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Title : Gen3i TX Jitter Compliance Requirements

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Document History

Version	Date	Comments
0.8	November 4, 2009	Initial review distribution.
0.9	November 10, 2009	Added jitter component limiting analysis to background section.
0.91	November 17, 2009	Added notes to clarify basis of 2Qber numbers and the RJ-DJ trade off.
1.0	Novenber 17, 2009	Revision update only after passing vote. No change from version 0.91.

1 Introduction

1.1 Problem Statement

The present Gen3i TX jitter compliance measurements include a RJ measurement which is subject to errors or differences in reported values induced by the various Jitter Separation methods used in the industry. The TX TJ(1e-12) limit is also based on this measured RJ, where the effect of the differences in reported RJ value is multiplied by 14 times. With the tighter budgets present at 6 Gb/s and above, these measurement errors or differences become a significant percentage of the compliance budget. These reported RJ level variations are aggravated by the presence of SSC and other TX jitter components, and the reported levels depend on the measurement algorithms used. Additionally there is no defined RJ measurement standard to resolve differences in reported levels observed between measurement equipment and lab sites.

1.2 Solution Summary

The proposed solution, is to base all TX Jitter Compliance Requirements on TJ(BER). A defined TJ(BER) measurement standard exists in the present specification which allows for the verification of reported values, improving correlation throughout the industry. (The full population BERT scan.) A measurement standard is essential for improving measurement correlation that leads to improved interoperability.

The TJ(1e-12) compliance limit is maintained at the present specification level, and a TJ(1e-6) compliance level is added that replaces the present RJ compliance limit. The TJ(1e-6) compliance level is calculated based on the present TJ(1e-12) and RJ compliance levels, and represents two points on a TJ(BER) compliance mask. The TJ(1e-6) compliance limit provides a DJ limiting characteristic, that is presently provided by defining the TJ(1e-12) limit based on the measured RJ with an addition for the DJ component that was defined in the specification tables. In the proposed method, all compliance limits are fixed in value and do not depend on other measurements that can be affected by Jitter Separation method variations.

1.3 Background

1.3.1 Introduction

As serial interface data rates have increased and timing compliance budget limits have decreased, the jitter measurement capabilities of test equipment need to be considered in more detail. Compliance measurement requirements in standards should be specified with these capabilities considered. For jitter measurements at a data rate of 6 Gb/s, variation of reported values due to jitter separation characteristics, and the jitter "noise floor" of the test equipment has become a significant percentage of the reported jitter level. The measurement of RJ (Random Jitter) is one critical measurement that exemplifies this situation.

When the Gen3i TX Jitter compliance requirements were developed for the present Serial ATA Revision 3.0 specification by the 6G PHY Working Group, the change to measuring RJ under special conditions, rather than measuring DJ as the previous Gen1i and Gen2i electrical specifications had specified, was done to reduce measurement errors due to jitter separation errors observed in the industry when measuring DJ.

For SATA 6Gb/s (Gen3i), the SATA-IO 6G PHY Working Group recognized that the measurement of RJ, with the tighter timing compliance requirements, must be done in a manner to minimize the error of this measurement. It had been observed that the reported RJ levels of JMDs (Jitter Measurement Devices) varied with the presence of other jitter components such as

ISI and other jitter components. The proposed solution for this was to measure RJ at the transmitter directly, with a clock like pattern, which would minimize ISI and therefore reduce the errors in the measurement of RJ. [Ref. 1]

Although this method addressed part of the issue, there are still remaining issues that make the reported RJ level a highly variable measurement. Jitter separation methods vary widely between JMDs. When the test signal contains SSC modulation or noncorrelated bounded jitter, some of this is included in the reported RJ, and its level depends on the jitter separation algorithm. The RJ "noise floor" of the JMDs is variable, and without a RJ measurement standard, it is difficult and error prone to compensate for this level added in the reported RJ level.

1.3.2 The New Gen3i TX Jitter Requirement Foundation

The present Serial ATA Revision 3.0 specification provides two concepts as being normative requirements, which form a foundation for this method. First, the TJ standard that all JMDs are compared against, is a full population BERT scan. Although no standard exists for DJ and RJ, the measurement of the final composite jitter TJ, has a defined measurement standard. Second, for SATA, the TJ is defined by the following equation: TJ = (14xRJ) + DJ. Although the SATA specification uses DJ_{pp} (peak to peak) in the specification tables for compliance, this equation is only valid in the general signal case, for the dual Dirac model of jitter [$TJ(BER) = (2Q_{BER} * \sigma) + DJ_{\delta\delta}$], where $2Q_{BER} = 14$ (for a BER = 1e-12), σ is the RJ 1 sigma value, and $DJ_{\delta\delta}$ is a dual Dirac model dependant quantity for deterministic jitter. [Ref. 2] If the measurement of DJ is not required for determining compliance, as with this new method, then the dual Dirac model for jitter is valid.

The proposed method uses only the measurement of TJ (that has a specified measurement standard) and compares the measurement to points on a compliance mask that is based on the dual Dirac model. Both of these fundamental concepts have a basis in the present SATA-IO standard.

1.3.3 Jitter and Bit Errors

The reason for specifying and controlling jitter, is to assure that sufficient timing margins exist such that a receiver can sufficiently recover data at an error rate that is acceptable for the system in which it is used. The essential requirement is the relative timing between the recovered clock and the data edge. The reference clock has been defined in the SATA standard using a model with a defined JTF. (Jitter Transfer Function) [Ref. 3] This JTF is also the standard for calibrating the JMD recovered or reference clock, such that its characteristics approach the defined model. The measurement of the TJ with the full population BERT scan (the TJ standard) measures the relative timing of the signal under test to the recovered clock. The TJ contains bounded DJ components and unbounded RJ components. (Note that this document uses the practical industry concepts of bounded and unbounded jitter. From a pure mathematical concept all jitter in a serial link is truncated at some time amplitude.) The inclusion of unbounded RJ in the TJ, results in requiring a TJ measurement that is a reported as a function of BER (Bit Error Rate) level. The relative contribution of the RJ and DJ components does not change the effects of the reported TJ at a specific BER level in the BERT scan or the BER in the actual receiver. What matters is the instantaneous relative timing between the recovered clock and the data edge at the data decision time or sampling time of the data recovery circuit.

