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Operator's Manual

OE695G

Optical-to-Electrical Converter

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Operator's Manual
April 2013





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WARRANTY

Teledyne LeCroy warrants this oscilloscope accessory for normal use and operation within specification for a period of one year from the date of shipment. Spare parts, replacement parts and repairs are warranted for 90 days.

In exercising its warranty, Teledyne LeCroy, at its option, will either repair or replace any assembly returned within its warranty period to the Customer Service Department or an authorized service center. However, this will be done only if the product is determined by Teledyne LeCroy's examination to be defective due to workmanship or materials, and the defect is not caused by misuse, neglect, accident, abnormal conditions of operation, or damage resulting from attempted repair or modifications by a non-authorized service facility.

The customer will be responsible for the transportation and insurance charges for the return of products to the service facility. Teledyne LeCroy will return all products under warranty with transportation charges prepaid.

This warranty replaces all other warranties, expressed or implied, including but not limited to any implied warranty of merchantability, fitness or adequacy for any particular purposes or use. Teledyne LeCroy shall not be liable for any special, incidental, or consequential damages, whether in contract or otherwise.

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OE695G Overview

The OE695G is designed to help troubleshoot optical-to-electrical signal integrity issues at the board level. For system integrators who measure both electrical and optical signals in their products, the OE695G provides electrical measurements on optical signals, while taking full advantage of the Teledyne LeCroy real-time oscilloscope tool set and the debugging capabilities of the Teledyne LeCroy Serial Data and Crosstalk Analysis software options.

When connected to the oscilloscope, the OE695G becomes an integrated part of the oscilloscope. Power is supplied to the OE695G by the oscilloscope (no external power supply is needed), and the OE695G communicates to the oscilloscope its identity and scaling information. The Optical Wavelength, Dark Calibration and Reference Receiver functions are all controlled from the oscilloscope's user interface.

The OE695G is unique in that it operates with a real-time oscilloscope, not a sampling oscilloscope, and uses a digital signal processing (DSP) filter to enable a user-selectable reference receiver response. Since the optical input signal is input to a real-time oscilloscope, it is possible to use the contiguous data acquisition of the real-time oscilloscope to obtain serial data pattern knowledge and provide Tj, Rj, and Dj decomposition to very high accuracy, like what is done with high-speed electrical serial data signals. The low cost and general utility of this optical to electrical converter makes it ideal for those who are already using real-time oscilloscopes for electrical serial data measurements, and need to also measure optical serial data signals as well.

Compatibility

- The OE695G converter is compatible with WaveMaster/SDA/DDA 8 Zi/Zi-A, LabMaster 9 Zi-A, and LabMaster 10 Zi series oscilloscopes using Teledyne LeCroy's 2.92mm interface and Teledyne LeCroy's ProLink interface through the use of the LPA-2.92 ProLink to 2.92mm adapter.
- Requires 6.9.0.0 or later version of Oscilloscope firmware.

Key Features:

- Frequency range DC to 9.5 GHz (electrical, -3 dB)
- Selectable reference receiver support, including:

8GFC (8.5 Gb/s)	ITU-T G.709 FEC (10.709 Gb/s)
10GBASE-W (9.953 Gb/s)	10 GbE FEC (11.096 Gb/s)
OC192 (STM64) (9.953 Gb/s)	10GFC FEC (11.317 Gb/s)
10GBASE-R (10.3125 Gb/s)	User Defined (up to 11.5 Gb/s)
10GFC (10.519 Gb/s)	None (maximum 12.667 Gb/s)*
ITU-T G.975 FEC (10.664 Gb/s)	

*Cannot meet reference receiver specification past 11.5 Gb/s.

- 62.5/125 μm multi-mode or single-mode fiber input
- Broad wavelength range (750 to 1650 nm)
- +7 dBm (5 mW) max peak optical power
- Low noise (as low as 25 pW/VHz)

Safety Information

Symbols

These symbols appear on the product or in this manual to alert you to important information.



High Voltage, risk of electric shock.



