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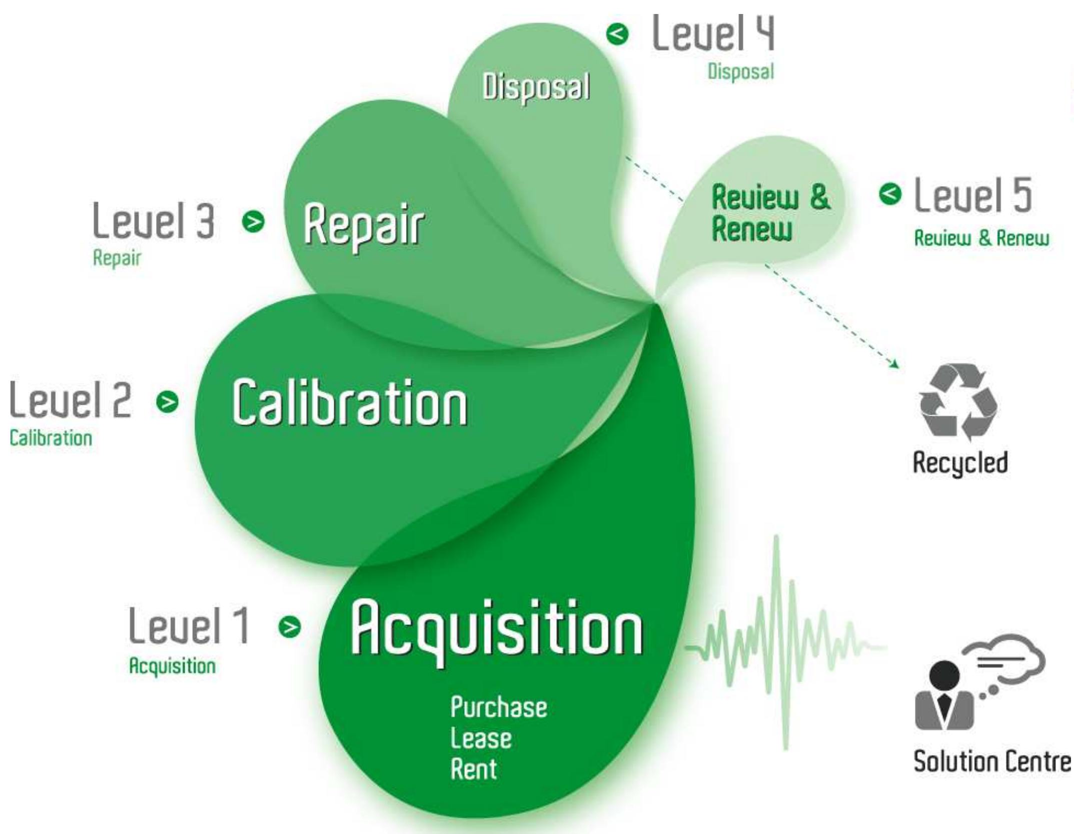

Product Lifecycle Management System

Disclaimer:

Form 080/01

User Manual

Tektronix

80C00 Series
Optical Sampling Modules

071-0435-07

This document applies to firmware version 2.00 and above.

www.tektronix.com

Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077-0001

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Tektronix warrants that the products that it manufactures and sells will be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If a product proves defective during this warranty period, Tektronix, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product.

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General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use this product only as specified.

While using this product, you may need to access other parts of the system. Read the *General Safety Summary* in other system manuals for warnings and cautions related to operating the system.

To Avoid Fire or Personal Injury

Ground the Product. This product is indirectly grounded through the grounding conductor of the mainframe power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making connections to the input or output terminals of the product, ensure that the product is properly grounded.

Observe All Terminal Ratings. To avoid fire or shock hazard, observe all ratings and markings on the product. Consult the product manual for further ratings information before making connections to the product.

Do not apply a potential to any terminal, including the common terminal, that exceeds the maximum rating of that terminal.

Do Not Operate Without Covers. Do not operate this product with covers or panels removed.

Avoid Exposed Circuitry. Do not touch exposed connections and components when power is present.

Wear Eye Protection. Wear eye protection if exposure to high-intensity rays or laser radiation exists.

Do Not Operate With Suspected Failures. If you suspect there is damage to this product, have it inspected by qualified service personnel.

Do Not Operate in Wet/Damp Conditions.

Do Not Operate in an Explosive Atmosphere.

Keep Product Surfaces Clean and Dry.

Provide Proper Ventilation. Refer to the manual's installation instructions for details on installing the product so it has proper ventilation.

Symbols and Terms

Terms in this Manual. These terms may appear in this manual:

WARNING. *Warning statements identify conditions or practices that could result in injury or loss of life.*

CAUTION. *Caution statements identify conditions or practices that could result in damage to this product or other property.*

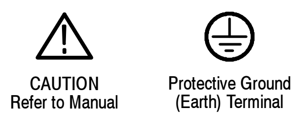
Terms on the Product. These terms may appear on the product:

DANGER indicates an injury hazard immediately accessible as you read the marking.

WARNING indicates an injury hazard not immediately accessible as you read the marking.

CAUTION indicates a hazard to property including the product.

Symbols on the Product. The following symbols may appear on the product:



Preface

This is the user manual for the 80C00 Series Optical Modules and their available options. It includes the following information:

- Describes the capabilities of the modules and how to install them
- Explains how to operate the modules: how to control acquisition, processing, and input/output of information
- Lists specifications of the modules

You may want to visit the Tektronix Website at http://www.tektronix.com for the latest revision of the user documentation. Select the Manuals link, then enter the part number or product name to locate the document.

A printed version of this manual is also orderable (see *Optional Accessories* on page 8).

Manual Structure

This manual is composed of the following chapters:

- *Getting Started* shows you how to configure and install your optical module.
- *Operating Basics* describes controlling the module using the front panel and the instrument user interface.
- *Reference* provides information on wavelength selection, clock recovery and optical bandwidth.
- *Specifications* contains specifications for the 80C00 Series Optical Modules.

Related Manuals

This document covers installation and usage of the sampling module and its features. For information of the main instrument in which the sampling module is used, refer to the user documents and online help provided with your 8000-series main instrument.

Contacting Tektronix

Phone	1-800-833-9200*
Address	Tektronix, Inc. Department or name (if known) 14200 SW Karl Braun Drive P.O. Box 500 Beaverton, OR 97077 USA
Web site	www.tektronix.com
Sales support	1-800-833-9200, select option 1*
Service support	1-800-833-9200, select option 2*
Technical support	Email: techsupport@tektronix.com 1-800-833-9200, select option 3* 6:00 a.m. – 5:00 p.m. Pacific time

*** This phone number is toll free in North America. After office hours, please leave a voice mail message.
Outside North America, contact a Tektronix sales office or distributor; see the Tektronix web site for a list of offices.**

Getting Started

The 80C00 Series Optical Modules and their available options are high-performance optical modules that support high bandwidth telecom and datacom standards. These modules can be installed in the CSA8000 and TDS8000 Series instruments.

Proper operation of the optical sampling modules requires that the appropriate TDS8000 and CSA8000 Series application software is installed on the main instrument. Table 1 lists the application software versions and the optical modules supported.

To display the version installed, select *About TDS/CSA8000* from the Help menu of the main instrument.

Table 1: CSA/TDS8000 Series application software version required

Application software version	Modules supported
1.0 [1]	80C01, 80C01-CR, 80C02, 80C02-CR
1.4 [1]	Added: 80C10
1.5 [1]	Added: 80C07B, 80C07B-CR1 80C08C, 80C08C-CR1, 80C08C-CR2, 80C08C-CR4, 80C11, 80C11-CR1, 80C11-CR2, 80C11-CR3, 80C11-CR4
2.0.1.3 [2, 3]	Added: 80C12 (limited)
2.0.1.5 or greater [2]	Added: 80C12

1 **Product application software version 1.x requires the Windows 98 operating system.**

2 **Product application software version 2.x requires the Windows 2000 operating system.**

3 **Product application software version 2.0.1.3 should be replaced with the latest version available for download from the Tektronix Website.**

Product Description

The optical modules provide the features shown in Tables 2 through 4. Table 9 on page 26 provides wavelength selections, filter, and bandwidth specifications for each module. Figures 1 and 2 on page 5 show the controls, connectors, and indicators.

Table 2: Optical module features (80C01 and 80C02)

Feature	80C01[1]	80C02[1]
Number of input channels	1	
Effective wavelength range	1100 nm to 1650 nm	
Supported standards or data filtering rates	OC-12/STM-4, OC-48/STM-16, OC-192/STM-64	OC-192/STM-64
Clock recovery, option	OC-12/STM-4, OC-48/STM-16	OC-192/STM-64
Absolute maximum nondestructive optical input[2]	5 mW average power; 10 mW peak power at wavelength with highest relative responsivity.	
Internal Fiber Diameter	9 μm/125 μm single mode[3]	
Optical return loss	> 30 dB	> 30 dB typical
Minimum optical bandwidth at optical connector	> 20 GHz	> 30 GHz
Output zero	< 10 μW immediately after dark calibration	
Independent channel deskew	Standard	
Offset capability at front of module	Standard	
Power meter	Standard	

1 **Some values in the table are typical.**

2 **The optical input powers below non-destructive levels may exceed saturation and compression limits of the module.**

3 **Compatible with single-mode fiber of equal or smaller diameter.**

Table 3: Optical module features (80C07B, 80C08C, and 80C12)

Feature	80C07B[1]	80C08C[1]	80C12[1]
Number of input channels	1		
Effective wavelength range	700 nm to 1650 nm		
Supported standards or data filtering rates	Standard: OC-48 / STM-16, 2 Gigabit Ethernet (ENET2500/2GBE), Infiniband Optional:[2] OC-3 / STM-1, OC-12 / STM-4, FibreChannel (FC1063/FC), Gigabit Ethernet (ENET1250/GBE), 2G FibreChannel (FC2125/2FC)	9.95328 Gb/s (10GBASE-W), 9.95328 Gb/s (OC-192/STM64), 10.3125 (10GBASE-R), 10.51875 (10GFC), 11.10 Gb/s (10GbE FEC), 10.66423 Gb/s (G.975 FEC), 10.709225 Gb/s (G.709 FEC)	Multi Gigabit Options:[3] 1.0625 Gb/s (FC1063) 2.125 Gb/s (FC2125) 3.125 Gb/s (10GBase-X4) 3.188 Gb/s (10GFC-X4) 3.318 Gb/s (VSR-5) 4.250 Gb/s (FC4250) 10 Gigabit Option (Option 10G): 9.95328 Gb/s (10GBase-W) 9.95328 Gb/s (OC-192/STM64) 10.3125 Gb/s (10GBase-R) 10.51875 Gb/s (10GFC) 10.66423 Gb/s (G.975 FEC) 10.709225 Gb/s (G.709 FEC) 11.10 Gb/s (10GbE FEC)
Clock recovery option	155.52 Mb/s (OC-3/STM-1), 622.08 Mb/s (OC-12/STM-4), 1062.5 Mb/s (FC1063/FC), 1250 Mb/s (ENET1250/GBE), 2125 Mb/s (FC2125/2FC), 2488.32 Mb/s (OC-48/STM-16), 2500 Mb/s (ENET2500/2GBE), 2500 Mb/s (Infiniband), 2666.06 Mb/s (OC-48-FEC)	9.95328 Gb/s (10GBASE-W/ OC-192/STM-64) (CR-1), 10.3125 Gb/s (10GBASE-R) (CR-1 & CR-2), 10.51875 Gb/s (10GFC) (CR-2 only), Continuous-rate from 9.8 Gb/s to 12.6 Gb/s (CR-4)[4]	Clock recovery supported with the use of the 80A05 Electrical Clock Recovery module (purchased separately).
Absolute maximum nondestructive optical input[5]	5 mW average power; 10 mW peak power at wavelength with highest relative responsivity.	1 mW average power; 10 mW peak power for 60 ms.	1 mW average power; 10 mW peak power for 60 ms.
Internal fiber diameter	62.5 µm/125 µm multimode mode[6]		
Optical return loss	>14 dB for multimode fiber >24 dB for single-mode fiber		
Minimum optical bandwidth at optical connector	>2.3 GHz	>9.5 GHz	>8.5 GHz >9.5 GHz with Option 10G
Output zero	<500 nW immediately after dark calibration ±2% (vertical offset)	<1 uW immediately after dark calibration ±2% (vertical offset)	
Independent channel deskew	Standard		

Table 3: Optical module features (80C07B, 80C08C, and 80C12) (cont.)

Feature	80C07B[1]	80C08C[1]	80C12[1]
Offset capability at front of module	Standard		
Power meter	Standard		

1 **Some values in the table are typical.**

2 **The 80C07B is shipped with five reference receiver filters. Three are standard, with the two remaining configured at the time of purchase. See Table 5 on page 6 for the optional configurations.**

3 **The 80C12 is available with a variety of options that support 2 to 4 filters. See Table 5 on page 6 for the optional configurations.**

4 **Continuous-rate clock recovery supporting any standard or user-definable rate in the range from 9.8 Gb/s to 12.6 Gb/s.**

5 **The optical input powers below non-destructive levels may exceed saturation and compression limits of the module.**

6 **Compatible with single-mode fiber of equal or smaller diameter.**

Table 4: Optical module features (80C10 and 80C11)

Feature	80C10[1]	80C11[1]
Number of input channels	1[2]	1
Effective wavelength range	1310 nm ±30 nm 1550 nm ±30 nm	1100 nm to 1650 nm
Supported standards or data filtering rates	OC-768/STM256, 43.018 Gb/s G.709 FEC	OC-192/STM-64 (9.953 Gb/s), 10GBASE-W (9.953 Gb/s), 10GBASE-R (10.31 Gb/s), 10GFC (10.518 Gb/s), G.975 FEC (10.66 Gb/s, G.709 FEC (10.71 Gb/s), 10GbE FEC (11.10 Gb/s)
Clock recovery option	None	9.95328 Gb/s (10GBASE-W/ OC-192/STM-64) (CR-1, CR2, & CR-3), 10.66423 Gb/s (CR-2), 10.70922 Gb/s (CR-3), Continuous-rate from 9.8 Gb/s to 12.6 Gb/s (CR-4)[3]
Absolute maximum nondestructive optical input[4]	20 mW average power; 60 mW peak power at wavelength with highest relative responsivity.	5 mW average power; 10 mW peak power at wavelength with highest relative responsivity
Internal fiber diameter	9 μm/125 μm single mode[5]	
Optical return loss	$>$30 dB	
Minimum optical bandwidth	$>$60 GHz, minimum $>$65 GHz, typical	$>$20 GHz
Output zero	1550 nm: ±[25 μW +0.04 × |Vertical Offset|] 1310 nm: ±[35 μW +0.04 × |Vertical Offset|]	10.71 Gb/s settings: $<$10 μW ±2% (vertical offset) 20 GHz, 30 GHz settings: $<$10 μW ±4% (vertical offset)
Independent channel deskew	Standard	

Table 4: Optical module features (80C10 and 80C11) (cont.)