Separation of jitter component types is useful in generating system budgets, since the bounded and unbounded components combine in different algebraic manners. [Ref. 2] If the TJ of the independent elements of the system are linearly summed to get the total system TJ, then the individual elements of the system are overly restricted due to this conservative approach. This is due to fact that the independent random jitter components combine as the root of the sum of the squares rather than the linear addition. [Ref. 4] By separating the bounded and unbounded components, the system jitter budget is more realistic.

In the case of the SATA Gen3i specification, the TX (transmitter) performance is specified through a CIC (Compliance Interconnect Channel), and the RX (receiver) tolerance is tested through the same CIC. Since no Gen3 SATA cable specification exists (not desirable, but this is the situation for SATA Gen3i) a system budget does not exist in conventional terms. Essentially the CIC defines the “worse case” cable or channel. Any cable or channel used that has more loss, or generates more ISI compared to the CIC is not guaranteed to provide the required system BER with the compliant transmitter and receiver.

Since the same CIC is used for both the TX testing and RX tolerance tests, verifying that the TX TJ is less than the compliance limit, and that the RX TJ tolerance is greater than the compliance limit ensures the BER requirements. (the presently defined values in the Gen3i specification provide margin between these two TJ levels) There is no basic need to separate the jitter components from a theoretical standpoint. Measurement of TJ at the target BER rate is all that is necessary.

When considering the general robustness of a data communication channel under varying conditions compared to the compliance test conditions, it may be desirable to limit the TX DJ contribution to the TJ. This is due to the characteristic of DJ being bounded and therefore its peak to peak level is “always” present, and yet with RJ being unbounded, its peak to peak level grows with time and does not always produce the maximum peak to peak level at all times. (“always” assumes that the analysis period is long enough compared to the repetition period of the composite DJ to capture the timing extremes.) In marginal data link conditions, and considering the error recovery mechanisms in the system, higher levels of DJ may be considered more detrimental to system operation compared to the RJ component.

In the present Gen3i electrical specification, the DJ is limited by specifying that the maximum TX TJ is the measured RJ (converted to a peak to peak value) plus a specified peak to peak value that represents DJ. The new method also provides some additional limiting for the DJ component of the TJ by specifying a tighter TJ(1e-6) requirement, than the TJ(1e-12) requirement, in a region of the TJ(BER) curve where the DJ contribution is more dominant. This method does not have the effects of the measurement errors or variation introduced due to jitter separation methods. Some trade-off between RJ and DJ is allowed, compared to the previous method of specifying RJ Max. (If the DJ is lower, more RJ is permissible, but the TJ(1e-12) requirement still limits both.)

1.3.4 The Bathtub Curve

Since the proposed method is based or visualized best by the use of the “Bathtub” curve, a brief discussion of this graphical representation of TJ(BER) is provided.

The BERT scan measures the TJ at a BER level. The desired confidence level is controlled by the instrument settings. Besides the tabular data output, a graphical plot of BER(x) is generated where “x” is the time position of the data decision point compared to the ideal sampling point. (center of the EYE) This set of curves can be viewed as the CDF (Cumulative Distribution Function) of errors. The CDF is the integral of PDF (Probability Density Function) of the errors. [Ref. 4] An error occurs if instantaneous relative timing of the data transition threshold crossing to the data decision time is insufficient or less. (coincident or on the wrong side of the data decision time)

The combined left and right BER(x) curves can be viewed as the EYE closure due to TJ as a function of BER level. Since the TJ includes the unbounded RJ component, the EYE closure increases for increased measurement time or number of bits checked. The resulting TJ(BER) plot may be inspected at any BER level to determine the TJ p-p level at that BER, since TJ(BER) is the total UI time minus the sum of the EYE closure plotted by the left and right BER(x) curves.

At the lower BER values the additional EYE closure with decreasing BER is dominated the unbounded RJ component. For this to be true, the DJ components present must be of sufficient frequency, at the timing extremes, to be detected during an individual measurement time at the higher BER levels.

The actual TJ(BER) with a BERT scan is a measurement, not an estimation, as long as sufficient number of bits are analyzed compared to the number of errors, such that the target confidence level is achieved at the target BER level.

1.3.5 The Compliance Mask

The proposed method of jitter compliance testing uses only the measured TJ(BER) from a full population BERT scan. Other types of JMDs may be used for generating this data, but the full population BERT scan is the TJ standard, in the case of measurement discrepancies.

In the proposed method, the measured TJ(BER), as represented by the left and right BER(x) curves, and are compared to a TJ(BER) compliance mask that is generated by the dual Dirac model of jitter. In this manner no jitter component separation is used, and the errors involved with that process are eliminated.

The dual Dirac model assumes that the RJ component is Gaussian, and the DJ follows has a bounded distribution. The equation for the dual Dirac model is as follows [Ref. 5]:

$$TJ(BER) \cong (2Q_{BER} \times \sigma) + DJ_{\delta\delta} \qquad (1)$$

The Q at a BER level is calculated using an equation containing the inverse ERF (error function) where the inverse ERF does not have a closed form solution. Although it has been suggested that good approximations exist, calculating BER as a function of Q does have a closed form solution, and is used in the proposal in an inverse search method. The σ is the rms value of the RJ and $DJ_{\delta\delta}$ is the model dependant dual Dirac DJ that should not be considered the same as DJ_{pp} (peak to peak). [Ref. 5] This use of $DJ_{\delta\delta}$ in this proposal does not affect the results, since the compliance mask is based on the RJ σ and the TJ(BER) only, which are present SATA Gen3i compliance parameters for jitter.