CAUTION of potential damage to equipment, or **WARNING** of potential for bodily injury. Attend to the accompanying information/product manual to protect against personal injury or damage. Do not proceed until conditions are fully understood and met.



DOUBLE INSULATION



PROTECTIVE (EARTH) TERMINAL

Precautions

Avoid personal injury, or damage to your accessory or any equipment connected to it, by reviewing and complying with the following safety precautions:

Use only as intended. The accessory is intended to be used only with the compatible Teledyne LeCroy instruments. Use of the accessory and/or the equipment it is connected to in a manner other than specified may impair the protection mechanisms.

Connect and disconnect properly. Avoid damage through excessive bending of cables and other equipment.

Do not use in wet/damp or explosive atmospheres.

For indoor use only. The accessory is intended for indoor use and should be operated in a clean, dry, environment.

Do not operate with suspected failures. Do not use the product if any part is damaged. All maintenance should be referred to qualified service personnel.

Keep product surfaces clean and dry.

Completely assemble the measurement instrument before circuit/signal contact. Connect accessory to the measurement instrument before connecting the instrument test leads to a circuit/signal being tested.

Do not apply a voltage to any input that exceeds the maximum rating of that input. Refer to the Specifications on Teledyne LeCroy website at www.teledynelecroy.com for detailed information.

Operating Environment

The accessory is intended for indoor use and should be operated in a clean, dry environment. Before using this product, ensure that its operating environment is maintained within these parameters:

Temperature: 5 to 40 °C.

Humidity: Maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % relative humidity at 40 °C.

Altitude: Up to 10,000 ft (3,048 m).

Operation

Connecting the Unit to the Oscilloscope

To connect the optical to electrical converter to the Teledyne LeCroy oscilloscope:

1. Attach the OE695G 2.92mm connections to the oscilloscope 2.92mm interface. Use a torque wrench to provide appropriate torque when tightening.
2. If connecting to a ProLink interface, first connect the LPA 2.92mm ProLink to 2.92mm adapter to the oscilloscope, then connect the OE695G to the adapter.
3. Connect the OE695G LEMO connector to the power connection of the oscilloscope 2.92mm interface or the LPA-2.92 adapter. Align the red dot on the cable to the red mark on the connector.
4. Verify the LEMO power connector is locked to the connection.
5. Connect the other end of the SMA cable to the converter, if not already connected. Use a torque wrench to ensure proper torque.
6. Connect the other end of the LEMO power cable to the OE695G.
7. To disconnect power, pull on the LEMO connector tip to release the lock and pull out the LEMO connector.

Connecting the Unit to the Optical Fiber

A plastic cap covers the FC/PC input connector. Carefully remove this cover and insert a fiber optic cable with a cladding dimension of 125 μm . The core diameter should nominally be 62.5 μm . Other core diameters may be used with the OE695G, but a smaller or larger diameter will alter the amount of light falling on the photo-receiver and impact the gain accuracy of the OE695G. Both multi-mode and single-mode fibers may be used with the OE695G provided they are mechanically compatible.

Operation with a Teledyne LeCroy Oscilloscope

After the OE695G connectors are attached, the converter can be controlled through the oscilloscope. Turning the VOLTS/DIV knob will control the oscilloscope's scale factor to give full dynamic range in $\mu\text{W}/\text{div}$.

Channel Dialog

When the OE695G is connected to a particular channel, the respective Channel dialog will change to reflect the connection of the device:

- An **OE695G tab** for controlling the converter is added to the Channel dialog (Figure 1)
- Gain settings are adjusted and vertical scale labels automatically change to $\mu\text{W}/\text{div}$ units
- Coupling, bandwidth limit (BWL), and other selections are prohibited since they must be preset to certain values to allow proper functioning of the OE695G.

Figure 1 shows the oscilloscope user interface menu for the OE695G converter. The dialog allows for the selection of the converter’s Dark Calibration, Reference Receiver selection and Optical Wavelength selection functions.

