

LE160 & LE320 Linear Equalizer Product Specifications & Performance Verification Technical Reference 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.

Supports LE160 & LE320 Product Firmware V1.0 and above



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Tektronix

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- In North America, call 1-800-833-9200.
- Worldwide, visit www.tektronix.com to find contacts in your area.

Warranty

Tektronix warrants that this product will be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If any such product proves defective during this warranty period, Tektronix, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product. Parts, modules and replacement products used by Tektronix for warranty work may be new or reconditioned to like new performance. All replaced parts, modules and products become the property of Tektronix.

In order to obtain service under this warranty, Customer must notify Tektronix of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. Customer shall be responsible for packaging and shipping the defective product to the service center designated by Tektronix, with shipping charges prepaid. Tektronix shall pay for the return of the product to Customer if the shipment is to a location within the country in which the Tektronix service center is located. Customer shall be responsible for paying all shipping charges, duties, taxes, and any other charges for products returned to any other locations.

This warranty shall not apply to any defect, failure or damage caused by improper use or improper or inadequate maintenance and care. Tektronix shall not be obligated to furnish service under this warranty a) to repair damage resulting from attempts by personnel other than Tektronix representatives to install, repair or service the product; b) to repair damage resulting from improper use or connection to incompatible equipment; c) to repair any damage or malfunction caused by the use of non-Tektronix supplies; or d) to service a product that has been modified or integrated with other products when the effect of such modification or integration increases the time or difficulty of servicing the product.

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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.

Comply with local and national safety 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.

This product is not intended for detection of hazardous voltages.

While using this product, you may need to access other parts of a larger system. Read the safety sections of the other component manuals for warnings and cautions related to operating the system.

When incorporating this equipment into a system, the safety of that system is the responsibility of the assembler of the system.

To avoid fire or personal injury

Use proper power cord. Use only the power cord specified for this product and certified for the country of use. Do not use the provided power cord for other products.

Ground the product. This product is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making connections to the input or output terminals of the product, ensure that the product is properly grounded. Do not disable the power cord grounding connection.

Power disconnect. The power cord disconnects the product from the power source. See instructions for the location. Do not position the equipment so that it is difficult to disconnect the power cord; it must remain accessible to the user at all times to allow for quick disconnection if needed.

Use proper AC adapter. Use only the AC adapter specified for this product.

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

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

Do not float the common terminal above the rated voltage for that terminal.

The measurement terminals on this product are not rated for connection to mains or Category II, III, or IV circuits.

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.

Use proper fuse. Use only the fuse type and rating specified for this product.

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

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.

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

Slots and openings are provided for ventilation and should never be covered or otherwise obstructed. Do not push objects into any of the openings.

Provide a safe working environment. Always place the product in a location convenient for viewing the display and indicators.

Avoid improper or prolonged use of keyboards, pointers, and button pads. Improper or prolonged keyboard or pointer use may result in serious injury.

Be sure your work area meets applicable ergonomic standards. Consult with an ergonomics professional to avoid stress injuries.

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.

To avoid electric shock. Do not touch exposed connections.

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.

Disconnect power. To avoid electric shock, switch off the product power and disconnect the power cord from the mains power before removing any covers or panels, or opening the case for servicing.

Use care when servicing with power on. Dangerous voltages or currents may exist in this product. Disconnect power, remove battery (if applicable), and disconnect test leads before removing protective panels, soldering, or replacing components.

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

Terms in the manual

These terms may appear in this manual:



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



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

Terms on the product

These terms may appear on the product:

- DANGER indicates an injury hazard immediately accessible as you read the marking.
- WARNING indicates an injury hazard not immediately accessible as you read the marking.
- CAUTION indicates a hazard to property including the product.

Symbols on the product



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.

