TELEDYNE TEST TOOLS
Everywhereyoulook™

Operator's Manual

T3SP-Series Time Domain Reflectometer

T3SP-Series Operator's Manual

Revision F - March 8, 2023
Relating to the following release versions:
Software Version Rev. 1.8.0 and later

T3 stands for Teledyne Test Tools.

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1. General Information about the T3SP Series

The T3SP series is developed to perform true differential TDR measurement. Complementary step signals with an ultra-wide bandwidth are emitted and acquired by the instrument. The signals are applicable to external components via the coaxial connectors.

Please read this operation manual carefully before commissioning the T3SP, to avoid incorrect operation of the instrument. Keep this manual carefully the entire life-time of the instrument. Subsequently the T3SP TDR is generally described as "device".

1.1 Intended Application

The device is exclusively intended for usage in conjunction with the delivered software. Upon request software libraries are available to integrate the device control into other software environments. Beware of using the device for purposes other than intended.

1.2 Disclaimer

Warranty or liability claims for personal or property injury are excluded if they are caused by one or more of the following reasons:

- Usage of the device for other purposes as described in this manual
- Disregarding the instructions for correct operation of the device
- Disregarding the safety instructions listed in this operation manual
- Opening of the instrument by the customer or user

1.3 Contents of Packing

- T3SP time-domain reflectometer
- USB 2.0 cable, Mini USB-B to USB-A
- External power supply: input 100-240VAC, output 24VDC, max. 3A
- Integrated ESD-protection module
- Metal or plastic storage and transport case
- ESD-protection kit
- Cables
- Calibration kit including RF connector torque wrench
- Adapters (optional)

2. Commissioning

Before the first start of operation you have to install the provided Seunis software. Please follow the installation instructions given by the software. Before starting the software connect the device and turn it on. The software automatically detects the connected instrument.

Remark: *In rare cases, the device cannot be found. Please see the troubleshooting section 14 for further information.*

2.1 General Remarks

The Seunis measurement software was designed to make series measurements and therefore the central element of the main window is a spreadsheet-like table. For a better understanding, some regularly used terms are defined below:

Sample	Synonym for object / device under test (DUT)
Sample List	Collection of samples in the spreadsheet table
(D)TTC = (Differential) Three-Term Correction	Error correction method, removes systematic device & external cable/connector errors
12TC = Twelve Term Correction	Error correction method for full 2-port S-parameter measurements. Only used if full 2-port measurement mode is available
Measurement Modes	The software is capable of measuring various parameters (impedance, S11, etc.). These functionalities are called measurement modes

2.2 Software Configuration File

Some specialized hidden options and functionalities can only be modified via the software configuration file *Seunis.config*. The default location of the configuration file is `C:\Users\<USERNAME>\AppData\Roaming\Teledyne`.

2.3 Software Startup

To start the software, the device must be switched on, as the available measurement modes are read out from the internal memory. Alternatively the software can be started with the Teledyne Viewer Key.

2.4 Power Supply & USB Connection

To enable measurements, connect the USB port of the instrument to a computer. Please follow the instructions given below:

- If available plug the Mini-USB-B plug connector of the USB-cable into the corresponding USB-jack connector of the device and the USB-A plug into a USB-port of your computer.
- Turn on the device by pressing the power button for more than 1 second. After a few seconds, the button LED changes to red. The device can be turned off by pressing the power button for more than 3 seconds.
- The 2-state red-green LED signals have the following meaning:

Green blinking LED:	Device switched off, battery charging active
Red blinking LED:	Device switched on, battery charging active
Red LED turned on:	Device switched on, battery charging finished

- The software will automatically probe your USB ports to communicate with the device. You can check if this was successful in the status bar on the bottom of the *Main Window*, which shows whether the device is *Connected* or *Not connected*.

- If the connection to the device failed, retry to connect by pressing CTRL-U or via the menu *Extras*. If you are not able to establish a connection, check the troubleshooting section 14 for further information.
- Like other RF-measurement systems, the device needs some time to warm-up for performing stable and accurate measurements. During the warm-up phase, measurements are prohibited. If the temperature is stable, the status bar shows OK. If you try to measure during the warm-up phase, the measurement is aborted, accompanied by an audio warning and the notification *Device temperature instable*.

2.5 Description of the Application Windows

2.5.1 Main Window

The *Main Window* (Fig. 1) allows the user to organize the measurement campaigns. The spreadsheet format is used to prepare sample lists, which can be worked off accordingly. The main functionality for organizing the data, results and further common tasks (e.g. saving, loading, exporting of data) can be controlled via the main menu. "At a glance" information and measurement results are also available.

All project relevant information can be stored in `mas` *Project Files*. Older software versions used the `sqc` format, these store less information and should therefore no longer be used.

The information saved in `mas` *Project Files* are:

- Traces, masks, results and settings for each sample
- Calibration and reference measurements
- Calibration kit data

