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## **Model 4950 10BASE-T1L Channel Emulator**

**Single Pair Ethernet (SPE) Testing Solution**



**Lab Test  
Instrument**

**Repeatable  
Testing**

**World's First Standard-Based Channel Emulator for Testing SPE 10BASE-T1L and PoDL with Integrated Power Measurements and SCCP Protocol Analyzer.**

Telebyte's Model 4950 offers the world's first standard-based channel / cable emulator designed for testing Single Pair Ethernet (SPE) and supports a universal test setup with two Model 4950-P01 Multifunction Probes at the Power Source Port and Powered Device or Load Port.

This full duplex link supports power and communications over the same data line connected to devices at the edge of the "smart factory" network. The cost-effective technology provides data and analytics for industrial automation including control systems and cloud applications for remote operation as well as monitoring and management of the entire "intelligent building." Elevators, HVAC, power, security access, wireless access points, sensors, industrial controls, cameras, robotics, railway and transportation as well as lighting may all be integrated on the enterprise network.

Suitable for Compliance, Power and Data, and Interoperability Testing.

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## Features Include:

- Simulation of Single Balanced Pair of Conductors of various cable types and lengths as defined in section 146.7.1 of IEEE 802.3-2022; APL Port Profile Specification v1.2, subclause 7.5; IEC 61156-13 section 6.3; and TIA 568.5 section 6.3
  - Simulation includes:
    - Attenuation supports two PHY operational modes (1.0 Vpp or 2.4 Vpp)
    - Differential Return Loss
    - Link Delay
    - DC Resistance
- Low Noise Floor of < -163 dBm/Hz
- Bandwidth DC to 20 MHz
- Integrated Current Monitor, 0 to +/-2.5A
- Integrated Voltage Monitor at each end of the link, 0 to +/-60 VDC
- Data logging of current and voltage from 500 Sa/s to 500 kSa/s
- Serial Communication Classification Protocol (SCCP) Analyzer to view register data and logic analyzer view of pulses with timing
- Fault Tolerance and Safety Testing with Short Circuits on the differential pair or on signal wires to the Shield (or Chassis Ground) for 75ms (Short Current not to exceed ~3.5A)
- Integrated Differential Mode Noise Injection at each end of the cable emulator Side A & B. Wide dynamic range noise output of -70dBm/Hz to -155dBm/Hz when integrating with the Arbitrary Waveform Generators with Impulsive Noise or Alien Crosstalk.
- Internal Power-line Ripple Noise Generation (1kHz to 1MHz) and Injection at each end of the cable emulator, Side A (Power Source) and Side B (Power Load) to test SPoE devices.
- Internal AWGN Noise Source on Side A & B with flat Noise outputs from -70dBm/Hz to -163dBm/Hz to test SNR margins
- Micro-Interrupts from 1ms to 65535ms in 1ms increments to simulate intermittent connections at wire joints (terminal box). Tests Power Over Data Line stability and Signal integrity path with reflections.
- Compliance Testing for Timers to test Maintain Full Voltage Signature for PoDL stability
- Supports PoDL Type E Power Class 10-15 Devices w/ 60V DC, 2A, 90Watts and Ethernet-APL Class A, C and 3
- 1 to 80.5 ohm variable Cable DC resistance emulation in 0.5 ohm increments
- Symmetric and Bi-directional emulation
- Integrated electronic circuit breaker and Current difference monitor (CDM)
- Repeatable, configurable, realistic
- Remote Control via telnet or SSH with a command line interface (CLI)
- Linux SBC with built-in web server for browser user interface
- Made in the USA



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**Current/Voltage Monitor**

The Model 4950 includes an integrated current and voltage monitor at the PSE, PD and Sense Voltage. The user may enable data logging to monitor current and voltage over the link at 500kSa/s for inrush current with power and energy calculations or at lower sample rates for long term thermal or stability testing of Power over Data Line. For safety, the unit opens the cable emulator in the event of over-current error conditions (electronic circuit breaker). Log data for Ethernet-APL intrinsically safe devices to ensure limits are maintained for Class A, C, 3 and 4. Support for Class B devices as well for 4-corner minimum and maximum voltage and current testing.

