



DPO70E1
33 GHz Optical Probe
User Manual





**DPO7OE1
33 GHz Optical Probe
User Manual**

Warning

The servicing instructions are for use by qualified personnel only. To avoid personal injury, do not perform any servicing unless you are qualified to do so. Refer to all safety summaries prior to performing service.

This document supports DPO7OE1 software version 1.0 and above.

www.tek.com

071-3558-00

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Contacting Tektronix

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USA

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Important safety information

This manual contains information and warnings that must be followed by the user for safe operation and to keep the product in a safe condition.

To safely perform service on this product, see the *Service safety summary* that follows the *General safety summary*.

General safety summary

Use the product only as specified. Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. Carefully read all instructions. Retain these instructions for future reference.

This product shall be used in accordance with local and national codes.

For correct and safe operation of the product, it is essential that you follow generally accepted safety procedures in addition to the safety precautions specified in this manual.

The product is designed to be used by trained personnel only.

Only qualified personnel who are aware of the hazards involved should remove the cover for repair, maintenance, or adjustment.

Before use, always check the product with a known source to be sure it is operating correctly.

This product is not intended for detection of hazardous voltages.

To avoid fire or personal injury

Do not operate without covers. Do not operate this product with covers or panels removed, or with the case open. Hazardous voltage exposure is possible.

Do not operate with suspected failures. If you suspect that there is damage to this product, have it inspected by qualified service personnel.

Disable the product if it is damaged. Do not use the product if it is damaged or operates incorrectly. If in doubt about safety of the product, turn it off and disconnect the power cord. Clearly mark the product to prevent its further operation.

Examine the exterior of the product before you use it. Look for cracks or missing pieces.

Use only specified replacement parts.

Do not operate in wet/damp conditions. Be aware that condensation may occur if a unit is moved from a cold to a warm environment.

Do not operate in an explosive atmosphere.

Keep product surfaces clean and dry. Remove the input signals before you clean the product.

Service safety summary

The *Service safety summary* section contains additional information required to safely perform service on the product. Only qualified personnel should perform service procedures. Read this *Service safety summary* and the *General safety summary* before performing any service procedures.

Do not service alone. Do not perform internal service or adjustments of this product unless another person capable of rendering first aid and resuscitation is present.

Verify safety after repair. Always recheck ground continuity and mains dielectric strength after performing a repair.

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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.*

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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



When this symbol is marked on the product, be sure to consult the manual to find out the nature of the potential hazards and any actions which have to be taken to avoid them. (This symbol may also be used to refer the user to ratings in the manual.)

The following symbols may appear on the product:



CAUTION
Refer to Manual

Compliance Information

This section lists the EMC (electromagnetic compliance), safety, and environmental standards with which the instrument complies.

Questions about the following compliance information may be directed to the following address:

Tektronix, Inc. PO Box 500, MS 19-045
Beaverton, OR 97077, USA
www.tek.com

Environmental compliance

This section provides information about the environmental impact of the product.

Product end-of-life handling

Observe the following guidelines when recycling an instrument or component:

Equipment recycling. Production of this equipment required the extraction and use of natural resources. The equipment may contain substances that could be harmful to the environment or human health if improperly handled at the product's end of life. To avoid release of such substances into the environment and to reduce the use of natural resources, we encourage you to recycle this product in an appropriate system that will ensure that most of the materials are reused or recycled appropriately.



This symbol indicates that this product complies with the applicable European Union requirements according to Directives 2012/19/EU and 2006/66/EC on waste electrical and electronic equipment (WEEE) and batteries. For information about recycling options, check the Tektronix Web site (www.tek.com/productrecycling).

Preface

This manual describes the installation, operation and maintenance of the DPO7OE1 33 GHz Optical Probe for use with the DPO/MSO70000 C/DX/SX model oscilloscopes.

Manual structure

This manual is composed of the following chapters:

- *Getting started* describes how to install and configure your optical module.
- *Operating basics* describes how to control the module using the front panel and the instrument user interface.
- *Reference* provides information on optical bandwidth, Optical Reference Receiver (ORR) performance, and nominal characteristics.
- *Appendix A* describes the Programming Interface (PI) commands.

Related documentation

The DPO7OE1 is used as part of a larger instrument system. Measurement, calibration, and other settings are set from the main instrument controls.

See the instrument online help and documentation for information on setting up and taking measurements, instrument specifications, programming commands, and performance verification procedures. You can download the latest version of these documents from the Tektronix website (www.tek.com/product-support).

Part number	Document
071-3357-xx	DPO70000SX Series Primary User Manual
071-2980-xx	MSO/DPO70000 Series Primary User manual
077-1377-xx	DPO7OE1 Specifications and Performance Verification Technical Reference
077-1378-xx	DPO7OE1 Declassification and Security Instructions
077-0048-xx	DPOJET Jitter, Noise and Eye Diagram Analysis Solution User Manual
077-1207-xx	PAM4 Analysis Software User Manual
077-1375-xx	DPO7OE1 Datasheet

Getting started

This section contains a description of the DPO7OE1 optical probe and information about features, options, accessories, and recommended software.

Product description

The DPO7OE1 is a 33 GHz, low noise, broad wavelength optical probe with Optical Reference Receiver (ORR) performance for 28 GBd PAM4 and PAM2 (NRZ). The DPO7OE1 can also be used as a conventional Optical-to-Electrical (O/E) converter for wide-bandwidth optical signal acquisition. The DPO7OE1 provides an FC/PC or FC/APC optical connection for Tektronix DPO/MSO70000 C/DX/SX model oscilloscopes for high-speed optical signal verification.

The DPO7OE1 is intended to be used as a test and measurement tool for general purpose characterization of ultra-fast optical signals, and for physical layer conformance testing of very-high bit rate, fiber-optic time-domain optical signals such as 100 Gb/s telecommunication or data communication signals.

The DPO7OE1 has a TekConnect interface that allows it to plug into any 70kC/DX/SX TekConnect channel. Optical signals up to 33 GHz may be acquired on the respective TekConnect channel that the DPO7OE1 is plugged into.



Figure 1: DPO7OE1 33 GHz optical probe with shuttle attached to carrier



Figure 2: DPO7OE1 with shuttle detached from carrier

Optical signals may also be acquired on a higher-bandwidth ATI channel by decoupling the DPO7OE1 shuttle from its carrier and coupling the shuttle RF output to the ATI 1.85 mm input connector on the oscilloscope. Acquiring signals on a high-bandwidth ATI channel maintains linear phase across the passband of the channel, making it possible to enable true optical reference receiver (ORR) quality filters up to bit-rates of 28.05 Gbps, which require a controlled frequency response up to 42 GHz.

The DPO7OE1 supports multi-carrier configurations and is compatible with either a single ATI channel or channels with the TekConnect interface. This versatility makes the DPO7OE1 optical probe suitable for use with all DPO70000SX, MSO/DPO70000DX, and MSO/DPO70000C series oscilloscopes.



Figure 3: DPO70OE1 supports multiple optical inputs and multi-carrier configurations

Key features

All DPO70OE1 optical probes are custom configured, high-bandwidth optical acquisition modules suitable for use in a variety of test and measurement applications and systems. Key features of the DPO70OE1 include:

- High bandwidth, real-time optical signal acquisition with responsivity from 750 nm through 1650 nm
- Calibrated vertical scale at 850 nm, 1310 nm, and 1550 nm
- Dual connectivity option: TekConnect or ATI
- Up to 33 GHz electrical bandwidth with DSP correction on TekConnect channels
- Up to 43 GHz electrical bandwidth with DSP correction on ATI channels
- Single-mode and Multi-mode (50um) optical fiber input compatibility
- FC/PC and FC/APC input connector option
- Measured S-parameters for unique, optimized DSP filter construction on every converter/channel pair
- Bandwidth Filter settings for baud rates up to 28.05 Gb/s (100Gigabit Ethernet, OTU4(x4), 32GFibreChannel)
- Up to 4 optical inputs on a single DPO70000C/DX/SX series scope

Options and accessories

Product options The following product options are available:

NOTE. Select an optical input connector type from the following mandatory, mutually exclusive options. One of these options must be ordered when you purchase the DPO7OE1.

Option	Description
FC/APC ¹	FC/APC optical input connector (typically used in research applications)
FC/PC	FC/PC optical input connector (typically used in network/data center network applications)

Standard accessories The following standard accessories are provided with the product:

Accessory	Tektronix part number
Hard case (see Figure 4: Hard case accessory on page 5)	024-0018-xx
User manual (English)	071-3558-xx
Optical fiber cleaning tool	006-8217-xx
ATI input support bracket	407-6082-xx
Certificate of Traceable Calibration	NA
One year warranty	NA

Optional accessories The following optional accessory is available:

Accessory	Tektronix part number
Optical connector cleaner	006-8327-xx

¹ Option FC/APC limits the probe responsiveness to the wavelength range 1260 nm to 1650 nm.



Figure 4: Hard case accessory

Required and recommended oscilloscope software

Required oscilloscope software version

The DPO7OE1 probe is compatible with all DPO70000SX, MSO/DPO70000DX, and MSO/DPO70000C Series oscilloscopes. To use the DPO7OE1, these oscilloscopes must be running one of the following firmware versions:

- **70 GHz oscilloscope models:** Version 10.8.0 or later.
- **All other oscilloscope models:** Version 10.8.1 or later.

**Recommended
oscilloscope application
software**

The DPO7OE1 optical probe enables deep analysis of PAM4 and PAM2 (NRZ) signaling by using the following Tektronix DPOJET Jitter and Eye Analysis and PAM4 Analysis software installed on the oscilloscope.

Application software	Description
PAM4-O	Optical measurements for PAM4
DJA	DPOJET Jitter and Eye Diagram Analysis with PAM4
DJAN	DPOJET Jitter and Eye Diagram Analysis with Vertical Noise Separation
SDLA	Serial Data Link Analysis

Installation

Electrostatic discharge

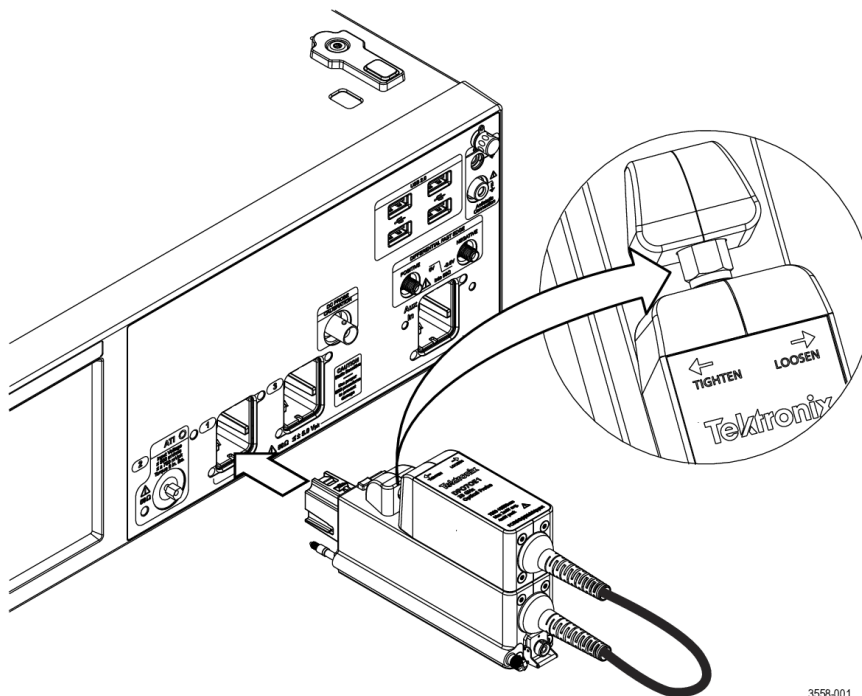
To prevent electrostatic damage to the main instrument and optical modules, follow the precautions described in this manual and the manuals accompanying your main instrument.