EMC compliance

EC Declaration of Conformity – EMC

Meets intent of Directive 2004/108/EC for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

EN 61326-1 2006 . EMC requirements for electrical equipment for measurement, control, and laboratory use. ^{1 2 3}

- CISPR 11:2003. Radiated and conducted emissions, Group 1, Class A
- IEC 61000-4-2:2001. Electrostatic discharge immunity
- IEC 61000-4-3:2002. RF electromagnetic field immunity
- IEC 61000-4-4:2004. Electrical fast transient / burst immunity
- IEC 61000-4-5:2001. Power line surge immunity
- IEC 61000-4-6:2003. Conducted RF immunity
- IEC 61000-4-11:2004. Voltage dips and interruptions immunity

EN 61000-3-2:2006. AC power line harmonic emissions

EN 61000-3-3:1995. Voltage changes, fluctuations, and flicker

European contact.

Tektronix UK, Ltd.
Western Peninsula
Western Road
Bracknell, RG12 1RF
United Kingdom

¹ This product is intended for use in nonresidential areas only. Use in residential areas may cause electromagnetic interference.

² Emissions which exceed the levels required by this standard may occur when this equipment is connected to a test object.

³ For compliance with the EMC standards listed here, high quality shielded interface cables should be used.

**Australia / New Zealand
Declaration of Conformity
– EMC**

Complies with the EMC provision of the Radiocommunications Act per the following standard, in accordance with ACMA:

- CISPR 11:2003. Radiated and conducted emissions, Group 1, Class A, in accordance with EN 61326- 1:2006.

Australia / New Zealand contact.

Baker & McKenzie
Level 27, AMP Centre
50 Bridge Street
Sydney NSW 2000, Australia

Safety compliance

This section lists safety and compliance information.

Equipment type

Test and measuring equipment.

Safety class

Class 1 – grounded product.

**Pollution degree
description**

A measure of the contaminants that could occur in the environment around and within a product. Typically the internal environment inside a product is considered to be the same as the external. Products should be used only in the environment for which they are rated.

- Pollution Degree 1. No pollution or only dry, nonconductive pollution occurs. Products in this category are generally encapsulated, hermetically sealed, or located in clean rooms.
- Pollution Degree 2. Normally only dry, nonconductive pollution occurs. Occasionally a temporary conductivity that is caused by condensation must be expected. This location is a typical office/home environment. Temporary condensation occurs only when the product is out of service.
- Pollution Degree 3. Conductive pollution, or dry, nonconductive pollution that becomes conductive due to condensation. These are sheltered locations where neither temperature nor humidity is controlled. The area is protected from direct sunshine, rain, or direct wind.
- Pollution Degree 4. Pollution that generates persistent conductivity through conductive dust, rain, or snow. Typical outdoor locations.

Pollution degree Pollution Degree 2 (as defined in IEC 61010-1). Note: Rated for indoor, dry location use only.

Measurement and overvoltage category descriptions

Measurement terminals on this product may be rated for measuring mains voltages from one or more of the following categories (see specific ratings marked on the product and in the manual).

- Measurement Category II. For measurements performed on circuits directly connected to the low-voltage installation.
- Measurement Category III. For measurements performed in the building installation.
- Measurement Category IV. For measurements performed at the source of low-voltage installation.

Mains overvoltage category rating

Overvoltage Category II (as defined in IEC 61010-1)

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 2002/96/EC and 2006/66/EC on waste electrical and electronic equipment (WEEE) and batteries. For information about recycling options, check the Support/Service section of the Tektronix Web site (www.tektronix.com).

Restriction of hazardous substances

This product is classified as an industrial monitoring and control instrument, and is not required to comply with the substance restrictions of the recast RoHS Directive 2011/65/EU until July 22, 2017.

Preface

This document lists the product specifications and provides procedures to verify instrument performance.

Related documentation

The following documentation is available to support your linear equalizer product. The documents can be downloaded from the Tektronix Web site at www.tektronix.com/manuals.