Feature	80C10[1]	80C11[1]
Offset capability at front of module	Standard	
Power meter	Standard	

1 Some values in the table are typical.

2 The 80C10 has two separate optical inputs, one for 1310 nm and one for 1550 nm.

3 Continuous-rate clock recovery supporting any standard or user-definable rate in the range from 9.8 Gb/s to 12.6 Gb/s.

4 The optical input powers below non-destructive levels may exceed saturation and compression limits of the module.

5 Compatible with single-mode fiber of equal or smaller diameter.

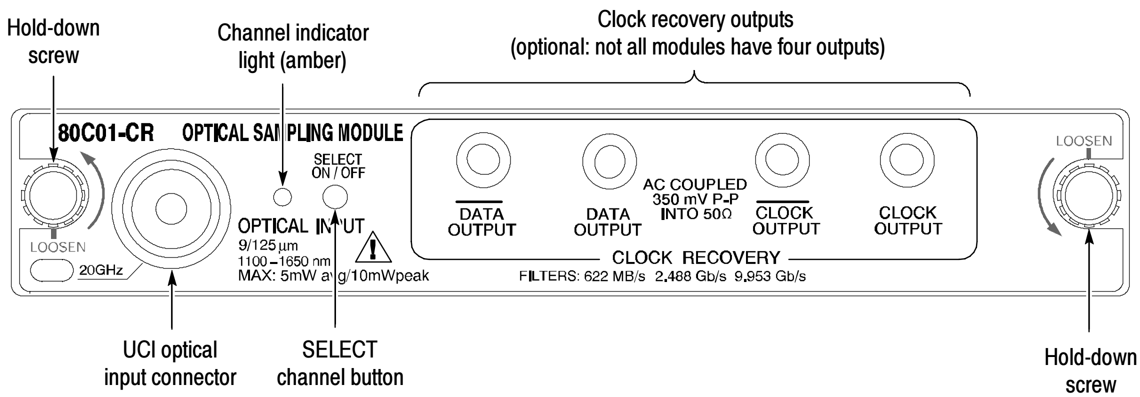


Figure 1: Typical Optical module front panel, 80C01-CR shown

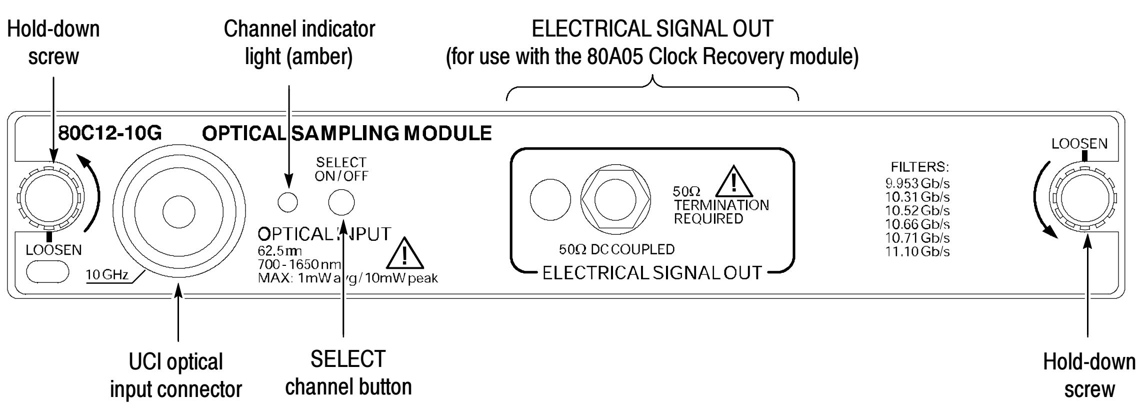


Figure 2: 80C12 Optical module front panel

Options and Accessories

This section lists the standard and optional accessories available for the sampling modules, as well as the product options.

Options

The following options can be ordered for the sampling modules:

Table 5: Available options

Module	Option	Description
80C01	Option CR	Adds 622.08 Mb/s and 2.48832 Gb/s clock recovery
80C02	Option CR	Adds 9.95328 Gb/s clock recovery
80C07B	Option CR1	Adds 155/622/1063/1250/2125/2488/2500/2666 Mb/s clock recovery
	Option F1	Adds reference receiver filters OC-3 (155 Mb/s) and OC-12 (622 Mb/s)
	Option F2	Adds reference receiver filters OC-3 (155 Mb/s) and FibreChannel (1063 Mb/s)
	Option F3	Adds reference receiver filters OC-3 (155 Mb/s) and Gigabit Ethernet (1250 Mb/s)
	Option F4	Adds reference receiver filters OC-3 (155 Mb/s) and 2G FibreChannel (2125 Mb/s)
	Option F5	Adds reference receiver filters OC-12 (622 Mb/s) and FibreChannel (1063 Mb/s)
	Option F6	Adds reference receiver filters OC-12 (622 Mb/s) and Gigabit Ethernet (1250 Mb/s)
	Option F7	Adds reference receiver filters OC-12 (622 Mb/s) and 2G FibreChannel (2125 Mb/s)
	Option F8	Adds reference receiver filters FibreChannel (1063 Mb/s) and Gigabit Ethernet (1250 Mb/s)
	Option F9	Adds reference receiver filters FibreChannel (1063 Mb/s) and 2G FibreChannel (2125 Mb/s)
	Option F10	Adds reference receiver filters Gigabit Ethernet (1250 Mb/s) and 2G FibreChannel (2125 Mb/s)
80C08C	Option CR1	Adds 9.95328 Gb/s and 10.3125 Gb/s clock recovery
	Option CR2	Adds 10.3125 Gb/s and 10.51875 Gb/s clock recovery
	Option CR4	Adds continuous clock recovery from 9.8 Gb/s to 12.6 Gb/s

Table 5: Available options (cont.)

Module	Option	Description
80C11	Option CR1	Adds 9.95328 Gb/s clock recovery
	Option CR2	Adds 9.95328 Gb/s and 10.66423 Gb/s clock recovery
	Option CR3	Adds 9.95328 Gb/s and 10.70922 Gb/s clock recovery
	Option CR4	Adds continuous clock recovery from 9.8 Gb/s to 12.6 Gb/s
80C12	Option F1	Adds reference receiver filters 1G FibreChannel (1.063 Gb/s), 2G FibreChannel (2.125 Gb/s), 4G FibreChannel (4.250 Gb/s)
	Option F2	Adds reference receiver filters 2G FibreChannel (2.125 Gb/s), 4G FibreChannel (4.250 Gb/s), 9 GHz optical bandwidth
	Option F3	Adds reference receiver filters 1G FibreChannel (1.0623 Gb/s), 2G FibreChannel (2.125 Gb/s), 9 GHz optical bandwidth
	Option F4	Adds reference receiver filters 2G FibreChannel (2.125 Gb/s), 10GBase-X4 (3.125 Gb/s), 4G FibreChannel (4.250 Gb/s), 10GFC-X4 (3.188 Gb/s)
	Option F5	Adds reference receiver filters 10GBase-X4 (3.125 Gb/s), 4G FibreChannel (4.250 Gb/s), 10GFC-X4 (3.188 Gb/s), 9 GHz optical bandwidth
	Option F6	Adds reference receiver filters 2G FibreChannel (2.125 Gb/s), 10GBase-X4 (3.125 Gb/s), 10GFC-X4 (3.188 Gb/s), 9 GHz optical bandwidth
	Option FC	Adds reference receiver filters 10GBase-X4 (3.125 Gb/s), VSR-5 (3.318Gb/s), 10GFC-X4 (3.188 Gb/s), 9 GHz optical bandwidth
	Option 10G	Adds reference receiver filters OC192/STM-64 (9.953 Gb/s), 10GFC (10.518 Gb/s), 10GBase-W (9.953 Gb/s), 10GBase-R (10.31 Gb/s), G.975 FEC (10.66 Gb/s), G.709 FEC (10.709 Gb/s), 10GBE FEC (11.10 Gb/s), 10 GHz optical bandwidth
All modules	Option C3	Three years of calibration service
All modules	Option C5	Five years of calibration service
All modules	Option D1	Calibration data report
All modules	Option D3	Three years of calibration data reports (requires Opt. C3)
All modules	Option D5	Five years of calibration data reports (requires Opt. C5)
All modules	Option R3	Extended repair warranty to three years
All modules	Option R5	Extended repair warranty to five years.

Standard Accessories

The following accessories are shipped with the module:

Table 6: Standard accessories

Item	Part number
Certificate of Traceable Calibration for product at initial shipment	Not orderable
Frequency response data[1]	Not orderable
FC/PC UCI adapter, installed	119-5115-xx
Fiber cleaning kit	020-2494-xx
SMA male 50 Ω termination (installed, one per clock recovery output connector)	015-1022-xx

1 **Frequency response data is provided for each module's filtered modes.**

Optional Accessories

The following accessories are orderable for use with the sampling module at the time this manual originally published. Consult a current Tektronix catalog for additions, changes, and details:

Table 7: Optional accessories

Item	Part number
D4/PC Universal Optical Input (UCI) adapter	119-4514-xx
Biconic UCI adapter	119-4515-xx
FC/PC UCI adapter	119-4516-xx
SMA 2.5 UCI adapter	119-4517-xx
SC/PC UCI adapter	119-4518-xx
DIN/PC UCI adapter	119-4546-xx
DIAMOND 2.5 UCI adapter	119-4556-xx
SMA UCI adapter	119-4557-xx
DIAMOND 3.5 UCI adapter	119-4558-xx
ST/PC UCI adapter	119-4513-xx
3.5 male to 3.5 female SMA	015-0552-xx
Slip-on SMA connector	015-0553-xx
CSA8000B & TDS8000B Service Manual	071-0438-xx
80C00 Series Optical Sampling Modules User Manual (printed)	071-0435-xx

Installation

The optical modules fit in the large slot in the front panel of a compatible instrument, such as a CSA8000 or TDS8000 Series instrument. Figure 3 shows the front panel of an 8000 Series instrument and the locations of the module compartments.

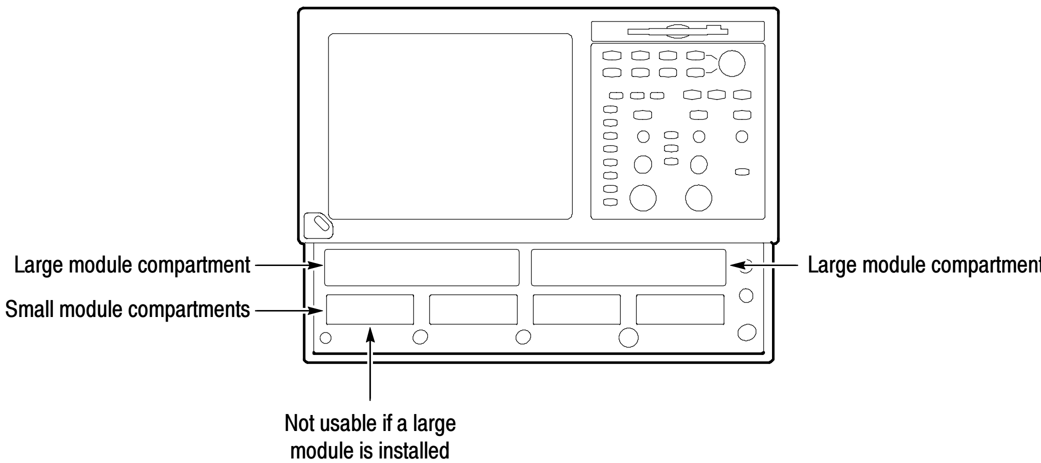


Figure 3: Module compartments

At least one module must be installed in the main instrument to acquire signals.

***NOTE**. Installing a large module, in either large compartment, disables some of the small compartment channels. Refer to the CSA8000 and TDS8000 Series Online Help about compartment interaction.*

The large compartments support single channel sampling modules, while the small compartments support single or dual channel sampling modules. Eight of the 10 inputs are usable at one time.

Electrostatic Discharge

To prevent electrostatic damage to the main instrument and optical modules, follow the precautions described in this manual and the manuals accompanying your main instrument.

Circuitry in the optical module is very susceptible to damage from electrostatic discharge and from over drive signals. Be sure to only operate the optical module in a static-controlled environment (grounded conductive table top, wrist strap, floor mat, and ionized air blower). Be sure to discharge to ground any electrostatic charge that may be present on electrical cables before attaching the cable to the optical module recovered clock and data outputs.

CAUTION. *The recovered clock and data outputs of the optical module are subject to damage from electrostatic discharge (ESD). To prevent damage from electrostatic discharge, store the optical module with the supplied SMA terminations installed. Store the module in a static-free container, such as the shipping container. Whenever you move the optical module from one instrument to another, use a static-free container to carry the optical module.*

Always use a wrist strap (provided with your instrument) when handling an optical module or making connections. Discharge to ground any electrostatic charge that may be present on cables before attaching the cable to the optical-module.

Module Installation

To install a large module, first power off the instrument using the front-panel On/Standby power switch. Then place the module into a compartment and slowly push it in with firm pressure. Once the module is seated, turn the hold-down screws clockwise to lock the module into place. See Figure 4.

NOTE. *To facilitate installation, turn the hold-down screws so that they are completely out (all the way counterclockwise), and then be sure to seat the module completely into its compartment. Doing so will help ensure the retaining ear on each screw rotates into position as you tighten the screws.*

CAUTION. *To prevent damage to the optical module or instrument, never install or remove a module when the front-panel On/Standby power switch is ON (powered-on).*

Once you have secured the module, you can turn on the instrument.

***NOTE**. When removing a module, after turning the hold-down screws counter-clockwise, use the module ejectors on the main instrument to eject the module.*

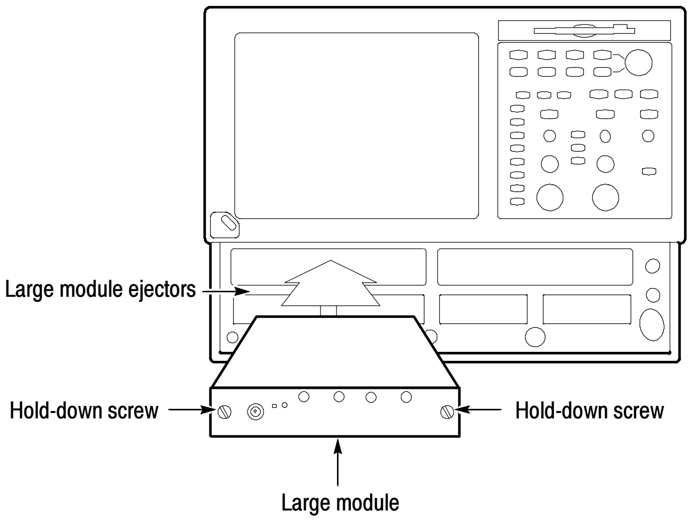


Figure 4: Installing a large module

***NOTE**. After first installing a sampling module(s) or after moving a sampling module from one compartment to another, you should run Compensation from the Utilities menu to ensure the instrument meets it specifications. You must run a compensation if an extender is installed, changed, or removed from a module. For instructions on running a compensation, see* Optimizing Measurement Accuracy *on page 19.*

After running Compensation, you must save the new values to retain them, otherwise they will be lost when turning the instrument power off.

Operating Basics

This section describes the front panel, connecting to the circuit under test, system interaction with the main instrument, and the programmer interface.

Usage

Handle your optical module carefully at all times.

CAUTION. *To avoid damaging your optical module, take the following precautions:*

Do not drop your module since damage and misalignment of the photodiode optical assembly can result. Store the module in a secure location when not in use.

Replace the protective cap on the input connector when the module is not in use.

To prevent loss of optical power or damage to the optical connectors, keep the connectors clean at all times. Also insure that all connectors and jumpers attached to the inputs are clean prior to insertion. *See* Cleaning Optical Connectors *on page 21.*

Connecting Optical Signals

Take care to preserve the integrity of the connectors by keeping them free of contamination. For cleaning information, see *Cleaning Optical Connectors* on page 21.

The input of the 80C01, 80C02, 80C10, and 80C11 modules (see note) can couple to single-mode optical fibers with a core diameter/cladding diameter of 9/125 μm. The 80C07B, 80C08C, and 80C12 modules can couple to any single-mode dimension or multimode dimension not exceeding a core diameter/cladding diameter of 62.5/125 μm. Alternate types can be coupled by use of UCI (universal connector interface) series adapters. Refer to a current Tektronix catalog for details.

NOTE*. The 80C10 has two separate optical inputs. The user must choose the correct one to use depending on 1310 nm or 1550 nm operation.*

Attach the fiber optic cable with a suitable connector or a UCI Interface adapter to the optical input receptacle as follows. Figure 5 illustrates the proper use of a UCI adapter.

1. Firmly press the cable connector or adapter into the interface ferrule until it reaches the stop.
2. Line up the key with the slot in the UCI adapter before inserting.

