Standard Electrical Taskgroup Report

-October '97 meeting-

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Charter

- **To define the electrical signaling parameters for 1394b PHY's**
  - **Primary focus is short-haul copper**
  - **Secondary focus is to assist the long-haul copper and fiber groups with physical signaling parameters**

Electrical Issues

- **Specifications for transmitters and receivers**
- **System jitter budget and optimal allocations**
- **Definitions for practical compliance measurements**
  - **Eye diagrams**
  - **Measurement points**
  - **Jitter measurements**
  - **Checklists for PHY vendors and OEM's**
- **Creation of useful simulation models**
  - **Spice for cable+connectors**
  - **Spice for packages and PC layouts**
  - **More general mathematical models for transmitters to receivers system modeling**
- **Electrical interface reference design**
  - **Aid to the designer**
  - **At the level of the IEEE Std. 1394-1995 electrical interface diagram and specification.**

Proposed Workplan

- **Process**
  - Private emails between taskgroup members
  - When issues become contentious or defined enough for discussion -- telephone conference calls
- **Timeline**
  - 0.5 rev. short-haul copper draft by December '97 meeting
- **Documentation**
  - The current draft is a good beginning spec. (stolen from gigabit ethernet!)

5. Electrical specifications

NOTE—The electrical specifications are subject to subtantial changes due to the lack of a defined connector and cable assembly at this time. Until the copper interconnect is defined and characterized no electrical parameters can be considered final.

This section specifies the electrical signaling properties for the physical layer. The focus is on short haul copper (4.5 meters and shorter). The standard IEEE Std. 1394-1995 Data/Strobe mode of signaling is not covered. Additionally, there will likely be a very low duty cycle signal to indicate “connected/sleep state” between connected nodes **(TBD)**.

5.1 Interfaces

All interface specifications are only valid at the point of entry and exit from the equipment. These points are identified as point-S, -S’, -R, and -R’ as shown in figure 5.1. The specifications assume that all measurements are made after a mated connector pair, relative to the source or destination.

The reference points for all connections are those points-S, -S’, -R, and -R’ where the cabinet Faraday shield transitions between the cabinet and the cable shield. If sections of transmission line exist within the Faraday

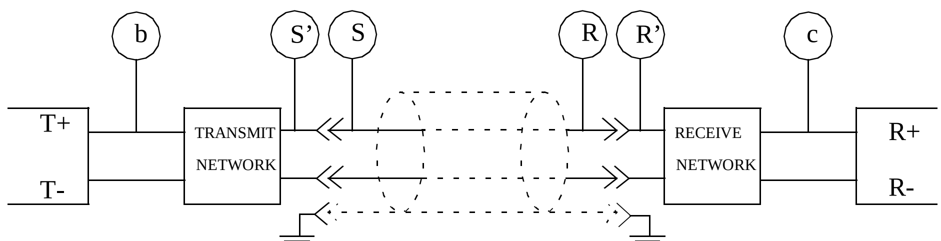

Figure 5-1—Measurement points

shield, they are considered to be part of the associated transmit or receive network, and not part of the cable plant.

Schematics in the diagrams in this clause are for illustration only and do not represent the only feasible implementation. The links described in this section shall be applied only to homogeneous ground applications such as between devices within a cabinet or rack, or between cabinets interconnected by a common ground return or ground plane. The restriction minimizes safety and interference concerns caused by any voltage differences that could otherwise exists between equipment grounds.

5.2 Transmitter electrical specifications

P1394b transmitters are bilingual devices. They must be electrically compatible at the pin level with IEEE Std. 1394-1995 signals, supporting all the standard electrical operating modes. Additionally, P1394b transmitters must support a new electrical specification for gigabit signaling. In this higher speed mode of operation the output driver is assumed to have new output levels, such as measured at point-b. The signal requirements for the transmit interface are listed in table 5-1.