- *LE160 & LE320 Quick Reference Installation Instructions* (Tektronix part number, 071-3222-xx). Printed instructions shipped with each instrument providing high-level installation information.
- *LE160 & LE320 Linear Equalizer Instruction Manual* (Tektronix part number, 077-0883-xx). PDF-only. This document provides high-level information for using and maintaining the linear equalizer.
- *LE160 & LE320 Linear Equalizer Declassification & Security Instructions* (Tektronix part number, 077-0882-xx). PDF only. Use these instructions to declassify or sanitize your instrument.

Specifications

This chapter contains specifications for the instrument. All specifications are guaranteed unless noted as "typical." Typical specifications are provided for your convenience but are not guaranteed. Specifications that are marked with the ✓ symbol are checked in Performance Verification.

All specifications apply to all models unless noted otherwise. To meet specifications, two conditions must first be met:

- The instrument must be in an environment with temperature, altitude, humidity, and vibration within the operating limits described in these specifications.
- The instrument must have had a warm-up period of at least 30 minutes.

For optimum performance using an external oscilloscope, please consult the documentation for any external oscilloscopes used with your Tektronix linear equalizer to determine the warm-up period and signal-path compensation requirements.

Data input (single-ended)

Number of taps	4 standard, 9 with Option 9T
Operating data rate range	LE160, 4 Gb/s to 21 Gb/s LE320, 8 Gb/s to 32 Gb/s ¹
Coupling	AC coupled
Maximum data input level	800 mV _{p-p} (typical) The maximum input signal level acceptable to the data input for proper operation. Not the input damage level.
Data input sensitivity	40 mV _{p-p} (typical) The minimum input signal level acceptable to the data input for proper operation
Data input termination	100 Ω differential 50 Ω single-ended
Connector type	2.92 mm female
Input return loss	(typical)

¹ Operation down to 8 Gbps is supported with single tap response.

LE160	10 dB RL 0.2 to 7 GHz 5 dB RL > 7 GHz to 30 GHz
LE320	10 dB RL 0.2 to 7 GHz 5 dB RL > 7 GHz to 30 GHz

Data output (differential)

Minimum settable amplitude range (DP/DN)	0 mV _{p-p} to 2000 mV _{p-p} maximum differential Pattern: 1100, taps set for flat loss
Settable amplitude resolution	0.15 dB (typical)
Coupling	AC coupled
✓ Skew between DP and DN	<2 ps (typical), 4 ps (specified), taps set for flat frequency response
Additive random jitter	
LE160	220 fs _{RMS} (typical), input pattern 1100 ²
LE320	300 fs _{RMS} (typical), input pattern 1100 ²
Tap range	-100 to +100 tap settings
Connector type	2.92 mm, female
Zero output state timing constant	±600 mV, single ended signaling level to 0 V ±10 mV in ≤ 40 UI = 2.9 ns; idle state (fall time after enable asserted) Time constant is based on 14 Gb SAS, fibre channel and PCIe Gen4. Timing from full output to 0 V. Hold at 0 for 2 ms minimum, then return to enable. Rise time expectation is on order of 30 to 40 ps. Latency of blanking period start is not timed to anything else.
Consecutive run length amplitude droop	<10 % maximum droop (typical) PCIe 16 Gb standard calibration pattern: 128 bit 1, 128 bit 0, single-ended, compared to 1100 pattern amplitude

² Additive Jitter. The LE320/LE160 can be configured to many conditions resulting in increased Data Dependent Jitter (DDJ) and Random Jitter (Rj), for example in a backplane emulation configuration. The LE320 can be tuned to have < 300 fs RJ RMS and < 6 ps of DDJ.

Physical characteristics

Dimensions are with bumpers attached.

Height 4.01 cm (1.58 in.)

Width 12.62 cm (4.97 in.)

Depth 9.02 cm (3.55 in.)

Weight 0.34 kg (12 oz.)

