1394 Copper Automotive Standard
(Supplement to IDB-1394)

June 20, 2008

Sponsored by:
1394 Trade Association

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Abstract
This specification extends the IDB-1394 Automotive Specification to include operation over copper cabling, including IEEE 1394 cables, coaxial, shielded twisted pair, and shielded quad.

Keywords
IEEE 1394, Serial Bus, automotive; IDB-1394, coaxial cable, shielded twisted pair cable, shielded quad cable, copper cable; 1394Cu
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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
IEEE Std 1394c-2006, Standard for a High Performance Serial Bus – Amendment 3
IEEE Std 1394-200X, Standard for a High Performance Serial Bus

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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 TS2008001)

This specification extends the IDB-1394 Automotive Specification to include operation over low-cost, high-performance copper cabling media. It defines the features and mechanisms that provide high-speed extensions in a forward and backward compatible fashion and the ability to signal over single hop distances of up to 8 meters with a minimum of 5 inline connectors, in an automotive environment. Critical vehicle functions and services are addressed that are non-safety related, including but not limited to multimedia and telematics applications at data rates of S400 or S800.
There are 2 annexes in this specification. Annex A is normative and is part of this specification. Annex B is informative and is not considered part of this specification.

This specification was accepted by the Board of Directors of the 1394 Trade Association on July 27, 2007. 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:

Eric Anderson, Chair
Max Bassler, Vice-Chair
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<thead>
<tr>
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<th>Name of Representative</th>
</tr>
</thead>
<tbody>
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<td>EqoLogic</td>
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</tr>
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<td>Littelfuse</td>
<td>Max Bassler</td>
</tr>
<tr>
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<td>Dave Thompson</td>
</tr>
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<td>Oxford Semiconductor</td>
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</tr>
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<td>Burke Henehan</td>
</tr>
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<td>Will Harris</td>
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Revision history

Revision 0.81 (Jan. 21, 2008) – distributed to task group

Revision 0.82 (Jan. 30, 2008) – added STP/STQ electrical specification and Power Management clauses

Revision 0.83 (Jan. 31, 2008) – marked up at AUWG meeting in Kona

Revision 0.84 (Feb. 07, 2008) – edits from the 1/31/8 AUWG meeting

Revision 0.85 (Feb. 13, 2008) – clause restructuring from the 1/31/8 AUWG meeting and added additional material submitted by clause authors

Revision 0.86 (Feb. 21, 2008) – changes from 2/14/8 conference call

Revision 0.87 (March 7, 2008) – changes from 2/25/8 conference call

Revision 0.88 (March 19, 2008) – changes from conference calls on 3/10/8 and 3/14/8. Submitted for Automotive WG ballot.

Revision 0.89 (April 25, 2008) – submitted to BRC for review of changes

Revision 0.90 (May 02, 2008) – final changes from BRC review, submitted for SIG ballot.

Revision 0.91 (June 09, 2008) – incorporated changes from the SIG ballot comments

Revision 0.92 (June 20, 2008) – fixed minor editorial errors
1394 Copper Automotive Standard (Supplement to IDB-1394)

1 Scope and purpose

1.1 Scope
This supplement is a full use standard that is intended to supplement the IDB-1394 Automotive Specification and IEEE 1394. It defines the features and mechanisms that provide high-speed extensions in a forward and backward compatible fashion and the ability to signal over single hop distances of up to 8 meters with a minimum of 5 inline connectors, in an automotive environment. Critical vehicle functions and services will be addressed that are non-safety related, including but not limited to multimedia and telematics applications at data rates of S400 or S800. Future versions of this standard may extend operation to higher data rates such as S1600 and S3200.

The following approved media and topics are included in this supplement:

- Copper interconnects that are compatible and supplemental with IDB-1394-POF used in a hybrid optical and electrical network.
- Copper interconnects for use as an embedded vehicle system network.
- Copper interconnects that can be used to attach clusters of embedded 1394 devices.
- Power management improvements.

The proceeding are arranged in no particular order.

1.2 Purpose
This specification extends the IDB-1394 Automotive Specification to include operation over low-cost, high-performance copper cabling media. Advantages of the 1394Cu copper backbone include higher speed, longer distances, improved power management, and improved EMC performance.

Types of cabling media covered by this specification include:

- coaxial cable
- shielded twisted quad (STQ) cable
- shielded twisted pair (STP) cable.

OEMs may specify exceptions to this standard to fit their needs.
<blank page>
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 organizations that control them.

- IEEE Std 1394a-2000, Standard for a High Performance Serial Bus—Amendment 1
- IEEE Std 1394c 2006, Standard for a High Performance Serial Bus—Amendment 3
- SAE/USCAR-2, Rev. 5, Performance Specification for Automotive Electrical Systems
- AMI-C 2002 1.0.2 Draft Common Message Set
- AMI-C 3013 Power Management Architecture
- AMI-C 3023 Power Management Specification
- AMI-C 3033 Power Management EPOC System Description
- AMI-C 3034 Power Management Test Document


2.3 References under development

At the time of publication, the following referenced specifications and standards were under development.

- IEEE Std 1394-2008, Standard for a High Performance Serial Bus. This standard, which will probably be issued in the second half of 2008, will replace the four IEEE 1394 specifications listed in clause 2.2.
- 1394 Trade Association Document TS2002005, “Base 1394 Test Suite Definition with Extension for 1394b”

2.4 Reference acquisition

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

1394 Trade Association, 1560 East Southlake Blvd, Suite 220, Southlake, TX  76092 USA; (817) 416-2200 / (817) 416-2256 (FAX); http://www.1394ta.org/

American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY  10036, USA; (212) 642-4900 / (212) 398-0023 (FAX); http://www.ansi.org/
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.”

3.1.2 Glossary

The following terms are used in this specification:

3.1.2.1 Coaxial cable: A cable in which a single center conductor is surrounded by a dielectric material and then a cylindrical shield that is often composed of layers of foil and metallic braid.

3.1.2.2 Inline connector: A connector which is in addition to the connectors at the ends of the cabling run.

3.1.2.3 Return loss: The ratio of outgoing signal power to reflected signal power.

3.1.2.4 Shielded twisted quad: Cable consisting of an overall shield enclosing two differential copper pairs arranged such that each pair is in the virtual groundplane of the other pair.

3.1.2.5 Shielded twisted pair: Cable consisting of two twisted pairs of copper conductors enclosed by a metallic shield to protect the cable from electromagnetic interference.

3.1.3 Abbreviations

The following are abbreviations that are used in this specification:

- BBC baseband coaxial
- CCP customer convenience port
FCP  function control protocol
FFS  For future specification
FOT  fiber optic transceiver
LPM  local power manager
OEM  original equipment manufacturer (including automotive manufacturers, tier suppliers, and
 components suppliers)
PCB  printed circuit board
PMD  physical media dependent
PMP  power management protocol
POPM  PHY-only power mode
SPM  system power master
STP  shielded twisted pair cable
STQ  shielded twisted quad
TDR  time domain reflectometry
VP   VersaPHY
WOT  wake on tone (see [B1])

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.

3.2.2 Bit, byte and quadlet ordering

This specification uses the facilities of Serial Bus, IEEE 1394, and therefore uses the ordering conventions of Serial
Bus in the representation of data structures. In order to promote interoperability with memory buses that may have
different ordering conventions, this specification defines the order and significance of bits within bytes, bytes within
quadlets and quadlets within octlets in terms of their relative position and not their physically addressed position.
Within a byte, the most significant bit, \textit{msb}, is that which is transmitted first and the least significant bit, \textit{lsb}, is that which is transmitted last on Serial Bus, as illustrated below. The significance of the interior bits uniformly decreases in progression from \textit{msb} to \textit{lsb}.

\begin{tabular}{|c|c|}
\hline
\textit{msb} & \textit{lsb} \\
\hline
\end{tabular}

\textbf{Figure 1 – Bit ordering within a byte}

Within a quadlet, the most significant byte is that which is transmitted first and the least significant byte is that which is transmitted last on Serial Bus, as shown below.

\begin{tabular}{|c|c|c|c|}
\hline
\textit{most significant byte} & \textit{second most significant byte} & \textit{next to least significant byte} & \textit{least significant byte} \\
\hline
\end{tabular}

\textbf{Figure 2 – Byte ordering within a quadlet}

Within an octlet, which is frequently used to contain 64-bit Serial Bus addresses, the most significant quadlet is that which is transmitted first and the least significant quadlet is that which is transmitted last on Serial Bus, as the figure below indicates.

\begin{tabular}{|c|c|c|}
\hline
\textit{most significant quadlet} & \textit{least significant quadlet} \\
\hline
\end{tabular}

\textbf{Figure 3 – Quadlet ordering within an octlet}

When block transfers take place that are not quadlet aligned or not an integral number of quadlets, no assumptions can be made about the ordering (significance within a quadlet) of bytes at the unaligned beginning or fractional quadlet end of such a block transfer, unless an application has knowledge (outside of the scope of this specification) of the ordering conventions of the other bus.
4 System Overview

4.1 System Requirements

This supplement covering copper interconnections shall supplement the existing IDB–1394 specification and IEEE 1394 standards to permit use of 1394 over copper cabling within the passenger compartment environment.

The 1394 Copper Automotive Specification (also referred to as 1394Cu) will define the automotive grade physical layers (e.g. cables, connectors) needed to ensure interoperability of all IEEE 1394 devices.

1394Cu requires an IEEE 1394 Beta PHY in the node driving the copper backbone and an IEEE 1394 bilingual PHY in the node driving the CCP.

4.2 System Topology

1394Cu defines a system architecture/topology that addresses the special needs of the automotive industry with respect to extended temperature range, coding of the interface, mechanical robustness and excellent electromagnetic shielding. The system topology consists of a POF and/or a copper backbone vehicle network and optionally one or more CCP interfaces which provide the ability to attach hot-pluggable portable devices to the vehicle’s internal 1394 backbone. The portable devices are not limited to, but consist mainly of multi-media devices. The CCP-interfaces typically consist of a standard 9-pin connector that may either be attached to the internal cabling directly or that is electrically connected to the 1394 backbone e.g. by an adapter board. These elements, in total, shall comprise a single logical IEEE 1394 network as shown in Figure 4.

Embedded devices shall implement a point-to-point tree topology as defined within the IEEE 1394 standard. IDB-1394 imposes no topology limitations (e.g. Daisy-chaining). Loops are permitted within the physical topology interconnect per IEEE 1394.

All link layer and transaction layer implementations conforming to this standard shall meet the performance criteria specified in IDB-1394 Automotive and IEEE 1394.

All implementations regarding basic serial bus management conforming to this standard shall meet the performance criteria specified in IEEE 1394 unless otherwise specified.

Networks which transmit isochronous data shall have at least one isochronous resource manager capable node.

4.3 Physical Layer -- Copper Backbone Embedded Devices

Embedded network devices generally refer to those electronic modules physically integrated within the vehicle. It is recommended the vehicle provide at least one unused embedded copper backbone port for expansion and test capabilities of the embedded copper backbone network at the end of the logical network. The embedded network (cables and connectors only) shall be S800 capable to allow expansion as future 1394Cu devices are introduced. The actual embedded devices and header may support S400 operation. Faster devices shall be backwards compatible and perform automated speed configuration as defined in the IEEE 1394 specification.

In-line Copper Backbone connectors are permitted in the embedded network and may be inserted between embedded devices to accommodate network routing throughout the vehicle.

1394Cu shall, at a maximum, permit operation between any two embedded devices separated by up to 8 meters of copper with five in-line connectors.
Figure 4 -- Hybrid System Topology
5 General Requirements

5.1 Introduction
This clause specifies the electrical and physical properties of 1394Cu Copper Backbone embedded network used to interconnect devices in the automotive embedded network. This is a unique class of products with an automotive grade Copper Backbone. The connectors and cables are designed to meet all the specific requirements of the automotive industry. The electrical test sequences found in this clause are based on the IEEE 1394 standard. The mechanical and environmental test parameters are reasonably stringent for typical automotive applications. STP, STQ and coax solutions may meet these requirements. The interface details of the connectors are found in clauses 8-10.

5.2 Notable elements of an automotive grade captive system:
– Cable and Connector Interface are not intended to support hot plug requirements.
– Connector types may differ in a given cable system assuming all electrical, mechanical and EMI requirements meet with specific and end application need.
– In systems that are not captive (Embedded), all specification requirements default to the CCP requirements defined by IDB-1394.

5.3 Copper Backbone Socket Environmental-, Aging- and Mechanical Criteria
The Copper Backbone socket as defined in this clause will be within the passenger compartment of a vehicle. The copper backbone has to meet specific requirements of the automotive industry. Table 1 summarizes the environmental, Table 2 the electrical and DC-requirements.

The connector system has to provide cable-to-cable (inline) connectivity and a sufficient number of mechanical codings.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temperature</td>
<td>+100°C, 1008h</td>
</tr>
<tr>
<td>Thermal Shock</td>
<td>99 cycles Tu-40°C, To+100°C</td>
</tr>
<tr>
<td>Temperature and Humidity</td>
<td>RH 80-100%, 40 Cycles, Tu-40°C, To+100°C</td>
</tr>
<tr>
<td>Mechanical Shock</td>
<td>10 Shocks, 35g, 10ms</td>
</tr>
<tr>
<td>Random Vibration</td>
<td>10 -1000Hz, Grms 1.81</td>
</tr>
</tbody>
</table>

Table 1 -- Environmental requirements of the automotive industry
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Units</th>
</tr>
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<tr>
<td>Mating Cycles</td>
<td>25</td>
<td></td>
<td>Cycles</td>
</tr>
<tr>
<td>Mating Force Connector Pair</td>
<td></td>
<td>55</td>
<td>N</td>
</tr>
<tr>
<td>Unmating Force Connector Pair</td>
<td></td>
<td>5</td>
<td>55 N</td>
</tr>
<tr>
<td>Retention Force Connector Lock</td>
<td></td>
<td>100</td>
<td>N</td>
</tr>
<tr>
<td>Connector Lock Manipulation Force</td>
<td>3</td>
<td>60</td>
<td>N</td>
</tr>
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<td>Polarization Feature Effectiveness</td>
<td>80</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Cable to Connector Retention Force</td>
<td>100</td>
<td></td>
<td>N</td>
</tr>
</tbody>
</table>

**Table 2 – Mechanical requirements of the automotive industry**

In order to meet the needs of the global automotive industry, this clause contains strong recommendations for the environmental and mechanical properties of cables, connectors and systems that ensure reliable operation. The specifications are widely accepted among the automotive industry and have been proven as a reliable means to guarantee proper operation of multimedia equipment within the complex automotive environment.

5.4 **Link length and number of inline connectors**

The 1394Cu copper backbone shall support links up to 8m in length. A link may contain up to 5 inline connectors. Longer links and/or additional inline connectors may optionally be supported.

5.5 **Copper Backbone Electrical Requirements**

5.5.1 **STP and STQ Electrical Requirements**

The copper backbone for STQ and STP shall meet the electrical requirements summarized in Table 3.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>System impedance (ZTP)</td>
<td>100 Ω or 110 Ω</td>
</tr>
<tr>
<td>Mated connector and termination impedance¹</td>
<td>ZTP +/- 15 Ω</td>
</tr>
<tr>
<td>Cable impedance</td>
<td>ZTP +/- 6 Ω</td>
</tr>
<tr>
<td>TDR rise time</td>
<td>160 ps</td>
</tr>
<tr>
<td>Propagation velocity within cable</td>
<td>min. 66 % c₀</td>
</tr>
<tr>
<td>Propagation delay skew within a mated connector pair – straight</td>
<td>max. 10 ps</td>
</tr>
<tr>
<td>Cable propagation delay skew within a wire pair</td>
<td>max. 10 ps/m</td>
</tr>
<tr>
<td>Maximum propagation delay skew of entire cable assembly</td>
<td>160 ps</td>
</tr>
<tr>
<td>Total insertion loss budget</td>
<td></td>
</tr>
<tr>
<td>f &lt; 250 MHz</td>
<td>&lt;4.8 dB</td>
</tr>
<tr>
<td>f &lt; 400 MHz</td>
<td>&lt;6.0 dB</td>
</tr>
<tr>
<td>f &lt; 500 MHz</td>
<td>&lt;6.8 dB</td>
</tr>
<tr>
<td>f &lt; 800 MHz</td>
<td>&lt;9.2 dB</td>
</tr>
<tr>
<td>f &lt; 1000 MHz</td>
<td>&lt;10.4 dB</td>
</tr>
<tr>
<td>Variation of insertion loss in the temp.-range -40°C to +100°C</td>
<td>+/- 0.05 dB/m (0 – 1 GHz)</td>
</tr>
<tr>
<td>Return loss -- mated connector pair</td>
<td>min. 20 dB (0 – 1 GHz)</td>
</tr>
<tr>
<td>Near end crosstalk -- mated connector pair</td>
<td>max. 5 % (differential TDT at 160 ps, 10-90% rise time) max. -30 dB (0 – 1 GHz)</td>
</tr>
<tr>
<td>Far end crosstalk -- mated connector pair</td>
<td>max. 5 % (differential TDT at 160 ps, 10-90% rise time) max. -30 dB (0 – 1 GHz)</td>
</tr>
</tbody>
</table>

Table 3 – STP/STQ copper backbone electrical requirements

¹ Termination = PCB attachment or cable termination
5.5.2 Coaxial Cable Electrical Requirements

The BBC PMD specification [B1] defines the electrical requirements for coaxial cables and connectors. For automotive, 50 ohm cabling shall be used. An informative summary is given in the next paragraphs. The norms can be found in [B1].