CAUTION. *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 any electrical cables before attaching them to the DPO7OE1 shuttle RF output.*

**TekConnect probe
installation**

The following procedure describes how to connect the DPO70E1 to the oscilloscope.



3558-001

Figure 5: Connecting the DPO70E1 probe to the oscilloscope

1. Remove the probe from the hard case.
2. If necessary, attach the probe shuttle to the carrier:
 - a. Set the shuttle into the slot on top of the probe carrier and slide the shuttle forward.
 - b. As shown on the shuttle label, tighten the nut on the probe shuttle counter-clockwise using a torque wrench set to 8 in-lbs.



CAUTION. To prevent damage to the probe, do not over-torque the shuttle electrical connector.

3. Plug the probe into the oscilloscope.
4. Tighten the thumbscrew on the rear of the probe to secure the probe to the oscilloscope.

Once the probe has been connected to the oscilloscope, the probe will be automatically detected by the system.

ATI channel installation

The following procedure describes how to connect the DPO7OE1 probe shuttle to an ATI channel on the oscilloscope.

Before you install the probe shuttle on the ATI channel, install the probe on the oscilloscope TekConnect Channel 1. See [TekConnect probe installation](#) on page 7.

1. Before disconnecting the shuttle from the probe carrier, install the ATI shuttle bracket on ATI channel of the oscilloscope.

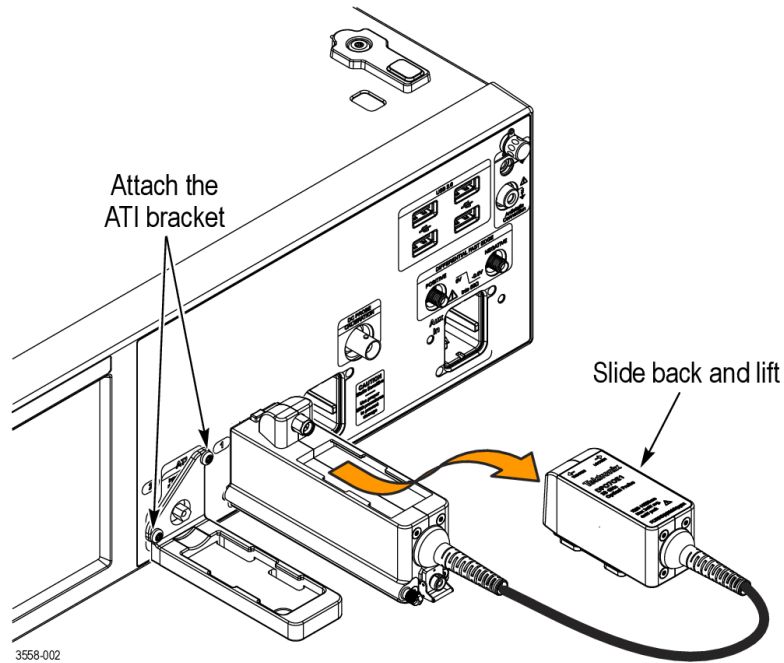


Figure 6: Attaching the ATI bracket and removing the shuttle from the probe carrier

2. Use a torque wrench set to 8 in-lbs. to loosen the shuttle nut on the probe by turning the nut clockwise (right). The directions for loosening and tightening the nut are on the label of the probe.



CAUTION. To prevent damage to the probe or to the ATI input connector on the oscilloscope, do not over-torque the shuttle electrical connector.

3. Turn the nut clockwise (right) to remove the shuttle.
4. Lift the shuttle off of the carrier by sliding the shuttle slightly back towards you and lift straight off.

5. Set the shuttle into the slot on top of the ATI bracket and slide the shuttle forward.

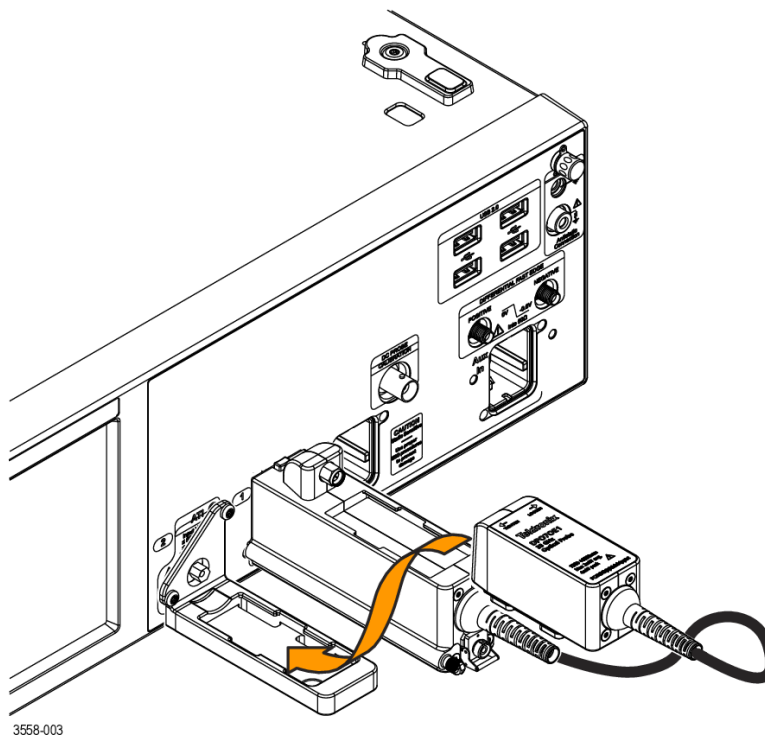


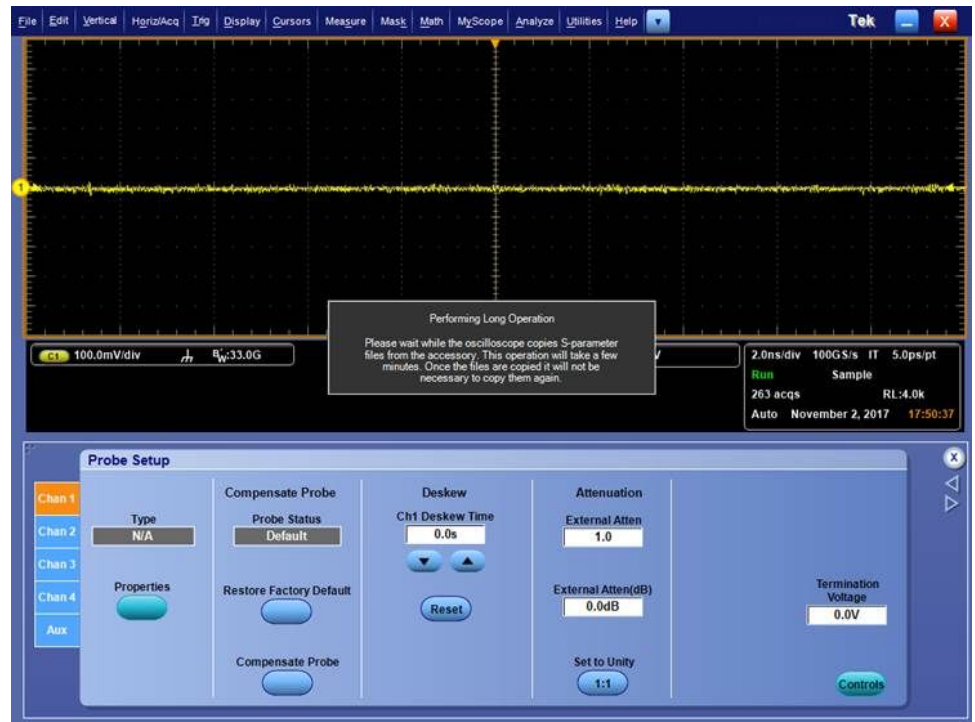
Figure 7: Attaching the shuttle to the ATI bracket

6. Tighten the nut on the shuttle counter-clockwise (left) using a torque wrench set to 8 in-lbs. to secure the shuttle to the ATI bracket.

Once the probe shuttle has been connected to the oscilloscope, the probe will be automatically detected by the system.

First turn on functional checks

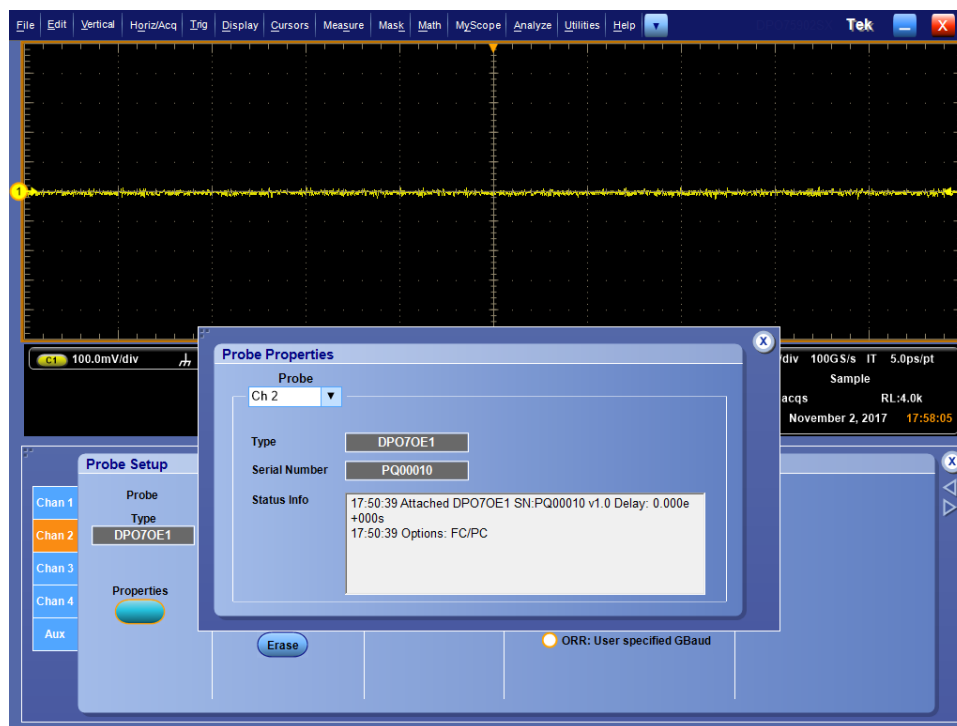
1. When a DPO70E1 is plugged into a 70k series oscilloscope for the first time, measured S-parameters for the probe are copied from the probe internal memory to build custom correction filters. The message pictured below appears on the screen while this process takes place. Total operation time may take over a minute.