**SCCP Protocol Analyzer**

This innovative product includes a Protocol Analyzer for the Serial Communication Classification Protocol (SCCP) to monitor or troubleshoot the half-duplex bi-directional serial data bus for communication between the Master PSE and Slave PD devices. The initialization sequence of reset, presence, write, and read pulses are presented with timestamped information in a tabular or graphical view similar to a logic analyzer. This information is available to the user via a web interface and/or remote commands. The CRC pass/fail criteria, Voltage Info, Power Info, Power Assign and Class Type Info register values may be checked as well.

**Cable Faults**

The Model 4950 can verify fault tolerance performance with short circuits on the Single Pair Ethernet link in 75ms increments to determine when the PSE shuts down the output power should a short circuit be detected between the differential pair or a signal wire to ground. The short condition can be placed at the PSE or PD end of the link with normal operation expected after the short circuit is removed.

Spurs may have up to four inline connections and Trunks may have up to ten inline cable connections. To emulate faulty connections at these terminal points such as a bent pin or exposure to moisture and air, this product supports mechanical faults called Micro-Interrupts. If these cable faults are subject to vibration from heavy equipment or HVAC, the line may experience impedance discontinuities which affects the signal path with reflections and an increased DC loop resistance affecting the DC power to the Powered Device which may cause the link to drop or underperform.

These micro-interrupts may be inserted from 1ms to 65535ms onto the twisted pair link to open a single wire or both wires to emulate a bad wire joint connection. These micro-cuts may be repeated periodically for long term testing and error monitoring.

**Noise Testing**

It is vital to test link performance in noisy conditions such as those found in factory environments with harsh EMI radiations. The Model 4950 features integrated differential mode noise injection at each end of the cable emulator and is designed to be used with Arbitrary Waveform Generators and the Telebyte Universal Noise Software (see separate datasheet). The Arbitrary Waveform Generators inject a mixture of noise in the frequency and/or time domain on the data line. This reduces the signal-to-noise margin and validates the data rate and stability of the DUT in the presence of complex noise.

The internal Power-line Ripple Noise Generator and Injector on each Side A & B is used to test with ripple noise at the Power Source Port or Power Load Port with 100mVpp at 1kHz & 10kHz, and 10mVpp at 100kHz and 1MHz. This Power-line Ripple noise may also be swept from 1kHz to 1MHz which may impact the data error rate.

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For standalone noise testing with only the cable emulator, two internal AWGN noise sources are also included, one on Side A and one on Side B, respectively to test with calibrated noise from -70dBm/Hz to -163dBm/Hz over 30MHz to ensure the device operates with the proper SNR margins.

The IEEE 802.3-2022 Alien Crosstalk Noise Rejection test may be performed with a Gaussian noise distribution at -106 dBm/Hz over 10MHz to see if the DUT maintains a BER of less than  $10^{-10}$ .

**Noise Capture**

Telebyte's Model 4975 (see separate datasheet) also supports the signal capture of real-world noise environments on the twisted pair including alien crosstalk, impulse noise, RFI, inductive noise, and the background noise floor. The captured noise can be recorded and imported for play back on the Telebyte Universal Noise Software on our supported Third Party Arbitrary Waveform Generators to replicate deployment testing different noise environments or installations during lab testing.

**Cable Emulation**

The 4950 simulates variable insertion loss, DC resistance, impedance and delay. There are various cable types existing in different environments and Telebyte supports multiple standards for single twisted pair cable.

Telebyte's repeatable test solution provides a variety of cable lengths and cable types for both the 1.0 Vpp and 2.4 Vpp transmit amplitude PHY operational modes, each with the applicable low and high insertion loss (attenuation) curves. The 1.0 Vpp (low voltage) is optimal for intrinsically safe applications or relatively low noise environments. For more severe noise environments with older and longer twisted pair cables (with high attenuation), a higher transmit level using 2.4 Vpp is beneficial. Testing both transmit amplitude conditions ensures devices are interoperable in multiple cable plant and EMC environments.

