Very Short Reach (VSR) OC-192 Four Fiber Interface Based on Parallel Optics

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4 Document Revision History

Version 0.4 – Draft – Baseline text

VSR4-03.0 – First released version 4/17/2000

VSR4-03.1 –Second released version 5/6/2003 incorporating changes from oif2002.345.03.

5 Project Summary

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This proposed specification is similar to work being performed at the Fibre Channel, Infiniband and IEEE 802.3ae working groups. The IEEE 802.3ae working group has a baseline standard protocol which is compatible with this proposed specification. The Fibre Channel and Infiniband have both specified the use of parallel fiber interconnects over short distance fiber links.

5.19.1 Overlaps
5.19.2 Unique viewpoints

6 Introduction

This technical document describes a functional low-cost SONET/SDH OC-192 interface for very short reach (VSR) applications.

The VSR interface utilizes four 2.5 Gbps vertical cavity surface emitting lasers (VCSEL) and a 4 fiber cable to transmit the OC-192 frame over ‘very short’ distances of up to 300m. The four fiber solution leverages the low cost parallel fiber VCSEL based technology currently being deployed in many optical backplane applications for digital crossconnect systems, terabit routers and terabit switches. Four fiber solutions are also being specified in the ANSI Fibre Channel standard and the Infiniband Industrial consortium. These applications and the VSR OC-192 applications have very similar optical power and jitter link budgets. The four fiber VSR OC-192 solution will map the OC-192 frame onto the parallel optical link with no bandwidth expansion and no overwriting of the SONET overhead bytes to maintain compatibility with SONET OC-192 overhead processors and framers.

The target performance of the four fiber VSR interface is to transmit the OC-192 data over 300m of 50 μm-core multimode (MM) ribbon fiber cable.

This document defines the functions for mapping from the OC-192 framer interface to the parallel optical interface. It also defines the optical interface. The electrical interface from the framer conforms to the common electrical interface defined in the ratified OIF SFI-4.1 Implementation Agreement.

6.1 Application

The application of the OC-192 VSR interface is to interconnect co-located equipment. Due to the short distances, use of interfaces designed to achieve longer distances, results in unnecessary cost and complexity. Examples of equipment that is often co-located within a central office and often interconnected are:

1. Routers,
2. Dense Wavelength Division Multiplexer (DWDM) terminals, and
3. SONET/SDH Add-Drop Multiplexers (ADMs).

7 Functional Overview

The OC-192 VSR is a bi-directional interface. A schematic of the VSR interface functional block diagram is illustrated in Figure 1.

7.1 Transmit Direction

- The “converter” device receives a 16-bit 622 Mb/s LVDS electrical signal from the OC-192 framer chip as defined in OIF SFI-4.1.
- The transmit data interface is source synchronous (i.e. the required 2.5 Gb/s high-speed data is synchronous with the 622MHz clock received from the OC-192 framer chip).
- The 16 bit parallel bus shall be mapped onto 4 parallel channels.
- Each channel contains OC-192 scrambled data demultiplexed into four channels. No additional scrambling or descrambling is performed by the converter device. Each individual channel will have 48 A1A2 SONET framing bytes (identical to an OC-48 data stream)
  - The A1A2 boundary is used to de-skew the four channels at the receiver.
- The 4 channels are forwarded to the parallel optics transmitter that transmits the data along the 4 optical fibers in the ribbon fiber at a bit rate of 2.488 Gb/s per channel. The interface to the optical fiber is the MTP® (MPO) connector[1].
- If each transmit lane is skewed by 4 bits relative to the other lanes the number of registers required of the Converter Block transmit function will be minimal (refer to Figure 2 below). The data will then launch from the device according to Figure 2 below.
- Note that in Figure 2 below each bit number refers to the bit number of the SFI4-1 transmit interface on the Converter Block. The letter prefix is used to indicate the order in which byte pairs are provided to the VSR4-3 Converter. The first SONET byte from the framer is made up of bits A08 (LSB) to A15 (MSB), the second SONET byte is made up of bits A00 to A07, etc. Figure 2 must be used as the reference for the receiver skew tolerance requirement specified in section 7.7 below.

