

# T3SP15D Data Sheet

## Time Domain Reflectometer (TDR)

### High-Resolution Calibrated True-Differential TDR

### Accurate Impedance Profile Measurements



#### Affordable Tools for Precision Debugging

- ✔ **True Differential TDR and Single-ended TDR** – Best for cables, differential design and twisted pair.
- ✔ **Accurate Impedance measurements, no ground connection required for differential.**
- ✔ **30 ps typ. Rise Time** – Less than 3 mm impedance measurement spatial resolution.
- ✔ **Precisely locate and detect impedance mismatches for signal integrity.**
- ✔ **Instant Cable and Connector Testing** – Verify the quality of your cables and connectors.
- ✔ **Detect even on your premium cables any imperfection that might be the root cause of measurement artifacts.**
- ✔ **Small Form Factor and Battery Powered** – Measure and analyze in the lab, factory floor or in the field.
- ✔ **Measure and analyze everywhere you go without an AC requirement.**
- ✔ **S-parameter: Differential  $S_{11}$  and Full 2-port Single-ended Measurements** – Analyze transmission lines, cable, connectors and adaptors in the frequency domain.
- ✔ **Precisely and rapidly identify any frequency related signal integrity impairments.**
- ✔ **Up to 50,000 points long memory** – Long TDR response capture with high resolution.
- ✔ **Characterize up to 40 m long cables with more detailed measurement data.**
- ✔ **Pre-Compliance for Emerging Serial Data Standards** – USB, BroadR-Reach and Automotive Ethernet.
- ✔ **Debug serial data standards easily.**

#### Key Specifications

Model	T3SP15D
Impedance Profile	Yes, True Differential TDR and Single-ended TDR
Rise Time	35 ps
Spatial Resolution (FR4)	≤ 3 mm
$S_{11}$ , Reflection	Yes, Differential ( $S_{dd11}$ ) and Single-ended ( $S_{11}$ )
Frequency	15 GHz
Full 2-port Single-ended	Yes ( $S_{11}$ , $S_{21}$ , $S_{12}$ , $S_{22}$ )
Impedance Profile Memory Trace	up to 50.000 points
Battery Operated (B-Models)	Yes
Dimensions	220 x 210 x 82.5 mm

# ULTRA-PORTABLE AND BATTERY POWERED



The battery option give you the freedom to work where you require

## Product Overview

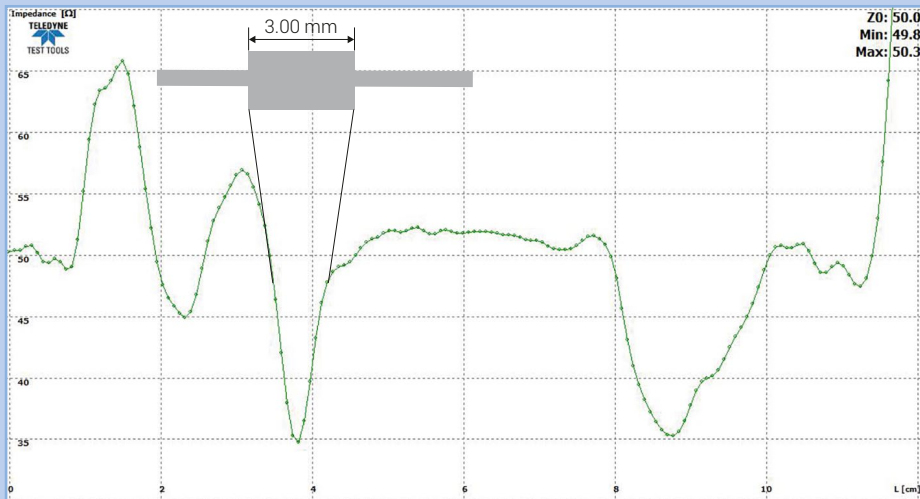
Today's modern fast bus speed designs make debugging signal integrity issues one of the most challenging tasks for engineers to perform efficiently and precisely. For example, take high operating frequencies and mix that with anything that affects your signal's rise time, pulse width, timing, jitter or noise content and you increase the risk of impacting reliability at the system level. If you want to ensure signal integrity you need to understand and control impedance within the transmission environment the signals travel through and the ideal tool to pinpoint those impedance problems are TDR instruments. The Teledyne Test Tools SP-series combines high resolution with a rapid refresh rate, quick data acquisition rate, ultra-portable design including a battery option all for a very attractive price. Use it out in the field and in the lab.

