HFCT-711/721 XPD

10Gbps XFP Transceiver

Application Note 5100

1. Introduction

The 1310 nm XFP transceiver is a high performance, cost effective module for serial optical data communications applications specified for signal rates of 9.95 Gb/s to 10.5 Gb/s. It is compliant to XFP MSA Rev 4.0. The module is designed for single mode fiber and operates at a nominal wavelength of 1310 nm. The transmitter section incorporates a directly modulated 1310 nm distributed feedback laser (DFB). The receiver section uses an MOVPE grown planar SEDET PIN photodetector for low dark current and excellent responsivity. Integrated Tx and Rx eye openers provide high jitter-tolerance and low jitter-generation and transfer for full XFI and SONET compliance. The internally ac coupled high speed serial I/O simplifies interfacing to external circuitry. The electrical interface is made using an industry standard 0.8 mm pitch 30-pin right angle connector. Optical connection is made via the duplex LC connector.

Figure 1 shows the XFP in comparison with a few other 10G transceiver form factors.

Figure 1. Left-Right, (a) 300 pin Transponder (b) X2 (c) Xenpak (d) XFP

It is intended for optical links of up to 10 km on typical SMF-28 fiber.

The dimensions of the XFP transceiver are shown in comparison with transceiver dimensions from other Multi-Source Agreements.

This document should be used in conjunction with the following other documents

- HFCT-711& 721XPD Product Datasheets
- HFCT-7x1XPD Characterization Reports
- XFP MSA Rev 4.0
- TIA/EIA-604-10A
- GR-253-CORE, SR-1 specifications
- IEEE 802.3ae 10Gbase-LR Specifications
- HFCT-5014 XFP Evaluation Board User Guide
- XFP GUI User Manual
- Avago Technologies White Paper "Considerations for High Speed PCB Track Design in 10Gb/s Serial Data Transmission," Steve Bowers and Herbert Lage
- Interoperability Reports and Reference Design documents

Table 1. 10G Optical Transceiver Form-Factor Comparison

	Height	Width	Length
XFP	8.5 mm	18.35 mm	78 mm
Xpak	11.84 mm	39.6 mm	86.34 mm
Xenpak	22 mm	51.3 mm	121 mm

1.1. Getting Additional Help

If you require additional help in designing the module into your system, please contact an Avago Technologies Field representative.

2. Module Description

This application note is intended for use as a design guide for system designers. It also details some important results of the Avago Technologies HFCT-7x1XPD characterization that will facilitate a better understanding of the XFP's performance.

2.1. Functional Description

The XFP uses the high-speed XFI interface to convert 10Gbps serial electrical data into an optical serial bit stream.

2.2. Transmitter Path Summary

The transmitter section of the HFCT-711 XPD and HFCT-721XPD houses a fully hermetic Transmitter Optical Sub Assembly with enhanced optical alignment and thermal features. The source used in these products is a Distributed Feedback Laser (DFB). The DFB operates at a nominal centre wavelength of 1310nm, and has extremely narrow spectral width for improved dispersion characteristics.

2.3. Receiver Path Summary

The receiver section of the HFCT-711XPD and HFCT-721XPD houses an MOVPE grown SEDET p-i-n receiver photodiode and an electronic pre-amplifier, for low dark current and excellent responsivity characteristics.

2.4. High-Speed (XFI) Path Summary

Tx and Rx eye openers provide high jitter-tolerance and low jitter generation and transfer for full XFI and SONET compliance. The internally ac coupled high speed serial I/O simplifies interfacing to external circuitry.

2.5. Low-Speed Signals

The XFP provides 7 low-speed signals that are used for reporting status as well as a means for the host board to control the XFP.

- Mod_NR
- Mod_DeSel
- Interrupt
- TX_DIS
- Mod_ABS
- RX_Los
- P_Down/RST

All the 7 pins are LVTTL compatible.

2.6. 2-wire interface

The XFP has static and dynamic memory contents that are accessible through a 2-wire interface. The 2-wire interface follows the communication protocol as outlined in the XFP MSA. The signaling scheme is based on Low Voltage TTL operating at a nominal voltage of 3.3V.

For a detailed description of the 2-wire communication protocol, please refer to the XFP MSA Rev 4.0.