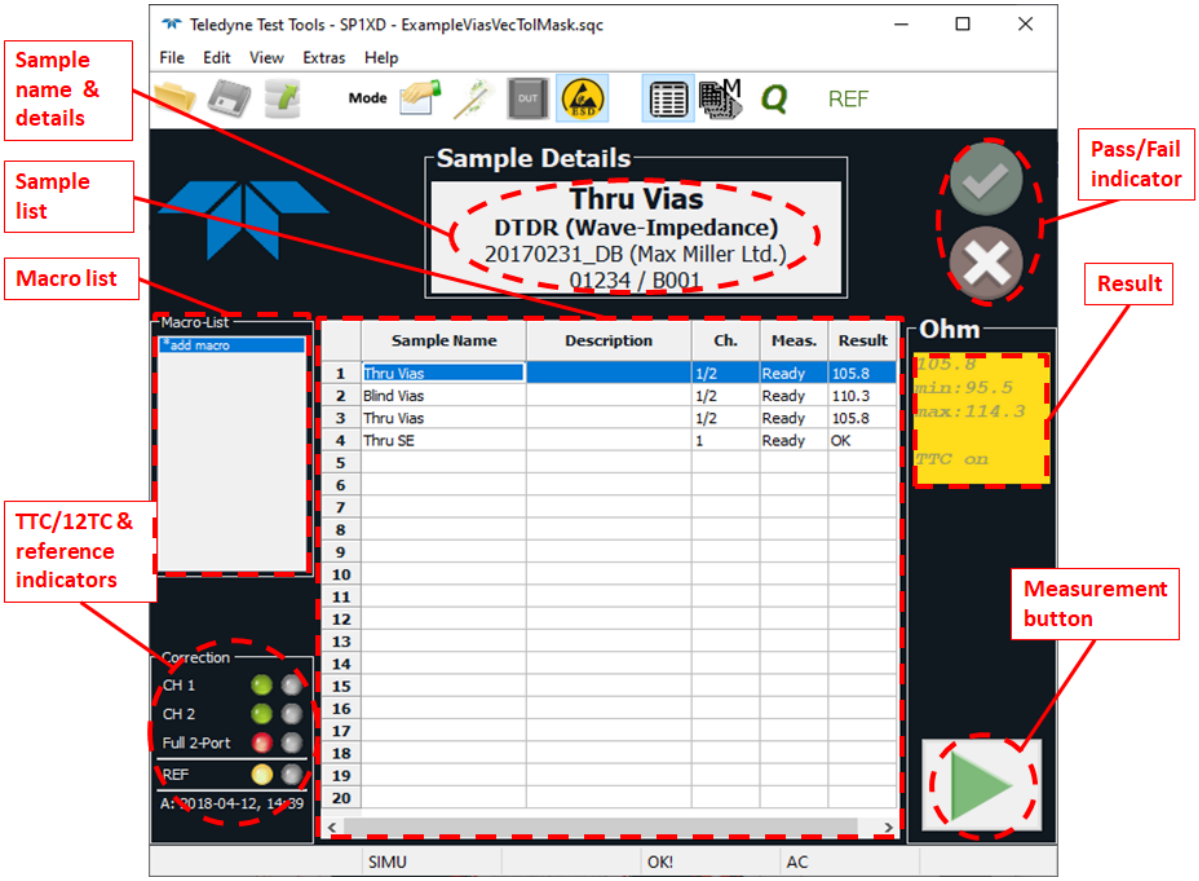


Figure 1: *Main Window* with sample list and control elements

- De-embedding data
- Time base and frequency settings
- Last axes and cursors states
- Project comment
- System diagnosis information

2.5.1.1 Samples

In the context of the *Seunis* software, measurements usually are referred to as *Samples*. These contain a range of other data in addition to the actual TDR measurement. The following is a list of some selected information stored in

each indivdual *Sample*:

- Sample name (must be defined on creation of sample)
- Description (some further piece of information, optional)
- Channel assignment
- Results of measurement (depends on measurement mode)
- Measurement mode (see chapter 5)
- TDR traces (see Figure 2)
- Time base settings
- Frequency setting
- Tolerance mask
- Part description and number, batch number, customer info
- Test standard (freely selectable description, e.g. IEC 61196)
- Meta and system diagnostic data

To create a new Sample, simply type a new name in the first empty line of the *Sample List*. On creation, only the name has to be defined, all other parameters are defined according to the current system settings (e.g. time base, frequency, measurement mode, test standard).

With very few exceptions, the settings can also be made or changed later. How to change the settings for a single or multiple *Samples* is explained later in the course of this manual. To get an overview of the settings to be changed, right-click an existing *Sample* in the list and select the *Change Samples Settings* menu item or open the *Impedance Measurement Properties Window*, as described in section 5.1.3.

2.5.1.2 Sample List

Basically the *Sample List* is collection of *Samples* as described in subsection 2.5.1.1. The following is a list of the table columns as shown in Fig. 1:

Sample Name: Measurement label, which must be a non-empty string. A new sample can be generated by filling in this field. Special characters should be avoided.

Description: Field for storing some additional information for each sample (not mandatory)

Channel: Indicates the selected channel(s) for the sample. Not directly editable.

Result: Indicates overall result for the measurement, content depends on measurement mode. Not available in all modes and not directly editable.

2.5.1.3 Carrying out Measurements

To start a measurement, define a sample as described above and click the *Measurement Button* (see figure 1 and 3 or press F5 on the keyboard).

It is possible to have several measurements carried out automatically one after the other. To achieve this, the corrsponding (unmeasured) samples must be selected in the table. Then start the measurements by right-clicking the *Measurement Button* and selecting the corrsponding item in the popup menu.

2.5.1.4 Macro List

The *Macro List* is suitable for performing recurring series measurements. *Macros* can be defined similar to *Samples*. When working in macro mode (see toolbar ), the listed macros are cyclically used as template for a new

measurements. The measurements are automatically labeled according to the macro name and pushed in to the *Sample List* for further use.