## Key Benefits

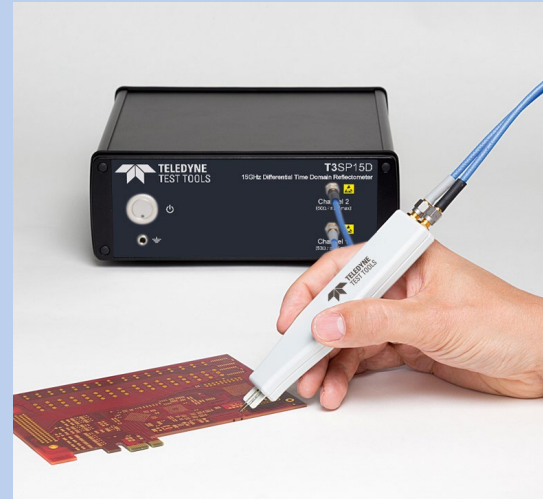
### Ultra-Portable and Battery Powered

Current TDR solutions for signal integrity measurements are based on sampling oscilloscopes which are designed to be used in electronics labs. The size and weight of a traditional sampling oscilloscope make it impossible to perform in the field TDR-measurements. The T3SP-series is designed as a portable and lightweight instrument that can easily be used wherever measurements have to be performed. The battery pack option allows up to 3 hours of operation.

# HIGH-RESOLUTION CALIBRATED TRUE DIFFERENTIAL TDR



*OSL calibration in time domain avoid aberrations effects in impedance plots and let the user identify impedance anomalies with less than 3 mm resolution*



*Based on the true differential design, there is no need for a physical ground connection if differential lanes are measured*

## True differential TDR

Most of the modern high-speed designs are implemented with differential transmission lines. Using a true differential TDR simplifies the setup for signal integrity measurements in such designs. In some scenarios the ground connection could be difficult to connect or not accessible if you want measure unshielded twisted pair cables. Most of the time, when you take measurements using a true differential TDR a ground connection is not required and gives you the flexibility to use TDR-probes without a ground connection.

## Fast TDR Repetition Rate

With up to 10 MHz repetition rate the T3SP-series is more than 300 times faster as conventional TDR-instruments which are based on sampling scopes. To achieve the highest possible dynamic range TDR-instruments need to acquire and average out hundreds of waveforms. The faster sampling rate delivers quicker and more accurate measurement results.

## Full Calibrated Impedance Plot

Reference impedance in all TDR instruments are relative; they are made by comparing reflected amplitudes to an incident amplitude. Using full OSL-calibration the T3SP-series is offering best accuracy for impedance measurements in time and frequency domain. Using

three calibration standards (open, short, load) in the time domain instead of using a simple normalization which is common in TDR-instruments offers vastly improved error correction for the setup. Using OSL-calibration in the time domain avoids irregularities in impedance plots, such as ringing that occurs after the TDR incident step.

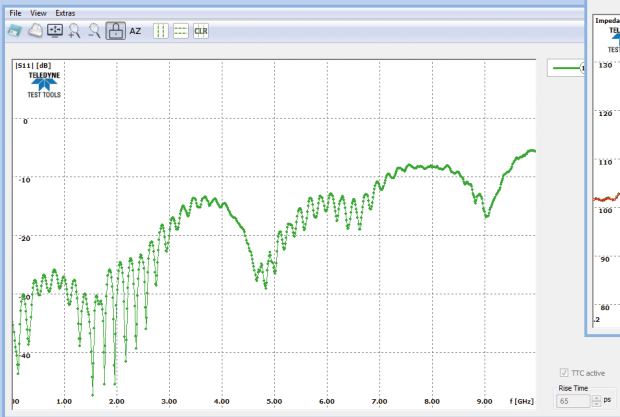
## Full calibrated S-Parameter

Many of the modern standards like Ethernet or USB require you to measure the impedance matching of the cables and connectors within the frequency domain (S-Parameter  $S_{11}$ ). These are the measures commonly made with traditional VNA instruments. The T3SP-series offers fully calibrated Differential  $S_{11}$  and Full Single-ended ( $S_{11}$ ,  $S_{21}$ ,  $S_{12}$ ,  $S_{22}$ ) S-parameters measurements up to 15 GHz using the same OSLT-calibration standards used by VNAs.