3. Applications

The Avago Technologies HFCT-711 XPD is designed for carrying OC-192, 10Gigabit Ethernet as well as 10 Gigabit Fibre Channel traffic. The HFCT-721 XPD is designed exclusively for 10Gigabit Ethernet and 10Gigabit Fiber Channel Applications.

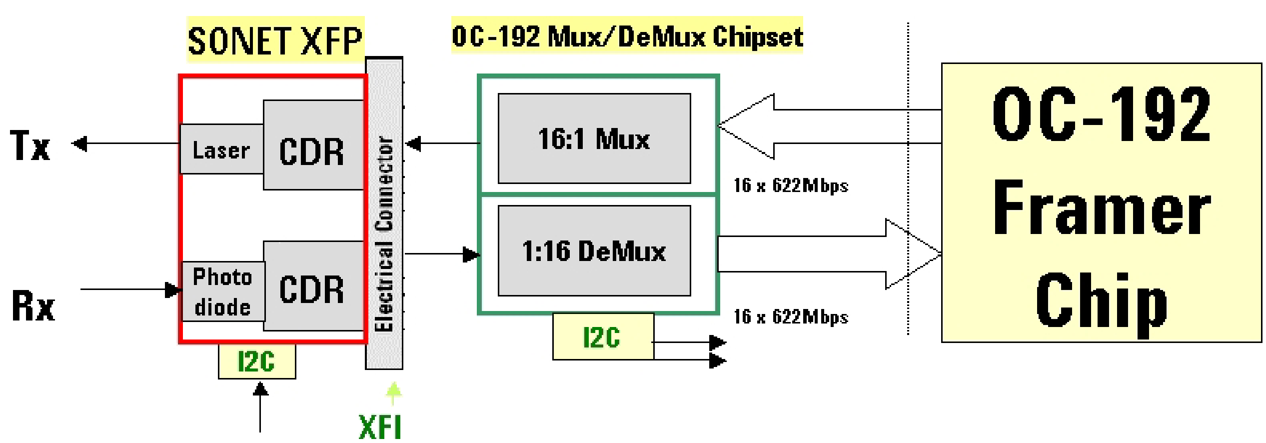

Figure 2. The HFCT-711XPD Configured for OC-192 Applications

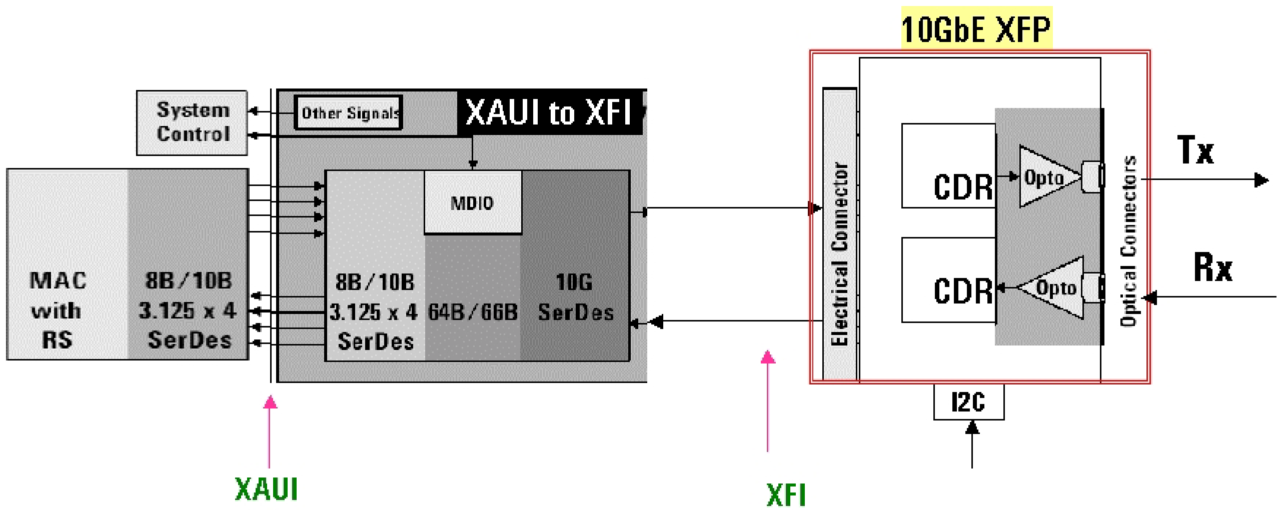

Figure 3. The HFCT-711XPD/HFCT-721XPD configured in a 10GbEthernet Application

4. Design Guidelines

4.1. PCB layout

Description

The XFP requires high-speed traces between the ASIC/SERDES and the XFP. This is referred to as the 'XFI Channel.' The channel provides a reliable high-speed connection between the ASIC and the XFP module on the host board.