2. Once complete, the message will disappear.

Verify that the message appears the first time the probe is attached to the instrument.

3. The probe model number and serial number can be verified in the Probe Properties screen, accessible from the Probe Setup menu.



4. Attach the probe to the instrument.
5. Select **Vertical > Vertical Setup**. Select the tab for the channel that the probe is attached to.
6. Press the **Properties** button.

The Probe Properties window is displayed.

7. Verify the probe model number and serial number.

Operating basics

This section presents the basic information necessary to connect and operate the DPO7OE1 optical probe.

Operational safety and probe handling

Refer to the *Important safety information* at the beginning of this document for more information on safety issues.



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

Do not drop the probe since damage and misalignment of the photodiode optical assembly can result. Store the module in a secure location, such as the hard case provided with the probe, when the probe is not in use.

Secure the shuttle to the probe carrier when storing the probe in order to protect the RF connectors.

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

Do not crush, crimp, or sharply bend the fiber optic cable.

Do not pull or yank the fiber optic cable.

To prevent loss of optical power or damage to the optical connectors, keep the connectors clean at all times. Check that all connectors and protective caps are clean before connecting them to the probe. See [Cleaning optical connectors](#) on page 17.

Connecting optical signals to the probe

This procedure describes how to connect a fiber optic cable to the DPO7OE1.

The DPO7OE1 O/E converter can be connected to optical fibers with a core diameter of up to 50 μm through the FC optical input.

Optical fibers being connected should be cleaned every time before making a connection. See [Cleaning optical connectors](#) on page 17.



CAUTION. *To maintain the high performance (low return loss), connect an adapter and cable between the input of the O/E converter and the device under test. When you make connections to other devices, leave the adapter and cable in place to protect the optical connector of the O/E converter from wear.*

FC/PC connections and FC/APC connections are not interchangeable. Interchanging these connections can potentially damage the optical input of the DPO7OE1 probe.

If you connect fiber cores larger than 50 μm , the O/E converters may still couple light, but the mismatch in core diameter will cause lower conversion gain.

The probe should be connected to the oscilloscope before you connect the fiber optic cable to the probe. See [TekConnect probe installation](#) on page 7. See [ATI channel installation](#) on page 8.

1. On the probe, unscrew the metal cap from the optical input receptacle.
2. Align the key on the optical fiber connector or adapter with the slot on the probe input, and then firmly press the cable connector or adapter into the interface alignment sleeve until it reaches the stop.

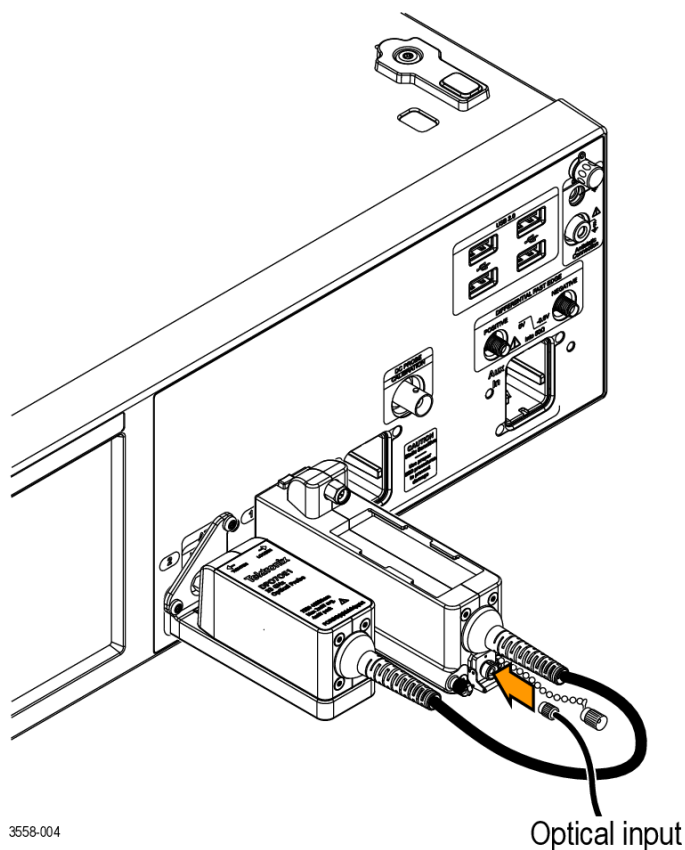


Figure 8: Connecting the optical input cable to the probe

3. Using finger pressure only, firmly tighten the cable connector or the adapter shell.

Once the fiber optic cable has been connected to the probe, the oscilloscope will be ready to perform measurements on the cable signal.

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 the input optical signal to below the Absolute Maximum Nondestructive Optical Input (peak) specification. To maintain the levels within performance range and to avoid clipping, use the following table to set the maximum optical input signal levels:

Table 1: Maximum optical signal levels

Average	Peak
4 mW	8 mW

NOTE. Optical probes may have dynamic ranges exceeded without obvious visual indication onscreen because the overloaded signal output of the photodetector may still be within the dynamic range of the oscilloscope electrical channel.

System interaction

Your optical probe is a part of a larger instrument system. Most optical probe 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.

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.

Cleaning optical connectors

To keep the DPO7OE1 in good operating condition, observe proper cleaning and handling techniques. 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 fiber-optic connectors, keep the connectors clean at all times.*

When cleaning the connectors with a swab, use gentle circular motions. Use only high quality or recommended cleaning supplies that are non-abrasive and leave no residue.

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

Required supplies

Use the following supplies to clean optical connectors:

- Dry, clean, and dust-free compressed air (such as Tektronix part number 118-1068-xx)
- FIS cassette cleaner (such as FI-6270) and/or FIS tape dispenser cleaner (such as FI-7111)
- Pipe cleaner

Cleaning procedure

To remove contamination, clean the fiber-optic connectors using the following procedure:



CAUTION. *Clean both ferrule end-faces with a dry cloth tape cleaner (cassette or tape dispenser).*

1. Remove the JAE connector from the probe:

- a. Unscrew the metal dust-cap from the optical connector.



Figure 9: Removing the metal dust-cap from the optical connector

- b. Lift up on the JAE connector latch and pull the connector away from the probe. This exposes the male fiber end-face behind the JAE connector.

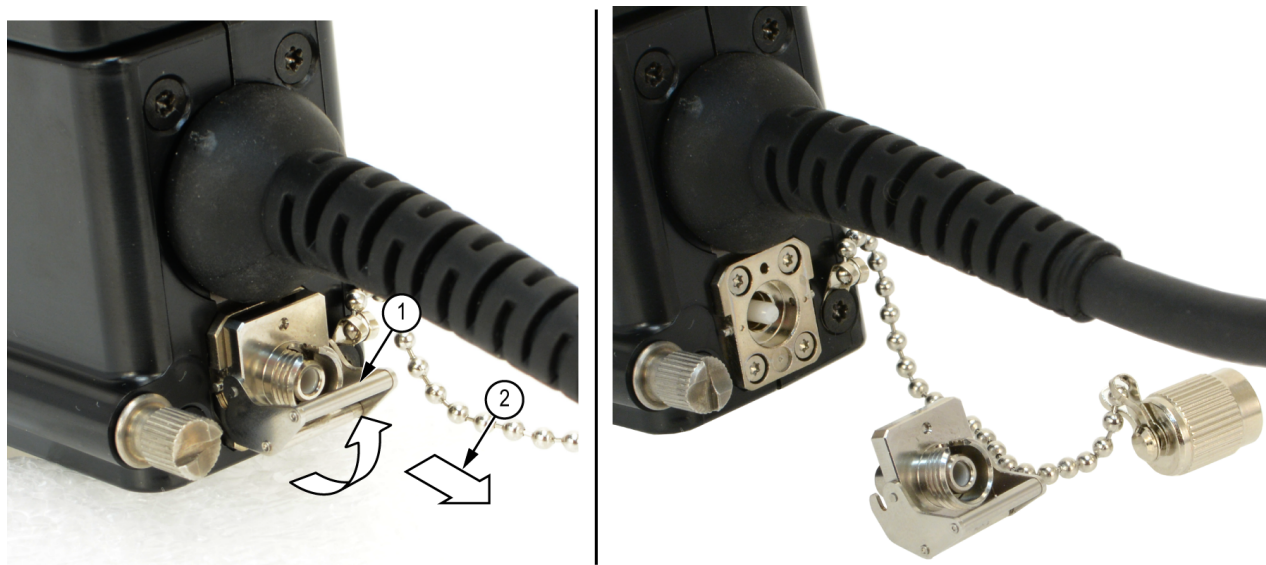


Figure 10: Removing the JAE connector from the probe

2. Clean contaminants from the inside wall of the hollow female-to-female ferrule alignment tube inside the JAE connector:
 - a. Use the compressed air can to clean the female input of the JAE connector end-to-end.
 - b. Use the pipe cleaner to clean the inside of the JAE connector.



Figure 11: Cleaning the JAE connector



CAUTION. Do not blow compressed air into the female input of the JAE connector when it is installed on the module.

3. Advance the fiber cleaning cassette or tape-dispenser cleaner to expose an unused clean section of the lint-free, dry, cleaning surface.
4. 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).
5. Install the JAE connector back on the cleaned fiber end-face. The latch will snap into position when the connector is properly installed.
6. When the module does not have a fiber attached to its input(s), attach the metal dust-cap to prevent airborne contaminants from lodging in the female optical input.
7. Use a cleaning cloth to clean any male fiber end-face input fiber or device that you attach to the JAE connector input.

NOTE. Use a similar cleaning method to clean the fiber end-face input fiber or device.

Cleaning the exterior of the probe

The case of the module keeps dust out and should not be opened. Remove the probe from the oscilloscope before cleaning the exterior of the probe.



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

Clean the exterior surfaces of the probe carrier and shuttle 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 connectors. Do not allow moisture inside the probe. Do not use abrasive compounds on any part of the probe casing that may damage the casing.



CAUTION. *To prevent damage to the probe, avoid the use of chemical cleaning agents which might damage the plastics in the probe. 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 probe. There are no user serviceable components and cleaning the interior is not required.

Probe setup

The DPO7OE1 has two factory-only configurable options, which determine the optical user interface and the optical wavelength range of the instrument:

- **Option FC/PC** uses an FC/PC ferrule connector, which is attached to a 50 μm core, multi-mode optical fiber. This fiber is spliced to the 50 μm core, multi-mode fiber coupled to the O/E photodiode. With this option, the wavelength range of the DPO7OE1 is 750 nm to 1650 nm.
- **Option FC/APC** uses an FC/APC ferrule connector, which has an angled physical contact interface to improve the optical return loss of the connector interface. This type of interface is only available with single-mode fiber pigtails, so this option limits the usable wavelength range of the DPO7OE1 to 1260 nm to 1650 nm.

