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**Information Technology –
Microprocessor Systems – Heterogeneous
InterConnect (HIC) (Low-Cost, Low-Latency
Scalable Serial Interconnect for
Parallel System Construction)**



Reference number
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Abstract: Enabling the construction of high-performance, scalable, modular, parallel systems with low system integration cost is discussed. Complementary use of physical connectors and cables, electrical properties, and logical protocols for point-to-point serial scalable interconnect, operating at speeds of 10 200 Mb/s and at 1 Gb/s in copper and optic technologies, is described.

Keywords: flow control, encoding schemes, OMI/HIC, packet routing, parallelism, point-to-point serial scalable interconnect, protocols, routing fabric, serial links, serialization, silicon integration, switch chip, transaction layer, wormhole routing.

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Information Technology – Microprocessor Systems – Heterogeneous InterConnect (HIC) (Low-Cost, Low-Latency Scalable Serial Interconnect for Parallel System Construction)

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CONTENTS

	Page
FOREWORD	8
INTRODUCTION	9
Clause	
1 Scope and object	15
2 Normative references	15
3 Definitions	17
3.1 General	17
3.2 Glossary	17
4 Physical media and logical layers	23
4.1 Physical media	23
4.2 Logical layers	24
4.3 Interaction of layers	27
4.4 Implementations defined in this International Standard	29
5 DS-SE and DS-DE	31
5.1 General	31
5.2 DS-SE: physical medium	32
5.3 DS-SE signal level	32
5.4 DS-DE: physical medium	38
5.5 DS-DE signal level	44
5.6 DS-SE and DS-DE character level	46
5.7 DS-SE and DS-DE exchange level	48
6 TS-FO-02 fiber optic link	51
6.1 Physical medium	51
6.2 Signal level	53
6.3 TS-FO character level	55
6.4 TS-FO exchange level	57
7 HS-SE-10	62
7.1 HS-SE physical medium	62
7.2 HS-SE signal level	66
7.3 HS character level (8B/12B code)	69
7.4 HS exchange level	86
8 HS-FO-10 fiber optic link	94
8.1 Physical medium	94
8.2 Signal level	97
8.3 Character level and exchange level	99
9 Common packet level	99
9.1 General discussion	99
9.2 Packet format	99
9.3 Networks and routing	100
9.4 Error detection, recovery, and reporting	101
10 Conformance criteria	101
10.1 Conformance statements	101
10.2 Definition of subsets	101

Annex A (normative) DS-DE connector specification	103
Annex B (normative) HS-SE connector specification	110
Annex C (normative) TS-FO and HS-FO connector specifications	116
Annex D (informative) Rationale	128
Annex E (informative) Switch chips, switches, and fabrics	132
Annex F (informative) Use of the transaction layer – Asynchronous transfer mode (ATM) example	134
Annex G (informative) Error handling	145
Annex H (informative) Flow control calculations	146
Annex I (informative) Synchronized channel communications	149
Annex J (informative) Example DS-SE driver circuit	152
Annex K (informative) DS-DE optional power supply recommendation	154
Annex L (informative) DS-DE fixed connector PCB recommendation	155
Annex M (informative) DS-DE cable (10 core) recommendation.....	156
Annex N (informative) DS-DE multiway connector housing recommendation.....	157
Annex O (informative) HS-SE fixed connector PCB recommendation.....	158
Annex P (informative) HS-SE cable recommendation	159
Annex Q (informative) HS-SE connector multiway housing recommendation.....	160
Annex R (informative) TS/HS-FO connector PCB and front panel cut-out recommendation .	161
Annex S (informative) TS/HS-FO fiber cable recommendation.....	162
Figure 1 – Protocol stack between nodes	23
Figure 2 – Exchange layer	26
Figure 3 – Protocol stack diagram showing interaction of layers	28
Figure 4 – Defined implementation of physical and logical layers.....	30
Figure 5 – DS-SE link signal propagation	33
Figure 6 – DS-SE timing reference model	35
Figure 7 – DS-SE link timings	36
Figure 8 – DS-SE link signal encoding	37
Figure 9 – DS-DE cable assembly twist example.....	40
Figure 10 – DE-DE extension adapter	40
Figure 11 – DS-DE fixed connector external view.....	41
Figure 12 – Multiple power connectors.....	43
Figure 13 – DS-SE/DS character encoding.....	46
Figure 14 – DS-SE/DS-DE parity coverage.....	47
Figure 15 – DS link states.....	49
Figure 16 – DS link start-up and reset.....	50
Figure 17 – TS-FO cable fibers/plugs wiring.....	52
Figure 18 – TS-FO extension adapter	52
Figure 19 – TS-FO fixed adaptor, external view and ferrule allocation.....	53
Figure 20 – TS-FO reference list.....	54
Figure 21 – TS-FO link states	58
Figure 22 – TS link start-up and reset	59

Figure 23 – TS-FO packet encoding.....	61
Figure 24 – Single braid and double braid link cables	64
Figure 25 – HS-SE cable pins/connectors wiring	65
Figure 26 – HS-SE extension adapter	65
Figure 27 – HS-SE fixed connector external view	65
Figure 28 – Input and output buffer electrical model	67
Figure 29 – Exchange level interconnection between two nodes	87
Figure 30 – Transmitter state machine controller-start-up.....	88
Figure 31 – Transmitter state machine controller-functional.....	89
Figure 32 – Transmitter state machine controller-shutdown	89
Figure 33 – Receiver state machine controller.....	90
Figure 34 – Exchange for start-up, functional and shutdown.....	91
Figure 35 – Exchange for bidirectional start-up	92
Figure 36 – HS-FO cable fibers/plugs wiring	95
Figure 37 – HS-FO extension adapter	96
Figure 38 – HS-FO fixed adapter, external view and ferrule allocation	96
Figure 39 – HS-FO reference link	98
Figure A.1 – DS-DE fixed connector front view.....	105
Figure A.2 – DS-DE fixed connector side view.....	106
Figure A.3 – DS-DE fixed connector top view	106
Figure A.4 – DS-DE connector latch.....	107
Figure A.5 – DS-DE free connector front view	108
Figure A.6 – DS-DE free connector side view.....	109
Figure A.7 – DS-DE free connector contact.....	109
Figure B.1 – HS-SE free connector front view	112
Figure B.2 – HS-SE free connector side view	112
Figure B.3 – HS-SE fixed connector front view	113
Figure B.4 – HS-SE fixed connector side view.....	113
Figure B.5 – HS-SE connector link.....	114
Figure B.6 – HS-SE contact interface dimensions	115
Figure C.1 – TS-FO/HS-FO link free connector	126
Figure C.2 – TS-FO/HS-FO link fixed connector	127
Figure F.1 – ATM network.....	134
Figure F.2 – ATM layers	136
Figure F.3 – Virtual channels and virtual paths.....	137
Figure F.4 – Example of virtual path and virtual channel switching.....	138
Figure F.5 – ATM cell header.....	139
Figure F.6 – Mapping reference model.....	140
Figure H.1 – Theoretical maximum transmission length calculation	147
Figure H.2 – Distance versus buffer size for DS and TS links	147

Figure H.3 – Distance versus buffer size for HS-SE links	148
Figure J.1 – DS-SE pad equivalent circuit	153
Figure J.2 – Simulation input waveforms	153
Figure K.1 – Optional power supply circuit.....	154
Figure L.1 – DS-DE fixed connector PCB layout	155
Figure M.1 – Recommended DS-DE link cable cross-section.....	156
Figure N.1 – DS-DE connector multiway housing.....	157
Figure N.2 – DS-DE (multiway) front panel cut-out	157
Figure P.1 – Recommended HS-SE link shielded cable cross-section.....	159
Figure O.1 – Recommended HS-SE fixed connector PCB layout	158
Figure Q.1 – HS-SE multiway housing.....	160
Figure Q.2 – HS-SE (multiway) front panel cut out	160
Figure R.1 – TS/HS-FO fixed connector PCB footprint.....	161
Figure R.2 – TS/HS-FO fixed connector front panel cut-out	161
Figure S.1 – Example of TS/HS-FO fiber cable structure	162
Table 1 – Identification format for technologies	30
Table 2 – Defined implementations	31
Table 3 – Driver to line impedance matching table	34
Table 4 – DS-SE input capacitance	34
Table 5 – DS-SE timing and swings	35
Table 6 – DS-SE output skew parameters	37
Table 7 – Identification of multiple link interfaces	38
Table 8 – DS-DE cable color code	38
Table 9 – Electrical and mechanical characteristics and safety certification of DS-DE cable...	39
Table 10 – DS-DE link cable conductors/connectors wiring	40
Table 11 – Pin allocation of DS-DE connector	41
Table 12 – DS-DE connector modularity specifications	41
Table 13 – DS-DE environmental constraints	42
Table 14 – Optional power supply	42
Table 15 – Optional power supply load.....	42
Table 16 – Optional power supply protective device	43
Table 17 – DS-DE signal levels.....	44
Table 18 – DS-DE correspondence	45
Table 19 – Attribution of attenuation budget	45
Table 20 – Attribution of skew budget	45
Table 21 – Terminator character codings	47
Table 22 – Link control character codings	47
Table 23 – Summary of main optical characteristics of TS-FO fibers	51
Table 24 – TS-FO connector modularity specifications	52
Table 25 – TS-FO signal allocation	53
Table 26 – TS-FO environmental constraints.....	53
Table 27 – TS-FO recommended transceiver characteristics	54

Table 28 – TS-FO link performance specification	55
Table 29 – Symbols allocated for character coding of data values	56
Table 30 – Symbols for control characters	56
Table 31 – Coding of control characters	57
Table 32 – Coding of INIT	57
Table 33 – HS-SE-10 links general characteristics	62
Table 34 – PCB track characteristics	62
Table 35 – Physical characteristics of a single coaxial cable	63
Table 36 – Electrical characteristics of a single coaxial cable	63
Table 37 – Mechanical performance and safety certification of link cables	64
Table 38 – Pin allocation of HS-SE connector	66
Table 39 – HS-SE environmental constraints	66
Table 40 – HS-SE environmental constraints	66
Table 41 – Operating rates for HS-SE-10 links	66
Table 42 – Attribution of attenuation budget	68
Table 43 – Driver side line logic levels for $V_{DD} = 3.3$ V (nominal)	68
Table 44 – Driver side line logic levels for $V_{DD} = 5.0$ V (nominal)	68
Table 45 – Driver side line swing when ac coupled into 50 Ω termination	68
Table 46 – Receiver electrical characteristics	69
Table 47 – Data characters	72
Table 48 – Control characters	83
Table 49 – Reserved L_chars for exchange level functions	87
Table 50 – Time-out values	92
Table 51 – Summary of main optical characteristics of HS-FO fibers	95
Table 52 – THS-FO connector modularity specifications	95
Table 53 – HS-FO signal allocation	96
Table 54 – HS-FO environmental constraints	96
Table 55 – HS-FO recommended transceiver characteristics for multimode fiber	97
Table 56 – HS-FO recommended transceiver characteristics for single mode fiber	97
Table 57 – HS-FO link performance specification	98
Table 58 – End_of_packet markers	100
Table 59 – Codes for EOP markers	100
Table 60 – Conformance identifications for connectors	101
Table 61 – Conformance identifications for link cables	101
Table 62 – Conformance identifications for link cable assemblies	102
Table 63 – Common identifications for link interfaces	102
Table A.1 – DS-DE connector requirements	103
Table B.1 – HS-SE connector requirements	110