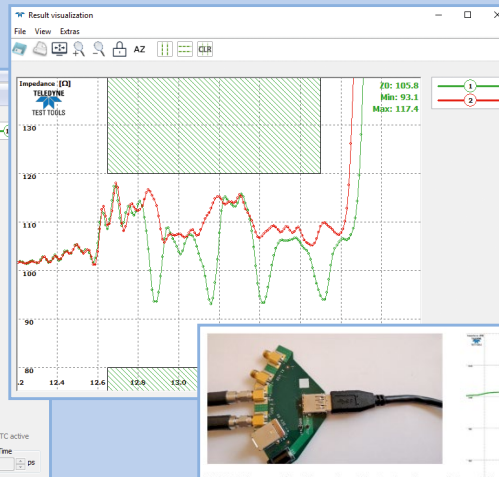
## Long Memory for Long D.U.T

The SP-series can acquire up to 50.000 points which gives you a long TDR record capture with high resolution on long DUTs. If the DUT you are going to measure is long, the number of points that can be acquired is limited by the timing resolution of the TDR-plot. Additionally, you have the flexibility to change the TDR repetition rate from 10 MHz to 1 MHz using the T3SP-series because it offers you the best timing resolution for cable lengths measuring up to 40 m.

# HIGH-RESOLUTION CALIBRATED TRUE DIFFERENTIAL TDR



The T3SP15D series offer S-parameter ( $S_{dd11}$  and Full Single-ended, i.e.  $S_{11}$ ,  $S_{21}$ ,  $S_{12}$ ,  $S_{22}$ ) measurements from DC up to 15 GHz



Less than 3 mm resolution on FR4 can show the effect of blind vias (red) vs. true vias (green)

USB2.0 specifications (incident rise time of the differential TDR set to 400 ps):

- Through Impedance (ZHSTHRU):  $70 \Omega \leq \text{ZHSTHRU} \leq 110 \Omega$   
(\*measured from 500 ps before the connector reference location until the time governed by the Termination Impedance specification\*)
- Termination Impedance (ZHSTERM):  $80 \Omega \leq \text{ZHSTERM} \leq 100 \Omega$   
(\*measurement time following the connector reference time\*)

Variable Rise Time to meet the standards specifications requirements

USB2.0 specifications: Impedance profile @400 ps risetime

## ESD-protection

High-frequency measurement devices are extremely sensitive to electrostatic discharge (ESD) and can lead to permanent damage to your measurement device. In addition, many laboratories have a requirement to take special precautions to protect their electronic equipment from any damage caused by ESD. The SP-series mitigates this risk by providing a higher degree of protection from this happening. Every SP-series model comes equipped with an ESD-protection module based on high-performance coaxial RF-switches. The way this works is the RF input circuitry is protected by isolating the device's RF-signal detector from the input connector when the device is not being used to take measurements.

## Measure Impedance, Return Loss and Insertion Loss

The high bit rates used in modern electronics design and future serial data standards extend well into the microwave region. For example, the High-speed Universal Serial Bus (USB3.1) supports transfer rates up to 10 GB/s over twisted-pair cables. These high bit rate transmissions through connectors and cables result in considerable distortion because of channel dispersion.

To keep the distortion to manageable levels, many standards specify the Impedance, return loss and insertion loss for cables and connectors. These measurements are represented by the S-parameter. The T3SP-series offer fully calibrated Differential  $S_{11}$  ( $S_{dd11}$ ) and full single-ended ( $S_{11}$ ,  $S_{21}$ ,  $S_{12}$ ,  $S_{22}$ ) S-Parameter measurements up to 15 GHz. This gives you the flexibility to store your output files in a variety of formats (CSV, Matlab and Touchstone) which can be easily used in tools like SI-Studio, Matlab or other simulation programs.