[1] The MTP is a registered trademark of US Conec

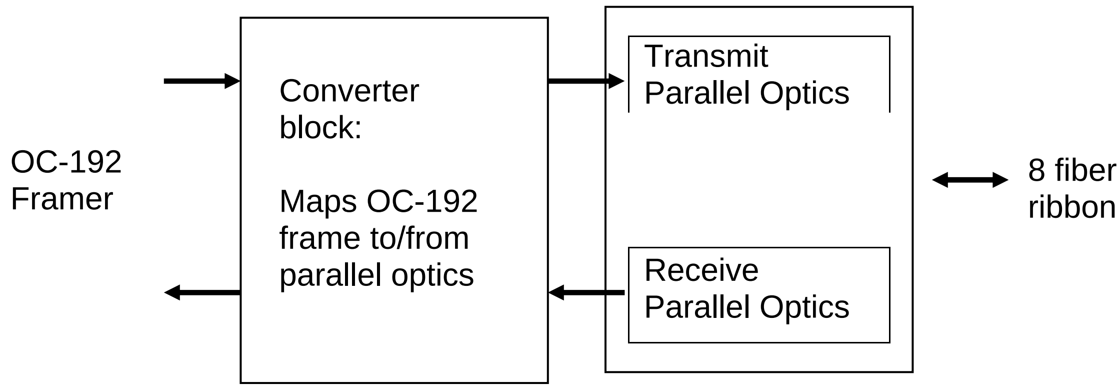


Figure 1: Functional block diagram of OC-192 four fiber VSR interface

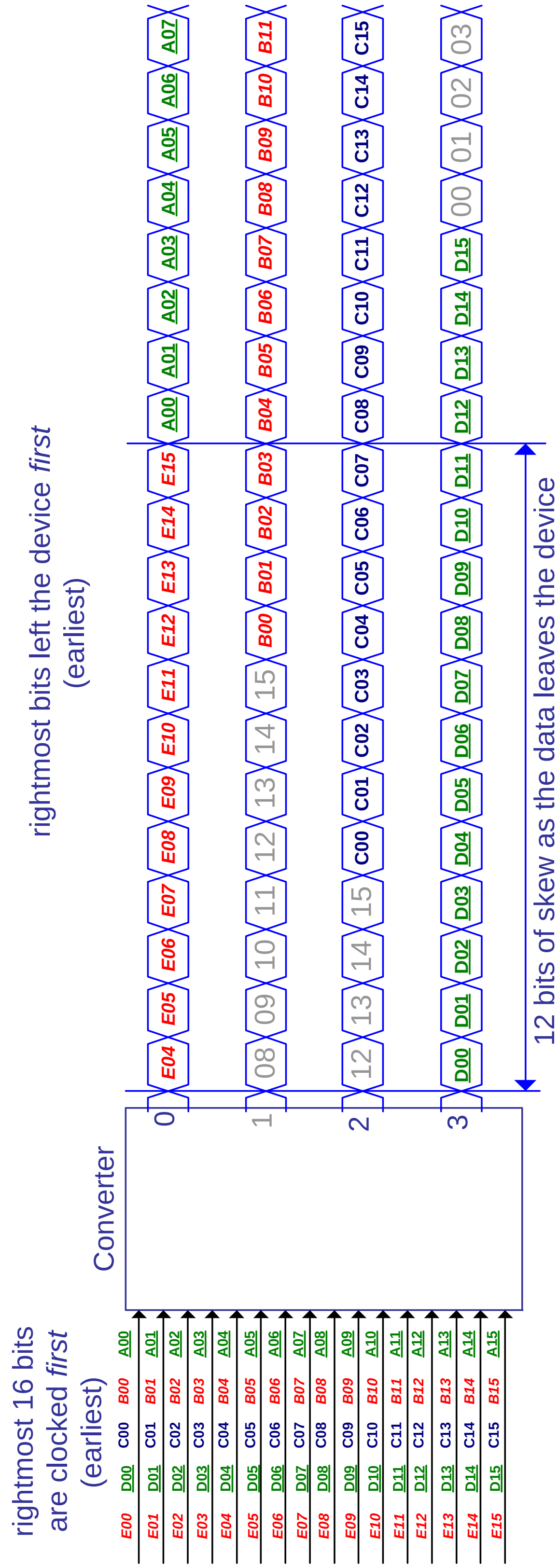


Figure 2: Required transmit bit ordering

7.2 The Receive Direction

- The parallel optical interface receives 4 optical signals from the fiber ribbon cable.
  - Each channel shall operate at 2.488 Gb/s.
  - The parallel optics receiver converts the signal to an electrical equivalent.
- The receive portion of the SERDES shall perform clock and data recovery on each channel.
- It will also de-skew the individual channels, by using the A1A2 boundary, to compensate for any inter-channel skew that may occur due to propagation delay differences between the channels.
- The “converter” shall recombine the 4 channels of data to a 16-bit wide data bus operating at 622 Mb/s. It shall not overwrite or replace any of the SONET framing or overhead bytes.
- The SERDES shall provide a 16-bit parallel 622 Mb/s LVDS signal for connection to the OC-192 framer chip retimed with a 622 MHz output clock.

7.3 Auto-Detection of Fiber Ribbon Cable Crossover

- The “converter” shall not auto-detect whether the fiber ribbon cable has a crossover. The ribbon fiber shall be constructed to avoid any crossovers of the fibers. Link polarity is to be maintained through the use of keyed adapters. The keyed concept enables the use of point to point, multiple interconnnect or crossconnected links.

7.4 Loss of Synchronization

- The “converter” shall detect a loss of synchronization (LOSyn) on any single channel within the 4 data channels, and indicate a loss of sync condition.

7.5 Fiber Ribbon (See Figure 7)

- The fiber ribbon shall be eight 50μm multimode optical fibers as specified by ANSI TIA/EIA-455-30B.
- Each fiber shall carry a separate channel.

7.6 OC192 Mapping to Data Channels

- The OC-192 frame shall be striped 2 bytes at a time across the 4 data channels.
- The first 2 bytes of the OC-192 frame shall be transmitted on channel 0, and the striping continues across the channels as shown.
- At the receiver, once the channels have been re-aligned, the reverse mapping shall re-assemble the OC-192 frame
- Figure 3 below illustrates the striping specified above:

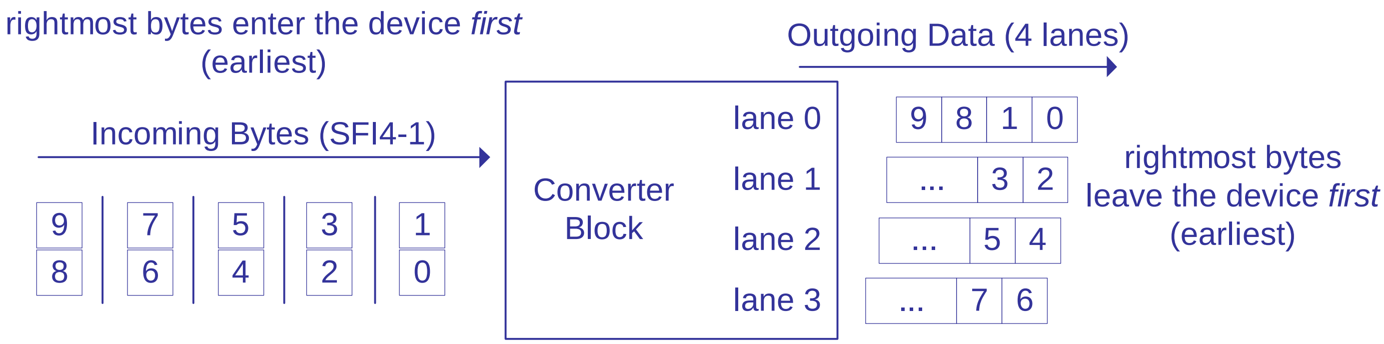


Figure 3: Required transmit byte ordering

7.7 Channel Encoding and Frame Delimiting (see Figure 6 & Table 1)

- Each channel shall maintain the original scrambled codes generated by the OC-192 framer.
  - The SONET/SDH A1A2 byte boundary shall be used for frame alignment and channel deskew.
  - The receiver has skew tolerance of at least 10 ns (typical inter-channel skew on a ribbon cable is 10 ps/m).

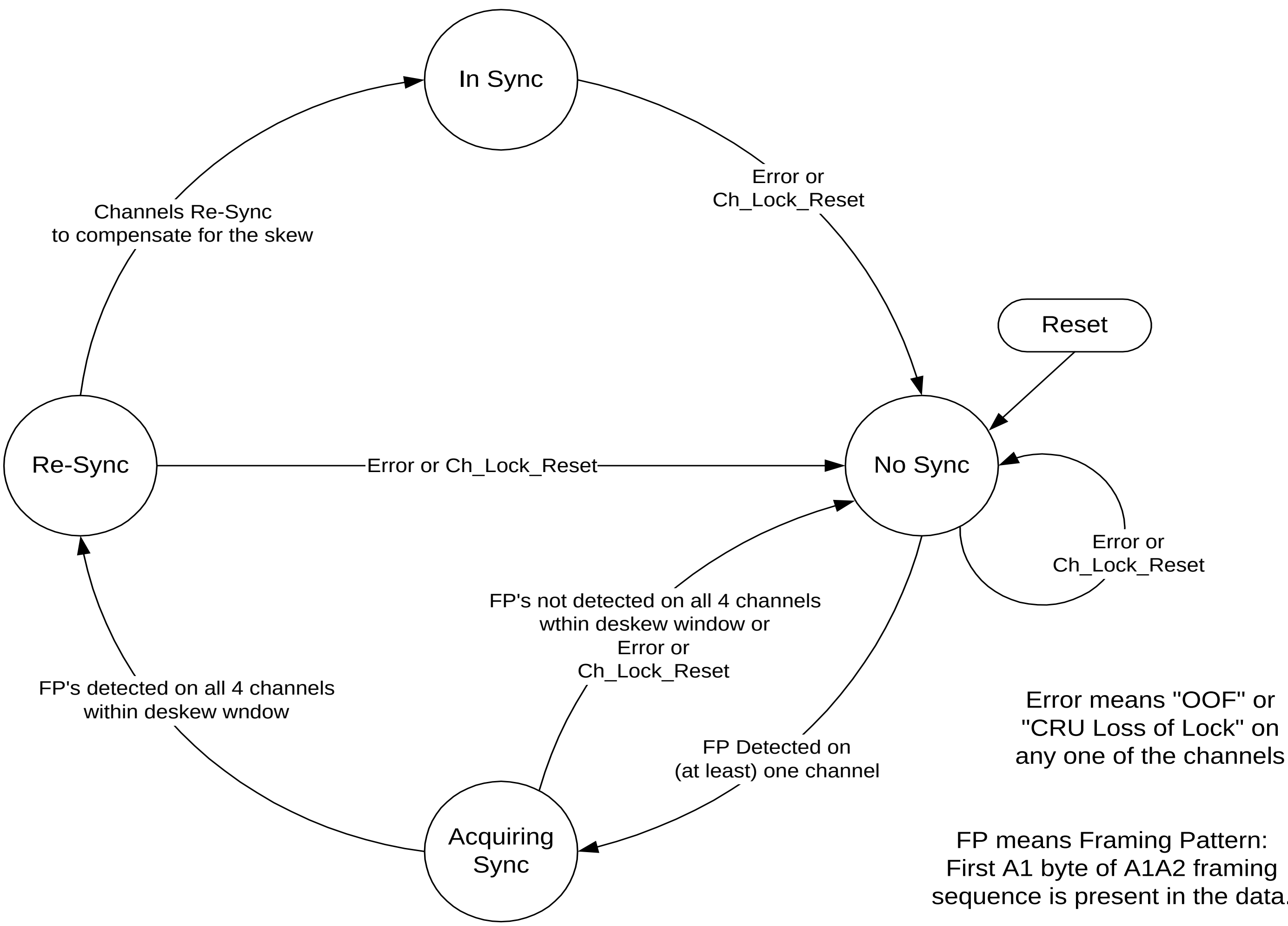
- The receiver in the converter shall use an algorithm to find the frame delimiters that is robust to local bit errors that may affect an individual frame delimiter.

