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S3200 Electrical Specification

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The 1394 Trade Association Board of Directors

Abstract

This specification defines the electrical parameters for transmission at S3200 in Beta mode over short haul copper connections.

Keywords

IEEE 1394, Serial Bus, S3200, Beta mode

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Contents

Tables

Figures

IEEE Copyright

Portions of this specification are copied from published IEEE standards, by permission.

The source documents are:

IEEE Std 1394-1995, Standard for a High Performance Serial Bus

IEEE Std 1394a-2000, Standard for a High Performance Serial Bus – Amendment 1

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This included the use of tables, graphs, abstracts and scope statements from IEEE Documents

Foreword (This foreword is not part of 1394 Trade Association Specification 2007010)

This specification defines the electrical parameters for transmission at S3200 in Beta mode over short haul copper connections. It is written as an amendment to 1394-2008.

This specification was accepted by the Board of Directors of the 1394 Trade Association. Board of Directors acceptance of this specification does not necessarily imply that all board members voted for acceptance. At the time it accepted this specification, the 1394 Trade Association. Board of Directors had the following members:

, Chair
, Vice-Chair
, Secretary

Organization Represented *Name of Representative*

....

The Silicon Working Group Working Group, which developed and reviewed this specification, had the following members:

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Azim	Mohammed		
Jalil	Oraee		
Gregor	Reiner		
Kenji	Sakamoto		

Revision history

Revision 0.14 (December 13, 2007)

First revision in the 1394 Trade Association specification format.

Revision 0.90 (December 20, 2007)

Correct equalizer gain text in paragraph 9.3.2.1 to 20dB.

Change TDR Rise Time in table 9-23 to 80ps.

Update 1394TA Address.

Revision 0.91 (January 11, 2008)

Format and table of contents cleanup.

Modify Table 9-23 notes (b) and (c) to fully define "through connector" and "at termination".

Add note to Table 9-37 to indicate that intrapair skew for TP2 to TP3 is defined by paragraph 4.4.4.3.

Revision 0.92 (January 15, 2008)

Remove Table 9-23 notes (b) and (c).

Revision 0.93 (February 13, 2008)

Update 1394TA Address.

Add editing instructions for 4.4.4.5 and 4.4.4.6. Add S-parameter descriptive text to 4.4.4.5.

Delete 3.1.2 and 3.1.3.

Update Table 4-34.

Change peak of equalizer curve to 3.7 GHz.

Revision 0.94 (February 15, 2008)

Make signal pairs attenuation curve in 4.4.4.3 normative.

Format and cleanup.

Revision 0.95 (April 1, 2008)

Editorial changes in response to 1394 Trade Association Membership Ballot

S3200 Electrical Specification

1 Scope and purpose

1.1 Scope

This specification defines the electrical parameters for transmission at S3200 in Beta mode over short haul copper connections.

1.2 Purpose

This specification builds upon the IEEE 1394b standard, preserving all the advantages of FireWire while offering a major and unprecedented boost in performance. The new speed uses the cables and connectors already deployed for FireWire 800 products, making the transition forward easy and convenient for 1394 product vendors and their customers. Because the 1394 arbitration, data, and service protocols are not modified for S3200, silicon and software vendors can deploy the faster speed FireWire quickly and with confidence that it will deliver its full potential performance.

2 Normative references

2.1 Reference scope

The specifications and standards named in this section contain provisions, which, through reference in this text, constitute provisions of this 1394 Trade Association Specification. At the time of publication, the editions indicated were valid. All specifications and standards are subject to revision; parties to agreements based on this 1394 Trade Association Specification are encouraged to investigate the possibility of applying the most recent editions of the specifications and standards indicated below.

2.2 Approved references

The following approved specifications and standards may be obtained from the organization that controls them.

IEEE Std 1394-1995, Standard for a High Performance Serial Bus

IEEE Std 1394a-2000, Standard for a High Performance Serial Bus—Amendment 1

IEEE Std 1394b-2002, Standard for a High Performance Serial Bus—Amendment 2

2.3 References under development

At the time of publication, the following referenced specifications and standard was under development.

IEEE Std 1394-2008, Standard for a High Performance Serial Bus

Throughout this document, prior to the approval and publication of IEEE Std 1394-2008, Standard for a High Performance Serial Bus, the term “IEEE 1394" shall be understood to refer to IEEE Std 1394-1995 as amended by IEEE Std 1394a-2000 and IEEE Std 1394b-2002. Following the approval and publication of IEEE Std 1394-2008, Standard for a High Performance Serial Bus, the term “IEEE 1394" shall be understood to refer to IEEE Std 1394-2008, Standard for a High Performance Serial Bus. Note that cross-references to IEEE 1394 use the numbering of IEEE Std 1394-2008.