In addition, it is highly recommended that the connectors are compliant with the electrical requirements of USCAR-17 [B14]

5.5.2.1 Coaxial cables (Informative)

Coaxial cables should have a nominal characteristic impedance of 50 ± 2 ohms. Table 4 gives nominal specifications for a couple of commonly used types of coaxial cable.

<table>
<thead>
<tr>
<th>Type</th>
<th>Characteristic Impedance (Ω)</th>
<th>Center Conductor DC Resistance (Ω/100m)</th>
<th>Attenuation (dB/100m) 250 MHz</th>
<th>500 MHz</th>
<th>1 GHz</th>
<th>Approx. Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample RG-174</td>
<td>50</td>
<td>31.8</td>
<td>46</td>
<td>70</td>
<td>112</td>
<td>2.5</td>
</tr>
<tr>
<td>Sample RG-58</td>
<td>50</td>
<td>3.4</td>
<td>27</td>
<td>41</td>
<td>66</td>
<td>6.4</td>
</tr>
<tr>
<td>Sample RTK-031</td>
<td>50</td>
<td>4.7</td>
<td>26</td>
<td>39</td>
<td>56</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Table 4 -- Coaxial cable specifications

5.5.2.2 Coaxial connectors (informative)

Coaxial connectors should have a nominal impedance of 50 ohm.

The return loss of a mated connector pair should be 30dB or greater at all frequencies from 1Mhz up to the fundamental frequency (250Mhz for S400, 500Mhz for S800). The mated connector pair can be board-mount connectors or inline connectors.

5.6 Validation Requirements

Tables of validation tests are provided in Annex A. Test Groups A through F are intended to evaluate the suitability of connector and connector/cable assemblies to be used in Class 2 automotive applications. The tests are USCAR 2 test methods used by major automotive OEM's to validate connector system performance. In addition to the USCAR 2 test methods, the test groups include tests, adaptations and requirements specific to 1394 connectors and cables in automotive applications. This test plan also includes 1394 signal integrity assessment before and after long term aging field simulation. Performing these tests and meeting the requirements will satisfy OEM validation objectives for connector/cable validation requirements. OEM's may require additional application specific tests and/or requirements which are beyond the scope of this document.

5.7 Copper Backbone EMI/EMS-Performance

The global automotive industry is very aware of the importance of very good EMI/EMS-performance of their products. The reason is to prevent unwanted interference of systems within a vehicle due to electromagnetic coupling. Malfunction of systems in a car due to EMI may cause fatal consequences. In order to meet these needs, this clause contains strong recommendations for the EMI/EMS-properties of cables, connectors and systems that
ensure correct operation. These are widely accepted among the automotive industry and have been proven as a reliable means to guarantee proper operation of multimedia equipment within the complex automotive environment.

Nevertheless, it is up to the OEM to change these specifications on his own responsibility.

5.7.1 EMI-Tests on System Level

The copper backbone shall meet the EMI-requirements following CISPR 25 Grade 5, latest revision.

The copper backbone shall meet the EMS-requirements following ISO 11452-4, latest revision. A test current of 100 mA shall be applied in closed loop configuration in the frequency range from 1 MHz to 400 MHz.

Alternatively, EMS-tests may also be carried out following the procedures described in ISO 11452-5, latest version. In this case, the test field strength shall be 200 V/m in the frequency range from 1 MHz to 400 MHz.

No bus resets may be observed in both test procedures at the specified limits.

5.7.2 EMI-Tests on Component Level

A very suitable means to ensure proper shielding of each of the components involved in the signal path is to evaluate their EMI-performance on component level. The advantage of this approach is, that measurements may be carried out before the integration of the whole system. When testing on system-level, the system integrator can therefore rely on the EMI/EMC-performance of each of the components of the copper backbone.

It is strongly recommended to carry out the EMI-test on component level by application of the coaxial test setups described by the specifications IEC62153-4-4, IEC62153-4-7 and IEC62153-4-10.

IEC 62153-4-4, Screening attenuation of cables -65 dB to 2 GHz
IEC 62153-4-7, Screening attenuation of connectors -65 dB to 2 GHz
IEC 62153-4-10, Screening attenuation of RF-feedthroughs -65 dB to 2 GHz

5.8 Copper Backbone Plating Criteria and Materials (lead free, RoHS)

The plated conductor surface has to meet all the mechanical, environmental and electrical requirements that are summarized in clause 5.3.

Connectors that are soldered to circuit boards have to withstand lead-free solder processes according to IEC61760-1 (max. soldering temperature 260°C peak, 10 sec.).

All components have to meet the RoHS-directive 2002/95/EG. The objective of this directive is to avoid or to limit the use of the following hazardous substrances:

Lead, Mercury, Cadmium, Chrome IV, PBB (Polybrominated Biphenyls), PBDE (Polybrominated Diphenyl Ethers).
6 STP and STQ PMD electrical specification

This specification defines the signal integrity requirements for Shielded Twist Pair (STP) and Shielded Twisted Quad (STQ) short haul copper for automotive applications. Both current (mandatory) and future (strongly encouraged but not mandatory) requirements are defined in this document. Current automotive implementation shall meet the requirements defined in IEEE 1394-2008.

6.1 Electrical Characteristics

This section defines the electrical characteristics needed by some automotive applications. While these electrical characteristics are not required at this time, to ensure interoperability it is strongly recommended that PHY silicon and system implementers design to the specifications set forth in this section.

6.1.1 Transmitter Electrical Specifications

All parameters defined in section 9.3.1 of IEEE 1394-2008 shall be used by this specification with the exception of the parameters listed in this section. The test methodology used to measure these parameters is specified in the 1394 Trade Association’s Base 1394 Test Suite Definition with Extension for 1394b Version 2.0.

<table>
<thead>
<tr>
<th>Differential amplitude</th>
<th>S400β</th>
<th>S800β</th>
<th>S1600β</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td>mV</td>
</tr>
<tr>
<td>Minimum</td>
<td>300/475²</td>
<td>350/600³</td>
<td>475</td>
<td>mV</td>
</tr>
</tbody>
</table>

Table 5 -- Short-haul copper transmitter characteristics in Beta mode

6.1.2 Jitter

All parameters defined in section 9.3.6 of IEEE 1394-2008 as supplemented by the 1394 Trade Association’s Base 1394 Test Suite Definition with Extension for 1394b shall be used.

6.1.3 Receiver Electrical Specifications

All parameters defined in section 9.3.2 of IEEE 1394-2008 as supplemented by the 1394 Trade Association’s Base 1394 Test Suite Definition with Extension for 1394b shall be used.

6.2 Electrical Measurements

Both Transmitter and Receiver characteristics shall be measured as defined in the 1394 Trade Association’s Base 1394 Test Suite Definition with Extension for 1394b. This base 1394 test definition defines beta transmit signal integrity at test points:

- TP2 for the Near End test and
- TP3 for the Far End test

² 475mV is the minimum requirement, but some designs may implement a minimum differential amplitude of 300 mV for highly noise-sensitive applications.
³ 600mV is the minimum requirement, but some designs may implement a minimum differential amplitude of 350mV for highly noise sensitive applications.
The test fixtures used to make both the Near End and Far End measures provide a Receiver Network. For both the Near and Far End tests, the receiver network along with oscilloscope probes only deteriorate the signal therefore the system implementer may consider the measurement worst case.

This specification also defines a beta receiver sensitivity test. The tester is calibrated using the Far End test methodology. The measurement points for the tests are shown below.

![Figure 5 – Measurement points (half connection is shown)](image)

### 6.3 System Performance Criteria

#### 6.3.1 Cable Types

Unlike the IEEE 1394 standards which define a set of parameters for a specific cable type this specification is intended to provide the generic transmitter and receiver requirements. It is then the requirement of each cable and connector specification to use these requirements and determine the performance of the interconnect system. This section provides a system performance table to be used by each cable and connector specification to indicate the number of inline connections and overall cable length supported.

#### 6.3.2 Interconnect Signal Power Budget

Each interconnect system shall specify its performance in terms of overall cable length using the following parameters:

- Data rate,
- Minimum transmit differential amplitude for a given data rate at TP2,
- Minimum receiver amplitude at TP3,
- Loss per inline and number of inlines,
- Loss per meter of cable,
- Loss per connector,
- and loss for aging.
All losses (inline, cable, connector, and aging) shall be measured at room temperature before and after aging tests.

All losses (inline, cable, connector, and aging) shall be calculated at the fundamental frequency of the specified data rate (e.g. S400 data rate: 245.76MHz).

The following table expresses the cable system budget for the various parameters that comprise the electrical system for IEEE 1394-2008.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data Rate</th>
<th>TP2</th>
<th>Inlines</th>
<th>Cable System</th>
<th>TP3</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential amplitude</td>
<td>S400</td>
<td>300</td>
<td>n*Inline attenuation</td>
<td>100 – I_{Atten}</td>
<td>200</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>475</td>
<td>I_{Atten}</td>
<td>275 – I_{Atten}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential Skew</td>
<td>S400</td>
<td>50</td>
<td>n*Inline skew I_{skew}</td>
<td>70 -I_{skew}</td>
<td>120</td>
<td>ps</td>
</tr>
<tr>
<td>Eye diagram violations</td>
<td>S400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Figures 9-26 and 9-27 of</td>
<td>See test specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[B2]</td>
<td>See test specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fig. 9-31 of [B2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deterministic Jitter</td>
<td>S400</td>
<td>244</td>
<td>n*Inline Deterministic Jitter</td>
<td>224 - I_{DJ}</td>
<td>468</td>
<td>ps</td>
</tr>
<tr>
<td>Random Jitter (RMS)</td>
<td>S400</td>
<td>22.38</td>
<td>0</td>
<td>0</td>
<td>22.38</td>
<td>ps</td>
</tr>
<tr>
<td>Differential amplitude</td>
<td>S800</td>
<td>600</td>
<td>n*Inline attenuation</td>
<td>400 – I_{Atten}</td>
<td>200</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>350</td>
<td>I_{Atten}</td>
<td>150 – I_{Atten}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential Skew</td>
<td>S800</td>
<td>35</td>
<td>n*Inline skew I_{skew}</td>
<td>82 -I_{skew}</td>
<td>117</td>
<td>ps</td>
</tr>
<tr>
<td>Eye diagram violations</td>
<td>S800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Figures 9-26 and 9-27 of</td>
<td>See test specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[B2]</td>
<td>See test specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fig. 9-31 of [B2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deterministic Jitter</td>
<td>S800</td>
<td>60</td>
<td>n*Inline Deterministic Jitter</td>
<td>105 - I_{DJ}</td>
<td>165</td>
<td>ps</td>
</tr>
<tr>
<td>Random Jitter (RMS)</td>
<td>S800</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>ps</td>
</tr>
</tbody>
</table>

Table 6 -- Interconnect Signal Budget

NOTE – IEEE 1394-2008 specifies 70ps and 82ps total differential skew budget for the cable at S400 and S800 respectively. Implementations wishing to go beyond 3 meters at S400 or 4.2 meters at S800 must use cables and/or PHY silicon that generate less differential skew and/or PHY silicon that can tolerate more differential skew than specified in IEEE 1394-2008.
7 Coax PMD electrical specification

7.1 Introduction

This clause defines the signal integrity requirements for coax copper automotive applications.

Coax uses the BBC PMD defined in [B1]. The coax PMD can be either integrated in the PHY, or it can be a discrete component interfacing the short haul copper PMD of a typical PHY.

Figure 6 illustrates the implementation with a pair of discrete coax transceivers. The function of the transceiver is to convert the PHY’s short haul copper PMD to the BBC PMD:

- It converts the impedance of 100 or 110Ω of the short haul copper cable to 50Ω used in automotive coax cables.
- It manages the transmission of the signal – in both directions – over the single coax cable.
- Typically, the transceiver uses equalization to recover the signal received after its travel over the coax link.
- It is usually combined with a WOT detection circuit.

7.2 Electrical Characteristics

The 1394Cu BBC PMD shall follow all the requirements in the BBC PMD specification [B1]. In addition, the BBC PMD shall meet the automotive requirements stated in this clause.

7.2.1 Cabling media

The coaxial cabling and connectors used shall have a characteristic impedance of 50Ω.

7.2.2 Data rate

Data rates of S400 and S800 shall be supported.

7.2.3 Number of connectors

Up to five mated inline connectors shall be supported between the transmitter and receiver, where an “inline” connector is defined as a wire to wire connector. The inline connectors are in addition to the connectors at each end of the link (TP2 and TP3, as illustrated in Figure 2 of the BBC PMD specification [B1]).
7.2.4 Wake-on-Tone operation

Ports using the BBC PMD shall support the PHY Layer Power Requirements and Wake-on-Tone (WOT) functionality as per clause 8. Details of the BBC WOT operation are provided in reference [B1].

7.3 System Performance Criteria

7.3.1 Cable Types

The BBC PMD specification [B1] defines the generic transmitter and receiver requirements. It is the requirement of each cable and connector specification to use these requirements and determine the performance of the interconnect system.

7.3.2 Interconnect Signal Power Budget

Each interconnect system shall specify its performance in terms of overall cable length using the following parameters:

- Data rate,
- Loss per inline and number of inline connections,
- Loss per meter of cable,
- Loss per connector,
- and loss for aging.

All losses (inline, cable, connector, and aging) shall be measured at ambient temperature before and after aging tests.

The BBC PMD specification [B1] defines the maximum attenuation of the interconnect system. The formula to calculate the performance of the interconnect system is also specified in [B1]. Both the attenuation budget table and the cable length formula are referenced in this section. This reference is informative, the nominal table and formula can be found in [B1].

7.3.2.1 Attenuation budget [Informative]

The BBC PMD shall support links, consisting of 50 ohm coaxial cable and connectors, with a maximum attenuation as specified in Table 7. The attenuation budget includes the loss of the coaxial cable and inline connectors (if any.) Both the maximum node-to-node attenuation and the frequency at which to measure the attenuation depend on the data rate.

<table>
<thead>
<tr>
<th>Data rate</th>
<th>Frequency (MHz)</th>
<th>Maximum Node-to-Node Attenuation (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100</td>
<td>250</td>
<td>12</td>
</tr>
<tr>
<td>S200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S800</td>
<td>500</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 7 -- Coax link attenuation budget
7.3.2.2 Cable length [Informative]

The maximum cable length can be calculated from the attenuation budget, and is a function of the data rate, type of coax cable and connectors used, and the number of inline connectors. For automotive applications, the cable length equation of [B1] has been modified to include the concept of design margin. The maximum cable length (in meters) is:

\[
\text{Max\_length} = \frac{\text{Atten\_budget} - \text{Design\_margin} - \sum \text{Inline\_connr\_atten}}{\text{cable\_atten}}
\]

Equation 1 -- Coaxial cable length calculation

Where:

- \(\text{Atten\_budget}\) is given by Table 7
- \(\text{Design\_margin}\) (dB) is optionally provided by the interconnect system manufacture and represents additional loss that may occur due to aging, manufacturing processes and temperature.
- \(\sum \text{Inline\_connr\_atten}\) is the sum (in dB) of the attenuation of all the inline connectors (if any) at the frequency specified in Table 7.
- \(\text{cable\_atten}\) is the attenuation of the coaxial cable (in dB/m) at the frequency specified in Table 7.
8 Power Management

8.1 Power Management overview

Car manufacturers require automotive power consumption profiles that are not met using existing 1394 specifications. These profiles are mandatory in order to prevent high battery discharge rates and conserve the total battery charge between vehicle starts (recharge cycles). It is also recognized that newer vehicles, most notably hybrid and non-internal combustion engines, will require more run time control over power consumption than tradition internal combustion engine vehicles.