- The requirement in 7.6 that “The first 2 bytes of the OC-192 frame shall be transmitted on channel 0” implies that the Converter knows the byte alignment of the data on the SFI4-1 interface. The SFI4-1 interface does not specify byte alignment. However, SFI4-1 does specify “For OC-192, bit 15 is the MSB and bit 0 is the LSB. The MSB is transferred first.” This implies the first byte of a transmit SONET frame would be transmitted on bits 8-15 of SFI4-1, and the second byte of a transmit SONET frame would be transmitted on bits 0-7 of SFI4-1. Since there is no requirement to “slip bits” between the transmit SFI4-1 framer and the Converter, bits 0 and 8 of the SFI4-1 interface are the least significant bits of bytes of a SONET frame, bits 1 and 9 are the next most significant, etc.

7.8 Loss of Synchronization (LOSyn)

- Loss of synchronization (LOSyn) is a state that shall exist when a channel is considered to be not operating
- The LOSyn algorithm shall be based on looking for A1A2 boundaries.

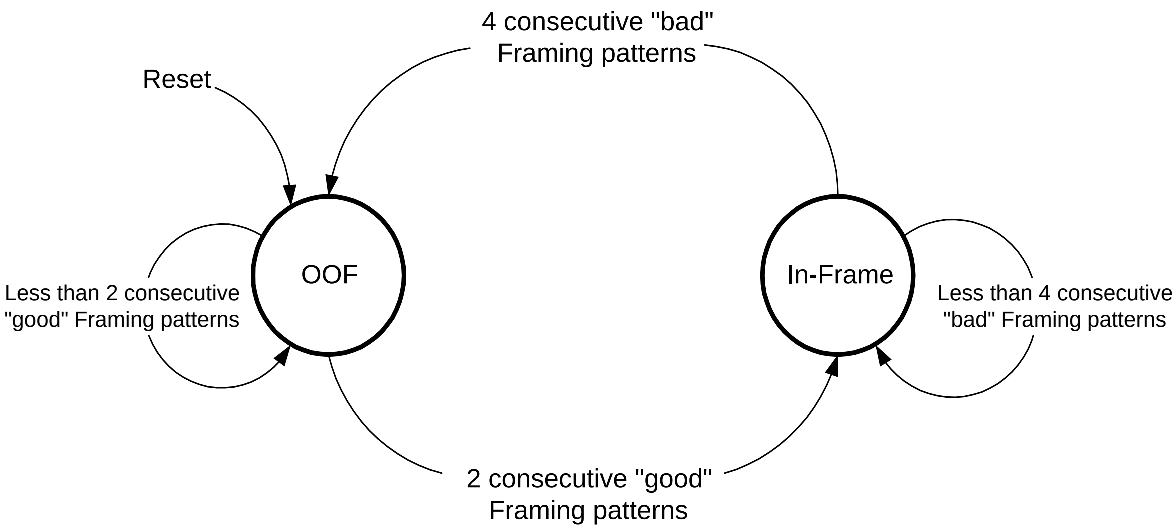
Figure 4: LOS State Machine



7.9 Out Of Frame State Machine

The Out of Frame (OOF) state machine is used by individual channels to indicate frame alignment. The OOF state machine searches the incoming data streams for the A1-A2 byte boundary with the correct 125 us separation.

Figure 5: OOF State Machine



8 Interface Specifications

There are two interface specifications: The electrical interface to the OC-192 framer and the optical interface to the parallel ribbon fiber.

8.1 Electrical Interface

This interface shall be compatible with the OIF SFI-4.1 Implementation Agreement. No further details will be given in this document.

8.1.1 Jitter budget

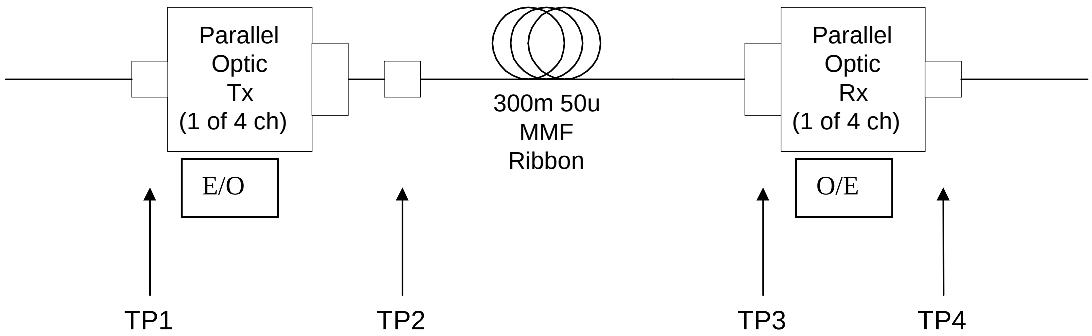


Figure 6: Jitter test points

Compliance point		TP1	TP2	TP3	TP4
Jitter Budget	TJ (UI)	0.27	0.46	0.52	0.73
	TJ (ps)	108	184	208	292
	DJ (ps)	28	76	76	122

Table 1: Jitter budget

8.2 Optical Interface

- The OC-192 VSR optical interface shall meet the specifications given in Table 2

- The interface will transmit on 50μm multimode ribbon fiber. The target distances are shown in Table 3.

Parameter	Min.	Max	Units
Transmit[1,2]			
P_{out}	-8	See footnote[3]	dBm
λ_c	830	860	nm
Extinction ratio	6		dB
$\Delta\lambda_{rms}$		0.85	nm
T_{rise}/T_{fall} (20-80%)		140	ps
RIN		-116	dB/Hz
Receive [4]			
P_{in}	-16[5]	-3	dBm
λ_c	830	860	nm
Return loss	12		dB
Signal detect – asserted[6]		-16.5/-22	dBm
Signal detect-de-asserted	-24/-31		dBm
Signal detect hysteresis	0.5/2		dB

Table 2: Optical Interface Specifications

Notes:
1. All specifications are per channel and at the end of a 2m patchcord
2. In the event of accidental transmitter to transmitter connection, no damage shall occur that will prevent the continued operation of the transmitter module within specification.
3. Output power for combined channels will be compliant with FDA Class 1 and IEC Class 3A eye safety requirements (all channels aggregated).
4. All receiver specifications are per channel.
5. Receiver sensitivity shall be such that the BER $\leq 10^{-12}$ with the minimum optical power and worst case extinction ratio including the optical path penalty (includes 1.5dB loss for connectors).
6. Signal detect signal is asserted when all channels are active. Signal is de-asserted when one or more channel's power drops below threshold.