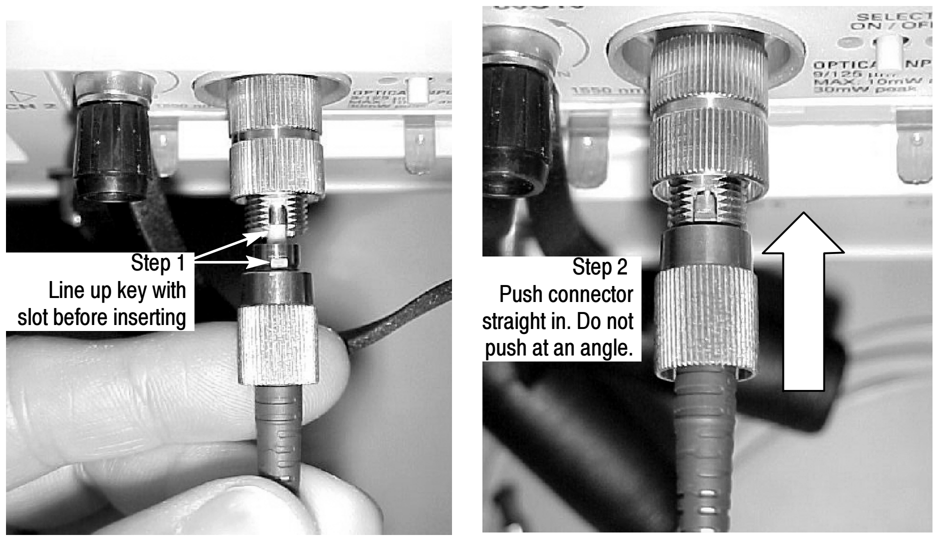


Figure 5: Connecting optical cables correctly

CAUTION. *Do not insert the connector into the UCI adapter at an angle. Do not insert the connector and then rotate to line up the key with the slot. Either action may damage the UCI adapter.*

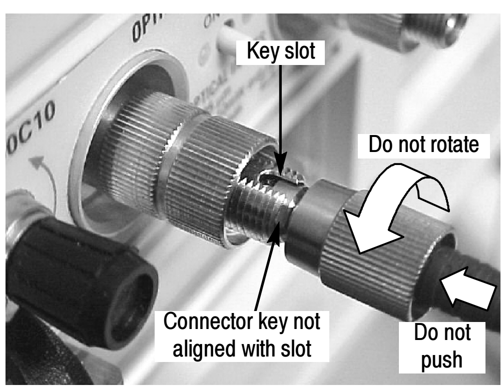


Figure 6: Incorrectly connecting optical cables

3. Firmly tighten the cable connector or the adapter shell. Tighten with finger pressure only.
4. To remove, unscrew the cable connector or adapter shell.

Attenuating Optical Signals

To keep the optical input power to an appropriate level, it may be necessary to attenuate the optical signal.

CAUTION. *To avoid damaging the optical input of the module, attenuate to the Absolute Maximum Nondestructive Optical Input specifications. To maintain the levels within performance range and to avoid clipping, attenuate optical signals as indicated in the table below:*

Module	*Average*	*Peak*
80C01	*5 mW*	*10 mW*
80C02	*5 mW*	*10 mW*
80C07B	*5 mW*	*10 mW*
80C08C	*1 mW*	*10 mW*
80C10	*20 mW*	*60 mW*
80C11	*5 mW*	*10 mW*
80C12	*1 mW*	*10 mW*

NOTE. *The 80C07B module can have a somewhat deteriorated response for signals larger than 200 $\mu W_{p\text{-}p}$ (1310 nm and 1550 nm) and 400 $\mu W_{p\text{-}p}$ (780 nm and 850 nm). The 80C08C module also can have a somewhat deteriorated response for signals larger than 500 $\mu W_{p\text{-}p}$. The 80C12 module can have a deteriorated response for signals larger than 500 $\mu W_{p\text{-}p}$ (1310 nm and 1550 nm) and 800 $\mu W_{p\text{-}p}$ (850 nm).*

NOTE. *Optical sampling modules may have dynamic ranges exceeded without obvious visual indication onscreen because the photodetector and/or filters used may not necessarily pass through overloaded signals to the samplers at the front end.*

System Interaction

Your optical module is a part of a larger instrument system. Most optical module functions are controlled automatically by the main instrument. These include such things as vertical scaling and horizontal sampling rate. You do not directly control these parameters; they are controlled for you as you perform tasks on the main instrument. The parameters that you control from the optical module front panel are explained in the *Front Panel Controls* section.

An additional optical module function that you control from the main instrument is external channel attenuation. External Attenuation lets you enter a number representing any external attenuation you have added to a channel.

Front Panel Controls

Typical optical module front panels are shown in Figures 7 and 8.

Channel Selection

Each channel has a SELECT channel button and an amber channel light. The button operates as follows:

- If the amber channel light is on, the channel is acquiring a waveform.
- If you press the button and the channel is not currently being acquired (for any channel or math waveform), then the instrument activates (turns on) the channel.
- If you press the button and the channel is currently active as a channel waveform, then the instrument selects the channel waveform.
- If the channel waveform is already selected when you press the channel button, the instrument turns the channel off.

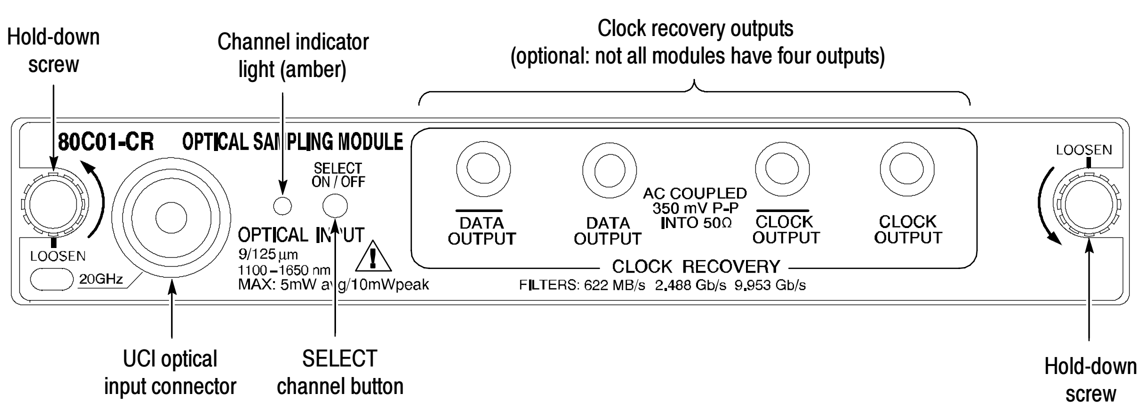


Figure 7: Typical Optical module front panel, 80C01-CR shown

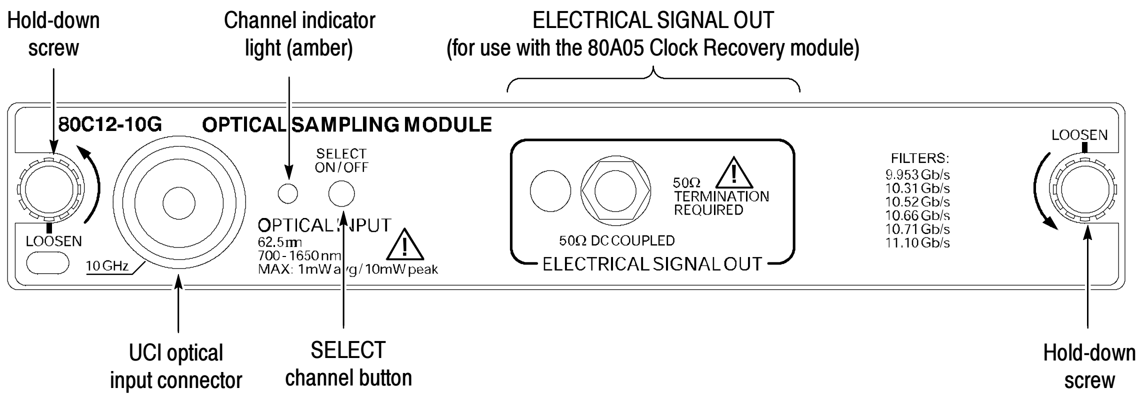


Figure 8: 80C12 Optical module front panel

Optical Input Connector

The optical input connector uses a universal connector interface (UCI) that allows use of many standard fiber-optic female connector styles. Some of the standard UCI interfaces supported are FC, ST, SC, and DIN. (Refer to a current Tektronix catalog for details.)

Outputs

Most optical modules provide optional clock and data-recovery circuitry, providing clock and data outputs; the recovered clock is internally routed to the main-instrument trigger circuit. The circuitry also provides front-panel output of normal and complemented clock, and on some modules, normal and complemented data.

The 80C12 module provides an electrical signal output. For clock recovery purposes, this signal must be routed to the input of an 80A05 Electrical Clock Recovery module within the same mainframe. Refer to the 80A05 User manual for details of using the module.

Table 8 provides a list of current modules and available outputs.

***NOTE**. Use 50 Ω terminations, provided with your optical module, on all unused outputs.*

Table 8: Clock recovery outputs

Modules	Front panel outputs
80C01-CR	DATA, $\overline{\text{DATA}}$, CLOCK, $\overline{\text{CLOCK}}$
80C02-CR	DATA, CLOCK, 1/16 CLOCK
80C07B-CR1	DATA, $\overline{\text{DATA}}$, CLOCK, $\overline{\text{CLOCK}}$
80C08C-CR1 80C08C-CR2 80C08C-CR4	CLOCK, 1/16 CLOCK CLOCK, 1/16 CLOCK CLOCK, 1/16 CLOCK

Table 8: Clock recovery outputs (cont.)

Modules	Front panel outputs
80C11-CR1 80C11-CR2 80C11-CR3 80C11-CR4	DATA, CLOCK, 1/16 CLOCK CLOCK, 1/16 CLOCK CLOCK, 1/16 CLOCK CLOCK, 1/16 CLOCK
80C12	ELECTRICAL SIGNAL OUT (for use with the 80A05 module)

You can disable the internal recovered clock from being used as the main instrument trigger by selecting external or internal triggering; select the recovered clock rate without actually selecting recovered clock as the trigger condition in order to activate the front-panel clock recovery signals.

Hold-Down Screws

Hold-down screws secure the module to the main instrument. Once the hold-down screws are loosened, use the eject levers to remove the module from a powered-down main instrument. Indicators on the hold-down screws point in the direction that the latch is pointing.

Commands From the Main Instrument Front Panel

The Vertical Setup dialog box lets you toggle between the basic and optical module controls. The basic and optical controls are shown in Figure 9.

You first select the channel you want to set in the Waveform section of the dialog box. Then you select the Setup Wavelength, Filter, Bandwidth, or Compensate controls in the dialog box to change those settings or to initiate a compensation. Optical modules with the clock recovery option also have source and rate controls in the Trigger dialog box.

Detailed information on these dialog boxes can be found in the *CSA8000 and TDS8000 Series Online Help*.

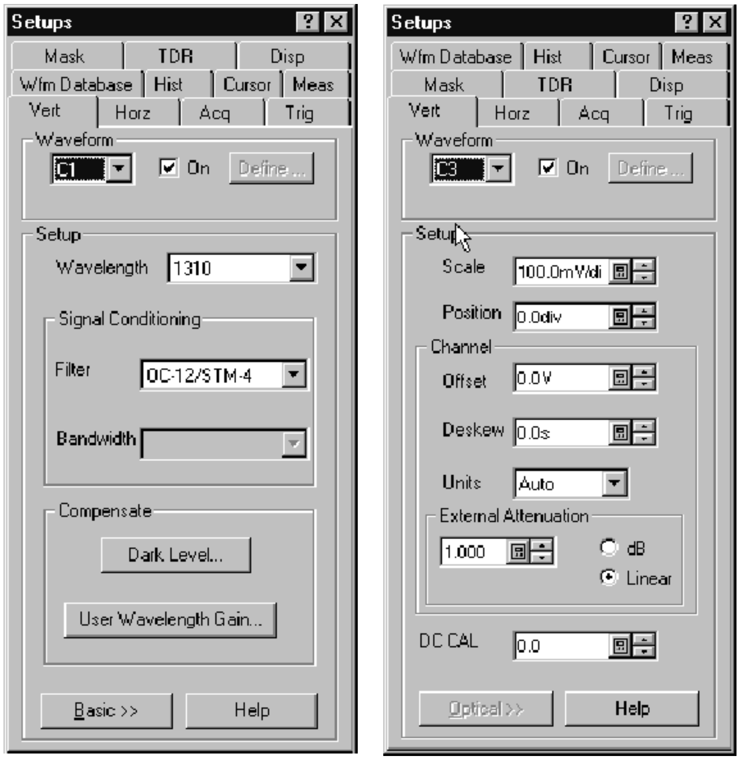


Figure 9: System Vertical menu

Programmer Interface Commands

The remote programming commands for all sampling modules are documented in the *CSA8000 & TDS8000 Series Programmer Guide* accessed from the instrument Help menu.

User Adjustments

All optical module setups, parameters, and adjustments are controlled by the main instrument. To save, recall, or change any module settings, use the main-instrument menus or front-panel controls. Consult the the *CSA8000 and TDS8000 Series Online Help*.

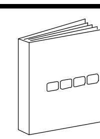
Optimizing Measurement Accuracy

Measurement accuracy of optical modules is increased (or maintained) by performing the following procedures:

- Vertical Compensation
- Cleaning the Optical Connectors
- Dark-Level and User Wavelength Gain Compensations

Perform Vertical Compensation

Performing a vertical compensation will maximize the accuracy of the automatic measurements you take. This procedure uses internal routines to optimize the vertical offset, gain, and linearity.

Overview	To perform optical compensations	Control elements and resources
Prerequisites	**1.** The instrument must have the optical sampling module(s) to be compensated in place. The acquisition system should be set to run continuously. **2.** Dust covers must be in place on all optical module channels (or otherwise eliminate the optical input). **3.** Power on the instrument and allow a 20 minute warm-up before doing this procedure	 See the instrument user documentation for details on operating the instrument controls.
Access the compensation routines	**4.** From the application menu bar, click **Utilities**, and then click **Compensation.**	

<table>
<tr><th>Overview</th><th>To perform optical compensations (cont.)</th><th>Control elements and resources</th></tr>
<tr><td></td><td>

5. In the Compensation dialog box, the main instrument (mainframe) and sampling modules are listed. The temperature change from the last compensation is also listed.

6. Wait until the Status for all items you wish to compensate changes from **Warm Up** to **Pass**, **Fail**, or **Comp Req'd**.

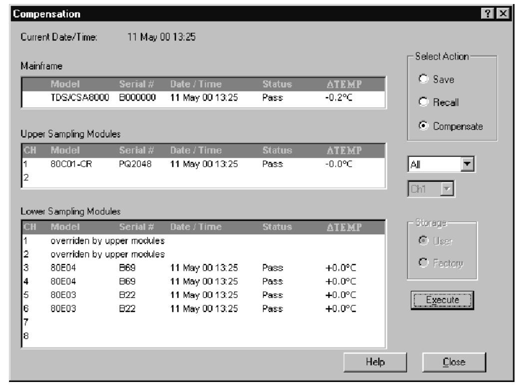
7. Under Select Action, click the **Compensate** option button.

8. From the top pulldown list, choose **All** (default selection) to select the main instrument and all its modules as targets to compensate.

9. Click the **Execute** button to begin the compensation.

10. Follow the instructions to disconnect inputs and install terminations that will appear on screen; be sure to follow static precautions when following these instructions.

</td><td>



</td></tr>
<tr><td>Verify that the compensation routines pass</td><td>

11. The compensation may take several minutes to complete. Verify that **Pass** appears as **Statu**s for the main instrument and for all sampling modules listed in the Compensation dialog box when compensation completes.

12. If instead **Fail** appears as **Status**, rerun the compensation. If **Fail** status continues after rerunning compensation and you have allowed warm up to occur, the module or main instrument may need service.

13. Click the **Save** option button under Select Action. Click the **Execute** button to save the compensation.

- If you don't save the new compensation values, they will be lost when the instrument is powered off.

</td><td></td></tr>
</table>

End of Procedure

Cleaning Optical Connectors

Small dust particles and oils can easily contaminate optical connectors and reduce or block the signal. Take care to preserve the integrity of the connectors by keeping them free of contamination.

CAUTION. *To prevent loss of optical power or damage to the optical connectors, keep the connectors clean at all times.*

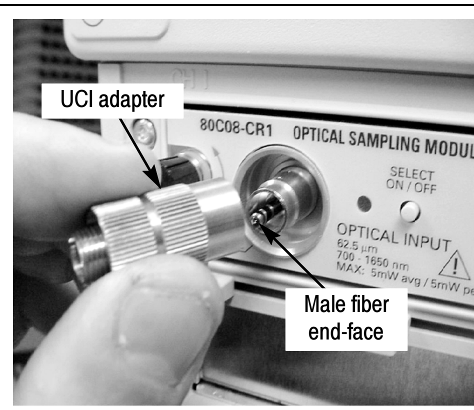
To reduce the need for cleaning, immediately replace protective caps on the optical connectors when not in use.