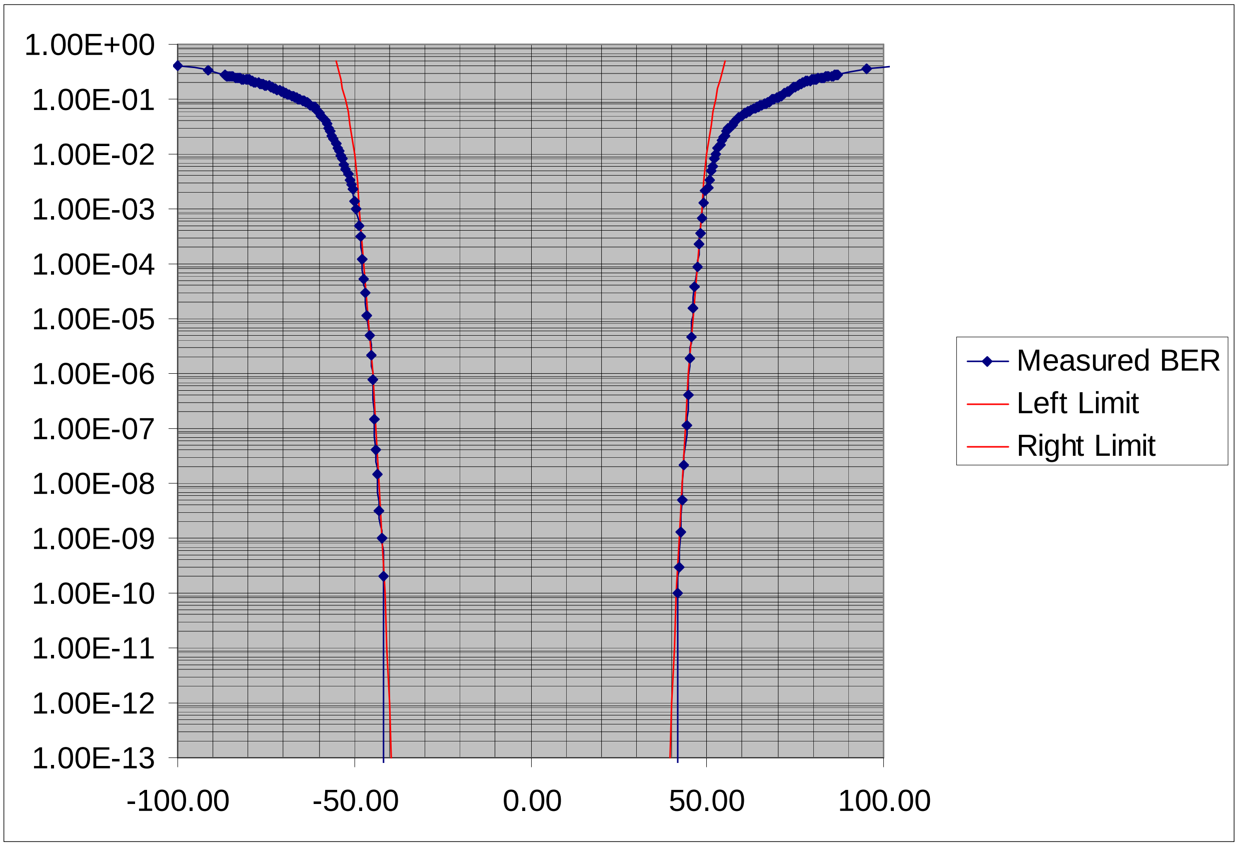
The mask is a plot of the TJ(BER) for the values of σ and $DJ_{\delta\delta}$ specified. The $DJ_{\delta\delta}$ is calculated from the specified TJ(1e-12), the specified σ, and the appropriate Q_{BER} for 1e-12. The convention for this compliance mask on the horizontal axis, is that it is symmetric around the ideal sampling point that has the coordinates of time and is defined as zero. Since σ and $DJ_{\delta\delta}$ are now known, the TJ(BER) may be determined as a function of BER by the use of equation 1, by incrementing Q_{BER}. The resulting bathtub curve mask is simply generated by using ½ the TJ(BER) to reduce the EYE width from each of the UI boundaries.

The Q_{BER} values, for a BER level, are calculated using the following equation [Ref. 5']:

$$BER_L(Q) = \rho_\tau \times erfc\left(\frac{Q}{\sqrt{2}}\right) \qquad (2)$$

The ρ_τ is the transition density. The value of 0.5 is used here as it is also was used to generate the SATA BER confidence level tables of the present SATA-IO specification. This assumption is used for 8b10b encoded data. The “erfc” is the complementary error function and is essentially the CDF of a normalized Gaussian PDF, at the specified location. For the plot below, the values for Q have been determined for chosen levels of BER (all factors of 10 down to a BER of at least 1e-12) by using equation 2 in a successive approximation method.

As an example, a measurement of a test signal with maximum RJ and TJ as presently specified in the Serial ATA Revision 3.0 Gen3i electrical specification is shown below, with a full compliance mask developed as described above to allow for the visualization of this new method. The plot shows a comparison of the measured data exported from the BERT to the compliance mask. If the measured TJ(BER) shown in blue, lies outside the boundaries of the mask shown in red, then the TX TJ is considered compliant. (the measured EYE is more open than required)



Maximum Jitter Example

The comparison plot shows a good agreement of the measured data to the ideal compliance mask, generated from the dual Dirac model equation.

The proposed method does not require the generation of the full compliance mask as shown in Red above. (a visualization example only) Additionally, the proposed method does not require a comparison of the measured TJ(BER) to the mask at all levels. This would also require specifying the resolution and method of the comparisons. This would require additional changes to JMDs to incorporate a compliant comparison mechanism, rather than just having the capability to report TJ(1e-6). The full mask adds nothing to the benefits of the simplified method of simply specifying the TJ at BER levels of 1e-6 and 1e-12.

The proposed method, maintains the present Gen3i TJ(1e-12) maximum TX Jitter requirement, and adds a second tighter maximum TX Jitter requirement at TJ(1e-6). The TJ(1e-6) requirement is calculated from the present maximum TJ(1e-12) requirement of 0.52 UI pp and the present specification for maximum RJ pp value of 0.18 UI at a BER of 1e-12. If the nominal data rate UI time span is used for conversion to ps, this equates to a TJ(1e-12) of 86.667ps and a RJ 1 sigma value of 2.143ps.