2.5.2 Oscilloscope Window

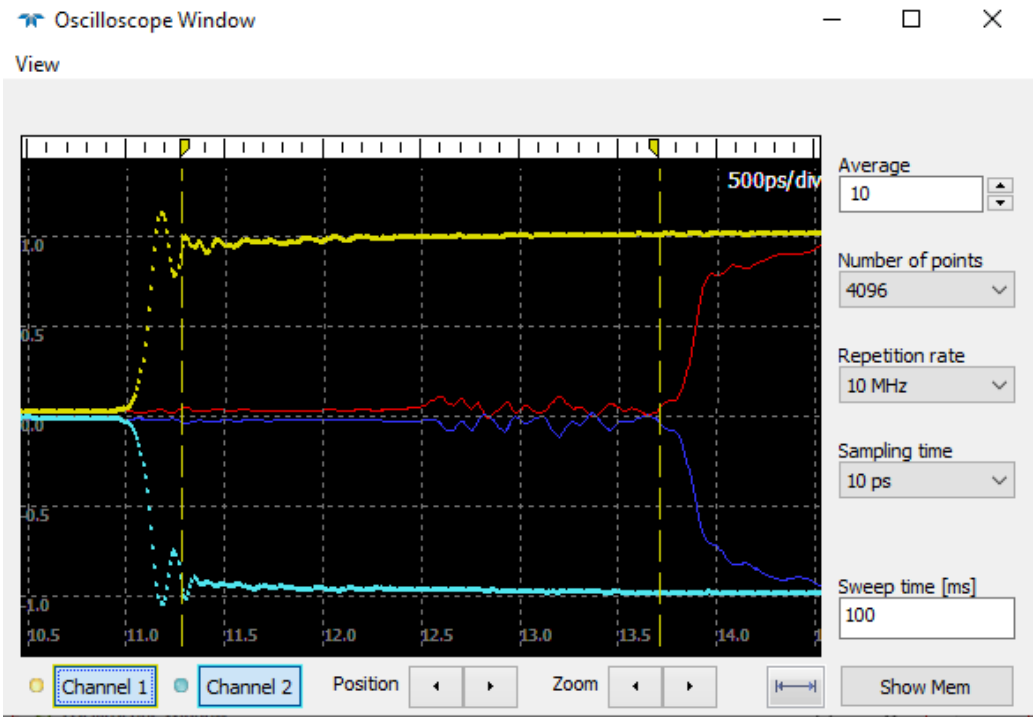


Figure 2: *Oscilloscope Window* showing a differential TDR measurement

General Remark

The *Oscilloscope Window* gives the user an overview over the current device setting (average, time base settings) and shows the real-time ("live") TDR trace(s), similar to an oscilloscopes screen. If an already measured *Sample* is selected in the *Main Window*, the corresponding uncorrected TDR trace(s) is/are displayed additionally.

Number of Averages

The number of curves to be averaged (repetition measurements) for a sample can be set in the *Average* field. In case a large number of averages is chosen it may be advantageous to display only an averaged version of the

trace(s). This can be activated via the menu entry *View* → *Display averaged Measurement*.

***Please note**: in the `Seunis.config` file a maximum number of averages can be set (`Compressed number of measurements`, default: `50`). If the selected number of averages exceeds this number, the number of stored repetition measurements is automatically compressed to this value without affecting the accuracy.*

TDR and Impedance View

The view can be switched to real-time impedance trace (menu *View* → *Show Impedance*). The impedance trace represents the uncorrected impedance (without TTC, see chap. 4). The traces of the currently selected sample in the sample list are not shown if impedance is turned on.

The live traces can be switched on/off via the *Channel* buttons. A linear interpolation between the points can be activated via *View* → *Interpolate Trace*. The background color can be changed via the *View* → *Change Background Color* menu entry.

Zooming & Moving

Zooming functions are available via *Position, Zoom & Fit buttons*. The zoom can be changed via the mouse (use mouse-wheel or hold left mouse button pressed down while dragging). A "fit-to-screen" is applied by a **double right-click** in the diagram. The TDR trace can be positioned by holding the middle button down while moving the mouse.

Memory Function

It is possible to display a previously acquired TDR trace on the screen by pressing the CTRL button and clicking the *Show Mem* button simultaneously. Either the live curve or a sample (average of all repetition measurements)

from the list can be displayed. The trace is displayed and saved into a temporary memory. It can be switched on/off by clicking the *Show Mem* button.

Description of the Menu Items

View:

Show Impedance	Switch between step response and impedance view. If impedance view is activated, no samples from the list are shown. For differential measurements, the differential impedance is displayed.
Interpolate Trace	Instead of the data points, the linearly interpolated trace is displayed.
Display averaged...	Instead of all repetition measurements, only the averaged trace is displayed.
Change BG Color	Change the diagram background color.

2.5.3 Result Visualization Window

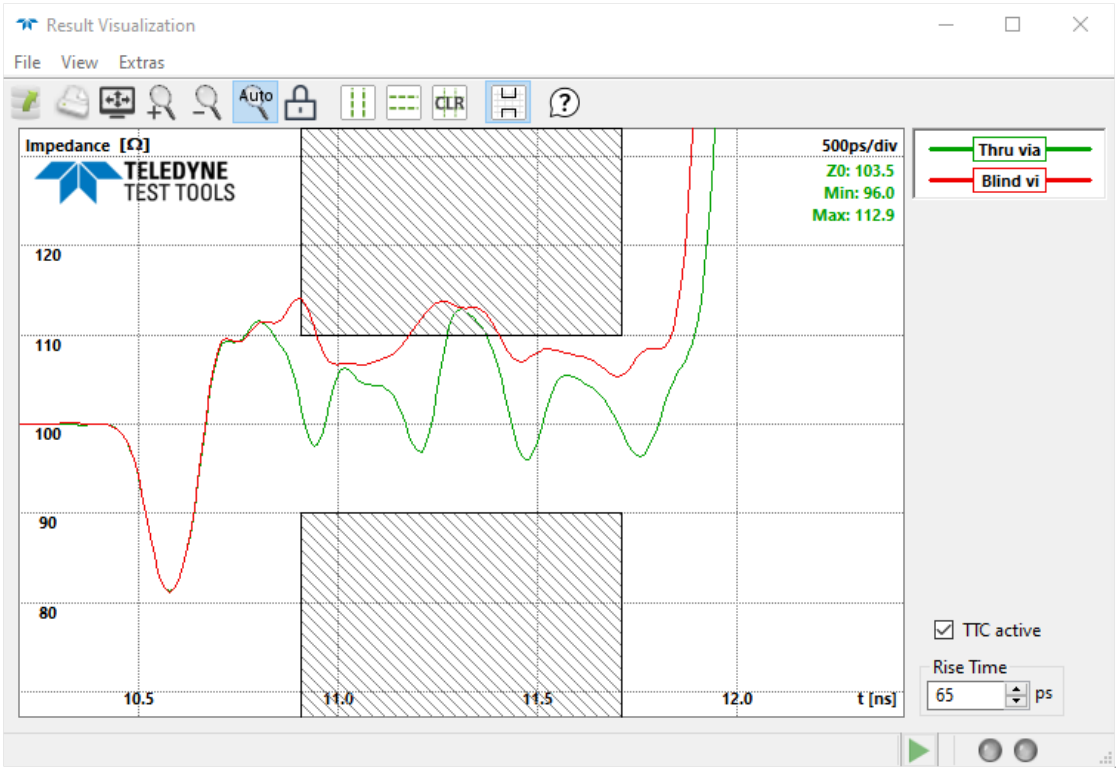


Figure 3: Impedance measurements results

General Remark

Most *Measurement Modes* (see chapter 5) yield more information than can be displayed in the yellow result field of the *Main Window*. To display the specific results in more detail the *Result Visualization Window* is used. The different kinds of visualizations depend on the currently selected measurement mode and are therefore described in the specific sections.

