4 FC-PI-6 functional characteristics

4.1 General characteristics

FC-PI-6 describes the physical link, the lowest level, in the Fibre Channel system. It is designed for flexibility and allows the use of several physical interconnect technologies to meet a wide variety of system application requirements.

The FC-FS-4 protocol is defined to operate across connections having a bit error ratio (BER) detected at the receiving port of less than or equal to 10^{-6}. It is the combined responsibility of the component suppliers and the system integrator to ensure that this level of service is provided at every port in a given Fibre Channel installation.

FC-PI-6 has the following general characteristics.

In the physical media signals a logical “1” shall be represented by the following properties:

1) Optical - the state with the higher optical power

2) Balanced copper - the state where the conductor identified as “+” is more positive than the conductor identified as “-”

Serial data streams are supported at signaling rate of 32GFC. 32GFC has transmitter and receiver clock tolerances of $\pm$100 ppm. A TxRx Connection bit error rate (BER) of $\leq 10^{-6}$ as measured at its receiver is supported. The basis for the BER is the encoded serial data stream on the transmission medium during system operation.

Fibre Channel identifies ten different specific categories of physical locations in the FC system:

- *alpha T* and *alpha R* are *reference points* used for establishing electrical signal budgets at the chip pins of the transmitter or receiver in an FC device or retiming element.

- *beta T* and *beta R* are *interoperability points* used for establishing signal budget at the disk drive connector nearest the alpha point. The *beta* point specifications are intra-enclosure specifications.

- *gamma T* and *gamma R* are *interoperability points* used for establishing singal budges at the external enclosure connector.

- *delta T* and *delta R* are *interoperability points* used for establishing signal budges at the internal connector of a removable PMD element.

- *epsilon T* and *epsilon R* are *interoperability points* used for establishing signal budget at internal connectors mainly in blade applications. The epsilon point specifications are for intra-enclosure specifications.

See FC- MSQS-2 (reference [30]) for further discussion of reference and interoperability points. Of particular interest for 32GFC are *gamma* interoperability for optical compliance (Clause 5) and *delta* interoperability for electrical compliance (Clause 6). An alternative to *epsilon* interoperability for backplane compliance is given in Clause 7. See Figure 1.

The requirements specified in FC-PI-6 shall be satisfied at separable connectors where interoperability and component level interchangeability within the link are expected. The interoperability points are defined at separable connectors since these are the points where different components can easily be added, changed, or removed. There is no maximum number of interoperability points between the initiating FC device and the addressed FC device as long as (1) the requirements at the interoperability points are satisfied for the respective type of interoperability point and (2) the end to end signal properties are maintained under the most extreme allowed conditions in the system.

It is the combined responsibility of the component (the separable hardware containing the connector portion associated with an interoperability point) supplier and the system integrator to ensure that intended interoperability points are identified to the users of the components and system. This is required because not all connectors in a link are interoperability points and similar connectors and connector positions in different applications may not satisfy the FC-PI-6 requirements.

No interoperability points are required for closed or integrated links and FC-PI-6 is not required for such applications. For closed or integrated links the system designer shall ensure that a BER of better than 10^{-6} as required by FC-FS-4 is delivered.

A *compliance point* is a physical position where Fibre Channel specification requirements must be met. Fibre Channel standards have historically considered interoperability points and compliance points to be co-located. This is not strictly correct. *Gamma* point optical compliance is measured at the end of a fiber optic patch cord, and for 32GFC, *delta* point electrical compliance is measured with Host Compliance Boards (HCB) and Module Compliance Boards (MCB) as defined in FC-MSQS-2 (reference [30]). Nevertheless for simplicity in the remainder of this clause, the terms compliance point and interoperability point will be used interchangeably.

Figure 1 shows the reclocker locations for 32GFC multi-mode and single-mode variants.

The signal and return loss requirements in this document apply under specified test conditions that simulate some parts of the conditions existing in service. This simulation includes, for example, duplex traffic on all Ports and under all applicable environmental conditions. Effects caused by other features existing in service such as non-ideal return loss in parts of the link that are not present when measuring signals in the specified test conditions are included in the specifications themselves. This methodology is required to give each side of the interoperability point requirements that do not depend on knowing the properties of the other side. In addition, it allows measurements to be performed under conditions that are accessible with practical instruments and that are transportable between measurement sites.