2.4 Reference acquisition

The references cited may be obtained from the organizations that control them:

Institute of Electrical and Electronic Engineers (IEEE), 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, USA; (732) 981-0060 / (732) 981-1721 (FAX); http://www.ieee.org/

In addition, many of the documents controlled by the above organizations may also be ordered through a third party:

Global Engineering Documents, 15 Inverness Way, Englewood, CO 80112-5776; (800) 624-3974 / (303) 792-2192; http://www.global.ihs.com/

3 Definitions and notation

3.1 Definitions

3.1.1 Conformance

Several keywords are used to differentiate levels of requirements and optionality, as follows:

3.1.1.1 expected: A keyword used to describe the behavior of the hardware or software in the design models assumed by this specification. Other hardware and software design models may also be implemented.

3.1.1.2 ignored: A keyword that describes bits, bytes, quadlets, octlets or fields whose values are not checked by the recipient.

3.1.1.3 may: A keyword that indicates flexibility of choice with no implied preference.

3.1.1.4 reserved: A keyword used to describe objects (bits, bytes, quadlets, octlets and fields) or the code values assigned to these objects in cases where either the object or the code value is set aside for future standardization. Usage and interpretation may be specified by future extensions to this or other specifications. A reserved object shall be zeroed or, upon development of a future specification, set to a value specified by such a specification. The recipient of a reserved object shall ignore its value. The recipient of an object defined by this specification as other than reserved shall inspect its value and reject reserved code values.

3.1.1.5 shall: A keyword that indicates a mandatory requirement. Designers are required to implement all such mandatory requirements to assure interoperability with other products conforming to this specification.

3.1.1.6 should: A keyword that denotes flexibility of choice with a strongly preferred alternative. Equivalent to the phrase “is recommended.”

3.2 Notation

3.2.1 Numeric values

Decimal and hexadecimal are used within this specification. By editorial convention, decimal numbers are most frequently used to represent quantities or counts. Addresses are uniformly represented by hexadecimal numbers. Hexadecimal numbers are also used when the value represented has an underlying structure that is more apparent in a hexadecimal format than in a decimal format.

Decimal numbers are represented by Arabic numerals without subscripts or by their English names. Hexadecimal numbers are represented by digits from the character set 0 – 9 and A – F followed by the subscript 16. When the subscript is unnecessary to disambiguate the base of the number it may be omitted. For the sake of legibility hexadecimal numbers are separated into groups of four digits separated by spaces.

As an example, 42 and $2A_{16}$ both represent the same numeric value.

4 S3200

To specify operation at S3200, amend clauses in IEEE 1394 as follows:-

4.4.4.3 Signal pairs attenuation

Revised last two sentences of the second paragraph to:
Connector/cable assemblies shall be swept through the frequencies listed in table 4.34 with the stop frequency of 4000MHz. Curves shall be smooth with no anomalous behavior, and signal pair attenuation shall be less than the worst-case curve described by the equation:

$$\text{insertion loss (dB)} < 3 * f + 4.5 * \text{sqrt}(f)$$
$$0.1 \text{ GHz} < f \text{ (GHz)} < 4 \text{ GHz}$$

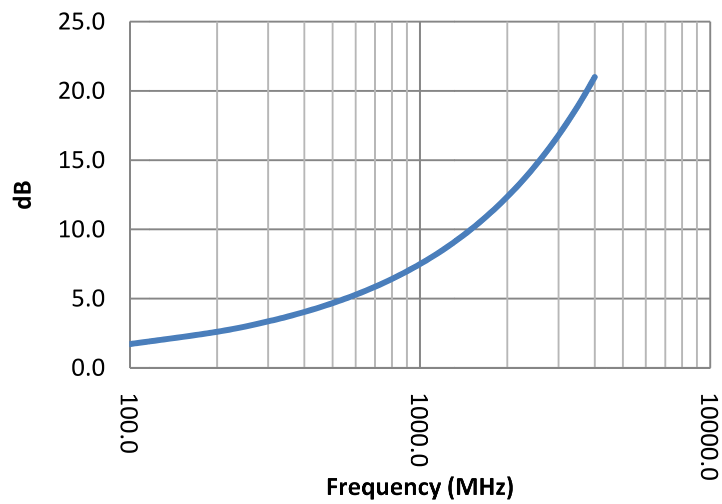


Figure 4-59A — S3200 Cable Insertion Loss

Revised table 4-34:

Table 4-34 — Signal pairs attenuation

Frequency	Cable attenuation (informative)	Connector allowance (informative)	Total attenuation	
			Min (normative)	Max (informative)
250 MHz	≤ 2.30 dB	1.00 dB	**n/a**	3.30 dB
400 MHz	≤ 2.90 dB	1.20 dB	**n/a**	4.10 dB
500 MHz	≤ 3.50 dB	1.35 dB	**n/a**	4.85 dB
800 MHz	≤ 4.60 dB	1.60 dB	**n/a**	6.20 dB
1000 MHz	≤ 5.50 dB	2.00 dB	**2.50 dB**	7.50 dB
1500 MHz	≤ 7.60 dB	2.40 dB	**2.75 dB**	10.0 dB
2000 MHz	≤ 9.50 dB	2.90 dB	**3.0 dB**	12.4 dB
3000 MHz	≤ 13.30 dB	3.50 dB	**4.0 dB**	16.8 dB
4000 MHz	≤ 16.60 dB	4.40 dB	**5.0 dB**	21.0 dB

6000 MHz (informative)	≤ 23.00 dB	6.00 dB	**5.0 dB**	29.0 dB

Delete section 4.4.4.5:

4.4.4.5 Signal pairs rise time degradation

Replace section 4.4.4.6 in its entirety :

4.4.4.6 Signal pairs intra-pair propagation skew

This Clause applies to type 1 cable assemblies only.

Intra-pair skew at DC does not provide a sound basis for measuring the contribution to jitter from skew-type effects at high frequencies. Indeed, the contribution to jitter is often considerably less than might be implied from a DC skew measurement.

S-parameters provide an effective method to completely define the characteristics of a cable, including attenuation, return loss, crosstalk, and skew. All parameters that affect the performance of a cable, including conversions between differential and common mode.

The net impact of skew-type effects is the introduction of jitter due to differential-to-common mode conversion, which may be derived directly from S-parameter measurements across a suitable frequency range by taking the difference between SDD21 and SCD21.

Differential-to-common mode conversion shall be less than:

10 * log (sin(pi * 0.1/(BASE_RATE*32*10/8/1000) * f))

Where:

0.1 represents a bound of 0.1UI jitter and
f is the frequency in GHz.
This shall be measured from 199.608 MHz to 3.145 GHz (0.05 of bit rate to 0.8 of bit rate).

The resulting curve is shown in the following graph:

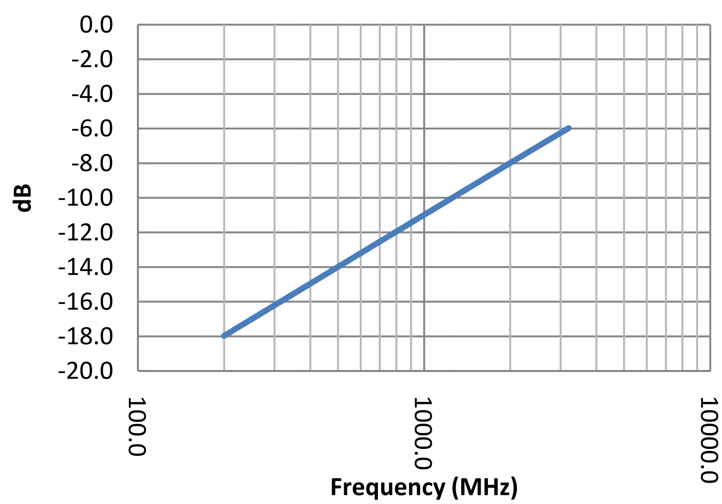


Figure 4-59B — S3200 Cable SCD21-SDD21

There is no requirement to meet a DC inter-pair skew parameter.

9.3.1 Transmitter electrical specifications

Updated Table 9-21 to add a column for S3200:

Table 9-21 — Beta mode short-haul copper transmitter characteristics

Parameter	S3200B	Units
Tolerance	+/- 100	ppm
Differential amplitude (Note 1)		
Maximum	800	mV
Minimum	555	mV
Maximum (OFF)	20	mV
De-emphasized differential output voltage ratio (Note 5)		
Maximum	4	dB
Minimum	1	dB
Rise and fall time (10%-90%)		
Maximum (Note 6)	175	ps
Minimum	80	ps
Differential skew (Note 3)	16	ps
	20%	actual rise time
Common-mode output impedance	< 55	Ohm
Maximum common-mode voltage	2.415	V

Amended Notes to Table 9-21:

6 - At S1600 and S3200, the 175 ps maximum for rise and fall times is informative. The eye diagram (Figure 9-14) should be used for S1600 and S3200 compliance testing.