This specification defines the facilities needed to manage the power modes of devices over a 1394 network. The facilities are discussed as follows:

- Power Management Overview
- PHY Layer Requirements
- Node Level Requirements
- System Power Manager and Local Power Manager
- Power Management Protocol
  - FCP-LPM Protocol
  - VP-AutoLPM Protocol.

8.1.1 Power Management Scope

The IEEE 1394-2008 standard provides a means to determine if an IEEE 1394 device is a power consumer, power provider, or self powered. The Standard also provides a means to manage PHY port power states through suspend, resume, disable, enable, standby, and restore functions. In addition, it defines a Link-On packet and signal that can be used to wake the layers above the PHY. While the Standard provides these facilities it doesn't provide the level of control needed to manage the complete power system of a car.

This specification defines the power management facilities required for vehicles. In doing so it defines power states, the specific power requirements for those states and the power management required to control the state transitions.

8.1.2 Functional Overview

1394 networks designed to meet this specification shall have one System Power Master (SPM) to manage the power mode of itself and connected devices. Devices, including the SPM node, may implement a Local Power Manager (LPM) which control the device’s transitioning between power modes.

This specification defines two methods whereby the SPM and LPM communicate power mode information. Both methods require the SPM to implement all IEEE 1394 defined layers (PHY, Link, Transaction and Serial Bus Management). The first method (FCP-LPM) uses IEC-61883-1 Function Control Protocol [B5] to communicate power control messages. FCP-LPM requires the LPM to implement the same IEEE 1394 layers as the SPM plus the LPM application. The second method (VP-AutoLPM) uses the 1394 Trade Association defined “VersaPHY Additions to 1394” and only requires the device to implement the PHY layer and LPM application which may reside in the SPM. Both methods are compatible and may be used in the same network as long as the SPM supports both.
8.1.3 IEEE 1394 Power Management

IEEE 1394-2008 provides limited power management capability. The capability is limited to power class reporting, PHY port state control, and the ability to notify the layers above the PHY to turn on. This specification does not support 1394 cable power therefore all devices shall report a power class of zero (000_2). This specification not only utilizes the IEEE 1394 defined PHY port state control, it adds an additional port state sleep.

8.1.4 Device Power Modes

This specification defines five device power modes. Off and Active are the only required power modes and can be implemented without an LPM. The other 3 power modes require an LPM.

- Ultra-Low Power
- Low Power
- PHY Only

Note: Additional power modes maybe be implemented but are beyond the scope of this standard.

8.1.5 Power Management Process Overview

To achieve the intended benefit of the Ultra-Low Power, Low Power, and PHY Only power modes, requires cooperation between the SPM, LPM and the PHY port states of the devices being managed. This specification defines the cooperative process used to manage the power of the entire 1394 network.
The goal of power management is to conserve power consumption when device functionality is not needed given the current power state of the vehicle and device.

The power of a 1394 device is managed in three fundamental blocks: PHY device, link controller, and applications. In this specification a single 1394 device may have multiple applications.

For example: a DVD player may have a DVD player and Local Power Manager (LPM) application, and the two communicate as needed to provide the desired user experience. To continue the example, the SPM may request the DVD player’s LPM to enter the Ultra-Low Power mode when the vehicle is switched from active to off. The DVD player’s LPM application receives the request and notifies the DVD player application that it needs to enter the Ultra-Low Power mode. Seeing the request to enter the Ultra-Low Power mode the DVD player application does the necessary house cleaning (perhaps saving state information such as track data and the like), notifies the LPM that it is entering the Ultra-Low Power state and then enters the Ultra-Low Power mode keeping the eject button active. The LPM communicates with the SPM that the DVD player is entering the Ultra-Low Power mode. In this example the LPM then places its PHY device into the Ultra-Low Power state. This is done by putting all ports into the sleep state (stops communicating on the 1394 bus), and turns on the wake detect circuitry. The LPM may then enter the ultra-low power state. If the user selects the eject button the LPM wakes to turn on the necessary circuitry needed to eject the DVD but doesn’t wake the 1394 bus for this event.

Note: the LPM maybe implemented in a processor or could be done with simple state logic.

As this example illustrates, if power states beyond Off and Active are implemented there is a process of communication to manage the change of power state. While this specification doesn’t mandate the process, it does provide the facilities needed to implement a managed power system for vehicles.

8.2 PHY Layer Power Requirements

This specification defines a PHYsical port state, Sleep, designed to facilitate the Ultra-Low Power mode. The following new facilities are required to implement the Sleep port state:

- Operation of the Sleep port state
- Register bits to control the Sleep port state
- Wake-on-tone detect

In addition to the Sleep port state this specification defines the VersaPHY Automotive Power Management Profile (VP-AutoLPM). While this profile defines new PHY Layer Power Management Facilities only those facilities which directly relate to the PHY port states will be discussed in this section. See clause 8.5.4 for a details on the VP-AutoLPM profile.

8.2.1 Automotive Port States
An overview of the different IEEE 1394-2008 port states is given below. In addition, an overview of the Sleep port state is also given.

8.2.1.1 Port Power States

IEEE 1394-2008 defines several port states. The states listed below are expected to be used during normal operation in various power states.

Active – port is connected and actively transmitting 8B10B symbols to maintain the connection. 1394 data can be sent and received in this state. Suspend, Standby and Sleep states are entered through this state. Disable maybe entered through any port state.
**Suspend** – port is connected (connection maintained by periodic tones) and in the suspended state as indicated by the Connected bit of one, Receive_OK and In_Standby of zero. The port can be reactivated by the connected port or by the local node.

**Standby** – port is connected (connection maintained by periodic tones) and in the standby state as indicated by the Connected and In_Standby bits equal to one and the Receive_OK of zero. The port can be reactivated by the connected port or by the local node. Only a child leaf nodes port may be put into the Standby state.

**Disabled** – port may or may not be connected (incoming tones are seen and it sends tones) while in the disabled state. Disabled is indicated by the Disabled bit set to one and Hard_disable bit set to zero. The port can not be reactivated by the connected port. It can be reactivated through other active ports or by the local node.

**Hard Disabled** – port may or may not be connected (incoming tones are not seen and doesn’t send tones) while in the hard disabled state. Hard Disabled is indicated by the Disabled and Hard_disable bits being set to one. The port can not be reactivated by the connected port. It can be reactivated through other active ports or by the local node.

**Sleep** – is a PHY port state that when all ports of the PHY enter this state the PHY shall enter the ultra-low power mode. While the port is in the Sleep state it may or may not be connected (incoming tones are see but it does not send tones). Sleep is indicated by the sleep bit set to one. The port can be reactivated by the connected port delivering tones through other active ports or by the local node.

**Off** – The PHY and associated ports are not powered. This occurs if a node/device is not connected to the power supply or the battery.

**8.2.1.2 Node vs Port View of Sleep**

Sleep is defined as a PHY port state however, in many applications it maybe simpler for the SPM to manage the PHY port state of Sleep and the node power mode of Ultra-Low Power mode as one mode of operation. Please see the VP-AutoLPM clause for details.

**8.2.2 PHY Registers**

This specification defines two new bits within the PHY register page 0: Port Status page. There is one Port Status page per port supported by the PHY. The two new bits are: sleep and sleep_mode.
The meaning of the sleep and sleep_mode register fields within the Port Status page are defined below. All other fields are defined by IEEE 1394-2008.

<table>
<thead>
<tr>
<th>Field</th>
<th>Size</th>
<th>Type</th>
<th>Power reset value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sleep</td>
<td>1</td>
<td>ru</td>
<td>0</td>
<td>If equal to one, the port is in the sleep state. If equal to zero, the port is not in the sleep state.</td>
</tr>
<tr>
<td>sleep_mode</td>
<td>1</td>
<td>rw</td>
<td>See Description</td>
<td>If set to one, the port supports the sleep state and may transition to it when appropriate. If set to zero, the port either does not support the sleep state or isn’t enable by the local node to transition to the sleep state. If power reset means of configuring this field are not provided, then it shall be initialized to 1.</td>
</tr>
</tbody>
</table>

8.2.3 Sleep Port State Behavior

The implementation of sleep mode leverages the existing protocols/techniques used in IEEE 1394-2008; “suspend/resume” and “standby/restore”. Suspend, resume, standby and restore are initiated by Remote command PHY packets. This allows power management to directly control the power states of each port individually, and to control the power states of ports on remote PHYs. In particular it addresses the issues of PHY only implementation (repeaters or hubs) as it allows remote control of entry to sleep.

Each port shall implement a mode of operation called “sleep-mode”. A per-port register field, sleep_mode, indicates whether sleep mode is available and enabled. If power-reset means of configuring this field are not provided, then it shall be initialized to TRUE.
Each port shall implement a port state identified as P13: Sleep. If a port is in P5 (Suspend), P9 (Standby), P12 (Loop disabled) and sleep_mode is set for the port, then it shall transition to P13.

While a port is in P13, disconnection is not promptly detected or reported. The connected flag maintains the same state as it had before entry into P13. On entry to P13 the port shall ensure that its sleep flag is set. It shall cease toning and shall wait for 2* DISCONNECTED_TONE_INTERVAL for the peer port to cease toning. The port shall then wait until either it detects an incoming tone or until the resume flag is set in the port register. It shall then ensure that the resume flag is set on all other ports in P13, ensure that the connected variable to false and exit to P0:Disconnected. Note that if two disconnected ports in P13 are connected, then the connection is not detected.

In P0: Disconnected, a port shall behave as specified in IEEE 1394-2008 and in particular it will normally commence toning to detect a peer connection. In addition, it shall clear its resume flag, and if it fails to detect a peer connection after sending four tones, then it shall set the sleep flag to cause it to transition back to P13: Sleep. Thus the power on sequence is for the node to detect all connections, and to put all disconnected ports to sleep. Connected ports are treated as in IEEE 1394 (the port start transitions to untested).

If a port is in P6 (Disabled) then it shall not transmit tones if sleep_mode is set.
8.2.4 Changes to the Port Connection Manager State Machine (Optional)

The enhancements to the IEEE 1394 port connection manager state machine are shown in Figure 9. All state transitions are unchanged except where shown in this figure in red.

Figure 9 -- Port Connection Manager State Machine Changes
8.2.5 Changes to Port Connection Manager C code (Optional)

The enhancements to the IEEE 1394 port connection manager C code are found below. All C code is unchanged except where shown in red.

typedef enum{P0,P1,P2,P3,P4,P5,P6,P7,P8,P9,P10,P11,P12,P13} port_state_type;

Figure 10 -- Data structures

// shared between port.c and node.c
#ifdef unsubscripted
const Beta_mode_only_port;  // TRUE if the port does not support DS mode, used to indicate
boolean force_disconnect;  // if a restore attempt fails, set true in P10 to force
// connection_status to cause a disconnection
// also if a loop in a Legacy cloud is detected
boolean in_standby;   // Port is in State P9:Standby or P10:Restore
boolean port_under_test;  // port currently being tested to ensure no loop
port_state_type port_state;
boolean rx_ok;   // In DS mode indicates the reception of a debounced TpBias signal
// In Beta mode, indicates synchronization with the peer port
boolean sending_tone;   // true whilst a tone is being transmitted
boolean sleep_mode;   // supports automotive low power mode
boolean untested;   // port is connected but untested
#else
const Beta_mode_only_port[NPORT];
boolean force_disconnect[NPORT];
boolean in_standby[NPORT];
boolean port_under_test[NPORT];
port_state_type port_state[NPORT];
boolean rx_ok[NPORT];
boolean sending_tone[NPORT];
boolean sleep_mode[NPORT];
boolean untested[NPORT];
#endif

Figure 11 -- Shared variables

boolean wake_in_progress() {  // TRUE if any port waking
int i;
  for (i = 0; i < NPORT; i++)
    if (sleep_mode[i] && resume[i])
      return(TRUE);
return(FALSE);
}

void wake_all_ports() {
  int j;
  for (j = 0; j < NPORT; j++)
    if (port_state[j] == P13)
      resume[j] = TRUE; // Resume all asleep ports
}

Figure 12 -- Node level processing
boolean sleep;  // indicates that the port is really well asleep
if (!(PMD_STATUS_request() & PMD_LOCAL_PLUG_PRESENT) ||
    (disabled && (hard_disable || in_standby || sleep_mode))) {  // give up if no plug or hard disabled
    if (((hard_disable || sleep_mode ) && disabled) || !(PMD_STATUS_request() &
        PMD_LOCAL_PLUG_PRESENT))
        return;  // good to return immediately if this becomes
        // TRUE anywhere from here in
        // here if (1) tried toning 4 times without detecting a tone;
        // (2) detected a connection and tried toning twice without detecting a tone;
        // (3) detected incoming TpBias
        if (sleep_mode) { // go to sleep
            sleep = TRUE;
            return;
        }
        if (dc_connected) {
            // Sleep actions
            if (port_state == P13) {
                Beta_mode = FALSE;
                toning = FALSE;
                while (sleep) // only when really asleep
                    if (signal_detect_OK())
                        sleep = FALSE;
                return;
            }  // here if P5, P6, P9 or P12 and connectivity established
            // look for disconnect or report bias/continuous tone
            if (Beta_mode) { // Beta mode - send a tone at periodic intervals
                know_still Beta mode = FALSE;
                toning = TRUE; // turn on the autonomous toner
                signal_detect_OK(); // flush any stale values (no need to wait)
                for (i = 0; i < RESUME_CHECKS; i++) {
                    if (port_state == P13) // transited to sleep
                        return;
                }
            }
            void sleep_actions() {
                if (wake_in_progress() && !sleep) // entered here from suspend, standby or loop_disabled
                    resume = TRUE;  // so that we wake up again too as soon as possible
                activate_connect_detect(0);  // background actions will stop toning
                wait_time(2*DISCONNECTED_TONE_INTERVAL); // long enough for the peer to enter sleep via suspend
                sleep = TRUE; // really asleep now
                while (sleep && !resume) // background clears sleep on hearing a tone
                    wake_all_ports();
                connected = FALSE;
            }

            Figure 13 -- Port actions

8.2.6 Wake-on Tone

This specification defines the requirements for the wake-on tone detector in the short haul copper environment. The actual detector circuit implementation and how it interfaces with the PHY silicon are beyond the scope of this document. An external device such as a combined equalizer and WOT support device may also be used, as described in clause 02.

The node shall consume less than 100uA while in the Ultra-Low Power mode. The PHY shall enter the Ultra-Low Power mode when all of its ports are either in the sleep or hard disabled state. Therefore the wake-on tone detector shall consume less than 100uA. If other circuitry in the node requires current while in the Ultra-Low Power mode then the tone detector circuit will need to consume less than 100uA. It is the system integrators responsibility to guarantee the node level 100uA requirement is met.
When a port enters the sleep state it shall activate the wake-on tone detector and shall not send any signal to the 1394 bus. When the attached PHY sends tones to a PHY port in the sleep state it shall detect the tones and shall notify the necessary circuitry to cause the PHY port to exit the sleep state. Other ports, if present, of the PHY shall also exit the sleep state when wake-on tone is detect by any port. The tone detector circuit shall qualify the incoming signal such that valid tones can be distinguished from noise.

![Wake-on Tone Functional Block Diagram](image)

**Figure 14 -- Wake-on Tone Functional Block Diagram**

**8.2.7 Wake Timing Characteristics**

1394 beta PHY’s consider a port connected when it detects tones. When a port is in the sleep state it shall not provide any signal (common mode or differential signal such as tones). When the connected port becomes active it will begin to send tones and shall continue to send tones until the port; i) is either hard disabled or ii) put back to sleep or iii) the connection process completes. As stated above there is no PHY specific required for wake timing therefore no PHY level timing is specified. However it should be noted there are system/network ramifications that should be considered and will be discussed later in this document.

**8.3 Node Level Power Requirements**

IEEE 1394 defines a minimal node to be a PHY only device. From a power management perspective the PHY’s power mode is controlled through remote command PHY packets or through the VP-AutoLPM. This implies, for PHY only devices there is a direct correlation between the PHY’s ports states and the power mode the device is in. For PHY only devices the power mode is managed totally by the SPM.
If the device contains 1394 functionality beyond the PHY it is considered a transaction capable node. Typically the transaction capability is enabled to allow communication with an application(s). Once this functionality is enabled Local Power Management (LPM) is required to control the power mode of the device, beyond off and active. For FCP-LPM implementations the location of LPM shall be in the device being controlled. For VP-AutoLPM implementations the LPM maybe implemented in the SPM or within the device being controlled. Either way the LPM must manage the power mode of the implementation above the PHY and will often control the power mode of the PHY itself.

### 8.3.1 Mapping of Port States to Node Power Modes (Informative)

The FCP-LPM protocol allows control over 3 node power modes; Active, Low Power, and Ultra-Low Power. VP-AutoLPM allows an additional node power mode of PHY Only. The PHY Only mode applies to transaction capable devices with some level of device power management being done at the PHY layer.

