Date: November 10, 2004
To: T10 Technical Committee
From: Bill Ham (bill.ham@hp,com)
Subject: SAS 1.1 PHY jitter MJSQ modifications

The following proposed changes to SAS 1.1 address jitter specifications in an effort to more closely reflect MJSQ methodology and definitions. Comments in other paragraphs of the PHY section are also included to document areas of concern that may need to be addressed separately. The final revision of this proposal shall include only changes to sections concerning jitter. Comments not related to jitter may be addressed by separate proposals.

Rev 1: Comments in other paragraphs of the PHY section not concerning jitter have been removed and are being addressed by other T10 proposals. Rev 1 includes only changes to sections concerning jitter.

Table 25 defines the general interface characteristics.

Table 25 — General interface characteristics

Characteristic	Units	1,5 Gbps	3,0 Gbps
Physical link rate	MBps	150	300
Bit rate (nominal)	Mbaud	1 500	3 000
Unit interval (UI)(nominal)	ps	$666,\overline{6}$	$333,\overline{3}$
Physical link rate tolerance at XR [b]	ppm	+350 / -5 350	+350 / -5 350
Physical link rate tolerance at IR and CR	ppm	± 100	± 100
Physical link rate tolerance at IT, CT, and XT	ppm	± 100	± 100
Media Impedance (nominal) [a]	ohm	100	100
A.C. coupling capacitor, maximum [c]	nF	12	12
Transmitter transients, maximum [d]	V	± 1,2	± 1,2
Receiver transients, maximum [d]	V	± 1,2	± 1,2
Receiver A.C. common mode voltage tolerance V_{CM}, minimum [e]	mV(P-P)	150	150
Receiver A.C. common mode frequency tolerance range F_{CM} [e]	MHz	2 to 200	2 to 200

[a] The media impedances are the differential impedances.
[b] Allows support for SATA devices with spread spectrum clocking (see ATA/ATAPI-7 V3). SAS initiator phys supporting being attached to SATA devices should also use these tolerances.
[c] The coupling capacitor value for A.C. coupled transmit and receive pairs.
[d] The maximum transmitter and receiver transients are measured at nodes V_P and V_N on the test loads shown in figure 46 (for the transmitter) and figure 47 (for the receiver) during all power state and mode transitions. Test conditions shall include the system power supply ramping at the fastest possible rate for both power on and power off conditions.
[e] Receivers shall tolerate sinusoidal common mode noise components within the peak-to-peak amplitude (V_{CM}) and the frequency range (F_{CM}).

5.3.3 Eye masks

5.3.3.1 Eye masks overview

The eye masks shown in this subclause shall be interpreted as graphical representations of the voltage and time limits on the signal at the compliance point. ~~The time values between X1 and (1 - X1) cover all but 10^{-12} of the jitter population. The random content of the total jitter population has a range of ± 7 standard deviations.~~The mask boundaries define the eye contour of the 1E-12 population at all signal levels. Current equivalent time sampling oscilloscope technology is not practical for measuring compliance to this eye contour. See MJSQ for methods that are suitable for verifying compliance to these masks.

5.3.3.2 Receive eye mask at IR, CR, and XR

Figure 48 describes the receive eye mask. ~~This eye mask applies to jitter after the application of a single pole high-pass frequency-weighting function that progressively attenuates jitter at 20 dB/decade below a frequency of ((bit rate) / 1 667)~~

The signal shall be measured using a jitter timing reference, e.g. Golden PLL, that approximates a single pole (20dB / decade) low pass filter with corner frequency of the signaling rate / 1667. This requirement accounts for the low frequency tracking and response time of CDRs in receiver devices.

