC)

Figure 5 shows the setup for testing jitter on a GBIC. A GBIC may be located in an HBA, JBOD or RAID system, as shown in Figure 2. The GBIC was tested two different ways and these are labeled Method 1 and Method 2.

Method 1 tested the transmit signal path from the electrical to optical conversion in the GBIC through an optical splitter and then the signal was converted back electrically using the ***WAVECREST*** OE-2 and connected to the AG-100. The measurement is done at the optical γ_T point. The purpose of this test was to illustrate the capability of measuring jitter in an optical loop or live network. The results using CRPAT at FC 2X data rate is shown in Figure 6. Figure 6(a) shows the histogram of the DCD&ISI component for each edge in the pattern. The DCD&ISI portion of the total jitter was 72.5 ps of the Total Jitter. Figure 6(b) shows the error probability density function or bathtub curve. At 10^{-12} BER the total jitter was 102 ps well below the FC specification.

Method 2 measured the jitter after the GBIC receiver using a standard vendor evaluation board. The differential signal from the pattern generator was sent to the GBIC and the optical fiber was looped back from the transmit to the receive side of the GBIC. The differential electrical signal from the GBIC was connected to the AG-100. The purpose of these tests was to characterize the jitter originating from the GBIC E/O and O/E. Other possible setups could include testing the GBIC at the receive and transmit γ and β compliant test points. The TJ at the 1× data rate was 135 ps composed of 91 ps of DJ and 3.56 ps 1σ of RJ. The plot of the power spectral density showed a spectral peak at 100 MHz contributing 4.4 ps of jitter.

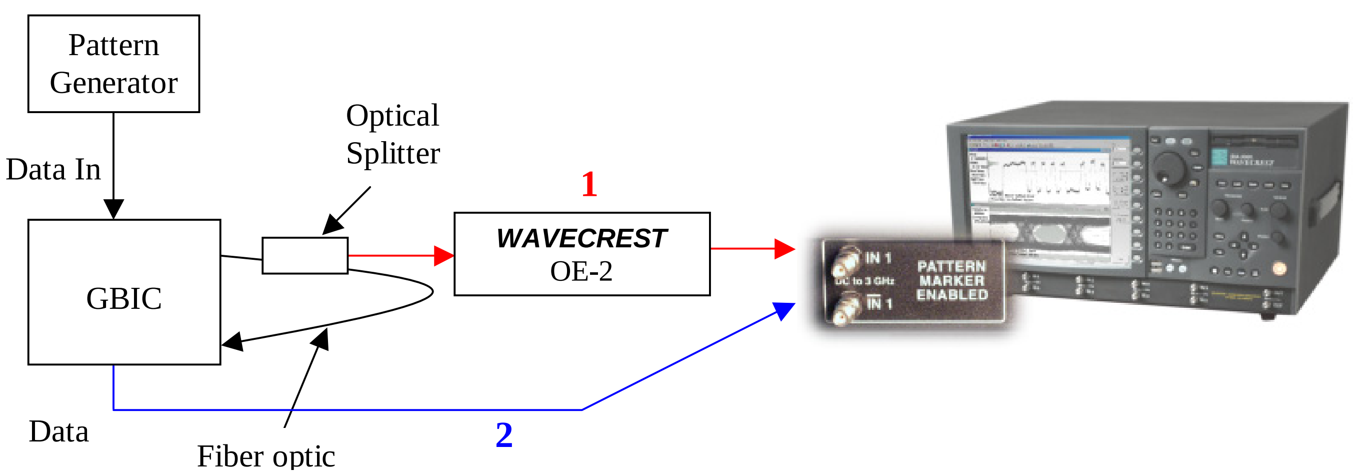
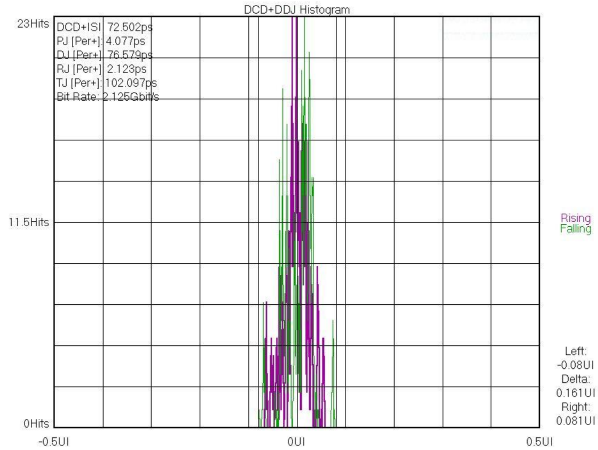
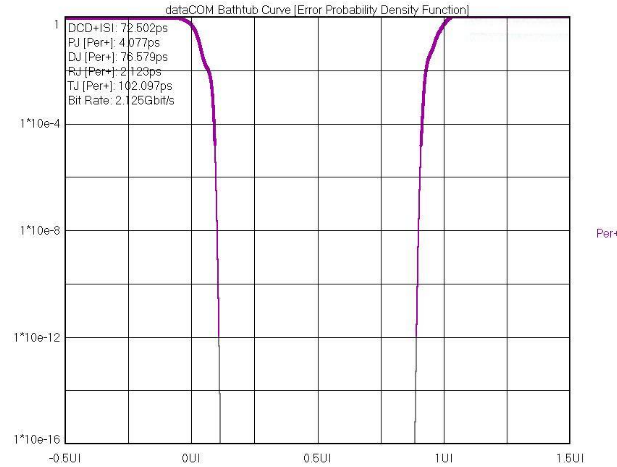