Design Tips

There are many factors affecting the signal integrity of high-speed data links: -

1. Track dimensions
2. Dielectric material properties of the PCB
3. The physical design of the pluggable connector (effects of implementation)
4. Discontinuities between the track and component pads (reflections)
5. Type and length of track used, microstrip / strip line
6. Physical configuration of vias
7. Data pattern-dependency of the signal quality – jitter
8. Temperature Dependency

The most common material used for designing tracks is FR-4. At 5.5 GHz, the e (dielectric constant) of FR-4 is ~ 4.2. For high-data rate systems, dielectric losses are higher than skin-effect losses. For short trace lengths, the use of lossy material may introduce additional attenuation that improves return loss in the XFI channel.

The introduction of vias into the high-speed path will lead to multiple reflections that degrade the quality of the signal.

For XFI channels where the transceiver and the Avago Technologies XFPs are close to each other, the use of standard FR-4 micro-strip lines with high losses becomes feasible.

For XFI channels that are much longer, the use of stripline interconnects incorporating low loss FR-4 material may be required. It is also important to follow the essential rules of via design, including (a) appropriate clearances and (b) back-drilling to reduce via stub lengths.

Please refer to Avago Technologies white paper on "Considerations for High Speed PCB Track Design in 10 Gbps Serial Data Transmission" for more detailed analysis and information.

The XFP MSA also offers useful design tips regarding the construction of the high-speed lines and vias, that will help minimize back-reflections, jitter and maintain signal integrity.

Module Characterization Data

The Avago Technologies XFP has been tested to all the XFI high-speed parameters.

Table 2. XFI Input Characterization Results

Transceiver Electrical Input	Datasheet Min	Datasheet Max	Nominal	Min	Max	Sample Size
Differential Input sensitivity (mV)			19.25	15.1	26.4	5
Differential Input Return Loss (SDD11)			> 1.7 dB margin	0.8 dB margin	-	3
Common Mode Input Return Loss (SCC11)			> 2.2 dB margin	2.0 dB margin	-	3

Table 3. XFI Output Characterization Results

Transceiver Electrical Input	Datasheet Min	Datasheet Max	Nominal	Min	Max	Sample Size
Differential Output Amplitude (mV)			484	448	512	26
XFI Fall Time	24 ps		33.4	29.3	48.3	26
XFI Rise Time	24 ps		37.18	33.3	54	26
Common Mode Output Return Loss (SCC22)			> 2.2 dB margin	1.5 dB margin	-	3
Differential Output Return Loss (SDD22)			> 2.8 dB margin	1.8 dB margin	-	3
XFI Mask (%)	0		26	10	48	26

4.2. Power Supply Filtering

Description

The XFP module requires the presence of a Host supplied power supply filtering scheme to reduce noise present in the power supply rails to the XFP transceiver.

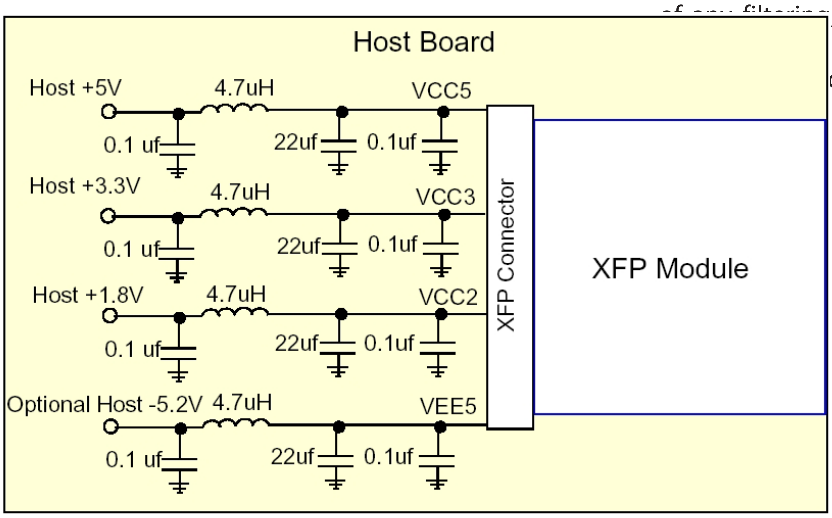

Figure 4. XFP MSA Filtering Scheme (courtesy : XFP MSA Association)

Design Tips

Agilent recommends that the system designer use the power supply filter recommended by the XFP MSA.