Environmental characteristics

Temperature

Operating 0 °C to +50 °C (32 °F to 122 °F)

Nonoperating -40 °C to +71 °C (-40 °F to 159.8 °F) with 15 C/hour maximum gradient

Humidity

Operating 5% to 95% relative humidity (% RH) up to +30 °C

5% to 45% RH above 30 °C up to 50 °C, non-condensing

Nonoperating 5% to 95% relative humidity (% RH) up to +30 °C

5% to 45% RH above 30 °C up to 50 °C, non-condensing

Altitude

Operating Up to 3000 m (9842 ft.)

Derate maximum operating temperature by 1 °C per 300 m above 1500 m altitude.

Nonoperating Up to 12,000 m (39,370 ft.)

Performance verification

This section describes the procedures to verify the performance of your instrument. Performance verification procedures confirm that a product meets or exceeds the performance requirements for the published specifications documented in the *Specifications* chapter of this manual. The performance verification procedures certify the accuracy of an instrument and provide a traceability path to national standards.

NOTE. *The performance verification procedure is not a calibration procedure. The performance verification procedure only verifies that your instrument meets key specifications. For your instrument to be calibrated, it must be returned to a Tektronix service facility.*

Prerequisites

The tests in this section make up an extensive, valid confirmation of performance and functionality when the following requirements are met:

- The linear equalizer and other test equipment used in these procedures must have been operating for a warm-up period of at least 20 minutes after starting the LE application and power applied to the linear equalizer.
- The linear equalizer must be operating at a stable ambient temperature.
- No error messages are displayed in the user interface.

Functional checks

This section describes procedures to verify that the instrument is functional, but might not meet the advertised performance specifications.

Required equipment The following table lists the required equipment to perform the functional checks.

Equipment	Minimum requirements	Example	Purpose
Pattern generator	Bit rate ≥ 16 Gb/s Rise/fall time ≤ 20 ps 20% to 80% ≥ 800 mV _{P-P} Pattern: 1010	Tektronix BSA175, BSA286C, or equivalent	Apply a test signal to the linear equalizer
Sampling oscilloscope	50 GHz minimum bandwidth	Tektronix DSA8300 with 80E108 or 80E11 modules installed, or equivalent	Check rise time and signal fidelity
Phase-matched cable set	2.92 mm, <2 ps matching, 1 m maximum	Tektronix pn (174-5969-00), standard part of LE160/LE320	
6 in. coaxial cable	2.92 mm, flex K-male to K-male	Tektronix pn (174-6362-00), standard part of LE160/LE320	

Functional setups Complete the functional setups before proceeding with the Warranted Characteristic tests.

Use the following diagram to help set up the instrument connections.