TTC/12TC Calibration

The software allows the correction of systematic errors by means of OPEN, SHORT, LOAD calibration, referred to here as *Three Term Correction (TTC)*.

An additional THRU is used for a full 2-port calibration (*12-Term Correction = 12TC*). The *TTC/12TC* can be activated/deactivated using the *TTC active* checkbox. Please note that deactivation is not allowed for certain measurement modes (e.g. all frequency domain modes) and so the button is disabled in this case.

Trace Display

The data points of the curves can be switched on and off via the menu entry *View* $\rightarrow$ *Show Data Points*.

Trace highlighting can be achieved by clicking on the corresponding entry in the legend (reset by clicking the entry again).

Live Traces

Working in *Quick Operation Mode* (see section 2.6.3) enables the user to view a "live" trace in the *Result Visualization Window*. This feature can be activated via the menu entry *Extras* $\rightarrow$ *Live*.

Rise Time Adjustment

The rise time of the step signal can be altered in time domain modes. Besides the standard functionality of increasing the rise time (simulation of slower digital signals), it is also possible to decrease the rise time down to a minimum of 25ps. In this way, a higher timebase and spatial resolution can be achieved. Make sure that the number of averages for the TTC and DUT measurements is sufficiently high to avoid "ringing" due to overweighted and erroneous spectral components. The rise time is equal for all measurements and saved in project `mas` files.

Zooming & Moving

The zoom area can be changed by dragging the mouse, or by using the

mouse wheel. Alternatively the buttons in the toolbar can be used.

Zooming only in a certain direction can be achieved by using the mouse-wheel while holding the CTRL-key (x-axis) or the SHIFT-key (y-axis). A "fit-to-screen" can be achieved by double right-clicking within the diagram.

Pressing the button with the lock symbol has the effect that in time domain measurement modes (as *TDR & DTDR*) the zoom is locked to the current zoom of the *Oscilloscope Window*. The result traces can be positioned by holding the middle button down while moving the mouse.

Measurement Button

A small green arrow button is located in the status bar to start a measurement. Pressing the button has the same effect as pressing the measurement button in the *Main Window* or pressing F5.

Cursors

The software features (delta) cursors for each displayed sample in the *Result Visualization Window*. Cursors can be set by pressing down the CTRL key while left-clicking a trace. The cursor values are displayed on top of the diagram in the cursor value field. If two cursors are set up for a trace the delta value is displayed as well. The cursor value field can be double-clicked to open an overview tabular.

Pressing the CTRL key and clicking a cursor again deletes the cursor. Alternatively all cursors can be cleared by pressing the CLR button in the toolbar.

Cursor labels can be set/reset by right-clicking them.

Horizontal cursors can be moved to the desired position by holding down the left mouse button.

The precision of the cursor values can be changed via the menu item *View → Set decimal places of cursor*.

Please note: at most **two cursors can be set** for each sample. That means that if two cursors are already set in impedance measurement mode and the measurement mode is changed (e.g. to S11 mode), no more cursors can be set. In this case delete the existing cursors before setting them in S11 mode.

Legend

By default the legend shows the sample name (only the first 8 characters). Alternatively the samples row number corresponding to the spread sheet row can be displayed. Use *View → Show sample names in legend* to toggle between the modes.

Data Export

The underlying data of the currently displayed samples can be exported to various formats. Currently supported formats are `csv`, `xlsx`, `mat` (Matlab) and `sp1`/`sp2` (Touchstone for S-parameters). To export data via the *Result Visualization Window* use the export button or the menu entry *File → Export*.

Please note: *the Touchstone export is available for S-parameter modes only. Data can be saved to the Touchstone format. Each selected sample is exported into an individual file. The frequency data points are exported in MHz, the scattering parameter values as magnitudes and degrees. Optionally the magnitude of the data can be limited to 0dB.*

Background Color

The background color of the diagram can be changed via the menu entry *View → Change Background Color*.

Help

Press the symbol in the toolbar, to get some useful information about how the Legend, Cursors, etc. can be set up.

Description of the Menu Items

File:

Export	Export data to various formats.
Close	Close the *Result Visualization Window*.

View:

TDR	TDR/impedance related functionality.
S-Parameter	Scattering-Parameter related functionality (optional).
Previous Parameter	Switching to previous S-parameter (optional, full 2-port).
Next Parameter	Switching to next S-parameter (optional, full 2-port).
Show Data Points	Show & hide trace data points.
Show Names in Legend	Show the first 8 characters of sample name in legend.
Set Axis manually	Set the diagrams axis manually.
Set Decimal Places	Change precision of cursor values.
Change BG color	Change the diagram background color.

Extras:

Set x-Mask in …	Change the tolerance mask x-limits to current x-axis for all displayed traces.
Set y-Mask in …	Change the tolerance mask y-limits to current y-axis for all displayed traces.

Set x/y-Mask in …	Change the tolerance mask x- and y-limits to current axis for all displayed traces.
Change Frequency	Change frequency settings.
Set optimized Frequency	Set optimized frequency setting for exporting de-embedding parameters.
Change Video Bandwidth	Change current video bandwidth.
Set Reference manually	Change reference position (point in time to be indicated in [nsec]) to a user-defined value. Make sure the current reference measurement is not empty (see section 5.1.2).
Live	Enable & disable live trace (only available in Quick Operation Mode, not for full 2-port mode).

2.5.4 Options Dialog

Some program settings can be changed in the *Options Dialog*. This information is persistent and restored on each startup of the program.