Module Characterization Data

Module characterization data shows that in the absence [illegible], the XFP nominally can tolerate up to [illegible] in the frequency range 10Hz to 10MHz. [illegible] defined by the point at which the [illegible]e receiver degrades by 1 dB.

4.3. EMI considerations

Design Tips

4.3.1. Gasketing

While designing for EMC considerations, it is recommended that the customer use both the front and rear EMI gaskets as called out in the XFP MSA.

The front gasket acts as an EMC seal that sits between the Bezel and the front of the XFP cage.

The rear EMI gaskets are provided along with the XFP cage to prevent any emissions from escaping the rear of the transceiver or the XFI connector.

4.3.2. Layout Considerations

For XFI channels where the transceiver and the Avago Technologies XFPs are close to each other, radiations from the traces will be minimal and contribute very little to the overall EMI of the system. In these cases, the use of standard FR-4 micro-strip lines with high losses becomes feasible.

For XFI channels that are much longer, the use of stripline interconnects incorporating low loss FR-4 material may be required. It is also important to follow the essential rules of via design, including (a) appropriate clearances and (b) back-drilling to reduce via stub lengths.

Module Characterization Data

The Avago Technologies family of 1310nm XFP transceivers shows high margins to the FCC Class B specifications for radiated emissions. The tests for radiated emissions were carried out in an anechoic chamber. The modules nominally show > 25 dB margin to the FCC Class B specifications.

4.4. Low-speed signaling

Description

The XFP provides 7 low-speed signals that are used for reporting status as well as a means for the host board to control the XFP.

- Mod_NR
- Mod_DeSel
- Interrupt
- TX_DIS
- Mod_ABS
- RX_Los
- P_Down/RST

Design Tips

All the 7 pins are LVTTL compatible (working on a nominal supply of 3.3V). Please ensure that the LVTTL output pins — Mod_Abs, Mod_NR, Rx_LOS, Interrupt pins are pulled up to Vcc on board using a resistor between 4.7k-10k ohms.

Module Characterization Data

Temperature	Tx ON	Tx OFF
-5 C	< 20 us	< 10 us
25 C	< 20 us	< 10 us
70 C	< 20 us	< 10 us

Parameter	Timing
Rx LOS Assert	< 10 us
Rx LOS Deassert	< 5 us

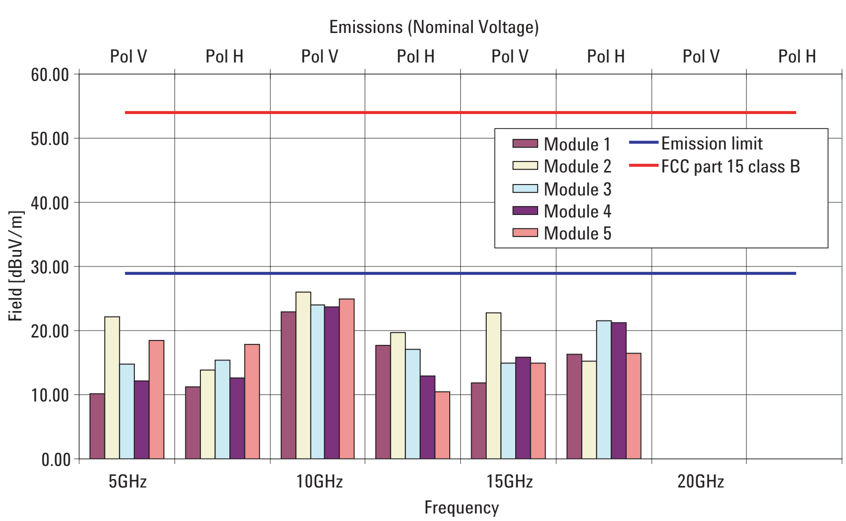

Figure 5. Agilent XFP Radiated Emissions

4.5. Optical Link Guidelines

Choosing the appropriate Link Length

The link length that the Avago Technologies HFCT-711XPD and Avago Technologies HFCT-721XPD transceivers can be used for must be decided on the basis of (a) Specific Application Needs and (b) Standards.