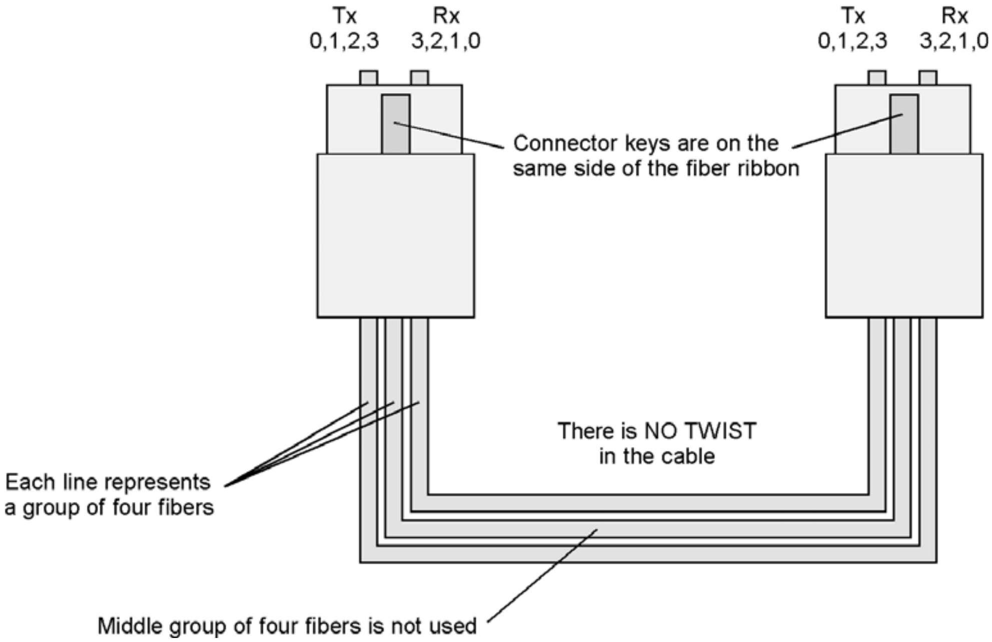


Figure 7: Connector/Fiber ribbon Orientation

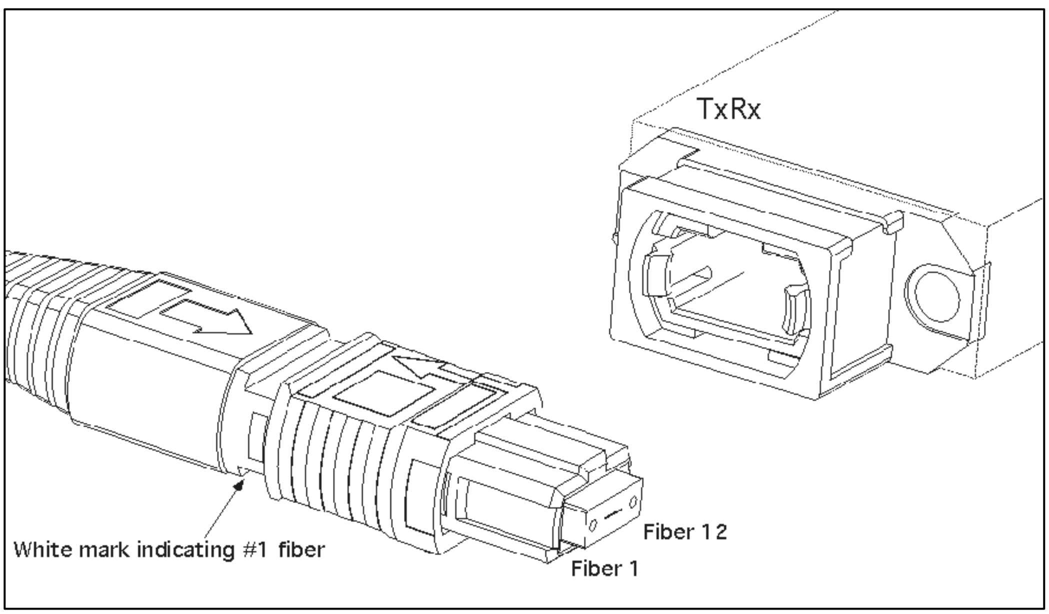


Figure 8: MTP Connector Interface
Note: Middle 4 fibers are unused
Note: Receptacle contains male guide pins
Note: Receptacle key location (top or bottom) may be vendor specific but must guarantee correct fiber orientation per fig.7 .

Fiber Effective Modal bandwidth[3]	Target Distance
500 MHz.km[1]	300m

Table 3: Target Distance

Notes:

1. Work is currently underway in TIA FO2.2 to standardize multimode fiber characterization with laser launches. For reference see:
   ANSI/TIA/EIA-455-203-2001: Launched Power Distribution Measurement Procedure for Graded-Index Multimode Fiber Transmitters
   ANSI/TIA/EIA-TIA-492AAAC-A: Detail Specification for 850-nm Laser-Optimized, 50-um core diameter/125-um cladding diameter class Ia graded-index multimode optical fibers

2. Advanced fiber under study to achieve >500m distances. Launch conditions currently under study by TIA FO2.1. ANSI/TIA/EIA-TIA-492AAAC-A: Detail Specification for 850-nm Laser-Optimized, 50-um core diameter/125-um cladding diameter class Ia graded-index multimode optical fibers is relevant to this effort.