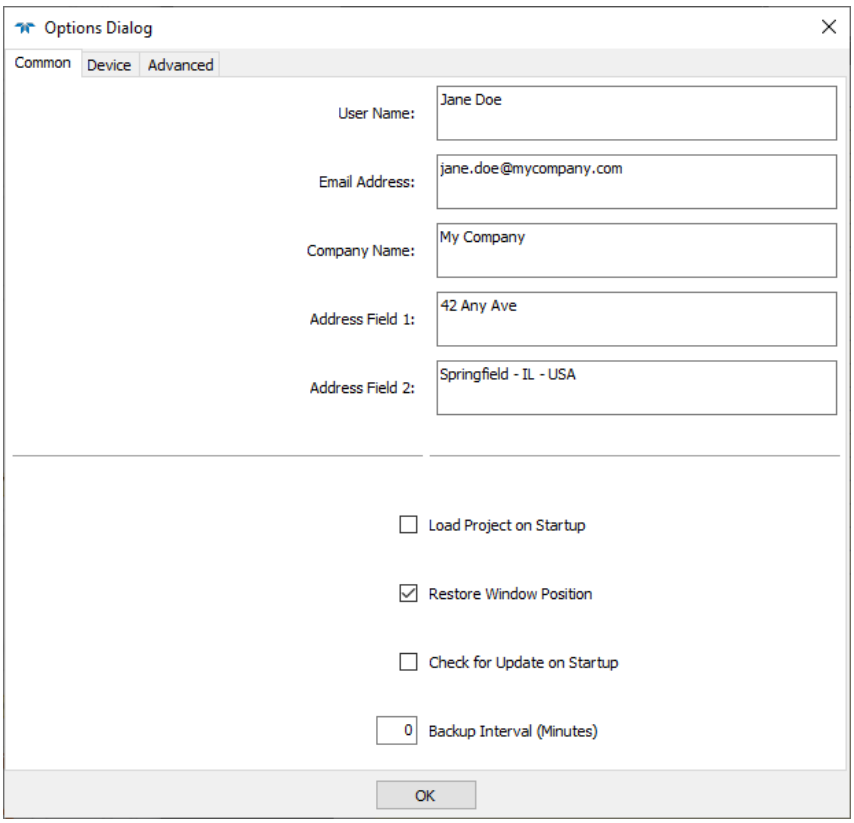


Figure 4: The *Common* tab in the *Options Dialog*

Common tab:

- The user name is saved automatically with the samples in the project files.
- The users email address.
- The company name and address is printed e.g. in the PDF reports.

- If *Load Project on Startup* is checked, the last known project file is automatically reloaded on startup.
- If *Restore Windows Position* is checked, the last known window arrangement is restored on startup.
- The software automatically saves backups to the user's application folder, and the backup interval can be set (minutes). If set to "0", immediate backup is activated, if set to "-1", backup is completely turned off (this is NOT recommended).

Device tab:

- In most cases the software is started with a connected device and it is intended to connect automatically. However if the software shall be started with a *Viewer Key* it is possible to deactivate the *Auto-Connect* on Startup.
- *Data Rate*: data transfer rate between device and software (read only)
- The *Single Shot Measurement* box should be checked, if all average measurements shall be carried out at once. Otherwise all measurements can be performed separately. This may be desirable in some very specific applications. By default this option is turned on.
- In some rare cases it may be necessary to switch off the instable signal protection during measurements, for this purpose the *Ignore Instable Signal* box can be checked. Usually this option should be unchecked.
- The last valid TTC is loaded automatically if the box is checked.
- In the *ESD auto-protection* field, the number of seconds is set after which the devices ESD-protection is activated automatically.

- If the ESD-auto-off time is set to 0 the ESD-protection is only turned off during the measurements. This is the safest operation mode and **recommended** to be used in **unsafe environments**.

Advanced tab:

- *Stop macro execution on failure:* see section 2.6.2 about macro mode measurements.
- *Enable frequency domain smoothing:* this option can be used for de-noising frequency domain results (see chapter 6).
- *Equalize transmission coefficients in F2P:* only enabled if *full 2-port S-parameter measurement mode* is available. If checked the mean value of S12 and S21 parameters are calculated, in order to suppress asymmetries of the measurement system. This option is only reasonable for linear passive DUTs.
- *Suppress various info ouput in PDF:* the user can suppress the output of the project comments, pass/fail information, dielectric constant, full PDF saving path, step rise time, time base, and signal velocity.
- *Set TTC-location:* for multi-user systems the saving location for the last known TTC/12TC can be modified. This circumvents problems with file access permissions.
- *Self-Test:* Perform a device self-test.
- **Please note:** generally the advanced tab is password protected. After program installation the password is empty. Once the password is given correctly, the protection is turned off until the Seunis program is closed. Use the ALT-P shortcut to reactivate it immediately. In case you have lost your password please contact Teledyne LeCroy support.

2.6 Software Operation Modes

The software provides three different operation modes; sample list mode (default), macro mode and quick mode. Each of these modes can be selected via the corresponding toolbar icons shown below:

	Sample List Operation Mode	(2.6.1)
	Macro Operation Mode	(2.6.2)
	Quick Operation Mode	(2.6.3)

2.6.1 Sample List Operation Mode

The sample-list mode is the default operation mode. It is activated on program startup and/or by clicking the sample list tool in the toolbar. The functionality was already described in section 2.5.1. Furthermore measurements made in macro operation mode (section 2.6.2) can be edited in this mode after exiting the macro operation mode.

2.6.2 Macro Operation Mode

In case the same sequence of measurements (optionally with different measurement modes or different impedance settings) has to be repeated over and over again, the macro mode can be used. Activate this operation mode by clicking the macro mode item in the toolbar.

Please note: *this mode can only be activated if valid macros are defined, either by double-clicking the add-macro item or by loading a macro definition file.*

The following functions are available via the *File* → *Macro-List* main menu entry or by right-clicking in the macro list:

- **Load Macro List:** Loads an existing macro list from file

- **Save Macro List:** Save current macro list to file
- **Move Up:** Move the currently selected macro item one position up in the list
- **Move Down:** Move the currently selected macro item one position down in the list
- **Clear:** Clear current macro list
- **Change Macro List Description:** Change the value to be inserted into the description field (2nd column) of the spreadsheet of the *Main Window*
- **Change Macro Entries:** Change a particular property **for all macros**
- **Rename Macro:** Rename the currently selected macro item
- **Copy:** Copy a macro
- **Paste:** Paste a macro
- **Delete Macro:** Delete the currently selected macro item
- **Macro Properties:** Select a *Measurement Mode* (see chapter 5) for the currently selected item. In case the selected mode requires impedance property settings, the *Impedance Measurement Properties Window* is opened (section 5.1.3).