Table 5-1—Transmitter characteristics

Parameter	S100-S400/1995	S800	S1600	S3200	Units
Signaling	Data/Strobe	8b/10b	8b/10b	8b/10b	
Nominal Data Rate		786.43	1,572.9	3,145.7	Mbs
Nominal Baud Rate		983.04	1,966.1	3,932.2	MBaud
Tolerance		+/-100	+/-100	+/-100	ppm
Differential Amplitude					
Max	IEEE Std. 1394-1995	800	800	800	mV
Min	IEEE Std. 1394-1995	600	600	600	mV
Deterministic Jitter	IEEE Std. 1394-1995	10	10	10	%(p-p)
Random Jitter	IEEE Std. 1394-1995	12	12	12	%(p-p)
Rise/Fall Time(20-80%)					
Max	IEEE Std. 1394-1995	417	208	104	ps
Min	IEEE Std. 1394-1995	**TBD**	**TBD**	**TBD**	ps
Differential Skew	IEEE Std. 1394-1995	25	12	6	ps

NOTE—Measurements for differential voltages means (V2 - V1), where V1 and V2 are the single-ended voltages, differential voltages are define exactly as in IEEE Std. 1394-1995

NOTE—Transmitter characteristics measured at point-S

The output driver in 8b/10b signaling shall have output levels, measured at the input to the cable (point-S), meeting the eye diagram requirements of figure 5-3, when terminated as shown in figure 5-2.

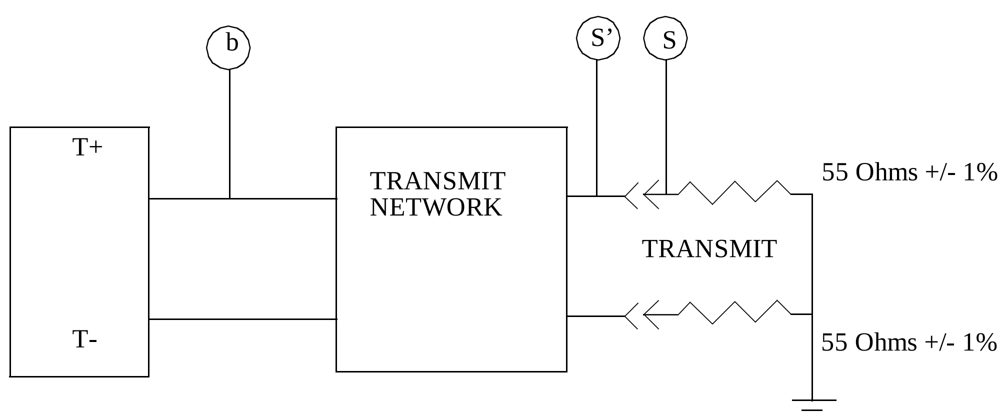

Figure 5-2—Balanced transmitter test circuit

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The amplitude limits in figure 5-3 are set to allow signal overshoot of 10% and undershoot of 20% relative to the amplitudes determined to be a logic 1 and 0.

The mask of the transmitter eye diagram is given in figure 5-3. The normalized transmitter output timing and differential amplitude requirements are specified in table 5-1 and figure 5-3.

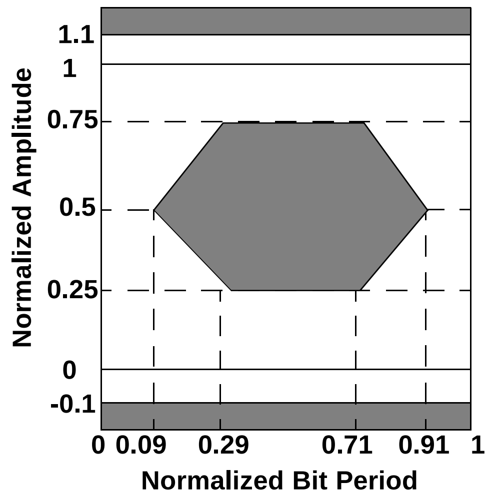

Figure 5-3—Eye diagram mask at point-S

NOTE—Do not scale this diagram. Eye dimensions are solely determined by their numerical values.

NOTE—All specifications, unless specifically listed otherwise, are based upon differential measurements.