Using the TJ(BER) equation based on the dual Dirac jitter model (Equation 1 above) the maximum TJ(1e-6) limit can be calculated. The 2Qber values used in all calculations are based on a classical single Gaussian distribution with a transition density of 0.5. These are equivalent to the 2Qber values for a dual Dirac distribution for a pattern with a transition density of 1.0:

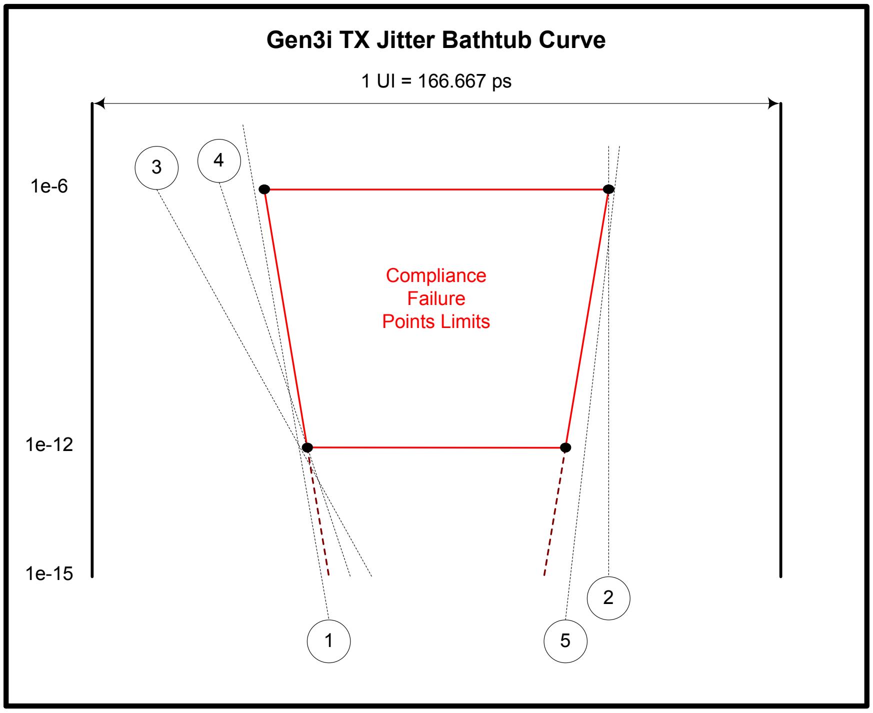
First, at TJ(1e-12): $DJ_{\delta\delta}$ = TJ(1e-12) – ($2Q_{BER}$(1e-12) * σ), where σ is the 1 sigma value of RJ.
If:
$2Q_{BER}$(1e-12) = 14.069,
σ = 2.143 ps,
and TJ(1e-12) = 86.667ps pp,
Then $DJ_{\delta\delta}$ = 56.517 ps pp

Second, at TJ(1e-6): TJ(1e-6) = ($2Q_{BER}$(1E-6) * σ) + $DJ_{\delta\delta}$
If:
$2Q_{BER}$(1e-6) = 9.507,
σ = 2.143 ps,
and $DJ_{\delta\delta}$ = 56.517 ps pp (from the first calculation),

Then TJ(1e-6) = 76.891 ps pp
Therefore, the new maximum TJ(1E-6) limit is 76.9 ps. (0.46 UI)

1.3.6 Jitter Component Limiting Analysis

This proposed method of limiting the TX jitter for the Gen3i electrical standard has the benefit of not requiring the jitter to be separated into its subcomponents DJ and RJ. Jitter separation introduces additional measurement errors and degrades correlation of measured results between different labs and test equipment. This method also has some capability of limiting the individual components, which is more than would be present if only TJ(1e-12) was used for the compliance limit. This section explains the jitter component limiting function of this method in a graphical manner and calculates the allowable jitter mixture for several jitter mixture cases.



The figure above can be viewed as the lower BER section of a bathtub curve. (No scale intended, chosen slopes provide visibility.) The TX jitter compliance limit points at TJ(1e-12) and TJ(1e-6) are shown on the corners of the trapezoid. In this type of graphical representation, a compliant PHY TX would exhibit a bathtub curve that remains outside the TX jitter compliance limit points. Although the compliance points are shown here connected by lines for clarity, only the TJ(1e-12) and TJ(1e-6) measurements dictate compliance. (Not a mask between these levels). Individual jitter mixture cases are shown only on one side, although they are near symmetric, on both sides of the plot in practice. This form is presented only to provide better understanding of the calculations and results that follow.

The following equations and constants were used for this analysis. (For reference)

TJ(ber) = (2Qber*RJ) + DJdd
2Qber = 14.069 at a ber of 1e-12
2Qber = 9.507 at a ber of 1e-6
2Qber = 15.883 at a ber of 1e-15 (info. only, not used for a requirement)
TJ(1e-12) present limit = 86.667 ps pp
TJ(1e-6) new limit = 76.891 ps pp
RJ(1 sig) present limit = 2.143ps

The following jitter mixture cases are numbered and can be visualized by viewing the like-numbered line provided on the figure above. Each case also explains which compliance criteria, TJ(1e-12) or TJ(1e-6) limits the maximum jitter. Note DJdd (not DJpp) is provided by the dual Dirac equation.

Case (1) Present Rev 3.0 spec. Limits: TJ(1e-12) = 86.7 ps, RJ = 2.14 ps, calc. DJdd = 56.5 ps
Max TJ is limited by both criteria. (Line shifted to view the compliance points clearly)

Case (2) Theoretical All DJ: TJ(1e-6) = 76.9 ps, RJ = 0.00 ps, DJdd = 76.9 ps
Max TJ limited to 76.9 ps. by TJ(1e-6). (Present DJpp limit in Rev 3.0 spec is 0.34 UI or 56.7ps for this case)

Case (3) Theoretical All RJ: TJ(1e-12) = 86.7 ps, RJ = 6.16ps, DJdd = 0.0 ps
Max TJ limited to 86.7 ps by TJ(1e-12) point.

Case (4) Practical Max RJ: TJ(1e-12) = 86.7 ps, RJ = 4.74 ps, DJdd = 20.0 ps (example)
Max TJ limited to 86.7 ps by TJ(1e-12) point.

Case (5) Practical Max DJ: TJ(1e-6) = 76.9 ps, RJ = 1.0 ps (example), DJdd = 67.4 ps
Max TJ limited to 76.9 ps by TJ(1e-6) point.