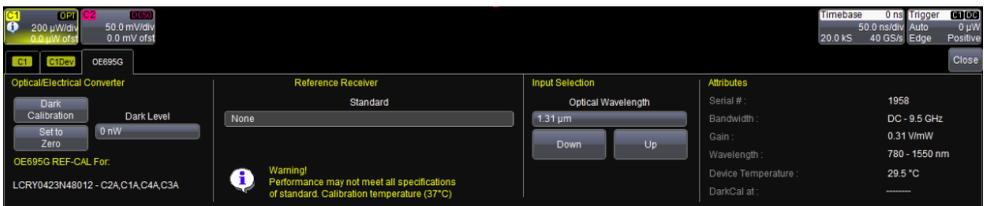


Figure 1: OE695G tab of the oscilloscope’s Channel dialog.

Dark Calibration

The OE695G incorporates a Dark Calibration function to measure the channel offset signal without any light present in the optical receiver.

To perform dark calibration, cover the OE695G input with the supplied cap, and press the **Dark Calibration** button on the OE695G dialog. A scale factor value will be calculated and displayed.

Dark calibration will vary with internal OE695G temperature (the dark calibration level variation with temperature is $-2 \mu\text{W}/^\circ\text{C}$ typical), so if the device temperature varies considerably, additional dark calibrations may be required. After a dark calibration is performed, the temperature it was performed at will be displayed in the Attributes section of the OE695G dialog, to the right.

Touch **Set to Zero** to reset the Dark Calibration value to zero.

Reference Receiver

The OE695G contains optional, built-in software reference receiver filters for common Fiber Channel, Ethernet, and ITU telecom standards. These reference receiver filters provide a 4-pole Bessel Thompson low pass filter response for the combined oscilloscope and optical-to-electrical (O-E) system with the -3dBe (electrical) power at $0.75 \times$ bitrate.

Available reference receiver filters include:

8GFC (8.5 Gb/s)	ITU-T G.709 FEC (10.709 Gb/s)
10GBASE-W (9.953 Gb/s)	10 GbE FEC (11.096 Gb/s)
OC192 (STM64) (9.953 Gb/s)	10GFC FEC (11.317 Gb/s)
10GBASE-R (10.3125 Gb/s)	User Defined (up to 11.5 Gb/s)
10GFC (10.519 Gb/s)	None (maximum 12.667 Gb/s)
ITU-T G.975 FEC (10.664 Gb/s)	

The software reference receiver supplied standard with the OE695G is based on a “nominal” oscilloscope response. The typical uncertainty in this standard reference receiver frequency response is ± 1.6 dBe up to $F_{\text{ref}} = 0.75 \times$ bit rate and ± 4 dBe $2 \times$ bitrate setting.

An OE695G-REFCAL OE695G reference receiver calibration can be purchased that will provide less uncertainty with the OE695G when used with a specific oscilloscope and a specific channel. This REFCAL is usually purchased at the time of initial OE695G and oscilloscope purchase. If this is the case, then Teledyne LeCroy will calibrate the specific OE695G to a specific serial number oscilloscope channel (channel 4 unless otherwise specified) and the resultant reference receiver uncertainty will be ± 0.85 dBe up to $F_{\text{ref}} = 0.75 \times$ bit rate, and ± 4 dBe $2 \times$ bit rate setting on the specified oscilloscope input channel on the 11, 17, 20, 30, 39, 50, 75, 90, or 100 mV/div gain ranges. The calibration will be indicated on the OE695G dialog, shown above. Multiple OE695G can be calibrated to unique oscilloscope channels to allow usage of multiple OE695G.

NOTE: If the OE695G-REFCAL is purchased after the initial OE695G/oscilloscope purchase, the oscilloscope must be returned to Teledyne LeCroy for the OE695G-REFCAL to be performed.

A custom reference receiver (User Defined) can be applied for any bit rate up to 11.5 Gb/s. Bit rates up to 12.5 Gb/s bit rates may be specified, but beyond 11.5 Gb/s, the reference receiver requirements cannot be maintained.