Table C.1 – TS-FO and HS-FO (multimode) connector requirements.....	116
Table C.2 – Performance and environmental specification for TS-FO and HS-FO (multimode) connector	119
Table C.3 – HS-FO (single-mode) connector requirements.....	121
Table C.4 – Performance and environmental specification for HS-FO (single-mode) connector	124
Table C.5 – Color coding of TS/HS-FO connectors.....	127
Table J.1 – Parameter spread for DS-SE link driver	152
Table L.1 – PCB details for DS-DE connector attachment	155
Table M.1 – Recommended DS-DE link cable specification	156
Table P.1 – Recommended HS-SE cable specifications	159

**INFORMATION TECHNOLOGY – MICROPROCESSOR SYSTEMS –
HETEROGENEOUS INTERCONNECT (HIC)
(LOW-COST, LOW-LATENCY SCALABLE SERIAL INTERCONNECT
FOR PARALLEL SYSTEM CONSTRUCTION)**

FOREWORD

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International Standard ISO/IEC 14575 was prepared by subcommittee 26: Microprocessor systems, of ISO/IEC joint technical committee 1: Information technology.

International Standards are drafted in accordance with ISO/IEC Directives, Part 3.

Annexes A, B and C form an integral part of this standard.

Annexes D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R and S are for information only.



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INTRODUCTION

(This introduction is not a normative part of ISO/IEC 14575:2000, but is included for information only.)

The construction of high-performance systems with parallel communications, parallel processing, and/or parallel I/O demands a fast, low-cost, low-latency interconnect. It must be fast and low-latency, otherwise it will be the limiting factor in system performance; and it must be low-cost, or it will dominate the system cost. It must also scale well in both performance and cost relative to the system size, otherwise highly parallel systems will be limited in performance or too expensive. Existing standards do not meet these criteria, because they are designed for communication over long distances (which incurs high costs), or because they aim at the extreme of currently achievable performance (which again increases costs), or because they are based on a restricted model such as a bus, which limits overall performance and scalability. A detailed rationale for this standard is given in annex D.

This standard has been developed to complement recent technical developments of highly integrated, low-power interconnect technology implemented in high-volume commodity VLSI processes, and to exploit the simplifications in encodings and protocols resulting from the use of relatively reliable media over relatively short distances. Aspects of the baseline for this standard have their origins in work on parallel systems, which has taken place in a number of ESPRIT projects. In particular, the routing strategy was established in the PUMA project, and the DS-Links were developed partially in the GP MIMD project. Work at interconnect for high-performance mainframe computers at Bull led to the development of the gigabit link technology implemented in Bi-CMOS and CMOS processes. More recently, these developments, together with corresponding optical technology, have been brought together in the OMI/HIC Project (Open Microprocessor Systems Initiative – High Performance Heterogeneous Interconnect – ESPRIT 7252).

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INFORMATION TECHNOLOGY – MICROPROCESSOR SYSTEMS – HETEROGENEOUS INTERCONNECT (HIC) (LOW-COST, LOW-LATENCY SCALABLE SERIAL INTERCONNECT FOR PARALLEL SYSTEM CONSTRUCTION)

1 Scope and object

This International Standard applies to physical connectors and cables, electrical properties, and logical protocols for point-to-point serial scalable interconnect, operating at speeds of 10 Mbit/s to 200 Mbit/s and at 1 Gbit/s in copper and optic technologies (as developed in Open Microprocessor Systems Initiative/Heterogeneous InterConnect Project (OMI/HIC)).

The object of this International Standard is to enable high-performance, scalable, modular, parallel systems to be constructed with low system integration cost; to support communications systems fabric; to provide a transparent implementation of a range of high-level protocols (communications, e.g. ATM, message passing, shared memory transactions, etc.), and to support links between heterogeneous systems.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

CISPR 22, *Information technology equipment – Radio disturbance characteristics – Limits of methods of measurement*

IEC 60352-5:1995, *Solderless connections – Part 5: Solderless press-in connections – General requirements, test methods and practical guidance*

IEC 60512-2:1985, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 2: General examination, electrical continuity and contact resistance tests, insulation tests and voltage stress tests*

IEC 60512-3:1976, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 3: Current-carrying capacity tests*

IEC 60512-4:1976, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 4: Dynamic stress tests*

IEC 60512-5:1992, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 5: Impact tests (free components), static load tests (fixed components), endurance tests and overload tests*

IEC 60512-6:1984, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 6: Climatic tests and soldering tests*

IEC 60512-7:1993, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 7: Mechanical operating tests and sealing tests*

IEC 60512-8:1993, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 8: Connector tests (mechanical) and mechanical tests on contacts and terminations*

IEC 60512-9:1992, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 9: Miscellaneous tests*

IEC 60793-1, *Optical fibres – Part 1: Generic specification*

IEC 60793-2:1998, *Optical fibres – Part 2: Product specifications*

IEC 60825-1:1993, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*

IEC 60825-2:2000, *Safety of laser products – Part 2: Safety of optical fiber communication systems*

IEC 60874-1:1999, *Connectors for optical fibres and cables – Part 1: Generic specification*

IEC 60917 (all parts), *Modular order for the development of mechanical structures for electronic equipment practices*

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test. Basic EMC publication*

IEC 61076-4-101:1995, *Connectors with assessed quality for use in d.c., low-frequency analogue and in digital high-speed applications – Part 4: Printed board connectors – Section 101: Detail specification for two-part connector modules having a grid of 2.0 mm for printed boards and backplanes*

IEC 61076-4-107, — *Connectors – Part 4-107: Detail specification for a twopart connector with assessed quality, for a basic grid of 2.0 mm, with free connectors for non-accessible insulation displacement*¹⁾

IEC 61300 (all parts), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures*

IEC 61156-1:1994, *Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification*

IEC 61196-1:1995, *Radio-frequency cables – Part 1: Generic specification – General, definitions, requirements and test methods*

IEC 61196-2:1995, *Radio-frequency cables – Part 2: Sectional specification for semi-rigid radio-frequency and coaxial cables with polytetrafluoroethylene (PTFE) insulation*

IEC 61754-6:1997, *Fibre optic connector interfaces – Part 6: Type MU connector family*

IEEE Std 100-1996, *The IEEE Standard Dictionary of Electrical and Electronics Terms*

IEEE Std 1301.3-1992, *IEEE Standard for Metric Practice for Microcomputers – Convection Cooled with 2.5 mm Connector (ANSI)*

¹⁾ To be published.

3 Definitions

3.1 General

Common terms are as defined in IEEE Std 100-1996. The terms defined in this clause are specific to this International Standard.

The word *shall* is used to indicate mandatory requirements strictly to be followed in order to conform with the standard and from which no deviation is permitted.

The word *should* is used to indicate that among several possibilities one is particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited.

The word *may* is used to indicate a course of action permissible within the limits of the standard.

3.2 Glossary

3.2.1

bit error rate (BER)

ratio of errors to the total number of bits being sent in a data transmission from one location to another

3.2.2

box

a mechanical unit that contains links; the links may either remain inside the box, connecting internal devices, or may leave the box in order to connect internal devices to external ones. A box is assumed to be an EMC compliant enclosure operating under a single electrical environment

3.2.3

character

a group of consecutive bits used to represent control or data information

Characters are of two types: normal characters (N_chars) or link characters (L_chars).

See also: **control character**, **data character**, **link character**, **normal character**.

3.2.4

character layer

layer of the protocol stack that specifies the representation of characters in terms of groups of consecutive bits

The character layer provides the service to the higher layers of the transmission of a continuous sequence of characters on a link.

3.2.5

coding

translation from the original set of bits (character) to a new set of bits (coded character) suitable for serial transmission

See also: **decoding**.

3.2.6

control character

character used for signalling purposes by the exchange, packet or transaction layers of the stack

Both N_chars and L_chars are used as control characters

See also: **link character**; **normal character**.

3.2.7

data character

character used for packet payload or packet header

A data character represents one of the values of a byte, i.e 0 to 255 (decimal). Only N_chars are used as data characters

See also: **link character**; **normal character**.

3.2.8

decoding

translation from the coded set of bits (coded character) to the original set of bits (character)

See also: **coding**.

3.2.9

deserialization

assembly of a coded character from the sequence of serial bits

See also: **serialization**.

3.2.10

destination

one or more destination_identifiers, identifying the destination node(s) to which the packet is to be transmitted

See also: **destination_identifier**.

3.2.11

destination_identifier (dest_id)

an implementation dependent identity of a destination node for a packet

3.2.12

destination node

terminal node(s) that is/are to receive a particular packet

See also: **node**.

3.2.13

digital sum variation

difference between the number of logical 1s and the logical 0s transmitted by a link output since commencing operation

See also: **running disparity**.

3.2.14

disparity

difference between the number of logical 1s and logical 0s in a character

A positive or negative disparity indicates an excess of 1s or 0s, respectively.

3.2.15

end_of_packet marker

a control character that indicates the end of a packet

See also: **packet**.

3.2.16

exchange layer

describes the procedure of the node-to-node exchange of characters to ensure the proper functioning of the link

The exchange layer provides the service to the higher layers of the transmission of an indefinite sequence of N_chars.

3.2.17

fabric

a device or a collection of devices that provide(s) a general routing capability, constructed from one or more switches using links

See also: **link**; **switch**.

3.2.18

flow control character (FCC)

a control character transmitted on a link in the opposite direction to data flow for each direction of data flow, i.e. to the transmitter of data from the receiver, indicating that the receiver has space reserved to receive a further F N_chars

The value of F is specified separately for each technology in this standard.