## Controlled Impedance Traces on Printed Circuit Boards (PCB)

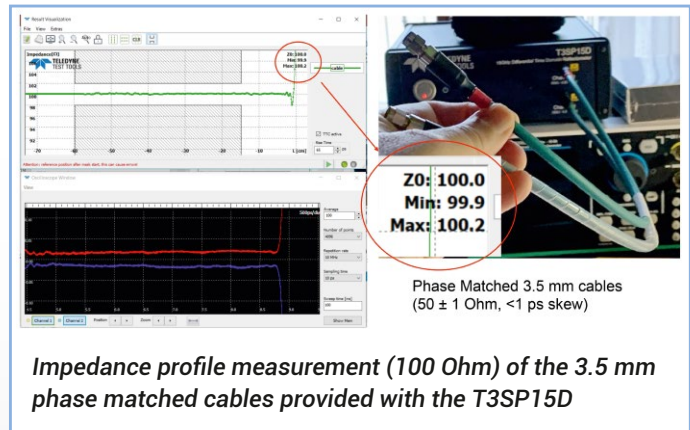
Due to increasing clock rates in high speed digital systems the necessity of controlled impedance PCBs is growing rapidly. Additionally, cables and connectors must meet high frequency design specifications and controlled impedance specifications. The T3SP-series helps you to measure wave impedances of PCBs, cables, and connectors very accurately and comfortably. In contrast to other systems on the market, the T3SP-series is designed for measuring specific traces on a PCB and for on-board tests, the TDR-Probes ensure accurate measurement for qualification testing and debugging assembled PCBs.

# INSTANT CABLES AND CONNECTORS TESTING

## Key Benefits

### Quality of cables and connectors instantly revealed

Assuming cables and connectors are perfect is a common mistake. You make a measurement that involves a fast edge or high bandwidth signal and something doesn't look quite right. In those situations, you add a bad cable or connector to your list of "usual suspects". Unless you have verified the quality of your cables and connectors, there is always the possibility that even your premium cables and connectors may have some imperfections that can cause measurement artifacts. The T3SP-series TDR reveals immediately the quality of your cables and connectors, identifying parts that are out of spec, due to damage or defects. This dramatically improves your productivity and increases the confidence in your design and results.



## T3SP15D + WAVEPULSER 40iX

The Teledyne LeCroy WavePulser 40iX and the Teledyne Test Tools T3SP15D are a perfect combination of complementary products to serve the requirements for testing, validating and troubleshooting cables, backplanes, connectors, and transmission lines on printed-circuit boards.



Model	WavePulser40iX	T3SP15D
<b>Time</b>		
Impedance Profile	Differential, Single-ended and Common-Mode	Differential and Single-ended
Rise Time	8.5 ps	35 ps
<b>Frequency</b>		
S-Parameters	Full 4 port Single-ended, Full Differential and Mixed-mode	Full 2 port Single-ended and Differential S <sub>11</sub>
Frequency	40 GHz	15 GHz
<b>ToolBox</b>		
De-embedding and Emulation	Yes	No
Eye Diagram and Jitter	Yes	No
<b>Platform</b>		
Number of ports	4	2
USB-connected	Yes	Yes
Battery powered	No	Yes

# MODEL SPECIFIC SPECIFICATIONS

Model	T3SP15D
Operating Frequency	15 GHz
S-parameter Measurements	Full Single-ended $S_{11}$ , $S_{21}$ , $S_{12}$ , $S_{22}$ and Differential $S_{dd11}$
Calibration Method	OSL and OSLT
Connector Type	2.92 mm

## Standard Measurement Capability

Measurement Modes	TDR, DTDR
Frequency Domain Displays	$S_{xy}$ (Magnitude, Phase), VSWR, Smith Chart
Insertion Loss Accuracy (max typ. @10 dB)	DC $\leq f < 5$ GHz: $\pm 0.5$ dB 5 GHz $\leq f < 10$ GHz: $\pm 0.75$ dB 10 GHz $\leq f < 15$ GHz: $\pm 1$ dB
Time Domain Displays	Oscilloscope Mode, Z – normalized to specified rise time, Step response
File Outputs	CSV, Matlab, Touchstone 1.0, PDF-Report

## Pulsar / Sampler and Time base

Step Amplitude	150 mV Single-ended / 300 mV differential (nominal top-base, 50 $\Omega$ termination)
Rise Time	35 ps (20 – 80 % typical – as measured by sampler) Rise Time could be limited by software (up to 1 ns)
Input Voltage Range	+/-325 mV (+/-2 V nondestructive)
Noise	< 500 $\mu V_{RMS}$ typical
Repetition Rate	1, 2, 5, 10 MHz
Acquisition Duration	50,000 Points
Max DUT length	40 meters (at 1 MHz sampling rate)
Equivalent Time Sample Rate	100 GS/s
Jitter	< 500 fs RMS typical