If the XFP transceiver is designed to carry OC-192 traffic, the link length specified in the GR-253 standards is 2 km.

If the XFP transceiver has been designed to carry 10 Gigabit Ethernet traffic, the maximum link length specified in the IEEE802.3ae standard is 10 km.

4.6. 2-wire Interface Design & Usage Guidelines

The Avago Technologies XFP module performs all the Read/Write functional capabilities outlined in the MSA. This includes:

- Packet Error Checking
- Current Address Read
- Random Read
- Multiple Read
- 4-byte Sequential Write

The XFP module always operates in a 'slave' mode and hence needs a master that can provide a clock for serial communication. Please note that the XFP module is allowed to hold the clock low for up to 500 us before continuing to execute a read or write command issued by the master.

Figure 6 below shows the memory map of the XFP module.

The lower 128 bytes of the EEPROM contain, among other things:

- Thresholds for Alarms & Warnings
- Digital Diagnostic Information
- Interrupts and flags
- Control/Status bits
- Page Select byte

Module Characterization Data

Table 4 shows a snapshot of the XFP software timing characteristics.

Table 4. XFP Software Timing Characteristics

Parameter (2-wire)	HFCT-711XPD	MSA values
TX_Disable assert time	< 15 ms	< 100 ms
TX_Disable deassert time	< 15 ms	< 100 ms
P_Down assert time	< 15 ms	< 100 ms
P_Down deassert time	< 40 ms	< 300 ms
RX_LOS assert time	< 15 ms	< 100 ms
RX_LOS deassert time	< 15 ms	< 100 ms
MOD_NR assert time	< 15 ms	< 100 ms
MOD_NR deassert time	< 15 ms	< 100 ms
Analog parameter data ready	< 100 ms	< 1000 ms
Interrupt assert delay	< 30 ms	< 200 ms
Interrupt negate assert delay	< 40 ms	< 500 ms

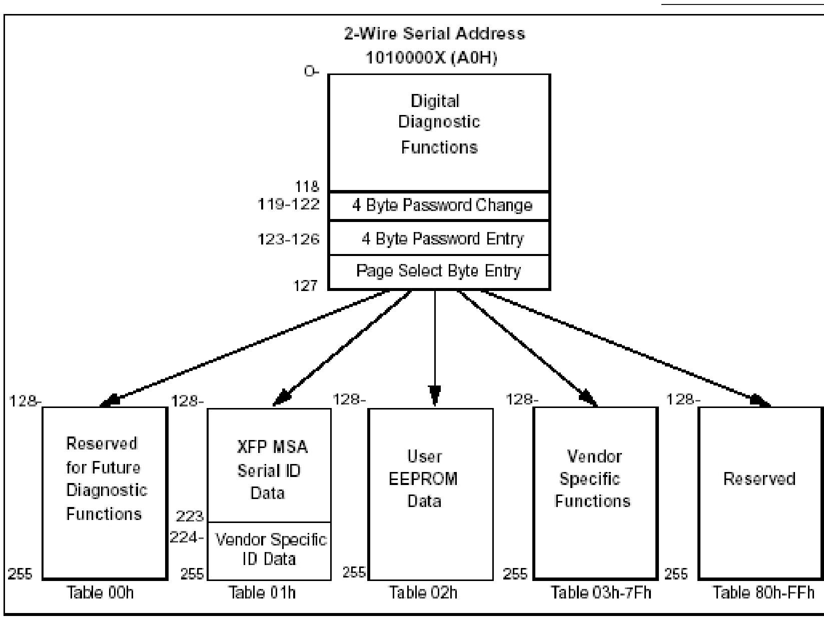

Figure 6. XFP EEPROM Content Map (courtesy: XFP MSA Association)

4.7. Mechanical Design Guidelines

The Avago Technologies HFCT-711XPD and HFCT-721XPD transceivers conform to the mechanical dimensions of the XFP 10 Gigabit Small Form Factor Pluggable Module MSA specification, revision 4.0, dated April 2004. They also conform to the TIA/EIA-604-10A specification for the LC fiber optic connector (FOCIS 10A).