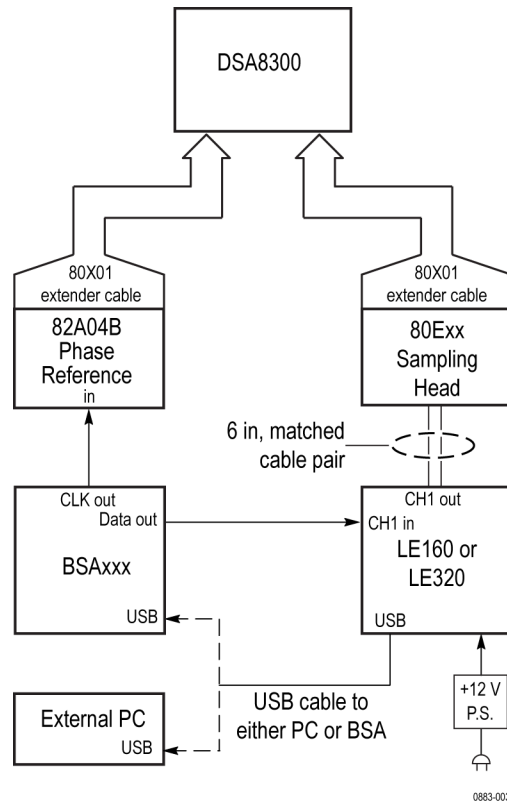


Figure 1: Functional check equipment setup

1. If you have not done so, connect the USB cable from the linear equalizer to the host PC.
2. Push the Power button on the linear equalizer and verify that the Power LED turns on.
3. Make sure that the LE application is running on the host PC by verifying that the linear equalizer connects to the PC through the graphical user interface.
4. Click the Connect tab at the top of the window.
5. Click the 4T tab to open the 4T window. The LE application should look similar to the following figure.

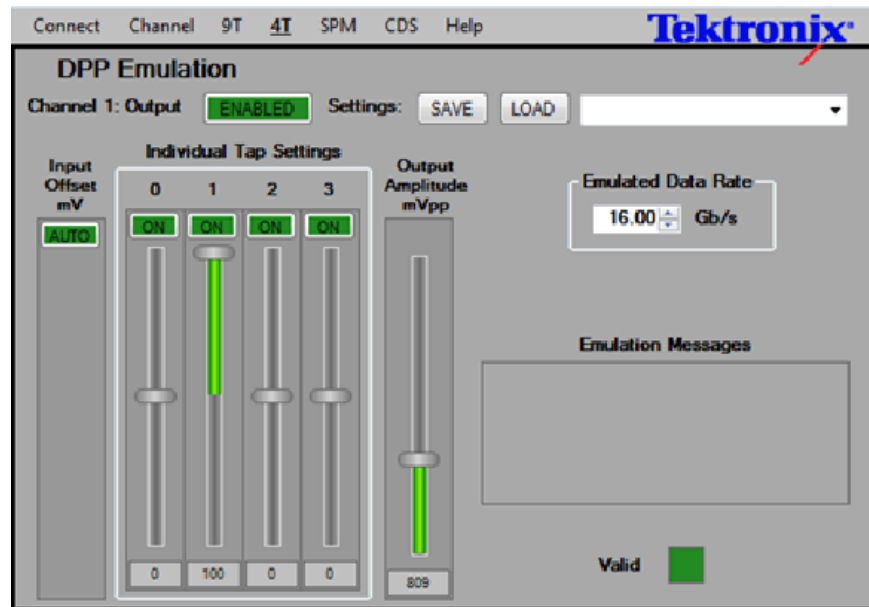


Figure 2: LE user interface

6. Complete the other connections as shown in the illustration.
7. Allow all equipment to warm up for at least twenty minutes.

Functional check procedure

Verify that the equipment is set up properly as shown in the previous diagram *Figure 1: Functional check equipment setup* on page 9.

1. Set up the pattern generator for a 16 Gbp/s 1010 waveform with a 800 mV_{p-p} output.
2. Verify that the linear equalizer is set up as follows:
 - a. Click the **Connect** button in the user interface to connect the application to the linear equalizer.
 - b. Select the **4T** tab.
 - c. Enable Channel 1 on the linear equalizer and set the amplitude for approximately 800 mV_{p-p} output.

The Channel 1 button should be highlighted in green.

- d. Adjust the **Output Amplitude** control on the linear equalizer to 800 mV_{p-p}.

The LE display should look similar to the following figure.