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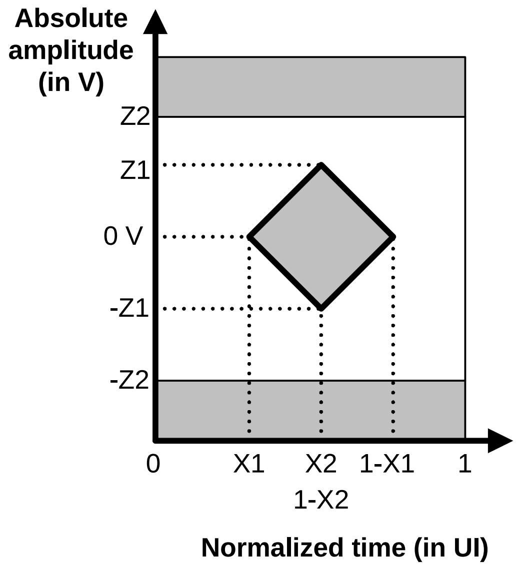

Figure 48 — Eye mask at IR, CR, and XR

Verifying compliance with the limits represented by the receive eye mask should be done with reverse channel traffic present in order that the effects of crosstalk are taken into account.

5.3.3.3 Jitter tolerance masks

Figure 49 describes the receive tolerance eye masks at IR, CR, and XR and shall be constructed using the X2 and Z2 values given in table 27. $X1_{OP}$ shall be half the value for total jitter in table 28 and $X1_{TOL}$ shall be half the value for total jitter in table 29, for applied sinusoidal jitter frequencies above ((bit rate) / 1 667).

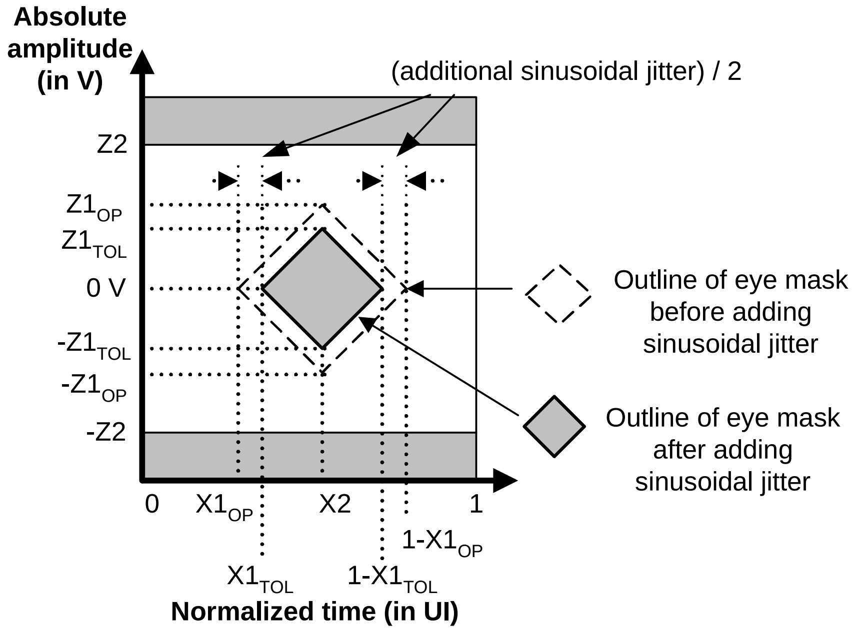

Figure 49 — Deriving a tolerance mask at IR, CR, or XR

The leading and trailing edge slopes of figure 48 shall be preserved. As a result the amplitude value of Z1 is less than that given in table 27 and $Z1_{TOL}$ and $Z1_{OP}$ shall be defined from those slopes by the following equation:

$$Z1_{TOL} = Z1_{OP} \times \frac{X2_{OP} - (0,5 \times \text{additional sinusoidal jitter}) - X1_{OP}}{X2_{OP} - X1_{OP}}$$

where:

a) $Z1_{TOL}$ is the value for Z1 to be used for the tolerance masks; and
b) $Z1_{OP}$, $X1_{OP}$, and $X2_{OP}$ are the values in table 27 for Z1, X1, and X2.

The X1 points in the receive tolerance masks are greater than the X1 points in the receive masks, due to the addition of sinusoidal jitter.

Figure 50 defines the applied sinusoidal jitter mask.