NOTE—All times indicated for TDR measurements are recorded times. Recorded times are twice the one way transit time of the TDR signal.

NOTE—The transmit differential skew is the maximum allowed time difference (on both low-to-high and high-to-low transitions) as measured at point-S, between the true and complement signals. This time difference is measured at the midway point on the signal swing of the true and complement signals. These are single ended measurements.

NOTE—The transmitter amplitude maximum specification indentifies the maximum differential signal that can be delivered into a resistive load matching that shown in figure 5-2.

NOTE—The transmitter amplitude minimum specification indentifies the minimum allowed differential eye amplitude opening that can be delivered into a resistive load matching that shown in figure 5-2.

NOTE—The transmitter jitter specifications are presently under review and may change in a future release of this standard.

NOTE—The normalized 1 is that amplitude determined to be the average amplitude when driving a logic 1. The normalized 0 is that amplitude determined to be the average amplitude when driving a logic 0.

NOTE—Eye diagram assumes the presence of only high frequency jitter components that are not tracked by the clock recovery circuit. For this standard the lower cutoff frequency for jitter is the baud rate divided by 2500.

5.3 Receiver electrical specifications

P1394b receivers are bilingual devices. They must be electrically compatible at the pin level with IEEE Std. 1394-1995 signals, supporting all the standard electrical operating modes. Additionally, P1394b receivers must support a new electrical specification for gigabit signaling. In this higher speed mode of operation the input is assumed to have new voltage levels, such as measured at point-c. For all links, the receiver shall be DC-coupled for Data/Strobe signaling and may be AC-coupled for 8b/10b signaling through a receive network located between points-R and -c as shown in figure 5-1. The signal requirements for the receiver interface are listed in table 5-2. The

Table 5-2—Receiver characteristics

Parameter	S100-S400/1995	S800	S1600	S3200	Units
Signaling	Data/Strobe	8b/10b	8b/10b	8b/10b	N/A
Data Rate	100-400	786.43	1,572.9	3,145.7	Mbs
Nominal Baud Rate	100-400	983.04	1,966.1	3,932.2	MBaud
Tolerance	IEEE Std. 1394-1995	+/-100	+/-100	+/-100	ppm
Minimum Differential Sensitivity	IEEE Std. 1394-1995	200	200	200	mV
Input Impedance @ R					
TDR Rise Time	N/A	85	85	85	ps
Exception Window	N/A	100	100	100	ps
Through Connection					
Balance Inputs	N/A	110+/- 10	110+/- 10	110+/- 10	Ohms
At Termination					
Balance Inputs	N/A	110+/- 10	110+/- 10	110+/- 10	Ohms
Differential Skew	N/A	5%	5%	5%	UI

NOTE—Measurements for differential voltages means (V2 - V1), where V1 and V2 are the single-ended voltages, differential voltages are define exactly as in IEEE Std. 1394-1995

receive network shall terminate the link by an equivalent impedance of 110 Ohms.

The receiver shall operate within the BER objective (10^{-12}) when a short haul copper data link is driven by a transmitter meeting the requirements defined in table 5-1 and figure 5-3, and a signal delivered to the receiver meeting the eye diagram requirements specified in figure 5-4.

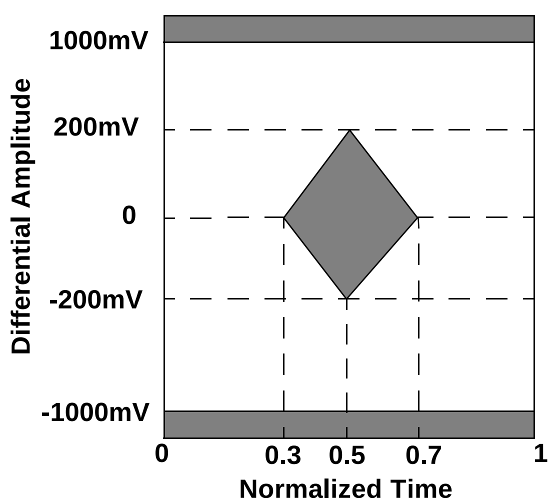

Figure 5-4—Eye diagram mask at point-R

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The minimum input amplitude to the receiver listed in table 5-2 and figure 5-4 is a worst case specification across all environmental conditions. Restricted environments may allow operation at lower minimum differential voltages, allowing significantly longer operating distances.