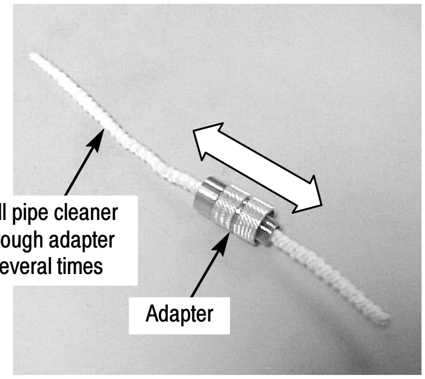
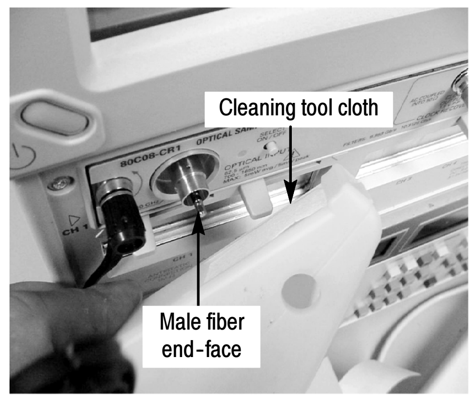
Use the following items to clean optical connectors:

- dry, clean, and dust-free compressed air
- fiber cleaning cassette and/or tape dispenser cleaner
- pipe cleaner

CAUTION. *Clean your connecting fiber (ferrule endface) with a dry cloth tape (cassetted or in a dispenser) cleaner. Both ferrule endfaces can be cleaned in this way.*

For safe and effective cleaning of the optical male fiber end-face exposed after removing the UCI adapter, Tektronix recommends the following method and tools.

Overview	To clean the optical connectors	Related information
Supplies required	**1.** One compressed air can, such as Tektronix part number 118-1068-01. One FIS cassette cleaner, (such as FI-6270) or one FIS tape dispenser cleaner (such as FI-7111).	Cleaning kits for optical connectors (such as the Tektronix Optical Connector Cleaner part number 020-2494-xx) are available from a number of suppliers.
Remove UCI adapter	**2.** Unscrew the UCI adapter and remove it. This exposes the male fiber end-face behind the UCI connector.	

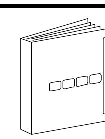
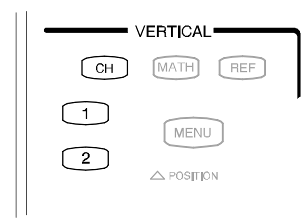
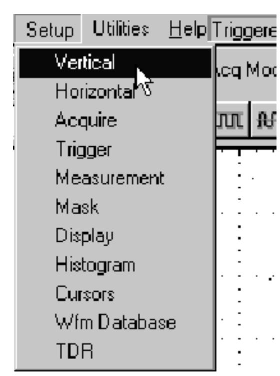
<table>
<tr><th>Overview</th><th>To clean the optical connectors (cont.)</th><th>Related information</th></tr>
<tr><td>Clean UCI adapter</td><td>3. Clean contaminates from the inside wall of the hollow female-to-female ferrule alignment tube inside the UCI adapter.
■ Use the compressed air can to clean the female input of the UCI adapter end-to-end.
■ Pull the pipe cleaner through the UCI adapter.
CAUTION. Do not blow compressed air into the female input of the UCI adapter when it is installed on the module.</td><td>
</td></tr>
<tr><td>Clean fiber input</td><td>4. Advance the fiber cleaning cassette or tape-dispenser cleaner to expose an unused clean section of the lint-free, dry, cleaning surface.
5. Lightly drag the clean, dry, surface of the cleaning tool cloth against the male end-face of the fiber input for a short distance (a centimeter or two).
6. Replace the UCI adapter back onto the cleaned fiber end-face.</td><td>
</td></tr>
<tr><td>Dust cap</td><td>7. When the module does not have a fiber attached to its input(s) ensure the black dust-cap is in place to prevent airborne contaminates from lodging in the female optical input.</td><td>
</td></tr>
<tr><td>Clean attaching devices</td><td>8. Clean any male fiber end-face input fiber or device that will be attached to the UCI input.</td><td>Use a similar cleaning method to clean the fiber end-face input fiber or device that will be attached.</td></tr>
</table>

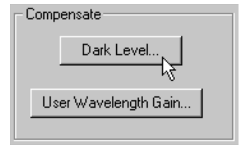
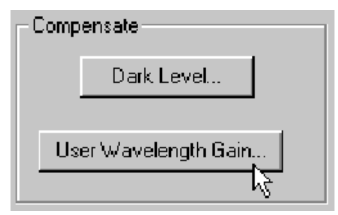
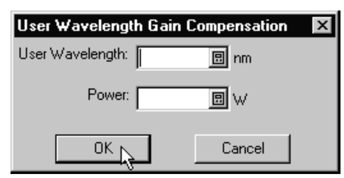
End of Procedure

Perform Dark-Level and User Wavelength Gain Compensations

Performing a dark-level calibration will maximize the accuracy of the extinction ratio and other optical automatic measurements you take. Performing a User Wavelength Gain compensation will optimize an optical channel for your custom input signal. Use the following procedure to perform either compensation; this procedure applies only to optical modules.

NOTE. *These procedures compensate the selected module and the its current bandwidth and filter selection. The compensation values are not saved when powering off the instrument.*

Overview	To perform optical compensations	Control elements and resources
Prerequisites	**1.** The instrument must have the optical sampling module(s) to be dark-level calibrated in place. The acquisition system should be set to run continuously.	 See the instrument user documentation for details on operating the instrument controls.
Select the waveform	**2.** Use the Vertical buttons to select the channel to be compensated.	
Access the dark-level compensation	**3.** From the application menu bar, click **Setup**, and then click **Vertical**.	

Overview	To perform optical compensations (cont.)	Control elements and resources
Run the dark-level compensation	**4.** In Vert Setup dialog box, click the **Dark Level** button under Compensation. Follow the instructions on screen. **5.** Repeat steps 2 and 4 for any additional optical channels that you want to compensate. If any of the following settings or conditions change after performing a dark level compensation, perform another compensation to maintain the specified accuracy. ■ Trigger rate setting ■ Vertical offset setting ■ Filter or bandwidth setting ■ Ambient temperature change of more than 1 °C ■ ELECTRICAL SIGNAL OUT front panel connection change (80C12)	
Run the user wavelength gain compensation	If you want, you can can compensate an optical channel for a custom input signal: **6.** In Vert Setup dialog box, click the **User Wavelength Gain** button under Compensation. Follow the instructions on screen. **7.** In the User Wavelength Gain Compensation dialog box, set the wavelength and power of the signal to be applied to the channel. ■ You must connect an optical signal to the module input with a precisely known amount of optical power. An independently-calibrated average optical power meter is used to measure this power precisely. Then signal is connected to the 80C00 with the same fiber cables. **8.** Press the **OK** button to execute the compensation. **9.** Repeat steps 2, 6, and 7 for any additional optical channels that you want to compensate.	

NOTE. *The 80C10 has two separate optical inputs each optimized for different wavelength regions (1310 nm or 1550 nm). Therefore, it supports two different user wavelength gain compensation calibrations, one for each input.*

End of Procedure

Cleaning

Exterior

The case of the module keeps dust out and should not be opened. Cleaning the exterior of the module is usually confined to the front panel. If you desire to clean the case, remove the module from the main instrument but first read the entire *Installation* procedure starting on page 9 for proper handling of the module.

WARNING. *To prevent injury, power down the instrument and disconnect it from line voltage before performing any cleaning.*

Clean the exterior surfaces of the module with a dry lint-free cloth or a soft-bristle brush. If any dirt remains, use a damp cloth or swab dipped in a 75% isopropyl alcohol solution. Use a swab to clean narrow spaces around controls and connectors. Do not allow moisture inside the module. Do not use abrasive compounds on any part of the chassis that may damage the chassis.

CAUTION. *To prevent damage, avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. Use only deionized water when cleaning the menu buttons or front-panel buttons. Use a 75% isopropyl alcohol solution as a cleaner, and rinse with deionized water. Before using any other type of cleaner, consult your Tektronix Service Center or representative.*

Do not open the case of the module. There are no user serviceable components and cleaning the interior is not required.

Optical Connectors

The procedure for cleaning the optical connectors begins on page 21 in the *Optimizing Measurement Accuracy* section.

Reference

This section describes how to select the optical module wavelength, how to enable clock recovery, and explains optical bandwidth.

Wavelength, Filter, and Bandwidth Selection

To select the optical wavelength, use the Vertical Setups menu. This menu is shown in Figure 9 on page 18.

First select the channel in the Waveform section of the menu. Then select the Wavelength that matches your system from the Setup Wavelength drop down box.

Use the Signal Conditioning boxes to select the filter and bandwidth appropriate for your optical standard.

For more information, consult the *CSA8000 and TDS8000 Series Online Help*.

Table 9: Wavelength, Filter, and Bandwidth selections

Module	Wavelength selections	Filter	Bandwidth
80C01	1310 nm 1550 nm User	None (select a bandwidth) OC-12/STM-4 (622.08 Mb/s) OC-192/STM-64 (9.953 Gb/s) OC-48/STM-16 (2.48832 Gb/s)	20 GHz 12.5 GHz
80C02	1310 nm 1550 nm User	None (select a bandwidth) OC-192/STM-64 (9.953 Gb/s)	30 GHz 20 GHz 12.5 GHz
80C07B	780 nm 850 nm 1310 nm 1550 nm User	None Standard: OC-48 / STM-16 2 Gigabit Ethernet (ENET2500 / 2GBE) Infiniband Optional: OC-3 / STM-1 OC-12 / STM-4 FibreChannel (FC1063 / FC) Gigabit Ethernet (ENET1250 / GBE) 2G FibreChannel (FC2125 / 2FC)	2.5 GHz

Table 9: Wavelength, Filter, and Bandwidth selections (cont.)

Module	Wavelength selections	Filter	Bandwidth
80C08C	780 nm 850 nm 1310 nm 1550 nm User	None (select a bandwidth) OC-192/STM-64 (9.953 Gb/s) 10GBASE-W (9.953 Gb/s) 10GBASE-R (10.31 Gb/s) 10GFC (10.518 Gb/s) G.975 FEC (10.66 Gb/s) G.709 FEC (10.709 Gb/s) 10GbE FEC (11.10 Gb/s)	10 GHz
80C10	1310 nm 1550 nm User	None (select a bandwidth) OC-768/STM-256 (39.813 Gb/s) G.709 FEC (43.018 Gb/s)	30 GHz 65 GHz
80C11	1310 nm 1550 nm User	None (select a bandwidth) OC-192/STM-64 (9.953 Gb/s) 10GBASE-W (9.953 Gb/s) 10GBASE-R (10.31 Gb/s) 10GFC (10.518 Gb/s) G.975 FEC (10.66 Gb/s) G.709 FEC (10.709 Gb/s) 10GbE FEC (11.10 Gb/s)	28 GHz
80C12	850 nm 1310 nm 1550 nm	None (select a bandwidth) 1G FibreChannel (1.0623 Gb/s) 2G FibreChannel (2.125 Gb/s) 10GBase-X4 (3.125 Gb/s) 10GFC-X4 (3.188 Gb/s) VSR-5 (3.318Gb/s) 4G FibreChannel (4.250 Gb/s) OC192/STM-64 (9.953 Gb/s) 10GFC (10.518 Gb/s) 10GBase-W (9.953 Gb/s) 10GBase-R (10.31 Gb/s) 10GBE FEC (11.10 Gb/s) G.975 FEC (10.66 Gb/s) G.709 FEC (10.709 Gb/s)	9 GHz 10 GHz with option 10G

Clock and Data Recovery

Clock and Data recovery is available on most modules as Options CR, CR1, CR2, CR3, or CR4. The 80C12 module comes standard with an electrical signal output that, when routed to an 80A05 Electrical Clock Recovery module, provides Clock recovery. The 80A05 must be installed in the same mainframe. Table 8 on page 16 provides a list of all available optical modules and the clock recovery available for each module.

- **DATA and $\overline{\text{DATA}}$ (recovered data).** These outputs provide a 50 Ω, AC-coupled, ~ECL/2 level signal from the optical module data signal. These signals are digitally buffered and retimed to be synchronous with the serial recovered clock.
- **CLOCK and $\overline{\text{CLOCK}}$ (recovered clock).** These outputs are clock signals synchronous with the incoming data signal.
- **1/16 CLOCK (recovered clock).** This output provides the clock signal at $1/16^{th}$ the rate.

Clock recovery options CR, CR1, CR2, and CR3 provide various predefined output rates (depending on the optical module model and the CR option). Clock recovery option CR4 provides both predefined selections and a continuous-rate selection. The continuous rate depends on the user entering the bit rate into the Trigger Setup dialog box of the main instrument with an accuracy better than 1000 ppm. Table 13 on page 55 summarizes the clock recovery options for all modules.

NOTE. *If clock and data recovery are enabled and no signal (or not the appropriate signal) is applied to the front panel, the recovered clock and data may free run.*

NOTE. *The recovered clock is simultaneously made available internally to the main instrument for use as the trigger; it is not necessary to attach a cable from the clock or 1/16 clock to the external trigger input. Simply select the recovered clock for triggering from the trigger menu.*

The 80C12 module uses the 80A05 Electrical Clock Recovery module for Clock and Data recovery. Refer to the 80A05 module user documentation for triggering information.

Optical Bandwidth

Traditionally bandwidth is defined as the frequency at which the power out is one half the power out at a frequency near DC. In the voltage domain the power dissipated into a resistive load (such as a 50 Ω termination of a sampler) is the V_{RMS}^2/R where V_{RMS} is the RMS of the voltage swing seen at the resistive load, and R is the resistance value. A logarithmic scale using decibels is typically used to describe a system's frequency dependent response. A value expressed in terms of a decibel relative to a reference is defined as:

$$dB = 10\log\left(\frac{value}{reference}\right)$$

For electrical bandwidths the reference of a system is commonly the response of the system to a sinusoidal frequency at or near DC. The point at which the system response (power is the common parameter that is referred to in many systems) is one half would therefore be:

$$dB = 10\log\left(\frac{0.5}{response\ at\ DC}\right) = -3dB$$

In terms of frequency, voltage, and resistance the bandwidth is expressed as:

$$-3dB = 10\log\left(\frac{V(f)^2}{R} \div \frac{V(DC)^2}{R}\right)$$

where V(f) is the RMS of the voltage swing response at the bandwidth frequency and V(DC) is the RMS voltage swing response at a frequency approaching DC. Further math yields $V(f) = 0.707 \times V(DC)$.

The expression is simplified by cancelling the R and moving the squared term inside the log expression to a multiple outside the log expression:

$$10\log\left(\frac{V(f)^2}{R} \div \frac{V(DC)^2}{R}\right) = 2 \times 10\log\left(\frac{V(f)}{V(DC)}\right) = 20\log\left(\frac{V(f)}{V(DC)}\right)$$

In the CSA8000 and TDS8000 series instruments, the vertical units displayed for an optical module are not in volts, but in watts, which are units of power. The optical-to-electrical converter inside the module outputs a voltage whose amplitude is linearly dependent on the incoming optical power; in this condition the voltage applied at the electrical sampler already represents optical power in its linear form (as opposed to having to square the voltage and divide by R). For the optical sampling modules then, the bandwidth where the displayed optical power is one half that approaching DC is:

$$dB = 10\log\left(\frac{0.5}{response\ at\ DC}\right) = -3dB$$

The V(f) is the frequency at which the vertical swing is one half (0.5) the V(DC) not 0.707. The optical bandwidth therefore corresponds to the traditional electrical bandwidth of –6 dB. During testing of optical modules by impulse testing, the resulting impulse waveform is converted to frequency by Fourier transform and the bandwidth is defined as –3 dB = 10 log(vertical swing at frequency / vertical swing at DC). During reference receiver curve calculation, however, the definition is changed to match the industry standard definition which assumes electrical bandwidths are –3 dB = 20 × log(vertical swing at frequency / vertical swing at DC).

Bandwidth for Unfiltered Frequency Settings

The curve calculation of frequency response for the unfiltered frequency settings (2 GHz, 2.5 GHz, 12.5 GHz, 20 GHz, 30 GHz, 40 GHz, 50 GHz, and 65 GHz) uses the definition for dB and bandwidth where –3 dB = 10 log(vertical swing at frequency / vertical swing at DC); that is, the optical bandwidth.

Bandwidth for Reference Receiver Settings

The curve calculation of frequency response for reference receiver settings (FC, GbE, and OC/STM standards) uses the definition of dB and bandwidth that matches the industry standard which assumes electrical bandwidths where –3 dB = 20 log(vertical swing at frequency / vertical swing at DC).

Specifications

This section contains specifications for the 80C00 Series Optical Modules. All specifications are guaranteed unless noted as “typical.” Typical specifications are provided for your convenience but are not guaranteed. Except for limits noted “typical,” specifications that are marked with the ✓ symbol are checked in the *Performance Verification* section of the service manual.

