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06-011r0 Towards a SAS-2 Physical Layer Specification

Serial Attached SCSI

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11/30/2005

YOUR PARTNER FOR SUCCESS

Physical Layer Working Group Goal

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- Draft a Specification which will:
  1. Meet the System Designers application requirements,
  2. Enable System Designers to build and test channels which are compliant,
  3. Permit IC vendors parts to interoperate in the systems,
  4. Enable IC vendors to design and test transmitters and receivers which are compliant,
  5. Support high volume manufacturing of systems and ICs,
  6. Support high port-count applications (low power/ small phy),
  7. Result in a robust interface.

Proposed Road Map

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- Establish General Link Assumptions & Goals
  - Based on Market need (STA) and technical contributions to date
- Compare to some other Relevant Specifications
- Propose a set of Electrical Specifications & Compliance test for discussion
  - Encourage counter proposals with proposed modifications
- Identify Specifications & Compliance Test which will need additional work and research
  - Recruit technical contributors
- Draft Document

Link Assumptions

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- Connectors are the primary interoperability point (Cables, Connectors, & Drives)
  - ASIC pin / AC coupling cap is a secondary compliance point when a connector not available
- SAS-2 Channels will require equalization (05-425r0) and will be a Closed-Eye Specification
  - On most stressful channels the eyes will be close at the far end compliance point
- A mixture of Tx De-emphasis and Rx equalization can equalize the SAS-2 channels.
  - 05-341r1, 05-426r0 & 05-428r0
- 10m reach goal can be supported with improved connectors (05-426r0)
- External cable reaches must be supported w/o equalized cables
- Three Channel Models Must be Supported
  - External Chassis to Chassis (inter-enclosure CT/CR)
  - ASIC to ASIC, {HBA-drive, HBA-Expander, Expander-Expander, Expander-Drive, …} (intra-enclosure IT/IR)
  - Low-Loss channel ASIC to ASIC
- Reduced Swing desired (see SAS Phy meeting notes)
- BER of 1e-15 desired (see SAS Phy meeting notes)
- Backwards to SAS-1 and SATA compatibility required

Review of Comparable Closed Eye Specification

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Good News, We are not alone

- Mature / Nearly Complete Closed-Eye Specifications
  - OIF CEI-6G-LR (6Gbps Backplane {1m + 2 connectors} NRZ)
    - http://oiforum.com/
  - IEEE 10GBase-LRM (10Gbps Multi Mode Fiber NRZ)
    - http://www.ieee802.org/3/aq/index.html
  - IEEE 10GBase-KR (10Gbps Backplane NRZ, XAUI backplanes)
    - http://www.ieee802.org/3/ap/index.html
- Other Closed eye spec's
  - RAPID-IO Gen 2 (very early phase) 05-199r0
  - IEEE 10GBase-T (10G on CAT 6,7) Multi-lane PAM encoding
  - Others …

Look at Transmit Specifications

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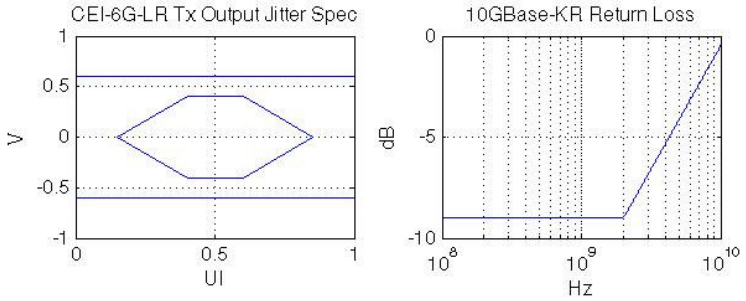
- What constitutes a Compliant Transmitter?
  - OIF CEI-6G-LR (6G Backplane)
    - Launch Eye, 2 tap Tx FIR, 6dB Boost
  - IEEE 10GBase-LRM (10GbE MMF)
    - Launch Power, Waveform shape, link budget based (TWDP)
  - IEEE 10GBase-KR (10GbE Backplane)
    - 3 tap FIR with back-channel adaptation