**Standards Based Cable Models, Each with an Allowable Cable Length**

**IEEE 802.3cg section 146.7.1 (1.0 Vpp)** 100m, 250m, 500m, 600m, 850m, 1000m

OR

**IEEE 802.3cg section 146.7.1 (2.4 Vpp)**

Lengths: 50m, 150m, 250m, 350m, 500m, 600m, 750m, 850m, 1000m, 1050m\*, 1100m, 1200m\*, 1250m\*  
1300m\*, 1350m\*, 1375m\*, 1425m\*, 1450m\*, 1475m\*, 1500m\*, 1550m\*, 1600m\*, 1700m\*

OR

**Ethernet-APL Spur Worst Case Cable Model (1.0 Vpp)** 200m

OR

**Ethernet-APL Trunk Worst Case Cable Model (2.4 Vpp)** 1000m

OR

**IEC 61156-13 section 6.3**

Lengths: 100m (A-100), 250m (A-250), 400m (A-400), 1000m (A-1000)

OR

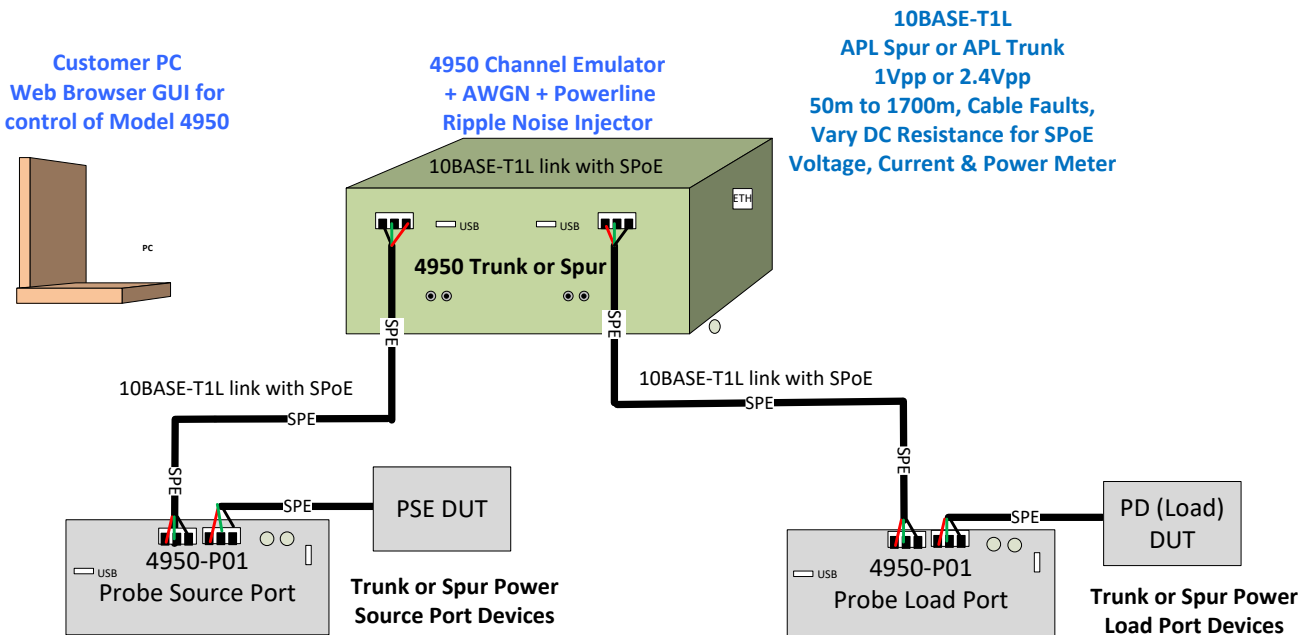
**TIA 568.5 section 6.3**

Lengths: 100m (SP-1-100), 250m (SP-1-250), 400m (SP-1-400), 1000m (SP-1-1000)