3.2.19

functional

a link interface becomes functional when the start-up procedure has successfully completed and the link interface is ready to transmit data

3.2.20

link

means of communicating digital information bidirectionally in serial format between two devices or subsystems

A link comprises two link interfaces connected by an appropriate medium (or media, for connections between boards or cabinets), such that the link output of each interface is connected to the link input of the other.

3.2.21

link cable

physical medium connecting two link interfaces, comprising two or more electrical or optical cables

3.2.22

link character (or L_char)

control characters used on a link in order to ensure flow control and the proper functioning of the link

See also: **normal character**.

3.2.23

link input

connection point for receiving signals

See also: **link interface**.

3.2.24

link interface (or port)

connection point comprising a link input and a link output and implementing one of the relevant conformance subsets defined in 10.2

See also: **link**.

3.2.25

link output

a connection point for transmitting signals

See also: **link interface**.

3.2.26

network

any set of devices or subsystems connected by links (directly or indirectly) joining a set of terminal nodes

3.2.27

node

a device or subsystem having one or more link interfaces

A node may be a terminal node (q.v.). A node may perform a routing function, routing packets between its node interfaces according to the information in the destination field of the packet.

3.2.28

node interface

link interface on a switch

See also: **link interface**; **switch**.

3.2.29

normal character (or N_char)

N_chars represent, at the minimum, the 256 values of a byte (i.e. all the data characters) plus a control character representing an end_of_packet marker

3.2.30

packet

a sequence of N_chars with a specific order and format

A packet consists of a destination followed by a payload. A packet is delimited by an end_of_packet marker.

See also: **destination**; **payload**.

3.2.31

packet layer

the layer of the protocol concerned with end-to-end transmission of information, possibly through a number of intermediate routers

It is at the packet layer that the routing decisions are taken.

3.2.32

payload

data (a message, a memory access request, an acknowledgment, etc.) that is to be transferred from the source node to the destination node

The data has a specific format, defined in the transaction layer. Note that a payload may be null.

See also: **packet**.

3.2.33

physical medium

See: transmission medium.

3.2.34

port

See: link interface.

3.2.35

routing function

inside a switch, this function determines to which numbered node interface a packet is to be sent, based on the information contained in the packet destination

See also: **switch**.

3.2.36

run length

maximum number of successive bits of the same value that can occur in the coded bit stream

3.2.37

running disparity

cumulative sum of the disparities of characters transmitted from the start of operation of the link up to the present time

A link has two running disparities, one for each direction.

3.2.38

serialization

the process of transmitting coded characters, one bit at a time

See also: **deserialization**.

3.2.39

signal

a measurable quantity (e.g. a voltage) that varies in time in order to transmit information

A signal propagates along a wire or an optic fiber. It is interpreted as a sequence of bits that is grouped into a sequence of characters by the character layer of the protocol stack. Signals are generated by a link output and are absorbed by a link input.

3.2.40

signal layer

the layer of the protocol stack at which signals are specified

3.2.41

sink

consumer of normal characters at a link interface

See also: **normal character**.

3.2.42

source

generator of normal characters at a link interface

See also: **normal character**.

3.2.43

source node

terminal node that originates data

See also: **destination node**.

3.2.44

switch

a routing device (for example, a box or board) providing a set of numbered node interfaces, constructed from one or more switch chips (or by other methods)

See also: **fabric, node interface, switch chip**.

3.2.45

switch chip

a very large scale integration (VLSI) integrated circuit with two or more link interfaces, between which it provides packet routing

See also: **link; switch**.

3.2.46

terminal node

node with one or more link interfaces that are used to originate or consume data across an interconnect complying with this standard

See also: **source; sink**.

3.2.47

transaction

a sequence of packets sent between two or more terminal nodes to perform some function

See also: **transaction layer**.

3.2.48

transaction layer

layer above the packet layer for use by applications

The transaction layer is unspecified in this standard.

See also: **transaction**.

3.2.49

transmission medium

means of transporting electrical or optical signals

See also: **signal**.

4 Physical media and logical layers

This International Standard defines a set of rules for information exchange (the logical layers) together with the ways in which it shall be implemented on a variety of physical media. The logical layers are defined as a protocol stack. Each layer of the protocol stack defines representations (information formats) in terms of the immediately lower layer, together with rules (protocols) for the exchange of these representations.

The use of the physical media and logical layers is illustrated in figure 1. The physical medium and the signal, character and exchange layers are concerned with point-to-point communication between adjacent nodes, while the packet layer provides end-to-end communication between terminal nodes.

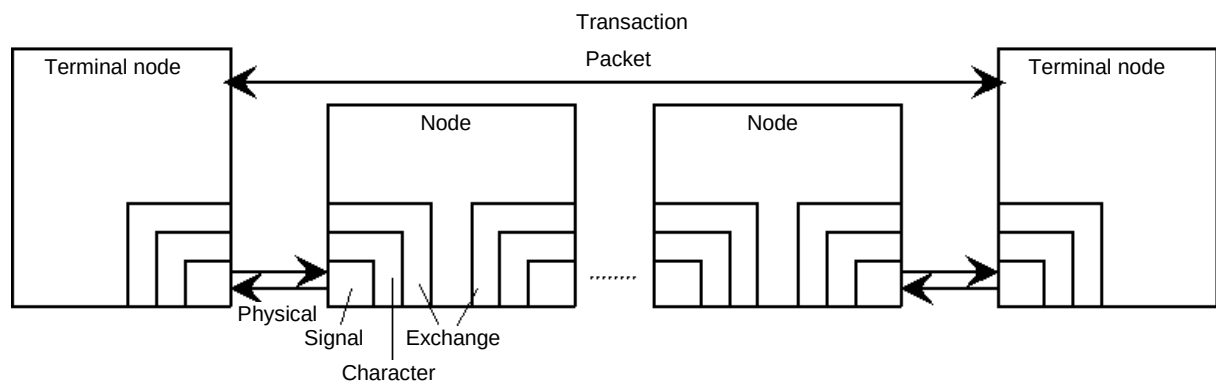


Figure 1 – Protocol stack between nodes

4.1 Physical media

For electrical links, the physical characteristics include the specification of

- a) circuit board physical characteristics,
- b) connectors and contacts,
- c) cables,
- d) shielding requirements,
- e) line impedance,
- f) crosstalk,
- g) electromagnetic emission,
- h) ESD susceptibility.

For optical links, the physical characteristics include the specification of

- optical transceiver properties,
- optical connectors,
- optical fiber.

4.2 Logical layers

4.2.1 Layer 0: signal layer

4.2.1.1 General description

For electrical links, the signal layer includes the specification of

- a) line signal levels and rates
- b) power budget, from which transmission distance may be calculated, taking into account the loss from the cables and connectors
- c) noise margins.

For optical links, the signal layer includes the specification of

- spectral center wavelength, aperture
- optical power budget.

It is important to note that there is a difference between signals and bits. Signals are the values of a measurable quantity (e.g. voltage levels) that are on the transmission line; bits are the logical 1s and 0s that the signals represent. The measurable quantities vary both in nature and in value depending on the implementation (CMOS, ECL, CML, light pulses on a fiber optic cable, etc.).

The signals may have various properties, such as limited running disparity, limited run length, and/or d.c. balance, over a period of time.

4.2.2 Layer 1: character layer

4.2.2.1 Definition of a character

Bits are transmitted in groups called characters. The character layer provides the service to the higher layers of the transmission of a continuous sequence of characters on a link.

4.2.2.2 General description

Characters are used by the higher layers of the protocol to communicate both data information and control information. The number and representations of the various control characters and the representations of the 256 possible data values varies according to the different types of links specified in this International Standard.

4.2.3 Layer 2: exchange layer

4.2.3.1 Definition of the exchange layer

A link is the means of communicating digital information bidirectionally in serial format between two very large scale integration (VLSI) devices. A link comprises two link interfaces connected by an appropriate medium (or media, for connections between boards or cabinets), such that the link output of each link interface is connected to the link input of the other.

The exchange layer describes the procedure of the node-to-node exchange of characters to ensure the proper functioning of the link.

4.2.3.2 General description

Two types of characters are defined: link character (L_char) and normal character (N_char).

- a) L_chars: L_chars are used on a node-to-node link in order to ensure flow control and the proper functioning of the link.
- b) N_chars: N_chars represent, at the minimum, the 256 values of a byte plus an end_of_packet marker. The exchange layer provides the service to the higher layers of the transmission of an indefinite sequence of N_chars. It is specified in such a way as to ensure that N_chars are not lost due to limitations of resources (e.g. lack of available buffer space).

L_chars may be arbitrarily interleaved with N_chars on the link as required by the exchange layer.

Note that in the text of this International Standard the data values of a byte (0 to 255) are referred to as data characters, and all the other used characters (i.e. all L_chars and the remainder of the N_chars) as control characters.

Consider two connected nodes, NODE_A and NODE_B (see figure 2). Each node uses a link interface or port (LINK_INTERFACE_A and LINK_INTERFACE_B, respectively) in order to communicate with the other node. Note that a node may have more than one link interface. Each link interface is divided into two parts: a transmitter and a receiver, referred to as transmitter_A and receiver_A for NODE_A and transmitter_B and receiver_B for NODE_B.

Each link interface has a N_char source (SOURCE_A and SOURCE_B) that supply N_chars to transmitter_A and transmitter_B, respectively, and a N_char sink (SINK_A and SINK_B) that accept data from receiver_A and receiver_B, respectively.

Exchange layer information generated and sent, for example, by transmitter_A is received and filtered by the receiver_B and passed directly to transmitter_B (and vice-versa). L_chars shall not be generated by the source nor written into the sink.

4.2.3.3 Flow control

The N_char sink associated with a link interface has a maximum capacity, defined by the physical implementation. N_chars are written into the sink by the receiver as it receives them at the link interface, and are read from the sink by the application using the link. In order to prevent sink overrun a flow control mechanism shall be implemented.

The source (at the other end of the link) maintains a credit associated with the receiving link interface that indicates how many N_chars the source can transmit over the link without overrunning the sink at the receiving end. For every N_char that the source sends, it shall decrement the credit by one. When the credit reaches zero, the source shall not send any further N_chars, but it may continue to send L_chars. The credit maintained by the source shall be increased by a block value (sometimes referred to as a "flit") of F characters when the source receives a Flow Control Character (FCC) from the opposite receiver. If this happens when the credit was zero (which will have inhibited the transmission of N_chars), then the source may recommence transmitting N_chars. An implementation may restrict the amount of credit that a source can record. If a FCC is received when this credit has its maximum value, the FCC may be discarded (ignored) without affecting the operation of the link. A source shall be able to record at least F N_chars of credit.

