

WAVECREST CORPORATION

OE-2

OPTICAL TO ELECTRICAL SIGNAL CONVERTER

USER'S GUIDE AND REFERENCE MANUAL

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OE-2™ USER'S GUIDE AND REFERENCE MANUAL

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ORGANIZATION

The manual is divided into three Sections and three Appendices. The following is a brief description of the information contained in each section. For quick reference to specific information, refer to the Table of Contents.

SECTION 1 — INTRODUCTION

This section introduces the user to the OE-2. Features and capabilities are described. An overview of the internal operation of the OE-2 is also included.

SECTION 2 — DESCRIPTION

Describes the front and back panels of the OE-2.

SECTION 3 — SET-UP AND MEASUREMENT

Describes the installation and set-up of the OE-2 as well as using *Virtual Instruments Signal Integrity*[™] software through a *WAVECREST* SIA-3000 or DTS-207x instrument.

APPENDIX A — SPECIFICATIONS

This section contains a comprehensive set of specifications for the OE-2.

APPENDIX B — GPIB COMMANDS

Includes various parameters, values and codes necessary for implementing remote control of the OE-2 via the IEEE-488 interface.

APPENDIX C — PREPROGRAMMED MEASUREMENT LIMITS

Includes a series of tables that show the preprogrammed measurement limits for each OE-2 model.

WARNING

Operating the OE-2 outside of the maximum operational specifications published in Appendix A of this manual can damage the instrument. The Wavecrest Warranty does not cover damage resulting from improper operation or mishandling of the OE-2.

INSPECTION

If the contents are incomplete or damaged, contact *WAVECREST CORPORATION* Customer Service: 1-800-733-7128.

- ❑ Inspect the shipping box for damage.
If the shipping box is damaged, or the cushioning materials show signs of stress, notify the shipping carrier as well as the *WAVECREST CORPORATION* office. Keep the shipping materials for the carrier's inspection.
- ❑ Check for accessories.
 - ❑ Power cord
 - ❑ Two (2) build-out SMA connectors for Dual-channel instrument; one (1) connector for Single-channel instruments
 - ❑ Two (2) optical build-out connectors for Dual-channel instrument; one (1) connector for Single-channel instruments
 - ❑ OE-2 User's Guide and Reference Manual
- ❑ Inspect the instrument.
If there is mechanical/physical damage, or if the instrument does not power up properly, notify *WAVECREST CORPORATION*. Keep the shipping materials for the carrier's inspection. *WAVECREST CORPORATION* will arrange for repair or replacement at their option.

SECTION I – INTRODUCTION

The *WAVECREST* OE-2 converts optical communications signals into electrical signals. In combination with a *WAVECREST* DTS or SIA system, the OE-2 enables accurate, high performance jitter measurements on optical signals. The OE-2 can be operated in local mode or it can be controlled through its GPIB interface using *WAVECREST's* *Virtual Instruments™ Signal Integrity (VISI)* software.

Features

The OE-2 incorporates all of the features needed for making single- or dual-channel, high performance optical signal measurements.

Fully Calibrated - The OE-2 is fully calibrated from the optical input to the electrical output permitting accurate signal level measurements without the need for additional instruments.

High Bandwidth - Enables measurement of high-speed data communication signals.

Built-in Amplifiers - Boosts low power signals to measurable levels.

Built-in Filters - Used to establish the noise bandwidth of optical signals. Available filter options include Fibre Channel, Fibre Channel 2X, Gigabit Ethernet, InfiniBand™, XAUI, and SONET OC-48.

Power Meter - Each channel of the OE-2 includes an average optical power meter.

High-Speed Measurements - *WAVECREST* DTS or SIA system with an OE-2 can quickly make highly accurate jitter measurements.

GPIB Interface - The OE-2 can be run remotely via the GPIB or locally via the front panel.

Dual Channel Capability - The OE-2 is available in single-channel or dual-channel models.



Figure 1 – Dual-Channel OE-2 shown with *WAVECREST* SIA-3000

How the OE-2 Works

The OE-2 consists of a high-performance optical-to-electrical converter followed by wide-bandwidth, signal processing devices. Dual-channel models incorporate two identical channels. The block diagram below shows the structure of one OE-2 channel.

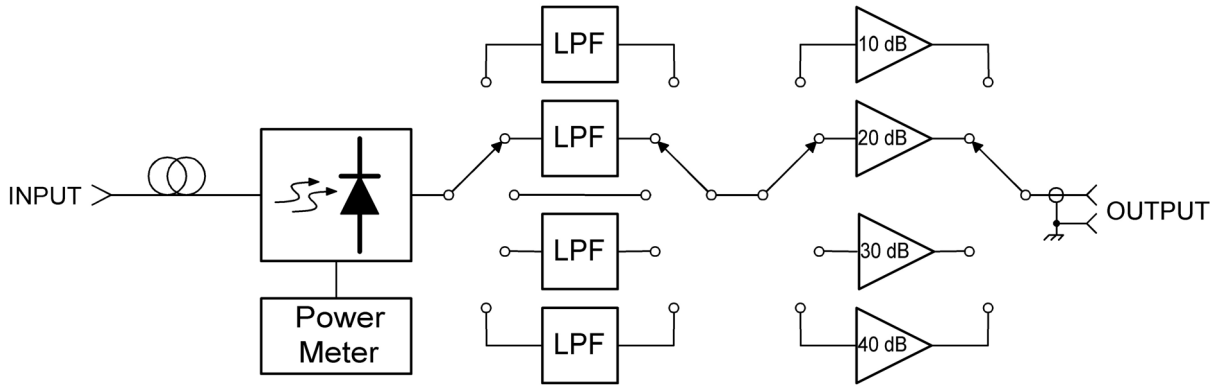


Figure 2 – Block diagram of an OE-2 channel

The optical input signal is converted to an electrical current using a low-noise, temperature-stabilized photo receiver. The electrical signal is then amplified by a wideband transimpedance amplifier (TIA) integrated within the photo receiver.

Because optical signals may have high levels of wideband noise, filters are often used to improve the signal-to-noise ratio. Communications standards require a fourth-order Bessel-Thomson low-pass filter characteristic with a cut-off frequency of 75% of the data rate. Each channel of the OE-2 has four filters—for different communications protocols—selectable by electronic switches. In addition, a fifth setting bypasses the filters for full-bandwidth operation.

Filter settings can be independently selected for each channel using front panel controls or through the GPIB interface.

A bank of wideband electronic amplifiers follows the filters. These electronically switched amplifiers amplify the electrical signal by approximately 10 dB, 20 dB, 30 dB or 40 dB. The amplifier setting can be independently selected for each channel using front panel controls or through the GPIB interface.

The average current in the photo receiver is measured to determine the average optical power of the input signal and is available only through the GPIB interface.

The signal gain in every filter and amplifier path in the OE-2 is measured and stored locally in the OE-2. These calibration values are used by *WAVECREST's VISI* software to display accurate optical signal power levels.

A central processor controls all OE-2 functions. The processor also handles communication with the GPIB interface port.

Laser Safety

Although the OE-2 optical to electrical converter does not emit laser energy, it does process optical signals from laser devices. Therefore, laser signals will be present at the OE-2 inputs.