\* Optional Cable Lengths

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## Example Test Setup



### Test Setup for 10BASE-T1L Testing

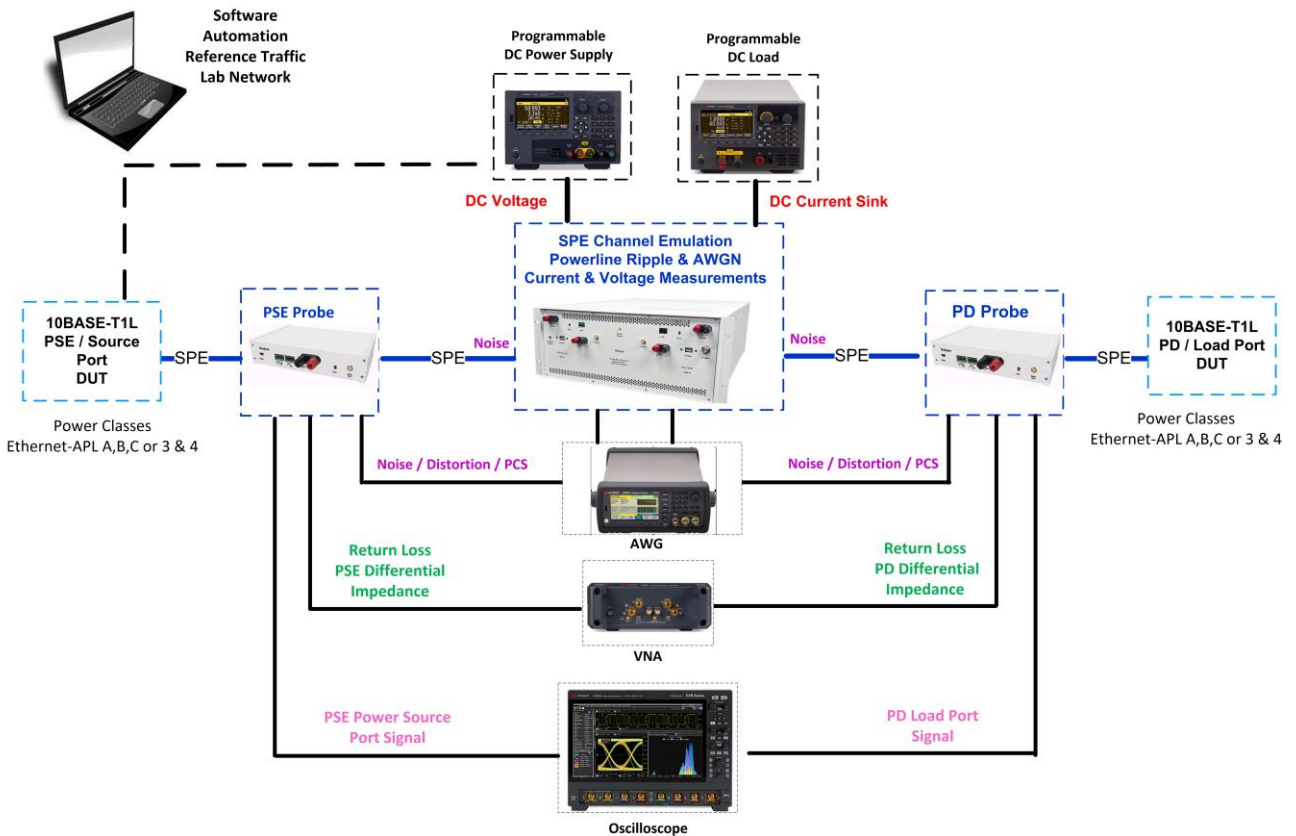
This test setup supports Power and Data testing of Single Pair Ethernet devices over short or long cable lengths. It measures the current, voltage and power of each device for Type E Power Classes 10-15 or Ethernet-APL Power Classes A,B,C for Spur ports and Classes 3 & 4 for Trunk Ports. The SNR or MSE values may be validated by turning on the AWGN noise sources to check for a drop in signal to noise margin reported by the SPE devices and to ensure the BER is acceptable with SNR margins of 20dB. The devices may also be tested with cable fault conditions of shorts or tested with non-zero ohm contact resistance on a single conductor at a terminal block. Data rate and errors in traffic may be tested over time to ensure stable performance.