	10GBase-LRM		10GBase-KR	
	802.3aq/Draft2.0	OIF-CEI-6G-LR	802.3ap/Draft2.0	Units
Transmitter				
Differential Voltage (pk-pk)	N.A.	400 -> 1200	800 -> 1200	mV
Common-Mode Voltage Limits	N.A.	0.1 -> 1.7	-0.4 -> 0.9	V
Differential Return Loss	N.A.	-8	(-9dB) see plot 4	
Common Mode Return Loss	N.A.	-6	-6	dB
Min. Transition Time (20%-80%)	N.A.	30	24	ps
Max Transition Time (20%-80%)	N.A.	Eye Diagram Limited	N.A.	ps
Output Impedance	N.A.	80 min/ 120 max	N.A.	ohm
Common Mode Impedance	N.A.	25	N.A.	ohm
Max. Intra-Pair Skew	N.A.	15	N.A.	ps
Random Jitter	0.033	0.15	0.15	UI
Duty Cycle Distortion	N.A.	0.05	N.A.	
Deterministic Jitter	N.A.	0.15	0.15	UI
Total Jitter	N.A.	0.3	0.3	UI
De-Emphasis (Tx FFE)	N.A.	2 Tap <= 6dB	3 Tap (adjustable)	Taps
Transmit waveform Dispersion Penality	5	N.A.	N.A.	dB

Look at Channel Specifications

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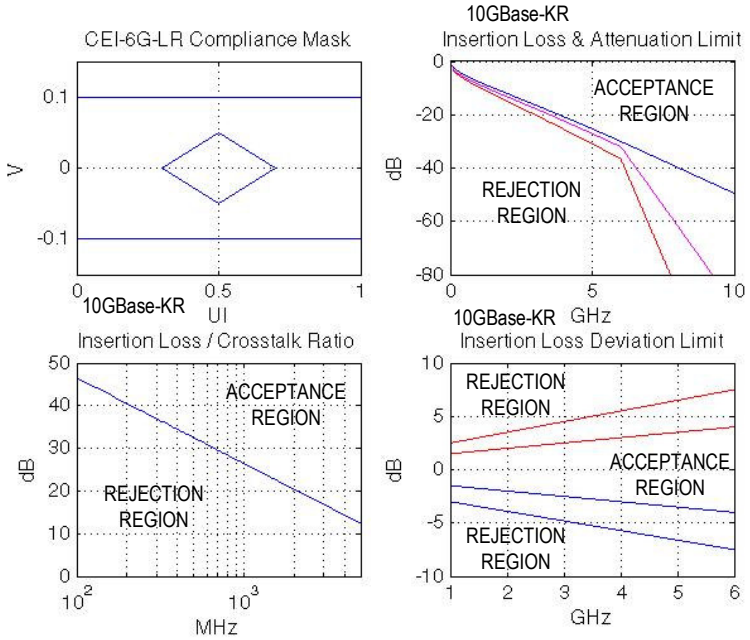
- What constitutes a Compliant Channel?
  - OIF CEI-6G-LR (6G Backplane)
    - S-parameters, Ref Tx (2 tap FFE) & Ref Rx (5 tap DFE), resulting StatEye opening (100mV, 0.4UI)
  - IEEE 10GBase-LRM (10GbE MMF)
    - Link Budget based
    - Pulse response and Penalty of Infinite length Equalizer (PIE-D) link budget based allocation
  - IEEE 10GBase-KR (10GbE Backplane)
    - Attenuation, Insertion Loss, Insertion Loss Deviation, & Insertion loss/ Crosstalk Ration (ICR)