The initial value of the credit shall be 0. The block size (value of F) is defined as a function of the technology used.

The sink should send a FCC to the source when it has the space to receive $F N_chars$. Each time the sink authorizes the sending of a FCC it shall reserve the space corresponding to $F N_chars$. While the sink has unreserved space available it should send FCCs until all its space associated with the link interface is reserved. One of the first actions of each sink after the link has been started from a reset condition should therefore be to send the number of FCCs corresponding to its unreserved space.

Using the flow control mechanism described above, there exists a theoretical maximum line length over which "continuous transmission" can be obtained in the case where every N_char written into the sink is immediately read out of the sink by the receiving application. This maximum length is determined by the size of the sink (which determines the number of FCCs that the receiver sends to the transmitter after the link has been started from a reset condition and thus the initial transmitter credit) and a number of implementation-dependent parameters. This is detailed in annex H.

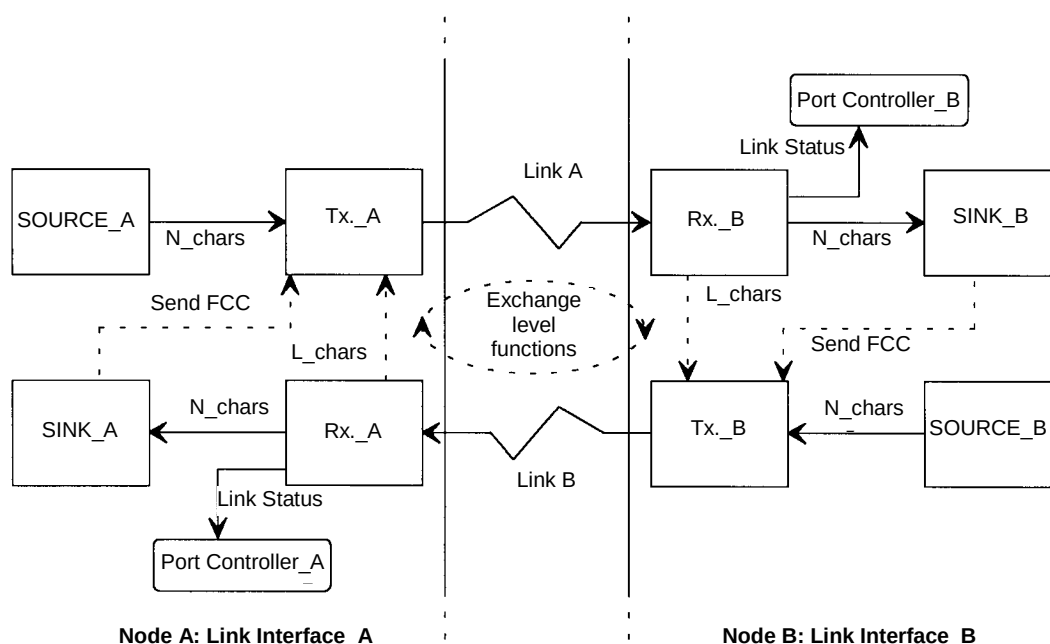


Figure 2 – Exchange layer

Exchange layer flow control greatly simplifies the higher layers of the protocol, since it prevents data from being lost due to buffer overflow and so removes the need for re-transmission unless errors occur. To the user of the system, the net result is that a link functions as a pair of fully handshaken first-in, first-outs, one in each direction. Note that the link interface regulates the flow of data items without regard to the higher layer objects that they may constitute. At any instant the N_chars buffered by a link interface may form part or all of one or more consecutive higher layer objects. L_chars , including FCC, do not belong to such objects and are not buffered.

4.2.4 Layer 3: packet layer

4.2.4.1 Definition of a packet

A packet is a sequence of characters (*N_chars* only) with a specific order and format. Constituent characters of different packets shall not be interleaved on a link. A packet consists of a *destination* followed by a *payload*. A packet is delimited by an *end_of_packet* marker.

4.2.4.2 General description

Terminal nodes generate (source node) and consume (destination node) packets. A network is any set of devices connected by links joining (directly or indirectly) a set of terminal nodes.

The protocol assumes the use of packet-switched networks in which the routing information necessary to correctly transmit the packet across the network is contained in the first *K N_chars* of the packet (where *K* is fixed throughout a subnetwork). It is at the packet layer that the routing decisions are taken. The protocol does not define a specific (or maximum) size for a packet. Successive packets transmitted on a link may have different lengths and/or destinations. Each packet is transmitted in its entirety, i.e. the transmission of a packet on a link shall be completed before the transmission of the successive packet may commence. Packets sent from a given source node to a given destination node over a network may be delivered in an order different from the sending order. The details of mechanisms to ensure in-order delivery are outside the scope of this International Standard.

4.2.4.3 Destination

The destination contains one or more destination identifiers (*dest_id*) that are used as the input to the routing function, enabling the routing network to transit the packet from its source node to its destination node. The destination could be null for specific case of a point-to-point link (i.e. the network is just one link). More than one *dest_id* may denote the same destination node. The method of allocating *dest_ids* to destinations is outside the scope of this International Standard. See also clause 9 and annex E.

4.2.4.4 Payload

The payload is the data (a message, a memory access request, an acknowledgment, etc.) that has to be transferred from the source node to the destination node. It has a specific format, defined in the transaction layer. Note that a payload may be null.

4.2.4.5 End of packet marker

A packet is delimited by an end of packet marker.

4.2.5 Layer 4: transaction layer

A transaction is a sequence of packets sent between two or more terminal nodes to perform some function. At this layer there are two concepts:

- a) definition of the specific payload formats necessary to perform the function;
- b) definition of the sequence of exchanges of packets necessary to perform the required function.

The definition of any form of transaction is outside the scope of this International Standard. Annexes F and I illustrate the use of the transaction layer.

4.3 Interaction of layers

The interaction of the layers is illustrated in figure 3.

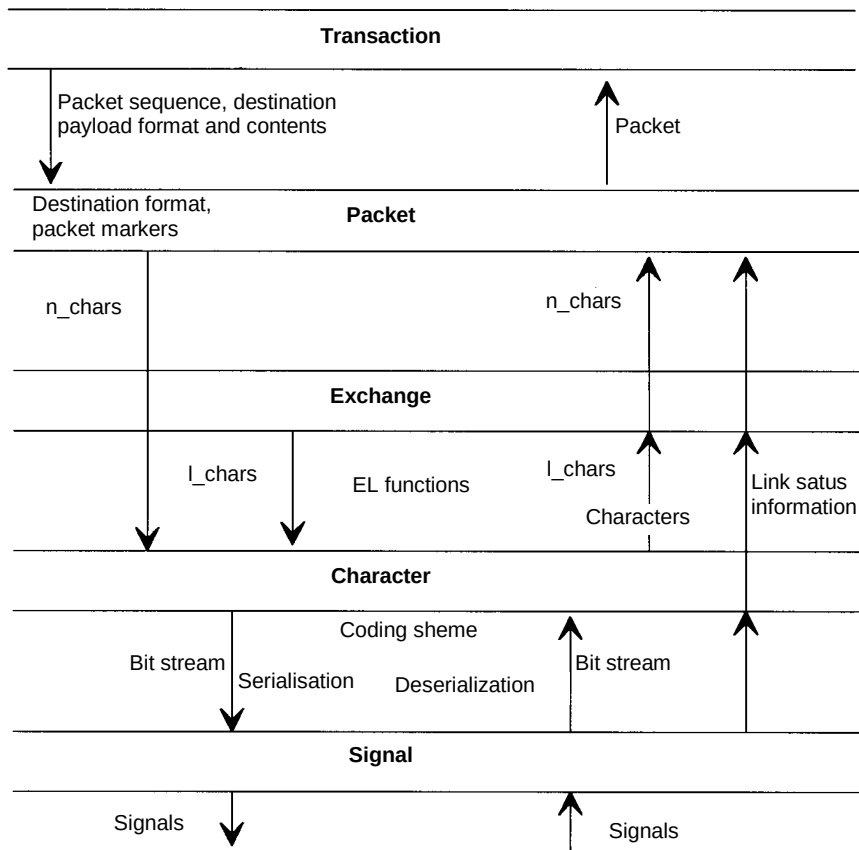


Figure 3 – Protocol stack diagram showing interaction of layers

4.3.1 "Downward going"

4.3.1.1 Transaction layer to packet layer

The transaction layer provides packets to the packet layer. The packet sequence, payload contents and destination address(es) are all determined by the transaction layer. The packet layer forms the packet destination from the destination address(es) and appends the packet with the appropriate end_of_packet marker.

4.3.1.2 Packet layer to exchange layer

The packet layer provides the sequence of N_chars that forms each packet to the exchange layer.

4.3.1.3 Exchange layer to character layer

The exchange layer passes the N_chars that have been provided to it by the packet layer onto the character layer. In order to perform the exchange layer functions, it interleaves L_chars arbitrarily into the sequence of N_chars . The sequence of N_chars is unchanged.

4.3.1.4 Character layer to signal layer

The character layer translates the characters (*N_chars* and *L_chars*) it receives from the exchange layer into a bit stream that it passes to the signal layer. The translation is formed of two parts: coding and serialization. Coding is the translation from the original set of bits (character) to a new set of bits (coded character) suitable for serial transmission. Serialization is the process of transmitting coded characters one bit at a time.

4.3.1.5 Signal layer

The signal layer takes the bit stream and outputs signals onto the physical medium.

4.3.2 Upward going

4.3.2.1 Signal layer to character layer

At the receiver end, the signal layer receives signals from the line and generates the corresponding bit stream.

4.3.2.2 Character layer to exchange layer

The character layer deserializes and decodes the bit stream to produce a sequence of characters. Deserialization is the assembly of a coded character from the sequence of serial bits. Decoding is the translation from the coded set of bits (coded character) to the original set of bits (character). The characters are passed to the exchange layer.

4.3.2.3 Exchange layer to packet layer

The exchange layer filters out *L_chars* for exchange layer functions and passes the *N_chars* to the packet layer.

4.3.2.4 Packet layer to transaction layer

The packet layer reconstitutes the packets from the received *N_chars*. This is a logical reconstitution and need not imply that a whole packet is physically assembled. Routing functions are carried out at the packet layer, based on the information in the packet destination. When necessary (e.g. when a packet has arrived at its destination node), the packets are delivered to the transaction layer.