Input Selection for Optical Wavelength

There are four standard optical wavelength selections at 785nm, 850nm, 1310nm and 1550nm. Custom optical wavelength can be adjusted between 750nm to 1650nm; however, gain of the OE695G can vary widely at different wavelengths, and calibration of gain is only performed at the standard wavelengths. At other wavelengths, gain is assumed to follow a linear slope, but this assumption will not yield the stated vertical level power accuracy specification. However, the overall signal fidelity will still be maintained.

Warning Messages

These messages may appear during operation with an oscilloscope.

Warning Message	Explanation
XML data not found	Warns that the XML file containing additional information regarding calibration of the probe is not present, and the probe would work in only a very limited way. If you see this message, stop using the probe and contact Teledyne LeCroy for support.
Nominal reference receiver response applied	The oscilloscope channel connected to the OE695G does not match any previously calibrated channels, therefore a nominal reference receiver response is applied.
Calibrated reference receiver response applied	The scope channel connected to the OE695G matches one of the recalibrated scope channels of the OE695G. This should be the normal operation mode.
Reference receiver active only at 10 GS/s or greater	The sampling rate is too low. Enter at least the minimum sampling rate necessary for the reference receiver.
Performance may not meet all specifications of standard. Calibration temperature (TEMP)	The temperature at which the probe was calibrated and the temperature of the connected probe are different. TEMP would be replaced by the calibration temperature.
Temperature changed since last Dark Calibration recommended	The Dark Calibration temperature and the current probe temperature are different.

Performance Verification Tests

CW Gain

Required Equipment

- OE695G and compatible oscilloscope
- CW laser source at the desired optical wavelength
- Variable optical attenuator (or use variable output level of CW source)
- Optical power meter calibrated for the optical wavelength of the source
- Multimode optical fiber patch cable

Procedure

1. Connect the OE695G to a compatible oscilloscope channel and allow to fully warm-up.
2. Configure the following settings:
 - a. Recall Default setup
 - b. Enable the channel with the OE695G, disable others
 - c. Configure the active channel for the optical wavelength matching the laser source
 - d. Create a measurement for the mean value of the channel
 - e. Enable measurement statistics.
3. Connect the optical attenuator (if used) input fiber to the laser source or connect a fiber patch cable to the output of the laser source. Before mating, carefully clean the fiber connections with an appropriate fiber cleaning cloth.
4. Set the attenuator/laser for an output level of approximately 60 μW .
5. Connect the patch/attenuator output cable to the optical power meter and note the Input Power Measurement: _____ μW
6. With the OE695G optical input cover closed, perform a dark calibration (page 6). Press **Clear Sweeps** on the oscilloscope front panel. From the

statistical mean value of the mean measurement, note the Residual Dark Level: _____ uW

7. Connect the patch/attenuator output cable to the OE695G optical input. Press **Clear Sweeps** on the oscilloscope front panel, and using the statistical mean of the mean measurement, note the Observed Power Level: _____ uW

8. Compute the normalized error fraction:

$$\text{err-frac} = [(Observed - Residual) - Input]/Input$$

The error fraction should be in the range $-\Delta < \text{err-frac} < +\Delta$ where Δ is determined by the sum of the magnitudes of the allowed OE695G uncertainty (e.g., 10% or 0.1) and the optical power meter uncertainty (e.g., 6% or 0.06). In this example $\Delta = 0.16$.

9. If an incorrect result is obtained, repeat the measurement sequence with careful cleaning and mating of the optical interfaces, which are prone to variation from small particles, oils, or other non-idealities.

Optical Reference Receiver Response

Required Equipment

- OE695G and compatible oscilloscope with 20 GHz or greater channel bandwidth
- < 1 ps FWHM optical pulsed laser source, 1550 nm optical wavelength
- Variable optical attenuator

Procedure

1. Connect the OE695G to a compatible oscilloscope channel with a channel specific calibration and allow to fully warm-up.
2. Preset the optical attenuator for high attenuation (safest for protecting the OE695G).
3. Connect the optical attenuator to the pulsed laser source.
4. Connect pulsed laser source *trigger* output to oscilloscope Aux input.