Figure 5



6(a)



6(b)

Figure 6

Test Example 4 - Testing at the board level using differential probes

In all of the examples described above, SMA connections were used to connect boards to the SIA-3000™. Another method of measuring jitter at the board level without using SMA connectors would be to use a high bandwidth differential probe.[1] Measurements using a differential probe have been made on various disk drive locations on a JBOD and on individual disk drive controller boards. The advantage of using a differential probe in these applications is because SMA connectors are not available. The SIA-3000 with PM50 card equipped with a high bandwidth differential probe is an excellent solution because a bit clock or trigger is not required to perform jitter measurements. The user has maximum flexibility in probing different locations throughout a system such as a backplane.

Test Example 5 – Transmit Rise/Fall time and Eye Mask Measurements for Electrical Cable Interface

This example describes how to perform eye mask measurements for the FC electrical interface 100SE-EL-S. Configure the SIA-3000 with scope card to measure the Eye Mask in Figure 7 according to the values in Table 2. The 20-80% rise/fall time values are to be computed as the time from 0.2*2*B to 0.8*2*B.

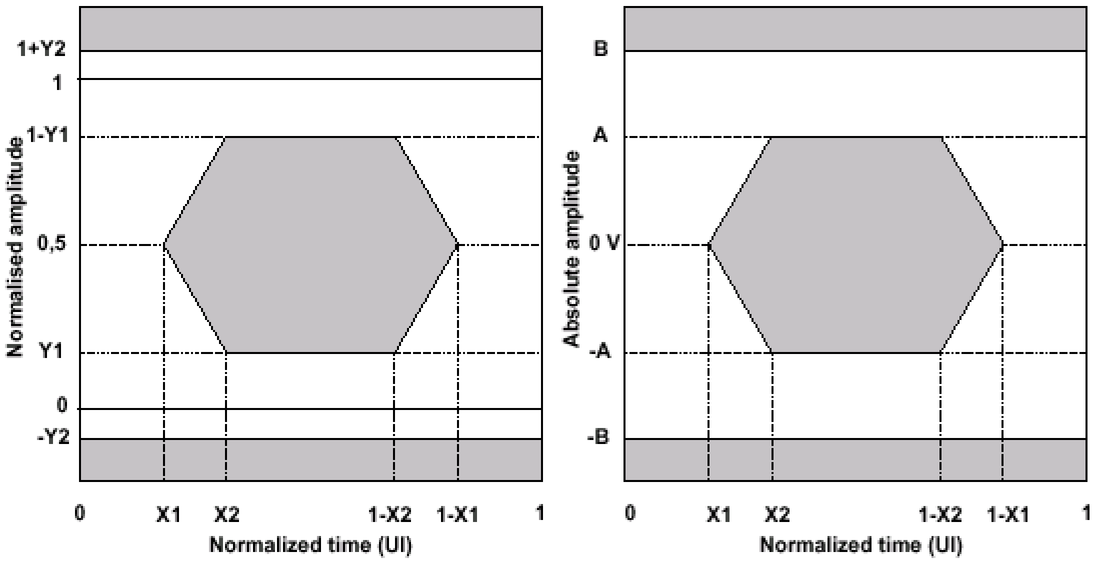


Figure 7 - Normalized and absolute eye diagram masks [3]

Eye mask measurements are to be made at various interoperability points. See Figure 8 for a depiction of these interoperability test points and Table 2 for compliance values.

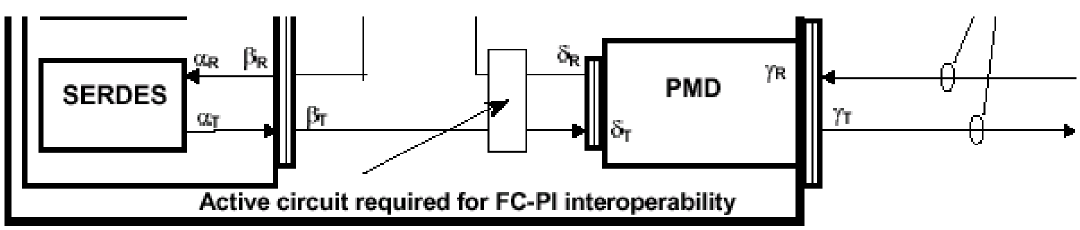


Figure 8 – Identification of FC Interoperability Test Points [3]

Table 2 - Transmitted signal characteristics [3]

Parameter	Units	100SE-EL-S
Beta T Point		
B	mV	1000
A	mV	300
X1	UI	0.115
X2	UI	0.305
Delta T Point		
B	mV	1000
A	mV	325
X1	UI	0.125
X2	UI	0.315
Gamma T Point		
B	mV	1000
A	mV	550
X1	UI	0.135
X2	UI	0.325
Eye mask normalized amplitudes		
Y1	None	0.2
Y2	None	0.1
Rise / Fall Time 20-80%		
Max	Ps	385
Min	Ps	100

Figure 9 is an example of a typical eye mask measurement. Figure 10 is an example of a typical rise/fall time measurement. Both measurements were performed at the Gamma T point on a 1× data signal.