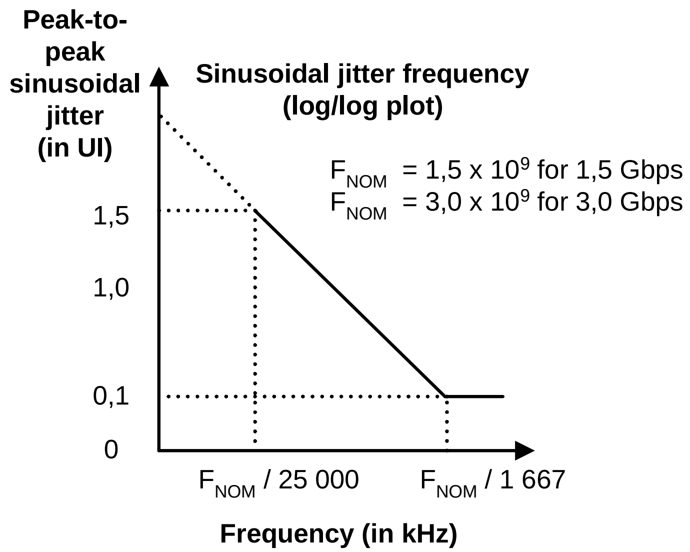

Figure 50 — Applied Sinusoidal jitter mask

5.3.4 Signal characteristics at IT, CT, and XT

This subclause defines the inter-operability requirements of the signal at the transmitter end of a TxRx connection as measured into the zero-length test load specified in figure 52. All specifications are based on differential measurements.

The OOB sequence shall be performed at signal voltage levels corresponding to the lowest supported transfer rate. Expander phys supporting being attached to SATA devices shall use SATA 1.0 signal levels (see ATA/ATAPI-7 V3) during the first OOB sequence after a power on or hard reset if the 1,5 Gbps transfer rate is supported. As soon as COMSAS has been exchanged, the expander phy shall increase its transmit levels to the SAS voltage levels specified in table 27. If a COMINIT is not received within a hot-plug timeout at SATA 1.0 signal levels, the expander phy shall increase its transmit levels to the SAS voltage levels and perform the OOB sequence again. If no COMINIT is received within a hot-plug timeout of the second OOB sequence the expander phy shall initiate another OOB sequence using SATA 1.0 signal levels. The expander phy shall continue alternating between sending COMINIT at SATA 1.0 signal levels and SAS signal levels until a COMINIT is received.

If the OOB sequence is completed at the SAS voltage level and a SATA device is detected rather than a SAS target device, the expander phy shall switch to SATA 1.0 voltage levels and repeat the OOB sequence.

NOTE 9 - SAS initiator phys supporting being attached to SATA devices may use the same algorithm as expander phys.

SAS initiator phys and SAS target phys shall transmit OOB signals at the lowest supported transfer rate using SAS signal levels.

5.3.5 Signal characteristics at IR, CR, and XR

Table 27 defines the compliance point requirements of the signal at the receiver end of a TxRx connection as measured into the test loads specified in figure 51 and figure 52.

Table 27 — Signal characteristics at IR, CR, and XR (part 1 of 2)

Compliance point	Signal characteristic	Units	SATA	1,5 Gbps	3,0 Gbps
IR [e]	Jitter (see figure 48) [b]	N/A	N/A	See table 28	See table 28
	2 x Z2	mV(P-P)	N/A	1 600	1 600
	2 x Z1	mV(P-P)	N/A	325	275
	X1 [a]	UI	N/A	0,275	0,275
	X2	UI	N/A	0,50	0,50
	Skew [d]	ps	N/A	80	75
	Max voltage (non-op)	mV(P-P)	N/A	2 000	2 000
	Minimum OOB ALIGN burst amplitude [c]	mV(P-P)	N/A	240	240
	Maximum noise during OOB idle time [c]	mV(P-P)	N/A	120	120
	Max near-end crosstalk [f]	mV(P-P)	N/A	100	100
CR	Jitter (see figure 48) [b]	N/A	N/A	See table 28	See table 28
	2 x Z2	mV(P-P)	N/A	1 600	1 600
	2 x Z1	mV(P-P)	N/A	275	275
	X1 [a]	UI	N/A	0,275	0,275
	X2	UI	N/A	0,50	0,50
	Skew [d]	ps	N/A	80	75
	Max voltage (non-op)	mV(P-P)	N/A	2 000	2 000
	Minimum OOB ALIGN burst amplitude [c]	mV(P-P)	N/A	240	240
	Maximum noise during OOB idle time [c]	mV(P-P)	N/A	120	120
	Max near-end crosstalk [f]	mV(P-P)	N/A	100	100