All specifications apply to all 80C00 Series Optical Modules listed in unless noted otherwise. To meet specifications, three conditions must first be met:

- The instrument must have been calibrated/adjusted at an ambient temperature between +20 °C and +30 °C.
- The instrument must have been operating continuously for 20 minutes within the operating temperature range specified.
- Vertical compensation must have been performed with the module installed in the same compartment used when the compensation was performed. Ambient temperature must be within ±2 °C of the compensation temperature.
- The instrument must be in an environment with temperature, altitude, humidity, and vibration within the operating limits described in these specifications

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***NOTE**. “Sampling Interface” refers to both the electrical sampling module interface and the optical module interface, unless otherwise specified.*

Table 10: Optical modules - Descriptions

Name	Characteristics
80C01	Long wavelength 1100 nm - 1650 nm. Unamplified O/E converter with two user-selectable optical bandwidths: 12.5 GHz, $>$20 GHz, or three user-selectable reference receiver responses: OC-12/STM-4 for 622.08 Mb/s SONET/SDH standards, OC-48/STM-16 for 2.488 Gb/s SONET/SDH standards, and OC-192/STM-64 for 9.953 Gb/s SONET/SDH standards.
80C02	Long wavelength 1100 nm - 1650 nm. Unamplified O/E converter with three user-selectable optical bandwidths: 12.5 GHz 20 GHz, 30 GHz, or one user-selectable reference receiver response: OC-192/STM-64 for 9.953 Gb/s Sonet/SDH standards.
80C07B	Broad wavelength 700 nm - 1650 nm. Amplified O/E converter with optical bandwidth of 2.5 GHz. The OC-48, 2GBE, INFINIBAND, and 2.5 GHz modes all use a physical path that has OC-48 reference receiver type response. There are eight user-selectable reference receiver responses: OC-3 / STM-1 OC-12 / STM-4 OC-48 / STM-16 ENET1250 / GBE ENET2500 / 2GBE INFINIBAND FC1063 / FC FC2125 / 2FC
80C08C	Broad wavelength 700 nm - 1650 nm. Amplified O/E converter with maximum optical bandwidth (in combination with the internal electrical sampler) of $>$9.5 GHz. There are five user-selectable reference receiver responses: 10GBASE-W for 9.95328 Gb/s 10 Gb/s Ethernet standard 10GBASE-R for 10.3125 Gb/s 10 Gb/s Ethernet FEC standard 10GBE FEC for 11.0957 Gb/s 10GFC for 10.51875 Gb/s 10 Gb/s FibreChannel standard OC-192/STM-64 for 9.953 Gb/s Sonet/SDH standards or two data filters: G.975 FEC 10.66423 Gb/s G.709 FEC 10.709225 Gb/s
80C10	Long wavelength 1310 nm and 1550 nm. Unamplified O/E converter with two user-selectable optical bandwidths: 30 GHz, 65 GHz, or two user-selectable reference receiver responses: OC-768/STM-256 for 39.813 Gb/s Sonet/SDH standards 43.018 Gb/s ITU-T Recommendation G.709 standard

Table 10: Optical modules - Descriptions (cont.)

Name	Characteristics
80C11	Long wavelength 1100 nm - 1650 nm. Unamplified O/E converter with two user-selectable optical bandwidths: 20 GHz, 30 GHz, or with five user-selectable reference receiver responses: OC-192/STM-64 for 9.953 Gb/s Sonet/SDH standards 10GBase-W for 10 Gb Ethernet 9.95338 Gb/s 10GBase-R 10.3125 10GBE FEC 11.0957 10GFC for 10G Fibre Channel 10.51875 or two data filters: G.975 FEC 10.66423 Gb/s G.709 FEC 10.709225 Gb/s
80C12	Broad wavelength 700 nm - 1650 nm. Amplified O/E converter with maximum optical bandwidth (in combination with the internal electrical sampler) of >8.5 GHz (>9.5 GHz in Option 10G). A variety of filter options are available that support 2 to 4 filters from the following list: FC1063 for 1.0623 Gb/s FibreChannel FC2125 for 2.125 Gb/s FibreChannel 10GBase-X4 for 3.125 Gb/s 10GFC-X4 for 3.188 Gb/s VSR-5 for 3.318 Gb/s FC4250 for 4.25 Gb/s Fibre Channel Some filter options support a filterless full-bandwidth setting (9 GHz) in place of one hardware filter. Option 10G provides the following reference receiver filter rates: SONET/SDH OC-192/STM-64 10GBase-W, 10 Gb Ethernet (9.95338 Gb/s) 10GBase-R (10.3125 Gb/s) 10G Fibre Channel (10.51875 Gb/s) G.975 FEC (10.66 Gb/s) G.709 FEC (10.71 Gb/s) 10GBE FEC (11.0957 Gb/s) >9.5 GHz full bandwidth

Table 11: Optical modules - Acquisition

Name	Characteristics
Number of input channels	1 optical
Internal fiber diameter[1]	

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
80C01, 80C02, 80C10, 80C11	9 µm/125 µm single mode
80C07B, 80C08C, 80C12	62.5 µm (Corning 62.5/125 CPC6 specs) multimode (compatible with single-mode fiber) cladding: 125 µm, buffer: 900 µm
Fiber connector	Rifocs UCI (universal connector interface) male connector
Optical return loss	
80C01, 80C02, 80C10, 80C11	> 30 dB for single-mode fiber
80C07B, 80C08C, 80C12	> 14 dB for multimode fiber > 24 dB for single-mode fiber
Absolute maximum nondestructive optical input[2]	
80C01, 80C02, 80C07B, 80C11	5 mW average power; 10 mW peak power at wavelength with highest relative responsivity.
80C10	20 mW average power; 60 mW power at wavelength with highest relative responsivity.
80C08C, 80C12	1 mW average power; 10 mW peak power for 60 ms at wavelength with highest relative responsivity.
Maximum operating ranges[11]	
80C01, 80C02	0 to 10 mW displayed limits, not including offset.
80C07B	0 to 1 mW displayed limits, not including offset.
80C08C, 80C12	0 to 2 mW displayed limits, not including offset.
80C10	0 to 30 mW displayed limits, not including offset.
80C11	5 mW average power; 10mW peak power at wavelength with highest relative responsivity. Optical input powers below non-destruct levels may exceed saturation and compression limits of the particular plug-in.
Effective wavelength range[3], typical	
80C01, 80C02, 80C11	1100 nm to 1650 nm
80C07B, 80C08C, 80C12	700 nm to 1650 nm
80C10	1550 nm: 1520 nm to 1580 nm 1310 nm: 1290 nm to 1330 nm

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
Calibrated wavelengths		
80C01, 80C02, 80C10, 80C11	1550 nm and 1310 nm ±20 nm	
80C07B, 80C08C	1550 nm, 1310 nm, 850 nm, and 780 nm (all ±20 nm)	
80C12	1550 nm, 1310 nm, and 850 nm (all ±20 nm)	
✓ Dark level	To achieve these levels, perform a dark level compensation. If any of the following settings or conditions change, you must perform another dark level compensation: Trigger rate setting Vertical offset setting Filter or bandwidth setting Ambient temperature change of more than 1 °C ELECTRICAL SIGNAL OUT front panel connection (80C12)	
80C01	OC-12/STM-4, OC-48/STM-16, OC-192/STM-64, 12.5 GHz	< 10 μW ±2% (vertical offset)
	20 GHz	< 10 μW ±4% (vertical offset)
80C02	OC-192/STM-64, 12.5 GHz	< 10 μW ±2% (vertical offset)
	20 GHz, 30 GHz	< 10 μW ±4% (vertical offset)
80C07B	All settings	< 500 nW ±2% (vertical offset)
80C08C	All settings	< 1.0 μW ±2% (vertical offset)
80C12	All settings	< 1.0 μW ±2% (vertical offset)
80C10	65 GHz 1550 nm	±[25 μW + 0.04 × |vertical offset|]
	65 GHz 1310 nm	±[35 μW + 0.04 × |vertical offset|]
80C11	OC-192, 10.71 Gb/s, 10.71 Gb/s, 10GBASE-W, 10GBASE-R, 10GBE FEC, 10GFC	< 10 μW ±2% (vertical offset)
	20 GHz, 30 GHz	< 10 μW ±4% (vertical offset)

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
Main-instrument display vertical scale factors		
	Maximum	*Minimum*
80C01, 80C02, 80C11	1 mW per division	10 µW per division
80C07B	100 µW per division	1 µW per division
80C08C, 80C12	200 µW per division	2 µW per division
80C10	3 mW per division	30 µW per division
	Full scale vertical on the display of the main instrument is 10 divisions. Maximum full scale and minimum full scale are therefore 10 times the values listed above. Vertical scale is adjustable in a 1-2-5 sequence. Between those settings, the scale can be adjusted in smaller increments.	
Vertical offset range		
80C01	± 8 mW offset relative to center of waveform display (5 divisions from either top or bottom of waveform display)	
80C02, 80C11	± 6 mW offset relative to center of waveform display (5 divisions from either top or bottom of waveform display)	
80C10	± 15 mW offset relative to center of waveform display (5 divisions from either top or bottom of waveform display)	
80C07B	± 1 mW offset relative to center of waveform display (5 divisions from either top or bottom of waveform display)	
80C08C, 80C12	± 4 mW offset relative to center of waveform display (5 divisions from either top or bottom of waveform display)	

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
DC vertical accuracy[4], typical	*Setting*	*Accuracy*
80C01, 80C07B, 80C08C, 80C12	All settings	± 25 µW ± 2% of [(vertical value) - (vertical offset)]
80C02	12.5 GHz, OC-192/STM-64	± 25 µW ± 2% of [(vertical value) - (vertical offset)]
	20 GHz	± 25 µW ± 4% of [(vertical value) - (vertical offset)]
	30 GHz	± 25 µW ± 6% of [(vertical value) - (vertical offset)]
80C10	30 GHz	± 25 µW ± 4% of [(vertical value) - (vertical offset)]
	39 Gb/s, OC-768/STM-256, 43 Gb/s (G.709), FEC43.02 Gb/s	± 25 µW ± 6% of [(vertical value) - (vertical offset)]
	65 GHz setting	± 25 µW ± 8% of [(vertical value) - (vertical offset)]
80C11	OC-192, 10.66Gb/s, 10.71Gb/s, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC	± 25 uW ± 2% of [(vertical reading) - (vertical offset)]
	20 GHz	± 25 uW ± 4% of [(vertical reading) - (vertical offset)]
	30 GHz	± 25 uW ± 6% of [(vertical reading) - (vertical offset)]
DC vertical difference accuracy[4], typical	The accuracy of the difference between two cursors in the vertical scale of the same channel.	
	Setting	*Accuracy*
80C01	12.5 GHz, OC-192/STM-64, OC-48/STM-16, OC-12/STM-4	± 2% of [difference reading]
	20 GHz	± 4% of [difference reading]
80C02	12.5 GHz, OC-192/STM-64	± 2% of [difference reading]
	20 GHz	± 4% of [difference reading]
	30 GHz	± 6% of [difference reading]
80C07B	All settings	± 2% of [difference reading]
80C08C, 80C12	All settings	± 2% of [difference reading]
80C10	30 GHz	± 4% of [difference reading]
	39 Gb/s, OC-768/STM-256, 43 Gb/s, FEC43.02	± 6% of [difference reading]
	65 GHz	± 8% of [difference reading]

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
80C11	OC-192, 10.66 Gb/s, 10.71 Gb/s, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC	± 2% of [difference reading]
	20 GHz	± 4% of [difference reading]
	30 GHz	± 6% of [difference reading]
Offset capabilities	Open loop. User assigned, fixed offset value is applied to channel.	
✓ Minimum optical bandwidth[5]	*Setting*	*Bandwidth*
80C01	20 GHz	> 20 GHz
	12.5 GHz	> 12.5 GHz
80C02	30 GHz	> 28 GHz > 30 GHz, typical[7]
	20 GHz	> 20 GHz
	12.5 GHz	> 12.5 GHz
80C02-CR	30 GHz	> 28 GHz > 29 GHz, typical[7]
80C07B	2.5 GHz	> 2.3 GHz
80C08C	10 GHz	> 9.5 GHz > 10 GHz, typical
80C10	30 GHz	> 30 GHz
	65 GHz	> 65 GHz
80C11, 80C11-CR	20 GHz	> 20 GHz
	30 GHz	> 28 GHz > 30 GHz (typical)
80C12	9 GHz (options F2, F3, F5, F6, FC)	> 8.5 GHz > 9 GHz, typical
	10 GHz (option 10G)	> 9.5 GHz > 10 GHz (typical)
Rise time, typical For peak optical signal input which creates $< 2\ mW_{pp}$ modulation depth.	*Setting*	*Rise Time*
80C01	OC-12/STM-4	750 ps ± 50 ps
	OC-48/STM-16	187 ps ± 15 ps
	OC-192/STM-64	47 ps ± 10 ps
	12.5 GHz	< 40 ps
	20 GHz	< 25 ps

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
80C02	30 GHz	< 16 ps
	20 GHz	< 25 ps
	12.5 GHz	< 40 ps
	OC-192/STM-64	47 ps ± 10 ps
80C10	65 GHz	7.4 ps
	30 GHz	16 ps
	OC-768/STM-256	12 ps
	G.709 43 Gb/s	11.2 ps
80C11	30 GHz	< 16 ps
	20 GHz	< 25 ps
	OC-192, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC	47 ps ± 10 ps
	10.66 Gb/s, 10.71 Gb/s	44 ps ± 10 ps
Rise time, typical For peak optical signal input which creates < 200 μW_{pp} modulation depth.	*Setting*	*Rise Time*
80C07B	OC-3	3.0 ns ± 170 ps
	OC-12	750 ps ± 50 ps
	ENET1250	373 ps ± 30 ps
	FC1063	440 ps ± 35 ps
	FC2125	220 ps ± 18 ps
	OC-48, ENET2500, INFINIBAND, 2.5 GHz	187 ps ± 15 ps

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
Rise time, typical For peak optical signal input which creates < 500 μW_{pp} modulation depth.	*Setting*	*Rise Time*
80C08C	10 GHz	< 50 ps
	10GBASE-W, 10GBASE-R, OC-192/STM-64, 10GFC, 10GBE FEC	47 ps ± 10 ps
80C12	FC1063	440 ps ± 35 ps
	FC2125	220 ps ± 18 ps
	10GBase-X4	141 ps ± 12 ps
	3.318 Gb/s	150 ps ± 12 ps
	FC4250	110 ps ± 9 ps
	9 GHz	< 56 ps
	10 GHz	< 50 ps
	OC-192, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC	47 ps ± 10 ps
	10.66 Gb/s, 10.71 Gb/s	44 ps ± 10 ps
Time domain vertical response aberrations, typical For peak optical signal input < 5 $mW_{p\text{-}p.}$	*Setting*	*Aberrations*
80C01	OC-12/STM-4, OC-48/STM-16	< 5%
	OC-192/STM-64, 12.5 GHz	< 10%
	20 GHz	< 15%
80C02	OC-192/STM-64	< 10%
	12.5 GHz	< 15%
	20 GHz	< 20%
	30 GHz	< 30%

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics	
80C07B	All settings	< 5% (typical)
80C11	OC-192, 10.66Gb/s, 10.71Gb/s, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC	< 10%
	20 GHz	< 20%
	30 GHz	< 30%
Time domain vertical response aberrations, typical For peak optical signal input < 2 $mW_{p\text{-}p}$.	*Setting*	*Aberrations*
80C08C	All settings	< 10% (typical)
80C12	All filter settings (options F1, F2, F3, F4, F5, F6, FC)	< 5% (typical)
	9 GHz setting (options F2, F3, F5, F6, FC)	< 10% (typical)
	All settings (option 10G)	< 10% (typical)
✓ Time domain vertical response aberrations, typical For peak optical signal input < 20 $mW_{p\text{-}p}$.	*Setting*	*Aberrations*
80C10	OC-768/STM-256, FEC43.02 Gb/s, 30 GHz	< 5% (maximum) < 3% (typical)
	65 GHz	< 10% (maximum) < 5% (typical)
✓ Vertical equivalent optical noise (maximum and typical)[8]	*Setting*	*Noise*
80C01	OC-12/STM-4, OC-48/STM-16 OC-192/STM-64, 12.5 GHz	< 12 μW_{rms} (maximum) < 8 μW_{rms} (typical)
	20 GHz	< 25 μW_{rms} (maximum) < 15 μW_{rms} (typical)