7 – Measurements of rise and fall times for S1600 and S3200 are performed with deemphasis disabled.

Amended second paragraph in 9.3.1:

De-emphasis shall be implemented for S1600 and S3200 transmissions when multiple bits of the same polarity are output in succession. Subsequent bits shall be driven at a differential voltage level 3.5 dB (±0.5 dB) for S1600 and 2.5 dB (±1.5 dB) for S3200 below the first bit. Individual bits, and the first bit of a sequence in which all bits have the same polarity, are always be driven between the Min and Max values as specified for the Differential Amplitude in Table 9-21. An example waveform illustrating de-emphasis and representing the bit sequence (from left to right) of "1001000011" is shown in Figure 9-12.

Amended Note:

Note: — The specified amount of de-emphasis for S1600 allows for designs to optimize maximum interoperability while minimizing complexity of managing configurable de-emphasis values. Thus, the primary benefits of de-emphasis are targeted for worst-case loss budgets of 7.5 dB, while being slightly less optimal for lower loss systems. However, this tradeoff is more than offset by the fact that there is inherently more voltage margin in lower loss systems.

Added Notes:

Note: The specified amount of de-emphasis for S3200 does not provide sufficient correction for the degradation of cables and connectors. Equalization or other methods are required at the receiver to provide correction for reliable operation across variable lengths and qualities of cables.

Note: Deemphasis levels for S3200 allow for a silicon implementation that is common with the S1600 levels. The deemphasis specification is measured at TP2, so S3200 will show more variance and less deemphasis than S1600, even with the same launch amplitude, due to high frequency rolloff of the silicon package and PCB parameters.

Revised Label of Figure 9-12

Figure 9-12 – Example of S1600 and S3200 de-emphasis

Revised Table 9-22 to be consistent with jitter tables and to add rows for S3200:-

Table 9-22 – Normalized time intervals at TP2

Speed	Symbol	Value	Units	Equivalent ps from idealized threshold
S3200	X1	0.23	UI	58
	X2	0.44	UI	110

Changed note:

11 – Normalized time intervals for S1600 and S3200 are measured with deemphasis disabled.

9.3.2 Receiver electrical specifications

Figure 9-17 is the receive eye diagram. This will not be provided for S3200, as it is totally closed.

Updated table 9-23 to include a column for S3200:

Table 9-23 — Short-haul copper receiver characteristics when using Beta mode

Parameter	S3200	Unit
Baud rate tolerance	+/-100	ppm
Minimum differential sensitivity	n/a	mV
Input impedance test conditions		
TDR rise time	80	ps
Exception window	700	ps
Input impedance @ TP3		
Through connection	Refer to 4.4.4.2	Ohm
At termination	110 +/- 10	Ohm
Differential skew	5%	Unit interval
Maximum differential skew tolerance	85	ps
Common-mode input impedance	>550	Ohm
Maximum common-mode input voltage	2.915	V
Fault voltage tolerance	-0.9 to +3.315	V
Rise/fall time tolerance	400	ps

Amended Note to Table 9-23:
[d]S1600 and S3200 rise/fall time tolerance should be measured with de-emphasis enabled.

Amended table 9-24 to include rows for S3200

Table 9-24 — Normalized time intervals forTP3

Speed	Symbol	Value	Units	Equivalent ps from idealized threshold
S3200	X1	n/a	UI	n/a
	X2	n/a	UI	n/a

After table 9-24 added:

9.3.2.1 S3200 Equalization (informative)

For proper receiver operation, an equalizer or other method is required to correct the incoming bitstream to achieve the bit error rate objective. A fixed equalizer with 16 dB of gain at 3.7 GHz (shown in the following figure) has been shown to produce an eye opening of 0.40 UI under worst-case conditions. However, a fixed equalizer setting may degrade the eye under non worst case conditions. An adaptive equalizer is preferred and may be easier to realize in implementation for correct operation in all conditions. It must still be able to provide enough gain to correct for worst-case conditions.