Case 1 represents the present maximum T(1e-12) and RJ limits in the SATA Rev. 3.0 specification. The calculated DJdd is provided for this case for reference only.

Cases 2 and 3 provide the analysis for theoretical cases that contain either all DJ (no RJ) or all RJ (no DJ). Although these cases do not exist in practicality, they are included as extreme mixture examples to show the jitter limiting characteristics of this method.

Cases 4 and 5 provide examples of cases where the TX jitter is dominated by RJ or DJ respectively. Example values of residual DJdd (20 ps) and RJ (1.0 ps 1 sig) are provided to allow for the calculation.

By comparing the cases, one can view the differences in jitter mixture containment of the present Rev. 3.0 spec. versus the new method.

For DJ containment, cases 1 and 5 can be compared, considering a practical environment. The DJdd level can increase by 19% if the TX jitter contains 1.0 ps 1 sigma of RJ.

As for RJ containment, a look at the EYE closure at a BER of 1e-15 is provided as an analysis tool. THIS IS NOT A REQUIREMENT, ONLY AN ANALYSIS TOOL. Case 1 and case 4 will be compared. For case 1, the present Rev. 3.0 specification, the TJ(1e-15) could be 90.6 ps, using the fact that for each 1 sigma of RJ level the TJ(BER) increases by the difference in 1e-12 and 1e-15 2Qber levels between 1e-12 and 1e-15. For the proposed compliance method, using the practical maximum RJ case 4, the TJ(1e-15) would be 95.3 ps, a 4.7ps TJ increase or 0.028 UI additional EYE closure.

To transmit 1e15 bits at 6 Gb/s requires 46.3 hours. This compares to the 2.8 min to transmit 1e12 bits. (related to the actual SATA Gen3i specification) This suggests that new method would allow a 0.028 UI more EYE closure some time during a 46.3 hour period, compared to the present method. Note that this is just a transmission time example. TJ(BER) measurement confidence levels are not part of this example.

So with the proposed method allowable DJ could increase by 19% if the RJ component was low, and the allowable RJ increase, if the DJ component was low, has a little effect, even in the long term transmission of data.

1.3.7 Summary

The proposed method replaces the TX maximum RJ jitter requirement with a maximum TX TJ(1e-6) requirement and maintains the present TJ(1e-12) TX maximum jitter requirement. The new maximum TJ(1e-6) TX jitter requirement is based on the present maximum TX TJ(1e-12) and RJ jitter requirements.

These two TJ(BER) maximum TX jitter requirements represent two points on a TJ(BER) compliance mask generated from the present Gen3i maximum TX jitter specifications. The added point at a BER of 1e-6, that has tighter requirements than at a BER of 1e-12, has the effect to limit the DJ level by measuring at a BER level at which the DJ is more dominant.

No jitter separation process, with the possible variations present, is used during the measurement of all TX maximum jitter requirements. The full population BERT scan is the measurement standard for all TX maximum jitter requirements, both TJ(1e-12) and TJ(1e-6).

For reference, a full population BERT scan is one that has measured a sufficient population to achieve a 95% confidence level of the resulting value.

1.3.8 References for the “Background” Section

Ref. 1: John Hill, “Gen3i Jitter Measurement Concepts (Rev. D)”, 5/19/2008. Available to SATA-IO 6G members only: http://lists.sata-io.org/mailman/private/6g/attachments/20080519/f6af5054/SATA-IO6GPHYWGJitterMeasConcepts-RevD.pdf

Ref. 2: Ransom Stephens, “What the Dual-Dirac Model is and What it is Not”, October, 2006. This is available from www.tek.com/jitter .

Ref. 3: John P. Hill, “Improving a Jitter Definition”, April 25, 2007. Document # 07-205r0 available from www.t10.org

Ref. 4: Mike Peng Li, *Jitter, Noise, and Signal Integrity at High-Speed*, Prentice Hall, 2007

Ref. 5: Ransom Stephens, “Jitter Analysis: The dual-Dirac Model, RJ/DJ, and the Q-Scale”, 2005. 5989-3206EN.pdf is available from www.agilent.com .

2 Technical Specification Changes

2.1 [7.2 Electrical Specifications – Table 31]

[**Editor’s Note:** The changes marked in red (and underlined/strikethrough) will be incorporated in section 7.2 Electrical Specifications in Table 31]

Parameter	Units	Limit	Electrical Specification							Detail Cross-Ref Section	Measurement Cross-Ref Section
			Gen1i	Gen1m	Gen1x	Gen2i	Gen2m	Gen2x	Gen3i		
TJ(1e-12) before and after CIC, Clk-Data JTF Defined	UI	Max		-			-		~~RJ p-p meas. + 0.34~~ 0.52	7.2.2.2.18 7.3	7.4.8 7.4.10
~~RJ before CIC, MFTP Clk-Data JTF Defined~~	~~UI~~	~~Max~~		~~-~~			~~-~~		~~0.18 p-p (2.14 ps 1 sigma)~~		
TJ(1e-6) before and after CIC, Clk-Data JTF Defined	UI	Max		-			-		0.46		

2.2 [7.4.10 Transmit Jitter (Gen3i)]

[**Editor's Note:** The changes marked in red (and underlined/strikethrough) will be incorporated in section 7.4.10 Transmit Jitter (Gen3i). Since most of the text is changing, the present section is shown in red strikethrough, and the new entire section that replaces it is in red.]