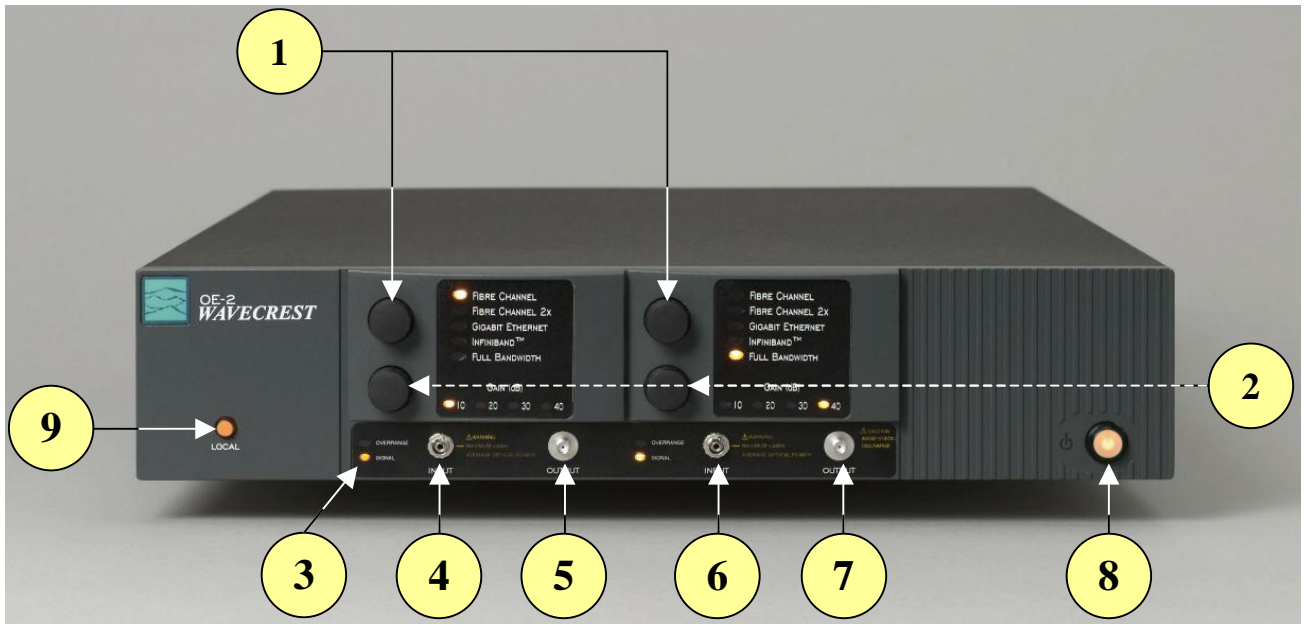
These signals present retinal and/or personal hazards because they are invisible and might not be detected until injury to the eye or skin has occurred. To prevent injuries, basic precautions should be followed.

- **NEVER** look directly into an optical signal connector. Always assume a laser beam is present.
- **NEVER** direct an optical output signal connector in a direction that could cause harm to personnel nearby.
- Always turn optical output signal devices OFF when not in use.
- Where practical, protective eyewear that is designed for the signal wavelengths used should be worn.

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SECTION 2 – FRONT AND BACK PANEL DESCRIPTIONS

This section describes the front and back controls and connectors of the OE-2.



Dual Channel OE-2 Front panel

Front Panel Controls and Connectors

1

Filter Selection

The OE-2 routes the converted signal through low-pass filters to establish a finite, repeatable measurement bandwidth for the OE-2. Fourth-order Bessel-Thomson low pass filters are exclusively used.

The filter selection knob selects one of the four low pass filters or full bandwidth. Filter options are described in Appendix A. Filters are independently selected for each channel; dual channel models can use two different filters.

Filter selection can also be made through the GPIB interface. See Appendix B for GPIB commands.

2

Amplifier Selection

The amplifier selection knob selects one of the four amplifier settings. The gain is approximately 10dB per amplifier.

- 10 dB
- 20 dB
- 30 dB
- 40 dB

Amplifier selection can also be made through the GPIB interface. See Appendix B for GPIB commands.

3

Over range LED/Signal LED

Two LEDs on the front of the OE-2 indicate optical input signal status. The lower “SIGNAL” LED is lit when the OE-2 senses an optical signal. If the upper “OVERRANGE” LED is blinking red, the optical signal power is beyond the input range of the instrument and should be removed to prevent damage to the optical detector.

If both LEDs are blinking, the O/E receiver temperature stabilization is not within range. Measurements made during this condition are not valid. If this occurs, turn off the unit for a few minutes and turn it back on. It may be necessary to move the OE-2 to a cooler location. If this condition persists, the unit should be serviced by an authorized *WAVECREST* service representative.

4

Channel 1 Optical Input

This FC/UPC input connector accepts either single-mode or multi-mode (up to 62.5 um) optical fibers. Optical signals from 770 to 1650 nm can be used.

Before attaching any connector to the OE-2, clean all optical connections using an optical fiber connector cleaner such as the NTT-ME CLETOP.

CAUTION: Do not exceed +3 dbm peak optical power.

5

Channel 1 Electrical Output

The electrical output signal is available at this 50 Ohm SMA connector. The converted electrical signal is a linear representation of the optical signal.

CAUTION: This output port is sensitive to electrostatic discharge. Use ESD protection when connecting to this port.

6

Channel 2 Optical Input

This FC/UPC input connector accepts either single-mode or multimode (up to 62.5 um) optical fibers. Optical signals from 770 to 1650 nm can be used.

Before attaching any connector to the OE-2, clean all optical connections using an optical fiber connector cleaner such as the NTT-ME CLETOP.

CAUTION: Do not exceed +3dbm peak optical power.

7

Channel 2 Electrical Output

The electrical output signal is available at this 50 Ohm SMA connector. The converted electrical signal is a linear representation of the optical signal.

CAUTION: This output port is sensitive to electrostatic discharge. Use ESD protection when connecting to this port.

8

Front Panel On/Off Switch

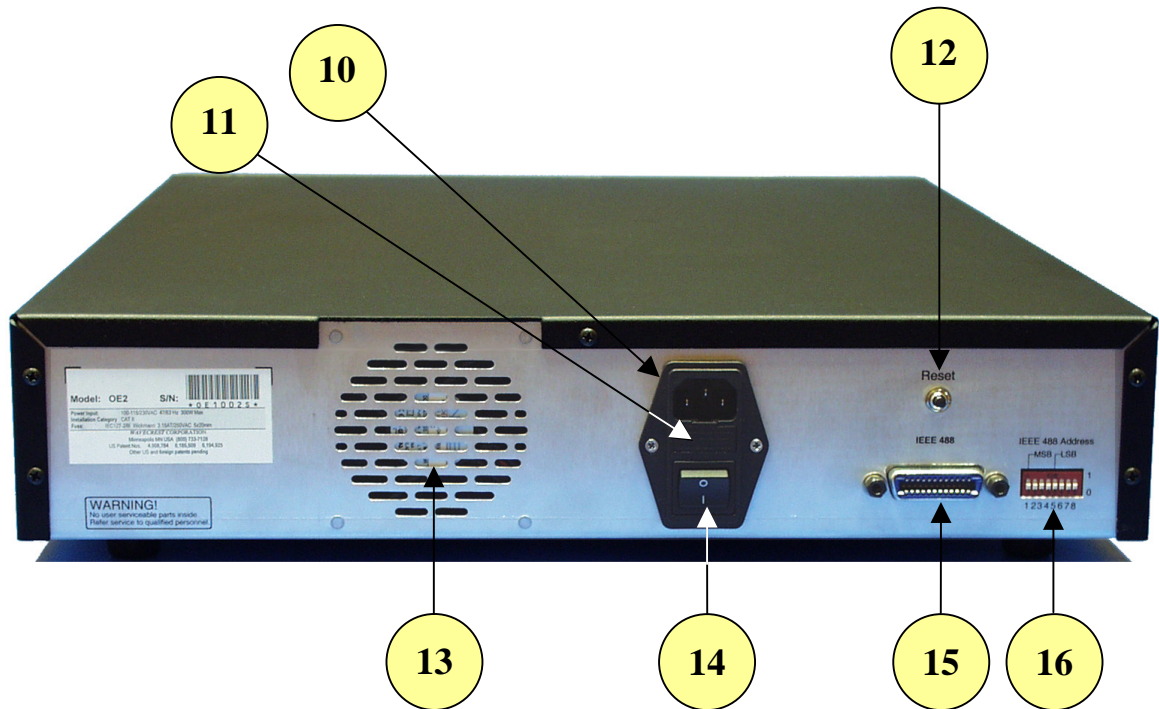
The front panel switch turns the internal power supply on or off.

9

Local/Remote Switch

The Local/Remote switch selects between local mode and remote GPIB operation. In local mode, settings are selected using the Filter and Amplifier Selection knobs. In GPIB remote operation, settings are selected by using OE-2-specific commands via the GPIB. The Local/Remote pushbutton is lit when in local operation.

Back Panel Controls and Connectors



OE-2 Back Panel

10

AC Input Port

IEC Inlet for AC cord. Connect to an AC source in the range of 100-264 VAC, 47-63 Hz.