The 4950-P01 Multi-function Probes support 10 probe modes to support all Ethernet-APL Data and Power Testing to integrate the universal test setup for power source ports and load ports. The Multifunction probes support the 100 ohm differential termination, allows the signal to the Oscilloscope, couple or decouples the voltage and current, connects a VNA for the MDI Return Loss Measurement, integrates the Distortion Circuit, supports the AWG PCS signal patterns. It also supports the 4950 voltage, current and sense voltage measurements.

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## Universal Test Setup

Automated Conformance Testing of Power and Data  
Source Ports (PSE) or Load Ports (PD)  
(Best in class version)







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## Specifications

Cable Emulator Specification									
<b>Simulation</b>	<p>Single Balanced Pair of Conductors as defined in:            IEEE 802.3cg section 146.7.1 (1.0 Vpp): 100m, 250m, 500m, 600m, 850m, 1000m            IEEE 802.3cg section 146.7.1 (2.4 Vpp): 50m, 150m, 250m, 350m, 500m, 600m, 750m, 850m, 1000m, 1050m*, 1100m, 1200m*, 1250m*, 1300m*, 1350m*, 1375m*, 1425m*, 1450m*, 1475m*, 1500m*, 1550m*, 1600m*, 1700m*</p> <p>Ethernet-APL Spur Worst Case Cable Model (1.0 Vpp): 200m</p> <p>Ethernet-APL Trunk Worst Case Cable Model (2.4 Vpp): 1000m</p> <p>IEC 61156-13 section 6.3: 100m (A-100), 250m (A-250), 400m (A-400), 1000m (A-1000)</p> <p>TIA 568.5 section 6.3: 100m (SP-1-100), 250m (SP-1-250), 400m (SP-1-400), 1000m (SP-1-1000)</p> <p>* Optional Cable Lengths</p>								
<b>Bandwidth</b>	DC to 20 MHz								
<b>Average Noise Floor</b>	< -165 dBm/Hz								
<b>Attenuation (Insertion Loss)</b>	Mean Absolute Error (MAE) < 1.0dB (0.1MHz to 20MHz)								
<b>Maximum Attenuation</b>	Theoretical attenuation of cable as defined by the applicable standard at 20MHz or 70db, whichever is less								
<b>Return Loss</b>	Better than 19 dB from 500kHz to 20MHz								
<b>DC Loop Resistance</b>	Variable from 1 ohm to 80.5 ohms in 0.5 ohm increments (+/- 0.2 ohms)								
<b>Delay</b>	Various between 0.1MHz to 20MHz								
<b>Maximum Current (Steady State)</b>	<table border="1"> <thead> <tr> <th>DC Loop Resistance (ohms)</th> <th>Maximum Current (Amps)</th> </tr> </thead> <tbody> <tr> <td>&lt; 9.5</td> <td>1.579</td> </tr> <tr> <td>&lt; 25</td> <td>0.600</td> </tr> <tr> <td>&lt; 65</td> <td>0.231</td> </tr> </tbody> </table>	DC Loop Resistance (ohms)	Maximum Current (Amps)	< 9.5	1.579	< 25	0.600	< 65	0.231
DC Loop Resistance (ohms)	Maximum Current (Amps)								
< 9.5	1.579								
< 25	0.600								
< 65	0.231								
<b>Maximum voltage</b>	60 VDC								
<b>Current Monitor</b>	0 to +/-2.5A, 95 uA resolution, +/- 1%								
<b>Voltage Monitor</b>	0 to +/-60 VDC, 5 mV resolution at PD and/or PSE side of link, +/- 1%								
<b>Data Logging</b>	Current and voltage from 500 Sa/s to 500kSa/s								
<b>Serial Communication Classification Protocol (SCCP) Analyzer</b>	CRC pass/fail criteria, Voltage Info, Power Info, Power Assign and Class Type Info register data. Reset, initialization, presence, write, and read pulses with timing information. Logic analyzer functionality showing Bit timing and register contents.								
<b>Short</b>	Short the BI_DA+ and BI_DA- in 75ms increments at the PD or PSE end of link for Fault Tolerance and Safety Testing (Short current not to exceed ~3.5 A)								
<b>Micro Interrupts</b>	Short term millisecond opening of the BI_DA+(PI+) or BI_DA-(PI-) signals from 1ms to 65535ms in 1ms steps. Interrupt is placed midspan of cable emulator.								
<b>Data Connectors</b>	2, 3-position Terminal Blocks for BI_DA+, BI_DA- & Shield								
<b>Control Connector</b>	1 Female CAT6A RJ45								
<b>Control</b>	802.3 Ethernet, including high-level command set for remote control, OR a web-based Graphic User Interface (GUI)								
<b>Power Supply</b>	88 to 250 VAC, 50 or 60 Hz								
<b>Dimensions</b>	[4U] W 19 in x H 7 in x D 25 in (W 482 mm x H 178 mm x D 635 mm)								