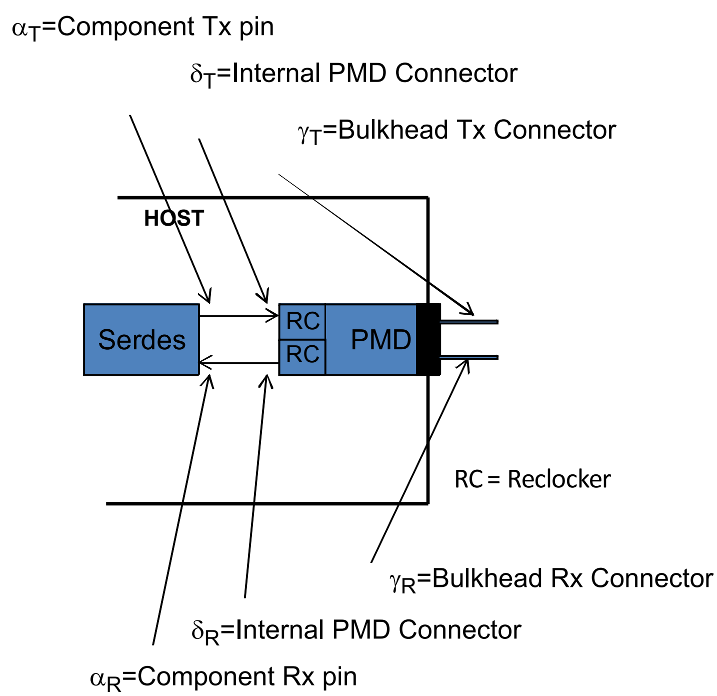

Figure 1 – reclocker location for all 32GFC PMDs

Measuring signals in an actual functioning system at an interoperability point does not verify compliance for the components on either side of the interoperability point although it does verify that the specific combination of components in the system at the time of the measurement produces compliant signals. Interaction between components on either side of the interoperability point may allow the signal measured to be compliant but this compliance may have resulted because one component is out of specification while the other is better than required.

The interface to FC-FS-4 occurs at the logical encoded data interfaces. As these are logical data constructs, no physical implementation is implied by FC-FS-4. FC-PI-6 is written assuming that the same single serial data stream exists throughout the link as viewed from the interoperability points. Other possible schemes for transmitting data, for example using parallel paths, are not defined in FC-PI-6 but could occur at intermediate places between interoperability points.

Physical links have the following general requirements:

a) Physical point-to-point data links; no multidrop connections along the serial path.

b) Signal requirements shall be met under the most extreme specified conditions of system noise and with the minimum compliant quality signal launched at upstream interoperability points.

c) All users are cautioned that detailed specifications shall take into account end-of-life worst case values (e.g., manufacturing, temperature, power supply).

The interface between FC-PI-6 and FC-FS-4 is intentionally structured to be technology and implementation independent. That is, the same set of commands and services may be used for all signal sources and communication schemes applicable to the technology of a particular implementation. As a result of this, all safety or other operational considerations that may be required for a specific communications technology are to be handled by the FC-PI-6 clauses associated with that technology. An example of this would be ensuring that optical power levels associated with eye safety are maintained.

4.2 FC-0 states

4.2.1 Transmitter states

The transmitter device is controlled by the FC-1 level. Its function is to convert the serial data received from the FC-1 level into the proper signal types associated with the transmission media.

4.2.2 Receiver states

The function of the receiver device is to convert the incoming data from the form required by the communications media employed, retime the data, and present the data and an associated clock to the FC-1 level.

4.3 Limitations on invalid code

FC-0 does not detect transmit code violations, invalid ordered sets, or any other alterations of the encoded bit stream. However, it is recognized that individual implementations may wish to transmit such invalid bit streams to provide diagnostic capability at the higher levels. Any transmission violation, such as invalid ordered sets, that follow valid character encoding rules shall be transparent to FC-0. Invalid character encoding could possibly cause a degradation in receiver sensitivity and increased jitter resulting in increased BER or loss of bit synchronization.

4.4 Receiver initialization time

The time interval required by the receiver from the initial receipt of a valid input to the time that the receiver is synchronized to the bit stream and delivering valid retimed data within the BER requirement, shall not exceed 20 ms. Should the retiming function be implemented in a manner that requires direction from a higher level to start the initialization process, the time interval shall start at the receipt of the initialization request.