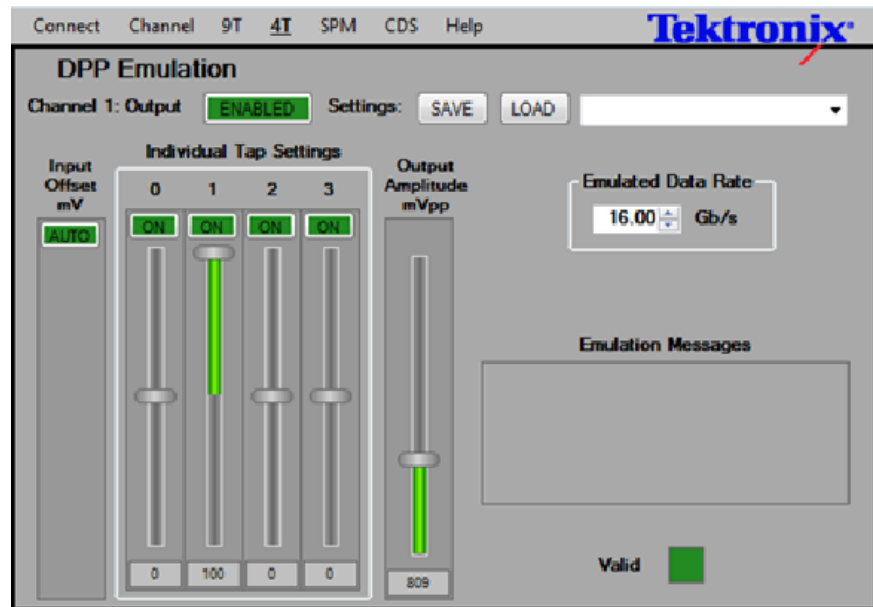


Figure 3: LE display with Channel 1 enabled

3. Set up the sampling oscilloscope as follows:
 - a. Connect the channel 1 oscilloscope out put to the Ch 1 + output of the linear equalizer.
 - b. Connect the channel 2 oscilloscope out put to the Ch 1 - output of the linear equalizer.
 - c. Set the vertical controls of the oscilloscope to 100 mV per division.
 - d. Set the horizontal controls of the oscilloscope to 10 ps per division.
 - e. Center the traces horizontally on the display as shown in the following figure.

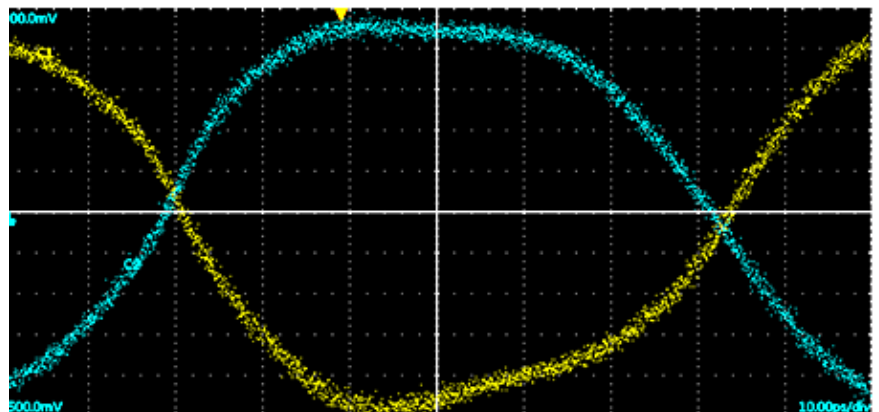


Figure 4: Sampling oscilloscope display

Warranted characteristics tests

The following procedures in this section verify the LE160/LE320 performance is within the warranted specifications.

Photocopy the test record at the end of this document and use it to record the performance test results.

Warm up information

Before continuing with this procedure ensure that all equipment has had a 20-minute warm-up period.

Check the skew between DP and DN

This check verifies the skew between the DP and DN meets the published specifications. Record the measurement results in the appropriate section in the Test Record. (See *Test record* on page 15.)

1. Ensure that the instruments are connected and set up. (See Figure 1: Functional check equipment setup.)
2. Set the pattern generator to output a 1010 pattern.
3. Enable the desired test channel on the linear equalizer and set the **Output Amplitude** control to 800 mV_{P-P}.
4. Check the Channel 1 skew between DP and DN:
 - a. Measure the positive crossing point on channel 1 of the oscilloscope. Record the value in "Scope Ch 1 measurement", row A in the Test Record.
 - b. Measure the negative crossing point on channel 2 of the oscilloscope. Record the value in "Scope Ch 2 measurement", row B in the Test Record.
 - c. Subtract the value from row A minus row B and enter in row C in the Test Record.
 - d. Reverse the oscilloscope input cables at the output of the linear equalizer.