Mechanical Tests

As required by the XFP MSA Revision 4.0, Avago Technologies has performed interoperability testing with EMI cages from the 3 existing (as of release) XFP cage vendors. For more information on interoperability testing data, please contact your local Avago Technologies Field Sales Engineer.

Avago Technologies has also performed several tests of the optical connector system to ensure robust design and reliability. Several tests are based on Telcordia GR-326, which is a single-mode connector specification, but components of it have been adopted for transceiver testing.

Table 5-1. EMI Cage Mechanical Testing Results

TEST	SPECIFICATIONS	AGILENT PERFORMANCE
Transceiver Retention	Axial pull on module in cage with force gauge.XFP MSA Specification of 90 N minimum.	Tested > 100 N.
Transceiver Insertion / Extraction Force	Insert/remove module with force gauge from known cage vendors. XFP MSA specification - insertion: 40 N, extraction: 30N.	Insertion, Extraction < 24 N (tested with 3 existing cage vendors)
Delatch Integrity/Tear-Out Strength	Intergrity: XFP MSA 50 insert/extract cycles. Tear-out strength: Clamp module and pull on delatch mechanism. Agilent specification: 50N (12 lbf) min. +45/-45 deg from horizontal.	100 cycles. Tested > 50N.

Table 6. Optical Mechanical Testing Results

TEST	SPECIFICATIONS	AGILENT PERFORMANCE
Fiber Connector Side-Load	Based on Telcordia GR-326 Rev 3, Sect. 4.4.3.4 Proof Test. <0.5 dB optical power loss increase. 20N (5lbf), N-S-E-W loading with duplex connector substitute. Check optical power before & after loading. Test at both initial and retest with 168H 85C/85RH pre-conditioning. Tests structural strength of module/optics.	Max 0.12 dB variation during side load after 85/85.
Fiber Connector Retention	Based on Telcordia GR-326 Rev 3, Sect. 4.4.3.4 Proof Test. 68N (15 lbf) axial pull on fiber, unpowered. Tests structural strength of module/retention of cable.	Tested > 80 N.
Transmission Under Applied Load - Axial	Based on Bellcore GR-326 Rev 3, Sect. 4.4.3.5. < 0.5 dB optical power loss increase during load. 20 N (5 lbf) axial pull on Tx (simplex) fiber.	0.1 dB max attenuation under load.

4.8. Thermal Design Guidelines

Avago Technologies specifies an XFP module case temperature range of 0°C to 70°C, measured on the top surface of the module, and guarantees performance within this temperature range. The application environment should be designed (module density, heatsink size, air flow rate, flow bypass, upstream components, PCB conductivity, etc.) to ensure the case temperature does not exceed this requirement.

For reference, the following graph shows the experimentally determined maximum case temperature of XFP modules for various port densities and air-flow rates in a 19 mm high duct. The actual performance in a specific application will depend on system specific parameters as described above. Avago Technologies can also provide compact CFD thermal models for the XFP transceiver to facilitate design.

5. XFP Testing Guidelines

5.1. HFCT-711/721 XPD Evaluation Board

The HFCT-5014 evaluation board can be used to test the Avago Technologies XFP transceivers for a variety of performance characteristics, including optical, electrical, low-speed hardware timings as well as 2-wire performance.

5.2. XFP Transmitter Eye Mask Measurement

Avago Technologies recommends customers using the Agilent 86105B optical plug-in to perform mask margin measurements on the Avago Technologies XFP transceivers. The 86105B plug-in has lower system noise than the 86106B plug-in leading to more accurate Mask Results.

The optical power at the input of the DCA should be at least above –4 dBm in order to avoid too a big impact of the plug in noise on the eye diagram measurement.

It is also important to configure the plug-in for the appropriate mask alignment method. The Eye Boundary method is the recommended way of aligning the Tx eye to the mask.

Vertical mask alignment using 0 and 1 level determined from the central 20% of the eye diagram (i.e. Eye Boundary) has gained wide industry acceptance. The 10 GB Ethernet standard (802.3ae-2002) along with the Fibre Channel (FC) standards (FC-PI2 and 10FC) reference OFSTP-4A (TIA/EIA-526-4A), which specifies this alignment technique.