11

Fuse

Primary AC fuse. Located inside of connector housing. Should be replaced with two Wickman 4AT/250V fuses (5x20 mm).

12

Reset Pushbutton

The Reset Pushbutton resets the microprocessor in the **OE-2** and sets the instrument to default filter and amplifier settings (the topmost filter setting and 10 dB, respectively). Pressing the reset button causes the **OE-2** hardware, including the IEEE-488 interface, to reset.

13

Fan Exhaust

Exhaust port for internal cooling fan. Maintain at least 1-inch (2.5 cm) clearance.

14

AC Primary Switch

Controls the AC mains to the instrument.

15

GPIB Input Connector

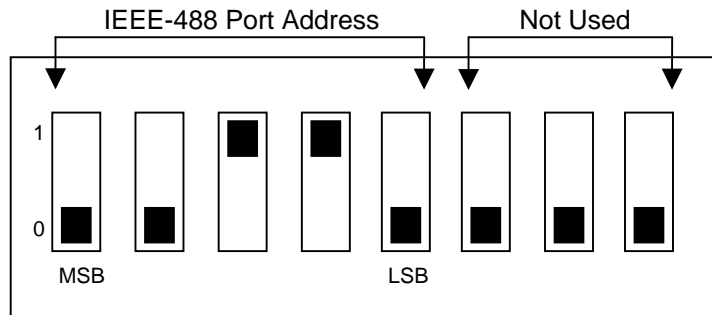
Connector for GPIB cable. Used for controlling the **OE-2** with a computer or other instrument. A GPIB device address can be set using the 32-position DIP switch (see below), with address 0 reserved for the controller and the remainder of the settings available at the user's discretion. A full GPIB command set is provided in Section 3.

16

GPIB Port Address Switch

Sets the address of the GPIB port. The address can be set from 1 to 31. Address 0 is reserved for the controller; the default OE-2 address is 6.

The switch settings are in binary format as shown in the drawing below. For example, the switch setting shown below selects port 6. The last three switches are not used.



SECTION 3 – SETUP AND MEASUREMENT

This section describes the set-up of the OE-2 and provides instructions that enable the user to take a quick measurement for rapid familiarization with the instrument.

In addition, this section describes the *Virtual Instrument Signal Integrity*[™] (*VISI*) software tools necessary for using the OE-2 with any *WAVECREST* measurement instrument. Please refer to the *VISI* User's Guide for detailed definitions and instructions of this and other *VISI* tools.

Test System Requirements

To use the OE-2, a complete test system consisting of the following components is needed:

- A *WAVECREST* OE-2
- A *WAVECREST* SIA or DTS (PC or Workstation with *VISI* installed) instrument
- A source of optical signals
- Interconnecting cables

Before attaching any connector to the OE-2, clean all optical connections using an optical fiber connector cleaner such as the NTT-ME CLETOP.

To prevent damage to the optical-to-electric (O/E) input connector, a build-out connector is included with the OE-2. The build-out connector can be replaced if it becomes damaged or dirty.

A dirty or scratched O/E input connector can severely degrade the input signal, resulting in inaccurate measurements.

NOTE: If the O/E input connector is damaged, the instrument must be returned to *WAVECREST* for repair.

Before Using the OE-2

To ensure the highest accuracy and proper GPIB operation, it is important that:

- ❑ All OE-2's are warmed up for at least ½ hour prior to taking a measurement.
- ❑ All OE-2 GPIB addresses have been correctly assigned (see page 8).
- ❑ An external calibration of the OE-2 is performed at least once each day (see page 12). The OE-2 should also be recalibrated if there has been a change of more than 5 C° in ambient temperature.

Instrument Setup

- ❑ Attach the power cord to the back of the instrument and to an appropriate power source. See Appendix A for specific power requirements.
- ❑ Attach the cleaned build-out connector to the OE-2 input.
- ❑ Attach the cleaned input signal cable to the build-out connector.
- ❑ Turn on main power on the back of the unit.
- ❑ Turn on front power switch. The front switch is typically used for daily operations and also allows easy access to power if the unit is mounted in a rack.

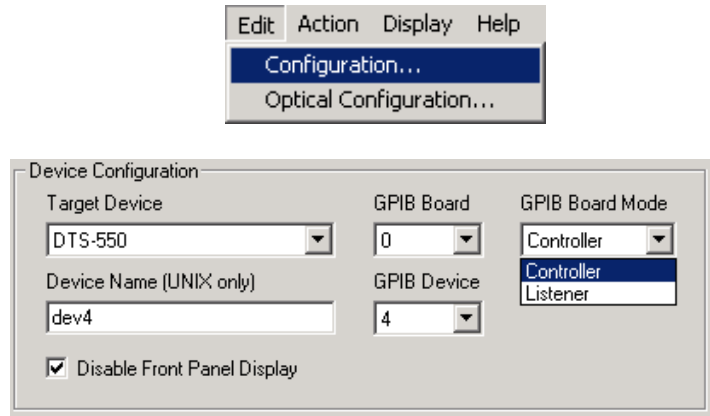
VISI SOFTWARE SETUP

Controller Mode

Edit | Configuration Menu

In order for the OE-2 to communicate with the SIA-3000™ using the GPIB bus, the SIA-3000 must be in the “Controller” mode. To select Controller mode:

- ❑ Select Edit | Configuration on the (pull-down) Menu Bar
- ❑ Select OE-2 in the Target Device pull-down Menu
- ❑ Select Controller in the GPIB Board Mode pull-down menu.
- ❑ Click “Apply”
- ❑ Click “Close”

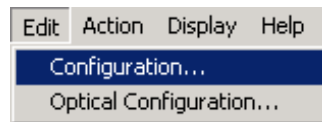


Optical Configuration

The Optical Configuration menu enables the user to:

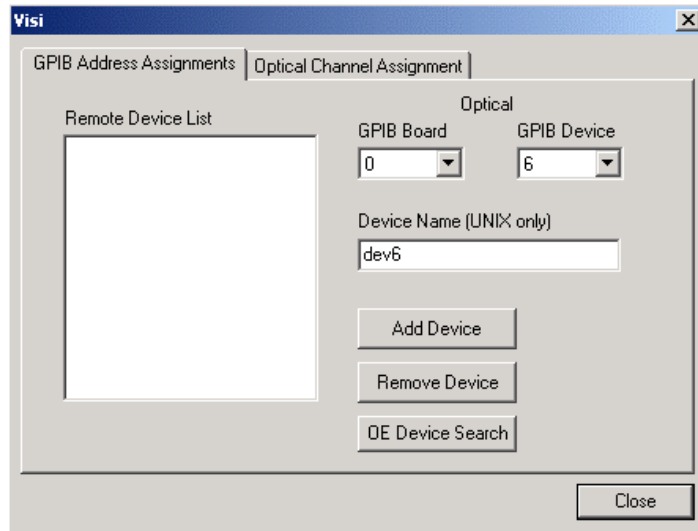
- Set up the IEEE-488 (GPIB) addresses for one or more OE-2’s (up to five OE-2’s can be addressed in a single VISI-based system).
- Assign each OE-2 channel to a *WAVECREST* SIA or DTS instrument channel.
- Set preliminary optical measurement parameters.

To access the Optical Configuration menu in VISI, select Edit|Optical Configuration on the (pull-down) Menu Bar (see figure below).



Manually Assigning GPIB Addresses

The GPIB Address Assignment window will appear (see figure below). The fields in this dialog box will be blank unless device assignments were previously made. The GPIB Address Assignments dialog box manages the address settings for both the GPIB host and all OE-2's.



Optical Configuration Dialog Box – GPIB Address Assignment

The Optical GPIB Board field controls the host GPIB address, that is, the GPIB address of the SIA controller or host controller computer. In most installations, this will be set to 0. In cases where a host computer has more than one GPIB interface bus connected to it, the Optical GPIB Board address should be set to the card address for the bus connected to the OE-2's.

The Optical GPIB Device field sets the address of the OE-2's connected to the GPIB bus. Set the Optical GPIB Device to the DIP switch setting on the back panel of the OE-2 and select the Add Device button. The OE-2 address will appear in the Remote Device List. In the case of multiple OE-2 installations, each remote device will have to be individually added.

The default address for the OE-2 is 6.

The Device Name (UNIX Only) field is not used at this time.