Oscilloscope Channel 1 should now be connected to the Ch 1 - output of the linear equalizer and oscilloscope Channel 2 should be connected to the Ch 1 + output of the linear equalizer.

- e. Measure the negative crossing point on channel 1 of the oscilloscope. Record the value in "Scope Ch 1 measurement", row D in the Test Record.
- f. Measure the positive crossing point on channel 2 of the oscilloscope. Record the value in "Scope Ch 2 measurement", row E in the Test Record.
- g. Calculate the difference between the measurements in row D minus row E. Record the difference in row F in the Test Record.
- h. Calculate the difference between the entries in row C minus row F. Divide that result by 2. Enter the divided value in row G.

This is the skew between the Ch 1 DP and DN outputs of the linear equalizer.

5. Check the Channel 2 skew between DP and DN:
 - a. Connect the channel 1 oscilloscope output to the Ch 2 + output of the linear equalizer.
 - b. Connect the channel 2 oscilloscope output to the Ch 2 - output of the linear equalizer.
 - c. Measure the positive crossing point on channel 1 of the oscilloscope. Record the value in "Scope Ch 1 measurement", row H in the Test Record.
 - d. Measure the negative crossing point on channel 2 of the oscilloscope. Record the value in "Scope Ch 2 measurement", row I in the Test Record.
 - e. Subtract the value from row A minus row B and enter in row J in the Test Record.
 - f. Reverse the oscilloscope input cables at the output of the linear equalizer.

Oscilloscope Channel 1 should now be connected to the Ch 1 - output of the linear equalizer and oscilloscope Channel 2 should be connected to the Ch 1 + output of the linear equalizer.

- g. Measure the negative crossing point on channel 1 of the oscilloscope. Record the value in "Scope Ch 1 measurement", row K in the Test Record.
- h. Measure the positive crossing point on channel 2 of the oscilloscope. Record the value in "Scope Ch 2 measurement", row L in the Test Record.
- i. Calculate the difference between the measurements in row D minus row E. Record the difference in row M in the Test Record.
- j. Calculate the difference between the entries in row J minus row M. Divide that result by 2. Enter the divided value in row N.

This is the skew between the Ch 2 DP and DN outputs of the linear equalizer.

6. Verify that the entries in rows G and N meet the specifications in the table near the top of the Test Record.

Test record

Photocopy this page and use it to record the performance test results for your instrument.

Table 1: LE160/LE320 test record

Instrument model number	
Serial number	
Verification performed by	
Verification date	

Characteristic	Specification
Skew between DP and DN	<4 ps, taps set for flat frequency response

Table 2: LE Channel 1 Worksheet test data

Characteristic	Measurement	Data
LE Ch 1 Measurement 1	A. Scope Ch 1 measurement	
	B. Scope Ch 2 measurement	
	C. Calculate: row A - row B	
LE Ch 1 Measurement 2 - After changing LE output cables	D. Scope Ch 1 measurement	
	E. Scope Ch 2 measurement	
	F. Calculate: row D - row E	
LE Ch 1 Skew between DP and DN	G. Calculate: (row C - row F) / 2	

Table 3: LE Channel 2 Worksheet test data

Characteristic	Measurement	Data
LE Ch 2 Measurement 1	H. Scope Ch 1 measurement	
	I. Scope Ch 2 measurement	
	J. Calculate: row H - row I	
LE Ch 2 Measurement 2 - After changing LE output cables	K. Scope Ch 1 measurement	
	L. Scope Ch 2 measurement	
	M. Calculate: row K - row L	
LE Ch 2 Skew between DP and DN	N. Calculate: (row J - row M) / 2	