4.5 Loss of signal (Rx_LOS) function

The FC-0 may optionally have a loss of signal function. If implemented, this function shall indicate when a signal is absent at the input to the receiver. The activation level shall lie in a range whose upper bound is the minimum specified sensitivity of the receiver and whose lower bound is defined by a complete removal of the input connector. While there is no defined hysteresis for this function there shall be a single transition between output logic states for any monotonic increase or decrease in the input signal power occurring within the reaction time of the signal detect circuitry.

4.6 Speed agile ports that support speed negotiation

This subclause specifies the requirements on speed agile ports that support speed negotiation.

a) The port transmitter shall be capable of switching from compliant operation at one speed to compliant operation at a new speed within 1 ms from the time the speed negotiation algorithm asks for a speed change for 8GFC. A repeater shall achieve compliant operation within 1 ms following an application of a compliant signal at its input. For 16GFC and 32GFC, the transmitter stabilization time shall be 3 ms or less (allowing up to two repeaters in the path).

b) The port receiver shall attain Transmission_Word synchronization within the receiver stabilization time (sub-clause 4.4) when presented with a valid input stream or from the time the algorithm asks for a receiver speed change if the input stream is at the new receive rate set by the port implementing the algorithm.

c) The port transmitter and port receiver shall be capable of operating at different speeds at the same time during speed negotiation.

4.7 Transmission codes

32GFC shall use 64b/66b codes for transmission.

4.8 Frame scrambling and emission lowering protocol

32GFC uses 64b/66b coding and scrambling that is inherent in the code as defined in FC-FS-4 (reference [29]).

4.9 Transmitter training

32GFC EL variants shall not use transmitter training. 32GFC EA variants must transmit the transmitter training signal during the link speed negotiation, but the transmitter training is optional. Transmitter training is defined in FC-FS-4 (reference [29]).

4.10 Forward error correction (FEC)

32GFC variants shall use FEC as defined in FC-FS-4 (reference [29]).

4.11 .Test patterns

32GFC shall use the test patterns stated in FC-MSQS-2 (reference [30]).

4.12 Fibre Channel variants nomenclature

The nomenclature for the Fibre Channel variants is illustrated in figure 2. Receiver type and fiber type indicates assumptions used for developing link budgets and does not indicate a requirement on receiver or fiber implementations

100-SM-LC-L

SPEED
3200 -- 3 200 MB/s
1600 -- 1 600 MB/s
1200 -- 1 200 MB/s
800 -- 800 MB/s
400 -- 400 MB/s
200 -- 200 MB/s
100 -- 100 MB/s

TRANSMISSION MEDIA
SM -- single-mode optics connecting to a gamma point (OS1, OS2)
M5 -- multimode 50 µm optics connecting to a gamma point (OM2)
M5E -- multimode 50 µm optics connecting to a gamma point (OM3)
M5F -- multimode 50 µm optics connecting to a gamma point (OM4)
M6 -- multimode 62.5 µm optics connecting to a gamma points (OM1)
SE -- unbalanced copper connecting to any interoperability point
DF -- balanced copper connecting to any interoperability point

INTEROPERABILITY POINT TYPE (formerly transceiver)
SN -- gamma point short wave LASER (850 nm) with limiting optical receiver
SA -- gamma point short wave LASER (850 nm) assuming a linear optical receiver
LL -- gamma point long wave LASER (1310 nm / 1550 nm) assuming a limiting optical receiver
LC -- gamma point for long wave LASER cost reduced (1310 nm) with limiting optical receiver
LZ -- gamma point for long wave LASER (1490 nm) with limiting optical receiver
LA -- gamma point long wave LASER (1310 nm / 1550 nm) assuming a linear optical receiver
EL -- any electrical point (includes SN PMD delta points) that assumes a non-equalizing reference receiver (with or without a compliance interconnect)
EA -- any electrical point that assumes equalizing receivers

DISTANCE
V -- very long distance (up to 50 km)
L -- long distance (up to 10 km)
M -- medium distance (up to 4 km)
I -- intermediate distance (up to 2 km)
S -- short distance (up to 70 m)

NOTE -- The acronym "LC" when used with the "LC" connector and when used to describe the "LC"

Figure 2 – Fibre Channel variant nomenclature

4.13 FC-PI-6 variants

Table 5 and Table 6 list variants by FC-PI-6 nomenclature, a reference to the clause containing the detailed requirements, and some key parameters that characterize the variant. The nomenclature is illustrated in figure 2.