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**Specifications (continued)**

<b>Integrated Noise Injector(s) Specification</b>	
<b>Bandwidth</b>	100 kHz to 30 MHz
<b>Input Impedance</b>	50Ω unbalanced SMA Connector
<b>Injection Type</b>	Differential Mode, balanced, high impedance
<b>Crest Factor</b>	Greater than 5
<b>Maximum RMS Output</b>	+5 dBm into 50Ω
<b>Dynamic Range of noise output when integrated with Arbitrary Waveform Generator</b>	-70dBm/Hz to -155dBm/Hz
<b>Connectors</b>	4 SMA Female for connection to Telebyte's Model 4975 Noise Generator

<b>Integrated Power-line Ripple Noise Injector(s) Specification</b>	
<b>Bandwidth</b>	1 kHz to 1 MHz
<b>Input Impedance</b>	50Ω unbalanced SMA Connector
<b>Injection Type</b>	Differential Mode, balanced, high impedance
<b>Crest Factor</b>	Greater than 5
<b>Voltage Output Range (peak to peak)</b>	10mV to 100mV
<b>Connectors (Side A and Side B)</b>	2 SMA Female for connection to Telebyte's Model 4975 Noise Generator

<b>Internal AWGN Noise Source Specification (Side A and Side B)</b>	
<b>Bandwidth</b>	100 kHz to 30 MHz
<b>Input Impedance</b>	50Ω unbalanced SMA Connector
<b>Injection Type</b>	Differential Mode, balanced, high impedance
<b>Crest Factor</b>	Greater than 5
<b>Dynamic Range</b>	-70dBm/Hz to -163dBm/Hz

<b>4950-P01: Single-Channel Differential Mode Probe</b>	
<b>Max. Signal Level (In Band)</b>	+/- 5 Vpp 0 dB attenuation, +/- 50 Vpp 20 dB attenuation
<b>Max. DC Voltage</b>	60 VDC
<b>Max. DC Current</b>	2.0 A
<b>Input Impedance</b>	> 4K-ohms Balanced
<b>Attenuation</b>	0 dB or 20 dB
<b>Output Noise Floor</b>	Below -145 dBm/Hz over Band
<b>Bandwidth</b>	20 kHz to 30 MHz
<b>Connectors</b>	Input: 2, 3 pos terminal block for inserting DUT into line and channel emulator AWG Input / Output: 50 ohms SMA connector VNA Return Loss: 50 ohms SMA connector
<b>Power Supply</b>	+5.0 V provided from USB connection or optional external modular supply

Specifications are subject to change without notice. Made in USA.