The VP-AutoLPM power management provides facilities which allow additional node power modes to be defined by the application.

Port states of OFF, Disconnect and Disabled are not provided in the table below.

<table>
<thead>
<tr>
<th>Node Power Modes</th>
<th>Port State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active</td>
</tr>
<tr>
<td>Active</td>
<td>X</td>
</tr>
<tr>
<td>PHY Only</td>
<td>X</td>
</tr>
<tr>
<td>Low Power</td>
<td>X</td>
</tr>
<tr>
<td>Ultra-Low Power</td>
<td>X</td>
</tr>
</tbody>
</table>

**Table 9 -- Mapping of Port States to Node Power Modes.**

a – Sleep is defined to be both a port state or it could be implemented as a PHY state using the VP-AutoLPM. If used as a PHY state, Sleep only applies to the Ultra-Low Power mode. See clause 8.5.4 for details.

### 8.3.1.1 Ultra-Low Power Mode

While in the Ultra-Low Power mode the device shall consume less than 100µA ($I_{device,max} = 100\mu\text{A}$). Each of the PHY’s ports shall be in either the Hard Disabled or Sleep port state when the device is in the Ultra-Low Power mode. The device includes the entire function of a particular box (e.g. DVD Player + 1394 interface). The sleep current above is based loosely on a requirement that the vehicle should still start after 500 – 1000 hours of battery drain from the sleeping electronics.

---

4 For the purpose of this discussion VersaPHY implementations are considered transaction cable nodes because it allows communication with applications.

5 PHY Only node power mode is only supported by VP-AutoLPM power management and is discussed in detail in that clause.

6 Ultra-Low Power mode is optional and requires additional analog and logic circuits not defined IEEE 1394-2008.
8.3.1.2 Low Power Mode

This specification doesn’t place any specific power consumption requirements on the Low Power mode. While in the Low Power mode all the devices ports shall be in one of the following states: suspend, standby, hard disabled or sleep.

8.3.1.3 PHY Only Power Mode

This specification doesn’t place any specific power consumption requirements on the PHY-Only Power Mode (POPM). Typically while in the POPM the PHY would be active and the rest of the device would be in a low or ultra-low power state. While in the POPM typically at least one of the PHY’s ports will be active. Other PHY ports may be in the following states: active, suspend, standby, hard disabled or sleep.

POPM is not supported by IEEE 1394-2008 PHY devices, it requires the support of the VersaPHY additions to 1394. POPM may be implemented at two levels of complexity: Minimal and VP-AutoLPM.

8.3.1.3.1 Minimal PHY Only Power Mode Requirements

A minimal PHY-Only Power Mode (POPM) implementation need only control when to activate the local link/transaction layer. To support a minimal PHY Only Power mode device in the system the following functions shall be supported:

PHY Requirements:
- Support for VersaPHY base register block (16 by 16-bit) set with OUI support.
- Reception of physical id addressed VersaPHY read request packets.
- Generation of VersaPHY read response packets.
- Support for LinkOn PHY packet and generation of the LinkOn signal.

SPM Requirements:
- Generation of physical id addressed VersaPHY read request packets.
- Reception of VersaPHY read response packets.
- Generation of LinkOn PHY packet.

The Organizationally Unique Identifier (OUI) location within the VersaPHY register set is used to discover and then track the device as the topology/node ids change. Note: the OUI could be the same OUI reported by the device’s Configuration ROM when the transaction layer is active. This also allows PHY only nodes to be tracked by the SPM. If the minimal POPM is used, the link/transaction layer shall implement the devices LPM functions.
8.3.1.3.2 VP-AutoLPM PHY Only Power Mode Requirements

A VP-AutoLPM PHY-Only Power mode implementation shall implement the VersaPHY Automotive LPM protocol described in clause 8.5.4. VP-AutoLPM PHY-Only Power mode implementations allow the device power to be managed at the PHY layer. For simple devices this approach allows the SPM to perform the LPM function and for more complex devices the LPM may be done by the device itself. In either case the PHY (VersaPHY) communicates directly with the LPM application.

8.3.1.4 Active Power Mode

This specification doesn't place any specific power consumption requirements on the Active Power Mode. While in the Active Power mode typically at least one of the PHY’s ports will be active. Other PHY ports may be in the following states: active, suspend, standby, hard disabled or sleep.

8.4 System Power Master and Local Power Manager

8.4.1 System Power Master (SPM)

The system power master is a dedicated device in the network, responsible for the general decision and execution of any Power Mode change. The SPM receives information about the environmental situation from various sources (network-internal and external). The SPM shall keep track of the Power Modes of all devices in the network. To achieve this, a SPM may send a request to any local power manager (LPM) instance in the network to get the current status. The decision upon a change of Power Mode is taken by the SPM, but it shall be done in a cooperative manner, i.e. an ongoing transmission or action shall usually not be broken by the SPM.

8.4.1.1 System Power Master Decisions (Informative)

The SPM decides autonomously about a change of any power mode. In implementations, the SPM enabled device may receive various information about the environmental situation from various sources. Possible external source are:

- Electronic Component Unit
- Head-Unit / Dashboard
- Ignition Sense
- Central Locking
- Remote Transmitter
- Remote Access
- Anti-Theft Alarm System
- Customer Convenience Port
- Battery Status Surveillance

Network internal sources are possible as well:

- Connection Status (active and used connections)
- User Activity

SPM can also be used for:

- Timer between external events
8.4.2 Local Power Manager (LPM)

The local power manager is the corresponding instance in each device (also included in the device holding the SPM instance). The LPM is responsible for the management of local power modes and the proper execution of commands sent by the SPM.

8.5 Power Management Protocols (PMP)

This section covers the Shutdown procedure, as the Re-Load / Re-Init procedure is basically executed by the Physical Layer and is initiated by means beyond the scope of this standard.

The Power Management Protocol (PMP) defines the communication between SPM and LPM instances. It provides all messages necessary for the power management of all devices in the network. Figure 15 shows devices connected via a 1394Cu Bus. One of these devices (e.g., the 1394 Bus manager) has extended capability to act as a System Power Master.

8.5.1 Automotive power management commands

There are five power management messages defined in this document; (1) ANNOUNCE, (2) SET, (3) FORCE, (4) ACKNOWLEDGE, (5) REJECT. Messages (1) to (3) are requests from the System Power Master (SPM) to Local Power Managers (LPMs). Messages (4) and (5) are responses from the LPM to SPM. The state parameters carried by a request are ACTIVE and INACTIVE.

1. SetPowerState(ANNOUNCE): SPM asks to LPM if every LPM can go to a requested state.
2. SetPowerState(SET): SPM commands every LPM to go to the requested state.

3. SetPowerState(FORCE): SPM forces every LPM to go to the requested state.

4. SetPowerState(ACKNOWLEDGE): LPM sends back to SPM if LPM can accept ANNOUNCE message.

5. SetPowerState(REJECT): LPM sends back to SPM if LPM can’t accept ANNOUNCE message.

The messages listed above may be implemented using FCP-LPM and VP_AutoLPM.

8.5.2 Procedures for the Power Management

The following Message Sequence Charts (MSC) show typical message flows between the SPM and the LPM in the network. In these examples, a network-wide Sleep state is shown, but also selective- sleep (i.e. put ports of selected devices into Sleep state) may be implemented. This may be accomplished by sending messages (marked as broadcast in the drawings) as unicast or multicast messages to one or more selected devices.

Figure 16 shows the procedure that is initiated by the SPM after the decision to put all ports of all nodes in the network into a Sleep state.

1. First is the announcement of the forthcoming mode-change. To reduce the number of used messages, this message (SetPowerState) contains an indicator for the exact purpose (mode: ANNOUNCE | SET | FORCE) of the message. Usually, the Shutdown procedure is initiated by sending a SetPowerState with the mode ANNOUNCE; Indicating that every LPM shall check to see if it’s device is able and willing to change into the announced mode (may be rejected for example in the case of ongoing data-transmission or user action).

2. After performing the internal check, every device shall respond whether it agrees on (ResponseCode: ACKNOWLEDGE) or rejects (ResponseCode: REJECT) the announced power mode change(message: SetPowerState with Parameter ResponseCode = ACKNOWLEDGE or REJECT).

3. After receiving the responses, the SPM may send the SetPowerState message again, with the parameter RequestCode= SET if no REJECT has been received. If at least one device rejects the announcement the power master shall not send the SetPowerState message with the mode. Upon the reception of a SetPowerState message with RequestCode = SET a device shall save it’s internal data, close all active connections and enter power saving condition within 100ms.

Figure 16 illustrates the usual case of a successful cooperative shutdown of the MSC into an inactive state.
Figure 16 -- Cooperative (usual) Change to Inactive State (Successful) (Informative)

Figure 17 illustrates the case of an unsuccessful cooperative attempt to shut down the MSC.
Figure 17 -- Cooperative (usual) Change to Inactive State (Not Successful) (Informative)

Figure 18 shows a procedure that may be used by a SPM in case of an urgent need for entering power saving condition (e.g., low battery). It is also based on the message SetPowerState with parameter RequestCode=FORCE. Upon the reception of this message, a device shall put its ports to sleep state and the higher layer to Inactive state within 100ms. The FORCE code may also be used in the case of a rejected announcement.

Figure 18 -- Forced Change to Inactive State (Informative)
8.5.3 FCP-LPM Protocol

The FCP-LPM automotive power management commands and responses are transported by the Function Control Protocol (FCP). FCP frame encapsulated device commands and responses within asynchronous block write transactions. Messages command/response for port state change and power mode state change are represented in Table 10 and Table 11, respectively. Please see AMI-C 3003 for additional details.

<table>
<thead>
<tr>
<th>Request code (8 bits)</th>
<th>Port Number (4 bits)</th>
<th>Port state (4 bits)</th>
<th>Response code (4 bits)</th>
<th>Zero Padding (12 bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTS(0100b) ACC(0001b) Reserved</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10 -- Message command/response for port state change

<table>
<thead>
<tr>
<th>Request code (8 bits)</th>
<th>Response code (4 bits)</th>
<th>Zero Padding (20 bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTS(0100b) ACC(0001b)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11 -- Message command/response for node power mode state change

The following list presents AMI-C guidelines for achieving interoperable 1394 power management implementations:

1. To enter SLEEP mode the SPM shall send a broadcast message SetPowerState with the mode ANNOUNCE to request every LPM to check whether its node is ready to go into a SLEEP state.

2. The LPM, after confirming with application, decides whether it should go to the SLEEP state. The decision is sent back to the SPM with response code ACKNOWLEDGE if the device is ready to go into SLEEP state or REJECT if the device is not ready.

3. The SPM, after receiving the response form LPM, sends a message SetPowerState again with the request code SET, if no REJECT was received from the LPM. The devices then enter the SLEEP state within 100msec.

4. If the SPM receives a REJECT response from the LPM, the SPM can decide either to terminate the transition to the SLEEP state or send a message SetPowerState to LPM with the request code FORCE. The LPM, upon receiving this command, puts its ports to the SLEEP state within 100msec.

5. When the LPM gets the SetPortState (SLEEP) command from the SPM, it prepares itself to transition mode to a desired power mode. During power down sequence, ports shall not transmit any signals (data or tong) on the network for 200ms. If no signals are received on the node’s port, this port changes to the SLEEP state (exception: port in hard disabled state). If all ports are in the SLEEP or hard disabled state, the node may change to the Ultra Low Power mode immediately.

The above guidelines have been validated through tests in an AMI-C proof-of-concept implementation. For details, see AMI-C 3003-4, AMI-C 1394 Automotive proof-of-concept implementation (steps 4, 5, and 6).

When the shutdown procedure was initiated, the local devices on the network implant methods to ensure the integrity of the data during power down, therefore on the power up command form the SPM, the devices may either boot up with data stored in the database (Re-Load) or, re-use default values (Re-Init) if the device cannot guarantee that the data base is consistent on power up. If the LPM re-loads the data during boot-up, it sends back a reboot
status DBCONSISTENT, If LPM Re-inits using the default values, it sends back a reboot status DBINCONSISTENT to the SPM.

8.5.3.1 FCP-LPM Messages

The following messages are defined to control power modes of automotive devices.

Messages: (mandatory)
status RebootIndication (in RebootStatus rebootstat)
status SetPowerState (in RequestCode requestcode
in PowerState powerstate
out ResponseCode responsecode)

Parameters: (mandatory)
enum RequestCode (ANNOUNCE | SET | FORCE)
enum ResponseCode (ACKNOWLEDGE | REJECT)
enum PowerState (INACTIVE | ACTIVE)
enum RebootStatus (DBCONSISTENT | DBINCONSISTENT)

Vendor specific parameter values are allowed and shall be ignored by a LPM that doesn’t support these additional values. The parameter values defined above shall be supported by every LPM.

The automotive power management commands and responses are transported by the Function Control Protocol (FCP) defined by IEC-61883-1 [B5], proposed standard for Digital Interface for Consumer Electronic Audio/Video Equipment. The FCP provides a simple means to encapsulate device commands and responses within IEEE 1394-2008 asynchronous block write transactions.

8.5.3.2 FCP-LPM Automotive CTS CODE

The cts field within the FCP frame defines the command transaction format used. For the automotive power management commands defined by this document, the cts field shall be the Automotive CTS Code.

8.5.3.3 FCP-LPM Automotive Message Sets and Application Layer Protocols

All automotive Multimedia devices shall utilize the existing IEC-61883 Function Control Protocol Specifications and the existing 1394 AV/C Specifications, as appropriate. In cases where automotive specific features are implemented (eg. door lock, etc), these functional message sets shall be defined in IDB-1394/2 Message Set Document. The automotive message sets shall utilize FCP as defined in IEC 61883-1 [B5].

8.5.4 VP-AutoLPM Profile

The VP-AutoLPM profile defines both the required and optional functions of the VersaPHY Local Power Manager. The use of the term “manager” doesn’t imply decision making capability on the part of the VersaPHY device but rather it contains the necessary registers to allow both the SPM and local application to communicate power state information and control state transitions.

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7 As defined in IEC61883-1 Edition 2 Table 8 Command Transaction Set Encoding.
8.5.4.1 VersaPHY Overview

VersaPHY is a 100% compatible extension to IEEE 1394-2008 designed to enable lower cost implementations by allowing communication between nodes without IEEE 1394 link or transaction layer overhead. While VersaPHY maybe used for additional functions within a vehicle this specification only defines the VersaPHY Automotive Local Power Manager profile. See the 1394 Trade Association VersaPHY Extension for 1394 specification [B3] for detail about VersaPHY.

8.5.4.2 Physical ID vs VersaPHY Labels

VersaPHY registers may be accessed using 1394 physical-ids or VersaPHY labels (VP-Label). In short VP-Labels allow the SPM and LPM to communicate using a fixed node/profile address that persists across bus resets and power cycles. This may sharply reduce the SPM and LPM software complexity especially around bus reset and device discovery.

Unlike physical-ids, multiple VP-Labels may be used to address a single IEEE 1394 device. For example, if a single device contained two functions, each function (VP-Function1 and VP-Function2) could have their own VP-Label (VP-Labela and VP-Labelb) allowing the SPM to manage the power of each function independently. In this case each VP-Function would have their own VP-Register space through which their power would be managed.

Note: The use of VP-Labels as a fixed node/profile address is not only useful for power management but maybe useful for other device functions.

8.5.4.3 VersaPHY Registers

The Power register is generically defined by the 1394 Trade Association's VersaPHY Additions for 1394 [B3]. This specification further defines Power register bits within this register for the VP-AutoLPM. In addition this specification makes specific requirements regarding the Configuration Version and Global Unique Identification registers. The VP_AutoLPM registers are defined in Table 12 through Table 14.