4.3.2.5 Link status information

Link status information is passed up between the layers from the signal layer to the packet layer. The link status information necessary is dependent on the implementation of the link and includes, for example, information on the calibration of the receiver, parity errors, etc. It is for each layer to filter the information that is relevant to its functioning and to pass up the remaining information.

4.4 Implementations defined in this International Standard

The physical and logical layers defined in this International Standard are illustrated in figure 4.

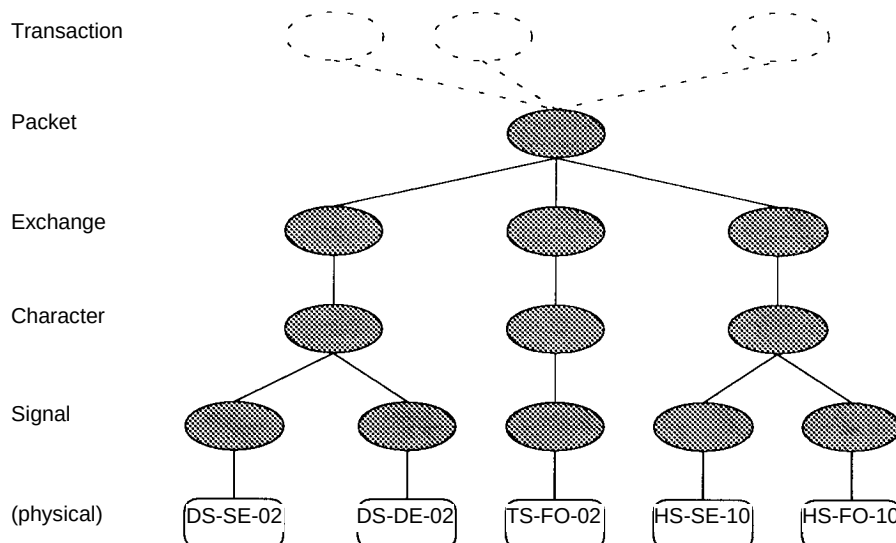


Figure 4 – Defined implementation of physical and logical layers

The physical layer may be implemented in a number of different technologies, identified according to signalling convention, transmission medium, and maximum operating speed.

The format for this identification is given by three parameters:

SC-TM-dd

The possible values of these parameters are given in table 1.

Table 1 – Identification format for technologies

Parameter	Values	Description
SC	DS	Data/strobe encoding
	TS	Three-of-six encoding
	HS	High-speed encoding
TM	SE	Single-ended electrical transmission
	DE	Differential electrical transmission
	FO	Fiber optic transmission
dd	Two digits, representing the maximum operating speed in units of 100 MBd	

Table 2 provides the major properties of each of the defined implementations.

Table 2 – Defined implementations

Technology	Baud rate	Maximum bidirectional data rate	Type of transmission (full duplex)	Maximum distance	Connector specification
Units	Bd	MByte/s	–	m	–
DS-SE-02	1.333-200 M	38	4 wires	1	None
TS-FO-02	250 M	39.4	2 multimode fibers	300	IEC 61754-6
DS-DE-02	1.333-200 M	38	8 wires	10	IEC 61076-4-107
HS-SE-10	700-1 000 M	160	2 coaxial cables	8	IEC 61076-4-107
HS-FO-10	700-1 000 M	160	262.5 μ m multimode fibers	100	IEC 61754-6
			2 50 μ m multimode fibers	1 000	IEC 61754-6
			2 single-mode fibers	3 000	IEC 61754-6

DS-SE links are intended for use for chip-to-chip and board-to-board interconnect. This International Standard does not therefore specify any cable/connector system for these links. DS-DE links are intended for interconnecting sub-racks and adjacent racks using a protocol compatible with DS-SE link from the character layer upwards. TS-FO links are intended to provide longer distance transmission using, necessarily, optical technology, but at speeds compatible with DS-SE links. The use of optical technology necessitates some differences at the exchange layer. HS-SE links are intended for high speed rack-to-rack interconnect. They can, of course, also be used between chips and between boards (across a backplane), given suitable attention to maintaining appropriate signal integrity. HS-FO links are intended to provide longer distance transmission using a protocol compatible with HS-SE links from the character layer upwards.

This International Standard specifies an appropriate cable/connector system for each of the technologies specified within this standard, with the exception of DS-SE links. The connector system is intended as a front-panel adapter and matching cable mounted connector.

This International Standard does not specify any backplane or mezzanine connector standards. This is considered more appropriately specified as an adjunct to specific existing backplane standards.

5 DS-SE and DS-DE

5.1 General

The DS-SE and DS-DE links are designed for point-to-point communication that may be on a single PCB, board to board (DS-SE links), or box to box (DS-DE links). Since this implies that transmission line problems might be present, the electrical level is specified as a transmission line system. In order to reduce the power required for each link (permitting single chips to have a large number of link ports) source-only termination is used for DS-SE links.

A DS-SE/DS-DE input is self-clocking, which means that in any particular system the actual operating speed may be chosen to suit the system, rather than the more normal case of having to engineer a system to suit a pre-determined transmission speed. The maximum speed at which it may run is a function of the maximum speed of the circuitry at each end, plus the properties of the medium connecting the two ends. A link may be operated at lower speeds, for example to provide power saving, down to a level at which the disconnection detection mechanism is triggered.

A link shall operate at a speed of 10 MBd unless and until the system in which it operates determines that it may operate at a different speed. The electrical specification of the link has been designed to allow operating speeds of up to 200 MBd, but the actual operating speed is left open to allow the design of any particular system to trade off engineering costs against operating speed. The means of setting the speed of a link is not defined within this International Standard.

5.2 DS-SE: physical medium

5.2.1 Transmission line requirements

For distances greater than a few centimeters, signal integrity considerations dictate that the link line has to be considered as a transmission line. Discontinuities or variations in characteristic impedance should be kept to a minimum. The transmission line may be made on PCBs but care shall be taken to provide a good ground or power plane beneath the link track and crosstalk with other tracks should be minimized (including between data and strobe lines of the same link). The longest length of line achievable will depend on the materials used for interconnect and the grounding arrangements.

DS-SE supports two standard nominal characteristic impedances for the physical medium, 50 Ω and 100 Ω . Drivers conforming to the DS-SE electrical standard shall support one of these impedances and may support both. Each direction (i.e. the data and the strobe line) of a single point-to-point link shall use either one or other impedance throughout the length of the link and use a matched driver. The opposing directions of a single point-to-point link may, however, use different impedances.

5.3 DS-SE signal level

5.3.1 General

Each connection of a DS-SE link shall be implemented as a unidirectional point-to-point transmission line. The transmission line shall have a characteristic impedance of either 50 Ω or 100 Ω and shall be terminated by high impedance at the receiver. The transmission line may be provided by PCB, coaxial or other suitable controlled impedance interconnect. The receiver shall be designed to accept standard TTL input switching levels with a high input impedance. The driver output impedance should be close to the characteristic impedance of the transmission line both when the driver is driving low or high and also while switching. This is to ensure that reflections generated by the receiver are sufficiently damped by the driver that they do not cause spurious transitions. The range 0.8 V to –2.0 V at the receiver is defined as the transition region. It is very important that the signal at the receiver is monotonic in the transition region, and that the reflections do not cause spurious transitions. This should be ensured by careful design of the interconnect and the driver output.

The propagation of signals is as follows. Assuming that the line is in a steady-state low condition, a high going transition is output by the driver. Because of the relatively high output impedance of the driver compared to the line, this is attenuated, typically to a level of about 1.4 V at the driver output. At the receiver, the high input impedance of the receiver (effectively an open circuit) causes this to appear as a 2.8 V step (taking the input cleanly through the transition region), and the reflection travels back down the line to the driver. Depending on how closely the driver output impedance is matched to the line, this may cause further reflections. It is crucial that the driver is matched sufficiently well that these reflections do not cause spurious transitions at the receiver, or interfere with subsequent output transitions. Propagation for a low-going transition is similar. Figure 1 shows example waveforms for the driver and the receiver end of the transmission line for a 100 Ω system operating from a 5 V supply.

Note that the signal levels at the receiver and the specification of the driver allows DS-SE links to be interconnected between devices operating from 5 V and 3.3 V supply rails as long as the inputs of the 3.3 V devices are tolerant of 5 V signals.

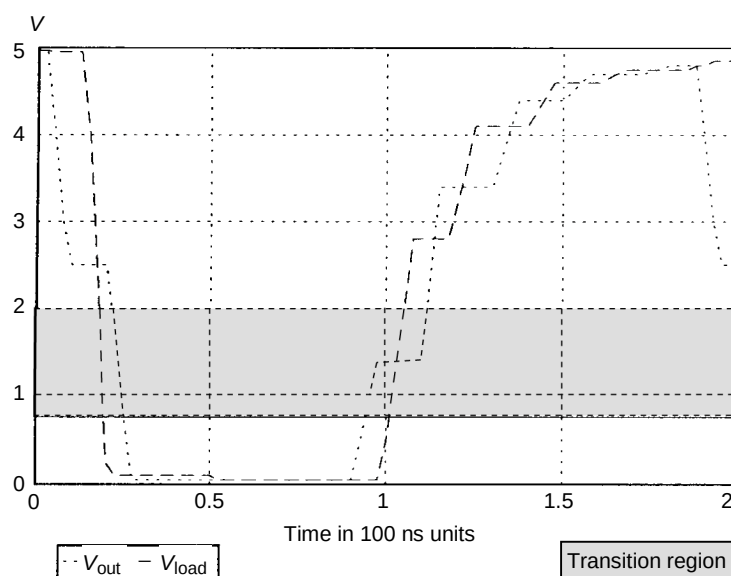


Figure 5 – DS-SE link signal propagation

5.3.2 DS-SE link driver

Each driver should have a nominal output impedance of either 50 Ω or 100 Ω depending on the transmission medium to terminate the reflections from the receiver. The output impedance shall be controlled when the output is fully on driving a high or low level, and also while switching. In order to be adequately matched, the characteristics of the driver and the transmission line shall be related as shown in the table 3.