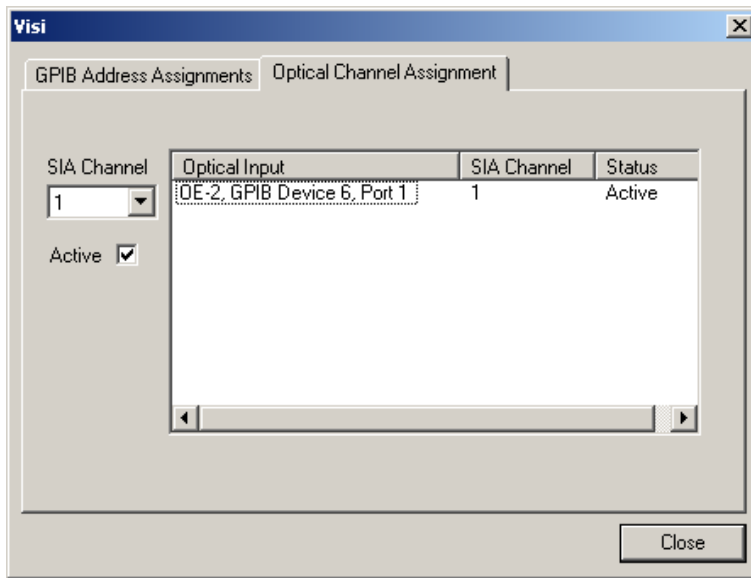
Automatically Assigning GPIB Addresses

To automatically assign GPIB addresses, click on the "OE Device Search" button to have *VISI* automatically search the GPIB network and identify all connected OE-2's.

When all OE-2's connected to the system are addressed, the next step is to poll the GPIB bus to see that each OE-2 is correctly addressed. This is done with the Optical Channel Assignment dialog box. Clicking on the Optical Channel Assignment tab will initiate the polling process. Each correctly addressed OE-2 will be shown in the Optical Input window along with its GPIB device address.

If a connected OE-2 does not appear in the dialog box, its address may be incorrectly set. Return to the GPIB Address Assignments window to correct the address settings.

Dual-channel OE-2's will occupy two lines in the Optical Input window - one for each optical-to-electrical channel path in the OE-2. The left-hand OE-2 channel will be named "Port 1" and the right-hand channel will be named "Port 2."



Optical Configuration Dialog Box - Optical Channel Assignments

Finally, it is necessary to assign each OE-2 channel to a channel of the *WAVECREST* DTS or SIA instrument by highlighting one line in the Optical Input field (corresponding to one channel path) and selecting the DTS or SIA input channel in the SIA Channel field. To activate this channel, click the "Active" box.

For example, if you have an optical signal connected to the left hand input port of the OE-2, and the electrical output of this same channel connected to the channel 3 input on a *WAVECREST* SIA-3000, the Optical Channel Assignment should read:

OE-2, GPIB Device 6, Port 1 3 Active

Channel Ports left in the inactive state will still pass signals, but *VISI* software will not recognize the channel port.

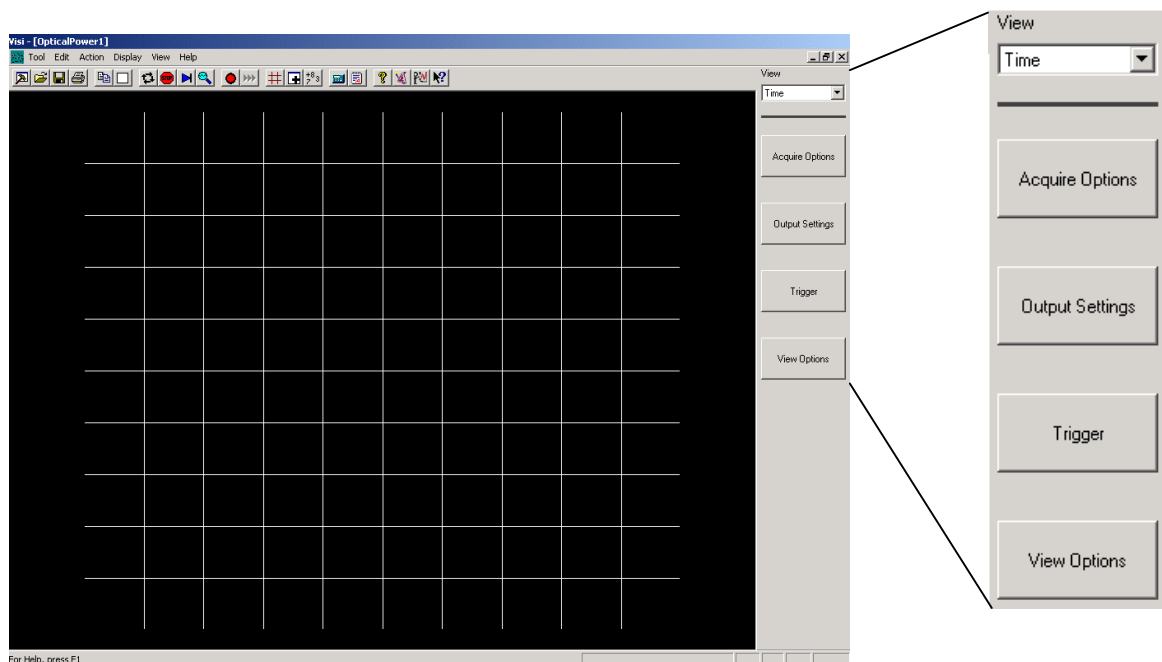
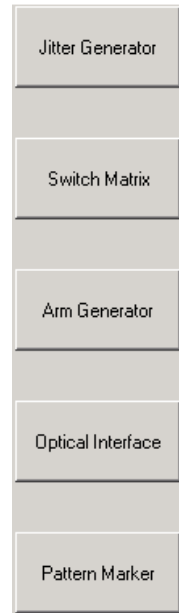
Setting Acquire Options

The Acquire Options dialog bar displays the OE-2 settings for optical signal measurements. In setting the Acquire Options, note that “channel” refers to the DTS or SIA channel.

To set the Acquire Options:

- ❑ From the Main Dialog Bar, select Utilities. The Utilities dialog bar will be displayed.

- ❑ From the Utilities Dialog Bar, select Optical Interface. The Optical Interface tool will be displayed.




- ❑ From the Optical Interface Dialog Bar, select Acquire Options. The Acquire Options dialog bar will be displayed (see figure to the right).

- Select the channel to view. (“Channel” refers to the DTS or SIA channel.) The software will poll the OE-2 configured to that channel to determine which filter bank options are installed.
- **WAVECREST**'s *VISI* software has preprogrammed set-ups for several popular communication standards, including Fibre Channel, Gigabit Ethernet, and Infiniband. When you select one of these filter set-ups, *VISI* will automatically select the filter and amplifier in the OE-2 and set the wavelength for measurements. In addition, *VISI* will set measurement limits from the standard's requirements such as rise and fall time, extinction ratio, optical modulation amplitude and average optical power. A Pass or Fail message will appear on the *VISI* display indicating whether the signal satisfies the standards limits. The default values for the preprogrammed settings are listed in Appendix C.

Select the “Standard” drop-down menu. Standards corresponding to the filters installed in the OE-2 will be listed in the “Standard” window. For example, if the OE-2 has filter option 1, with Fibre Channel, Gigabit Ethernet and Infiniband filters installed, those standards will appear in the drop-down list.

- Select a protocol from the drop down menu in the “Protocol” field for the type of signal to be measured. The protocol identifies the sub-section of the communication standard. Once the standard and protocol are selected, the preprogrammed settings will be shaded, preventing you from changing them.

If “User-Defined” is selected, all settings and limits may be selected or changed.

- Select  (RUN) and *VISI* will continuously make measurements.
- If the signal level is too low, the gain of the OE-2 amplifier can be increased in the Amplifier window.



The screenshot shows a vertical panel of settings for the VISI software. At the top is a button labeled "External Calibration". Below it are several drop-down menus: "SIA Channel" set to "Chan1", "Standard" set to "User Defined", "Protocol" (empty), "Filter Setting" set to "Full Bandwidth", "Wavelength (nm)" set to "850", and "Amplifier (dB)" set to "20".