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics		
80C01-CR	OC-12/STM-4, OC-48/STM-16 OC-192/STM-64, 12.5 GHz		$< 15\ \mu W_{rms}$ (maximum) $< 10\ \mu W_{rms}$ (typical)
	20 GHz		$< 25\ \mu W_{rms}$ (maximum) $< 15\ \mu W_{rms}$ (typical)
80C02	OC-192/STM-64, 12.5 GHz		$< 10\ \mu W_{rms}$ (maximum) $< 6\ \mu W_{rms}$ (typical)
	20 GHz		$< 15\ \mu W_{rms}$ (maximum) $< 10\ \mu W_{rms}$ (typical)
	30 GHz		$< 30\ \mu W_{rms}$[7] (maximum) $< 20\ \mu W_{rms}$ (typical)
80C02-CR	OC-192/STM-64, 12.5 GHz		$< 12\ \mu W_{rms}$ (maximum) $< 7\ \mu W_{rms}$ (typical)
	20 GHz		$< 20\ \mu W_{rms}$ (maximum) $< 15\ \mu W_{rms}$ (typical)
	30 GHz		$< 40\ \mu W_{rms}$[7] (maximum) $< 30\ \mu W_{rms}$ (typical)
80C07B[12]	OC-3/STM-1, OC-12/STM-4, ENET1250, FC1063		$< 1\ \mu W_{rms}$ (maximum) $< 0.50\ \mu W_{rms}$ (typical)
	FC2125		$< 1.5\ \mu W_{rms}$ (maximum) $< 0.85\ \mu W_{rms}$ (typical)
	OC-48/STM-4, ENET2500, INFINIBAND, 2.5 GHz		$< 1.5\ \mu W_{rms}$ (maximum) $< 0.70\ \mu W_{rms}$ (typical)
80C08C (no clock recovery)	All settings	1310 nm, 1550 nm	$< 3.0\ \mu W_{rms}$ (maximum) $< 1.7\ \mu W_{rms}$ (typical)
		850 mm	$< 5.0\ \mu W_{rms}$ (maximum) $< 3.0\ \mu W_{rms}$ (typical)
		780 nm	$< 6.0\ \mu W_{rms}$ (maximum) $< 3.5\ \mu W_{rms}$ (typical)
80C08C-CR1, 80C08C-CR2 80C08C-CR4	All settings	1310 nm, 1550 nm	$< 3.5\ \mu W_{rms}$ (maximum) $< 1.9\ \mu W_{rms}$ (typical)
		850 nm	$< 5.5\ \mu W_{rms}$ (maximum) $< 3.3\ \mu W_{rms}$ (typical)
		780 nm	$< 6.6\ \mu W_{rms}$ (maximum) $< 3.9\ \mu W_{rms}$ (typical)

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics		
80C10	OC-768/ STM-256	1310 nm	$< 110\ \mu W_{rms}$ (maximum) $< 75\ \mu W_{rms}$ (typical)
	43.02 Gb/s FEC	1550 nm	$< 60\ \mu W_{rms}$ (maximum) $< 40\ \mu W_{rms}$ (typical)
	30 GHz	1310 nm	$< 90\ \mu W_{rms}$ (maximum) $< 55\ \mu W_{rms}$ (typical)
		1550 nm	$< 50\ \mu W_{rms}$ (maximum) $< 30\ \mu W_{rms}$ (typical)
	65 GHz	1310 nm	$< 220\ \mu W_{rms}$ (maximum) $< 150\ \mu W_{rms}$ (typical)
		1550 nm	$< 120\ \mu W_{rms}$ (maximum) $< 85\ \mu W_{rms}$ (typical)
80C11 (no clock recovery)	OC-192, 10.66Gb/s, 10.71Gb/s, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC		$< 8\ \mu W_{rms}$ (maximum) $< 5.5\ \mu W_{rms}$ (typical)
	20 GHz		$< 14\ \mu W_{rms}$ (maximum) $< 10\ \mu W_{rms}$ (typical)
	30 GHz (Warranted at ambient temperatures below 30 °C only)		$< 30\ \mu W_{rms}$ (maximum) $< 20\ \mu W_{rms}$ (typical)
80C11-CR1, 80C11-CR2, 80C11-CR3, 80C11-CR4	OC-192, 10.66Gb/s, 10.71Gb/s, 10Gbase-W, 10Gbase-R, 10GBE FEC, 10GFC		$< 9\ \mu W_{rms}$ (maximum) $< 6\ \mu W_{rms}$ (typical)
	20 GHz		$< 15\ \mu W_{rms}$ (maximum) $< 11\ \mu W_{rms}$ (typical)
	30 GHz (Warranted at ambient temperatures below 30 °C only)		$< 35\ \mu W_{rms}$ (maximum) $< 25\ \mu W_{rms}$ (typical)
80C12	FC1063 FC2125 FC4250 10GBase-X4 10GFC-X4 3.318 Gb/s	1310 nm, 1550 nm	$< 3.0\ \mu W_{rms}$ (maximum) $< 1.7\ \mu W_{rms}$ (typical)
		850 mm	$< 4.8\ \mu W_{rms}$ (maximum) $< 2.7\ \mu W_{rms}$ (typical)
	9 GHz	1310 nm, 1550 nm	$< 6.0\ \mu W_{rms}$ (maximum) $< 3.4\ \mu W_{rms}$ (typical)
		850 mm	$< 9.6\ \mu W_{rms}$ (maximum) $< 5.4\ \mu W_{rms}$ (typical)
	All settings option 10G	1310 nm, 1550 nm	$< 6.0\ \mu W_{rms}$ (maximum) $< 3.4\ \mu W_{rms}$ (typical)
		850 mm	$< 9.6\ \mu W_{rms}$ (maximum) $< 5.4\ \mu W_{rms}$ (typical)

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ OC-3/STM-1 155 Mb/s Reference Receiver setting frequency response[7]	In the 155.52 Mb/s NRZ setting, the scalar frequency response is verified to fall within fourth-order Bessel-Thompson reference receiver boundary limits. The OC-3/STM-1 nominal scalar frequency response matches the ITU 155.52 Reference Receiver Nominal curve with the following tolerance:

(MHz) Frequency	Lower	(dB) Nominal	Upper
0.000	-0.50	0.00	0.50
23.33	-0.61	-0.11	0.39
46.65	-0.95	-0.45	0.05
69.98	-1.52	-1.02	-0.52
93.30	-2.36	-1.86	-1.36
116.7	-3.50	-3.00	-2.50
140.0	-5.67	-4.51	-3.35
155.5	-7.25	-5.71	-4.17
163.3	-8.08	-6.37	-4.66
186.6	-10.74	-8.54	-6.35
209.9	-13.55	-10.93	-8.31
233.3	-16.41	-13.41	-10.41

Name	Characteristics
✓ OC-12/STM-4 622 Mb/s Reference Receiver setting frequency response[7]	In the 622.08 Mb/s NRZ setting, the scalar frequency response is verified to fall within fourth-order Bessel-Thompson reference receiver boundary limits. The OC-12/STM-4 nominal scalar frequency response matches the ITU 622.08 Reference Receiver Nominal curve with the following tolerance:

(MHz) Frequency	Lower	(dB) Nominal	Upper
0.000	-0.50	0.00	0.50
93.3	-0.61	-0.11	0.39
186.6	-0.95	-0.45	0.05
279.9	-1.52	-1.02	-0.52
373.2	-2.36	-1.86	-1.36
466.7	-3.50	-3.00	-2.50
559.9	-5.67	-4.51	-3.35
622.1	-7.25	-5.71	-4.17
653.2	-8.08	-6.37	-4.66
746.5	-10.74	-8.54	-6.35
839.8	-13.55	-10.93	-8.31
933.1	-16.41	-13.41	-10.4

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ OC-48/STM-16 2.488 Gb/s Reference Receiver setting frequency response[7]	Scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits. SONET OC-48/STM-16 frequency response boundary limits are described in ITU-T G.957 Tables I.1 and I.2. For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the Bessel-Thompson transfer function and listed below:

(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0.000	-0.50	0.00	0.50
373.3	-0.61	-0.11	0.39
746.5	-0.95	-0.45	0.05
1119.7	-1.52	-1.02	-0.52
1493.1	-2.36	-1.86	-1.36
1866.3	-3.50	-3.00	-2.50
2239.5	-5.67	-4.51	-3.35
2488.3	-7.25	-5.71	-4.17
2612.8	-8.08	-6.37	-4.66
2986.0	-10.74	-8.54	-6.35
3359.3	-13.55	-10.93	-8.31
3732.6	-16.41	-13.41	-10.41

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ OC-192/STM-64 9.953 Gb/s Reference Receiver setting frequency response[7]	Scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits. Tektronix manufactures and tests the 80C01, 80C02, 80C08C[10], 80C11[10], and 80C12 optical modules using 10 Gb reference receivers to have a new superior and tighter tolerance OC-192/STM-64 Reference Receiver response. ITU experts recently agreed on the minimum performance specifications for 10 Gbit/s (STM-64/OC-192) optical reference receivers (San Antonio ITU Study Group 15 February 2000). These specifications are used to establish system interoperability and test conformance of optical interfaces to draft ITU-T Recommendation G.691 which is scheduled to be completed in April 2000 (see ITU table A.1/G.691 from the WD 16-48 document from Study Group 15 dated February 2000). For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function and listed below:

(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0.000	-0.85	0.00	0.85
1493.2	-0.96	-0.11	0.74
2986.0	-1.30	-0.45	0.40
4478.8	-1.87	-1.02	0.17
5972.4	-2.71	-1.86	-1.01
7465.0	-3.86	-3.00	-2.16
8958.0	-6.19	-4.51	-2.83
9953.28	-7.87	-5.71	-3.55
10451.2	-8.75	-6.37	-3.99
11944.0	-11.53	-8.54	-5.56
13437.2	-14.45	-10.93	-7.41
14930.4	-17.41	-13.41	-9.41

Table 11: Optical modules - Acquisition (cont.)

<table>
<tr><th>Name</th><th colspan="4">Characteristics</th></tr>
<tr><td rowspan="15">✓ OC-768/STM-256 39.813 Gb/s Reference Receiver setting frequency response[7]</td><td colspan="4">Bessel-Thompson Scalar Frequency Response curve for margin testing and tolerance at various frequencies; based on ±1.00 DC to 0.75x(data rate) and ±5.0dB at 1.5x(data rate).

NOTE. The table below is a discrete list of some specific values that are commonly listed in ITU standards; curve and tolerances are actually a continuous function.</td></tr>
<tr><td>(GHz)
Frequency</td><td>Lower</td><td>(dB)
Nominal</td><td>Upper</td></tr>
<tr><td>0</td><td>-1.00</td><td>0</td><td>0.50</td></tr>
<tr><td>5.97</td><td>-1.10</td><td>-0.10</td><td>0.40</td></tr>
<tr><td>11.94</td><td>-1.45</td><td>-0.45</td><td>0.05</td></tr>
<tr><td>17.92</td><td>-2.02</td><td>-1.02</td><td>-0.52</td></tr>
<tr><td>23.89</td><td>-2.86</td><td>-1.86</td><td>-1.36</td></tr>
<tr><td>29.86</td><td>-4.00</td><td>-3.00</td><td>-2.50</td></tr>
<tr><td>35.83</td><td>-5.96</td><td>-4.51</td><td>-3.33</td></tr>
<tr><td>39.81</td><td>-7.42</td><td>-5.71</td><td>-4.15</td></tr>
<tr><td>41.80</td><td>-8.20</td><td>-6.37</td><td>-4.62</td></tr>
<tr><td>44.79</td><td>-9.42</td><td>-7.42</td><td>-5.42</td></tr>
<tr><td>47.78</td><td>-11.22</td><td>-8.54</td><td>-5.87</td></tr>
<tr><td>53.75</td><td>-14.83</td><td>-10.93</td><td>-7.03</td></tr>
<tr><td>59.72</td><td>-18.41</td><td>-13.41</td><td>-8.41</td></tr>
<tr><td rowspan="14">✓ 10GBASE-W Reference Receiver setting frequency response[7]

✓ 10GBASE-R Reference Receiver setting frequency response[7]

✓ 10GBE FEC Reference Receiver setting frequency response[7]

✓ 10GFC Reference Receiver setting frequency response[7]

✓ 10.66 Data Filter setting frequency response[7]

✓ 10.709 Data Filter setting frequency response[7]</td><td colspan="4">For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function for 10.00000 Gb/s reference receivers (as specified for the 9.95328 Gb/s rate of the 10GBASE-W) and listed below:</td></tr>
<tr><td>(MHz)
Frequency</td><td>Lower</td><td>(dB)
Nominal</td><td>Upper</td></tr>
<tr><td>0</td><td>-0.85</td><td>0.00</td><td>0.85</td></tr>
<tr><td>1500</td><td>-0.96</td><td>-0.11</td><td>0.74</td></tr>
<tr><td>3000</td><td>-1.30</td><td>-0.45</td><td>0.40</td></tr>
<tr><td>4500</td><td>-1.87</td><td>-1.02</td><td>0.17</td></tr>
<tr><td>6000</td><td>-2.71</td><td>-1.86</td><td>-1.01</td></tr>
<tr><td>7500</td><td>-3.86</td><td>-3.00</td><td>-2.16</td></tr>
<tr><td>9000</td><td>-6.19</td><td>-4.51</td><td>-2.83</td></tr>
<tr><td>10000</td><td>-7.87</td><td>-5.71</td><td>-3.55</td></tr>
<tr><td>10500</td><td>-8.75</td><td>-6.37</td><td>-3.99</td></tr>
<tr><td>12000</td><td>-11.53</td><td>-8.54</td><td>-5.56</td></tr>
<tr><td>13500</td><td>-14.45</td><td>-10.93</td><td>-7.41</td></tr>
<tr><td>15000</td><td>-17.41</td><td>-13.41</td><td>-9.41</td></tr>
</table>

Table 11: Optical modules - Acquisition (cont.)

<table>
<tr><th>Name</th><th colspan="4">Characteristics</th></tr>
<tr><td rowspan="15">✓ 10GBASE-X4 Reference Receiver setting frequency response[7]</td><td colspan="4">In 10GBase-X4 setting, scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits.

10GBASE-X4 frequency response boundary limits are derived by simply scaling all frequency values by 2.5X as described in IEEE 802.3z section 38.6.5 (this section refers to ITU G.957 for tolerances).

For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the Bessel-Thompson transfer function and listed below:</td></tr>
<tr><td>(MHz)
Frequency</td><td>Lower</td><td>(dB)
Nominal</td><td>Upper</td></tr>
<tr><td>0.000</td><td>-0.50</td><td>0.00</td><td>0.50</td></tr>
<tr><td>468.8</td><td>-0.61</td><td>-0.11</td><td>0.39</td></tr>
<tr><td>937.5</td><td>-0.95</td><td>-0.45</td><td>0.05</td></tr>
<tr><td>1406</td><td>-1.52</td><td>-1.02</td><td>-0.52</td></tr>
<tr><td>1875</td><td>-2.36</td><td>-1.86</td><td>-1.36</td></tr>
<tr><td>2344</td><td>-3.50</td><td>-3.00</td><td>-2.50</td></tr>
<tr><td>2813</td><td>-5.67</td><td>-4.51</td><td>-3.35</td></tr>
<tr><td>3125</td><td>-7.25</td><td>-5.71</td><td>-4.17</td></tr>
<tr><td>3281</td><td>-8.08</td><td>-6.37</td><td>-4.65</td></tr>
<tr><td>3750</td><td>-10.74</td><td>-8.54</td><td>-6.35</td></tr>
<tr><td>4219</td><td>-13.55</td><td>-10.93</td><td>-8.31</td></tr>
<tr><td>4688</td><td>-16.41</td><td>-13.41</td><td>-10.41</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="14">✓ 10GFC-X4 (3.188 Gb/s) Reference Receiver setting frequency response[7]</td><td colspan="4">In 10GFC-X4 setting, scalar frequency response falls within Industry standard, Bessel-Thompson reference receiver boundary limits.