Table 3 – Driver to line impedance matching table

		$V_{dd} = 3.0 \text{ V to } 3.6 \text{ V}$				$V_{dd} = 4.5 \text{ V to } 5.5 \text{ V}$			
		Z_n		Z_p		Z_n		Z_p	
	Units	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
$Z_0 = 45 - 55$	Ω	29	56	37	67	32	52	55	123
$Z_0 = 90 - 110$	Ω	58	112	73	135	64	104	110	247

Z_0 is the characteristic impedance of the transmission line. Z_n is the impedance of the driver when the output is driving low, and Z_p the impedance when it is driving high. The figures depend on the supply voltage used by the driver because the input threshold is fixed.

It is recommended that nominal 50 Ω characteristic impedance transmission lines be used in nominal 3.3 V systems and on backplanes.

On power on and reset, a DS-SE link output shall hold both the data and strobe signals low.

Annex J gives an example DS-SE link driver circuit for a 100 Ω transmission line with 5 V supplies.

5.3.3 DS-SE link receiver

A DS-SE link input shall present a high impedance termination to the transmission line. An impedance of >10 k Ω is recommended. This high input impedance is essential to ensure that the correct signal levels are produced at the receiver input.

The input threshold of the receiver is nominally 1.4 V and shall be within the transition region, which is defined as 0.8 V to 2.0 V.

The input capacitance is modeled as described in 5.3.4 (see figure 6) and specified in table 4.

Table 4 – DS-SE input capacitance

Symbol	Parameter	Units	10 MBd		100 MBd		200 MBd		Notes
			Min.	Max.	Min.	Max.	Min.	Max.	
C_i	Input capacitance	pF	–	300	–	30	–	4	–

5.3.4 DS-SE link timing

A link shall operate at a speed of 10 MBd, until the system in which it operates shall determine it may operate at a different speed. A link may be operated at a speed lower than its nominal speed to suit the transmission medium. If a link is operated at a lower speed, the same timing constraints shall apply at the receiver inputs.

DS-SE parameters are relative to a reference model, as shown in figure 6.

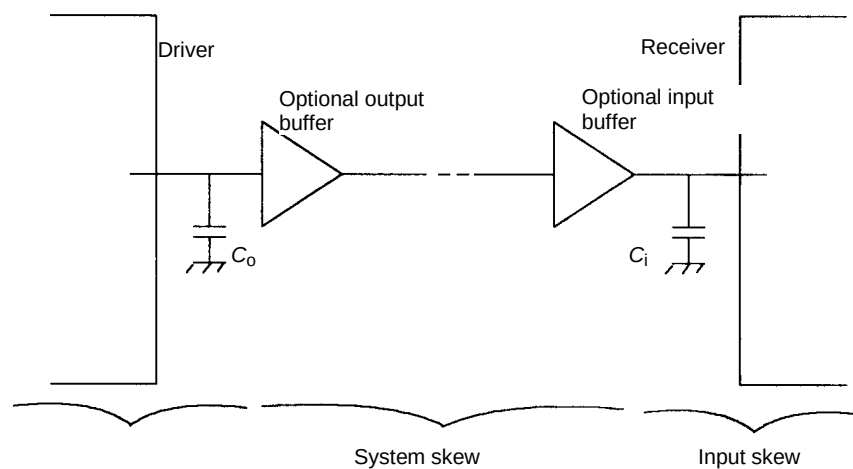


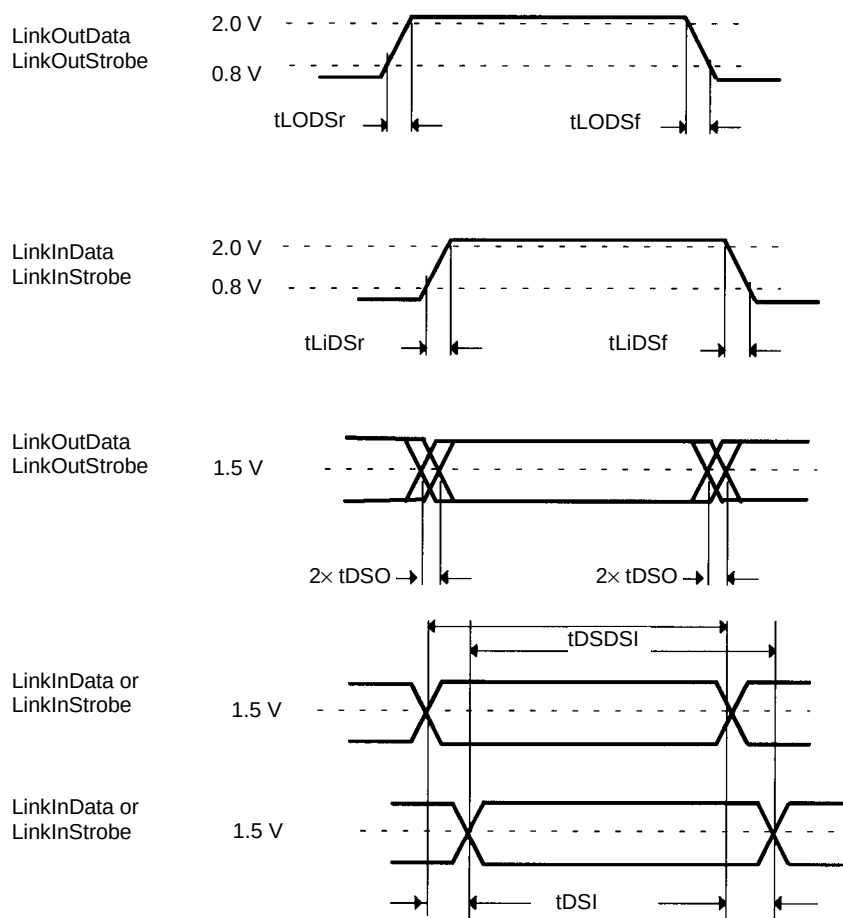
Figure 6 – DS-SE timing reference model

This model shows the possibility of buffers in the signal path, in which case the output impedance of the second buffer is assumed to be not more than 100 Ω , and C_o is assumed to be not more than C_i . If buffers are not used then C_i and C_o are combined into a single capacitive load that may be twice the figure given in table 4. If the output drivers are matched to 100 Ω , and it is required to use 50 Ω transmission lines, then buffers will be required.

Three sets of timing parameters are defined (see table 5 and figure 7), to allow for operation at the default speed of 10 MBd (DS-SE-00 links), 100 MBd (DS-SE-01 links), and 200 MBd (DS-SE-02 links). A higher speed link type will always be able to operate at a lower speed.

Table 5 – DS-SE timing and swings

Symbol	Parameter	Units	10 MBd		100 MBd		200 MBd		Notes
			Min.	Max.	Min.	Max.	Min.	Max.	
tDSI	D/S edge min. separation	ns	–	20	–	2.5	–	1	1.2
tDSDSI	Sustainable input bit period	ns	80	750	9	750	4.5	750	3
tLIDSf	Input fall time (2.0 V – 0.8 V)	ns	–	100	–	100	–	100	4
tLIDSr	Input rise time (0.8 V – 2.0 V)	ns	–	100	–	100	–	100	4



NOTE 1 t_{DSI} is the minimum separation between consecutive edges on the data and strobe inputs (one edge of either sense on each wire) that the link can discriminate correctly. An implementation shall not require this to be greater than the appropriate value specified in table 5.

NOTE 2 The same figure applies to consecutive edges of opposite sense on either the data or the strobe input.

NOTE 3 In general a link input cannot handle a continuous stream of edges separated by t_{DSI} . This figure specifies the sustained bit period that shall be accepted for the nominal baud rate. The maximum nominal bit time is determined by disconnect time-out period of the link receiver.

NOTE 4 This is the slowest edge that the input shall accept.

Figure 7 – DS-SE link timings

The output skew is determined by parameters given in table 6.

Table 6 – DS-SE output skew parameters

Symbol	Parameter	Units	10 MBd		100 MBd		200 MBd		Notes
			Min.	Max.	Min.	Max.	Min.	Max.	
tDSO	Output D/S skew	ns	–	±5	–	±1	–	±0.5	1
tLODSf	Output fall time (2.0 V – 0.8 V)	ns	–	40	–	4	–	2	–
tLODSr	Output rise time (0.8 V – 2.0 V)	ns	–	40	–	4	–	2	–

NOTE This is a skew measured at the 1.5 V threshold relative to the nominal time at which it is specified to cross it, defined in terms of consecutive edges. For example, if two consecutive edges are nominally 5 ns apart, the length of time between the time at which each will cross the threshold can be 5 ns ± tDSO.

Allowable system skew is determined by the constraint that the sum of tDSI, the range of tDSO and the system skew shall not exceed nominal bit time. Thus, for DS-SE-01 links the system skew shall not exceed 5.5 ns.

5.3.5 DS-SE link signals

Information on a DS-SE link shall be transmitted using two connections, referred to as data and strobe respectively, in each direction. Each connection shall satisfy the electrical constraints specified in the previous subclause. The data line carries binary data values, and the accompanying strobe line changes state each time the next bit has the same value as the previous one (this does not correspond with the usual meaning of "strobe", which would be a signal that indicates every time that another signal is valid). By this means each DS pair carries an encoded clock, in a way that allows up to a full bit-time of skew-tolerance between the two connections. Figure 8 shows the form of signals on the data and strobe connections.

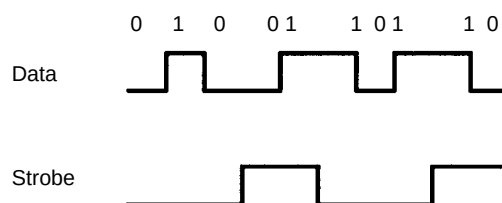


Figure 8 – DS-SE link signal encoding

Since the data-strobe system carries a clock, the links are asynchronous; the receiving device synchronizes to the incoming data. This means that DS-SE (and DS-DE) links autobaud; the only restriction on the transmission rate is that it does not exceed the maximum speed of the receiver. This also simplifies clock distribution within a system, since the exact phase or frequency of the clock on a pair of communicating devices is not critical. It is not essential that both link outputs of one link connection should operate at the same speed, nor that a link output operates at a constant speed. A link output might choose to vary its speed of operation to reduce power consumption when there is no data to be transmitted, for example. The only constraint on the transmission rate is that the bit time limits given in table 5 are not violated, and that it is high enough to prevent a disconnect timeout being triggered (see 5.7.4.2).

A DS-SE link output transmits information on a pair of lines, and a DS-SE link input receives information on a pair of lines. A DS-SE link interface shall comprise a DS-SE link output and a DS-SE link input.

A device providing one or more DS-SE link interfaces shall identify the pins used for each link interface by a convention (using subscription where multiple links are supported) based on function and direction of transmission as shown in table 7.