	802.3aq/Draft2.0	OIF-CEI-6G-LR	802.3ap/Draft2.0	Units
Channel				
Compliance Points	Optical Connector	ASIC	ASIC	
Differential Bulk Impedance	N.A.	N.A.	100+/- 10%	ohm
Differential Skew	N.A.	N.A.	20	ps
Attenuation	MMF Model Based	N.A.	see plot 1	dB
Insertion Loss	MMF Model Based	N.A.	see plot 1	dB
Insertion Loss Deviation	MMF Model Based	N.A.	see plot 2	dB
Maximum Total Next	N.A.	N.A.	see ICR	dB
Insertion Loss to Crosstalk Ratio (ICR)	N.A.	N.A.	see plot 3	dB

Look at Receiver Specifications

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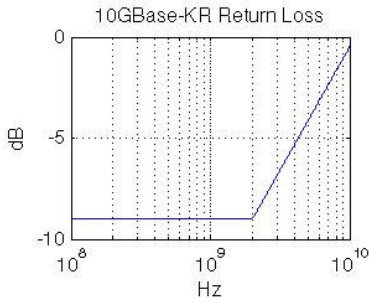
- What constitutes a Compliant Receiver?
  - OIF CEI-6G-LR (6G Backplane)
    - Measure BER with Crosstalk+SJ+DJ + RJ loaded compliance channel or filter (sec. 2.4.4)
    - Jitter Tolerance "receiver shall tolerate … with any compliant channel" (sec. 7.4.2.8)
    - Unbounded requirement (infinite number of possible compliant channels)
  - IEEE 10GBase-LRM (10GbE MMF)
    - Simple Stressed Sensitivity, Comprehensive Stressed Sensitivity (multiple reference channels), jitter tolerance
  - IEEE 10GBase-KR (10GbE Backplane)
    - Rx Interference test w/ ISI stress
    - More tests in development, I think



	10GBase-LRM		10GBase-KR	
	802.3aq/Draft2.0	OIF-CEI-6G-LR	802.3ap/Draft2.0	Units
Receiver				
Reference Rx	N.A.	5 tap DFE	N.A.	
BER	1.00E-12	1.00E-15	1.00E-12	
Differential Impedance	N.A.	100+/- 20%	N.A.	ohm
Max Operational Input Voltage	N.A.	1200	1200	mV
Max Non-Operational Input Voltage	N.A.	N.A.	1600	mV
Differential Return Loss	N.A.	-8	(-9dB) see plot 4	dB
Common Mode Return Loss	N.A.	-6	-6	dB
EITbase	N.A.	N.A.	15	mV

Proposed Methodology

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Not so Good News, No one agrees on how to do a closed eye specification

- Proposal
  - Why not pick what we think is the “best” of each specification, refine as appropriate for SAS-2
  - Specify a Compliant Transmitter, Channel, and Receiver
  - Specify Transmitter, Channel, and Receiver Compliance Test
    - Define the Test Setup / hardware, data collection and processing method
    - Define the testing such that it is reproducible by multiple vendors with high confidence