8.3 Optical connector

- The optical connector shall be the MTP™ (MPO).

Connector references:

1. IEC 61754-7 Fiber Optic Connector Interfaces - Part 7: Type MPO Connector Family
2. EIA/TIA-604-5 "Fiber optic Connector Intermateability Standard" (FOCIS 5)
3. JIS C 5891-1993
4. HIPPI 6400-OPT (final stages of approval, MTP has been adopted)

Appendix A: Optional SFI-4.2 Electrical Interface

Overview

SFI-4.2 is a four-lane framer-SERDES electrical interface to support OC-192/STM-64 and other 10Gbps applications. VSR-4.3 specifies SFI-4.1 as the electrical interface and includes detail on data mapping since 16 electrical lanes are converted to four optical lane. The following characteristics apply to the SFI-4.2 option for VSR-4.3:

1) The SFI-4.2-to-optical-VSR-4.3 data mapping is defined as lane-to-lane. That is, lane 0 of SFI-4.2 maps to lane 0 of VSR-4.3

2) A retimer in the VSR-4.3 device is optional

3) Optical specs match most recent IEEE8023.ae link model 3.1.16a.

4) Stressed receiver sensitivity is informative.

5) Jitter test points TP2 and TP3 are the only compliance points

Interface Specifications

There are three interface specifications: the optical interface to the parallel ribbon fiber (points TP2 and TP3), the electrical interface to a VSR4-3 electrical interface, points TP1 and TP4, and the electrical interface to an SFI4.2 interface, points A and D. The single-direction of the interface is shown in Figure B1.

. The optical interface is compliant if jitter specifications at TP2 and TP3 shown in Table B4 are met. In an optional implementation using SFI4.2 interface, then jitter at A and D has to be compliant with the OIF Implementation Agreement SxI-5. In this case a re-timer/de-skew module may be needed.

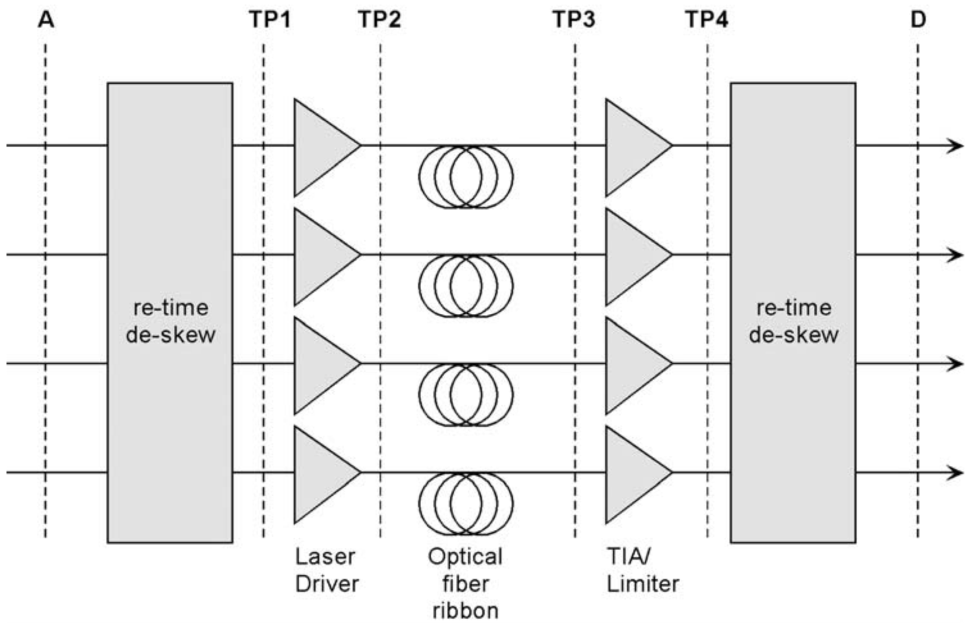


Figure B1 – Timing reference points of the electrical and optical interfaces (single direction only)

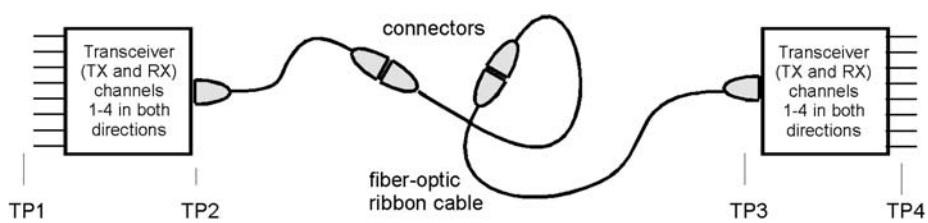


Figure B2 – Cabling model

VSR4-3 Electrical Interface

The electrical interface at TP1 and TP4, if used and accessible, shall be compatible with the OIF SFI-4.1 Implementation Agreement. No further details will be given in this document.

SFI-4.2 Electrical Interface

The electrical interface at A and D, if used, shall be compatible with OIF SxI-5. The jitter requirements are given in Table B4.

Optical Interface

The OC-192 VSR optical interface shall meet the specifications given in Table B2.