The following procedures describe how to setup the DPO7OE1 optical probe using a TekConnect installation. The setup procedure for an ATI installation is the same except the channel number and available bandwidth frequencies will be different.

Configuration overview

Before taking measurements with the DPO7OE1 probe, you should perform the following steps:

1. Install the probe on the oscilloscope.
2. Select **Vertical > Vertical Setup** to open the Vertical Setup screen. See [Vertical Setup settings](#) on page 22.
3. On the oscilloscope, select the channel with the probe installed.
4. Click **Probe Cal** to open the Probe Setup screen. See [Probe Setup settings](#) on page 28.
5. Select the wavelength of the signal you are measuring. If necessary, create a custom wavelength.
6. Perform a Signal Path Compensation (SPC) to ensure that your measurements have the highest level of accuracy. See [Signal path compensation](#) on page 32.
7. Perform a Dark Cal calibration to correct any DC offset error caused by photodiode leakage current; commonly referred to as Dark Current. See [Dark level compensation](#) on page 32.
8. Attach the optical input signal cable to the DPO7OE1.
9. Select the desired Frequency Response setting.
10. On the Vertical Setup screen, verify that the Termination, Coupling, and Bandwidth settings are correct.
11. Use the Position, Scale, Offset, Invert, and Vertical Zoom settings to obtain the desired view of the waveform.
12. Use the Deskew and Attenuation controls to compensate for propagation delays of different length signal cable and probe combinations and to set the input/output ratio of any external attenuation or gain between the signal and input channels.

Vertical Setup settings

This section describes the settings on the Vertical Setup screen. To view the Vertical Setup screen for the probe, select **Vertical > Vertical Setup**, and then select the oscilloscope channel with the DPO7OE1 probe installed.

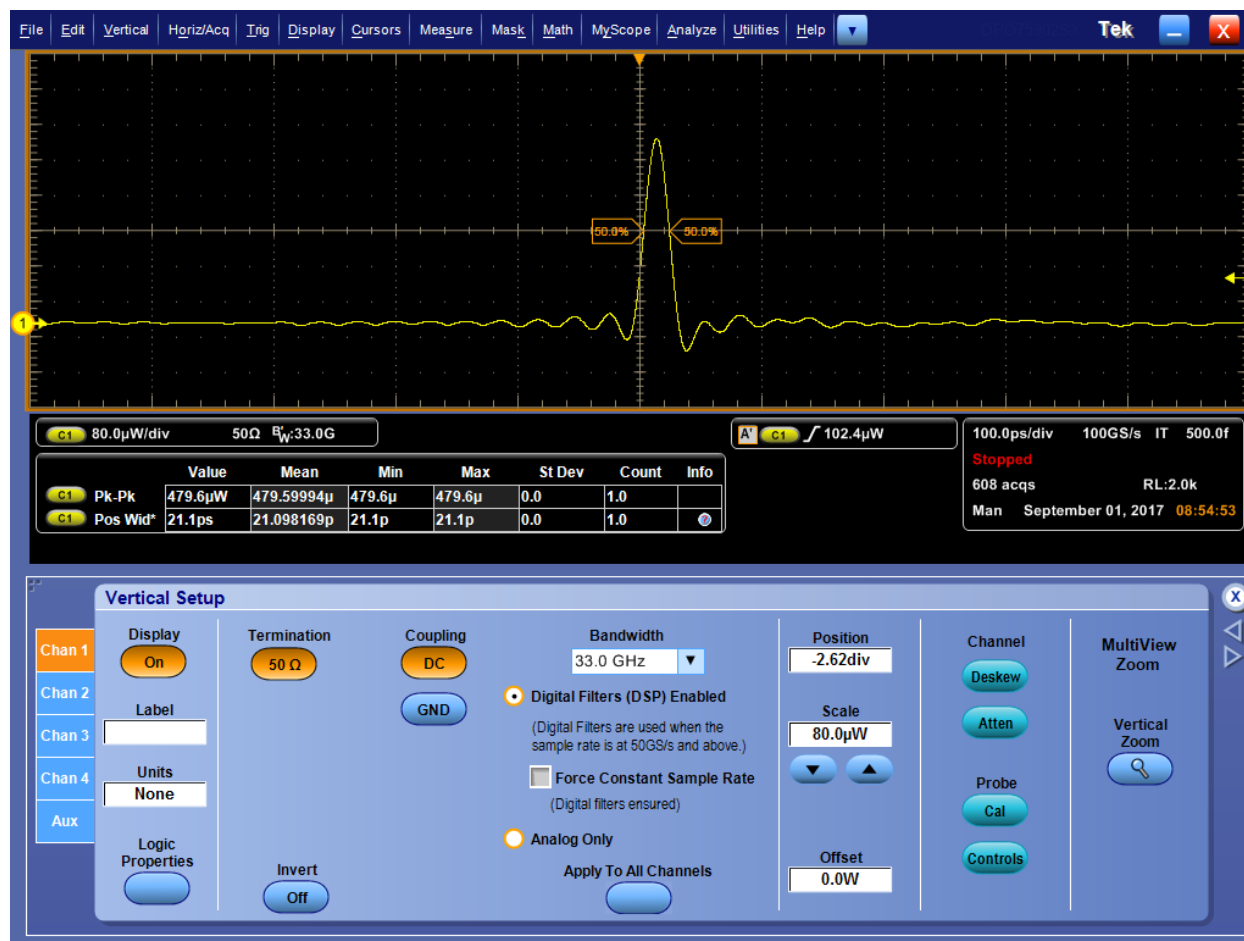


Figure 12: Vertical Setup screen

- **Display.** Click the Display button to turn the channel waveform display on or off.
- **Label.** Use the Label entry box to assign a label to the waveform as follows:
 1. Click in the Label entry box, and then use the pop-up keyboard to create a label for the selected waveform.
 2. Click in the X Position and Y Position entry boxes to activate them.
 3. Use the multipurpose knobs to position the label on the graticule. You can also position the label anywhere on the screen by clicking and dragging it to the desired location.
- **Units.** Click in the Units entry box to select custom vertical units for the waveform display.
- **Logic Properties.** Click Logic Properties when you want to specify the voltage threshold level(s) of the Ch1-Ch4 (live) and M1-M4 (math) channels to use as logic waveforms and to include in a bus.

- **Termination.** The Termination button displays the input termination, which is automatically set by the oscilloscope.
- **Invert.** Click Invert to turn the inverting of the waveform on or off.
- **Coupling.** Use the Coupling controls to select the desired input coupling:
 - Select **DC** to display waveforms with AC and DC components.
 - Select **GND** to display a zero-volt waveform. Use this selection to establish the ground reference point on the display.
- **Bandwidth.** Use the Bandwidth drop-down list to select the bandwidth of the input signal. Bandwidth refers to the range of frequencies the instrument can acquire and display accurately with less than 3 dB attenuation.

NOTE. To take accurate measurements, the input frequency should be much less than the rated bandwidth of the instrument. A good rule to follow is to ensure the bandwidth of the instrument system is three to five times the bandwidth of the signal that you want to measure.

Enable or disable Bandwidth Enhancement on the oscilloscope channel:

NOTE. The Bandwidth Enhancement controls allow you to use DSP processing to achieve more accurate rise time measurements, to extend the bandwidth, and to flatten the passband at the full sample rate. Enhanced Bandwidth also provides a matched response across enabled channels for channel-to-channel comparisons and differential measurements.

- Click **Digital Filters (DSP) Enabled** to activate the Bandwidth Enhancement filters.

NOTE. When the probe shuttle is connected to the ATI input channel on the oscilloscope, you cannot turn off DSP because DSP is required for all ATI channel acquisitions.

- Click **Apply to All Channels** to apply Bandwidth Enhancement to all channels simultaneously.
- Click **Force Constant Sample Rate** to have the instrument take the constant sample rate that you set in the Horizontal control window, and apply a sample rate supported by DSP. It then enables DSP and selects the appropriate bandwidth.
- Click **Analog Only** to disable Bandwidth Enhancement and return to Analog operation. The Bandwidth drop-down list adds (HW) to the selection indicating a hardware/analog-only filter.

- **Position and Scale.** Set the vertical position and scale sensitivity:

NOTE. *You can also use the dedicated knobs on the Auxiliary Front Panel to control the position and scale of the selected waveform.*

- Click in the Position entry box and use the multipurpose knobs to adjust the position of the waveform.
 - Click in the Scale entry box and use the multipurpose knobs to adjust the vertical sensitivity.
- **Offset.** Click in the Offset entry box and use a multipurpose knob to set the offset value.

NOTE. *Use the Offset controls to set the value of the selected Channel vertical offset. This shifts the vertical acquisition window to match the waveform data you want to acquire.*

Use the Offset control to eliminate clipping the waveform. The offset control affects the vertical acquisition window by subtracting a DC bias from the waveform. This moves the level at the vertical center of the acquisition window of the selected channel. Visualize offset as scrolling the acquisition window toward the top of a large signal for increased offset values and scrolling toward the bottom for decreased offset values.

The offset control affects the waveform display by defining the channel reference indicator to match the offset rather than the ground level. The offset affects only channel waveforms as compared to the position control that affects all waveforms, including math and reference waveforms.

- **Deskew and Attenuation.** Use the Deskew and Attenuation controls to compensate for propagation delays of different length signal cable and probe combinations and to set the input/output ratio of any external attenuation or gain between the signal and input channels. See [Deskewing optical channels](#) on page 26.

NOTE. *Use the Deskew/Attenuation/Invert controls to change the settings after you set up the Vertical Setup controls.*

- **Probe Cal.** Click the Probe Cal button to open the Probe Setup screen where you can perform probe compensation. See [Probe Setup settings](#) on page 28.

- **Probe Controls.** Click the Probe Controls button to open the Probe Controls screen shown below.