When performing measurements in macro operating mode, a descriptor input dialog is raised after completion of the first macro measurement. This description is used for all further macro measurements performed within the current cycle. After measuring the last macro, the indicator automatically jumps back to the first macro and a new description is requested. The

software automatically enumerates the description; however the string can be overwritten according to the user's needs.

After finishing a macro measurement, the measurement is pushed into the *Sample List* and can be treated like any measurement in sample list operation mode.

A new macro can quickly be created based on an existing sample. To create the macro, right-click a sample and select ***Create Macro from Sample***.

Please note: *In case the user performs impedance measurements with a tolerance mask, an input dialog is raised in case the impedance trace is outside the defined tolerance. This behavior can be changed in the advanced tab of the Options Dialog.*

2.6.3 Quick Operation Mode

In case some quick measurements shall be performed without any need to store the data and/or the results, the quick-measurement operation mode can be used.

After clicking the quick operation item  in the toolbar, the measurement mode can be chosen as usual (see *Measurement Mode*, chapter 5). In case the selected mode uses further settings, the *Impedance Measurement Properties Window* can be opened at any time (section 5.1.3).

In quick operation mode a permanent update of the trace in the *Result Visualization Window* can be activated ("live mode").

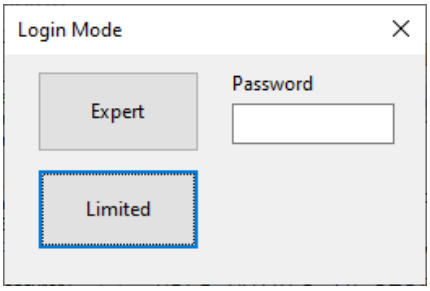
Please note: *the quick-measurements are volatile and there is no possibility to store quick-measurements by pushing them into the sample list or to export the data.*

2.7 Login with Limited User Privileges

It is possible to deny a full access to all features of the software. "Limited" users can only perform basic actions (e.g. measuring, loading, saving). In order to distinguish between a (password protected) full access and a limited access, please change the following line in the *Seunis.config* (see section 2.2) file as follows:

```
Login mode = "0"
```

After restarting the software, a login dialog appears at startup:



Users with limited rights can use the software by clicking the *Limited* button. For a full access (Expert) a password is required. The password to be used is the same as in the *Options Dialog* (see section 2.5.4).

3. Quick Start Guide

This chapter is intended to enable the user to quickly perform a standard single-ended TDR measurement. Although the standard TDR-measurement mode is probably not always the first choice for engineers, it is highly recommended to work through this chapter, because a great deal of functionality described here is applicable to other measurement modes as well.

Please note: *optionally the three-term correction (TTC) algorithms can be applied for obtaining error-corrected results. The TTC technique, being essential (or at least useful) for most of the measurement modes, is described in chapter 4.*

The software provides the opportunity to display and store classical TDR traces (step responses) for further use. In comparison to the more sophisticated impedance measurements (e.g. for controlled impedance traces on PCBs or other transmission lines) no special processing of the TDR data is required.

The following points will help you to easily perform your first standard TDR measurement:

1. Make sure the software is installed, the device is connected and at least the ***TDR measurement mode*** is available. This can be checked by pressing the toolbar button *MODE* in the *Main Window*. Highlight ***TDR/Wave Impedance*** in the measurement mode selection dialog and click ***OK***.

2. During the very first program start, the software prompts for a ***Username*** and an ***Email*** address. These settings can be changed in the *Options Dialog* (see section 2.5.4) later. The options are accessible via the main menu ***Extras*** → ***Options***.

3. A convenient standard arrangement of all windows can be saved as

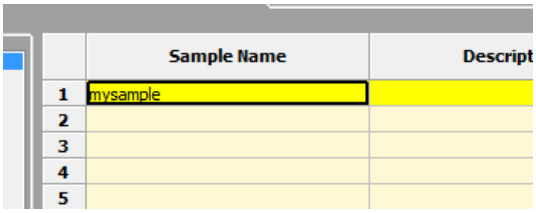
default via ***View*** → ***Set default Arrangement***. To recall your user-defined or a preset arrangement of the windows, the following shortcuts are available:

- ***ALT-W:***
  Recall user-defined window arrangement (also available after a software restart)
- ***CTRL-ALT-W:***
  Recall factory-default windows arrangement (uses two screens if available)
- ***CTRL-ALT-SHIFT-W:***
  Recall factory-default windows arrangement (always uses single screen)

4. Click the toolbar button  to make sure you are in the ***Sample List Operation Mode***.

5. Prepare an empty sample list by clicking ***File*** → ***New*** in the *Main Window*. In case a *three term correction (TTC)* is currently loaded, a question dialog is raised. Click ***NO*** to clear the existing *TTC*, in this example the *TTC* shall not be considered.

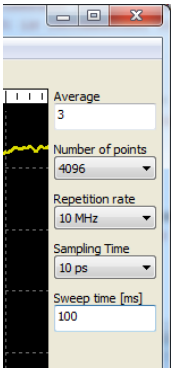
6. Select the upper left cell and type in a ***Sample Name***. You may add more informative details of your samples in the ***Description*** column.



Remark: *it is possible to prepare lists in other spreadsheet applications and to copy the data into the sample list (copy & paste).*

7. Now select the requested measurement mode. The easiest way to do this, is to right-click the sample and click ***Select Measurement Mode***. Select the measurement mode ***TDR/Wave Impedance***. Alternatively the ***MODE*** button in the toolbar can be used.

8. In the *Oscilloscope Window* the length of the TDR trace can be chosen via the pull-down menu ***Number of points***. Standard values from 512 to 32768 are available, the ***Sampling Time*** is preset to $t_s = 10\,\text{ps}$.



9. The ***Repetition rate*** of the device is selectable via the corresponding pull-down menu. By default the instrument is shipped with the following repetition rates: 10/5/2/1 MHz.