Proper triggering is also required for reliable measurement of the eye diagram. The Agilent 83495A optical plug in with clock recovery could be used in conjunction with the 86105B for optimal performance. The Agilent 86107A high precision timebase plug in could also be used to achieve the lowest possible DCA jitter.

In case the 83495 or the 86107A should not available at the customer's lab, triggering directly from the pattern generator 10 GHz clock is recommended (high speed triggering option on the DCA mainframe is required.

Additional information on using the 86100 for eye diagram measurements can be found in the application note, "Characterizing High Speed Optical Transmitters: Compliance Testing with the Agilent Technologies 86100A Infiniium DCA", which is available on the Agilent Technologies Web Site:

http://cpliterature.product.agilent.com/litweb/pdf/5968-9249E.pdf

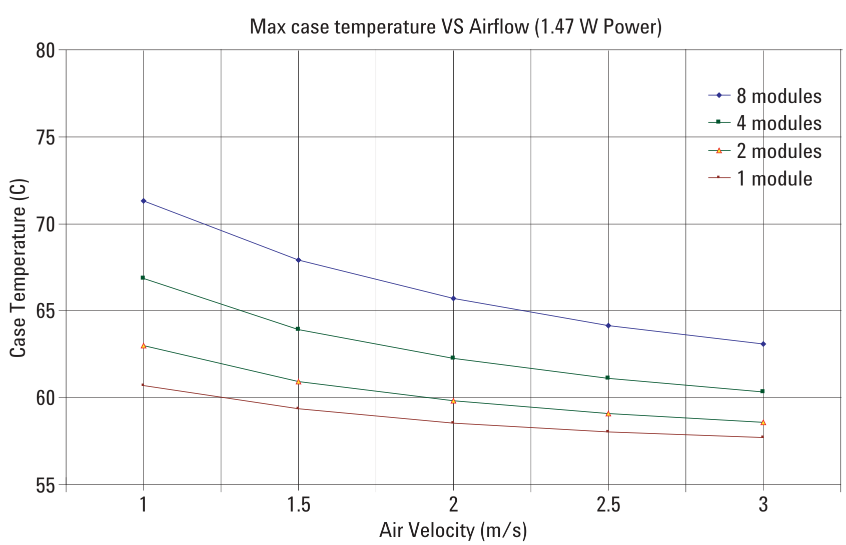

Figure 7. Max Case Temperature (for T ambient = 55C and 47 mm pitch)

5.3. XFP Jitter Generation Testing

Jitter generation is a parameter specified for SONET/SDH equipment, and therefore only applies to the HFCT-711XPD . Avago Technologies recommends that customers use the Avago Technologies J7231B OmniBER OTN for all jitter testing on XFP modules. An attenuator should be used to provide approximately –8 - –10dBm optical input power to the OTN. (Aanand, I changed this because the new high-accuracy OTN's require about 2dB more power.)

The electrical input to the XFP module should be differential and be provided by a source with as low a jitter as possible. The differential signals should be applied to the module through high quality cable or PCB traces which should be as short as possible, since some of the jitter generated here will be transferred to the optical output. Care should be taken to ensure that impedence matching is as good as possible throughout the setup.

It is recommended that SONET framed data be used for the test as this will better reflect true operating conditions.

Table 7. Comparison of Agilent Stressed Receiver Test Set-up and IEEE specifications

	IEEE Specification	Measured
Extinction Ratio (min)	3.5 dB	3.94 dB
VECP (min)	2.2 dB	2.31 dB
VECP with ISI only (min)	>1.46 dB	1.51 dB
DJ with ISI only (min)	<0.25 UI	0.15 UI
Applied Jitter (4 MHz)	0.05-0.15 UI	0.1 UI
Overall Jitter (min)	>0.3 UI	0.3 UI

The output of the Avago Technologies Stressed Eye set-up was compared to the IEEE specifications:

5.4. XFP Stressed Eye Sensitivity

The IEEE 802.3ae Stressed Receiver Sensitivity test is one of the normative requirements for 10G optical receivers.

Set-Up

The set-up used to generate the Stressed Receive Eye is shown below.