External Calibration

An external calibration must be performed for each channel. Keep in mind that, when you press the “External Calibration” button, only the channel that is selected in the “Channel” field will be calibrated.

To perform the external calibration:

- ❑ From the Optical Interface Dialog Bar, click on Acquire Options
- ❑ Remove the optical signal from the input connector
- ❑ Select the SIA Channel that you would like to calibrate
- ❑ On the Acquire Options menu, select the External Calibration button

The calibration will be performed and, when complete, the message, “The calibration was successfully completed,” will appear. Reconnect your signal after the calibration process is done.

In the event that a calibration error warning appears, repeat the calibration process making sure:

- ❑ All optical signals are removed from the optical input
- ❑ The correct channel is selected
- ❑ The OE-2 GPIB Address and Optical Channel Assignments are correct (under Edit|Optical Configuration pull-down menu)

Output Setting Options

The Output Settings dialog bar enables the user to set the units of measure, such as milliwatt or microwatts, for optical measurements. Pass/fail limits for optical power, modulation and rise and fall time measurements are accessible through this selection.

To access the Output Settings, select the Output Settings button on the Dialog Bar. Select the appropriate optical settings from the drop-down menus or enter the desired value into the available data fields. The following output settings are available when a specific “Protocol” on the Acquire Options menu has not been selected. The settings are preset when a specific “Standard” has been selected (see Appendix C).

Power units - Select from units of dBm, mW or mW for all power measurements.

Average power limit - Pass-Fail limit value.
(The minimum average optical power limit, specified in [power units])

Modulation Measure - Select either "extinction ratio" or "optical modulation amplitude".

Modulation units - Select unit of measure for modulation

When extinction ratio is selected

- Ratio
- dB
- Percentage

When Optical Modulation Amplitude is selected

- Milliwatts
- Microwatts

Modulation limit - Pass/Fail limit for modulation.
(The minimum average extinction ratio or OMA (as selected), specified in [modulation units])

Rise Time limit - Pass-Fail limit for rise time measurement.
(The maximum rise time in picoseconds)

Fall Time limit - Pass-Fail limit for fall time measurement.
(The maximum fall time in picoseconds)

Select any of the devices on the list to display the current settings.

The screenshot shows a vertical dialog bar with the following settings:

- Power Units:** dBm (dropdown menu)
- Avg Power Limit:** -10.000000 (text input field)
- Modulation Measure:** Optical Mod Amp (dropdown menu)
- Modulation Units:** uW (dropdown menu)
- Modulation Limit:** 100.000000 (text input field)
- Rise Time Limit (ps):** 300.000000 (text input field)
- Fall Time Limit (ps):** 300.000000 (text input field)

Trigger Options

The Trigger Dialog Bar enables the user to set up trigger sources and conditions on the DTS or SIA instrument.

Trigger - Select trigger source.

Trigger Method - Select Auto to set the trigger threshold voltage to the 50% voltage point of the Pulsefind values on the selected trigger channel. Voltage is displayed in "Trigger Voltage." Select "User" to manually enter a threshold voltage in "trigger Voltage." Limits are +/- 1.1 volts.

Trigger Voltage - Displays the threshold voltage used to trigger the instrument. If User is selected in the Trigger Method box, the user can enter a value. Limits are +/- 1.1 volts.

Trigger Edge - Selects the rising or falling edge to trigger the instrument.

Trigger
Chan1
Trigger Method
Auto
Trigger Voltage
0.000000
Trigger Edge
Rising

View Options

The View Options menu enables the user to change the oscilloscope display. The following settings can be specified or modified to customize your view:

Mode

Dot Connect - Measurements are displayed as a point-to-point, straight-line plot.

Persistence - Measurements are displayed as individual dots in the plot window.

Delay - the minimum time delay from the trigger event to the measure event

Range - the full time span of the display

Resolution - the granularity of the display

Hits per Measure - Determines the number of time measurements that will be made for each edge or point on the plot.

Mode
Dot Connect
Delay (ns)
20.000000
Range (ns)
80.000000
Resolution (ns)
0.050000
Hits Per Measure
300

The View pull-down menu at the top of the dialog bar provides the user with two ways to see the acquired measurement data.



Time – Time domain plot of the signal

Summary – Text in a table format, used for pass/fail testing, displays the comparisons to the output settings

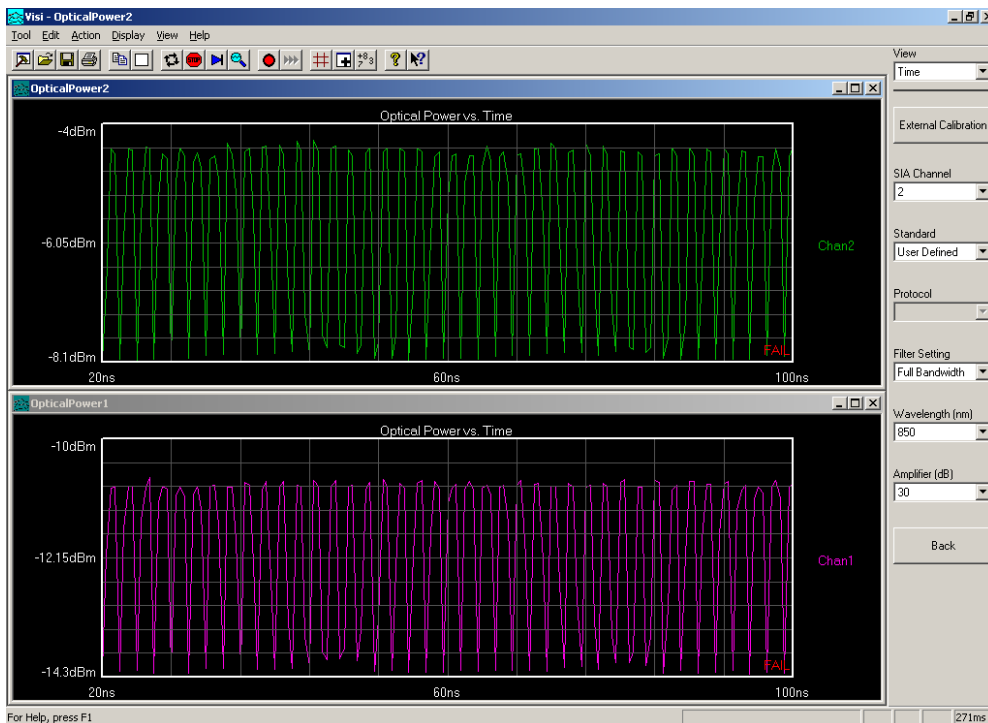
View
Time
Time
Summary


Taking a Measurement

Two types of measurements are available once the setup of the instrument has been completed and are available from the Tool Bar or the Action pull-down menu.


- Single/Stop command  (Action menu)
Use this command to acquire a single measurement in *VISI*. It is also used to stop a series of measurements from being taken after the Run command is issued. This command affects the current tool only.
- Run command  (Action menu)
Use this command to repetitively acquire new measurements in *VISI*. Measurements will be acquired until either the Single/Stop command is issued or an error occurs. This command affects the current tool only.

As shown below, you may also display multiple windows to allow monitoring of more than one channel.



Adding a view () opens a new (default) tool window associated with the active tool. There may be many opened window views of one tool, but all views reflect any measurements or settings for that tool.

To see both a measurement plot and summary page:

- ❑ Open a tool.
- ❑ Select Add from the View pull-down menu or click on the  (New View) button.
- ❑ Select Summary from the View menu on the Dialog Bar.