Table B2 – Optical interface specifications

Parameter	Min.	Max	Units
Transmit[1,2]			
Transmitter P_{out}	-8	-2.5[3]	dBm
Transmitter OMA	-7.2		dBm
λ_c	830	860	nm
Extinction ratio[8]	6		dB
$\Delta\lambda_{rms}$		0.85	nm
T_{rise}/T_{fall} (20-80%)		130	ps
$RIN_{12}OMA$		-118	dB/Hz
Receive [4]			
Receiver P_{IN}		-2.5	dBm
Receiver OMA	-15[5]		dBm
Stressed Receiver OMA[6,8]	-11.5[5]		dBm
λ_c	830	860	nm
Return loss	12		dB
Signal detect – asserted[7]		-17	dBm
Signal detect-de-asserted[7]	-30		dBm
Signal detect hysteresis[7]	0.5		dB

Notes:

All specifications are per channel and at the end of a 2m patch cord.

In the event of accidental transmitter to transmitter connection, no damage shall occur that will prevent the continued operation of the transmitter module within specification.

Output power for combined channels will be compliant with Class 1M eye safety requirements of IEC 60825-1, Amendment 2 (all channels aggregated).

All receiver specifications are per channel.

Receiver sensitivity shall be such that the BER $\leq 10^{-12}$ with the minimum optical power and worst case extinction ratio.

The stressed receiver sensitivity is measured in the center of the eye diagram per IEEE 802.3ae specification for 10GBASE-S using 2.9 dB vertical-eye closure penalty (min), 0.2UI peak-to-peak deterministic jitter, 33ps Duty Cycle Dependent Deterministic Jitter and 6 dB ER (ER penalty = 2.2 dB). All channels not under test are receiving signals with optical modulation of 6 dB, or higher, above “Receiver OMA” (min). The test pattern shall be PRBS23. The stressed receiver modulation given in the table does not include the effect of clock-and-data recovery (CDR) circuits. If systemlevel measurements that include CDR circuitry are to be performed, it is recommended that the stressed receiver modulation be increased by 1.0 dB to –10.5 dBm. Stressed receiver modulation and stressed compliance signal vertical-eye closure values are calculated theoretically and are informative.

Average signal power is specified at the worst-case extinction ratio. The signal detect signal is asserted when all monitored channels are active. The signal detect signal is de-asserted when the optical power of one or more of the monitored channels drops below threshold. At a minimum, channels 0 and 3 shall be monitored.

The interface will transmit on 50μm multimode ribbon fiber. The cabling model is shown in Figure B2. The target distance is shown in Table B3.

Table B3 – Link power budget and penalties.

Parameter	Specification
Fiber	50 μm MM fiber ribbon
Fiber Cable Max. Attenuation	3.5 dB/km @ 850nm
Minimum Modal bandwidth per	500 MHz.km
Link Power Budget	7.8 dB
Maximum Combined Connector Loss	1.5 dB
Minimum Operating range	2-300 m

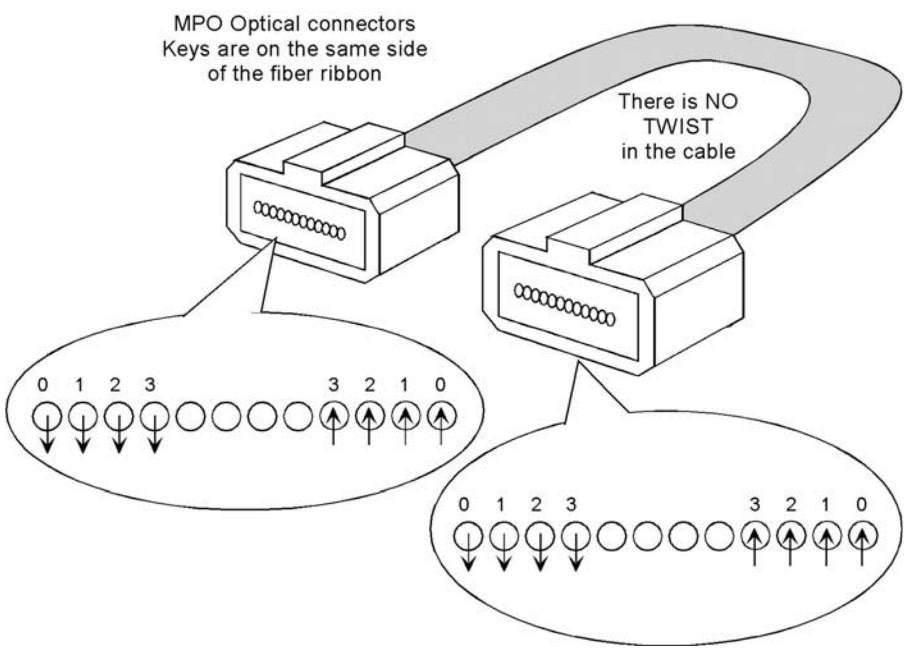


Figure B4 – Connector and fiber ribbon orientation

Optical connector

The optical connector shall be a 12-fiber MPO connector (IEC 61754-7 Fiber Optic Connector Interfaces - Part 7: Type MPO Connector Family). MPO optical connectors have both male and female versions. The guide pins are installed in the optical receptacle. The middle 4 fibers are not used or needed. The key location in the optical receptacle (top or bottom) may be vendor specific, but must guarantee correct fiber orientation per Figures B4 and B5.