Table 27 — Signal characteristics at IR, CR, and XR (part 2 of 2)

Compliance point	Signal characteristic	Units	SATA	1,5 Gbps	3,0 Gbps
XR	Jitter (see figure 48) [b]	N/A	See table 28	See table 28	See table 28
	2 x Z2	mV(P-P)	600	1 600	1 600
	2 x Z1	mV(P-P)	225	325	275
	X1 [a]	UI	0,275	0,275	0,275
	X2	UI	0,50	0,50	0,50
	Skew [d]	ps	50	80	75
	Max voltage (non-op)	mV(P-P)	2 000	2 000	2 000
	Minimum OOB ALIGN burst amplitude [c]	mV(P-P)	240	240	240
	Maximum noise during OOB idle time [c]	mV(P-P)	120	120	120
	Max near-end crosstalk [f]	mV(P-P)	< 50	100	100

[a] The value for X1 shall be half the value given for total jitter in table 28. The test or analysis shall ~~include the effects of a single pole high-pass frequency weighting function that progressively attenuates jitter at 20 dB/decade below a frequency of ((bit rate) / 1 667).~~be measured using a jitter timing reference, e.g. Golden PLL, that approximates a single pole (20dB / decade) low pass filter with corner frequency of the signaling rate / 1667. This requirement accounts for the low frequency tracking and response time of CDRs in receiver devices.

[b] The value for X1 applies at a total jitter probability of 10^{-12}. At this level of probability direct visual comparison between the mask and actual signals is not a valid method for determining compliance with the jitter output requirements. See MJSQ

[c] With a measurement bandwidth of 1,5 times the baud rate (i.e. 4,5 GHz for 3,0 Gbps).

[d] The skew measurement shall be made at the midpoint of the transition with a repeating 0101b pattern on the physical link. The same stable trigger, coherent to the data stream, shall be used for both the Rx+ and Rx- signals. Skew is defined as the time difference between the means of the midpoint crossing times of the Rx+ signal and the Rx- signal.

[e] If being attached to SATA devices is supported at the IR location, requirements of SATA shall be met at IR.

[f] Near-end crosstalk is the unwanted signal amplitude at receiver terminals DR, CR, and XR coupled from signals and noise sources other than the desired signal. Refer to SFF-8410.

5.3.6 Jitter

Table 28 defines the maximum allowable jitter at IR, CR, and XR.

Table 28 — Maximum allowable jitter at IR, CR, XR

Compliance point	1,5 Gbps [a, b]		3,0 Gbps [a, b]	
	Deterministic jitter [e]	Total jitter [c, d, e, f]	Deterministic jitter [e]	Total jitter [c, d, e, f]
IR	0,35	0,55	0,35	0,55
CR	0,35	0,55	0,35	0,55
XR	0,35	0,55	0,35	0,55

[a] Units are in UI. All DJ and TJ values are level 1.

[b] The values for jitter in this section are measured at the average signal amplitude point.

[c] ~~Total jitter is the sum of deterministic jitter and random jitter. If the actual deterministic jitter is less than the maximum specified, then the random jitter may increase as long as the total jitter does not exceed the specified maximum total jitter.~~{This note adds no value and implies that there is a specification on random jitter values.}

[d] Total jitter is specified at a CDF level of 10^{-12}.