   Recommendation: *For most measurements (e.g. for line impedance measurements on PCBs) an interval of* ***4096 points*** *in combination with a repetition rate of* ***10 MHz*** *is suitable.*

10. The number of average measurements can be chosen in the ***Oscilloscope Window***. The signal-to-noise ratio (SNR) increases with the number of averages. At least 10 averages are recommended.

    Please note: *if a high number of averages is chosen (e.g. greater 50), the number of stored repetition measurements is compressed to the number given in the* `Seunis.config` *file (see entry* `Compressed number of measurements`*, the default value is* `50`*).*

11. The real-time TDR trace is shown (yellow) in the ***Oscilloscope Window***. Alternatively, an impedance trace can be displayed ***(View → Show Impedance)***.

12. By default, all average measurements are carried out by one single trigger event. If this currently should not be the case, open the Device Tab in the Options Dialog via the menu item ***Extras → Options (Device)*** and make sure the ***Single-Shot Measurement*** checkbox is checked.

13. Make sure the first row is still highlighted. The highlighted sample will actually be measured. Best practice is to click on the line number in the table on the far left.

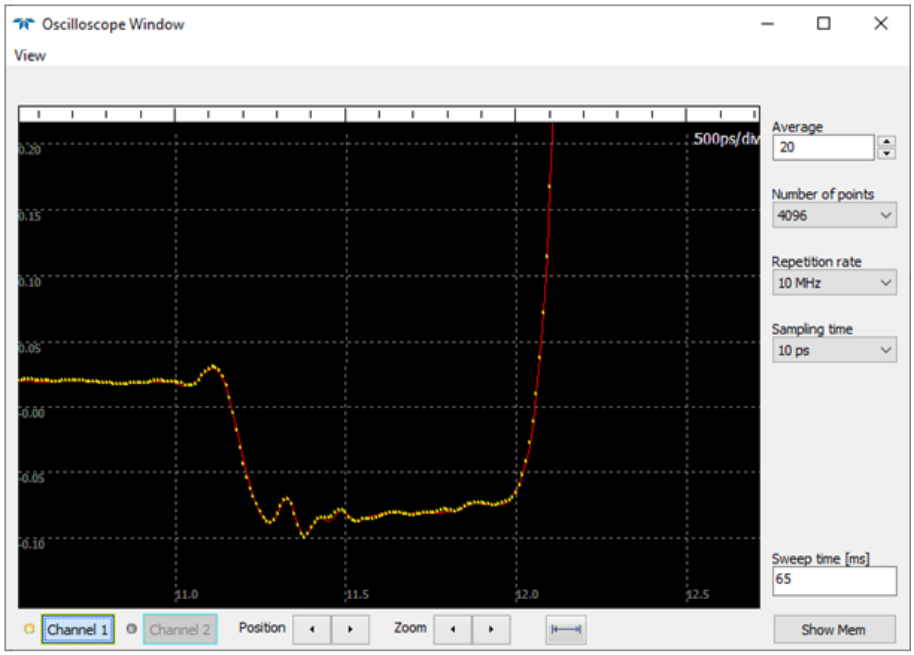
14. Measure the sample either by clicking the ***measure button***  in the right-lower corner of the *Main Window*, or by using the ***F5-key***.

    Please note: *if the TDR signal is temporarily instable, measuring is prohibited. Please make sure the signal is stable before measuring. Instabilities usually occur when there is a bad contact between probe and the object under test. Please check the contacting by means of the real-time trace in the* ***Oscilloscope Window****.*

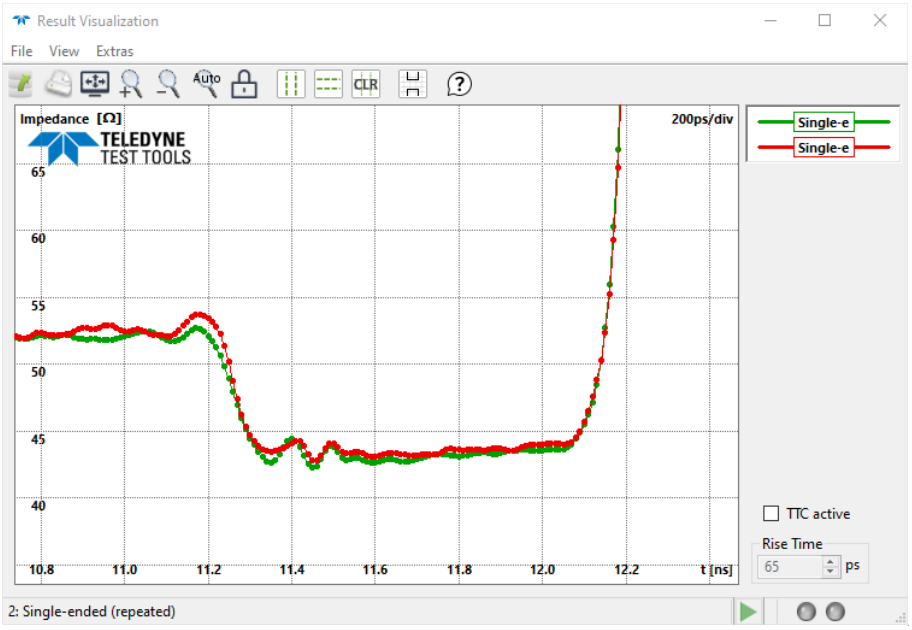
15. Now the TDR traces (all average measurements) are additionally displayed (red) in the ***Oscilloscope Window***. Please note that these are not displayed when the impedance trace is displayed instead of the TDR trace.

    Remark: *the measurement* ***data can be deleted*** *using the shortcut* ***STRG-D*** *or via the main menu* ***Edit → Delete Avg Measurements****. This only clears the TDR data, all other information is preserved. Complete rows can be removed by using the menu entry* ***Edit → Delete Samples(s)****. All highlighted rows will be deleted.* ***Caution: an UNDO function is currently not available!***

16. You can zoom into the TDR trace by using the mouse or the toolbar buttons below the diagram. Press the left mouse button within the display screen and select the zoom-area or use the mouse wheel. To reset the view to full-view ***double right-click*** within the plot.