10GFC-X4 frequency response boundary limits are described in ANSI FC-PC. The scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function and listed below (based on ± 0.5 dB from DC to 0.75x(rate) and ± 3.0 dB at 1.5x(rate):</td></tr>
<tr><td>(MHz)
Frequency</td><td>Lower</td><td>(dB)
Nominal</td><td>Upper</td></tr>
<tr><td>0.000</td><td>-0.50</td><td>0.00</td><td>0.50</td></tr>
<tr><td>478.1</td><td>-0.61</td><td>-0.11</td><td>0.39</td></tr>
<tr><td>956.3</td><td>-0.95</td><td>-0.45</td><td>0.05</td></tr>
<tr><td>1434</td><td>-1.52</td><td>-1.02</td><td>-0.52</td></tr>
<tr><td>1913</td><td>-2.36</td><td>-1.86</td><td>-1.36</td></tr>
<tr><td>2391</td><td>-3.50</td><td>-3.00</td><td>-2.50</td></tr>
<tr><td>2869</td><td>-5.67</td><td>-4.51</td><td>-3.35</td></tr>
<tr><td>3188</td><td>-7.25</td><td>-5.71</td><td>-4.17</td></tr>
<tr><td>3347</td><td>-8.08</td><td>-6.37</td><td>-4.65</td></tr>
<tr><td>3825</td><td>-10.74</td><td>-8.54</td><td>-6.35</td></tr>
<tr><td>4303</td><td>-13.55</td><td>-10.93</td><td>-8.31</td></tr>
<tr><td>4781</td><td>-16.41</td><td>-13.41</td><td>-10.41</td></tr>
</table>

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ 10.66 Gb/s Reference Receiver setting frequency response[7]	This Reference Receiver is essentially identical to the OC-192 9.95328 Gb/s rate with the following changes: the frequency scale for the tolerance curves and nominal -3 dB breakpoints are scaled linearly by the ratio of (10.664 Gb/s)/(9.95328 Gb/s); for example: the 9.953 Gb/s reference receiver has a nominal -3 dB response at 0.75 × 9.95328 GHz = 7.465 GHz. This 10.66 Gb reference receiver has a nominal -3 dB response at (10.664/9.95328) × 7.465 GHz = 7.998 GHz. For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function, the frequencies scaled as described above, and then listed below:

(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0	-0.85	0	0.85
1599.8	-0.96	-0.11	0.74
3199.2	-1.30	-0.45	0.40
4798.6	-1.87	-1.02	-0.17
6398.9	-2.71	-1.86	-1.01
7998.0	-3.86	-3.00	-2.16
9597.7	-6.19	-4.51	-2.83
10664.0	-7.87	-5.71	-3.55
11197.5	-8.75	-6.37	-3.99
12796.9	-11.53	-8.54	-5.56
14396.7	-14.45	-10.93	-7.41
15996.5	-17.41	-13.41	-9.41

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ 10.71 Gb/s Reference Receiver setting frequency response[7]	This Reference Receiver is essentially identical to that for the OC-192 9.95328 Gb/s rate with the following changes: the frequency scale for the tolerance curves and nominal -3 dB breakpoints are scaled linearly by the ratio of (10.709 Gb/s)/(9.95328 Gb/s); for example: the 9.953 Gb/s reference receiver has a nominal -3 dB response at 0.75 × 9.95328 GHz = 7.465 GHz. This 10.71 Gb reference receiver has a nominal -3 dB response at (10.709/9.95328) × 7.465 GHz = 8.032 GHz. For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function, the frequencies scaled as described above, and then listed below:

(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0	-0.85	0	0.85
1606.6	-0.96	-0.11	0.74
3212.8	-1.30	-0.45	0.40
4819.0	-1.87	-1.02	-0.17
6426.0	-2.71	-1.86	-1.01
8032.0	-3.86	-3.00	-2.16
9638.4	-6.19	-4.51	-2.83
10709.2	-7.87	-5.71	-3.55
11245.0	-8.75	-6.37	-3.99
12851.1	-11.53	-8.54	-5.56
14457.7	-14.45	-10.93	-7.41
16064.4	-17.41	-13.41	-9.41

Name	Characteristics
✓ FEC 43.02 Gb/s Reference Receiver setting frequency response[7]	The forward error correction method defined in ITU-T standard G.709 creates an additional overhead upon a standard OC-768 (STM256) 40 Gb/s data stream in which the data rate is effectively increased by a ratio of 255/236. Table 7-1 in G.709 standard lists this explicit serial data rate on the physical layer.

(GHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0	-1.00	0	0.50
6.45	-1.10	-0.10	0.40
12.90	-1.45	-0.45	0.05
19.36	-2.02	-1.02	-0.52
25.81	-2.86	-1.86	-1.36
32.26	-4.00	-3.00	-2.50
38.71	-5.96	-4.51	-3.33
43.02	-7.42	-5.71	-4.15
45.17	-8.20	-6.37	-4.62
48.40	-9.42	-7.42	-5.42
51.63	-11.22	-8.54	-5.87
58.08	-14.83	-10.93	-7.03
64.53	-18.41	-13.41	-8.41

Table 11: Optical modules - Acquisition (cont.)

<table>
<tr><th>Name</th><th colspan="4">Characteristics</th></tr>
<tr><td rowspan="3">✓ ENET2500 (2 GBE) 2.50 Gb/s Reference Receiver setting frequency response[7]</td><td colspan="4">Scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits.

2.50 Gb/s frequency response boundary limits are derived by simply scaling all frequency values by 2X as described in IEEE 802.3z section 38.6.5 (this section refers to ITU G.957 for tolerances). For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the Bessel-Thompson transfer function and listed below:</td></tr>
<tr><td>(MHz)
Frequency</td><td>Lower</td><td>(dB)
Nominal</td><td>Upper</td></tr>
<tr><td>0.000
375
750
1125
1500
1875
2250
2500
2625
3000
3375
3750</td><td>-0.50
-0.61
-0.95
-1.52
-2.36
-3.50
-5.67
-7.25
-8.08
-10.74
-13.55
-16.41</td><td>0.00
-0.11
-0.45
-1.02
-1.86
-3.00
-4.51
-5.71
-6.37
-8.54
-10.93
-13.41</td><td>0.50
0.39
0.05
-0.52
-1.36
-2.50
-3.35
-4.17
-4.66
-6.35
-8.31
-10.41</td></tr>
<tr><td rowspan="3">✓ ENET1250 (GBE) 1.25 Gb/s Reference Receiver setting frequency response[7]</td><td colspan="4">Scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits.

1.250 Gb/s frequency response boundary limits are described in IEEE 802.3z section 38.6.5 (this section refers to ITU G.957 for tolerances).

For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the Bessel-Thompson transfer function and listed below:</td></tr>
<tr><td>(MHz)
Frequency</td><td>Lower</td><td>(dB)
Nominal</td><td>Upper</td></tr>
<tr><td>0.000
187.5
375
562.5
750
937.5
1125
1250
1312.5
1500
1687.5
1875</td><td>-0.50
-0.61
-0.95
-1.52
-2.36
-3.50
-5.67
-7.25
-8.08
-10.74
-13.55
-16.41</td><td>0.00
-0.11
-0.45
-1.02
-1.86
-3.00
-4.51
-5.71
-6.37
-8.54
-10.93
-13.41</td><td>0.50
0.39
0.05
-0.52
-1.36
-2.50
-3.35
-4.17
-4.66
-6.35
-8.31
-10.41</td></tr>
</table>

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics			
✓ FC1063 (1.0625 Gb/s) Reference Receiver setting frequency response[7]	In FC1063 setting, scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits. Fiber Channel frequency response boundary limits are described in ANSI FC-PC. For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function and listed below:			
	(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
	0.000	-0.50	0.00	0.50
	159.5	-0.61	-0.11	0.39
	318.9	-0.95	-0.45	0.05
	478.4	-1.52	-1.02	-0.52
	637.9	-2.36	-1.86	-1.36
	797.4	-3.50	-3.00	-2.50
	956.8	-5.67	-4.51	-3.35
	1063	-7.25	-5.71	-4.17
	1116	-8.08	-6.37	-4.66
	1275	-10.74	-8.54	-6.35
	1435	-13.55	-10.93	-8.31
	1595	-16.41	-13.41	-10.41
✓ FC2125 (2.125 Gb/s) Reference Receiver setting frequency response[7]	In FC2125 setting, scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits. 2G FiberChannel frequency response boundary limits are described in ANSI FC-PC. For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function and listed below:			
	(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
	0.000	-0.50	0.00	0.50
	318.8	-0.61	-0.11	0.39
	637.5	-0.95	-0.45	0.05
	956.3	-1.52	-1.02	-0.52
	1275	-2.36	-1.86	-1.36
	1594	-3.50	-3.00	-2.50
	1913	-5.67	-4.51	-3.35
	2125	-7.25	-5.71	-4.17
	2231	-8.08	-6.37	-4.65
	2550	-10.74	-8.54	-6.35
	2869	-13.55	-10.93	-8.31
	3188	-16.41	-13.41	-10.41

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ FC4250 (4.25 Gb/s) Reference Receiver setting frequency response[7]	In FC4250 setting, scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits. 4G FiberChannel frequency response boundary limits are described in ANSI FC-PC. For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function and listed below:

(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0.000	-0.50	0.00	0.50
637.5	-0.61	-0.11	0.39
1275	-0.95	-0.45	0.05
1913	-1.52	-1.02	-0.52
2550	-2.36	-1.86	-1.36
3188	-3.50	-3.00	-2.50
3826	-5.67	-4.51	-3.35
4250	-7.25	-5.71	-4.17
4462	-8.08	-6.37	-4.65
5100	-10.74	-8.54	-6.35
5738	-13.55	-10.93	-8.31
6375	-16.41	-13.41	-10.41

Table 11: Optical modules - Acquisition (cont.)

Name	Characteristics
✓ VSR-5 (3.318 Gb/s) Reference Receiver setting frequency response[7]	In 3.318 Gb/s setting, scalar frequency response falls within industry standard, Bessel-Thompson reference receiver boundary limits. At the time of publishing this document, a standard for VSR-5 frequency response boundary limits has not been defined. The scalar frequency response curve and tolerance boundaries used for 10GBase-X4 scaled to the VSR-5 bit rate will be used for this rate until a standard has been defined. The exact bit rate is given by the formula: $\frac{768 \text{ x } 51.84\ Mb/s}{12} = 3317.76\ Mb/s$ For convenience, the scalar frequency response of the output amplitude (for sinusoidal swept optical input) has been interpreted from the published Bessel-Thompson transfer function and listed below:

(MHz) Frequency	*Lower*	*(dB) Nominal*	*Upper*
0.000	-0.50	0.00	0.50
497.7	-0.61	-0.11	0.39
995.3	-0.95	-0.45	0.05
1493	-1.52	-1.02	-0.52
1991	-2.36	-1.86	-1.36
2488	-3.50	-3.00	-2.50
2986	-5.67	-4.51	-3.35
3318	-7.25	-5.71	-4.17
3484	-8.08	-6.37	-4.65
3981	-10.74	-8.54	-6.35
4479	-13.55	-10.93	-8.31
4977	-16.41	-13.41	-10.41

1 **Single-mode fiber (Corning SMF-28 specs).**

2 **The optical input powers below nondestructive levels may exceed saturation and compression limits of the module.**

3 **The optical wavelengths that the product accepts and still provides a reasonable (25% of peak optimum) wavelength conversion gain.**

4 **Vertical accuracy specifications are referenced to an internal optical power meter reading for a given optical input, and limited to a temperature range within ±5 °C of previous channel compensation and an ambient temperature within 20 °C to 35 °C.**

5 **Optical bandwidth is the frequency at which the responsivity of the optical to electrical conversion process is reduced by 50% (6 dB).**

6 **Optical bandwidth of the 50 GHz module is defined as (0.48/risetime).**

7 **This specification is limited to the instrument operating in an ambient temperature between +20 °C and +30 °C. Nominal freq response is specified for optical input signals of modulation magnitude such that $2mW_{pp}$ or less signal is applied at the sampler input.**

8 **The optical channel noise with no optical noise input (Dark Level).**

[9] **Clock recovery versions reduce the power reaching the vertical channel (splitter to clock recovery produces loss). Therefore, the non-clock recovery modules more closely exhibit the typical noise performance.**

[10] **The factory calibration and verification of these tolerances are performed in a stable ambient environment of +25 °C ±2 °C. The module is specified to perform within these tolerances over an operating temperature range of +20 °C and +30 °C.**

[11] **Certain performance characteristics such as reference receiver and filter settings may have more restricted power levels in order to maintain guaranteed performance.**

[12] **The 80C07B optical noise specifications given are for the 1310 nm wavelength setting. The noise at wavelength setting 780 nm is typically increased by a factor of 2.0. The noise at 850 nm is typically increased by a factor of 1.6. The noise at 1550 nm is typically the same as at 1310 nm.**

Table 12: Optical Power Meter

Name	Characteristics
Optical power meter range	
80C01, 80C02, 80C07B, 80C11	+4 dBm to -30 dBm, typical
80C10	+13 dBm to -21 dBm, typical
80C08C, 80C12	+0 dBm to -30 dBm, typical
Optical power meter accuracy, typical	5% of reading + connector uncertainty ±20 nm (typical): 780 nm (80C07B, 80C08C) 850 nm (80C07B, 80C08C, 80C12) 1310 nm and 1550 nm (80C01, 80C02, 80C07B, 80C08C, 80C10, 80C11, 80C12)

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4)

Name	Characteristics
Effective wavelength range (clock recovery path)	
80C01, 80C02	1270 nm to 1600 nm
80C07B, 80C08C, 80C12	700 nm to 1650 nm
80C11	1270 nm to 1600 nm

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics
Operating data rates[5]	
80C01-CR	622.08 Mb/s ±1000 ppm (OC-12/STM-4)
	2.48832 Gb/s ±1000 ppm (OC-48/STM-16)
80C02-CR	9.95328 Gb/s ±1000 ppm (OC-192/STM-64)
80C07B-CR1	155.52 Mb/s ±1000 ppm (OC-3/STM-1)
	622.08 Mb/s ±1000 ppm (OC-12/STM-4)
	1062.5 Mb/s ±1000 ppm (FC1063/FC)
	1250 Mb/s ±1000 ppm (ENET1250/GBE)
	2125 Mb/s ±1000 ppm (FC2125/2FC)
	2488.32 Mb/s ±1000 ppm (OC-48/STM-16)
	2500 Mb/s ±1000 ppm (ENET2500/2GBE)
	2500 Mb/s ±1000 ppm (Infiniband)
	2666.06 Mb/s ±1000 ppm (OC-48-FEC)
80C08C-CR1	9.95328 Gb/s ±1000 ppm (10GBASE-W)
	10.3125 Gb/s ±1000 ppm (10GBASE-R)
80C08C-CR2	10.3125 Gb/s ±1000 ppm (10GBASE-R)
	10.51875 Gb/s ±1000 ppm (10GFC)
80C08C-CR4	Continuous from 9.8 Gb/s to 12.6 Gb/s (User must enter the bit rate into the main instrument with an accuracy better than 1000 ppm)
	Pre-defined selections at 9.95338 Gb/s, 10.3125 Gb/s, 10.51875 Gb/s, 10.66423 Gb/s, 10.709225 Gb/s, 11.0957 Gb/s (The input bit rate must be within 1000 ppm of the selected rate)

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics	
80C11-CR1	9.95328 Gb/s ±1000 ppm (OC-192/STM-64)	
80C11-CR2	9.95328 Gb/s ±1000 ppm (OC-192/STM-64)	
	10.66423 Gb/s ±1000 ppm (10Gb FEC)	
80C11-CR3	9.95328 Gb/s ±1000 ppm (OC-192/STM-64)	
	10.70922 Gb/s ±1000 ppm (G.709 FEC)	
80C11-CR4	Continuous from 9.8 Gb/s to 12.6 Gb/s (User must enter the bit rate into the main instrument with an accuracy better than 1000 ppm)	
	Pre-defined selections at 9.95338 Gb/s, 10.3125 Gb/s, 10.51875 Gb/s, 10.66423 Gb/s, 10.709225 Gb/s, 11.0957 Gb/s (The input bit rate must be within 1000 ppm of the selected rate)	
80C12	Clock recovery provided with the use of the 80A05 Electrical Clock Recovery module.	
For the 80C02-CR module, the incoming data stream must be of non-return-to-zero format (NRZ) and must have a data sequence content which provides both isolated 1s and multi-consecutive mark sequences (that is 2,3,4 and so forth logical 1s in a consecutive row). Note that a fixed pattern of 10101010. . . does not meet the data sequence content:. The 80C02-CR clock recovery functions may not properly lock to such a pattern. The 80C02-CR will, however, typically lock to a 11001100. . . pattern (this is equivalent to a 2.48832 GHz optical square wave).[5]		
✓ Optical sensitivity range, clock recovery (optical input power)[1]	*Maximum*	*Minimum*
80C01	+ 5.0 dBm (3.16 mW), typical	-10.0 dBm (100 µW), typical
80C02	+7.0 dBm (5.0 mW), typical	-10.0 dBm (100 µW), typical -7.5 dBm, warranted
80C07B	-4.0 dBm (400 µW), warranted	-16.0 dBm (25 µW), warranted