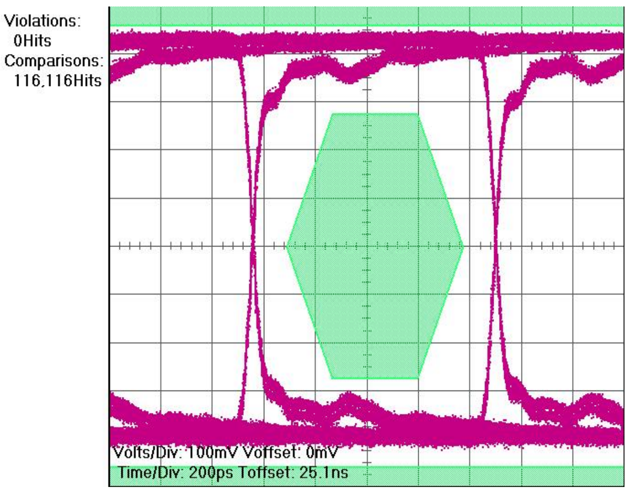


Figure 9 – Eye Mask Measurement

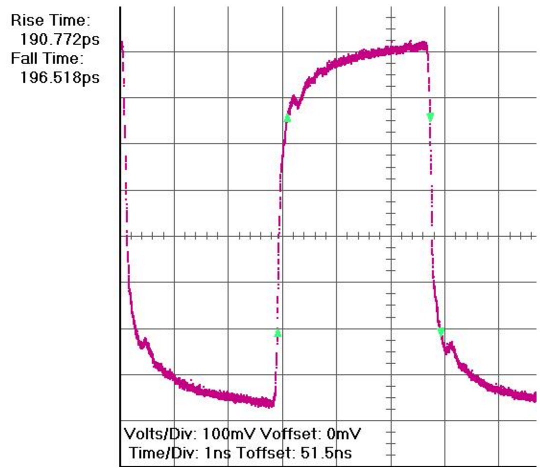


Figure 10 – Rise/Fall Time Measurement

Jitter measurement methodology using only data patterns

Below is an overview for the methodology using the *VISI*™ - dataCOM tool for jitter compliance measurements using known pattern with marker. This overview will describe how the Random and Deterministic jitter components are measured.[2] This method requires a pattern marker that will indicate the repeat interval of the data signal to the *VISI* software. A pattern marker can be created from the repeating data pattern by using the PM50 Pattern Generator or other source such as a trigger from a pattern generator. This data acquisition method provides a robust means of measuring jitter components including Duty Cycle Distortion (DCD) + Intersymbol Interference (ISI), Periodic Jitter (PJ), Random Jitter (RJ) and estimating Total Jitter (TJ) at a user specified Bit Error Rate (BER). In addition, the magnitude of the periodic components can viewed as a function of frequency. The magnitude of RJ can also be viewed as a function of frequency.

The first step that is performed in this method is accurately measuring the unit interval (UI). This is done by making a series of pattern length measurements, calculating the mean and dividing by the pattern length. Next, a pattern match of the data must be done to identify the phase relationship of the pattern marker and the measured data stream relative to the expected bit sequence. This eliminates the need to have the pattern marker at the beginning of the expected pattern. The expected pattern is compared against the measured pattern and rotated, if necessary, until the expected pattern matches the measured pattern. Next, DCD/ISI is measured from the difference between the expected edge location and the mean of the actual edge location.

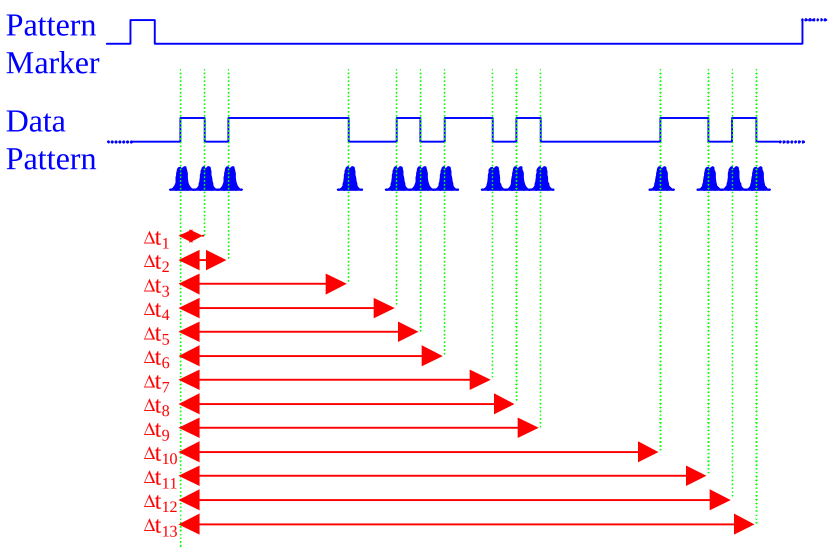


Figure 7

Each Δt is compared to the ideal transition location and the difference, in direction and magnitude, is placed in an array and this is illustrated in Figure 7. The DCD+ ISI measurement is calculated based on the peak-to-peak spread of this array.