<table>
<thead>
<tr>
<th>Block</th>
<th>Offset</th>
<th>Bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0 E I</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>W B reserved</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
<td>V S r r O ID type G</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>Short Config Ver[0:7]</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
<td>GUID[0:7]</td>
</tr>
<tr>
<td>0</td>
<td>A</td>
<td>GUID[16:23]</td>
</tr>
<tr>
<td>0</td>
<td>C</td>
<td>GUID[32:39]</td>
</tr>
<tr>
<td>0</td>
<td>E</td>
<td>GUID[48:55]</td>
</tr>
</tbody>
</table>

Table 12 -- VP_AutoLPM Base Registers for VP-Label Access
<table>
<thead>
<tr>
<th>Block</th>
<th>Offset</th>
<th>Bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>E I Owner 0 0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>W B reserved 0 0</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
<td>V S r r O ID type G</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>Short Config Ver[0:7]</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
<td>GUID[0:7] GUID[8:15]</td>
</tr>
<tr>
<td>0</td>
<td>A</td>
<td>GUID[16:23] GUID[24:31]</td>
</tr>
<tr>
<td>0</td>
<td>C</td>
<td>GUID[32:39] GUID[40:47]</td>
</tr>
<tr>
<td>0</td>
<td>E</td>
<td>GUID[48:55] GUID[56:63]</td>
</tr>
</tbody>
</table>

Table 13 -- VP_AutoLPM Base Registers for Physical_ID Access
<table>
<thead>
<tr>
<th>Field</th>
<th>Bus Access</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>*</td>
<td></td>
<td>Enabled – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. May be fixed to 1 if device can always be enabled.</td>
</tr>
<tr>
<td>I</td>
<td>*</td>
<td></td>
<td>Immediate Response Enable – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. May be fixed to 0 if device is unable to make immediate responses to VP-Label based requests.</td>
</tr>
<tr>
<td>VP-Label</td>
<td>*</td>
<td></td>
<td>VersaPHY Label – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. May be any valid VP-Label; static, orphan, or controller assigned.</td>
</tr>
<tr>
<td>Physical_ID</td>
<td>RO</td>
<td></td>
<td>IEEE-1394 Physical_ID value of the node containing the function as collected during Self ID phase of last bus reset. Simple devices with static VP-Labels in pre-configured systems not requiring Physical_ID based discovery may use a constant 1111112 as their Physical_ID. These devices shall not respond to Physical_ID based requests.</td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td></td>
<td>Bus Reset Response – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. May be fixed to 0 if bus reset responses are not supported.</td>
</tr>
<tr>
<td>Power</td>
<td>*</td>
<td></td>
<td>Power field – Generically defined in <em>VersaPHY Extensions to IEEE-1394</em>. Specific definition is given in the clause 8.5.4 of this document.</td>
</tr>
<tr>
<td>V</td>
<td>RO</td>
<td></td>
<td>Valid – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. May be fixed to 1 if function is always valid.</td>
</tr>
<tr>
<td>S</td>
<td>RO</td>
<td></td>
<td>Self Enabled – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. If V is fixed to 1, S shall also be fixed to 1.</td>
</tr>
<tr>
<td>O</td>
<td>RO</td>
<td></td>
<td>Owner Field Available – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. Fixed to 0 if Owner field is not supported.</td>
</tr>
<tr>
<td>ID_Type</td>
<td>RO</td>
<td>01_2</td>
<td>Identification Type – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. Set to 01_2 for all VP-AutoLPM profile implementations. This invokes the shortest identification fields to simplify VP-AutoLPM devices.</td>
</tr>
<tr>
<td>G</td>
<td>RO</td>
<td></td>
<td>GUID available – Defined in <em>VersaPHY Extensions to IEEE-1394</em>. Set to 1 for VP-AutoLPM profile implementations.</td>
</tr>
<tr>
<td>Instance_nOffset</td>
<td>RO</td>
<td></td>
<td>Instance ID and Offset of next VP-Function – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. Set to 00_16 for single function VP-Devices.</td>
</tr>
<tr>
<td>Short_Config_Ver</td>
<td>RO</td>
<td>90_16</td>
<td>Short Configuration Version – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. A0_16 is reserved to identify VersaPHY Automobile Local Power Manager functions.</td>
</tr>
<tr>
<td>Power_Profile_Rev</td>
<td>RO</td>
<td>00_16</td>
<td>VP-AutoLPM Revision – Set to 00_16 for devices compliant with this revision of the VP-AutoLPM profile specification.</td>
</tr>
<tr>
<td>GUID</td>
<td>RO</td>
<td></td>
<td>Globally Unique Identifier – As defined in <em>VersaPHY Extensions to IEEE-1394</em>. Combination of a 32 bit IEEE assigned Organizational Unique Identifier and a 32 bit unique identifier assigned by that organization.</td>
</tr>
</tbody>
</table>

**Table 14 -- Field Definitions for VP_AutoLPM Base Registers**
8.5.4.4 Power State Register
The VersaPHY base register block allocates 5 bits from register 3 of block 0 in both the VP-Label addressed space and the Physical_ID space to optionally manage the power state of each VP-Function (or the entire VP-Device if that function represents the entire device).

8.5.4.4.1 Power Control Fields
The 5 bits allocated for power control are separated into two fields; R_Mode and Power_State, as illustrated in Table 15.

The R_Mode bits are used for requests from the SPM to the LPM, the response from the LPM back to the SPM, reporting the current status of the device function, and indicating the initialization status of the device function after a status change.

Writes to Power_State contain the requested Power_State. The VP-Function shall always report the current Power_State in all write and read responses.

<table>
<thead>
<tr>
<th>Bit</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>R_Mode</td>
<td>Power_State</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 15 -- Power control fields

Five of the eight power states are defined by this specification as shown in Table 16. The remaining states are implementation dependant.

<table>
<thead>
<tr>
<th>State</th>
<th>Power_State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off (key off or not in vicinity of vehicle)</td>
<td>000&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Ultra Low Power</td>
<td>001&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Low Power</td>
<td>010&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>PHY Only</td>
<td>011&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Profile Defined</td>
<td>100&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Profile Defined</td>
<td>101&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Profile Defined</td>
<td>110&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>On</td>
<td>111&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Table 16 -- Power states
8.5.4.4.2 Requests

Three requests are supported: Announce, Set, and Force (Table 17.)

The SPM can “Announce” a power state change to collect an indication from the VP-Function whether or not it is ready and able to transition to the announced power state. No change in power state is performed by the VP-Function after an Announce request.

After receiving an affirmative indication from a VP-Function to an Announce request, the SPM may then issue a “Set” request for the VP-Function to enter the specified power state.

Whether or not the target VP-Function responds positively to an Announce request, the SPM may issue a “Force” request to compel a VP-Function to transition to the specified power state.

<table>
<thead>
<tr>
<th>Request</th>
<th>R_Mode</th>
<th>Power_State</th>
</tr>
</thead>
<tbody>
<tr>
<td>reserved</td>
<td>00₂</td>
<td>Any state (no action)</td>
</tr>
<tr>
<td>Announce Power State</td>
<td>01₂</td>
<td>Requested State</td>
</tr>
<tr>
<td>Set Power State</td>
<td>10₂</td>
<td>Requested State</td>
</tr>
<tr>
<td>Force Power State</td>
<td>11₂</td>
<td>Requested State</td>
</tr>
</tbody>
</table>

Table 17-- Power write requests

8.5.4.4.3 Responses

Each power state write request from the SPM shall be honored with a write response from the VP-Function. There are two possible responses; Accepted and Rejected (Table 18).

If the VP-Function is able to accept the request, it responds by echoing the R_Mode bits from the request in the R_Mode field of the write response.

If the VP-Function is unable to accept the request, it responds with 0’s in the R_Mode field.

The response value of the Power_State field should indicate the current Power_State of the VP-Function. This value is not necessarily the same value contained the request. It may take longer to implement the request than to generate the response, or in the power off case, a response should be sent before the VP-Function suspends operation.

<table>
<thead>
<tr>
<th>Response</th>
<th>R_Mode</th>
<th>Power_State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accepted</td>
<td>Echo Request R_Mode</td>
<td>Current Power_State</td>
</tr>
<tr>
<td>Rejected</td>
<td>00₂</td>
<td>Current Power_State</td>
</tr>
</tbody>
</table>

Table 18 -- Power write responses

8.5.4.4.4 Reads

Power read responses are specified in Table 19. The SPM is also able to understand the current power status of any VP-Function by issuing a read request to the power register. The R_Mode field of the read response from the VP-Function should indicate if it is processing a request or idle.
### 8.5.4.4.5 Initial Value / Internal Change

After VP-Function power up, or if the VP-Function changes power states on its own, it may issue an unsolicited write response to indicate its power state to the SPM (Table 20). If the VP-Function has restored internal states or variables to previous values, it should report an R_Mode of 0b11. If the VP-Function does not issue an unsolicited write response, it should hold R_Mode = 0b11 until the first read or write request to the register containing the Power field.

**Table 19 -- Power read responses**

<table>
<thead>
<tr>
<th>Current Activity</th>
<th>R_Mode</th>
<th>Power State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>00₂</td>
<td>Current Power State</td>
</tr>
<tr>
<td>Processing Announce</td>
<td>01₂</td>
<td>Current Power State</td>
</tr>
<tr>
<td>Processing Set</td>
<td>10₂</td>
<td>Current Power State</td>
</tr>
<tr>
<td>Processing Force</td>
<td>11₂</td>
<td>Current Power State</td>
</tr>
</tbody>
</table>

### 8.5.4.5 Example of VP-AutoLPM Implementation

This specification only defines the functions needed by the SPM to manage the power state of a VP-AutoLPM device. This section provides a simple example of how the VersaPHY function might be implemented in a device.

In this example:

- The device can only receive one command at a time. If more than one command is sent to the device before a response is returned it will respond immediately with rejected.
- The VersaPHY implementation interfaces directly with the VP-AutoLPM application within the device. Presumably this is done through a slow speed serial interface that is commonly found on most microcontrollers.
- The VersaPHY implementation has registers (Application registers) that are not visible from the 1394 bus. These registers are updated by the VP-AutoLPM through the slow speed serial interface or by the VersaPHY power function directly.
- The VersaPHY implementation interfaces directly to the power supply and controls its power state.
- The VersaPHY implementation controls the PHY power state (and perhaps other functions).

**VersaPHY Application registers (VP-Appl):**

- Response Register
- Current State
8.5.4.5.1 Receive ANNOUNCE Ultra Low Power from SPM

The SPM performs a VersaPHY write request to the Power register asking the device to prepare to transition from the current state (which happens to be ON) to the Ultra Low Power State. \([R\_Mode = 01_{2} - \text{ANNOUNCE}], \ [\text{Power\_State} = 001_{2} - \text{Ultra Low Power}]\)

The VersaPHY saves the tLabel and address from the request and turns this register write into a command it sends to the VP-AutoLPM. The VP-AutoLPM process the command and writes the VP-Appl.Response register with the appropriate value (Echo Request R_Mode if accepted and 00\(_{2}\) if rejected). When the VP-Appl.Response register is updated this causes VersaPHY to generate a VersaPHY write response with the saved tLabel and address along with the data written into the VP-Appl.Response register. If the ANNOUNCE is accepted the VP-AutoLPM beings preparing the device to enter the Ultra Low Power State.

8.5.4.5.2 Receive SET Ultra Low Power from SPM

The SPM performs a VersaPHY write request to the Power register asking the device to transition from the current state (which happens to be ON) to the Ultra Low Power State. \([R\_Mode = 10_{2} - \text{SET}], \ [\text{Power\_State} = 001_{2} - \text{Ultra Low Power}]\)

The VersaPHY saves the tLabel and address from the request and turns this register write into a command it sends to the VP-AutoLPM. The VP-AutoLPM process the command and writes the VP-Appl.Response register with the appropriate values. (Echo Request R_Mode if accepted and 00\(_{2}\) if rejected). When the VP-Appl.Response register is updated this causes VersaPHY to generate a VersaPHY write response with the saved tLabel and address along with the data written into the VP-Appl.Response register. If the SET is accepted the VP-Appl.Current state register is updated with Ultra Low Power (001\(_{2}\)). Additionally the VP-AutoLPM puts all of the device except the PHY layer (including VersaPHY) into the Ultra Low Power state.

The VersaPHY implementation sets the Sleep Mode for each port (if not already done). It then suspends or puts into standby each PHY port (PHY makers may elect to provide a single step process by which all ports are suspended). The PHY then enters the Ultra Low Power State. Optionally the VersaPHY could instruct the Power Supply to only provide trickle power at this point.

8.5.4.5.3 Receive Wake-on Tone

When the PHY detects Tones it shall wake from the Ultra Low Power State. At this point the VP-Appl.Current state register is updated to PHY Only (011\(_{2}\)). Depending on the application VersaPHY could automatically wake the rest of the device (application) or it could wait to receive a ANNOUNCE and SET ON state from the SPM.

8.5.4.5.4 PHY Only Power State

While in the PHY Only power state the devices is capable of the repeating packets. With VersaPHY the GUID could be used to identify the device even though the application is still in the Ultra Low Power state thus conserving power if the device is not needed at that time.

8.5.5 System Power Master and Local Power Manager

The system power master (SPM) is an additional part of a 1394 network that controls the power mode of the entire network. One SPM entity shall be a part of every 1394Cu network. A local power manager (LPM) entity shall be implemented in each device requiring a specific state to fulfill low power requirements. It shall be responsible for the local power mode management of a particular node. The LPM shall receive commands from the SPM. If no LPM is implemented in a device, the ports shall disable the toning upon detection of missing toning from connected ports.
The SPM initiates the Ultra Low Power Mode by sending software commands on the data bus (FCP-LPM or VP-AutoLPM). Receipt of tones shall awaken the node (if PHY Only mode then only the PHY will be woke by the tones).

Any node may wakeup the network by starting to send tones on the data bus. To wakeup the network nodes shall initiate tones on all ports. Receipt of tones on one port shall cause all other non-Hard Disabled ports to begin toning.

Nodes cannot change from a higher power mode to a lower power mode autonomously (example: Active to Low Power). The SPM determines the power mode of each node on the entire network and transmits the corresponding commands. The details on the decision taken by the system power master are implementation specific and are beyond the scope of this specification.

8.5.6 Port State Transitions
The system power master (SPM) initiates power mode transitions of the network. The SPM is a functional component of the higher layers. Higher layer transitions, functions, SPM and LPM will be discussed in clause 6. The transition of the network to an ultra low power mode shall be controlled by the SPM via a sleep command (message) to the nodes of the network.

Upon reception of the Ultra Low Power Mode command, the node shall begin a power down sequence. The local power manager (LPM) of the corresponding node is responsible for execution of the desired power mode. During the power down sequence, ports shall not transmit any signals (data or toning) on the bus for 200ms. If no signals are received on node’s port this port shall change to the Sleep state (exception: port in hard disabled state).

Any node in the Ultra Low Power mode may be awakened by an internal or external event (timer, device is turned on, ignition on… etc). Once awoken, the ports in the Sleep states will be moved to the Active states. Once in the Active state, the port will resume toning and connected ports shall awaken by detecting the corresponding bus activity. The wakeup signal (bus traffic) will be propagated around the bus resulting in the network moving to the Active mode.

In the ignition-off case, the network may be in the Sleep state.

8.5.7 Customer Convenience Port (CCP)
The CCP is used to extend the in-car network with carry-on devices or after-market devices. To guarantee automotive power management functionality, even in the case of CCP-connected devices, some requirements shall be set:

- The configuration ROM will have a specific section dedicated to indicate the automotive capability of a device.

- Any port (at least any electrical port) of an automotive capable device shall be able to be hard disabled as defined in the existing 1394 specifications.

Non-automotive devices may not support the Sleep state and may cause the network to wakeup erroneously. To prevent this from happening, the CCP port may be hard disabled as shown in Figure 19.
The CCP may remain in automotive listen mode if a sleep mode capable device is directly connected to the CCP as in Figure 20. The carry-on automotive devices may wakeup the in-car network. All ports of carry-on automotive devices in sleep mode with a connection to legacy devices shall be hard disabled.
If a non-Sleep state capable device is connected to any port of an automotive device or the CCP, the SPM shall detect this device and shall be able to hard disable the peer port or the CCP as shown in Figure 21. The SPM shall also be responsible for reactivating the disabled ports upon wakeup. All non-Sleep state capable devices shall be implemented as a leaf node.

![Figure 21-- Automotive Device Connecting to a Non-Sleep State Capable Device](image)

### 8.5.7.1 CCP Power Requirements

The CCP shall provide power to remote devices. The CCP shall be either a Primary power provider or an Alternate power provider as per 1394TA 1999001-1 Rev 1.0 based on OEM implementation. It shall not be a power consumer or a self-powered device.

The power provision may be disabled at the CCP in case of the port being in Sleep state. In the case of a deep fade of battery power, the power provided by the CCP may become unstable or disconnected.

A CCP capable node shall send a self-ID packet during the self-ID phase. It shall define in the “pwr” field the power consumption and source characteristics as described in the IEEE Std 1394-1998 clause 16.3.4.1 Self ID Packet.
9 Coaxial cables and connectors

9.1 Introduction

Coaxial cable and connectors are well-suited to use in automobile wiring harnesses for a variety of reasons.