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics		
80C08C-CR1/ -CR2	+0.0 dBm (1.0 mW), typical	*1550 nm, 1310 nm*	
		-15.0 dBm (32 μW), typical -13 dBm (50 μW), warranted[6]	
		850 nm, 780 nm	
		-12 dBm (64 μW), typical	
80C08C-CR4	+0.0 dBm (1.0 mW), typical	*Bit Rate: 9.8 Gb/s to 11.25 Gb/s* *1550 nm, 1310 nm*	
		AOP @ ER ≥8.2 dB[7]	*(OMA)*[8]
		-15 dBm typical -13 dBm warranted[6]	-12.3 dBm typical -11.3 dBm warranted[6]
		Bit Rate: 9.8 Gb/s to 11.25 Gb/s *850 nm, 780 nm*	
		AOP @ ER ≥8.2 dB[7]	*(OMA)*[8]
		-12 dBm typical -10 dBm warranted[6]	-9.3 dBm typical -8.3 dBm warranted[6]
		Bit Rate: 11.25 Gb/s to 12.6 Gb/s *1550 nm, 1310 nm*	
		(AOP @ ER ≥8.2 dB)[7]	*(OMA)*[8]
		-12.5 dBm typical -11.5 dBm warranted[6]	-10.8 dBm typical -9.8 dBm warranted[6]
		Bit Rate: 11.25 Gb/s to 12.6 Gb/s *850 nm, 780 nm*	
		(AOP @ ER ≥8.2 dB)[7]	*(OMA)*[8]
		-9.5 dBm typical -8.5 dBm warranted[6]	-7.8 dBm typical -6.8 dBm warranted[6]

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics		
80C11-CR1/-CR2/ -CR3	+7 dBm (5.0 mW), typical	-10.0 dBm (100 µW), typical -7.5 dBm, warranted[6]	
80C11-CR4	+7 dBm (5.0 mW), typical	*Bit Rate: 9.8 Gb/s to 11.25 Gb/s*	
		AOP @ ER ≥8.2 dB[7]	*(OMA)*[8]
		-12 dBm typical -9 dBm warranted[6]	-10.3 dBm typical -7.3 dBm warranted[6]
		Bit Rate: 11.25 Gb/s to 12.6 Gb/s	
		(AOP @ ER ≥8.2 dB)[7]	*(OMA)*[8]
		-10.5 dBm typical -7.5 dBm warranted[6]	-8.8 dBm typical -5.8 dBm warranted[6]
80C12 Clock recovery provided by 80A05 module	0 dBm (1.0 mW), typical	*Bit Rate: 150 Mb/s to 2.7 Gb/s 1550 nm, 1310 nm*	
		AOP @ ER ≥8.2 dB[7]	*(OMA)*[8]
		-13.1 dBm (48.6 µW) warranted[6]	-11.5 dBm (71.4 µW) warranted[6]
		Bit Rate: 150 Mb/s to 2.7 Gb/s 850 nm	
		(AOP @ ER ≥8.2 dB)[7]	*(OMA)*[8]
		-11.5 dBm (70.7 µW) typical	-9.8 dBm (104 µW) typical

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics		
		Bit Rate: 2.7 Gb/s to 11.19 Gb/s 1550 nm, 1310 nm	
		AOP @ ER $\geq$8.2 dB[7]	*(OMA)*[8]
		-11.4 dBm (72.8 µW) warranted[6]	-9.7 dBm (107 µW) warranted[6]
		Bit Rate: 2.7 Gb/s to 11.19 Gb/s 850 nm	
		(AOP @ ER $\geq$8.2 dB)[7]	*(OMA)*[8]
		-9.7 dBm (106 µW) typical	-8.1 dBm (156 µW) typical
		Bit Rate: 11.19 Gb/s to 12.5 Gb/s 1550 nm, 1310 nm	
		AOP @ ER $\geq$8.2 dB[7]	*(OMA)*[8]
		-10.1 dBm (97.2 µW) warranted[6]	-8.5 dBm (143 µW) warranted[6]
		Bit Rate: 11.19 Gb/s to 12.5 Gb/s 850 nm	
		(AOP @ ER $\geq$8.2 dB)[7]	*(OMA)*[8]
		-8.5 dBm (141 µW) typical	-6.8 dBm (208 µW) typical
Clock and data electrical output amplitudes[2]			
80C01		$>$300 mV_{pp}, typical	
80C02	Serial DATA output	$>$700 mV_{pp}, typical	
	Serial CLOCK output	1.5 V_{pp}, typical	
	1/16th CLOCK output	600 mV_{pp}, typical	
80C07B	Serial CLOCK output	450 mV_{pp}, typical	
	Serial DATA output	450 mV_{pp}, typical	
80C08C-CR1/ -CR2	Serial CLOCK output	1.0 V_{pp}, typical	
	1/16th CLOCK output	600 mV_{pp}, typical	

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics	
80C08C-CR4	Serial CLOCK output	800 mV_{pp}, typical
	1/16th CLOCK output	600 mV_{pp}, typical
80C11-CR1	Serial DATA output	> 700 mV_{pp}, typical
	Serial CLOCK output	900 mV_{pp}, typical
	1/16th CLOCK output	600 mV_{pp}, typical
80C11-CR2/ -CR3	Serial CLOCK output	1.5 V_{pp}, typical
	1/16th CLOCK output	600 mV_{pp}, typical
80C11-CR4	Serial CLOCK output	800 mV_{pp}, typical
	1/16th CLOCK output	600 mV_{pp}, typical
80C12	ELECTRICAL SIGNAL OUT	400 mV_{pp}, maximum (dependent on optical input amplitude)
Clock and data rise time and fall times[2]		
80C01	Serial DATA output	< 30 ps
	Serial CLOCK output	< 30 ps
80C02	Serial DATA output	< 30 ps
	Serial CLOCK output	< 30 ps
	1/16th CLOCK output	< 300 ps
80C07B	Serial DATA output	< 150 ps
	Serial CLOCK output	< 150 ps
80C08C	Serial CLOCK output	< 30 ps
	1/16th CLOCK output	< 300 ps
80C11	Serial CLOCK output	< 30 ps
	1/16th CLOCK output	< 300 ps
Jitter Transfer Bandwidth[5]		
80C08C-CR1, 80C08C-CR2	4 MHz maximum 2 MHz minimum	
80C08C-CR4	4 MHz maximum 2 MHz minimum 1 MHz typical	
80C11-CR1 80C11-CR2 80C11-CR3	8 MHz maximum 5 MHz minimum 7 MHz typical	
80C11-CR4	4 MHz Maximum 1 MHz Minimum 2 MHz Typical	

Table 13: Optical modules - Clock recovery options (CR, CR1, CR2, CR3, and CR4) (cont.)

Name	Characteristics	
✓Recovered clock timing jitter[3, 4]		
80C01	$<$ 8.0 ps $_{rms}$ maximum $<$ 4.0 ps $_{rms}$ typical	
80C02	$<$ 2.0 ps $_{rms}$ maximum $<$ 1.0 ps $_{rms}$ typical[5]	
80C07B	OC-3 setting	$<$ 32.0 ps $_{rms}$ maximum $<$ 12.0 ps $_{rms}$ typical
	OC-12 setting FC1063 (FC) setting ENET1250 (GBE) setting	$<$ 8.0 ps $_{rms}$ maximum $<$ 4.0 ps $_{rms}$ typical
	FC2125 (2FC) setting	$<$ 6.0 ps $_{rms}$ maximum $<$ 3.0 ps $_{rms}$ typical
	OC-48 setting OC-48-FEC setting ENET2500 (2GBE) setting INFINIBAND setting	$<$ 4.0 ps $_{rms}$ maximum $<$ 2.2 ps $_{rms}$ typical
80C08C	$<$ 2.0 ps $_{rms}$ maximum $<$ 1.0 ps $_{rms}$ typical[5]	
80C11	$<$ 2.0 ps $_{rms}$ maximum $<$ 1.0 ps $_{rms}$ typical[5]	

1 **These powers are the average optical input coupled into the external Optical Sampling Module optical input connector. The range is defined for recovered clock, a 50% duty cycle of the incoming NRZ data (also referred to as 50% mark density), a PRBS pattern of 2^{23-1}, and an extinction ratio of $\geq$ 8.2 dB (at eye center).**

2 **Output is 50 Ω AC coupled: specification is for output amplitude at the bulkhead outputs and does not include RF loss of attached cables.**

3 **The clock jitter is applicable to both the external electrical output and the system jitter experienced when the recovered clock is the source of the waveform trigger for the system.**

4 **Jitter performance of the system while using the optical module clock recovery as the trigger source is warranted only while no active signal is applied to the main instrument's External Trigger (or Prescaler) input.**

5 **Internal use for trigger results in a total system jitter of**

$$\geq \sqrt{sum\ of\ squares}$$

therefore, the displayed waveform may normally exhibit :

$$\sqrt{(mainframe\ jitter^2 + OCR\ jitter^2)}$$

6 **Sensitivity is only warranted for operating ambient temperatures below +30 °C.**

[7] **The AOP (Average Optical Power) range is defined for recovered clock that has a resulting jitter that is less than the specified maximum, a 50% duty cycle of the incoming data (also referred to as 50% mark density), a PRBS pattern of 2^{23} - 1, and an extinction ratio of $\geq$8.2 dB (at eye center).**

[8] **The OMA (Optical Modulation Amplitude) input level is defined as (P_{HIGH} - P_{LOW}). For an extinction ratio of 8.2, the OMA is 1.47 $\times$ AOP or AOP(dBm) + 1.68 dB.**

[9] **The acceptable signal types and patterns for the specified modules are:**

Module	**NRZ**	**RZ**	**1010 . . .**
80C02-CR	Y	N	N
80C07B-CR1	Y	N	Y
80C08B-CR2	Y	Y	Y

Table 14: Optical modules - Mechanical

Name	Characteristics
Construction material	Chassis parts constructed of aluminum alloy; front panel constructed of plastic laminate; circuit boards constructed of glass-laminate. Cabinet is aluminum.
Weight	
80C01	1.13 kg (2.50 lbs) 1.34 kg (2.95 lbs) (with clock recovery)
80C02	0.95 kg (2.10 lbs) 1.22 kg (2.70 lbs) (with clock recovery)
80C07B	0.95 kg (2.10 lbs) 1.36 kg (3.0 lbs) (with clock recovery)
80C08C	0.95 kg (2.10 lbs) 1.22 kg (2.70 lbs) (with clock recovery)
80C10	0.95 kg (2.10 lbs)
80C11	0.95 kg (2.1 lbs) 1.22 kg (2.70 lbs) (with clock recovery)
80C12	1.31 kg (2.89 lbs)) (F1, F2, F3, F4, F5, F6, FC)
	0.98 kg (2.16 lbs) (option 10G)
Overall dimensions	Height: 25.6 mm (1.0 in) Width: 166.7 mm (6.5 in) Depth: 307.7 mm (12.0 in)

Table 15: Optical modules - Environmental

Name	Characteristics	
Temperature	Installed and operating	+10 °C to +40 °C
	Reference receivers frequency response tolerances, 30 GHz mode, and Optical power meter accuracy	+20 °C to +30 °C
	Installed and non-operating	-22 °C to +60 °C
Humidity	Installed and operating	20% to 80% relative humidity with a maximum wet bulb temperature of 29 °C at or below +40 °C, (upper limit derates to 45% relative humidity at +40 °C) non-condensing.
	Reference receivers frequency response tolerances	+20 °C to +30 °C
	Optical power meter accuracy	+20 °C (80% RH) to +30 °C (80% RH)
	Installed and non-operating	5% to 90% relative humidity with a maximum wet bulb temperature of 29 °C at or below +60 °C, (upper limit derates to 20% relative humidity at +60 °C) non-condensing.
Altitude: installed	Operating	3,048 m (10,000 feet).
	Nonoperating	12,190 m (40,000 feet).

Glossary

Accuracy
The closeness of the indicated value to the true value.

Analog-to-Digital Converter
A device that converts an analog signal to a digital signal.

Attenuation
A decrease in magnitude (for optical systems this is usually optical power) of a signal.

Autoset
A means of letting the instrument set itself to provide a stable and meaningful display of a given waveform.

Average Optical Power (AOP)
The time averaged measurement of the optical power over a much longer time period than the bit rate of the signal.

Bandwidth
The difference between the limiting frequencies of a continuous frequency spectrum. Bandwidth is the frequency at which the power out is one half the power out at a frequency near DC. The range of frequencies handled by a device or system. Bandwidth is a measure of network capacity. Analog bandwidth is measured in cycles per second. Digital bandwidth is measured in bits of information per second. See *Optical Bandwidth* on page 29.

Channel
A place to connect a signal or attach a network or transmission line to sampling heads. Also, the smallest component of a math expression. A transmission path between two or more stations.

Channel Number
The number assigned to a specific signal input connector. The top channel of the left-most sampling head compartment of the main instrument is always channel 1, regardless of any repositioning or omission of sampling heads.

Clock
A signal that provides a timing reference.

Common Mode
A circumstance where a signal is induced in phase on both sides of a differential network.

dB

Decibel: a method of expressing power or voltage ratios. The decibel scale is logarithmic. It is often used to express the efficiency of power distribution systems when the ratio consists of the energy put into the system divided by the energy delivered (or in some cases, lost) by the system. One milliwatt of optical power is usually the optical reference for 0 dBm. The formula for decibels is:

$$dB = 20\log\left(\frac{Vi}{Vl}\right) \qquad \text{for optical,} \quad dB = 10\log\left(\frac{Po}{Pi}\right)$$

where V_i is the voltage of the incident pulse, V_l is the voltage reflected back by the load, P_o is the power out, P_i is the power in, and log is the decimal-based logarithmic function. See *Optical Bandwidth* on page 29.

dBm

A logarithmic measure of power referenced to 1 milliwatt (1 mW optical power = 0.0 dBm):

$$dBm = 10 \ \log\left(\frac{optical\ power}{1\ mW}\right)$$

Degradation

A deterioration in a signal or system.

Differential Mode

A method of signal transmission where the true signal and its logical compliment are transmitted over a pair of conductors.

Digital signal

A signal made up of a series of on and off pulses.

Digital transmission system

A transmission system where information is transmitted in a series of on and off pulses.

Extinction Ratio

The ratio of two optical power levels of a digital signal generated by an optical source. P_1 is the optical power level generated when the light source is high, and P_2 is the power level generated when the light source is low.

$$r_e = \frac{P_1}{P_2}$$

FEC: Forward Error Correction

Additional bits and/or coding added to a data stream to allow for automatic error detection and correction at the receiving end. These extra bits and/or coding tend to increase a serial data rate above the original non-FEC data stream in order to accommodate the extra information added by the FEC.

Fiber Optics
A method of transmitting information in which light is modulated and transmitted over high-purity, filaments of glass. The bandwidth of fiber optic cable is much greater than that of copper wire.

Impedance
The opposition to an AC signal in the wire. It's very much like resistance to a DC signal in a DC circuit. Impedance is made up of resistance and inductive and capacitive reactance.

Initialize
Setting the instrument main instrument to a completely known, default condition.

Internal Clock
An internally generated trigger source that is synchronized with the Internal Clock Output signal.

Mode
A stable condition of oscillation in a laser. A laser can operate in one mode (single mode) or in many modes (multimode).

Modulation
A process whereby a signal is transformed from its original form into a signal that is more suitable for transmission over the medium between the transmitter and the receiver.

Multimode Cable
A thick cored optical fiber (compared to single mode cable) that can propagate light of multiple modes.

OMA (Optical Modulation Amplitude)
The difference between the average power levels of the logic 1 level, High, and the logic 0 level, Low, of the optical pulse signal. The levels are the Means of the logical levels sampled within an Aperture of the logical 1 and 0 regions of the pulse. The logical 1 and 0 time intervals are marked by the crossings of a reference level determined as the Average Optical Power (AOP) of the signal.

Protocol
Formal conventions that govern the format and control of signals in a communication process.

Recovered Clock
A clock signal derived from and synchronous with a received data sequence.

Setting
The state of the front panel and system at a given time.

Single-Mode Cable

An optical cable with a very small core diameter (usually in the range of 2-10 microns). Such cables are normally used only with laser sources due to their very small acceptance cone. Since the cone diameter approaches the wavelength of the source, only a single mode is propagated.

Trigger

An electrical event that initiates acquisition of a waveform as specified by the time base.

Waveform

The visible representation of an input signal or combination of signals.

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