SAS-2 Transmitter Specification

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First Pass Numbers

	10GBase-LRM		10GBase-KR				
	802.3aq/Draft2.0	OIF-CEI-6G-LR	802.3ap/Draft2.0	Typical SAS-1		SAS-2	Units
Transmitter							
Differential Voltage (pk-pk)	N.A.	400 -> 1200	800 -> 1200	1600	1600	800 -> 1200	mV
Common-Mode Voltage Limits	N.A.	0.1 -> 1.7	-0.4 -> 0.9	A.C. Coupled	A.C. Coupled	A.C. Coupled	V
Differential Return Loss	N.A.	-8	(-9dB) see plot 4	N.A.	N.A.	(like 10GBase-KR)	dB
Common Mode Return Loss	N.A.	-6	-6	N.A.	N.A.	-6	dB
Min. Transition Time (20%-80%)	N.A.	30	24	67	67	50	ps
Max Transition Time (20%-80%)	N.A.	Eye Diagram Limited	N.A.	273	137	75	ps
Output Impedance	N.A.	80 min/ 120 max	N.A.	60 min/ 115 max	60 min/ 115 max	60 min/ 115 max	ohm
Output Impedance Mismatch	N.A.	N.A.	N.A.	5	5	5	ohm
Common Mode Impedance	N.A.	25	N.A.	15 min/ 40 max	15 min/ 40 max	15 min/ 40 max	ohm
Max. Intra-Pair Skew	N.A.	15	N.A.	20	15	15	ps
Random Jitter	0.033	0.15	0.15	0.2	0.2	0.15	UI
Duty Cycle Distortion	N.A.	0.05	N.A.	N.A.	N.A.	?	UI
Deterministic Jitter	N.A.	0.15	0.15	0.35	0.35	0.15	UI
Total Jitter	N.A.	0.3	0.3	0.55	0.55	0.3	UI
De-Emphasis (Tx FFE)	N.A.	<= 6dB	3 Tap (adjustable)	N.A.	N.A.	2Tap 6dB	Taps
Transmit waveform Dispersion Penality	5	N.A.	N.A.	N.A.	N.A.	N.A.	dB

Open Items

- DCD Budget
- Common Mode return loss, constant or frequency dependent?

SAS-2 Transmitter Compliance Test

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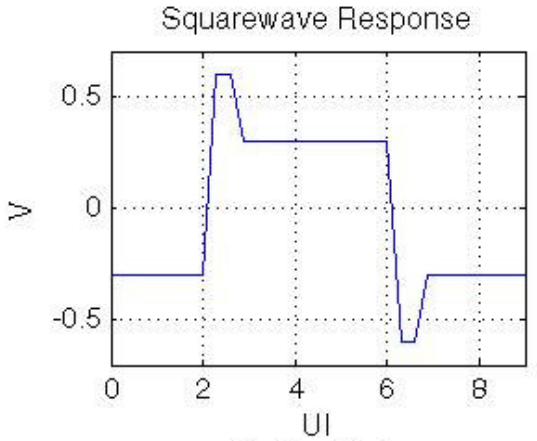
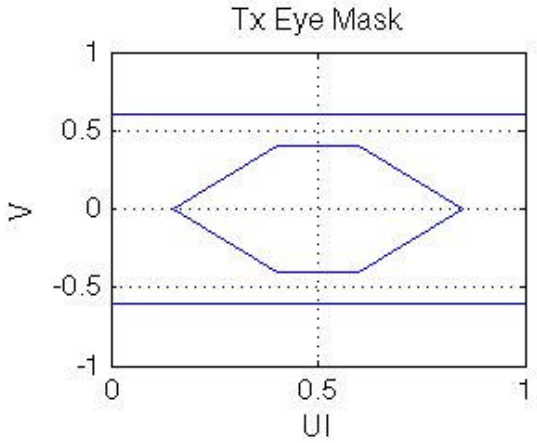
- Options
  - Eye mask for swing and jitter (10GBase-KR &OIF-CEI)
  - Waveform for DE (10GBase-KR)
  - StatEye w/ "Compliance channel with open eye at ½ boost setting" (which channel, who's code?) (OIF-CEI section 2.4.3)
  - Transmit Waveform Dispersion Penalty (TWDP) (10GBase-LRM)
- Implication
  - Eye mask and waveform capture is easy to implement (10GBase-KR)
  - Non-standard compliance channel and StatEye code, repeatability?
- Proposal
  - Investigate if an Eye mask test & waveform capture is adequate





Can we minimize the complexity of this test?