- They have a very simple construction consisting of a center conductor surrounded by a dielectric material and a shield. Because of this, coaxial cabling has a small diameter and low cost.
- Coaxial cable and connectors provide excellent high-frequency transmission characteristics, including tight control of characteristic impedance.
- Coaxial connectors are very simple and easy to install and fully automatic crimping is possible.
- Coax typically uses layers of foil and braided shields to provide excellent EMC performance.
- Coax is a mature media which has been used for decades in broadcast, networking, and video applications.

Coaxial cable and connectors are readily available from dozens of manufacturers around the world.

This document defines the automotive grade physical layers (e.g. cables and connectors) needed to ensure interoperability of all 1394Cu-coax devices. The physical layer is useable at either S400 or S800 dependent on the transceiver capabilities.

9.2 Coaxial cable and connectors

9.2.1 Coaxial cable

The coaxial cable shall meet the requirements of clause 5.5.2. The attenuation data in Table 4 will be used in example calculations later in this clause. Note that the attenuation of different types of coaxial cable, as well as RG-174, RG-58, and RTK-031 from different manufacturers, may differ considerably from the sample values shown in the table.

9.2.2 Connectors

The coaxial connectors shall meet the requirements of clause 5.5.2.

The FAKRA connector (as specified in DIN 72594-1, ISO 2860-1 and SAE/USCAR 18-2) is commonly used, although other types of connectors may also be used.

Figure 22 and Figure 23 illustrate the FAKRA interface specification. These figures are informative, the nominal figures can be found in DIN 72594-1.
Figure 22 -- Male FAKRA interface specifications (Informative)

Figure 23 -- Female FAKRA interface specifications (Informative)
9.3 Coax system performance criteria

The following table provides an example interconnect system power budget. It uses the cable attenuation data of the sample RG174, RG58, and RTK-031 coax cables of Table 4, and the maximum insertion loss of a FAKRA inline connector as specified by DIN 72594-1.

<table>
<thead>
<tr>
<th>Cable type</th>
<th>Data rate</th>
<th>Number of inline connections</th>
<th>Inline connection loss (dB)</th>
<th>Cable loss (dB/m)</th>
<th>Design margin</th>
<th>Total interconnect length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample RG-174</td>
<td>S400</td>
<td>0</td>
<td>0</td>
<td>0.46</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5 × 0.15</td>
<td>0.46</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>S800</td>
<td>0</td>
<td>0</td>
<td>0.7</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5 × 0.15</td>
<td>0.7</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Sample RG-58</td>
<td>S400</td>
<td>0</td>
<td>0</td>
<td>0.27</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5 × 0.15</td>
<td>0.27</td>
<td>0</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>S800</td>
<td>0</td>
<td>0</td>
<td>0.41</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5 × 0.15</td>
<td>0.41</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Sample RTK-031</td>
<td>S400</td>
<td>0</td>
<td>0</td>
<td>0.26</td>
<td>0</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5 × 0.15</td>
<td>0.26</td>
<td>0</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>S800</td>
<td>0</td>
<td>0</td>
<td>0.39</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5 × 0.15</td>
<td>0.39</td>
<td>0</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 21 -- Coax signal power budget

NOTE – Design Margin is optionally provided by the interconnect system manufacture and represents additional loss that may occur due to aging, manufacturing processes and temperature. If not provided in the table system integrators may request this information independently.
10 Shielded Twisted Quad (STQ) copper backbone

10.1 Introduction

This clause defines copper backbone cable and connector types known as Shielded Twisted Quad construction, or STQ. Unlike in the use of consumer-accessible interfaces defined by current IEEE 1394 cables and connectors, the following provides guidance for STQ copper cable and connector use in automotive systems in a captive environment. Where there is a need to transition from the captive environment to that of a consumer interface, all guidance within this specification will default back to the IEEE 1394 specification.

The STQ provides two differential pairs to the customer. Conventional approaches would apply two separately shielded differential pairs, as is depicted in the top section of Figure 24. Due to the differential excitation of the wire pairs, one wire of a differential pair carries the exact mirror image electrical potential of the adjacent wire. The electrical potentials of the two wires sum up to zero at the symmetry plane of the differential pair. A virtual electrical ground plane may therefore be assumed in the symmetry plane of each of the two pairs. The virtual groundplanes for pairs I and II are added to the schematic drawing.

The highest packing density is achieved if the four wires of the two differential pairs are arranged in the shape of a twisted quad. This situation is also depicted in Figure 24. The twisted quad may be derived from the two independent differential pairs by twisting one of the pairs 90° and by covering the resulting quad with a common braid.

By twisting one of the pairs by 90°, each differential pair is located in the virtual ground plane of the adjacent pair. Interference and crosstalk are therefore reduced dramatically.

The use of a quad cable almost doubles the signal density when compared to an individually shielded pair. Nevertheless, individual shielded pairs can be adapted as well by minor modifications of the shield design. The prerequisite for the realization of a low distortion differential datalink is to maintain the proper balanced impedance/capacitance relationships within the cable and the connector. Cable or connector imbalances would cause time delay differences (skew), high jitter values and reflection loss.

![Figure 24 -- Schematic drawing of shielded twisted quad cable](image-url)
10.2 The STQ Copper Backbone

This clause describes the realisation of the STQ interface. It is an open interface standard that has been developed in close cooperation with OEMs worldwide. Therefore it meets all the specific requirements of the automotive industry that are summarized in clauses 4, 5, and 6.

10.2.1 STQ Connector Specification

The STQ connector shall be compliant with the specifications of Figure 25, Figure 26, and Figure 27.

Figure 25 -- STQ Connector Specification, Part 1 of 3
Figure 26 -- STQ Connector Specification, Part 2 of 3
1) REFERENCE FOR TUMBLING CIRCLES OF CENTER CONTACTS
2) Au-PLATING
3) NO BURR AND SHARP EDGES PERMITTED
4) BLANK CUT AREA PERMITTED
5) REFERENCE IS THE HOLE IN THE INSULATOR
6) MOULD INCLINE INSIDE TOLERANCE
7) ◯ = NUMBER FOR PINNING

<table>
<thead>
<tr>
<th></th>
<th>TRANSMITTER CONTROL BOX</th>
<th>RECEIVER CONTROL BOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIN</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>WIRE</td>
<td>BLUE   ORANGE  GREEN</td>
<td>BROWN   GREEN   ORANGE BLUE</td>
</tr>
<tr>
<td>FIREWIRE</td>
<td>TPA+ TPA- TPA+ TPA+</td>
<td>TPA+ TPA- TPA- TPA+</td>
</tr>
</tbody>
</table>

8) CONTROL BOX MANUFACTURER IS RESPONSIBLE FOR EMC-Screening
    behind the interface, the respective OEM-Standards
9) POSITION RELATIVE TO OUTER CONTACT ORIENTATION ACCORDING TO GUIDE
    ELEMENTS IN THE PLASTIC HOUSING (Ref.), REFERING TO REFERENCE PLANE 1
10) POSITION RELATIVE TO OUTER CONTACT ORIENTATION ACCORDING TO GUIDE
    ELEMENTS IN THE PLASTIC HOUSING (Ref.), REFERING TO REFERENCE PLANE 2
11) REQUIRED SPACE FOR RIGHT ANGLE JACK WITH CABLE UP/DOWN
    HAS TO BE CONSIDERED ON DEVICE DESIGN
12) REQUIRED SPACE FOR ACTUATION
13) DISTORTION ALLOWED UP TO Ø2.7 COAXIAL WITH D
14) CONTACT-OVERLAP IN MATED CONDITION, > 1mm.

---

Figure 27 -- STQ Connector Specification, Part 3 of 3
10.2.2 Pinning of the STQ System

PCB-connectors generally have male gender. In order to make inline-connections possible, cable connectors are available in male and female gender. Two electrical devices may be connected by a cable with two connectors of female gender (cable I). Additional inline-cables feature connectors of different gender on either side of the cable (cable II). Multiple cables may be connected in series. The pin-assignment of the STQ system is defined in a way that multiple inline cables may be connected in series without any change of the signal wiring. Table 22 gives a schematic overview of the STQ signal wiring for the case of one inline connection.

<table>
<thead>
<tr>
<th>PCB, male</th>
<th>Cable I</th>
<th>Cable II</th>
<th>PCB, male</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>female</td>
<td>female</td>
<td></td>
</tr>
<tr>
<td>TPA+</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>TPB-</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>TPA-</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>TPB+</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 22 -- Wiring table for an STQ-link with one inline-connection

The pin assignment for male and female STQ-connectors is defined as shown in Figure 28.

Figure 28 -- Pin assignment of male (left) and female (right) STQ-connectors, schematic view

In order to ease the wiring of signals between the STQ-PCB-connector and the pinning of PHY-devices, a suitable topology of the traces on the circuit board is recommended. Figure 29 gives a schematic view of the routing topology for the link whose wiring table is given in Table 22. In order to keep the drawing simple, only the pins of cable connectors are shown.

As is required, the routing of the signals fits the pinning of PHY devices without additional crossing of the signal traces.

Figure 29 -- Wiring topology for STQ-link with one inline-connection. Pinning of cable connectors is drawn.
Some manufacturers supply layout recommendations for their connectors that are optimized for a specific board stackup. In the ideal case, these layout recommendation are verified by means of numerical electromagnetic simulations. For the STQ-connectors, the required crossing of the TPA-lines should be included with the layout as is depicted in Figure 30 for a four layer stackup. The numbering of the pins is included in the drawing. STQ-connectors may be designed as pin-in-paste (see Figure 30) or selective wave solder types. They may be realized as straight or right-angle connectors. Each design will potentially require a dedicated circuit board-layout to achieve optimum performance. It is recommended to add the numbering of the signal pins on the silkscreen of the circuit board.

Figure 30 -- Layout of the copper traces of a four layer PCB stackup
10.2.3 STQ Copper Cable Specification

10.2.3.1 Copper Backbone Cable Performance Criteria
STQ cable shall meet the S400 performance criteria found in IEEE 1394.

10.2.3.2 STQ Cable Construction
STQ cable shall be constructed as indicated in Figure 31.

![Figure 31 -- STQ Cable Construction](image)

Design parameters for STQ cable are given in Table 23.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ref. # in Figure 31</th>
<th>Description and Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor</td>
<td>1-4</td>
<td>Tin plated, stranded copper wire, Cu ETP1 acc. to EN 13602, conductor stranding 7x0.16 mm nom. diam., cross section 0.14 mm² nom., conductor Ø 0.48 mm max.</td>
</tr>
</tbody>
</table>
| Insulation  | 1-4                  | PP with ISO 6722 class B compliant properties, wall thickness 0.36 mm nom., core Ø1.20 ± 0.05 mm
   Colours of insulator:
   - Conductor 1: RAL 8003, brown
   - Conductor 2: RAL 6018, green
   - Conductor 3: RAL 2003, orange
   - Conductor 4: RAL 5015, blue |
| Stranding   | 1-4                  | Total stranding lay length 40 mm nom., stranding Ø 2.90 ± 0.20 mm                                                                                           |
| Shield      | 5                    | Braid design tin plated copper wires 16x8x Ø 0.1 mm, visual coverage 92% nom.
   Shield Ø, 3.30 ± 0.20 mm                                                                                       |
| Foil        | 6                    | Braid tin plated copper wires, Cu ETP1 according to EN 13602 PVC/Al foil 30µm/25µm, visual coverage 100%, shield Ø 3.40 ± 0.2 mm                        |
| Sheath      | 7                    | PVC lead free, colour: customer specific, hardness shore 88A wall thickness 0.60 mm nom., outer- Ø 4.60 ± 0.2 mm nom.                                |
| Marking     | A-->B [Manufacturer Cable Denomination] / Order Number                                                             |

Table 23 -- STQ Design Data (for reference only)
10.3 STQ Signal Power Budget

For new PHY designs, the differential output amplitude is defined by clause 6.1.1. The amplitudes defined herein are considered in Table 24. Clause 0 gives an overview how the maximum length may be increased by using equalization.

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Cable Loss (dB/m)</th>
<th>Loss per In-line Connection (dB)</th>
<th>Differential Amplitude (mV)</th>
<th>Number of Inline Connections</th>
<th>Total Interconnect Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S400</td>
<td>0.60</td>
<td>0.1</td>
<td>475*</td>
<td>0</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>8.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>8.50</td>
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<td></td>
<td></td>
<td>3</td>
<td>8.30</td>
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<td></td>
<td></td>
<td>4</td>
<td>8.15</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>8.0</td>
</tr>
<tr>
<td>S800</td>
<td>0.85</td>
<td>0.1</td>
<td>600*</td>
<td>0</td>
<td>8.80</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>8.65</td>
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<td>4</td>
<td>8.15</td>
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<td></td>
<td></td>
<td></td>
<td>5</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Table 24 -- Signal power budget for the STQ system

* The required amplitude of the eye-mask at TP3 is 200 mV. Thus, if PHYs at 300-350 mV differential output voltage are used, equalizer technology following clause 12 must be applied in order to prevent eye violations.
11 Shielded Twisted Pair (STP) cables and connectors

11.1 Introduction

This clause defines copper backbone cable and connector types known as Shielded Twisted Pair construction, or STP. Unlike in the use of consumer-accessible interfaces defined by current IEEE 1394 cables and connectors, the following provides guidance for STP copper cable and connector use in automotive systems in a captive environment. Where there is a need to transition from the captive environment to that of a consumer interface, all guidance within this specification will default back to the IEEE 1394 specification.

11.2 Shielded Twisted Pair Cable Structure

STP copper cable and connector structure is represented by numerous connection systems in industry and most notable for the purpose of this standard by those connector types defined in IEEE 1394. Cable structure varies by both performance and construction and is defined by the end application requirements. Most STP cables consist of the following seven (7) basic elements in part or in full.

- Twisted pair wires structured to meet impedance requirements
- Drain wires
- Shield (or Shields) for twisted pair
- Outer braid
- Internal isolating material
- Outer isolating material
- Optional individual wire(s) (non-twisted pair) for alternative use such as power and ground

Figure 32 illustrates a typical Shielded Twisted Pair copper cable structure. Two sets of twisted pair wires exist with each having two drain wires. Both twisted wire pair and drain wires are wrapped by an isolation material providing electrical barrier from other conductive elements. This structure is repeated for a second pair and further isolated from the other pair.

Finally the entire structure is gathered and wrapped with an outer braid that will be terminated to shield ground of the connector. The outer braid shield is then covered with an overall jacketed isolation material meeting requirements of the end application.

For automotive applications, supplying cable power may not be required, so this cable does not include additional power wires.
Figure 32 -- Typical Shielded Twisted Pair copper cable structure

Figure 33 illustrates an STP cable which incorporates all of the seven basic elements and is compliant with the IEEE 1394 specification for Beta cables (see clause 4.4 of IEEE 1394-2008). In addition to the elements present in Figure 32, two insulated wires are included for purpose of providing power and ground.
11.3 Shielded Twisted Pair Connectors

This clause provides specifications for multiple types of STP connectors and cables which address the general requirements for implementing a functional link within an automotive environment. The connector type choice is open to end user selection for that which is most suitable to the captive end application.
11.3.1 STP general connector requirements

Automotive manufacturers have many of their own internal requirements. The following STP connector types attempts to leverage across a majority of these mechanical and performance requirements and provide a baseline that establishes a working STP connector that meets the defined requirements outlined within this specification.

11.3.2 Design

The following STP connector types are designed with consideration for key attributes necessary to meet mechanical, electrical, and EMI performance requirements outlined within this specification. Specific performance or application requirements may be identified in addition to those outlined and should be understood to be outside the scope of this specification and may not fully align with the original design intent of the following STP connector types.

11.4 Shielding

All STP cable, cable connectors, and printed circuit board mount connectors defined in this clause provide shielding to assure link performance to the guidelines outlined within this specification. Each of the components of a given STP connection type shall together provide overall EMI protection to the levels defined when affectively implemented within an overall system.

11.5 Inline Connections (Separable link)

All mechanical, electrical, and EMI requirements of an STP cable plug and printed circuit board mount interface to that plug shall apply to a separable link connector interface referred within this specification as an “Inline Connector”. The use of inline cables is illustrated in Figure 34.

```
Host  Inline  Inline  Target
```

**Figure 34 -- Inline connections**

11.6 Cable length

An STP connection system shall support minimally a single link between modules and meet the defined mechanical and electrical requirements. These modules will however be placed within the automobile at some substantial length apart. In addition the routing at times will affect length and installation concerns of the application will demand one (1) or more separable links.

The maximum length of the STP connection system will be defined by a series of variables associated with connector and cable design. Application demands will direct the need for a given level of performance requirement and number of separable links. It is the goal of this specification to allow various solutions and not limit to a single set of requirements that all connection systems must meet at the extreme level of performance application.