Table 7 – Identification of multiple link interfaces

DS_SE_data_in	For input of data to the device through the link interface
DS_SE_strobe_in	
DS_SE_data_out	For output of data from the device through the link interface
DS_SE_strobe_out	

A DS-SE link is constructed by connecting the DS_SE_data_out and DS_SE_strobe_out of one link interface to the DS_SE_data_in and DS_SE_strobe_in respectively of the other link interface, and vice versa.

The DS_SE_data_out and DS_SE_strobe_out of a link interface may be connected to the DS_SE_data_in and DS_SE_strobe_in respectively of the same link interface to create a loopback, e.g. for link testing.

5.4 DS-DE: physical medium

5.4.1 Link cable

A DS-DE link cable shall provide ten connections. Eight connections (in four pairs) shall support the eight signals in the DS-DE link; the ninth and tenth connections shall support an optional remote power facility.

A recommendation for the DS-DE cable is given in annex M.

Each connection in the cable shall be color coded as given in table 8 and have the characteristics as given in table 9. Note that attenuation and skew budgets are given in 5.5.3 and 5.5.4.

Table 8 – DS-DE cable color code

Component	Conductor 1	Conductor 2
Pair 1	Red	Green
Pair 2	Brown	Blue
Pair 3	Orange	Yellow
Pair 4	Violet	Gray
Pair 5	Black	White

The link cable shall be clearly marked "ISO/IEC 14575 DS-DE Link Cable".

5.4.2 Connector

The connector system consists of a through-panel (fixed) connector and a cable-mounted (free) connector.

It provides the following features:

- a) A full duplex link connection per connector
- b) Option for multiple connections on the cable connector
- c) Complete screening
- d) Robust
- e) Latching
- f) Small size

The DS-DE connectors shall be as specified in IEC 61076-4-107.

Table 9 – Electrical and mechanical characteristics and safety certification of DS-DE cable

Electrical characteristics	
Differential impedance	95 $\Omega \pm 10 \Omega$
EMC	Cable shall allow system to meet CISPR limits
Near end crosstalk (backward)	2 % maximum at 100 MHz measured on 10 m sample in differential mode
Far end crosstalk (forward)	4 % maximum at 100 MHz measured on 10 m sample in differential mode
Mechanical performance	
Flexibility	A 60 mm maximum radius shall result when 610 mm of cable is loaded with a suspended weight of 100 g
Flex life	1 000 cycles through 180° at 60 mm bend radius and 100 g load. Following this test, the insulation and jacket should be free of cracks and the conductors free of opens and shorts.
Minimum bending radius (static operation)	40 mm
Safety certification	
For cables up to 10 ft (3 m) in the US	IEC 61156: AWM style 20276, 80C, 30 V, VW1
For cables 10 ft (3 m) to 100 m	IEC 61156 class 2 power limited circuit cable (CL2)

The (free) connector at either end of the cable shall be connected to the conductors in the cable according to table 10.

Table 10 – DS-DE link cable conductors/connectors wiring

Pin	Conductor	Pin
1a	Pair 2 brown	2e
2a	Pair 2 blue	1e
1b	Pair 1 red	2d
2b	Pair 1 green	1d
1c	Pair 5 white	1c
2c	Pair 5 black	2c
1d	Pair 3 orange	2b
2d	Pair 3 yellow	1b
1e	Pair 4 violet	2a
2e	Pair 4 grey	1a

Note that the effect of the cable/plugs assembly is to provide a single twist in each of Pairs 1, 2, 3, and 4, and to provide a single twist between Pairs 1 and 3 and between Pairs 2 and 4. This is shown in figure 9 using Pairs 2 and 4 as an example.

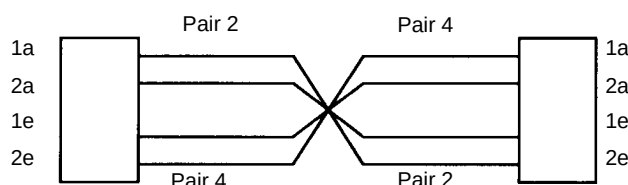


Figure 9 – DS-DE cable assembly twist example

Any extension adapters allowing multiple segments of cables to be used shall also provide such a twist, so that the effect of any such cable/adapter/cable combination is to provide a single twist, as illustrated in figure 10.

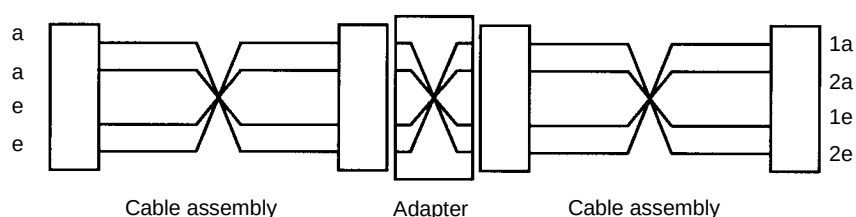


Figure 10 – DE-DE extension adapter

The allocation of DS-DE signals to the connector pins shall be as given in table 11 (which is oriented to correspond to the external view of the through-panel (fixed) connector when mounted on the upper surface of a horizontal PCB. See figure 11.) The direction of the signals is as on the fixed connector.

Table 11 – Pin allocation of DS-DE connector

	2	1	
e	DS_DE_data_in_plus	DS_DE_data_in_minus	(Chamfer corners at this side of the connector)
d	DS_DE_strobe_in_plus	DS_DE_strobe_in_minus	
c	No connect or optional power return	No connect or optional power	
b	DS_DE_strobe_out_minus	DS_DE_strobe_out_plus	
a	DS_DE_data_out_minus	DS_DE_data_out_plus	

Table 12 – DS-DE connector modularity specifications

Characteristic	Specification
Modularity	Fixed connector modules shall be placed on a 6 mm pitch, or their centerlines separated by more than 12 mm
Connector width	5.9 mm maximum

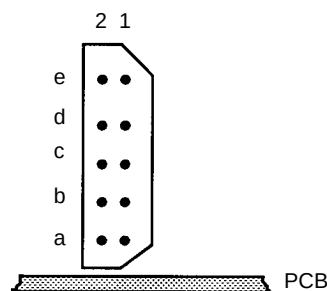


Figure 11 – DS-DE fixed connector external view

Pins 1c and 2c of the DS-DE fixed connector are either both left unconnected on the PCB, or are used to implement an optional power supply, as specified in 5.4.4. It is recommended that fixed DS-DE link connectors with neither source nor sink power connections should include 10 MΩ bleeders to ground on pins 1c and 2c to prevent static build-up on otherwise unconnected power conductors.

In addition to the interface specification of IEC 61076-4-107, the connectors shall have the properties described in table 12.

Annex L provides a recommendation for the PCB layout of the fixed connector.

5.4.3 Environmental constraints

The environmental requirements for the DS-DE link cables and connectors are application dependent. However, as a minimum, the cables and connectors shall meet the constraints in table 13. Note that specific applications may have requirements for extended temperature range, or other environmental parameters.

Table 13 – DS-DE environmental constraints

Parameter	Value
Operating temperature	–10 °C to +60 °C
Non-operating temperature	–40 °C to +85 °C

5.4.4 Optional power supply to DS-DE cable

5.4.4.1 Optional power supply

An explanation of the remote power, and recommendations of components that should meet the following specification, are given in annex K.

Pin 1c either provides an output power supply based on the equipment's 5 V VCC, with a self-healing fuse for overcurrent protection and a (Schottky) diode for reverse-current protection, or provides power to local circuitry from a remote source. Components should be chosen to meet the specification given in table 14. Pin 2c provides for power return.

Table 14 – Optional power supply

Symbol	Parameter	Value
I _{pHold}	Hold current, the operating current that the overcurrent protection device will pass without going high impedance	750 mA minimum
V _{pOHmin.}	Output voltage with respect to pin 2c at maximum steady-state output current	3.75 V minimum at 750 mA
V _{pOHmax.}	Output voltage with respect to pin 2c at any output current greater than a leakage current of 1 mA	5.0 V maximum
I _{pReverse}	Reverse-current	1 mA maximum at reverse voltage of 12 V with respect to pin 2c

The load drawn from this power supply at the end of 500 mm cable with conductors as specified for the DS-DE link cable, shall meet the specification given in table 15. The product of power used and cable length shall not exceed 1 W × m.

Table 15 – Optional power supply load

Symbol	Parameter	Value
P _p	Power consumption	2.5 W maximum
V _{pRemoteLow}	Lowest input voltage with respect to pin 2c at remote power supply at which the remote power supply is able to supply the required power	3.5 V maximum
V _{pRemoteHigh}	Highest input voltage with respect to pin 2c at remote power supply that the remote power supply can tolerate	5.0 V minimum

5.4.4.2 Power supply protection

The above specification for the remote power supply defines the minimal requirements for operation in the absence of a fault. It is recommended that the overcurrent protection device meets the specification given in table 16 in the event of an overcurrent fault.

Table 16 – Optional power supply protective device

Symbol	Parameter	Value
IpTrip	Trip current, the minimum current that will cause the overcurrent protection device to switch to a high-impedance state	2.5 A
TpTrip	Trip time, the maximum time for the over-current protection device to switch to its high impedance state with a fault current of 10 A	0.5 s
TpReset	Reset time, the time from when a fault is removed to when the over-current protection device returns to its specified characteristics	1 h maximum (but note typical recovery to within 20 % of specification, normally within less than 1 min)

5.4.4.3 Layout convention

It is recommended that in any block of adjacent DS-DE link connectors, the end connector with space adjacent to its pins 1 (the end with the D chamfers of the connector pointing outwards from the block), be supplied with power on pin 1c, and that if more than one connector in any block be supplied with power, all such connectors should be adjacent (see figure 12). Equipment need not have special markings to identify connectors supplying power, but it is recommended that such connectors are clearly documented.

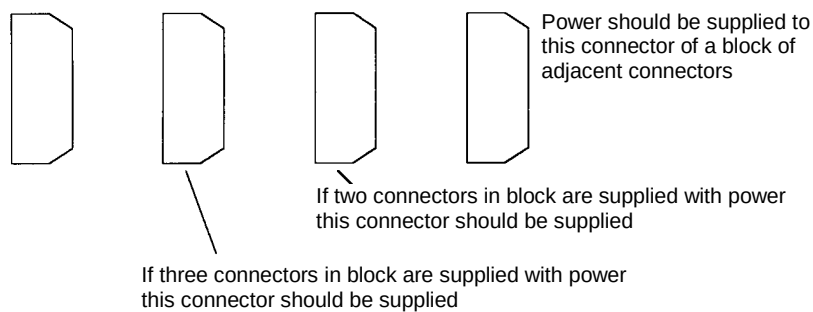


Figure 12 – Multiple power connectors

5.5 DS-DE signal level

5.5.1 General

Differential signalling may be used, e.g. for connections between equipment. Differential signalling provides the following advantages over single-ended signalling.