SAS-2 Channel Specification

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- First Pass Numbers

	10GBase-LRM		10GBase-KR				
	802.3aq/Draft2.0	OIF-CEI-6G-LR	802.3ap/Draft2.0	Typical SAS-1		SAS-2	Units
Channel							
Compliance Points	Optical Connector	ASIC	ASIC	Connector	Connector	Connector/ASIC	
Differential Bulk Impedance	N.A.	N.A.	100+/- 10%	100+/- 10%	100+/- 10%	100+/- 10%	ohm
Differential Impedance Mismatch	N.A.	N.A.	N.A.	5	5	5	ohm
Differential Connector Impedance	N.A.	N.A.	N.A.	100+/- 15%	100+/- 15%	100+/- 15%	ohm
Differential Skew	N.A.	N.A.	20	10	10	10	ps
Differential Skew (external Cable)	N.A.	N.A.	N.A.	20	20	TBD	ps
Common Mode Impedance	N.A.	N.A.	N.A.	32.5+/- 7.5	32.5+/- 7.5	32.5+/- 7.5	ohm
Attenuation	MMF Model Based	N.A.	see plot 1	see plot 1	see plot 1	TBD	dB
Insertion Loss	MMF Model Based	N.A.	see plot 1	see plot 1	see plot 1	TBD	dB
Insertion Loss Deviation	MMF Model Based	N.A.	see plot 2	N.A.	N.A.	TBD	dB
Maximum Total Next	N.A.	N.A.	see ICR	-26	-26	TBD	dB
Insertion Loss to Crosstalk Ratio (ICR)	N.A.	N.A.	see plot 3	N.A.	N.A.	TBD	dB

SAS-2 Channel Compliance Test

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- Options:
  - StatEye w/ reference Tx & Rx (who's code, what is the proper reference Tx and Rx) (OIF-CEI)
  - Attenuation, Insertion loss limit, Insertion loss Deviation (10G Base-KR)
  - Interference to Insertion Loss Ratio (ICR) limit (10G Base-KR)
  - PIE-D limit (10G Base-LRM)
- Implication
  - System designers will need to ensure channel compliance with StatEye (OIF)
  - Differential S-Parameters relatively easy to collect and apply a mask (10G Base-KR)
- Proposal
  - Investigate if 10GBase-KR Attenuation, Insertion loss, Insertion loss deviation cover example SAS-2 channel measurements
  - Investigate if 10GBase-KR return loss mask will work with the example SAS-2 channel measurements
  - Determine if channels passing the mask pass the StatEye test

SAS-2 Receiver Specification

VITESSE

- First Pass Numbers

	10GBase-LRM		10GBase-KR				
	802.3aq/Draft2.0	OIF-CEI-6G-LR	802.3ap/Draft2.0	Typical SAS-1		SAS-2	Units
Receiver							
Reference Rx	N.A.	5 tap DFE	N.A.	N.A.	N.A.	X-Tap DFE	
BER	1.00E-12	1.00E-15	1.00E-12	1.00E-12	1.00E-12	1.00E-15	
Differential Impedance	N.A.	100+/- 20%	N.A.	100+/- 15%	100+/- 15%	100+/- 15%	ohm
Differential Impedance Mismatch	N.A.	N.A.	N.A.	5	5	5	ohm
Common Mode Impedance	N.A.	N.A.	N.A.	20 min/ 40 max	20 min/ 40 max	20 min/ 40 max	ohm
Common-Mode Tolerance (2-200MHz)	N.A.	N.A.	N.A.	150	150	150	mV
Max Operational Input Voltage	N.A.	1200	1200	1600	1600	1200	mV
Max Non-Operational Input Voltage	N.A.	N.A.	1600	2000	2000	2000	mV
Differential Return Loss	N.A.	-8	(-9dB) see plot 4	N.A.	N.A.	TBD 10GBase-KR?	dB
Common Mode Return Loss	N.A.	-6	-6	N.A.	N.A.	-6	dB
EITbase	N.A.	N.A.	15	N.A.	N.A.	N.A.	mV