## Internal ESD Protection Relays

Frequency Rating	>15 GHz
Rated Life	2 million actuations per contact

Model	T3SP15D
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## Battery (Option)

Type	Internal Li-Ion-Battery, 2.2 Ah
Operational Time	> 3 hours * (in ESD-protection mode)
Recharging Time	3 hours

## Physical Dimensions

Dimensions	Without connectors: 220 x 210 x 82.5 mm With connectors: 242 x 210 x 82.5 mm Coax connector spacing: 28 mm
Shipping Dimensions	500 mm x 400 mm x 200 mm
Weight	2600 g (2800 g with battery)
Shipping Weight	7300 g (including travel case and accessories)

## Power Requirements

Voltage	100 – 240 VAC, 50 – 60 Hz, 1.7 A with distributed external power adapter
Max. Power Consumption	17 watt (42 watt with battery)

## Temperature Range

Operation	0 °C – 40 °C
Store	-20 °C – 80 °C (0 °C – 40 °C with Battery)

## Recommended PC Configuration

Operating System	Windows 7, Windows 8, Windows 10
Processor	Dual core or better recommended
Memory	Minimal 2 Gbyte
Hard Drive	Minimal 25 Mbyte
Display Resolution	1024 x 768 or larger
Connectivity	USB 2.0

# TDR PROBES

## T3SP-DPROBE



The high precision differential TDR Probe T3SP-DPROBE provides an 18 GHz, high performance solution for TDR circuit board impedance characterization and high-speed electrical signal analysis applications. The ergonomic and robust case design providing best ratio of thickness and width. The robust measuring tips guarantee a long life and high repeatability of the measurements.

Parameter	Value / Unit	Comments
Impedance	100 Ω	VSWR < 1.05
Electrical Length	690 ps	
Probe Tips	Fixed Blades	Copper beryllium (3 pairs of replacement tips included)
Pitch	0.1 – 5 mm	adjustable
Pin Configuration	Signal – Signal	
Connectors	SMA female	compatible with 2.92 mm and 3.5 mm connectors
Frequency Range	DC – 18 GHz	valid for probe without tips
Dimensions	130 × 34 × 14 mm	casing only
	157.5 × 34 × 14 mm	with connectors and tips
Material	Aluminum	
Specials		direct in-circuit TDR testing

## T3SP-DPROBE-F



The economic differential TDR Probe T3SP-DPROBE-F provides an ideal solution for TDR circuit board impedance characterization on a very attractive price. It is the ideal probe for fast and accurate PCB impedance measurements up to 5 GHz.

Parameter	Value / Unit	Comments
Impedance	100 Ω	VSWR < 1.05
Electrical Length	830 ps	
Probe Tips	Spring-loaded pin	
Pitch	2.54 mm	fixed
Pin Configuration	Signal – Signal	
Connectors	SMA female	compatible with 2.92 mm and 3.5 mm connectors
Frequency Range	DC – 5 GHz	valid for probe without tips
Dimensions	131 × 32 × 13.2 mm	casing only
	131 × 32 × 15.6 mm	with connectors and tips
Material	Polystyrene	

## T3SP-SEPROBE-F



The T3SP-SEPROBE-F Single-ended TDR probe provides an ideal solution for TDR circuit board impedance characterization at a very attractive price. It is the ideal single-ended probe for fast, accurate and repeatable accurate PCB impedance measurements up to 5 GHz.

Parameter	Value / Unit	Comments
Impedance	50 Ω ±1 Ω	
Electrical Length	850 ps	
Probe Tips	spring-loaded	
Pitch	2.54 mm	fixed
Pin Configuration	S-G	
Connectors	SMA female	compatible with 2.92 mm and 3.5 mm connectors
Frequency Range	DC – 5 GHz	valid for probe with tips
Dimensions	131 × 32 × 13.2 mm	casing only
	131 × 32 × 15.6 mm	with connectors and tips
Material	Polystyrene	

## T3SP-SEP



The high precision Single-ended T3SP-SEP TDR probe provides a 10 GHz, high performance and repeatable solution for TDR circuit board impedance characterization for all the high-speed single-ended electrical signal analysis applications. The variable pitch combined with the compact dimension make this probe an ideal solution for high repeatable TDR single-ended measurements.