5. Configure the following settings:
 - a. Recall Default setup
 - b. Enable the channel with the OE695G, disable others
 - c. Configure the active channel for 1550 nm optical wavelength, 50 uW/div, Sin x/x interpolation
 - d. Configure the trigger for Aux In, Normal, and adjust the trigger level for proper trigger
 - e. Locate the optical pulse (reduce attenuation if necessary) and adjust oscilloscope time settings to center the pulse on screen with 1 ns/div.
6. Adjust the optical attenuator for peak pulse amplitude 60 uW.
7. Set channel pre-processing averaging to 10,000.
8. Create a dual Math Trace:
 - a. Rescale(FFT(<targetchannel>))
 - b. FFT parameters: Output Type = Power Spectrum, Window = Rectangular, else defaults
 - c. ReScale parameters: First Multiply by= 2.0, else defaults
 - d. Zoom: Horizontal Center= 10 GHz, Scale/div= 2 GHz, Vertical Scale = 10 dB/div, Center = adjust as necessary to display trace on screen.

NOTE: The scale factor makes the vertical units dBe (electrical) instead of dBo (optical power). Optical reference receiver specifications are in terms of dBe.

9. With the OE695G optical input cover closed, perform a dark calibration (page 6).
10. Connect the attenuator output cable to OE695G optical input.
11. Configure the channel optical receiver for the desired response (e.g., Custom - 10 Gb/s (Fr = 7.5 GHz)).
12. Press **Clear Sweeps** on the oscilloscope front panel.
13. Observe frequency response and compare it to the ideal BT-4 response in the table below, confirm it is within limits.

Freq/Fr	4BT Ideal Response (dBe)	Allowed Tolerance (dB)	Max Limit (dBe)	Min Limit (dBe)
0	0	0.85	+0.85	-0.85
0.2	-0.11	0.85	+0.74	-0.96
0.4	-0.45	0.85	+0.40	-1.30
0.6	-1.02	0.85	-0.17	-1.87
0.8	-1.86	0.85	-1.01	-2.71
1.0	-3.01	0.85	-2.16	-3.86
1.2	-4.51	1.48	-3.03	-5.99
1.4	-6.37	2.11	-4.26	-8.48
1.6	-8.54	2.74	-5.80	-11.28
1.8	-10.93	3.37	-7.56	-14.30
2.0	-13.41	4.00	-9.41	-17.41

Care and Maintenance

Cleaning the OE695G

The exterior of the converter should be cleaned with a soft cloth moistened with either water or 75% isopropyl alcohol solution only. Under no circumstances should moisture be allowed to penetrate the converter.

The fiber connector can be cleaned by blowing residue-free air into the connector to remove loose particles. A cleaning cloth tape specifically made for fiber cleaning may also be used by first removing the FC universal connector adapter from the front panel to expose the internal fiber interface.

Calibration Interval

The recommended calibration interval is one year. Adjustment should be performed only by qualified personnel.

Service Strategy

Defective products must be returned to a Teledyne LeCroy service facility for diagnosis and repair or replacement. Defective products under warranty are repaired or replaced. Before returning a product as defective, perform the following troubleshooting procedures:

- Verify the Teledyne LeCroy oscilloscope is running firmware 6.9.0.0 or higher. To verify the firmware version of your oscilloscope, choose **Utilities > Utilities Setup** from the menu bar, then touch the **Status** tab.

- Check the power connector is plugged in and locked, and the SMA cable is connected.

Returning a Product for Calibration or Service

Return a probe for calibration or service by contacting your local Teledyne LeCroy sales representative. They tell you where to return the product. All returned products should be identified by both **model** and **serial number**. Provide your name and contact number, and a description of the defect or failure (if possible).

Products returned to the factory require a **Return Material Authorization (RMA)** acquired by contacting your nearest Teledyne LeCroy sales office, representative or the North America Customer Care Center.

Return shipment should be prepaid. Teledyne LeCroy cannot accept COD or Collect Return shipments. We recommend air-freighting.