Periodic and random jitter components are determined by taking the variance of timing measurements from the histogram at each unit interval. The variance is the square of the standard deviation. If any "holes" in the variance record exists, they will be interpolated by either a cubic or linear fit. An FFT of the autocorrelation function is used to determine the periodic components. The Fourier transform of the autocorrelation function is commonly referred to as the power spectral density or power spectrum. The RJ component is determined by subtracting the spectral components, summing the background then taking the square root to provide a 1-sigma value.

Alternatively RJ can be calculated by fitting Gaussian tails to both sides of each transition histogram. This technique is called TailFit™. Each TailFit RJ component is then placed into the FFT plot. From this plot, the Blackman-Tukey algorithm is used to estimate RJ across a specified frequency band.

Tailfit should be used to determine RJ when significant amounts of PJ exist since the variance based FFT will overstate the amplitude of the background RJ. Pattern Marker mode is the preferred methodology when significant amounts of Deterministic Jitter are present. It is faster and more accurate than the other methods when a pattern marker is available.

Software Setup - Jitter Measurements

This section provides general instructions for setting up the *VISI*™ software Known Pattern with Marker tool. The requirements for this tool are a known pattern and a pattern marker. The pattern marker will be generated internally using the PM50 card of the SIA-3000.

From the initial startup screen (Figure 12), select the dataCOM Tools button.

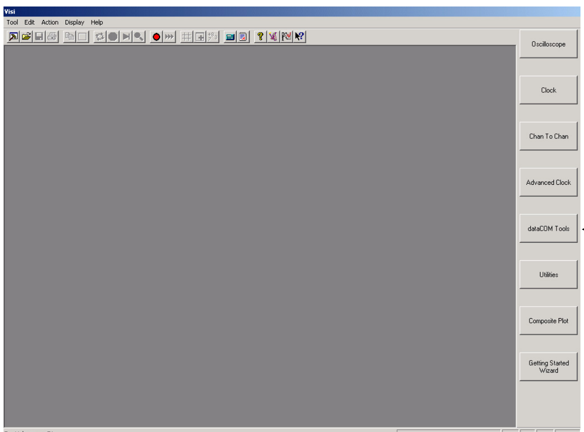


Figure 12 - Initial *VISI*™ Startup Screen

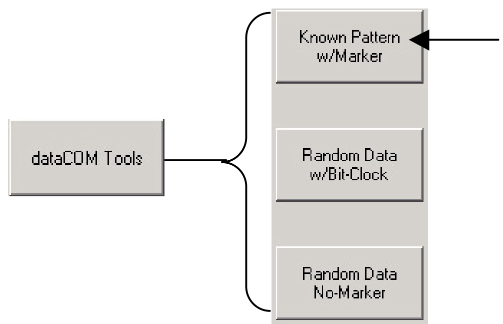


Figure 13 – dataCOM Category

Next, select the Known Pattern w/Marker tool (Figure 13). Figure 14 shows the dataCOM tool window.