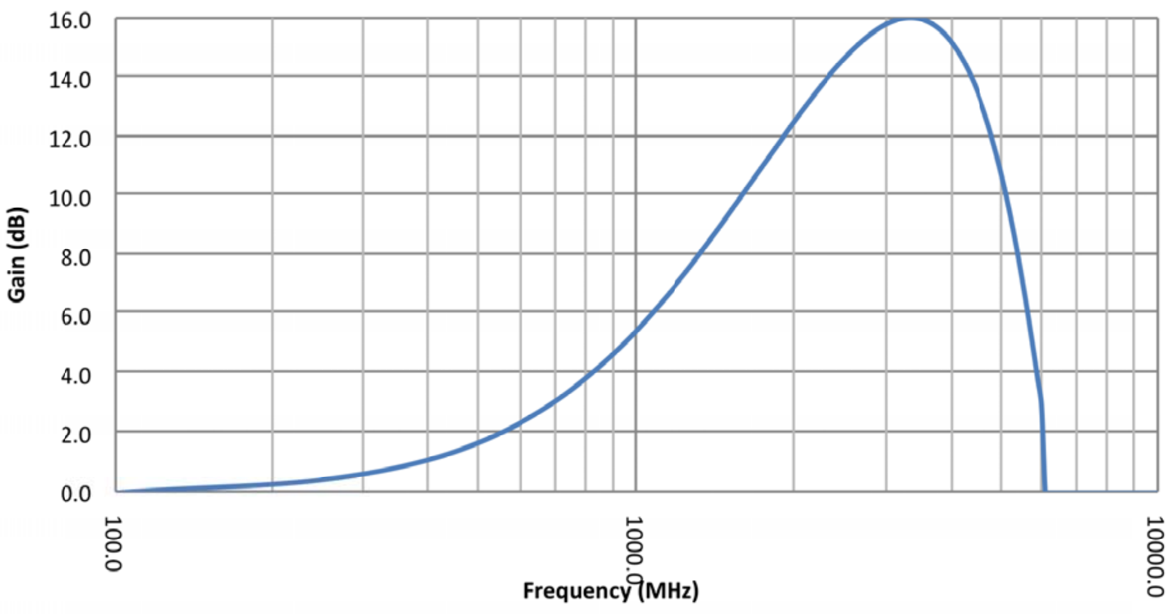


Figure 9-17B – Example S3200 Fixed Equalizer Function

9.3.3 Electrical measurements

Added paragraphs:

9.3.3.7 S3200 Bit Error Rate (BER)

The S3200 receiver Bit Error Rate is a measure of the number of incorrect symbol decisions made by the receiver and clock recovery mechanism over a period of time. BER is measured using worst-case transmission conditions and is expressed in terms of number of incorrect bit decisions over the number of bits that were transmitted.

The device shall employ a loopback mode which transmits received 10B characters such that the transmitted characters can be compared against the received characters. The test fixture must initially provide a K28.5 character stream to allow the device to achieve character synchronization. The device will not begin to transmit the received data until it has achieved a reliable character synchronization. To accommodate frequency offset between the test fixture and the device, the test fixture must transmit exactly four D28.2 characters every 1000 characters. The receiver shall employ a FIFO that initially holds four received characters before sending them to the transmitter. On receiving three D28.2 characters, the device will either insert an additional D28.2 character if its FIFO is depth is less than four characters, or remove the last received D28.2 character if its FIFO depth is four or more characters. Since D28.2 characters have even disparity, the disparity will remain unchanged when these characters are added or removed by the device.

The measurement is performed at the connector of the device under test. The test may be done with worst-case cables and a real transmitter (with de-emphasis), or by directly applying a shaped waveform into the connector.

9.3.3.8 S3200 Electrical Test Configuration

The S3200 electrical tests are configured using a modified speed toning pattern. The actual speed tone encoding and negotiation sequence remain unchanged, but when the STOP bit (bit 8) is encoded as 1 the device is placed into Electrical Test mode, and the TS bits (bits 6 & 7) are used to determine the operation of the device transmitter. See section *14.8.3 Beta-mode speed negotiation*. The encoding of these tone bits are as follows:

Table 9-24A — S3200 Electrical Test Selection

TS1	TS2	Mode	De-emphasis
0	0	Transmit alternate K28.5	OFF
0	1	Transmit alternate K28.5	ON
1	0	Transmit D21.5	ON
1	1	BER	ON

When speed negotiation is complete, the test fixture will transmit a continuous tone to the device. In BER mode, the test fixture will switch to a random character stream after it detects that the receiver has achieved character synchronization. After the device enters an electrical test mode, it shall remain in that mode until it detects that it is no longer receiving either a valid 8B/10B stream (in BER mode) or a continuous tone (in other modes).