SAS-2 Receiver Compliance Test

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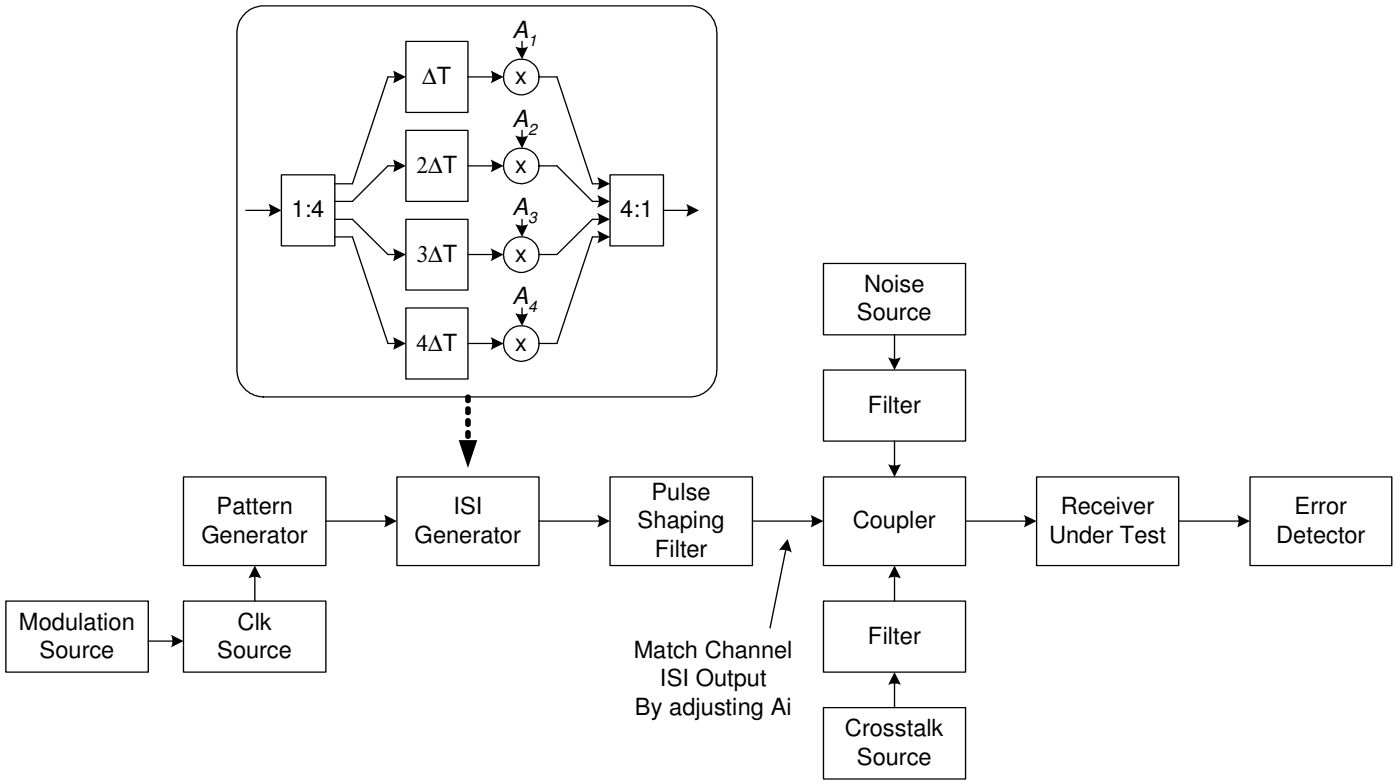
Proposal

- Stressed sensitivity w/ Jitter and Interference (same as OIF-CEI, & 10GBase-KR)
- Standardize test setup and channel with 10GBase-LRM ISI Generator
- Generate ISI coefficients for worst case channels



Incomplete list of Issue not addressed

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- Connector to ASIC allocation
- Specific compliance test for each specification
- Jitter tolerance mask
- Crosstalk limits and methodology
- Many many more…