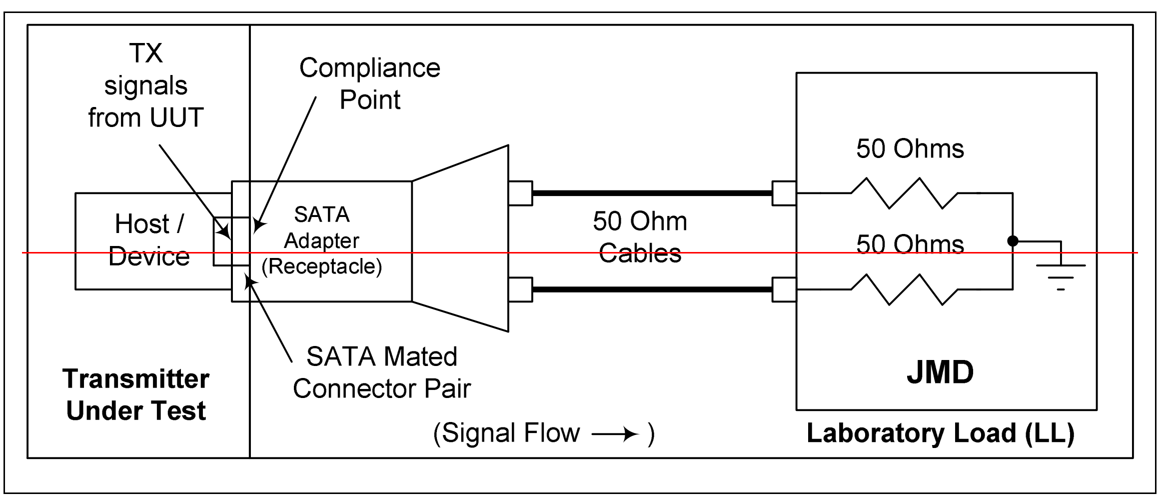
[Editor's Note: Present Section:]

7.4.10 Transmit Jitter (Gen3i)

~~The Transmit Jitter values specified in Table 31 refer to the output signal from the unit under test (UUT) at the mated connector into a Laboratory Load (LL) when measuring Random Jitter (RJ) or from the unit under test through a Compliance Interconnect Channel (CIC) into a Laboratory Load when measuring Total Jitter (TJ). The signals are not specified when attached to a system cable or backplane. All the interconnect characteristics of the transmitter, package, printed circuit board traces, and mated connector pair are included in the measured transmitter jitter. Since the SATA adapter is also included as part of the measurement, good matching and low loss in the adapter are desirable to minimize its contributions to the measured transmitter jitter.~~

~~The Random Jitter is measured with a MFTP pattern and the Total Jitter is measured with each of the specified patterns in section 7.2.4.1 and section 7.2.4.3.4. The measurement of jitter is described in section 7.4.8.~~

~~First, the Random Jitter of a Gen3 MFTP pattern is measured directly into the Laboratory Load as is shown in Figure 156. The measured value shall meet the Transmit Jitter level for Random Jitter (RJ) for Gen3i in Table 31. The actual measured value of Random Jitter during this test is referred to as the Measured Random Jitter (RJ_{meas}) and is used to calculate the allowable TJ level for the second Transmitter Jitter Test, so this value needs to be recorded.~~



~~**Figure 156 – Transmitter Random Jitter Test (Gen3i)**~~

The second Transmit Jitter test measures the Total Jitter (TJ) through the Gen3i Compliance Interconnect Channel (see Section 7.2.7) into the Laboratory Load as is shown in Figure 157.

The allowable Total Jitter (TJ) level is calculated based on the equation in Section 7.4.8 that defines Total Jitter as the sum of Deterministic Jitter (DJ) plus 14 times the standard deviation of the Random Jitter (RJ). The maximum DJ level to be added to the RJ_{meas} value obtained in the first Transmit Jitter test is listed in Table 31. The sum of the RJmeas and the allowable DJ defines the maximum TJ level that the Transmit Jitter shall have.

The measured RJ from a JMD is typically reported as a standard deviation value (one sigma). The RJ must be multiplied by 14 to convert it to a peak-to-peak value before adding it to the allowable DJ level, which is a peak-to-peak value.

To clarify the maximum allowable TJ calculation for the second test, the following example is provided. The values in Table 31 provide the Gen3i TX Jitter compliance requirements. The following values are only an example. If the maximum allowable RJ is 0.18 UI p-p and the actual measured RJ (RJmeas) from the first Transmit Jitter test is 0.10 UI p-p (1.19 ps 1 sigma) and the allowable DJ addition is 0.34 UI p-p, then the maximum allowable TJ for the second Transmit Jitter test is: TJ (UI p-p) = DJ (UIp-p) + RJ_{meas} (UI p-p) = 0.34 (UI p-p) + 0.10 (UI p-p) = 0.44 (UI p-p). This is the maximum allowed TJ for the transmitter under test. It can be seen that if the RJmeas from the first test is at the maximum limit of 0.18 (UI p-p) and the allowable DJ addition is 0.34 (UI p-p), then the maximum allowable TJ is 0.52 (UI p-p).

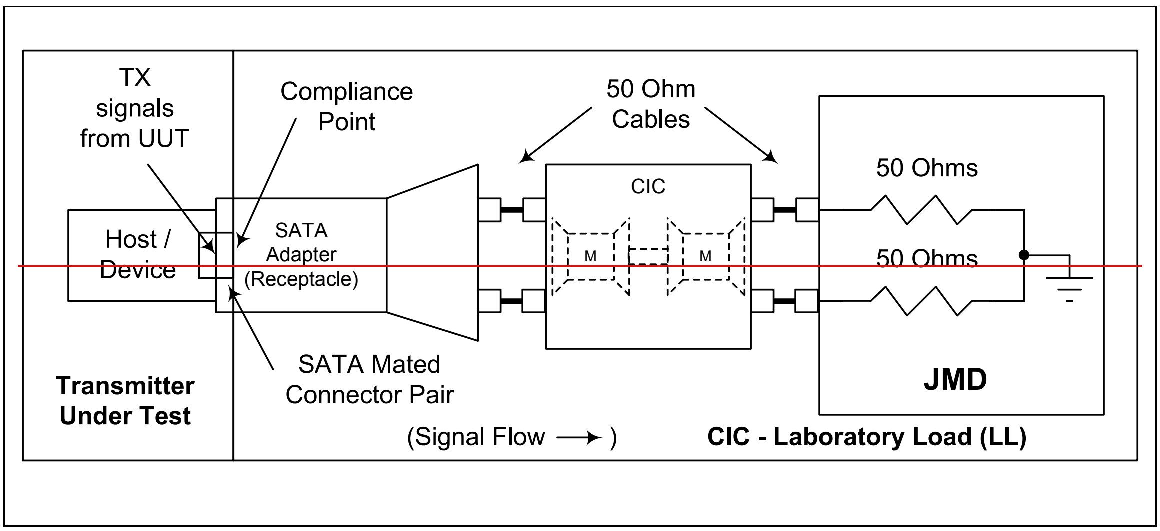


Figure 157 – Transmitter Total Jitter Test (Gen3i)

The Transmit Jitter shall meet both requirements as listed in Table 31 using the methods of the first test for RJ and the second test for TJ defined in this section. The methods used for Gen3i Transmit Jitter testing are intended to minimize RJ measurement error and allow for the TJ to be verified by a full population BERT scan as described in Section 7.4.8. This method also puts an upper limit on both DJ and RJ so neither may dominate the TJ.