The PHY silicon, connectors and cable type will impact the following parameters which determine the performance of a particular link:

- Data rate
- Signal transmission amplitude
- Cable attenuation
Table 25 and Table 28 illustrate how these variables affect the performance of the system for STP – Type A and Type B cables and connectors.

11.7 Cross-over termination management for Tx/Rx pairs

It should be understood that cross over termination of Transmit / Receive pairs is vital to silicon performance and requires care to implement. This function is independent of cable types of multiple pair construction.

There are two approaches to managing Tx/Rx cross-over. One approach focuses the solution on silicon and PCB routing to the PCB-mount connector. The second approach provides the required cross-over in the terminations of the cable conductors on the connectors. This method uses a cross-over cable. When separable links are introduced, in-line cables maintain the cross-over provided by the initial cross-over cable.

There should never be more than one cross-over cable introduced in a given link regardless of the number of in-line connections introduced. Each link must consist of one cross-over cable and, if needed, one or more in-line cables as defined in cross-over termination management tables for each STP type.

11.8 Shielded Twisted Pair – Type A (STP – type A)

The following connector type supports the cable structure known as Shielded Twisted Pair (STP). This STP – type A connector structure leverages the existing USCAR-30 connector and is proven to meet the requirements of that document as well as this specification with specific variations and reference as outlined below.

Some of the connector attributes are not directly specified in this section and are implied by the performance requirements in this clause.
11.8.1 STP – Type A; Copper Body Socket Profile and Interface (Normative)

![Figure 35 -- STP – Type A; Copper Body Socket Profile and Interface (Normative)](image)

**Notes**

1. All dimensions are in mm.
2. Unless otherwise specified, tolerances linear ± 0.15 and angular ± 5°
3. Interpret dimensions and tolerances per ANSI Y-14.5M-1994

11.8.2 STP – Type A PCB Footprint Layouts

For reference purposes, PCB footprint layouts for single-bay and dual-bay STP Type-A connectors are shown in Figure 36 and Figure 37, respectively.
Figure 36 – STP - Type A Single-Bay Copper Body Socket PCB footprint (Reference)
Notes for Figure 36 and Figure 37:
1. All linear dimensions are in mm
2. Unless otherwise specified, tolerances linear ± 0.15 and angular ± 5°
3. Interpret dimensions and tolerances per ANSI Y-14.5M-1994
4. Datum Surfaces
   a) Datum X - Top Surface of PC Board
   b) Y and YY - Orientation hole closest to pad matrix
   c) Z and ZZ - Remaining orientation hole
5. Phantom outline of COPPER BACKBONE socket
6. Pad layout details are common to single and dual bay socket

11.8.3 System Keying Options

Figure 38 shows the minimal keying options that are available for the STP – Type A connector. Additional keying may be available. See Reference [B17] for the most current options available. Determination of the functionality of each key is not specified in this document.
11.8.4 STP – Type A; Copper Body Socket Panel Cutout (Reference)

Panel Cutout provides the minimal clearance suggested for assurance of clearance and locking function. For maximum EMI/EMS-performance, care should be given to enclosure design to guard against excessive emissions. Use of best known practices apply.
11.8.5 STP Signal Power Budget – Type A Connector and Cable System

Table 25 illustrates the maximum cable lengths available using STP – Type A cables and connectors.

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Cable loss (dB/m)</th>
<th>Loss per Inline Connection (dB)</th>
<th>Differential Amplitude (mV)</th>
<th>Number of Inline Connections</th>
<th>Total Interconnect Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S400</td>
<td>0.6</td>
<td>0.1</td>
<td>475*</td>
<td>0</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>8.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>8.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>8.30</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>4</td>
<td>8.15</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>5</td>
<td>8.0</td>
</tr>
<tr>
<td>S800</td>
<td>0.85</td>
<td>0.1</td>
<td>600*</td>
<td>0</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>1</td>
<td>8.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>8.50</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>3</td>
<td>8.30</td>
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<td></td>
<td>4</td>
<td>8.15</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Table 25 -- STP Signal power budget – Type A

* The required amplitude of the eye-mask at TP3 is 200 mV. Thus, if PHYs at 300-350 mV differential output voltage are used, equalizer technology following clause 12 must be applied in order to prevent eye violations.

11.8.6 STP – Type A Cross-over termination management

Table 26 and Table 27 provide termination management information for STP – Type A cross-over and in-line cables, respectively.

Table 26 -- STP – Type A Cross-over cable wiring diagram
### Table 27 -- STP – Type A In-line cable wiring diagram

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Contact #</th>
<th>Wire Colors</th>
<th>Contact #</th>
<th>Signal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPA+</td>
<td>5</td>
<td>Green</td>
<td>5</td>
<td>TPA+</td>
</tr>
<tr>
<td>TPA-</td>
<td>4</td>
<td>Red</td>
<td>4</td>
<td>TPA-</td>
</tr>
<tr>
<td>Signal Shield</td>
<td>3</td>
<td>Signal Shield Drain Wire</td>
<td>3</td>
<td>Signal Shield</td>
</tr>
<tr>
<td>TPB+</td>
<td>2</td>
<td>Blue</td>
<td>2</td>
<td>TPB+</td>
</tr>
<tr>
<td>TPB-</td>
<td>1</td>
<td>Orange</td>
<td>1</td>
<td>TPB-</td>
</tr>
<tr>
<td>Cable Braid</td>
<td>Shell</td>
<td>Braid to Shell Termination</td>
<td>Shell</td>
<td>Cable Braid</td>
</tr>
</tbody>
</table>

#### 11.9 Shielded Twisted Pair – Type B (STP – type B)

The following connector type supports the cable structure known as Shielded Twisted Pair (STP). This STP – type B connector structure leverages the existing IEEE 1394 connector known as the 9-circuit Beta connector and meets the requirements of clause 4.4 of IEEE 1394-2008.

Illustrations provide understanding of how the existing 1394 Beta connector could be packaged to support automotive applications. This does not indicate work has been done to verify the full extent of mechanical and EMI performance capability to meet those outlined by this specification with content focused toward the automotive environment.

Some of the connector attributes are not directly specified in this section and they are implied by the performance requirements in this clause.
11.9.1 STP – Type B; Copper Body Socket Profile and Interface (Normative)

Figure 40 -- STP - Type B Copper Body Socket Profile and Interface (Normative)

Notes:
1. All dimensions are in mm.
2. Unless otherwise specified, tolerances linear ± 0.15 and angular ± 5°
3. Interpret dimensions and tolerances per ANSI Y-14.5M-1994

11.9.2 STP Type - B PCB Footprint Layouts

For reference purposes, PCB footprint layouts for single-bay and dual-bay STP Type-B connectors are shown in Figure 41 and Figure 42, respectively.
Figure 41 – STP – Type B Single-Bay PCB Footprint Layout (Reference)

Figure 42 – STP – Type B Dual-Bay PCB Footprint Layout (Reference)

Notes for Figure 41 and Figure 42.
1. All linear dimensions are in mm
2. Unless otherwise specified, tolerances linear ± 0.15 and angular ± 5°
3. Interpret dimensions and tolerances per ANSI Y-14.5M-1994
4. Datum Surfaces
   d) Datum X - Top Surface of PC Board
   e) Y and YY - Orientation hole closest to pad matrix
   f) Z and ZZ - Remaining orientation hole
5. Phantom outline of COPPER BACKBONE socket
6. Pad layout details are common to single and dual bay socket

**11.9.3 STP – Type B System Keying Options**

Additionally, there are a number of keying options that are available. Figure 43 shows the keying options that are available for the system. Determination of the functionality of each key has not been determined.

![Figure 43 – STP – Type B System Keying Options (Reference)](image)
11.9.4 STP – Type B; Copper Body Socket Panel Cutout (Reference)

Panel Cutout provides the minimal clearance suggested for assurance of clearance and locking function. For maximum EMI/EMS-performance, care should be given to enclosure design to guard against excessive emissions. Use of best known practices apply.

![Diagram of STP – Type B Copper Body Socket Panel Cutout](image)

Figure 44 – STP – Type B Copper Body Socket Panel Cutout (Reference)
11.9.5 STP Signal Power Budget – Type B Connector and Cable System

Table 28 illustrates the maximum cable lengths available using STP – Type B cables.

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Cable loss (dB/m)</th>
<th>Loss per Inline Connection (dB)</th>
<th>Differential Amplitude (mV)</th>
<th>Number of Inline Connections</th>
<th>Total Interconnect Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S400</td>
<td>0.6</td>
<td>0.1</td>
<td>475*</td>
<td>0</td>
<td>8.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>1</td>
<td>8.65</td>
</tr>
<tr>
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<td>3</td>
<td>8.30</td>
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<td>5</td>
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<td>S800</td>
<td>0.85</td>
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<td>600*</td>
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<td>8.80</td>
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<td>2</td>
<td>8.50</td>
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<td></td>
<td>5</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Table 28 – STP Signal Power Budget – Type B

* The required amplitude of the eye-mask at TP3 is 200 mV. Thus, if PHYs at 300-350 mV differential output voltage are used, equalizer technology following clause 12 must be applied in order to prevent eye violations.

11.9.6 STP – Type B Cross-over termination management

STP – Type B cross-over cables shall meet the requirements of IEEE 1394 Type 1 cables (see IEEE 1394-2008, clause 4.4.2). Note that providing the power and ground conductors is optional.

STP – Type B in-line cables shall provide termination management as indicated in Table 29.

<table>
<thead>
<tr>
<th>In-line Connector</th>
<th>Connector Plug (Target)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Name</td>
<td>Contact #</td>
</tr>
<tr>
<td>TPB-</td>
<td>1</td>
</tr>
<tr>
<td>TPB+</td>
<td>2</td>
</tr>
<tr>
<td>TPA-</td>
<td>3</td>
</tr>
<tr>
<td>TPA+</td>
<td>4</td>
</tr>
<tr>
<td>TPA (R)</td>
<td>5</td>
</tr>
<tr>
<td>Ground</td>
<td>6</td>
</tr>
<tr>
<td>Status Contact</td>
<td>7</td>
</tr>
<tr>
<td>Power</td>
<td>8</td>
</tr>
<tr>
<td>TPB (R)</td>
<td>9</td>
</tr>
<tr>
<td>Plug Shield</td>
<td>Shell</td>
</tr>
</tbody>
</table>

Table 29 -- STP – Type B In-line cable wiring diagram
12 Use of Equalizers and Wake-Up elements in Electrical Links (Informative)

12.1 Introduction

This document defines and specifies a number of methods for connecting 1394 nodes together in point to point or network topologies.

Two of the electrical systems specified are STP, with the specification of connectors and cables defined in clause 11 and STQ, whose systems components are described in clause 10. Both of these interconnect systems use the short haul copper PMD, which is the PMD integrated in all legacy beta and bilingual PHYs. The third system type is coax, defined in clause 9. Within this standard, the coax interconnect technique is unique in requiring the use of the BBC PMD. The BBC PMD is usually not integrated into legacy PHYs, but is implemented in an external electronic component at each end of the cable.

As described in Clause 9, this component is a transceiver that manages full duplex communication on the single coax cable. A part of the transceiver circuit is an adaptive “equalizer” that allows the system to recover degraded signals that have been attenuated over the cable length and across the connectors employed. This explains the greater length achievable with the BBC PMD compared to the short-haul copper PMD. Usually, a wake-on tone detector is integrated into the transceiver component. This is a “wake-up” element that allows the physical layer controller and other components of a node to be switched on to active mode when the wake-up element detects an incoming signal. This facilitates –especially with legacy PHYs not supporting automotive power management- the “ultra low power” stand-by mode of which car electrical systems must be capable to ensure that battery resources are not drained during extended periods without engine operation.

Some of the techniques used in the coax transceiver, in particular the equalizer and the wake-on tone detector, can equally be designed and implemented for STP and STQ cable-based links. The equalizer will extend the cable range and/or increase the number of in-line connectors tolerated. The wake-up element will provide a means for the STP and STQ based links to meet the ultra low power mode without the need for any extra cabling, even with legacy PHYs. Indeed, these two functions can be combined as is the case in the coax transceiver, to give extra cable margin and provide the wake-up function.

12.2 Equalizer Function

12.2.1 Principles

An equalizer should determine the attenuation characteristics of the cable and connectors and then apply selective amplification and signal filtering (as a function of data frequency). In all electrical connection systems, the high frequency components degrade more than low frequencies; the exact characteristics of the attenuation are, however, cable and data rate specific. The functionality of an equalizer is illustrated in Figure 45.
The recovery capacity of an equalizer should be expressed at the principle carrier frequency at the prevailing data-rate. To the equalizer, the harmonics are of little importance. Hence, for 1394Cu data-rates, the key frequencies are as indicated in Table 30.

12.2.2 Desirable Features

The principle features that can be sought in equalizer specifications include the following.

- High recovery rates (usually measured in dB)
- Adaptivity – the ability to cope with different data rates and lengths of cable
- Device cost – usually best for standard production technologies like CMOS
- Power consumption – during operation and, especially, in stand-by or sleep mode

12.2.3 Calculating results of equalization

The recovery capacity of an equalizer should be expressed at the principle carrier frequency at the prevailing data-rate. To the equalizer, the harmonics are of little importance. Hence, for 1394Cu data-rates, the key frequencies are as indicated in Table 30.
<table>
<thead>
<tr>
<th>Data rate</th>
<th>Frequency (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S100</td>
<td>62.5</td>
</tr>
<tr>
<td>S200</td>
<td>125</td>
</tr>
<tr>
<td>S400</td>
<td>250</td>
</tr>
<tr>
<td>S800</td>
<td>500</td>
</tr>
<tr>
<td>S1600</td>
<td>1000</td>
</tr>
</tbody>
</table>

Table 30 -- Principle Carrier Frequencies

Similarly, the rate of attenuation and other losses of the cable and connector systems should be considered at these frequencies.

The use of an equalizer “gives back” its specified signal recovery, allowing the signal budget to be enhanced by the number of dB offered by the equalizer. The cable length calculation formula of clause 1 can be generalized to calculate the maximum cable length of a given equalizer. The maximum cable length (in meters) is:

\[
\text{Max\_length} = \frac{\text{Equalizer\_compensation} - \text{Design\_margin} - \sum \text{Connector \_atten}}{\text{cable\_atten}}
\]

Equation 2 -- Cable length calculation with equalizer

Where:
- \(\text{Equalizer\_compensation}\) is the maximum recovery capacity of the equalizer circuit (dB)
- \(\text{Design\_margin}\) (dB) is optionally provided by the interconnect system manufacture and represents additional loss that may occur due to aging, manufacturing processes and temperature.
- \(\sum \text{Connector \_atten}\) is the sum (in dB) of the attenuation of all the connectors at the frequency specified in Table 30.
- \(\text{cable\_atten}\) is the attenuation of the coaxial cable (in dB/m) at the frequency specified in Table 30.

As an example, Table 31 shows an illustration of the Total Interconnect Length an STQ connector and cable system might achieve with an equalizer recovering 15 dB.
Table 31 -- Illustration of impact of Signal Power Budget in STQ system

12.3 Wake-on-Tone

The car network must be able to remain in a very low power consumption state when not in use, so that, when the car is switched off, there is limited drain on the battery. With legacy PHYs, there are two fundamental ways in which this can be achieved:

- A separate line connected to the physical layer controller chip (PHY) that signals to the PHY to “wake up.” This approach is detailed in Reference [B4].
- A device that detects a signal coming from another node on the network, and in turn sends a simple signal to the PHY to make it wake and power its node

The second option requires no separate wiring and hence has merit. There are existing standards defined for Plastic Optical Fibre links used in Automotive networks. A purely electric network can emulate the Wake-on-LAN operation of an FOT as specified in TS-2004024 (PMD for Fiber Optic Wake-on-LAN, Revision 1.1). The circuitry required can be integrated into a PHY or can be contained in separate device. Alternately, if an equalizer is used, the two functions can be combined in a single device.
Annex A  
(normative)

Validation Requirements

A.1 Sample Distribution

The number of samples required by each performance group regardless of circuit size is given by Table 32 and Table 33.