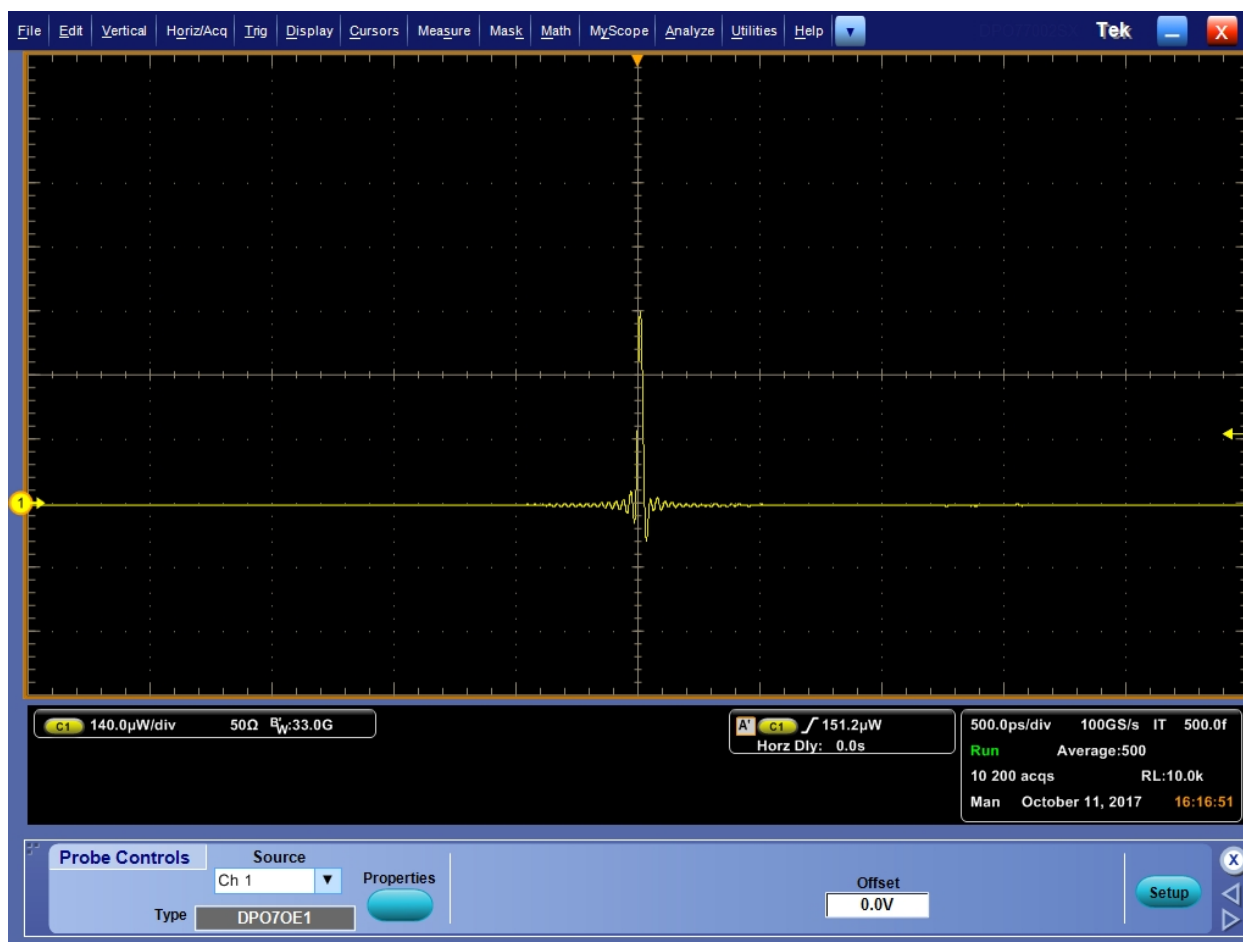


Figure 13: Probe Controls screen

- **Vertical Zoom.** Click Vertical Zoom to enable MultiView Zoom, which allows you to use the Multipurpose knobs to zoom in on the waveform.

Deskewing optical channels. Perform the following steps to deskew TekConnect and ATI channels:

1. Set the trigger mode to edge and adjust the trigger level on the reference channel until you have a stable trigger.
2. Open the Deskew Tool under the Analyze Menu.
3. Select the channels to deskew. Ensure that each channel has a live signal attached and it has an edge that is within 0.5 UI of the edge on the trigger channel.
4. Select the slope and level for each channel.
5. Wait for a sufficient population to be accumulated (the indicator near the To Mean button turns green).

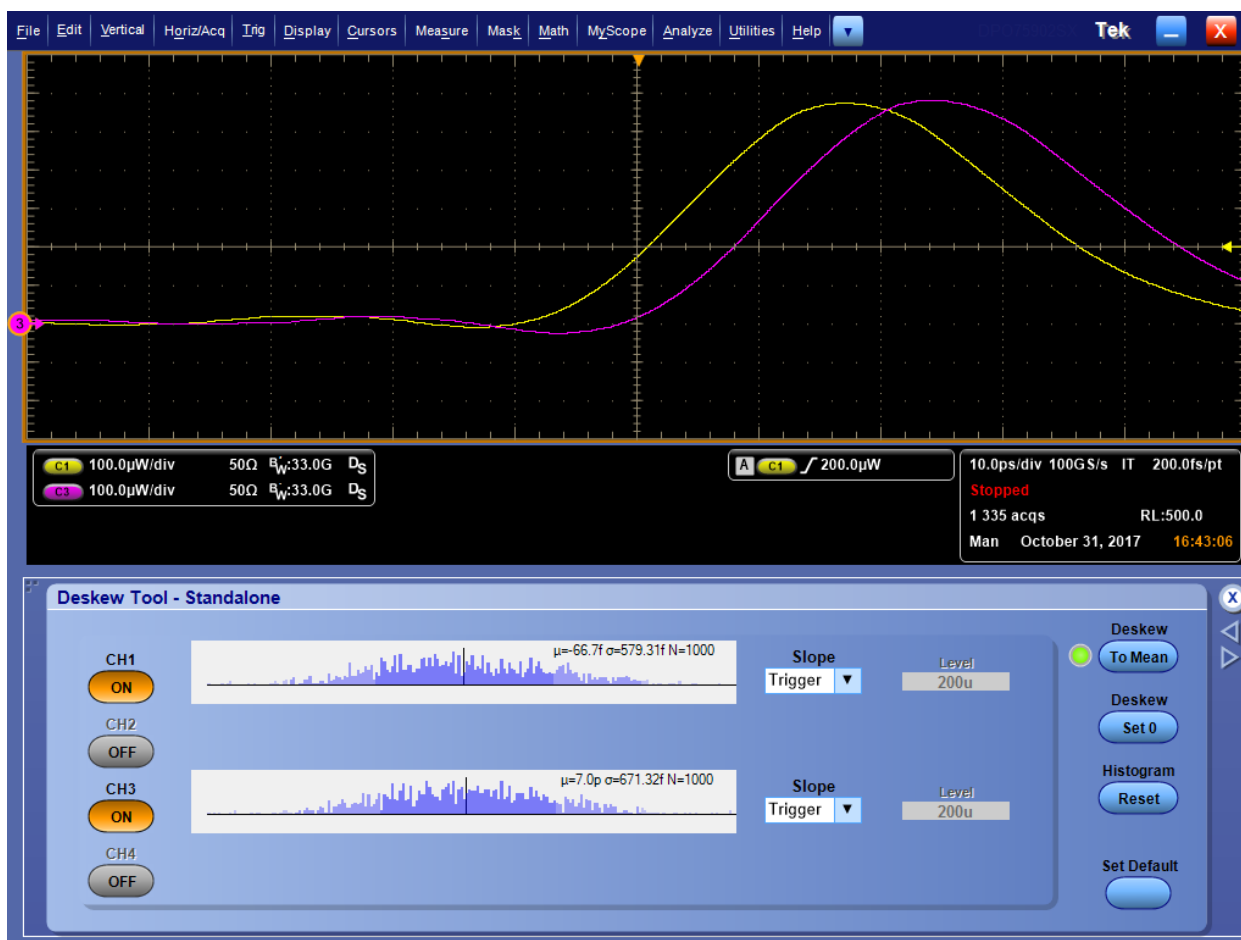


Figure 14: Example of initial deskewed waveform

6. Press the **To Mean** button.

7. Repeat steps 4 through 6 multiple times. Since the difference in resolution between ps and fs is large, the first deskew attempt gets you close and the second attempt gets into the fs range.

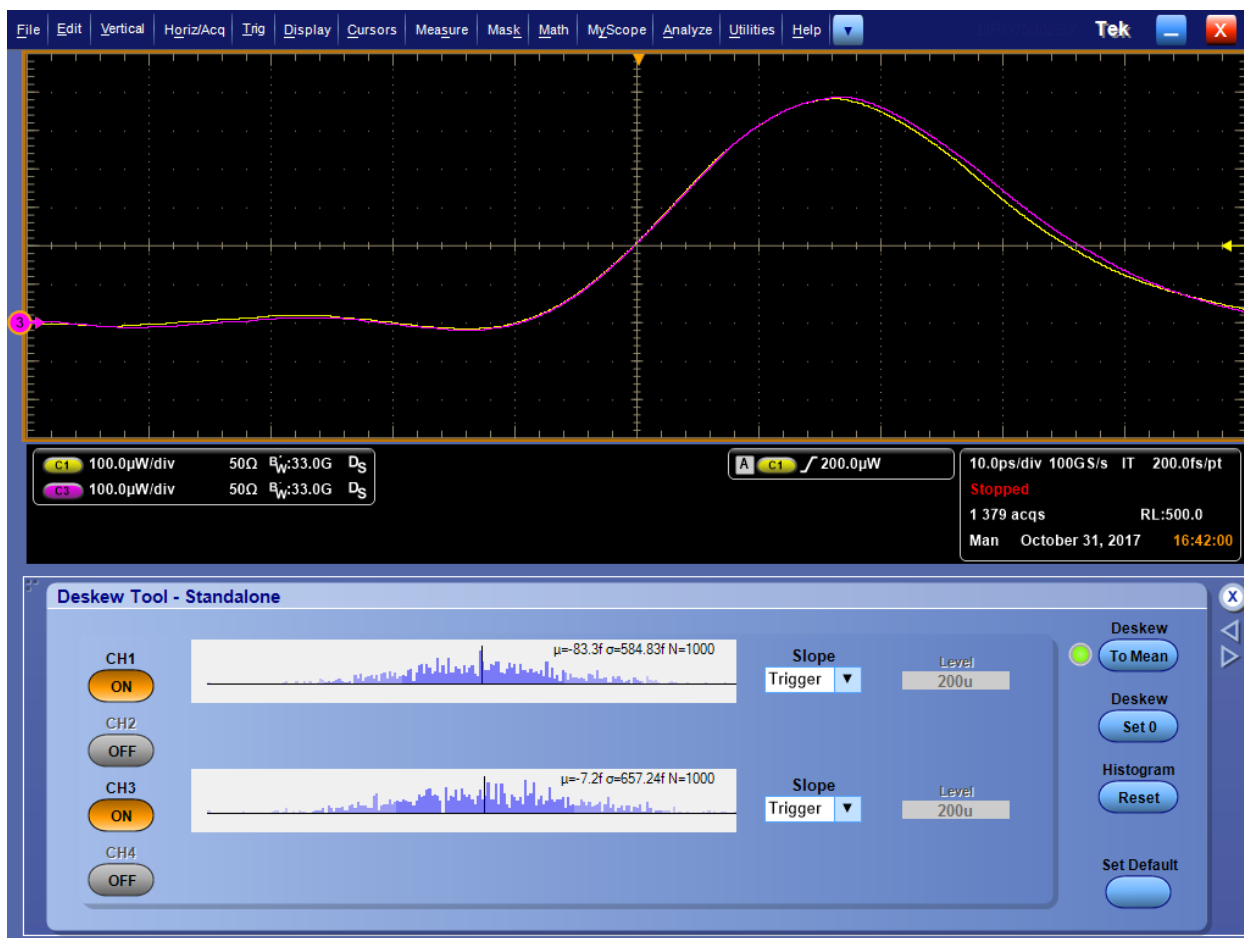


Figure 15: Example of final deskewed waveform

Probe Setup settings This section describes the settings on the Probe Setup screen. On the Vertical Setup screen, click **Probe Cal** to open the Probe Setup screen shown below.