APPENDIX A – SPECIFICATIONS AND REQUIREMENTS

OE-2™ SPECIFICATIONS

Functional Specifications—Optical

Wavelength Range	770 to 1650 nm
Conversion Gain(850nm) ^{1,2}	5,500 V/W (850 nm/40 dB amp)
Conversion Gain(1550nm) ^{1,2}	20,000 V/W (1550 nm/40 dB amp)
Maximum Input Level ³	+3 dBm
Input Damage Level	+10 dBm
Polarization Dependent Loss ⁴	<0.1 dB
Input Return Loss ⁴	>20 dB
Input Connector Type	FC/UPC Multimode
Input Connector Core Diameter	62.5 μm
Optical Power Measurement Accuracy ⁵	±0.5 dB

Functional Specifications—Electrical and System

Input Data Rate	155 Mb/s to 6 Gb/s
Frequency Response ^{1,6,7,8}	100 kHz – 4 GHz
Passband Ripple ^{1,6,7,8}	±0.5 dB
Rise time (20-80%) ^{1,6,7,9}	90 ps
Intersymbol Interference ^{1,10}	2.6% of UI
Filter Response	4 th Order Bessel-Thompson
Amplifier Block Gain Accuracy ¹¹	8.5 ±1.0 dB
Output Impedance	50 Ohms Nominal
Output Return Loss ¹	20 dB
Output Return Loss	>15 dB
Output Connector	SMA

Notes:

1. Typical value.
2. With maximum amplifier gain selected.
3. Peak operational signal level.
4. Measured in Single Mode fiber.
5. Over the range of –18 to +3 dBm at 850 nm or over the range of –22 to +3 dBm for 1310 and 1550 nm operation
6. Measured by 650 fs (FWHM) mode-locked laser impulse.
7. Calculated –3 dB frequency response from an FFT of impulse response.
8. Full Bandwidth, 20 dB amplifier positions selected.
9. Measured with 20 GHz oscilloscope.
10. Peak-to-Peak ISI contribution simulated from mode-locked laser response using a 2.5 Gb/s PRBS 2⁷-1 pattern with the Infiniband filter and 20 dB amplifier positions selected.
11. Per amplifier at 100 MHz.

Low Pass Filter Response Characteristics

The OE-2 includes four switchable filters. The following filter options are available. A fifth path provides full-bandwidth operation (no filter).

Model OE-2-1	Model OE-2-2	Model OE-2-3	Model OE-2-4
Fibre Channel	2X Fibre Channel	Fibre Channel	Fibre Channel
2X Fibre Channel	Gigabit Ethernet	2X Fibre Channel	2X Fibre Channel
Gigabit Ethernet	Infiniband	Gigabit Ethernet	Gigabit Ethernet
Infiniband	XAUI	XAUI	OC-48

Standard	Design Cut-off Frequency
Fibre Channel	797 MHz
2X Fibre Channel	1.594 GHz
Gigabit Ethernet	937.5 MHz
Infiniband	1.875 GHz
XAUI	2.344 GHz
SONET OC-48	1.866 GHz

Calculated Measurement Accuracy

Extinction Ratio¹²±1 dB

Optical Modulation Amplitude^{12,13}±12%

Notes:

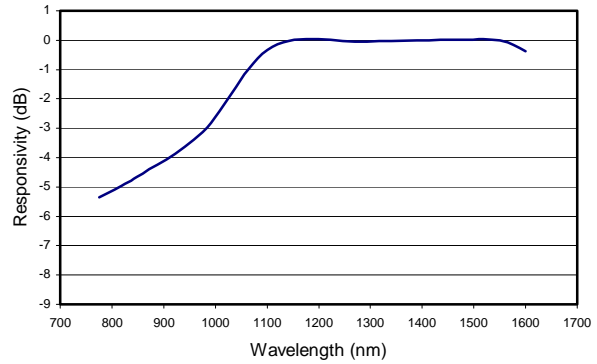
12. Using an SIA-3000, M3.2 Channel Card, VISI software with a 100-125 MHz square wave, 850 nm, average optical power level of -5 dBm (per Fibre Channel or Gigabit Ethernet standards)
13. Percent of reading.

Miscellaneous Characteristics

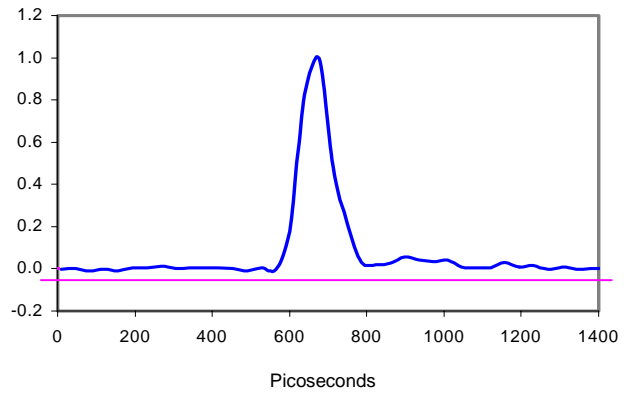
Calibration Interval..... 1 year

AC Mains Voltage 90-264 VAC

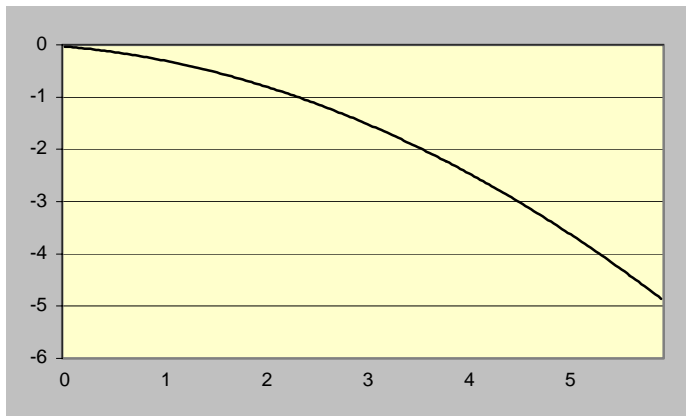
AC Mains Frequency..... 50/60 Hz



Typical OE-2 Responsivity versus Wavelength.



OE-2 Impulse Response to a 650 femtosecond mode-locked laser impulse (full bandwidth, 20 dB amplifier selected).



OE-2 Frequency Response (calculated from the FFT of a 650 femtosecond mode-locked laser impulse; full bandwidth, 20 dB amplifier selected).

Notes:

- A. Typical measurements provide non-warranted information about system performance or capabilities.
- B. Wavecrest continually engages in research related to product improvement. New material, production methods, and design refinements are introduced into existing products without notice as a routine expression of that philosophy. For this reason, the OE-2 may differ in some respect to the specifications stated in this document.
- C. The OE-2 will comply with these specifications after a 30-minute warm-up period.

Interface Requirements

The optical inputs are high return loss FC/UPC connectors. Either single mode or multi-mode fibers can be accepted.

The electrical outputs are SMA connectors.

The OE-2 includes an IEEE-488 interface. The connector and address selection switch are located on the rear panel of the instrument.

Power Requirements

The OE-2 operates on 100-120 VAC & 200-240 VAC ($\pm 10\%$), 47-63Hz. The OE-2 is rated for 275 Watts.

Fuses: (2) two 2AT/250V, 5 x 20 mm.

Power supply is auto ranging.

The AC input appliance coupler or separable plug on the power cord is the disconnect device. For safe operation, the OE-2 should be installed to allow easy operator access to the disconnect device.

Communications Requirements

The OE-2 uses English-language IEEE-488.2 commands. The command list is shown in Appendix III.

Environmental Requirements

Temperature Range

Operating +15°C to +35°C

Storage..... -40°C to + 55°C

Humidity 0-85% RH, non-condensing

Ventilation - A minimum of two inches of unobstructed airflow must be maintained on each side and rear panel of the instrument (air inlet and exhaust openings) to provide adequate ventilation for the OE-2. To maintain the highest accuracy, the OE-2 air intake should not be near sources that would cause ambient temperature fluctuations. Temperature fluctuations greater than 5°C will require that OE-2 be recalibrated.

Elevation (Altitude) to 6500 feet (2000 meters)

Indoor Use Only The OE-2 is intended for indoor use only.

Installation Category..... CAT II

Pollution Degree 2 per IEC 664

Product Life Requirements

Product lifetime is five years minimum with recommended factory calibration intervals of one year.

Maintaining Proper Instrument Grounding

Both 120VAC and 230VAC power sources require an earth ground at the power connection. Failure to provide this safety ground could result in improper measurements and/or electrical shock danger to the operator.

Only qualified service personnel should perform maintenance procedures on the OE-2. When maintenance is performed, NO protective earth ground connections should be removed.

NOTE: Where this product is installed at areas requiring main power connections other than the three-pronged North American power plug, the main power cord must be replaced with the cord and plug appropriate to the location. The main supply cord must be rated to meet or exceed the current rating on the IEC connector (10 amps) and must meet the requirements of H05VV power cords in IEC 227 or IEC 245. If the appropriate power cord cannot be obtained locally, contact the *WAVECREST CORPORATION* factory and one will be provided.