<table>
<thead>
<tr>
<th>Cable Plug to Board Socket Header Configurations</th>
<th>Performance Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Sockets, not assembled to printed circuit board</td>
<td>3</td>
</tr>
<tr>
<td>Sockets, assembled to printed circuit board</td>
<td>10</td>
</tr>
<tr>
<td>Plug Terminals</td>
<td></td>
</tr>
<tr>
<td>Plug Housings with TPA's w/o Terminals Installed</td>
<td></td>
</tr>
<tr>
<td>Plugs assemblies, not terminated to cable</td>
<td>3</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, ~ 75 mm long</td>
<td>3</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, &gt; 75 mm long&lt;sup&gt;1&lt;/sup&gt;</td>
<td>3</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, &gt; 100 mm long&lt;sup&gt;2&lt;/sup&gt;</td>
<td>10</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, &gt;= 1m long.</td>
<td></td>
</tr>
<tr>
<td>Socket and Plug assemblies configured for signal integrity measurements&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Table 32 -- Number of Samples Required, Cable to Board
<table>
<thead>
<tr>
<th>Cable to Cable Configurations</th>
<th>Performance Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Sockets, not assembled to a cable</td>
<td>3</td>
</tr>
<tr>
<td>Socket Terminals Terminated to Wires</td>
<td></td>
</tr>
<tr>
<td>Socket Housings with TPA’s w/o Terminals Installed</td>
<td></td>
</tr>
<tr>
<td>Cable assemblies with a Socket assembled to one end, ~ 75 mm long</td>
<td>10</td>
</tr>
<tr>
<td>Cable assemblies with a Socket assembled to one end, &gt; 75 mm long&lt;sup&gt;1&lt;/sup&gt;</td>
<td>3</td>
</tr>
<tr>
<td>Cable assemblies with a Socket assembled to one end, &gt; 100 mm long&lt;sup&gt;2&lt;/sup&gt;</td>
<td>10</td>
</tr>
<tr>
<td>Cable assemblies with a Socket assembled to one end, &gt;= 1m long</td>
<td>5</td>
</tr>
<tr>
<td>Plugs, not assembled to cable</td>
<td>3</td>
</tr>
<tr>
<td>Plug Terminals Terminated to Wires</td>
<td></td>
</tr>
<tr>
<td>Plug Housings with TPA’s w/o Terminals Installed</td>
<td></td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, ~ 75 mm long</td>
<td>10</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, &gt; 75 mm long&lt;sup&gt;1&lt;/sup&gt;</td>
<td>3</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, &gt; 100 mm long&lt;sup&gt;2&lt;/sup&gt;</td>
<td>10</td>
</tr>
<tr>
<td>Cable assemblies with a Plug assembled to one end, &gt;= 1m long</td>
<td>5</td>
</tr>
<tr>
<td>Socket and Plug assemblies configured for signal integrity measurements&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Table 33 -- Number of Samples Required, Cable to Cable

Notes for Table 32 and Table 33:
1) Samples are to be prepared to facilitate resistance measurements made at points on the wire 75 mm back from the contact/wire termination.
2) Samples are to be prepared to facilitate clamping the cable 100mm back from the connector housing in a vibration fixture and resistance measurements made at points on the wire 75 mm back from the contact/wire termination.
3) Samples are to be prepared to facilitate high speed signal integrity measurements. Configurations are to include any necessary SI fixtures.
4) One connector pair mis-mate orientation. See Test Group F.4
5) The same samples are used for phases E.2, E.3, and E.4.
A.2 Performance Group A: Basic Construction, workmanship, dimensions, and plating thickness

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be performed</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Title</td>
<td>ID No.</td>
<td>Performance Level</td>
</tr>
<tr>
<td></td>
<td>Severity or conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1</td>
<td>Visual Inspection</td>
<td>USCAR-2, Rev. 5, 5.1.8</td>
<td>With aid of 10X magnification; No evidence of deterioration, cracks, deformities, etc., that could affect their functionality or distort their appearance. No deviation from dimensional tolerances of critical dimensions.</td>
</tr>
<tr>
<td>A.2</td>
<td>Plating Thickness Measurements</td>
<td></td>
<td>No deviation from plating materials and thickness specifications.</td>
</tr>
</tbody>
</table>

Table 34 – Performance Group A
### A.3 Performance Group B: Copper Socket DC Electrical Functionality when Subjected to Mechanical Shock and Vibration

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be performed</th>
<th>Severity or conditions</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.1</td>
<td>None</td>
<td>Mount socket rigidly. Insert plug by hand.</td>
<td>Dry Circuit Resistance</td>
<td>USCAR-2, Rev. 5, 5.3.1</td>
</tr>
<tr>
<td>B.2</td>
<td>Connector Cycling</td>
<td>Cycle connector 25x.</td>
<td>Dry Circuit Resistance</td>
<td>USCAR-2, Rev. 5, 5.3.1</td>
</tr>
<tr>
<td>B.3</td>
<td>Vibration</td>
<td>Vibration per Figure 5.4.6.3, For components not coupled to engine. Grms=1.81.</td>
<td>Circuit Continuity Monitoring 7 ohms greater than 1 microsecond</td>
<td>USCAR-2, Rev. 5, 5.1.9</td>
</tr>
<tr>
<td>B.4</td>
<td>Mechanical Shock (Specified Pulse)</td>
<td>10 half-sine wave impulses (10 milliseconds duration at 35 Gs force)</td>
<td>Circuit Continuity Monitoring 7 ohms greater than 1 microsecond</td>
<td>USCAR-2, Rev. 5, 5.1.9</td>
</tr>
<tr>
<td>B.5</td>
<td>None</td>
<td></td>
<td>Dry Circuit Resistance</td>
<td>USCAR-2, Rev. 5, 5.3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Visual Inspection</td>
<td>USCAR-2, Rev. 5, 5.1.8</td>
</tr>
</tbody>
</table>

**Table 35 -- Performance Group B**
A.4 Performance Group C.1: Copper Socket DC Electrical Functionality when Subjected to Humidity Stress

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be performed</th>
<th>Sevorty or conditions</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.1.1</td>
<td>None</td>
<td>Mount socket rigidly. Insert plug by hand.</td>
<td>Dry Circuit Resistance USCAR-2, Rev. 5, 5.3.1</td>
<td>50 millionhs maximum initial per mated contact</td>
</tr>
<tr>
<td>C.1.2</td>
<td>Connector Cycling</td>
<td>Cycle connector 25x.</td>
<td>Dry Circuit Resistance USCAR-2, Rev. 5, 5.3.1</td>
<td>30 millionhs maximum change from initial per mated contact</td>
</tr>
<tr>
<td>C.1.3</td>
<td>Temperature/Humidity Cycling</td>
<td>-40 to 100C per class 2 environment. Maximum humidity per Figure 5.6.2.3. Total duration 320 hours (40 cycles).</td>
<td>Dry Circuit Resistance USCAR-2, Rev. 5, 5.3.1</td>
<td>30 millionhs maximum change from initial per mated contact</td>
</tr>
</tbody>
</table>

Table 36 -- Performance Group C.1

A.5 Performance Group C.2: Copper Socket Isolation Resistance Functionality when Subjected to Humidity Stress

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be performed</th>
<th>Severity or conditions</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.2.1</td>
<td>Connector Cycling</td>
<td>Cycle connector 25x.</td>
<td>Isolation Resistance USCAR-2, Rev. 5, 5.5.1.4</td>
<td>Resistance between adjacent terminals must exceed 20 megohm at 500 VDC.</td>
</tr>
<tr>
<td>C.2.2</td>
<td>Temperature/Humidity Cycling</td>
<td>-40 to 100C per class 2 environment. Maximum humidity per Figure 5.6.2.3. Total duration 320 hours (40 cycles).</td>
<td>Isolation Resistance USCAR-2, Rev. 5, 5.5.1.4</td>
<td>Resistance between adjacent terminals must exceed 20 megohm at 500 VDC.</td>
</tr>
</tbody>
</table>

Table 37 -- Performance Group C.2
### A.6 Performance Group C.3: Copper Socket Signal Integrity Functionality when Subjected to Humidity Stress

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be performed</th>
<th>Severity or conditions</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.3.1</td>
<td>Mated Connector and Termination Impedance</td>
<td>160 ps rise time at 50 ps, 100ps, and 150 ps beyond the connector launch plane</td>
<td>Impedance - Differential Mode (Connector Only)</td>
<td>IEEE Std 1394-2000 Annex K.3 System Impedance (ZTP) = 100 Ω; ZPTAConn = 100 Ω ±/− 15 Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>System Impedance (ZTP) = 110 Ohms: ZPTA Conn = 110 Ω ±/− 15 Ω</td>
</tr>
<tr>
<td>C.3.2</td>
<td>Cable Impedance</td>
<td></td>
<td>Impedance - Differential Mode (Cable Assembly)</td>
<td>IEEE Std 1394-2000 Annex K.3 System Impedance (ZTP) = 100 Ω; ZTPA = 100 Ω ±/− 6 Ω ZTPB = 100 Ω ±/− 6 Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>System Impedance (ZTP) = 110 Ohms: ZTPA = 110 Ω ±/− 6 Ω ZTPB = 110 Ω ±/− 6 Ω</td>
</tr>
<tr>
<td>C.3.3</td>
<td>Propagation Velocity within a cable</td>
<td></td>
<td>Velocity of Propagation Differential Mode</td>
<td>IEEE Std 1394-2000 Annex K.5 min 66% C_o</td>
</tr>
<tr>
<td>C.3.4</td>
<td>Propagation Delay Skew within a mated connector pair -- straight</td>
<td></td>
<td>Propagation Skew - Differential Mode</td>
<td>IEEE Std 1394-2000 Annex K.6 max 10 ps</td>
</tr>
<tr>
<td>C.3.5</td>
<td>Propagation Delay Skew within a wire pair</td>
<td>Per meter</td>
<td>Propagation Skew - Differential Mode</td>
<td>IEEE Std 1394-2000 Annex K.6 max 10 ps/m</td>
</tr>
<tr>
<td>C.3.7</td>
<td>Total Cable Insertion Loss (Attenuation)</td>
<td></td>
<td>Attenuation</td>
<td>IEEE Std 1394-1995 Annex K.4 f &lt; 250 MHz &lt; 4.8 dB f &lt; 400 MHz &lt; 6.0 dB f &lt; 500 MHz &lt; 6.8 dB f &lt; 800 MHz &lt; 9.2 dB f &lt; 1000 MHz &lt; 10.4 dB</td>
</tr>
</tbody>
</table>

**Table 38, part 1 -- Performance Group C.3**
<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be performed</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.3.8</td>
<td>Return Loss (Mated Connector Pair)</td>
<td>Return Loss ANSI/EIA 364-108</td>
<td>0 - 1 GHz -20 dB max</td>
</tr>
<tr>
<td>C.3.9</td>
<td>Near End Cross Talk (Mated Connector Pair)</td>
<td>Cross Talk IEEE Std 1394-2000 Annex K.8</td>
<td>max. 5 % (differential TDT at 160 ps, 10-90% rise time) max. -30 dB (0 – 1 GHz)</td>
</tr>
<tr>
<td>C.3.10</td>
<td>Far End Cross Talk (Mated Connector Pair)</td>
<td>Cross Talk IEEE Std 1394-2000 Annex K.8</td>
<td>max. 5 % (differential TDT at 160 ps, 10-90% rise time) max. -30 dB (0 – 1 GHz)</td>
</tr>
<tr>
<td>C.3.11</td>
<td>Connector Cycling USCAR-2, Rev. 5, 5.1.7 Cycle connector 25x.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.3.12</td>
<td>Temperature/Humidity Cycling USCAR-2, Rev. 5, 5.6.2</td>
<td>-40 to 100C per class 2 environment. Maximum humidity per Figure 5.6.2.3. Total duration 320 hours (40 cycles).</td>
<td></td>
</tr>
<tr>
<td>C.3.13 - C.3.22</td>
<td>Repeat C.3.1 through C.3.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE – Phase C.1, C.2, and/or C.3 can be combined if the sample configuration is suitable for the laboratory.

Table 38, part 2 -- Performance Group C.3
### A.7 Performance Group D: Copper Socket DC Electrical Functionality when Subjected to Thermal Shock

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be Performed</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Title</td>
<td>ID No.</td>
<td>Severity or conditions</td>
</tr>
<tr>
<td>D.1</td>
<td>None</td>
<td></td>
<td>Mount socket rigidly. Insert plug by hand.</td>
</tr>
<tr>
<td>D.2</td>
<td>Connector Cycling</td>
<td>USCAR-2, Rev. 5, 5.1.7</td>
<td>Cycle connector 25x.</td>
</tr>
<tr>
<td>D.3</td>
<td>Thermal Shock</td>
<td>USCAR-2, Rev. 5, 5.6.1</td>
<td>-40 to 100C per class 2 environment. Total duration 100 cycles, 30 minute dwell.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Visual Inspection</td>
</tr>
</tbody>
</table>

**Table 39 -- Performance Group D**
### A.8 Performance Group E: Copper Socket Mechanical Functionality when Subjected to Temperature Life Stress

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be Preformed</th>
<th>Severity or conditions</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Title</td>
<td>ID No.</td>
<td>Title</td>
<td>ID No.</td>
</tr>
<tr>
<td>E.1</td>
<td>Mate Force Only</td>
<td></td>
<td>Connector-Connector</td>
<td>USCAR-2,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mating/Un-mating Force</td>
<td>Rev. 5,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.4.2</td>
</tr>
<tr>
<td>E.2</td>
<td>Connector Cycling</td>
<td>USCAR-2, Rev. 5,</td>
<td>Cycle connector</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.1.7</td>
<td>25x.</td>
<td></td>
</tr>
<tr>
<td>E.3</td>
<td>High temperature</td>
<td>USCAR-2, Rev. 5,</td>
<td>100 C for 1008 hours</td>
<td></td>
</tr>
<tr>
<td></td>
<td>exposure</td>
<td>5.6.3</td>
<td>mated</td>
<td></td>
</tr>
<tr>
<td>E.4</td>
<td>Un-mate Force w/ &amp;</td>
<td></td>
<td>Connector-Connector</td>
<td>USCAR-2,</td>
</tr>
<tr>
<td></td>
<td>w/o Lock</td>
<td></td>
<td>Un-mating Force Only</td>
<td>Rev. 5,</td>
</tr>
<tr>
<td></td>
<td>Actuation Force</td>
<td></td>
<td></td>
<td>5.4.2</td>
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</table>

**NOTE** – Phase E.1 and E.2 can be combined if the sample configuration is suitable for the laboratory.

**Table 40 -- Performance Group E**
### A.9 Performance Group F: General Tests

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be Performed</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Title</td>
<td>ID No.</td>
</tr>
<tr>
<td><strong>F.1</strong></td>
<td>Connector/Cable Axial Pull test (5 cable assemblies with connector at one end 1m long, 5 mating connectors.)</td>
<td>Fix connector housing and apply a 100N load to the cable for one minute on cable axis.</td>
<td>Continuity</td>
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<tr>
<td><strong>F.2</strong></td>
<td>Cable Flexing (5 cable assemblies with plug at one end 1m long, 5 mating connectors.)</td>
<td>Test Condition 1, Dimension X = 25 mm, 25 Cycles</td>
<td>Continuity</td>
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<tr>
<td><strong>F.3</strong></td>
<td>Audible Click (5 mating connector pairs w/o humidity aging, 5 mating connector pairs w/ humidity aging.)</td>
<td>95% - 98% RH @ 40C, 6 hours Minimum</td>
<td>Audible Click</td>
</tr>
</tbody>
</table>

Table 41, part 1 -- Performance Group F
<table>
<thead>
<tr>
<th>Phase</th>
<th>Test to be Performed</th>
<th>Measurements to be performed</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.4</td>
<td>Polarization Feature Effectiveness (1 mating connector pair per mis-mating orientation)</td>
<td>USCAR-2, Rev. 5, 5.4.7</td>
<td>80N, Continuity, USCAR-2, Rev. 5, 5.4.7</td>
</tr>
<tr>
<td>F.5</td>
<td>Cavity Damage (5 plug terminals, 5 plug housings, 5 socket terminals, 5 socket housings)</td>
<td>Visual Inspection, USCAR-2, Rev. 5, 5.1.8</td>
<td>Remove force, fully seat terminal and fully seat secondary lock (TPA). Terminal/Connector Extraction Force, USCAR-2, Rev. 5, 5.4.1</td>
</tr>
<tr>
<td>F.6</td>
<td>Connector Drop (10 Plug &amp; Socket Connector Cable Assemblies)</td>
<td>Visual Inspection, USCAR-2, Rev. 5, 5.1.8</td>
<td>3 Drops of each unmated connector @1m</td>
</tr>
</tbody>
</table>

Notes for Table 41:
1) Test Group F is not sequential. Each phase above is an independent test with separate sets of samples for each phase.
2) Cable length for Test Phase F.1 may be changed to facilitate laboratory and test equipment requirements.
3) Phase F.5 is applicable to connector systems with secondary locks (TPA’s).

Table 41, part 2 -- Performance Group F
Annex B
(informative)

Bibliography


[B18] AMI-C 2002 1.0.2 Draft Common Message Set

AMI-C 3013 Power Management Architecture
AMI-C 3023 Power Management Specification
AMI-C 3033 Power Management EPOC System Description
AMI-C 3034 Power Management Test Document