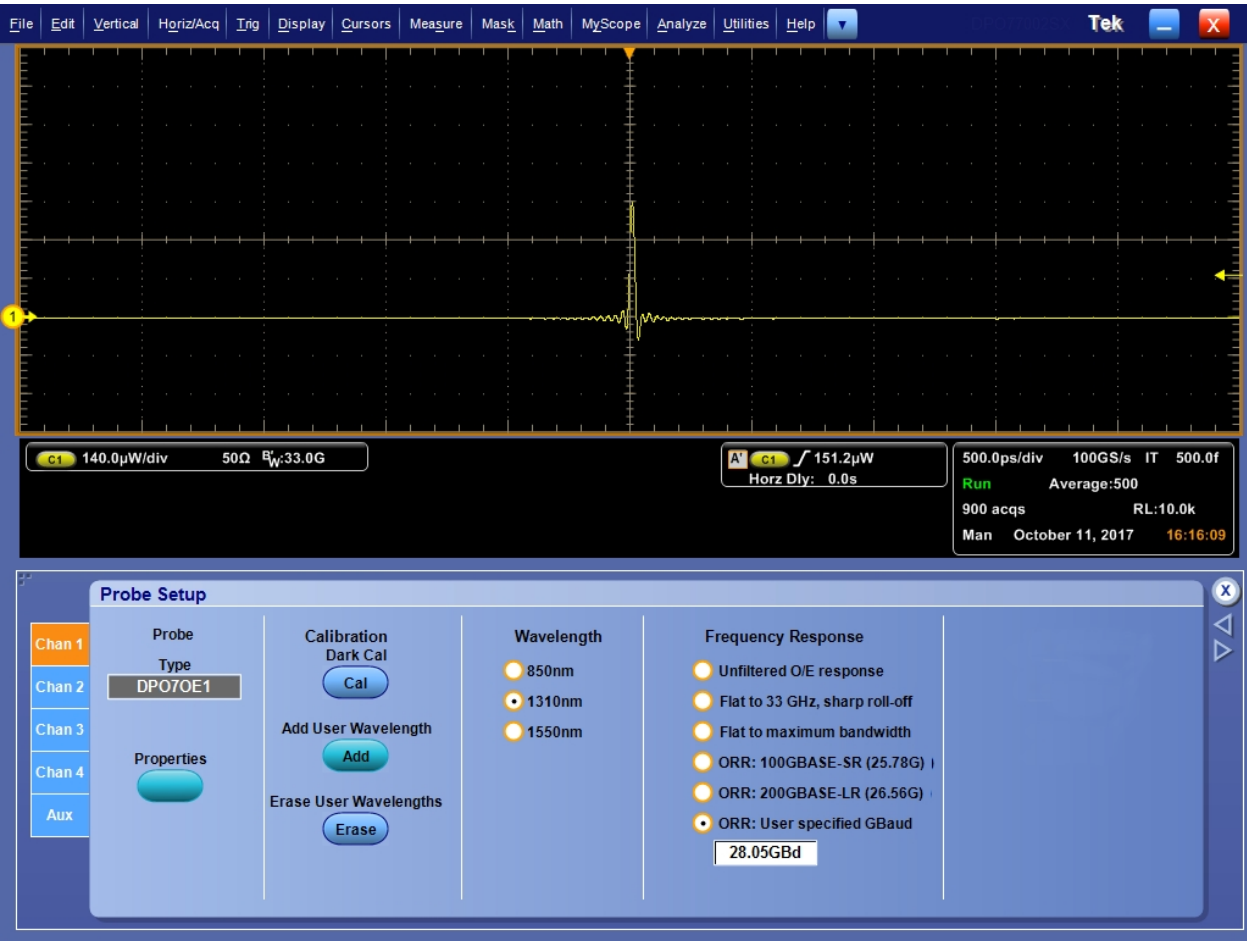


Figure 16: Probe Setup screen

- **Properties.** Click Properties to view the Probe Properties screen, which displays the selected channel number, the probe type and serial number, and the probe status.

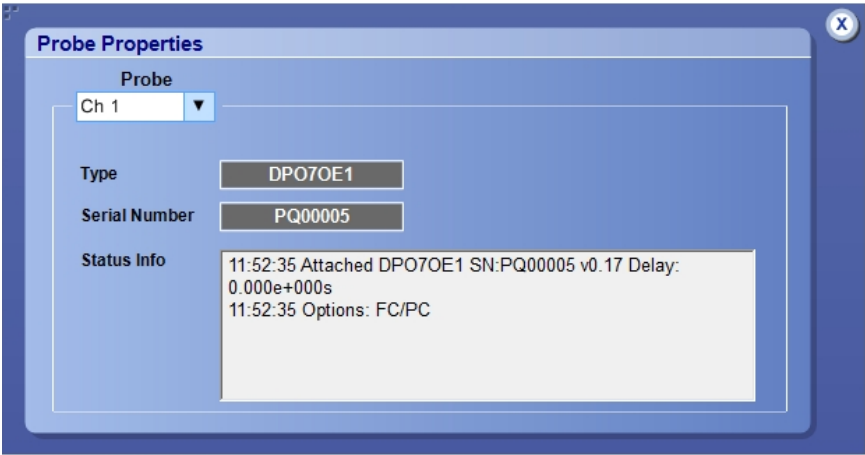
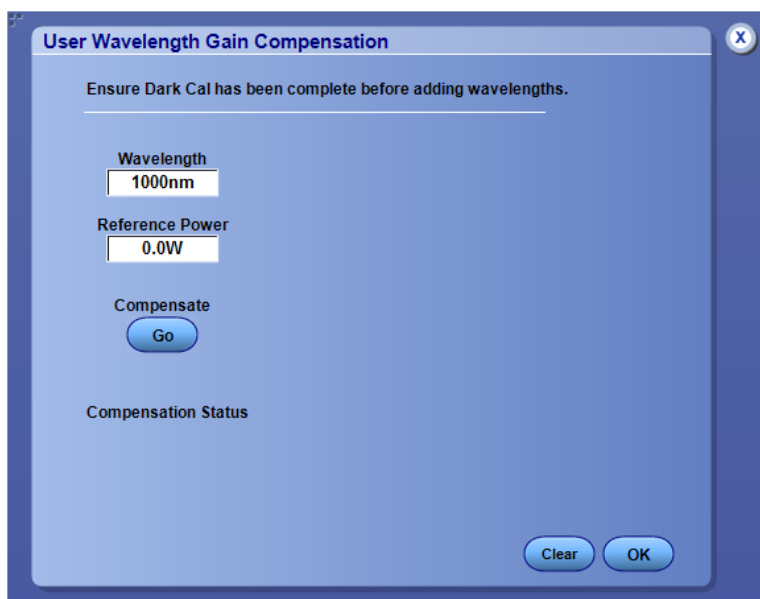


Figure 17: Probe Properties screen

- **Calibration Dark Cal.** Click Calibration Dark Cal to perform dark level compensation for the probe. See [Dark level compensation](#) on page 32.
- **Add User Wavelength.** Click Add User Wavelength to create a custom wavelength, which will be added to the list of standard Wavelength selections (850 nm, 1310 nm, and 1550 nm). See [Adding user wavelengths](#) on page 30.
- **Erase User Wavelengths.** Click Erase User Wavelengths to remove all custom wavelengths from the Wavelength list.
- **Wavelength.** Use the Wavelength radio buttons to select the wavelength of the input signal: 850 nm, 1310 nm, or 1550 nm. The 850 nm setting does not appear for probes with the Option FC/APC ferrule connector. When custom user wavelengths have been added, an additional User Cal'd radio button appears with a drop-down list where you can select from the custom wavelengths.
- **Frequency Response.** Use the Frequency Response radio buttons to select the desired O/E compensation correction. When you select the **ORR: 28GB-FC (28.05G)** option, an entry box appears, as shown above, where you can enter a custom frequency. See [Bandwidth for the Flat filter settings](#) on page 42. See [Bandwidth for the ORR filter settings](#) on page 42.

Adding user wavelengths. Perform the following steps to add user wavelengths:

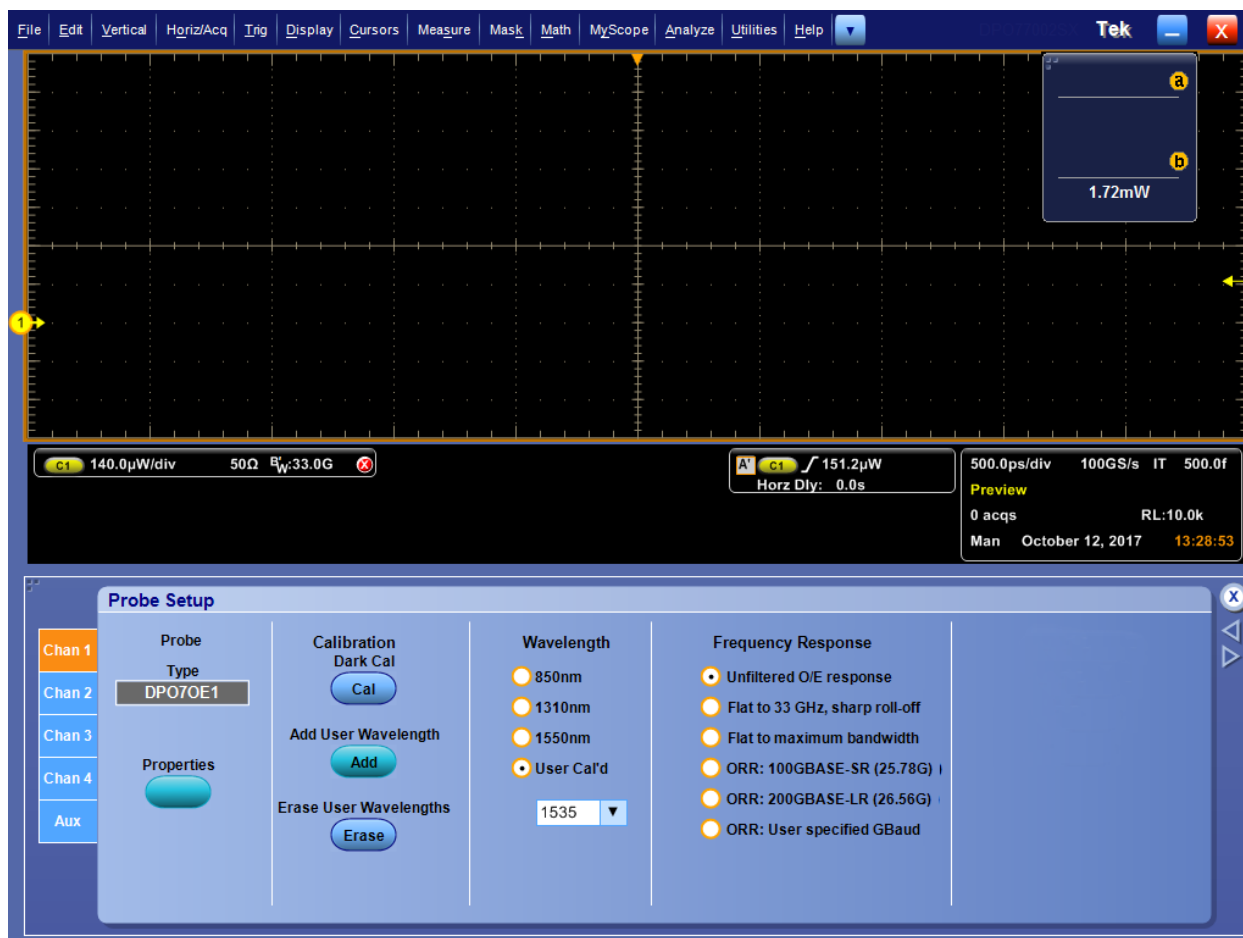
1. From the Probe Setup screen, click **Add User Wavelength**. This opens the User Wavelength Gain Compensation screen shown below.