Fuse Replacement

The IEC plug-in at the back of the OE-2 provides the input connection for the AC power cord. A small compartment on the IEC plug houses two Wickman 2AT/250V fuses (5x20mm). To gain access to the fuses, remove the power to the OE-2 and disconnect the power cord. With a small screwdriver, pry open the fuse compartment on the IEC plug. Remove the fuses and install the new fuses prior to closing the compartment and reinstalling the power cord.

Cleaning Instructions

Periodic cleaning of the OE-2 cabinet may be required. Use a clean, lint-free cloth to dust outer surfaces after electrical power has been removed. If needed, dampen cloth with light amounts of water or alcohol.

Intended Use Of Equipment

The OE-2 should be used only for its intended purpose as outlined in this manual. To avoid possible injury, the OE-2 should not be operated with the top cover or other panels removed. Refer installation and maintenance to qualified service personnel.

To avoid explosion, do not operate the OE-2 in or near an atmosphere of explosive gases

APPENDIX B - GPIB COMMANDS

The following GPIB commands are supported in the OE-2.

Table B1. IEEE.2 Common Commands

Command	Definition
*CLS	Clear Status
*ESR?	Event Status Register Query
*LRN?	NS
*OPC?	Operation Complete Query
*RCL	*rcl <0/1> Recall settings from register 0 or register 1
*SAV	*sav <0/1> Save current settings to register 0 (power-up) or register 1
*STB?	Status Byte Query
*TST?	NS
*ESE	NS
*IDN?	Identification Query
*OPC	Operation Complete Command
*OPT?	NS
*RST	Reset
*SRE	NS
*TRG	NS
*WAI	NS

Note: NS = Not Supported

Table B2. WAVECREST Common Commands

Command	Command Syntax	Query Syntax
SYSTEM	:SYSTEM	:SYSTEM
HEADer	:HEADER<ON OFF 1 0>	:HEADER ?
LONGform	:LONGFORM<ON OFF 1 0>	:LONGFORM ?
VERsion		:VERSION ? WAVECREST, MODEL#, NN.NN

Table B3. OE-2 Specific Commands

Command	Command Syntax	Query Syntax
CHANnel (Root command)	:CHANnel <string> Valid strings: 1 - Channel1, 2 - Channel2	CHANnel ?
INStalled	No write command.	:INStalled ? Return value: comma delimited string as follows: <TYPE, FILT, AMPL,WAVE,MODEL,VERSION> TYPE, FILT,AMPL,WAVE are defined later in the table. MODEL refers to the # of channels, SING or DUAL. VERSION refers to the hardware release (6 characters, BXX.XX for Beta and RXX.XX for production.
FILTer	:FILTer <string> Valid strings: FC - Fibre Channel FC2X - Fibre Channel 2X GBE - Gigabit Ethernet IB - Infiniband XAUI - XAUI OC48 - SONET OC48 FBW - Full Bandwidth	:FILTer ? Return the current filter setting string.
AMPLifier	:AMPLifier <string> Valid strings: 10DB - 10 dB Gain 20DB - 20 dB Gain 30DB - 30 dB Gain 40DB - 40 dB Gain	:AMPLifier ? Return the current amplifier setting string.
WAVElength	:WAVElength<Float ¹ > Floating point string representing a wavelength from 770E-9 to 1650E-9 m.	:WAVElength ? Returns a string representing the floating point value of the wavelength.
ACResponse	:ACResponse<Float> Written only during calibration. (units: W/V)	:ACResponse ? Returns a string representing the AC Response for the current filter, amplifier and wavelength settings.
AVEPwr	No write command.	:AVEPwr ? Returns a string representing the floating point value of the current average optical power into the OE-2.
TYPE	No write command.	:TYPE Return value : delimited ASCII String representing the type of RFM installed FC/FC2X/GBE/IB/FBW FC2X/GBE/IB/XAUI/FBW FC/FC2X/GBE/XAUI/FBW FC/FC2X/GBE/OC48/FBW

¹ A floating-point number is given in scientific notation format as X.XXXXXXE-YY or X.XXXXXXE+YY.

Table B3. OE-2 Specific Commands cont.

Command	Command Syntax	Query Syntax
NULLOffset	:NULLOffset<Float> Used to calibrate the OE-2 when no optical power is present. When using a short calibration no string is required. When using a long cal the string represents the null offset in bits.	:NULLOffset ? Return value: Floating point value representing the last stored null offset of the OE-2.
AVERaging	AVERaging <string> Valid strings: OFF – averaging off 1-40 – set number of samples averaged in firmware	AVERaging ? returns current state of averaging
System (root command) ADFormat	:ADF <string> Valid Strings: BITS VOLTS	:ADF ? return a string representing the current format.
CALibrate (root command) CALType	: CALType <string> Valid strings: 0 – Short cal 1 – Long cal SHORT – short cal LONG – long cal	:CALType ? return a string representing the current calibration type.

OE-2 Specific Commands Description

CHANnel (CHANx): Root command that specifies the channel to which a subcommand applies. On a Dual Channel OE-2, ‘x’ may take on values of ‘1’ or ‘2’. On a Single Channel OE-2, ‘x’ may only take on a value of ‘1’.

ACResponse: Channel subcommand that provides a query response only. The AC response of the OE-2 Channel is determined from the current wavelength, filter, and amplifier settings. This constant, in units of W/V, is used to convert the electrical output of the OE-2 in volts to optical input power. When combined with the average power reading the level and magnitude of the input optical signal can be determined. The AC Response is valid at 100MHz. Example read: ‘:CHAN1:ACR?’.

AMPLifier: Channel subcommand that sets the amplifier for the specified channel or reads the current setting. Valid amplifier settings are ‘10DB’, ‘20DB’, ‘30DB’, and ‘40DB’. Example write: ‘CHAN1:AMPL 20DB’.

AVEPwr: Channel subcommand that provides a query response only. The average power of the input optical signal is returned in units of watts. Example read: ‘:CHAN1:AVEP?’.

AVERaging: Channel subcommand that specifies the amount of firmware averaging of the O/E average power measurement. When off, an average power query retrieves the instantaneous measurement. When averaging is on, the firmware averages some number of 40 samples taken every second. For example, for the command “:CHAN1: AVE 10”, the firmware would average every 10 samples. An AVEP query will return the last averaged value. When averaging is on, the number of independent readings available every second is reduced. In the example above, the number of independent readings is reduced from 40 to 4.

FILTer: Channel subcommand that sets the filter for the specified channel or reads the current setting. Valid filter settings depend upon the type of channel that is installed in the **OE-2**. Valid settings can be determined from the TYPE field of the INStalled query. Example read: ':CHAN1:FILT?'.

INStalled: Channel subcommand that provides a query response only. When queried the command returns a comma delimited field with information pertaining to the specified channel. The fields returned are channel type (or option), current filter setting, current amplifier setting, current wavelength setting, **OE-2** Channel Status (Single/Dual), and **OE-2** release (B01.00 – Beta 1.00, R01.00 Production 1.00). Example read: ':CHAN1:INS?'.

NULLoffset: Channel subcommand that sets or reads the null offset of the specified channel. The null offset value is computed from a calibration that is performed when the specified channel's optical input is dark. The null offset is then used to compensate the power monitor for this 'null' condition. When performing a null offset calibration, the null offset must first be written to zero. Example write: ':CHAN1:NULL 0'.

TYPE: Channel subcommand that provides a query response only. The type (or option) of the **OE-2** channel is returned in a '/' delimited field. The return string contains the filter positions that are available for the specified channel. Valid strings are given in the chart above. Example read: ':CHAN1:TYPE?'.

WAVElength: Channel subcommand that set the wavelength for the specified channel or reads the current setting. The wavelength setting determines the calibration constant that is used in the average power measurement. Any wavelength setting that does not match the input optical wavelength will result in an incorrect average power reading. Wavelength units are meters. Example write: ':CHAN1:WAVE 1550E-9'.

SYSTEM: Root command for system wide commands.