The lengths specified in table 5 and table 6 are the minimum lengths supported with transmitters, media, and receivers all simultaneously operating under the most degraded conditions allowed. Longer lengths may be achieved by restricting parameters in the transmitter, media, or receiver. If such restrictions are used on the link components then interoperability at interoperability points within the link and component level interchangeability within the link is no longer supported by this standard.

Table 5 – Fibre Channel variants not in this document

note 1	**100** (note 2)	**200** (note 2)	**400** (note 3)	**800** (note 3)	**1600** (note 3)
SM OS1, OS2	**100-SM-LC-L** 1 300 nm 0.5 m - 10 km	**200-SM-LC-L** 1 300 nm 0.5 m - 10 km	**400-SM-LC-L** 1 300 nm 0.5 m-10 km	**800-SM-LC-L** 1 300 nm 0.5 m-10 km	**1600-SM-LC-L** 1 300 nm 0.5 m-10 km
	100-SM-LL-V 1 550 nm 0.5 m - 50 km	**200-SM-LL-V** 1 550 nm 0.5 m - 50 km	**400-SM-LC-M** 1 300 nm 0.5 m-4 km	**800-SM-LC-I** 1 300 nm 0.5 m-1.4 km	**1600-SM-LZ-I** 1 490 nm 0.5 m-2 km
MM 62.5 µm OM1	**100-M6-SN-I** 780/850 nm 0.5 m - 300 m	**200-M6-SN-I** 850 nm 0.5 m - 150 m	**400-M6-SN-I** 4850 nm 0.5 m-70 m	**800-M6-SN-S** 4850 nm 0.5 m-21 m	**1600-M6-SN-S** 850 nm 0.5 m-15 m
				800-M6-SA-S 4850 nm 0.5 m-40 m	
MM 50 µm OM2	**100-M5-SN-I** 780/850 nm 0.5 m - 500 m	**200-M5-SN-I** 850 nm 0.5 m - 300 m	**400-M5-SN-I** 850 nm 0.5 m-150 m	**800-M5-SN-S** **850 nm** **0.5 m-50 m**	**1600-M5-SN-S** **850 nm** **0.5 m-35 m**
				800-M5-SA-I 850 nm 0.5 m-100 m	
MM 50 µm OM3	**100-M5E-SN-I** 780/850 nm 0.5 m - 860 m	**200-M5E-SN-I** 850 nm 0.5 m - 500 m	**400-M5E-SN-I** 850 nm 0.5 m-380 m	**800-M5E-SN-I** **850 nm** **0.5 m-150 m**	**1600-M5E-SN-I** **850 nm** **0.5 m-100 m**
				800-M5E-SA-I 850 nm 0.5 m-300 m	
MM 50 µm OM4			**400-M5F-SN-I** 850 nm 0.5 m-400 m	**800-M5F-SN-I** 850 nm **0.5 m-190 m**	**1600-M5F-SN-I** **850 nm** **0.5 m-125 m**
				800-M5F-SA-I 850 nm 0.5 m-300 m	**1600-SM-LC-L** 1 300 nm 0.5 m-10 km
EL Balanced	**100-DF-EL-S**	**200-DF-EL-S**	**400-DF-EL-S**	**800-DF-EL-S**	**1600-DF-EL-S**
EA Balanced				**800-DF-EA-S**	**1600-DF-EA-S**
EL Unbalanced	**100-SE-EL-S**	**200-SE-EL-S**			

Notes:

1 For 10GFC variant refer to 10GFC (reference [1]) and FC-PI-3 (reference [2]).

2 This is obsoleted technology. For information refer to FC-PI-2 (reference [3]).

3 Information about these variants can be found in FC-PI-5 (reference [1])

Table 6 – Fibre Channel Variants in FC-PI-6

	3200
SM **OS1, OS2** sub-clause 5.3	**3200-SM-LC-L** 1 300 nm 0.5 m-10 km
	3200-SM-LZ-I
MM 50 µm **OM2** sub-clause 5.4	**3200-M5-SN-S** **850 nm** **0.5 m-?? m**
MM 50 µm **OM3** sub-clause 5.4	**3200-M5E-SN-I** **850 nm** **0.5 m-??m**
MM 50 µm **OM4** sub-clause 5.4	**3200-M5F-SN-I** 850 nm 0.5 m-100 m
EL Balanced clause 6	**3200-DF-EL-S**
EA Balanced clause 6	**3200-DF-EA-S**