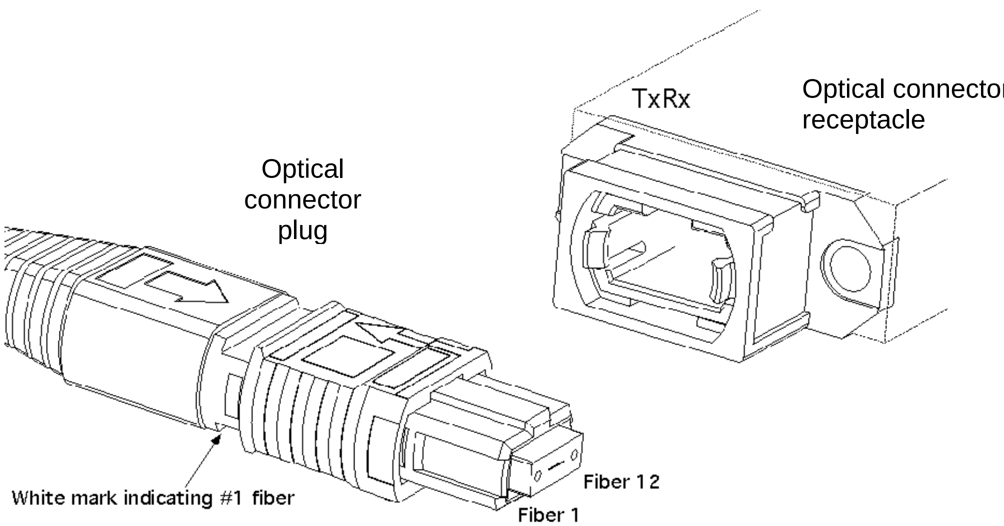


Figure B5 – MPO connector interface

Jitter requirements

The jitter budget is shown in Table B4. TP2 and TP3 are normative compliance points for the optical interface. Reference points A and D are normative compliance points for SFI-4.2 with the data jitter reference points taken from document SxI-5 and are shown here for informative purposes. The data in SxI-5 takes precedence of the data shown for points A and D in Table B4.

Table B4 – Data jitter budget

Compliance point	A	TP1	**TP2**	**TP3**	TP4	D
TJ (UI)	0.35	0.25	**0.45**	**0.51**	0.73	0.65
DJ (UI)	0.17	0.07	**0.195**	**0.195**	0.29	0.35

Notes:

This table accounts for high-frequency jitter only.

Unit interval is 1/(data bit rate).

Maximum random jitter is equal to the maximum total jitter minus the actual deterministic jitter.

Measurement of the Optical Parameters

All measurement of the optical parameters shall be made through a 2m optical patch cable and according to IEEE 802.3ae scaled for the actual symbol rate. Where tests specify the use of a fourth-order Bessel-Thompson filter, as specified by the Recommendation ITU-T G.957, the filter 3-dB frequency shall be 75% of the symbol rate.

Center Wavelength and Spectral Width

The center wavelength and spectral width shall be measured as in IEEE 802.3ae.

Optical power measurements

The optical power shall be measured as in IEEE 802.3ae.

Optical modulation amplitude measurements

The optical modulation shall be measured as in IEEE 802.3ae.

Relative Intensity Noise (RINOMA) measurements

The RIN shall be measured as in IEEE 802.3ae.

Transmitter Rise/Fall Characteristics

The transmit rise/fall characteristics shall be measured as IEEE 802.3ae.

Jitter measurements

The jitter measurements shall be measured as in IEEE 802.3ae.

Appendix B

Voting Companies at time of document approval

AMCC
Accelerant Networks
Agilent Technologies
Alcatel
America Online
Analog Devices
Anritsu
Artisan Components
ASTRI
AT&T
Atrica Inc.
Avici Systems
Big Bear Networks
Bit Blitz Communications
Bookham Technology
Booz-Allen & Hamilton
Broadcom
Cadence Design Systems
Calient Networks
Caspian Networks
China Telecom
Chunghwa Telecom Labs
Ciena Corporation
Cisco Systems
CIVCOM
CoreOptics
Corrigent Systems
Corvis Corporation
Cypress Semiconductor
Data Connection
Department of Defense
Diablo Technologies
ELEMATICS
Elisa Communications
Emcore
Ericsson
ETRI
FCI
Finisar Corporation
Flextronics
Force 10 Networks
Fujitsu
Furukawa America
Galazar Networks
Gennum Corporation
Harris Corporation
Helix AG
JDS Uniphase
Juniper Networks
KDDI R&D Laboratories
Kodeos Communications
KT Corporation
Lattice Semiconductor
LSI Logic
Lucent
Lumentis
Marconi Communications
MCI
MergeOptics GmbH
Mindspeed
Mintera
Mitsubishi Electric Corporation
Molex
Multilink Technology Corporation
Multiplex
Mysticom
Navtel Communications
NEC
NIST
Nortel Networks
NTT Corporation
OpNext
PhotonEx
Photuris, Inc.
Phyworks
PMC Sierra
Princeton Optronics
Procket Networks
Quake Technologies
Qwest Communications
Sandia National Laboratories
Santur
SBC
Scintera Networks
Siemens
Silicon Access Networks
Silicon Laboratories
Silicon Logic Engineering
StrataLight Communications
Sun Microsystems
Sycamore Networks
Tektronix
Telcordia Technologies
Telecom Italia Lab

Hi/fn
Hitachi
Ibiden
IBM Corporation
IDT
Ignis Optics
Industrial Technology Research Institute
Infineon Technologies
Infinera
Innovance Networks
Intel
Intelligent Photonics Control
Interoute
Intune Technologies, Ltd.
Iolon
Japan Telecom
Tellabs
Tellium
Teradyne
Texas Instruments
Toshiba Corporation
TriQuint Semiconductor
T-Systems/ Deutsche Telekom
Turin Networks
Tyco Electronics
US Conec
Velio Communications
Vitesse Semiconductor
W.L. Gore & Associates
Winchester Electronics
Xanoptix
Xignal Technologies
Xilinx