NOTE—Do not scale this diagram. Eye dimensions are solely determined by their numerical values.

NOTE—All specifications, unless specifically listed otherwise, are based on differential measurements.

NOTE—The receiver sensitivity identifies the minimum p-p eye amplitude at point-R to meet the BER objective.

NOTE—Eye diagrams assume the presence of only high frequency jitter components that are not tracked by the clock recovery circuit. For this standard the lower cutoff frequency for jitter is the Baud rate divided by 2500.

NOTE—The input impedance at point-R, for the termination, shall be recorded 4.0 ns following the reference location determined by an open connector between point-R and -R'.

NOTE—All times indicated for TDR measurements are recorded times. Recorded times are twice the one way transit times of the TDR signal

5.4 System electrical specifications

The system shall meet the operational requirements listed in table 5-3.

Should a case occur where, through a cabling error or the incorrect use of in-line splices or other adapters, two transmitters or receivers are directly connected, no damage shall occur to any transmitter, receiver, or other link component in the system. The link shall be able to withstand such an invalid connection without component failure or degradation for an indefinite period of time.

Cable shield(s) shall be earthed (chassis ground) through the bulkhead connector shell(s) on both ends of the cable as shown in figure 5-1.

NOTE—The maximum operable distance for a specific link type is calculated by dividing the loss per meter of the cable plant at a frequency equal to 1/2 times the maxium link baud rate into the available link-loss budget. This loss budget is calculated as $loss = 20\log_{10}((minOutputAmplitude)/(minInputAmplitude))$.

NOTE—No more than two connection points shall be present between the transmitter and receiver for the data link.

Table 5-3—System electrical specifications

Parameter	S100-S400	S800	S1600	S3200	Units
Data Rate	100-400	786.43	1,572.9	3,145.7	Mbs
Nominal Baud Rate	100-400	983.04	1,966.1	3,932.2	MBaud
Tolerance	IEEE Std. 1394-1995	+/-100	+/-100	+/-100	ppm
Operating Distance	0-4.5	0-4.5	0-4.5	0-4.5	meters
Cable Impedance	110	110	110	110	Ohms
Link Impedance @ S'					
TDR Rise Time	N/A	85	85	85	ps
Exception Window	N/A	100	100	100	ps
Through Connection	N/A	110+/- 10	110+/- 10	110+/- 10	Ohms
Cable	N/A	110+/- 10	110+/- 10	110+/- 10	Ohms
Differential Skew	N/A	5%	5%	5%	UI

NOTE—The link impedance measurement identifies the impedance mismatches present in the cable plant when terminated in its characteristic impedance. This measurement includes mated ocnnectors at both ends of the cable (points S'/S and R/R') and any intermediate connectors or splices between these locations. The link termination shall match that shown in figure 5-2.

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NOTE—The exception window used with specific impedance measurements identifies the maximum time period during which the measured impedance is allowed to exceed the listed impedance tolerance.

NOTE—The maximum excursion within the exception window at point-R shall not exceed +/- 33% of the nominal cable impedance.

NOTE—The link impedance at point-R', for the cable, shall be recorded 4.0 ns following the reference location determined by an open connector between point-R and -R'.

5.4.1 Compensation networks

An optional equalizer network, when present in a link, shall exist and operate as part of the cable plant. It shall be used to correct for frequency selective attenuation loss of the tranmitted signal, as well as timing variations due to the differences in propagation delay between higher and lower frequency signal components. An equalizer shall need no adjustment.

For those cables containing embedded equalization circuits, the operation of the cable may be length specific. All cables containing such circuits shall be marked with information indentifying the specific designed operational characteristics of the cable assembly.

Cables shall not be concatenated.

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