CAUTION. To prevent incorrect measurements, be sure to perform a *Dark Cal* calibration before adding a user wavelength. See [Dark level compensation](#) on page 32.

2. Click in the **Wavelength** entry box and enter the wavelength of your input signal in nanometers. Enter only the number.
3. Click in the **Reference Power** entry box and enter the power in Watts. Enter the number and unit prefix. The reference power needs to be between 400 μ W and 3.2 mW. An error message will appear if the reference power entry is not in the correct range.
4. After you enter the Wavelength and Reference Power values, click **Compensate Go**. A message appears while the oscilloscope computes the correct gain.
5. Click **OK** to save the calculated wavelength and gain.

6. The Probe Setup screen will now show an additional **User Cal'd** radio button with a drop-down list of all user wavelengths.



Calibration

The DPO7OE1 is factory calibrated. The user can select one of three supported factory wavelengths:

- 850 nm (Option FC/PC only)
- 1310 nm
- 1550 nm

Dark level compensation

Precise optical measurements require that a dark level compensation has been done beforehand. Dark level compensation measures the average DC output of the DPO7OE1 when no light is present at the optical input. This measured value is then subtracted from all sampled values.

Use the following procedure to perform a dark level calibration prior to performing Extinction Ratio measurements:

1. Ensure no light source is entering the probe by removing all cables and using the attached cap to cover the O/E converter.
2. Open the Probe Setup screen.
3. Select the probe channel.
4. Click the **Dark Compensation Cal** button.

The display will pause for approximately 30 seconds while the calibration is performed.

Signal path compensation

Perform the Signal Path Compensation (SPC) regularly to ensure that your measurements have the highest level of accuracy. Tektronix considers it a best practice to run SPC when using the instrument to measure signals with higher sensitivity (10 mV/div and lower) settings regardless of temperature shift or time since it was last run. Failure to perform SPC may result in the instrument not meeting warranted performance levels.

SPC corrects for DC inaccuracies caused by temperature variation or by long-term drift. SPC optimizes the acquisition system, corrects DC offset, and interleaves calibration. SPC is adversely affected by input signals with AC components, so it is critical that all signals are removed from the oscilloscope inputs prior to running SPC.

Use this procedure to optimize the acquisition system:

- If the temperature has changed more than 5 °C (9 °F) since the last signal path compensation (SPC), or if it has been more than 30 days since the last SPC was performed.
- If using the instrument to measure signals with higher sensitivity (10 mV/div and lower) run SPC at least once a week
- If the front panel SPC status icon is not green

NOTE. *To view the SPC status icon, you must click the checkbox next to the selection in the instrument calibration UI that says "Always show SPC status icon (even when passing)."*

- If you replace or insert drive media
- If you change the configuration of your multi-instrument system, such as changing which instrument is the master or an extension
- If you change the reference clock from internal to external, or visa versa.

1. Prerequisites:

- Instrument must be powered on until Utility > Instrument Calibration > Temperature Status is Ready. This typically takes 20 minutes to an hour depending on the oscilloscope model.
- All channel input signals must be removed.
- If the timebase external reference mode is selected, leave the external reference signal connected and active.

2. Select **Instrument Calibration**.

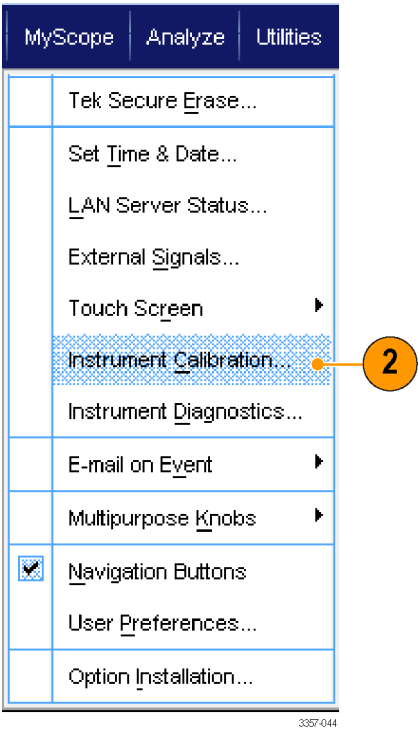


Figure 18: Utility menu on DPO70000 oscilloscopes

- When the Temperature Status changes to Ready, click **Run SPC** to start the calibration. Calibration may take 10 to 15 minutes.

NOTE. Before running the SPC calibration, remove all channel input signals.

If you use a drive that has not had SPC run while in the current instrument, you will see a no prior SPC warning message. If you see this warning, run SPC.

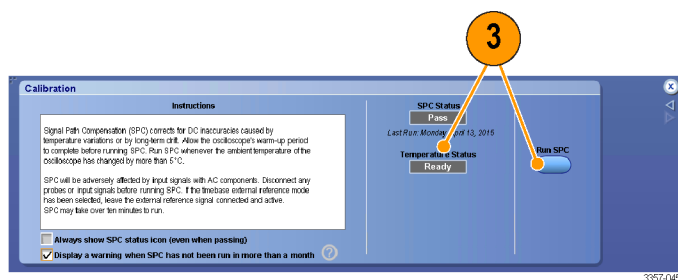
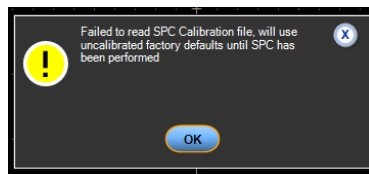


Figure 19: Calibration menu on DPO70000 oscilloscopes

4. If the instrument does not pass, recalibrate the instrument, or have the instrument serviced by qualified service personnel.

NOTE. To always show the SPC status icon or display a warning when SPC has not been run in more than a month, click the corresponding check box.

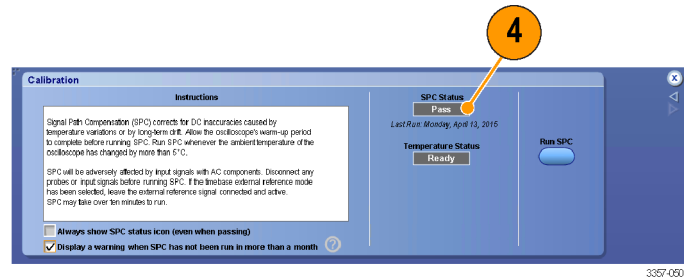
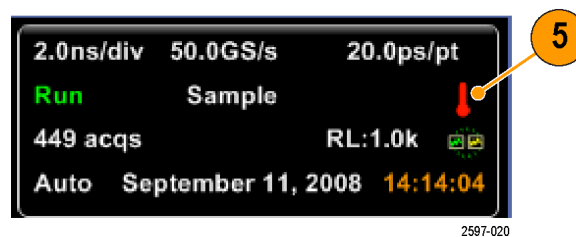


Figure 20: Calibration menu on DPO70000 oscilloscopes

5. If the SPC needed icon is red, perform a signal path compensation. Check the color of the SPC Status icon:
 - Green indicates that SPC successfully passed and the temperature is stable.
 - Yellow indicates that the instrument is in the warm up state or that it has been over 30 days since SPC was last run.
 - Red indicates that SPC needs to be run (the temperature has varied more than 5 °C, SPC failed, or SPC has not been run).



Signal path compensation status. The following table lists the possible status messages for signal path compensation and the recommended action.

Status	Meaning and recommended action
Compensated	The instrument had warmed up, there were no failures during the signal path compensation procedure, and the current operating temperature is within 5 °C of the operating temperature when the previous signal path compensation was run.
Fail	One or more failures occurred during the signal path compensation procedure. Contact your local Tektronix service representative for further action.
Temp	The operating temperature is not within 5 °C of the previous signal path compensation.
Warming up	The instrument has not warmed up. Wait for the instrument to complete its warm up period before running the signal path compensation procedure.

Optical filter and bandwidth settings

All bandwidth settings are done with DSP filters constructed by the oscilloscope software. Each individual converter has measured S-parameters stored in its internal memory that get used by the scope to construct each filter. The signal is not routed through any hardware filters.

The following table lists all of the available settings.

Filter name	3 dB optical bandwidth	4th order Bessel-Thomson	ORR compliant
Unfiltered O/E response	30 GHz	No	No
Flat to 33 GHz, sharp roll-off	33 GHz	No	No
Flat to maximum bandwidth	43 GHz ¹	No	No
28GB-FC28GB-FC	28.05 GHz	Yes	Yes ²
OTU4	27.95 GHz	Yes	Yes ²
200GBase-LR	26.56 GHz	Yes	Yes ²
100GBase-SR	25.78 GHz	Yes	Yes ²

¹ 43 GHz bandwidth is only available on ATI channels. On TekConnect channels, the two Flat filter options are identical.

² ORR compliance available only on ATI channels. The 23 GHz and 33 GHz channels have a bandwidth limit filter at the respective frequencies that windows the BT filter response in the frequency domain.

Electrical output

When mounted to the ATI support bracket, the O/E electrical output is limited to stay within the non-destruct input range of the ATI channel.



CAUTION. To prevent damage to the probe, always use the ATI support bracket when attaching the shuttle to an ATI channel.

Overload indicator

A red Overload indicator will appear on the oscilloscope screen when the channel has exceeded the dynamic range of the channel into which the DPO7OE1 shuttle is currently attached. As shown below, when you hover the cursor over the indicator, the message Overload will appear.

Probe Dynamic Range indicator

When you are changing the Vertical Setup settings, the Probe Dynamic Range indicator appears on the left side of the waveform display. The figure below shows a waveform exceeding the dynamic range of the channel and the overload indicator turned on.



3558-005

Figure 21: Overload indicator

Correcting for conversion gain

Conversion gain of the O/E converter is calculated at three standard wavelengths: 850 nm, 1310 nm, 1550 nm. Conversion gain has units of V/W. The channel waveform is corrected by dividing the sampled voltage output of the O/E converter by the conversion gain for the wavelength selected in the Probe Setup menu.