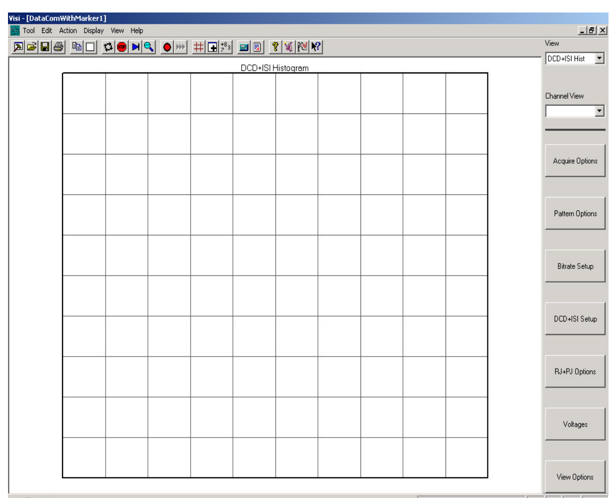


Figure 14 – Initial dataCOM Screen

Next, click on the acquire options button (Figure 15). Click on the 'Arm Number' button and this will bring up the Arm selection dialog box. Use the SIA-3000 keypad to enter the channel for the Pattern Marker signal. This will be the channel the PM50 card is attached to (typically, channel 1). Ensure the "Pattern Marker" box is checked. Next select the 'Add/Del Channel' button to select the data signal channel. Finally, set the 'Corner Freq (kHz)' to the FC spec level (637kHz for 1.0625Gbps).

For data with significant amounts of PJ, enable TailFit™ by selecting RJ+PJ Options, and in the TailFit pulldown select 3 (Figure 16). This number represents the number of histograms (from the collected UI histograms) to perform TailFit on.

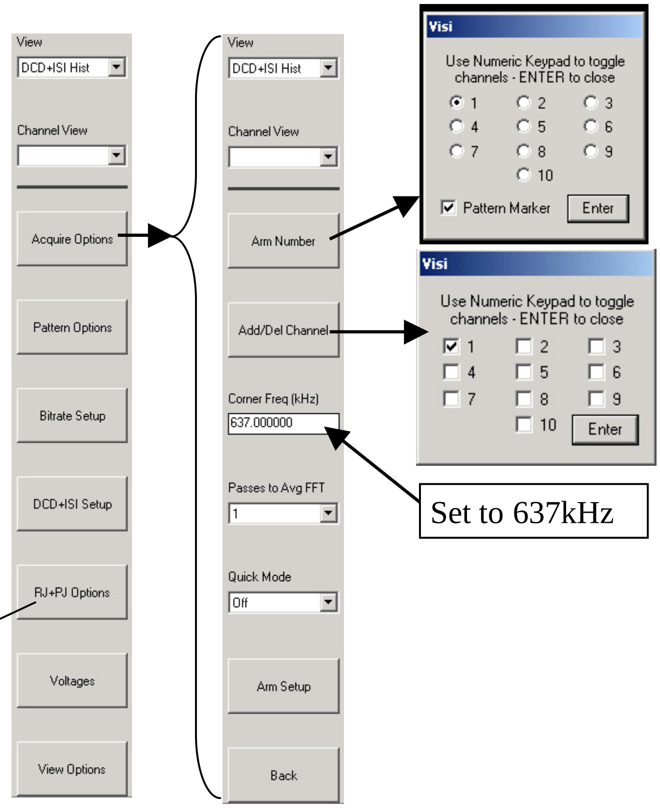


Figure 15 - Acquire Options Setup

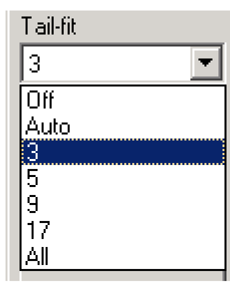


Figure 16 - RJ+PJ Option / Tail-fit

Enable the DCD+ISI High Pass Filter @ 637kHz (see Figure 17).

Figure 17 - DCD+ISI High Pass Filter Settings

Summary

With the SIA-3000™, you can make compliant timing and voltage measurements. This application note reviewed a variety of signal integrity measurements performed on typical FC systems and components. The applications tested were: FC HBA, JBOD and GBIC. Measurements were performed at the board level using a differential probe. All measurements were taken using the SIA-3000 with PM50 card and dataCOM software. The measurement equipment and techniques can be easily expanded to other systems and components for Gigabit Ethernet, Infiniband™ and XAUI.

References

[1]Tektronix P6330 3GHz differential probe.

[2]Jan Wilstrup, "A Method of Serial Data Jitter Analysis Using One-Shot Time Interval Measurements, ***WAVECREST*** website.

[3]Fibre Channel Physical Interfaces (FC-PI) Rev 13, American National Standard for Information Technology

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