Parameter	Value / Unit	Comments
Impedance	50 Ω ±1 Ω	
Electrical Length	100 ps	
Probe Tips	spring loaded	
Pitch	1.0, 1.27, 1.65, 2.0 & 2.5 mm	variable
Pin Configuration	S-G	
Connectors	2.92 mm female	compatible with SMA and 3.5 mm connectors
Frequency Range	DC – 10 GHz	
Dimensions	29.8 × 9.0 mm	(length × diameter)
Material	Brass	
Specials		direct in-circuit TDR testing

# TDR ACCESSORIES

## T3SP-CASE

The T3SP-CASE aluminum case is an ideal choice to safely store and transport your T3SP15D instrument and additional accessories. Included with the T3SP15D-BUNDLE and T3SP15D-B-BUNDLE models.

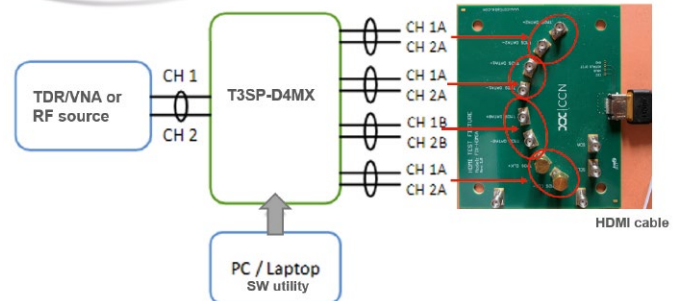


## T3SP-D4MX-BUNDLE (Differential High-frequency DP4T/2:8 Multiplexer)

The T3SP-D4MX-BUNDLE phased matched RF multiplexer provides a versatile RF switch for differential and single-ended TDR applications. It includes a matched cable set, making it ideal for combining with the T3SP15D for instant testing of cables and multi-pair connectors.

### Included with T3SP-D4MX-BUNDLE:

- T3SP-D4MX Multiplexer Mainframe
- 1 x pair of phase matched cables ( $\pm 2$  ps), 8-inch, Channel Inputs
- 4 x pairs of phase matched and color-coded cables (black, white, yellow and red), 24-inch, Channel Outputs
- 2 m USB2.0 cable with ferrite
- 10 conductive protective caps
- Conformance Certificate



**Testing differential impedance for:  
USB, HDMI, Display Port, Automotive Ethernet ...**

## Ordering information

Product Description	Product Code
Differential TDR, 35 ps Rise Time, ESD protection, 2 phase matched 3.5 mm cables, 3.5 mm Cal. Kit, Aluminum Case, Differential $S_{11}$ and Single-ended $S_{11}$ , $S_{21}$ , $S_{12}$ , $S_{22}$	T3SP15D-BUNDLE
Differential TDR, 35 ps Rise Time, ESD protection, 2 phase matched 3.5 mm cables, 3.5 mm Cal. Kit, Aluminum Case, Internal Battery, Differential $S_{11}$ and Single-ended $S_{11}$ , $S_{21}$ , $S_{12}$ , $S_{22}$	T3SP15D-B-BUNDLE
Differential High-frequency DP4T/2:8 Multiplexer	T3SP-D4MX-BUNDLE
Phase Matched 3.5 mm cables ( $50 \pm 1$ Ohm, $<1$ ps skew)	T3SP-CABLE-3.5MM
Differential TDR-Probe (high precision, 18 GHz, 0.5 – 5.0 mm variable pitch)	T3SP-DPROBE
Differential TDR-Probe (economic, 5 GHz, 2.5 or 5 mm fixed pitch)	T3SP-DPROBE-F
Single-ended TDR-Probe (fixed pitch 2.54 mm)	T3SP-SEPROBE-F
Single-ended TDR-Probe (high precision, 10 GHz, variable pitch)	T3SP-SEP
OSLT Calibration Kit 3.5MM with torque wrench, female	T3SP-CALKIT-3.5MM
Storage and Travel Case (aluminum suitcase for TDRs and accessories)	T3SP-CASE
Demo and Verification Board	T3SP-BOARD

Standard warranty is one year (for warranty extension please contact Teledyne LeCroy Service)

### Included with T3SP15D-BUNDLE and T3SP15D-B-BUNDLE

T3SP15D or T3SP15D-B (internal battery) time-domain mainframe, 1 x pair of phase matched cables ( $\pm 2$  ps), OSLT calibration Kit (@26.5 GHz, 2.92 mm with certificate), torque wrench, USB Hasp (to enable TDR application to run off-line), USB2.0 cable, Mini USB to USB-A, External Power Supply, Aluminum case (T3SP-CASE), Calibration and Performance Certificate, 1 year warranty.