Reference

This section provides reference information such as optical bandwidth considerations and product specifications.

Optical and electrical bandwidth

Optical bandwidth is defined to be the frequency at which the optical power passed by the device is half the optical power passed at DC. For optical signals, a DC signal refers to a CW signal which is unmodulated, as this is converted by the photodetector into a DC current. For optical systems, this is the frequency f_c at which the following equation is satisfied:

$$-3 \text{ dBo} = 10 \log\left(\frac{P_{fc}}{P_{DC}}\right)$$

Note that because PIN diodes are square law detectors, meaning they directly convert Watts into Amps, the voltage at the sampler scales linearly with the power and not with the square root of the power. This has led to another definition of bandwidth often used in optical systems, known as the electrical bandwidth (BWe). The electrical bandwidth is the frequency f_c at which the following equation is satisfied:

$$-3 \text{ dBe} = 20 \log\left(\frac{P_{fc}}{P_{DC}}\right)$$

Bandwidth for the Flat filter settings

The following describes the Flat filter settings in the Frequency Response portion of the Probe Setup screen. See [Probe Setup settings](#) on page 28.

The electrical -3 dBe bandwidth is used for the Flat filter options. The optical/electrical converter used in the DPO7OE1 has a frequency response which approximates a 4th order Bessel-Thomson curve with about 30 GHz of optical bandwidth. In order to perform DSP correction on the O/E converter, the frequency response is measured during calibration and stored into the flash memory of the probe.

The oscilloscope software takes the measured response, stored as 2-port s-parameters, and creates a Finite Impulse Response (FIR) filter which flattens the O/E frequency response up to the filter bandwidth. The response is different for short wavelengths (<1260 nm) versus long wavelengths (>1260 nm), and the response will be different when measured directly at the O/E output versus at the TekConnect output.

Bandwidth for the ORR filter settings

The following describes the ORR filter settings in the Frequency Response portion of the Probe Setup screen. See [Probe Setup settings](#) on page 28.

The bandwidth for the ORR filter options is defined as the frequency f_c where the measured signal amplitude A_{f_c} at f_c and the signal amplitude A_{DC} at DC have the relation

$$-3 \text{ dBe} = 20 \log\left(\frac{P_{f_c}}{P_{DC}}\right)$$

and f_c is equal to 0.75 times the symbol rate.

The response follows a 4th Order Bessel-Thomson (BT4) curve, defined by

$$H(y) = \frac{105}{105 + 105y + 45y^2 + 10y^3 + y^4}$$

where

$$y = 2.114p; p = \frac{j\omega}{\omega_c}; \omega_c = 2\pi f_c$$

Ideal BT4 filters are created for each filter bandwidth and applied to the flattened response of the O/E. Thus, if the flattening Finite Impulse Response (FIR) filter is working correctly, then all filter settings for that wavelength will work correctly.

Optical reference receiver performance

Achieving Optical Reference Receiver (ORR) response requires sufficient instrument bandwidth to ensure smooth frequency roll-off characteristics beyond the data rate. For design of Datacenter Networking equipment, an ORR with a fourth-order Bessel-Thomson (BT4) frequency response is generally used. For NRZ (PAM2), the reference receiver's -3 dB electrical bandwidth is set to a frequency of 75% of the optical symbol rate and its bandwidth limit guard bands are specified to a frequency of 150% of the optical symbol rate. Using these values for a 28 GBd optical signal yields the following frequency response requirements:

Optical reference receiver attenuation	Frequency
-3 dB	$0.75 * 28 \text{ G} = 21 \text{ GHz}$
Nominal: -10 dB Range: -7 to -20 dB	$1.50 * 28 \text{ G} = 42 \text{ GHz}$

For PAM4 signals the BT4 filter is tuned lower. The electrical bandwidth is set to a frequency corresponding to 50% of the symbol rate. The ORR BT4 filters for the important symbol rates of PAM4 standards, such as 26.5625 GBd, are also available in the DPO7OE1.

The DPO7OE1 can be used in conjunction with 50 GHz and higher ATI channels on the DPO70000SX instruments, providing ample bandwidth for a smooth BT response for up to 28 GBd data. The graph below shows a typical frequency response of the DPO7OE1 on a DPO77002SX real-time oscilloscope.

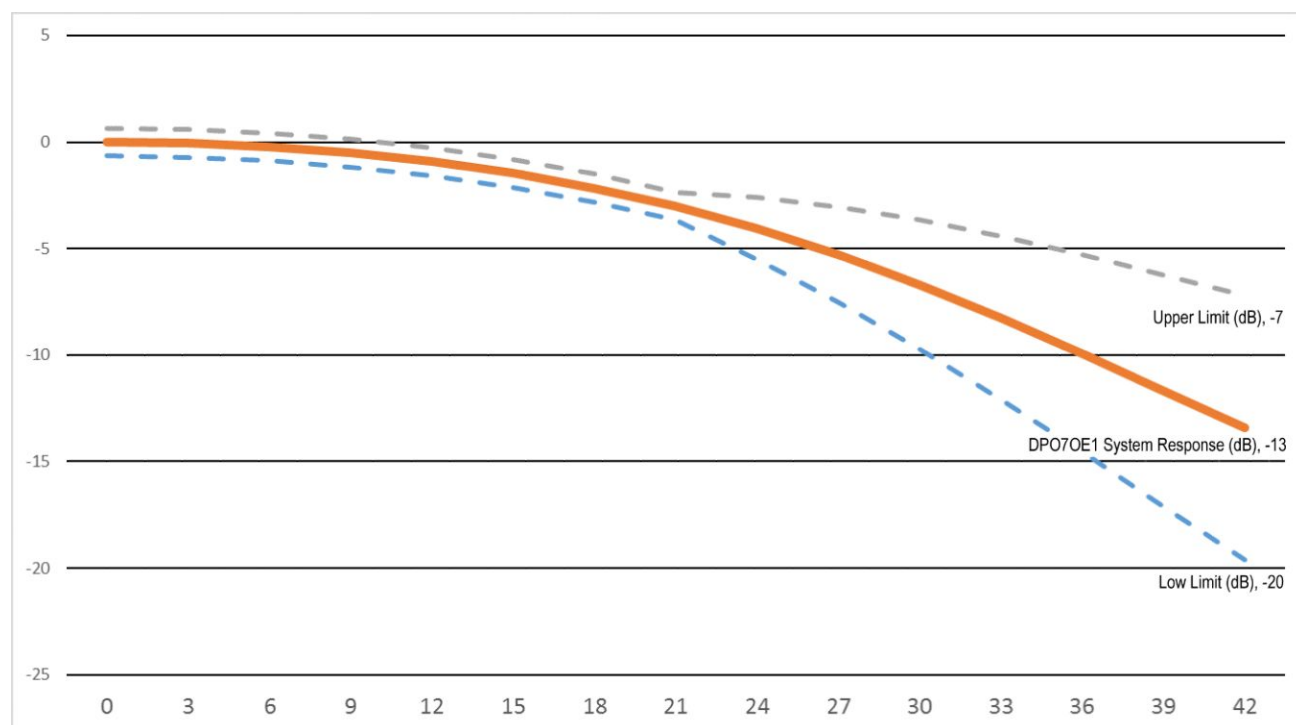


Figure 22: Fourth order Bessel-Thompson frequency response of the DPO7OE1 Optical Probe and DPO70000SX ATI channel

The smooth, controlled system response with the DPO7OE1 and DPO70000SX oscilloscope is possible because the oscilloscope's system software calculates the BT4 filters using the S-parameters unique to the optical probe and the oscilloscope channel. Most real-time oscilloscopes today have a rather sharp roll-off (e.g. "brick wall") at or just above the rated channel bandwidth. This response limits the ability to replicate a true BT4 response, which has a much more gradual roll-off characteristic. Without a true BT4 response, the signal's eye opening will be reduced, adversely impacting the accuracy of the measurement.

Appendix A: Programming Interface (PI) commands

This section describes the Programming Interface (PI) commands you can use to query or control the probe. For more information about the PI commands supported by your oscilloscope, refer to the *MSO/DPO5000/B, DPO7000/C, DPO70000/B/C/D/DX/SX, DSA70000/B/C/D, and MSO70000/C/DX Series Programmer Manual* (Tektronix part number 077-0010-24 and above).

CH<x>:OPTIcal:RCVR

This command sets or queries the Optical Reference Receiver (ORR) DSP filter used to compensate for the applied optical signal. Using the USER value requires the optional, numeric second argument. The units for <NR1> are in Baud. 28.6 GigaBaud example: `:CH1:OPTI:RCVR USER, 28.6E9`.

Group Vertical

Syntax `CH<x>:OPTIcal:RCVR {OFF|FLAT|FLAT33|ENET257R4|ENET266PAM4|OTU2795|FC28050|USER} [, <NR1>]`

Arguments The Optical Reference Receiver DSP filter used to compensate for the applied optical signal.

Examples `CH1:OPTIcal:RCVR ENET257R4` sets the DSP filter to ENET257R4.
`CH1:OPTIcal:RCVR?` might return `:CH1:OPTIcal:RCVR ENET257R4` indicating the DSP filter is set to ENET257R4.

CH<x>:OPTIcal:RCVR:USERVALue? (query only)

This command queries the Baud rate for the user-specified Optical Reference Receiver (ORR) filter.

Group Vertical

Syntax CH<x>:OPTIcal:RCVR:USERVALue?

Returns Returns the Baud rate for the user-specified ORR filter.

CH<x>:OPTIcal:WLENGth

Get or set the optical wavelength (in nanometers) that is used by the Probe and oscilloscope to compensate for the applied optical signal. Use the optional second argument to specify whether the to recall the factory calibration values or the user-programmed calibration values.

Group Vertical

Syntax CH<x>:OPTIcal:WLENGth <NR1> [, USER|, FACTory]
CH<x>:OPTIcal:WLENGth?

Arguments <NR1> is the optical wavelength (in nanometers).

USER specifies user-programmed calibration values that can be loaded onto the probe through a separate utility.

FACTory specifies using factory calibration values. The second argument defaults to FACTory if none is specified.

CH<x>:OPTIcal:WLENgth:LIST? (query only)

Query returns the comma-separated list of wavelengths with calibrated responses from the Probe. The units for the returned values are in nanometers.

Group Vertical

Syntax CH<x>:OPTIcal:WLENgth:LIST?

CH<x>:PRObe:GAIN? (query only)

This query-only command returns the gain factor of the probe that is attached to the specified channel. The channel is specified by x. The value of x can range from 1 through 4. The “gain” of a probe is the output divided by the input transfer ratio. For example, a common 10x probe has a gain of 0.1.

Group Vertical

Syntax CH<x>:PRObe:GAIN?

Examples CH2:PROBE:GAIN? might return :CH2:PROBE:GAIN 0.1000E+00, indicating that the attached 10X probe delivers 0.1 V to the Channel 2 BNC for every 1.0 V applied to the probe input.