9.3.6 Jitter specifications

Added row to Table 9-30 for S3200

Table 9-30 — S3200B short haul copper jitter output

Speed	Corner frequency	Units
S3200B	2.358	MHz

Added Tables 9-36A and 9-36B

Table 9-36A — S3200B short haul copper jitter output

Jitter output	ps			
Compliance Point	DJ pk-pk	RJ RMS	RJ pk-pk	TJ pk-pk
TP1	33	3	42	75
TP1 to TP2	41	0	0	41
TP2	**74**	3	42	**116**
TP2 to TP3	149	0	0	149
TP3	223	3	42	268
TP3 to TP4	>65	0	0	>65
TP4				>330

Table 9-36B — S3200B short haul copper jitter tolerance

Jitter tolerance	ps				
Compliance Point	DJ pk-pk	RJ RMS	RJ pk-pk	Sinusoidal pk-pk	TJ pk-pk
TP1	NA	NA	NA	NA	NA
TP2	74	3	42	30	146
TP3	**219**	3	42	**30**	**298**
TP4	NA	NA	NA	NA	NA

9.3.7 Intrapair Skew

Updated Table 9-37 to include S3200 Intrapair Skew:

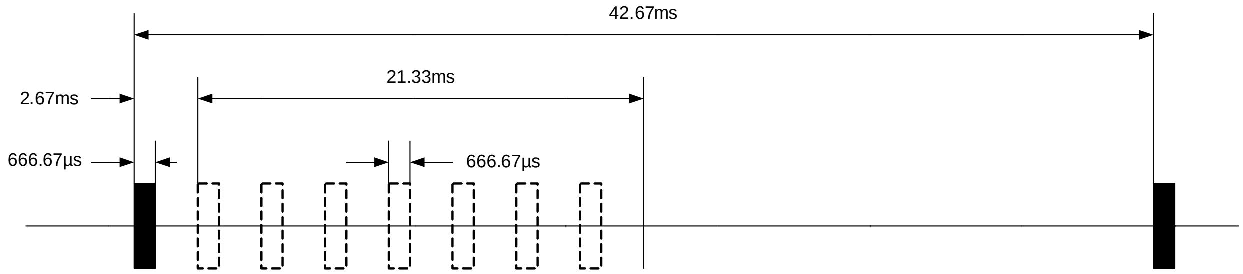
Table 9-37 — Intrapair Skew

	Intrapair Skew (ps)	
Compliance point	**S3200**	
	Contr	*Cumul*
TP1	8	8
TP1 to TP2	16	
TP2		24
TP2 to TP3	25[a]	
TP3		49[a]
TP3 to TP4	16	
TP4		65[a]

[a]Intrapair skew from TP2 to TP3 for S3200 is defined by paragraph *4.4.4.6 Signal pairs intra-pair propagation skew* and will change with frequency. The table entry of 25 ps is a nominal low-frequency value that is useful for measurement.

14.8.3 Beta-mode speed negotiation

Updated Figure 14-4:



ack	1	0	0	FOP	PIL	0	S100 Connection
	0	1	0	FOP	PIL	0	S200 Connection
	1	1	0	FOP	PIL	0	S400 Connection
	0	0	1	FOP	PIL	0	S800 Connection
	1	0	1	FOP	PIL	0	S1600 Connection
	0	1	1	FOP	PIL	0	S3200 Connection
	0	1	1	TS1	TS2	1	S3200 Electrical Test

Figure 14-4 — Speed code timing diagram

Amended the third paragraph after Figure 14-4:

Three further bits in the speed code are allocated to indicate whether the peer port is in Connection mode or Electrical Test mode, the PIL_Capable and FOP_Capable properties of the peer port, and the electrical test configuration requested by the peer port. Connection mode is indicated by a zero as the last bit in the sequence, while a one indicates that the device is to enter the S3200 Electrical Test Mode.

In Connection mode, port that is not PIL_Capable shall not acknowledge a received speed code with the FOP_Capable bit set, and a port that is not FOP_Capable shall not acknowledge a received speed code with the PIL_Capable bit set. See Clause 18 for the behavior of PIL_Capable and FOP_Capable ports.

In Electrical Test mode, the bits TS1 and TS2 define the electrical test configuration. See section *9.3.3.8 S3200 Electrical Test Configuration.*