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## Ordering Options

Model Number	Description
<b>4950-000</b>	<p><b>10BASE-T1L Channel Emulator with Integrated Power Measurements</b></p> <p>IEEE 802.3cg section 146.7.1 (1.0 Vpp): 100m, 250m, 500m, 600m, 850m, 1000m</p> <p>IEEE 802.3cg section 146.7.1 (2.4 Vpp): 50m, 150m, 250m, 350m, 500m, 600m, 750m, 850m, 1000m, 1100m</p> <p>Ethernet-APL Spur Worst Case Cable Model (1.0 Vpp): 200m</p> <p>Ethernet-APL Trunk Worst Case Cable Model (2.4 Vpp): 1000m</p> <p>IEC 61156-13 section 6.3: 100m (A-100), 250m (A-250), 400m (A-400), 1000m (A-1000)</p> <p>TIA 568.5 section 6.3: 100m (SP-1-100), 250m (SP-1-250), 400m (SP-1-400), 1000m (SP-1-1000)</p> <p>Integrated high frequency (100kHz to 30MHz) differential mode noise injectors on Side A and Side B</p>
<b>4950-001</b>	<p><b>10BASE-T1L Channel Emulator with Integrated Power Measurements and SCCP Protocol Analyzer</b></p> <p>IEEE 802.3cg section 146.7.1 (1.0 Vpp): 100m, 250m, 500m, 600m, 850m, 1000m</p> <p>IEEE 802.3cg section 146.7.1 (2.4 Vpp): 50m, 150m, 250m, 350m, 500m, 600m, 750m, 850m, 1000m, 1100m</p> <p>Ethernet-APL Spur Worst Case Cable Model (1.0 Vpp): 200m</p> <p>Ethernet-APL Trunk Worst Case Cable Model (2.4 Vpp): 1000m</p> <p>IEC 61156-13 section 6.3: 100m (A-100), 250m (A-250), 400m (A-400), 1000m (A-1000)</p> <p>TIA 568.5 section 6.3: 100m (SP-1-100), 250m (SP-1-250), 400m (SP-1-400), 1000m (SP-1-1000)</p> <p>Integrated high frequency (100kHz to 30MHz) differential mode noise injectors on Side A &amp; Side B</p> <p>Internal Power-line Ripple Noise Generator and Injector (1kHz to 1MHz) from 10mVpp to 100mVpp on Side A &amp; Side B</p> <p>Internal AWGN Noise Sources on Side A &amp; B for flat Gaussian noise from -75dBm/Hz to -150dBm/Hz</p>

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### Ordering Options (continued)

Model Number	Description
<b>4950-002</b>	<p><b>10BASE-T1L Channel Emulator Extended Length with Integrated Power Measurements and SCCP Protocol Analyzer</b></p> <p>IEEE 802.3cg section 146.7.1 (1.0 Vpp): 100m, 250m, 500m, 600m, 850m, 1000m</p> <p>IEEE 802.3cg section 146.7.1 (2.4 Vpp): 50m, 150m, 250m, 350m, 500m, 600m, 750m, 850m, 1000m, 1050m, 1100m, 1200m, 1250m, 1300m, 1350m, 1375m, 1425m, 1450m, 1475m, 1500m, 1550m, 1600m, 1700m</p> <p>Ethernet-APL Spur Worst Case Cable Model (1.0 Vpp): 200m</p> <p>Ethernet-APL Trunk Worst Case Cable Model (2.4 Vpp): 1000m</p> <p>IEC 61156-13 section 6.3: 100m (A-100), 250m (A-250), 400m (A-400), 1000m (A-1000)</p> <p>TIA 568.5 section 6.3: 100m (SP-1-100), 250m (SP-1-250), 400m (SP-1-400), 1000m (SP-1-1000)</p> <p>Integrated high frequency (100kHz to 30MHz) differential mode noise injectors on Side A &amp; Side B</p> <p>Internal Power-line Ripple Noise Generator and Injector (1kHz to 1MHz) from 10mVpp to 100mVpp on Side A &amp; Side B</p> <p>Internal AWGN Noise Sources on Side A &amp; B for flat Gaussian noise from -75dBm/Hz to -150dBm/Hz</p>
<b>4950-P01</b>	<p><b>Single-Pair Multi-Function Probe (SEE SEPARATE DATASHEET)</b></p> <p>Required for each device on the link segment, Power Source Port and Device Load Port</p> <p>Differential Mode Probe 20kHz to 250 MHz</p> <p>100 Ohm Termination</p> <p>Distortion Circuit</p> <p>Return Loss Circuit</p> <p>AWG Circuit</p> <p>DC Power Binding Posts</p> <p>Voltage Sense Binding Posts</p> <p>USB Power and Control from the Model 4950 Channel Emulator</p> <p>NOTE: 4950-P01 is an optional component of the 4950 channel emulator and is not a standalone product. 4950-P01 must be purchased with the 4950 channel emulator.</p>