Transmitter jitter is measured into the Laboratory Load (LL), or in conjunction with the Compliance Interconnect Channel; both have very good impedance matching. The jitter in an actual system is higher since load and interconnects mismatch results in reflections and additional data dependent jitter. It is generally not possible to remove the effects of the SATA adapter on jitter since jitter due to mismatch depends on the entire test setup.

[Editor's Note: New Replacement Section:]

7.4.10 Transmit Jitter (Gen3i)

The Transmit Jitter values TJ(1e-12) and TJ(1e-6) specified in Table 31 refer to the output signal from the unit under test (UUT) at the mated connector into a Laboratory Load (LL), and from the unit under test through a Compliance Interconnect Channel (CIC) into a Laboratory Load. The signals are not specified when attached to a system cable or backplane. All the interconnect characteristics of the transmitter, package, printed circuit board traces, and mated connector pair are included in the measured transmitter jitter. Since the SATA adapter is also included as part of the measurement, good matching and low loss in the adapter are desirable to minimize its contributions to the measured transmitter jitter.

The Total Jitter parameters are measured with each of the specified patterns in section 7.2.4.1 and section 7.2.4.3.4. The measurement of jitter is described in section 7.4.8.

One of the measurements of the Transmit Total Jitter parameters on the TX signal shall be measured directly into the Laboratory Load as is shown in Figure 156.

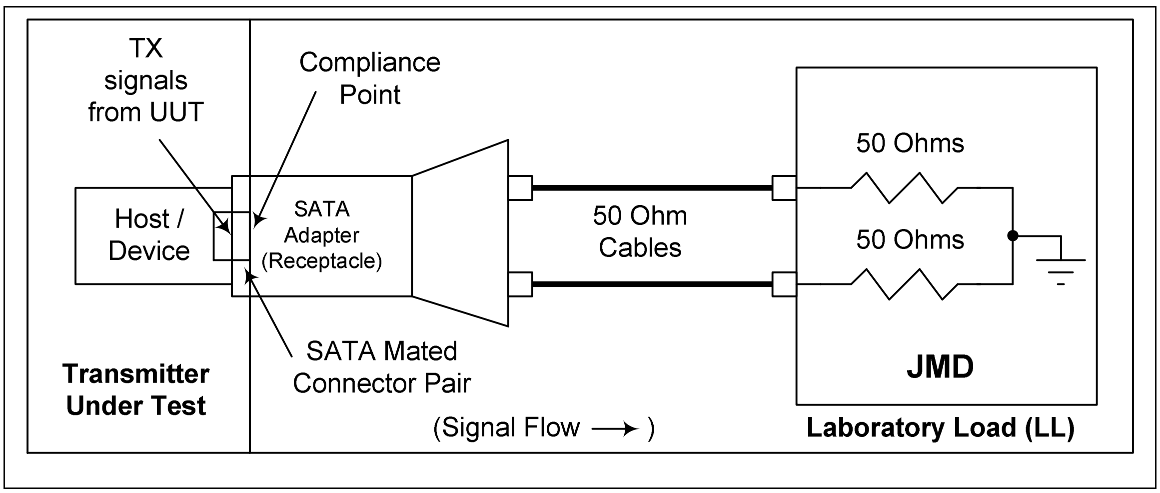


Figure 156 – Transmitter Jitter Test at TX (Gen3i)

The second measurement of the Transmit Total Jitter parameters measures the jitter on the TX signal after passing through the Gen3i Compliance Interconnect Channel (see Section 7.2.7) into the Laboratory Load as is shown in Figure 157.

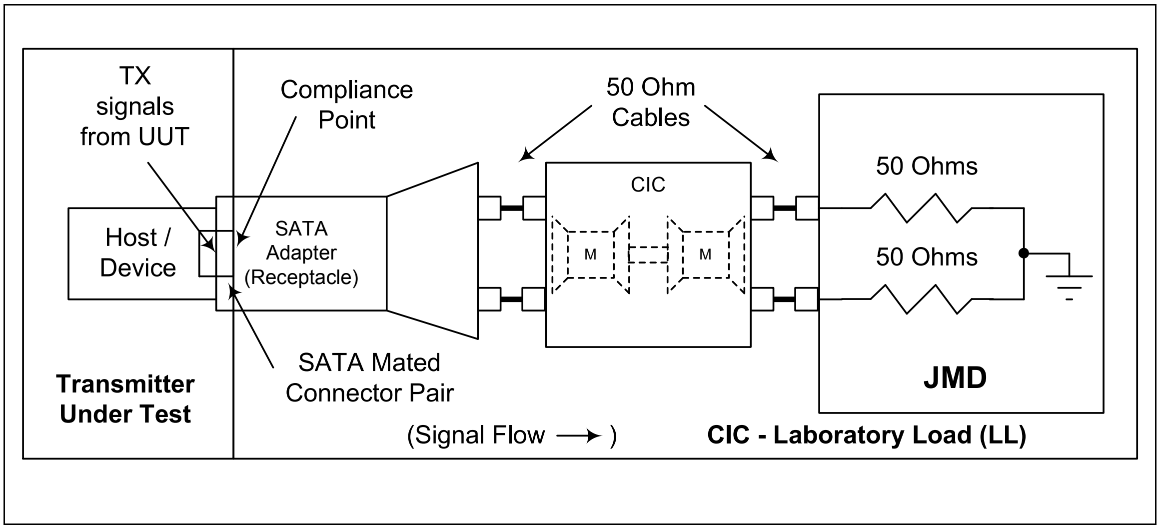


Figure 157 – Transmitter Jitter Test Through the CIC (Gen3i)

The Transmit Jitter shall meet both The TJ(1e-12) and TJ(1e-6) requirements as listed in Table 31 both directly at the TX and after the Gen3i CIC.