1. Contact your local Teledyne LeCroy sales or service representative to obtain a Return Material Authorization.
2. Remove all accessories from the product. Do not include the manual.
3. Pack the product in its case, surrounded by the original packing material (or equivalent) and box.
4. Label the case with a tag containing
 - The RMA
 - Name and address of the owner
 - Probe model and serial number
 - Description of failure
5. Package the product case in a cardboard shipping box with adequate padding to avoid damage in transit.
6. Mark the outside of the box with the shipping address given to you by the Teledyne LeCroy representative; be sure to add the following:
 - ATTN: <RMA assigned by the Teledyne LeCroy representative>
 - FRAGILE
7. Insure the item for the replacement cost of the product.

8. If returning a product to a different country, also:

- Mark shipments returned for service as a “Return of US manufactured goods for warranty repair/recalibration.”
- If there is a cost involved in the service, put the service cost in the value column and the replacement value of the product in the body of the invoice marked “For insurance purposes only.”
- Be very specific as to the reason for shipment. Duties may have to be paid on the value of the service.

Certifications

This Teledyne LeCroy accessory is CE Compliant and bears the CE mark.

EMC Compliance

EC DECLARATION OF CONFORMITY

The OE695G Optical-to-Electrical Converter meets intent of the European Council Directive 2006/95/EEC for Product Safety and 2004/108/EEC for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

EN 61326-1:2006, EN 61326-2-1:2006 EMC requirements for electrical equipment for measurement, control and laboratory use.

Electromagnetic Emissions:

EN 55011/A2:2002 Radiated and Conducted Emissions, Group 1, Class A ^{1,2}

Electromagnetic Immunity:

EN 61000-4-2:2001 Electrostatic Discharge Immunity (± 4 kV contact discharge, ± 4 kV air discharge, ± 4 kV vertical/horizontal coupling planes) ³

EN 61000-4-3:2006 RF Radiated Electromagnetic Field Immunity (3 V/m, 80 MHz to 1 GHz; 3 V/m, 1.4 GHz to 2 GHz; 1 V/m, 2 GHz to 2.7 GHz, 80% amplitude modulated with 1 kHz sinewave) ³

1 Emissions which exceed the levels required by this standard may occur when the probe is connected to a test object.

2 This product is intended for use in nonresidential areas only. Use in residential areas may cause electromagnetic interference.

3 Meets Performance Criteria “B” limits of the respective standard: during the disturbance, product undergoes a temporary degradation or loss of function or performance which is self-recoverable.

Safety Compliance

The accessory meets intent of EC Directive 2006/95/EC for Product Safety. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

EN 61010-1:2010 Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements

EN 61010-2:030:2010 Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-030: Particular requirements for testing and measuring circuits

EN 61010-031/A1:2008 Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 031: Safety requirements for hand-held probe assemblies for electrical measurement and test.

- Installation (Overvoltage) Category I: Refers to signal level which is applicable for equipment measuring terminals that are connected to source circuits in which measures are taken to limit transient voltages to an appropriate low level.
- Pollution Degree 2: Refers to an operating environment where normally only dry non-conductive pollution occurs. Occasionally a temporary conductivity caused by condensation must be expected.

Environmental Compliance

END-OF-LIFE HANDLING



The probe is marked with this symbol to indicate that it complies with the applicable European Union requirements to Directives 2002/96/EC and 2006/66/EC on Waste Electrical and Electronic Equipment (WEEE) and Batteries.

The probe is subject to disposal and recycling regulations that vary by country and region. Many countries prohibit the disposal of waste electronic equipment in standard waste receptacles. For more information about proper disposal and recycling of your

Teledyne LeCroy product, please visit teledynelecroy.com/recycle.

RESTRICTION OF HAZARDOUS SUBSTANCES (ROHS)

This probe has been classified as Industrial Monitoring and Control Equipment and is outside the scope of the 2011/65/EU RoHS Directive until 22 July 2017 (per Article 4, Paragraph 3).

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