- a) Increased noise immunity
- b) Avoidance of ground loops between equipment

A DS-DE link interface may be constructed by connecting two differential drivers and two differential receivers to a DS-SE link interface as follows.

- Each connection point of the DS-SE link output is connected to the input of a differential driver, generating a pair of balanced signals from the on-board DS-SE electrical specification. The two pairs of signals form the DS-DE link output.
- Each connection point of the DS-SE link input is connected to the output of a differential receiver, converting two pairs of balanced signals into two signals conforming to the on-board DS-SE electrical specification. The two pairs of signals form the DS-DE link input.

A DS-DE link interface shall have the logical properties that it would inherit if connected to a DS-SE link interface in this way. This is the recommended implementation of a DS-DE link interface.

A DS-DE link is constructed by connecting two DS-DE link interfaces by a suitable eight-wire transmission line, in the manner defined in 5.4.

A system built using DS-DE links shall meet CISPR limits concerning electromagnetic emissions.

5.5.2 DS-DE signals

Each connection in a DS-DE link shall be made with a nominal 95 Ω transmission line. The transmission line shall be terminated at the receiver inputs: the combination of receiver input impedance and line termination shall be 100 Ω .

The signalling uses a pair of balanced pseudo-ECL signals. Pseudo-ECL signals have ECL-levels shifted by 5 V. See table 17.

Table 17 – DS-DE signal levels

Parameter	Units	Min.	Typ	Max.
Driver differential output voltage	V	0.8	1.0	1.4
Driver common mode output voltage	V	2.5	–	4
Driver output rise time (20 % – 80 %)	ns	0.5	–	2
Receiver input impedance (including termination resistance)	Ω	90	100	110
Receiver input common mode voltage	V	–1.2	–	7.2
Receiver sensitivity	mV	200	–	–

The relevant buffer shall not be placed more than 3 cm from the corresponding fixed connector unless the tracks between the buffer and the connector are matched to 100 Ω .

The DS-SE connection consists of four signals. Each pair of DS-DE signals is specified by reference to a corresponding DS-SE signal, as defined in table 18. Note that DS-DE signals need not be implemented by being derived from the corresponding DS-SE signals.

Table 18 – DS-DE correspondence

Single-ended side	Differential side	
DS_SE_data_out	DS_DE_data_out_plus	DS_DE_data_out_minus
DS_SE_strobe_out	DS_DE_strobe_out_plus	DS_DE_strobe_out_minus
DS_SE_data_in	DS_DE_data_in_plus	DS_DE_data_in_minus
DS_SE_strobe_in	DS_DE_strobe_in_plus	DS_DE_strobe_in_minus

In each differential pair, the plus version of the signal is positive going when the corresponding single ended signal is positive going, and vice versa.

A link shall connect two sets of differential pairs by connecting the DS_DE_data_out_plus of one set to DS_DE_data_in_plus of the other set, DS_DE_strobe_out_plus of one set to DS_DE_strobe_in_plus of the other set, and similarly for the _minus signals.

5.5.3 DS-DE attenuation budget

The total attenuation for each of the DS-DE signals (from output of the driver to input of the receiver) shall be less than or equal to 6 dB at 100 MHz. This attenuation shall be divided following the guidelines given in table 19.

Table 19 – Attribution of attenuation budget

Parameter	Maximum attenuation / dB
Output of driver to output of connector	0.5
Across cable	5
Input to connector and input of receiver	0.5

5.5.4 DS-DE skew budget

The skew shall be divided following the guidelines given in table 20.

Table 20 – Attribution of skew budget

Parameter	Maximum skew between D and S/ns		
	10 MBd	100 MBd	200 MBd
Output of differential driver to output of connector	5	0.5	0.35
Across cable	15	1.5	1.3
Input to connector and input of differential receiver	5	0.5	0.35

If the DS-DE links are implemented by using transceivers to convert between the differential signals and the corresponding single ended DS-SE signals, then the differential skew between D and S shall be controlled so that the resulting single ended signal respects the guidelines given in 5.3.1.

5.5.5 DS-DE link timing

DS-DE link timing is as for DS-SE timing (see 5.3.4, with references to DS-SE replaced by DS-DE).

5.5.6 EM susceptibility

A system using DS-DE links shall meet or exceed IEC 60801-4 specifications on EM susceptibility as a function of the intended operating environment. To reduce susceptibility to EMC it is recommended that it is ensured that the fixed connector is connected to housings by using appropriate EMC brackets and/or gaskets (similar to B.3), or that small common-mode chokes are used in series on the signal lines, and the power lines if connected. A suitable specification for such chokes is 200 Ω min at 20 Hz to 300 MHz, 800 Ω typ at 100 MHz.

5.6 DS-SE and DS-DE character level

In order to provide efficient support for higher level protocols, it is useful to be able to encode characters that may contain a data byte or control information (in other standards these might be referred to as symbols). Each character shall start with a parity bit followed by a control bit that is used to distinguish between data and control characters. In addition to the parity and control bits, data characters contain 8 b of data, and control characters have 2 b to indicate the character type. This is illustrated in figure 13.

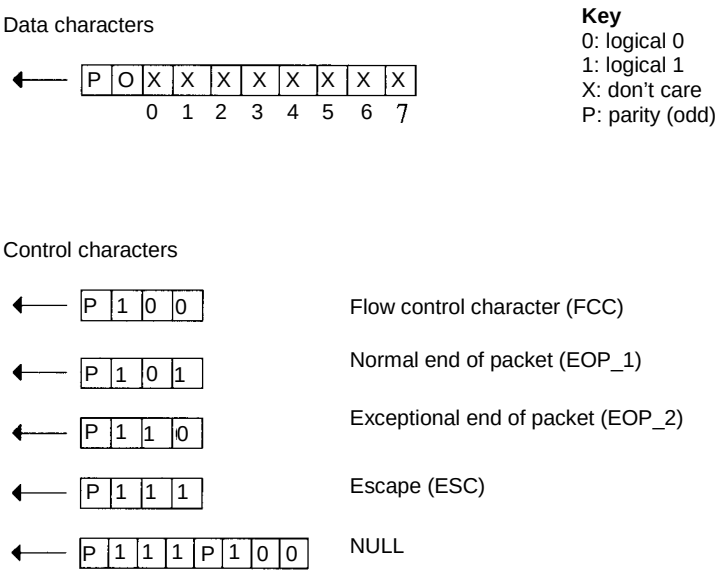


Figure 13 – DS-SE/DS character encoding

Data bits shall be transmitted using the "little endian" convention, i.e. the least significant bit of data shall be transmitted first (immediately after the zero control bit). The first bit transmitted after a reset state shall be a zero (which implies that the first transition is on the strobe wire).

The parity bit in any character covers the parity of the data/control flag in the same character, and the data or control bits in the previous character, as in figure 14. This allows an error in any single bit of a character, including the character type flag, to be detected even though the characters are not all the same length. The parity bit is set such that the total number of 1s in all the bits covered (including the parity bit) is odd.

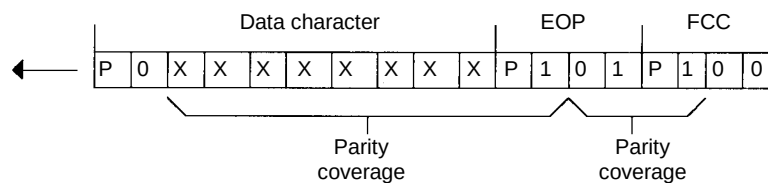


Figure 14 – DS-SE/DS-DE parity coverage

DS-SE/DS-DE links code the *N_chars* EOP_1 and EOP_2 as shown in table 21, in which P indicates the position of the parity bit in the character.

DS-SE/DS-DE links define and code *L_chars* as shown in table 22, and their application is discussed in 5.7.

The null character is composed of two characters. The scope of the parity bit in a character that follows a null character includes only the second 4 b control character of the null character; i.e. it will be a one if the following character is a data character, and will be a zero if the following character is a control character.

Table 21 – Terminator character codings

Name	Description	Code
EOP_1	Normal end_of_packet marker	P101
EOP_2	Exceptional end_of_packet marker	P110

Table 22 – Link control character codings

Name	Description	Code
FCC	Flow control character	P100
ESC	Escape character	P111
NULL	Null character	ESC P100

5.7 DS-SE and DS-DE exchange level

5.7.1 General

Once a link output has been started it shall send characters continuously at such a rate that the bit time constraints given in table 4 are never exceeded, unless and until instructed to cease operation or an error is detected. In the absence of other characters, a DS-SE/DS-DE link transmits NULL characters. This ensures the following:

- a) physical disconnection of a link is immediately detected; because a DS-SE/DS-DE link transmits characters continuously even in the absence of a message, a physical disconnect can be assumed if the inputting link detects that there are no characters being received, given that some have been received previously;
- b) the final parity bit of a packet is transmitted immediately; because the parity of each character is validated by the parity bit of the following character, the validation of the final character of a packet would otherwise be delayed for an arbitrary amount of time.

5.7.2 DS-SE and DS-DE initialization

After reset, a DS-SE link output shall maintain both signals at their reset level until started, i.e. instructed to begin operation (note that receipt of a character by the corresponding link input may be taken as such an instruction). Thereafter it shall send only NULL characters unless and until at least one character has been received by the corresponding link input since reset. After the link output has been started and at least one character has been received by the corresponding link input since reset, the link shall begin normal operation. In normal operation, N_chars provided for transmission are sent when there is flow control credit available, and flow control credit is issued by transmitting FCCs corresponding to available space in the link input buffer. A timeline diagram illustrating DS-SE and DS-DE initialization and reset is given in figure 16.

If a link interface is reset during normal operation, then it shall cease to transmit. This will be detected as a disconnection error by the receiving interface, which then will also cease to transmit. After the exchange of silence protocol, described in 5.7.4.2 and illustrated in figures 15 and 16, both ends of the link will enter the ready state and normal operation may begin. The exchange of silence protocol allows the reset procedure to have the desired effect if the two links are operating in separate reset domains.