ADFormat: System subcommand that sets or reads the current A/D format. The A/D format specifies the way results are returned. When set to BITS the AVEP command returns the bit reading from the A/D Converter in the power monitor. When set to WATTS the AVEP command converts the A/D voltage into a power reading. The BITS mode is used during a null offset calibration.

CALIBRATE: Root command for calibration commands.

CALType: Calibrate subcommand that sets or reads the current calibration type. A short calibration does not require any external readings but may be less accurate than a long cal. During a long cal the ADFormat is set to BITS and readings are taken with the AVEPwr command. The readings can be averaged over several seconds to improve the accuracy of the calibration. The averaged value (in BITS) is then written using the NULLoffset command. Example Cal sequence:

Short Cal:

```
:CAL:CALT SHORT
:CHAN1:NULL
```

Long Cal:

```
:CAL:CALT LONG (set long cal mode)
:SYSTEM:ADFORMAT BITS (set format to BITS)
:CHAN1:NULL 0 (Zero out the current null)
:CHAN1:AVEP? (Read this multiple times over a period of several seconds and average the results)
:CHAN1:NULL <AVERAGED DATA> (write the averaged data)
:SYSTEM:ADFORMAT WATTS (return format to WATTS)
```

APPENDIX C – PREPROGRAMMED MEASUREMENT LIMITS

The following Charts show the preprogrammed measurement limits for each OE-2 model. See Section 3 for more information on the measurement limit presets.

Table C1. OE-2 Option 1

Protocol	Filter	Wavelength	Power Units	Average Power Limit	Modulation Measure	Modulation Units	Modulation Limit	Rise/Fall times Limits (in ps)
“User Defined” Defaults	“Filter 1”	850 nm	dBm	(1)	OMA	uW	(1)	(1)
Gigabit Ethernet 1000BASE-SX	GE	850 nm	dBm	-9.5	ER	dB	9	260 rise 210 fall
Gigabit Ethernet 1000BASE-LX Single Mode	GE	1300 nm	dBm	-11.0	ER	dB	9	260
Gigabit Ethernet 1000BASE-LX Multimode	GE	1300 nm	dBm	-11.5	ER	dB	9	260
Fibre Channel 100-SM-LC-L	FC	1300 nm	dBm	-9.5	OMA	mW	(4)	320
Fibre Channel 200-SM-LC-L	FC2X	1300 nm	dBm	-11.7	OMA	mW	(4)	160
Fibre Channel 100-M5-SN-I	FC	850 nm	dBm	-10	OMA	mW	0.156	300
Fibre Channel 100-M6-SN-I	FC	850 nm	dBm	-10	OMA	mW	0.156	300
Fibre Channel 200-M5-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150
Fibre Channel 200-M6-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150
Infiniband 1X-SX	IB	850 nm	dBm	(2)	OMA	mW	0.196	150
Infiniband 1X-LX	IB	1300 nm	dBm	(2)	OMA	mW	0.186	150
Infiniband 4X-SX	IB	850 nm	dBm	(2)	OMA	mW	0.150	150
Infiniband 12X-SX	IB	850 nm	dBm	(2)	OMA	mW	0.150	150

- (1) Leave blank for user setting
- (2) Not specified or multiple specs in the standard. The user must establish the limit.
- (3) The Fibre Channel standard offers a tradeoff between spectral center wavelength, RMS spectral width, and minimum OMA. The user must establish the limit.

Table C1. OE-2 Option 2

Protocol	Filter	Wavelength	Power Units	Average Power Limit	Modulation Measure	Modulation Units	Modulation LLimit	Rise/Fall times Limits (in ps)
“User Defined” Defaults	“Filter 1”	850 nm	dBm	(1)	OMA	uW	(1)	(1)
Gigabit Ethernet 1000BASE-SX	GE	850 nm	dBm	-9.5	ER	dB	9	260 rise 210 fall
Gigabit Ethernet 1000BASE-LX Single Mode	GE	1300 nm	dBm	-11.0	ER	dB	9	260
Gigabit Ethernet 1000BASE-LX Multimode	GE	1300 nm	dBm	-11.5	ER	dB	9	260
Fibre Channel 200-SM-LC-L	FC2X	1300 nm	dBm	-11.7	OMA	mW	(4)	160
Fibre Channel 200-M5-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150
Fibre Channel 200-M6-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150
Infiniband 1X-SX	IB	850 nm	dBm	(2)	OMA	mW	0.196	150
Infiniband 1X-LX	IB	1300 nm	dBm	(2)	OMA	mW	0.186	150
Infiniband 4X-SX	IB	850 nm	dBm	(2)	OMA	mW	0.150	150
Infiniband 12X-SX	IB	850 nm	dBm	(2)	OMA	mW	0.150	150

- (1) Leave blank for user setting
- (2) Not specified or multiple specs in the standard—leave blank
- (3) Future product—reserved. Do not show in **OE-2** software, available with **SIA-3000**
- (4) The Fibre Channel standard offers a tradeoff between spectral center wavelength, RMS spectral width, and minimum OMA. Leave OMA limit blank for user to input a limit.

Table C1. OE-2 Option 3

Protocol	Filter	Wavelength	Power Units	Average Power Limit	Modulation Measure	Modulation Units	Modulation Limit	Rise/Fall times Limits (in ps)
“User Defined” Defaults	“Filter 1”	850 nm	dBm	(1)	OMA	uW	(1)	(1)
Gigabit Ethernet 1000BASE-SX	GE	850 nm	dBm	-9.5	ER	dB	9	260 rise 210 fall
Gigabit Ethernet 1000BASE-LX Single Mode	GE	1300 nm	dBm	-11.0	ER	dB	9	260
Gigabit Ethernet 1000BASE-LX Multimode	GE	1300 nm	dBm	-11.5	ER	dB	9	260
Fibre Channel 100-SM-LC-L	FC	1300 nm	dBm	-9.5	OMA	mW	(4)	320
Fibre Channel 200-SM-LC-L	FC2X	1300 nm	dBm	-11.7	OMA	mW	(4)	160
Fibre Channel 100-M5-SN-I	FC	850 nm	dBm	-10	OMA	mW	0.156	300
Fibre Channel 100-M6-SN-I	FC	850 nm	dBm	-10	OMA	mW	0.156	300
Fibre Channel 200-M5-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150
Fibre Channel 200-M6-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150

- (1) Leave blank for user setting
- (2) Not specified or multiple specs in the standard—leave blank
- (3) Future product—reserved. Do not show in **OE-2** software, available with **SIA-3000**
- (4) The Fibre Channel standard offers a tradeoff between spectral center wavelength, RMS spectral width, and minimum OMA. Leave OMA limit blank for user to input a limit.

Table C1. OE-2 Option 4

Protocol	Filter	Wavelength	Power Units	Average Power Limit	Modulation Measure	Modulation Units	Modulation Limit	Rise/Fall times Limits (in ps)
“User Defined” Defaults	“Filter 1”	850 nm	dBm	(1)	OMA	uW	(1)	(1)
Gigabit Ethernet 1000BASE-SX	GE	850 nm	dBm	-9.5	ER	dB	9	260 rise 210 fall
Gigabit Ethernet 1000BASE-LX Single Mode	GE	1300 nm	dBm	-11.0	ER	dB	9	260
Gigabit Ethernet 1000BASE-LX Multimode	GE	1300 nm	dBm	-11.5	ER	dB	9	260
Fibre Channel 100-SM-LC-L	FC	1300 nm	dBm	-9.5	OMA	mW	(4)	320
Fibre Channel 200-SM-LC-L	FC2X	1300 nm	dBm	-11.7	OMA	mW	(4)	160
Fibre Channel 100-M5-SN-I	FC	850 nm	dBm	-10	OMA	mW	0.156	300
Fibre Channel 100-M6-SN-I	FC	850 nm	dBm	-10	OMA	mW	0.156	300
Fibre Channel 200-M5-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150
Fibre Channel 200-M6-SN-I	FC2X	850 nm	dBm	-10	OMA	mW	0.196	150

- (1) Leave blank for user setting
- (2) Not specified or multiple specs in the standard—leave blank
- (3) Future product—reserved. Do not show in **OE-2** software, available with **SIA-3000**
- (4) The Fibre Channel standard offers a tradeoff between spectral center wavelength, RMS spectral width, and minimum OMA. Leave OMA limit blank for user to input a limit.

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