## Platform selection guide

Product Code	Mainframe and Phase matched cables	Calibration Kit and Torque wrench (Bundle-models)	Internal Battery (B-models)	Impedance Profile, Step Response	S-parameter ( $S_{dd11}$ )	S-parameter (SE $S_{11}$ , $S_{21}$ , $S_{12}$ , $S_{22}$ )
T3SP15D-BUNDLE	YES (3.5 mm cables)	YES (3.5 mm OSLT Cal kit)	NO	YES (rise time 35 ps)	YES (up to 15 GHz)	YES (up to 15 GHz)
T3SP15D-B-BUNDLE	YES (3.5 mm cables)	YES (3.5 mm OSLT Cal kit)	YES	YES (rise time 35 ps)	YES (up to 15 GHz)	YES (up to 15 GHz)

# ABOUT TELEDYNE TEST TOOLS



## Company Profile

Teledyne LeCroy is a leading provider of oscilloscopes, protocol analyzers and related test and measurement solutions that enable companies across a wide range of industries to design and test electronic devices of all types. Since our founding in 1964, we have focused on creating products that improve productivity by helping engineers resolve design issues faster and more effectively. Oscilloscopes are tools used by designers and engineers to measure and analyze complex electronic signals in order to develop high-performance systems and to validate electronic designs in order to improve time to market.

The Teledyne Test Tools brand extends the Teledyne LeCroy product portfolio with a comprehensive range of test equipment solutions. This new range of products delivers a broad range of quality test solutions that enable engineers to rapidly validate product and design and reduce time-to-market. Designers, engineers and educators rely on Teledyne Test Tools solutions to meet their most challenging needs for testing, education and electronics validation.

## Location and Facilities

Headquartered in Chestnut Ridge, New York, Teledyne Test Tools and Teledyne LeCroy has sales, service and development subsidiaries in the US and throughout Europe and Asia. Teledyne Test Tools and Teledyne LeCroy products are employed across a wide variety of industries, including semiconductor, computer, consumer electronics, education, military/aerospace, automotive/industrial, and telecommunications.

Distributed by:

**ADMESS Vertriebs GmbH**  
Ernst-Kiefer-Straße 9  
67292 Kirchheimbolanden  
Germany

**Tel.: +49 (0) 6352 / 78 99 8 - 0**  
**Telefax: +49 (0) 6352 / 78 99 8 - 20**  
**E-Mail: [info@admess.de](mailto:info@admess.de)**  
**[www.admess.de](http://www.admess.de)**

[teledynelecroy.com](http://teledynelecroy.com)

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T3 stands for Teledyne Test Tools.

## Teledyne LeCroy (US Headquarters)

700 Chestnut Ridge Road  
Chestnut Ridge, NY, USA 10977-6499

Phone: 800-553-2769 or 845-425-2000  
Fax Sales: 845-578-5985  
Phone Support: 1-800-553-2769  
Email Sales: [contact.corp@teledynelecroy.com](mailto:contact.corp@teledynelecroy.com)  
Email Support: [support@teledynelecroy.com](mailto:support@teledynelecroy.com)  
Web Site: <http://teledynelecroy.com/>

## Teledyne LeCroy (European Headquarters)

### Teledyne GmbH

Im Breitspiel 11c  
D-69126 Heidelberg, Germany

Phone: +49 6221 82700  
Fax: +49 6221 834655  
Phone Service: +49 6221 8270 85  
Phone Support: +49 6221 8270 28  
Email Sales: [contact.gmbh@teledynelecroy.com](mailto:contact.gmbh@teledynelecroy.com)  
Email Service: [service.gmbh@teledynelecroy.com](mailto:service.gmbh@teledynelecroy.com)  
Email Support: [tlc.t3.appsupport.eu@teledyne.com](mailto:tlc.t3.appsupport.eu@teledyne.com)  
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