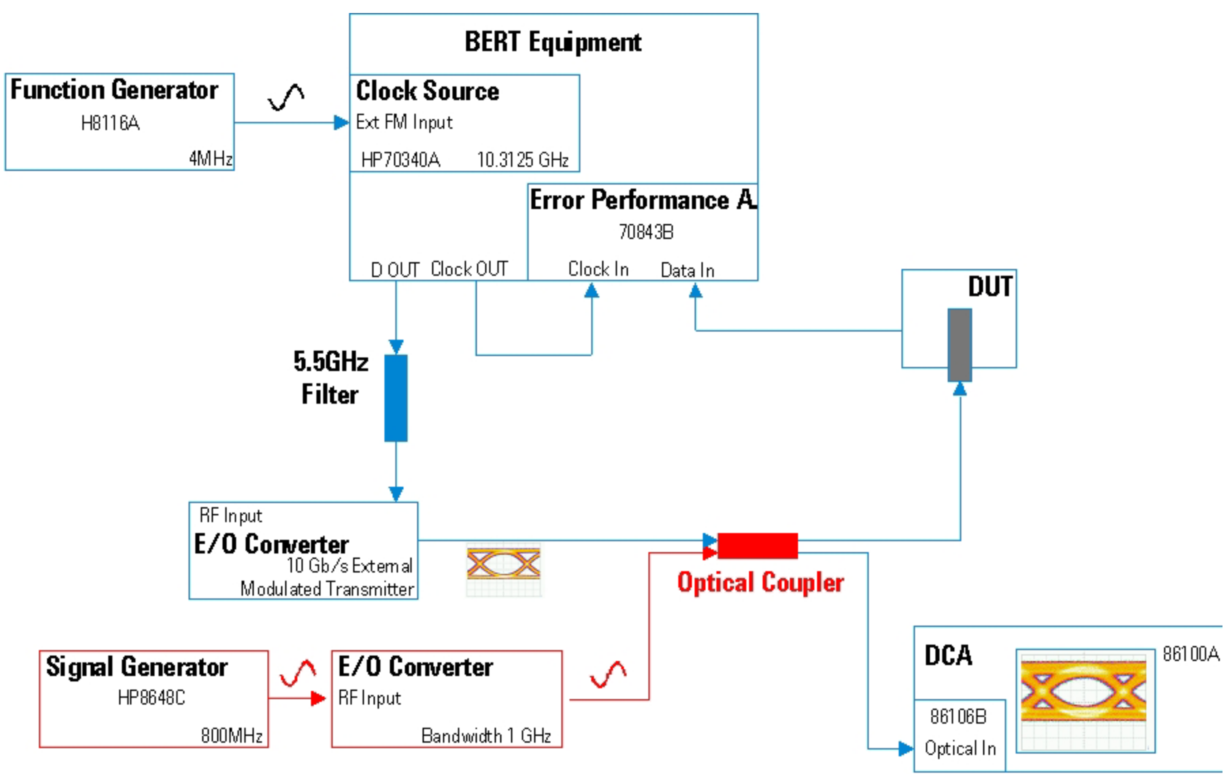

Figure 8. Agilent Stressed Receiver Test Set-Up

Results

5 Avago Technologies XFP modules were tested for Stressed Receiver Sensitivity performance using the set-up described above. The results are shown in the table below:

Table 8. Agilent XFP Stressed Receiver Test Results

	Temp -5C		Temp 25C			Temp 70C		Min Margin
	Vnom-5%	Vnom+5%	Vnom-5%	Vnom	Vnom+5%	Vnom-5%	Vnom+5%	
No.	**OMA [dBm]**	**OMA [dBm]**	**OMA [dBm]**	**OMA [dBm]**	**OMA [dBm]**	**OMA [dBm]**	**OMA [dBm]**	**dB**
1	-14.62	-14.74	-14.15	-14.10	-14.37	-13.35	-13.28	2.98
2	-15.63	-15.52	-15.59	-15.28	-15.90	-14.35	-15.00	4.05
3	-15.11	-15.25	-14.72	-15.00	-15.10	-13.00	-13.80	2.70
4	-15.40	-15.54	-15.30	-15.20	-15.60	-13.50	-14.30	3.20
5	-14.80	-15.10	-14.90	-14.79	-15.20	-13.01	-13.90	2.71

Avago Technologies' experience on SRS is that IEEE specs allow a wide range of different stressed eyes, all giving different SRS results. It is recommended that XFP SRS be tested by measuring BER at XFI output, instead of placing it in XFI loopback and measuring BER on TX output with an external receiver, as the narrow jitter transfer bandwidth of TX side can induce errors not due to the RX side.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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