[e] The deterministic and total values in this table apply to jitter ~~after application of a single pole high-pass frequency-weighting function that progressively attenuates jitter at 20 dB/decade below a frequency of ((bit rate) / 1 667).~~measured using a jitter timing reference, e.g. Golden PLL, that approximates a single pole (20dB / decade) low pass filter with corner frequency of the signaling rate / 1667. This requirement accounts for the low frequency tracking and response time of CDRs in receiver devices. Values for DJ and TJ shall be calculated from the CDF for the jitter population using the method defined in MJSQ clause 8.

[f] If total jitter received at any point is less than the maximum allowed, then the jitter distribution of the signals is allowed to be asymmetric. The total jitter plus the magnitude of the asymmetry shall not exceed the allowed maximum total jitter. The numerical difference between the average of the peaks with a BER < 10^{-12} and the average of the individual events is the measure of the asymmetry. Jitter peak-to-peak measured < (maximum total jitter - |Asymmetry|).

5.3.7 Receiver jitter tolerance

Table 29 defines the amount of jitter the receiver shall tolerate at IR, CR, and XR.

Table 29 — Receiver jitter tolerance

Compliance point	1,5 Gbps [a]			3,0 Gbps [a]		
	Applied sinusoidal jitter [b, c]	Deterministic jitter [e, f, h]	Total jitter [h]	Applied sinusoidal jitter [b, d]	Deterministic jitter [e, g, h]	Total jitter [h]
IR	0,10	0,35	0,65	0,10	0,35	0,65
CR	0,10	0,35	0,65	0,10	0,35	0,65
XR	0,10	0,35	0,65	0,10	0,35	0,65

[a] Units are in UI. All DJ and TJ values are level 1.

[b] The jitter values given are normative for a combination of deterministic jitter, ~~random jitter~~ total jitter, and applied sinusoidal jitter that receivers shall be able to tolerate without exceeding a BER of 10^{-12}. Receivers shall tolerate applied sinusoidal jitter of progressively greater amplitude at lower frequencies, according to the mask in figure 50 with the same deterministic jitter and ~~random~~ total jitter levels as were used in the high frequency sweep.

[c] Applied sinusoidal swept frequency: 900 kHz to > 5 MHz.

[d] Applied sinusoidal swept frequency: 1 800 kHz to > 5 MHz.

[e] No value is given for random jitter. For compliance with this standard, the actual random jitter amplitude shall be the value that brings total jitter to the stated value at a probability of 10^{-12}. The additional 0,1 UI of sinusoidal jitter is added to ensure the receiver has sufficient operating margin in the presence of external interference.

[f] Deterministic jitter: 900 kHz to 750 MHz.[This is the bandwidth of the instrument - not the DJ itself]

[g] Deterministic jitter: 1 800 kHz to 1 500 MHz. [This is the bandwidth of the instrument - not the DJ itself]

[h] The deterministic and total values in this table apply to jitter ~~after application of a single pole high-pass frequency-weighting function that progressively attenuates jitter at 20 dB/decade below a frequency of ((bit rate) / 1 667)~~measured using a jitter timing reference, e.g. Golden PLL, that approximates a single pole (20dB / decade) low pass filter with corner frequency of the signaling rate / 1667. This requirement accounts for the low frequency tracking and response time of CDRs in receiver devices. Values for DJ and TJ shall be calculated from the CDF for the jitter population using the method defined in MJSQ clause 8.

5.3.8 Compliant jitter test pattern (CJTPAT)

The CJTPAT within a compliant protocol frame shall be used for all jitter testing unless otherwise specified. Annex A defines the required pattern on the physical link and information regarding special considerations for scrambling and running disparity.

5.3.9 Impedance specifications

Table 30 defines impedance requirements.

Table 30 — Impedance requirements (part 1 of 2)

Requirement	Units	1,5 Gbps	3,0 Gbps
Time domain reflectometer rise time 20 % to 80 % [a, b]	ps	100	50
Media (PCB or cable)			
Differential impedance [b, c, d]	ohm	100 ± 10	100 ± 10
Differential impedance imbalance [b, c, d, g]	ohm	5	5
Common mode impedance [b, c, d]	ohm	32,5 ± 7,5	32,5 ± 7,5