The TJ(1e-6) requirement is calculated from the TJ(1e-12) requirement of 0.52 UI pp and the specification for the maximum RJ pp value of 0.18 UI at a BER of 1e-12. If the nominal data rate UI time span is used for conversion to ps, this equates to a TJ(1e-12) of 86.667ps and a RJ 1 sigma value of 2.143ps.

This calculation is performed using the dual Dirac equation TJ(BER) = ($2Q_{BER}$ * σ) + $DJ_{\delta\delta}$, where σ is the 1 sigma value of RJ, and $2Q_{BER}$ is based on a single Gaussian RJ distribution with a transition density of 0.5. This is equivalent to a dual Diac distribution with a transition density of 1.0.

At a BER level of 1e-12, $DJ_{\delta\delta}$ = TJ(1e-12) - (14.069 * σ) = 86.667 ps – (14.069 * 2.143ps) = 56.517 ps.

At a BER level of 1e-6, TJ(1e-6) = (9.507 * σ) + $DJ_{\delta\delta}$ = (9.507 * 2.143ps) + 56.517 ps = 76.891 ps pp or 0.46 UI.

The tighter requirement at TJ(1e-6) is added to constrain the DJ component of TJ, without requiring actual jitter separation which can contain variable results depending on the method used. A tradeoff between RJ versus DJ is possible with this criteria, but the DJ component is limited more than measuring TJ(1e-12) alone. If the RJ 1 sigma value is 1.0ps, then the allowable $DJ_{\delta\delta}$ could be 19% larger than the 56.5ps derived in the calculation above. If the $DJ_{\delta\delta}$ was 20.0 ps, then the RJ 1 sigma value could be 4.74 ps. These calculations are based on the equations above as an example of the trade off between RJ and DJ allowed by these maximum jitter criteria. The $DJ_{\delta\delta}$ used in these equations should not be confused with DJ_{pp} which is not equivalent in the general case.

The full population BERT scan is the jitter measurement reference standard for both the TJ(1e-6) and TJ(1e-12) measurements for all JMD TJ estimation methods. A full population BERT scan is one that has analyzed a sufficient population of bits versus errors to achieve a 95% confidence level.

Transmitter jitter that is measured into the Laboratory Load (LL), or in conjunction with the Compliance Interconnect Channel. Both have very good impedance matching. The jitter in an actual system is higher since load and interconnects impedance mismatch results in reflections and additional data dependent jitter. It is generally not possible to remove the effects of the SATA adapter on jitter since jitter due to mismatch depends on the entire test setup.

2.3 [Section 4.1.104]

[**Editor's Note:** The changes marked in red (and underlined/strikethrough) will be incorporated in section 4.1.104]

4.1.104 TJ (total jitter)

Unless further specified by including the BER level, TJ has a ~~P~~peak to peak value of (14 * RJ_{σ}) + DJ. For Gen3i TX jitter, TJ(1e-12) and TJ(1e-6) are specified and measured directly. RJ and DJ are not directly specified.

2.4 [Section 7.3]

[**Editor's Note:** The changes marked in red (and underlined/strikethrough) will be incorporated in section 7.3]

Extrapolation of results from small sample size to large sample size involves assumptions. This specification defines two assumptions as normative. First, the random jitter has a Gaussian distribution. Second, the total jitter (at a BER of 1e-12) is the sum of the deterministic jitter plus 14 times the standard deviation of the random jitter. These allow the separation of deterministic from random jitter, and an estimate of the total jitter for an equivalent BER of 10^{-12} from a much smaller sample size.

2.5 [Section 7.4.8]

[**Editor's Note:** The changes marked in red (and underlined/strikethrough) will be incorporated in section 7.4.8]

Jitter is the difference in time between a data transition and the associated Reference Clock event, taken as the ideal point for a transition. The causes of jitter are categorized into random sources (RJ) and deterministic sources (DJ). Although the total jitter (TJ) is the convolution of the probability density functions for all the independent jitter sources, this specification defines the random jitter as Gaussian and the total jitter (at a BER of 1e-12) as the deterministic jitter plus 14 times the random jitter. The TJ specifications of Table 31 and Table 33 were chosen at a targeted BER of 10^{-12}. In Table 31, Gen3i TX jitter is specified by providing limits for TJ(1e-12) and TJ(1e-6). The BERT scan method described in section 7.4.8.1 is the only method that measures the actual TJ and is used as the reference for all TJ estimation methods. The method for estimating TJ is unique to each measurement instrument.

2.6 [Section 7.4.8.1]

[**Editor's Note:** The changes marked in red (and underlined/strikethrough) will be incorporated in section 7.4.8.1]

When measuring TJ and extracting the DJ and RJ components, it is common to encounter RJ measurements that are higher than actual random jitter. This is often encountered in systems where noise from the system causes jitter that is not correlated with the Serial ATA channel activity. For example, power supply noise from a system, which contaminates a transmitter's bit clock generator, may cause variations in the bit clock which impact jitter directly.

When making random jitter measurements, this non-correlated DJ is often included in the result which, when multiplied by 14 may lead to non-compliance to jitter specifications. This is inappropriate since non-correlated DJ is bounded, non-Gaussian and should not be multiplied by 14. Furthermore, non-correlated DJ is included in normal DJ measurements.

Extracting non-correlated DJ from RJ measurement lies beyond the scope of this document since it usually requires in-depth knowledge of the characteristics of the non-correlated DJ and an appropriate algorithm for its measurement/extraction. Consequently, it is the readers' responsibility to characterize and then extract non-correlated DJ from their RJ measurements

These jitter separation issues are not present for the Gen3i electrical specification for TX jitter, when TJ(1e-12) and TJ(1e-6) are measured directly with a full population BERT scan. A full population BERT scan is one that has analyzed a sufficient population of bits versus errors to achieve a 95% confidence level at the BER level being measured. Estimations of the TJ(BER) levels based on the separation of RJ and DJ components or measurements at lower population levels shall be validated by comparing the reported values to those of the full population BERT scan which is the TJ reference standard.