17. In the ***Result Visualization Window*** the averaged TDR trace (step response) or the impedance trace can be displayed. To switch the view between the step response and the impedance trace use the ***View*** → ***TDR*** submenus ***Impedance*** and ***Step Response(+/-)***. Alternatively, the shortcut ***CTRL-ALT-F11/F12*** can be used.



Please note: *for displaying traces of multiple measurements in the result visualization window, highlight these in the spreadsheet of the Main Window by holding the CTRL-key pressed. The legend shows the colored sample indicators accordingly.*

18. For ***zooming*** use the mouse and/or the toolbar buttons. An auto-zoom function is available and can be activated by pressing the toolbar button Auto. Alternatively the zoom can automatically be adjusted to the current oscilloscope zoom by clicking the lock symbol in the toolbar.

19. Data can be exported in different formats via the menu item ***File*** → ***Export*** or the disk symbol (toolbar) in the ***Result Visualization Window***.

20. For further sample settings (e.g. impedance mask, signal velocity, etc.) please refer to section 5.1.3.

21. After completing a measurement, switch to the next line of the sample

list and create a new sample if necessary.

22. It is possible to change sample properties for multiple samples at once. This is done by selecting the desired samples (CTRL-key & select) and using the menu entry ***Extras*** → ***Change Sample Settings*** in the *Main Window* or by right-clicking the selected samples.

23. If all samples have been measured, save your work via the menu ***File*** → ***Save As*** in the *Main Window*. All the data will be stored in a project `mas` file and can be reloaded afterwards.

4. Three-Term & 12-Term Correction

4.1 Fundamentals

In the scope of this manual the three-term correction is abbreviated with **TTC** (or DTTC for differential modes) and the twelve-term correction with **12TC**. TTC and 12TC are powerful tools to reduce systematic errors of the measurement system. Activating TTC/12TC leads to a **significantly increasing accuracy** of the measurement results and is therefore **highly recommended to be used** whenever applicable. To reduce time and effort for performing the required TTC/12TC calibration measurements some useful tools are integrated in the software to simplify and speed up your work.

4.2 Requirements

The fundamental mechanisms of the TTC/12TC are adopted from frequency domain methods and enhanced with newest TDR data-processing algorithms. For using TTC/12TC the following requirements must be fulfilled:

1. A calibration kit (open, short, load = OSL) must be available for performing the required TTC measurements. These are available from Teledyne Test Tools and/or other third party vendors.

2. In addition to the OSL-standards, a thru standard must be available (OSLT) for applying 12TC calibration.

3. A configuration file containing the coefficients of your specific calibration kit (e.g. `my_calkit.ckd`) must be located in the *Config* subfolder of the software (e.g. c:\Program Files (X86)\seunis\Config). Please contact Teledyne LeCroy for further information about how to create the `ckd` file for your specific calibration kit. The `ckd` file that is pre-installed with the software is consistent with the calibration kit shipped with the device.

4.3 Calibration Wizard

For the user's convenience a TTC/12TC-wizard is included in the software. To start the wizard, please use the magic wand from the *Main Window*'s toolbar or select *Extras* → *Three-Term Correction* from the main menu. A selection dialog appears and lets the user choose between:

1. Differential TTC (DTTC, available with differential measurement modes)
2. Single-ended TTC (for channel 1 only, use DTTC for channel 2)
3. Save current TTC/12TC for immediate reload
4. Reload last known TTC/12TC
5. Reset currently loaded TTC/12TC
6. Full 2-port calibration (only if F2P measurement module is available)

If you choose 1., 2., or 6. the TTC-wizard will guide you through the necessary steps towards a reliable TTC, DTTC or 12TC; nevertheless subsequently some helpful remarks are enlisted:

- In the start window, an existing TTC/12TC can be reloaded. Please ensure that the currently used measurement setup (in the first place the attached cables and time base settings of the device) is identical to that of the original TTC/12TC.
- If a TTC/12TC is loaded from a previously **wizard-saved** file, the wizard jumps directly to the last window and you are done. This is only necessary if different TTCs/12TCs (e.g. for different time bases) shall be handled in parallel.
- A TTC/12TC can be reloaded from wizard-saved TTC `mas` files and also be imported from standard project `mas` files.

Please note: *From Seunis version 1.8.0, the wizard-saved TTC files completely comply with standard project* `mas` *files. However, only the TTC/12TC data is stored (no measurements and settings etc.). Older wizard-saved* `sqc` *files cannot be restored any more. To reload these, open them as normal project and store them in* `mas` *format. From within the wizard, this* `mas` *file can be loaded to restore the TTC data.*

- If a new TTC/12TC calibration shall be performed, the wizard asks for the calibration kit to be used.
- In the following steps the standards *Open*, *Short* and *Load* (50 Ω) have to be measured. The wizard automatically jumps to the next step. The user can use the *Back* button to redo a measurement.
- For a 12TC calibration the additional *Thru* and *No connection* measurements (50 Ω loads or alternatively no standards on both ports) have to be carried out.
- Please note that a 12TC automatically includes DTTC & single-ended TTCs on both ports. DTTC includes single-ended TTCs on both ports.
- The number of averages for the TTC/12TC measurements can be set in the *Oscilloscope Window* ***(recommendation*** $\geq$ ***50***, especially for high frequency measurements it can be advantageous to set averaging up to ***2000***).
- In the last step the user can optionally save the TTC/12TC data to a `mas` file, containing TTC/12TC data only. This file can either be reloaded by the wizard or opened as normal empty project file.

  This method can be of interest for users working with frequently changing TTC/12TCs (e.g. due to changing time bases). If you work with an unchanging measurement setup, saving the TTC/12C is not necessary

at this stage.

- On completion of the wizard the TTC/12TC data is automatically stored for reuse (see **4.**: Reload last known). The previous TTC/12TC is replaced and **cannot be recovered** anymore.

- A differential TTC (DTTC) can be extended to a 12TC. If a DTTC is active and a full 2-port calibration is initiated, the wizard asks the user, if the current DTTC shall be extended.

- In case a **multiplexer** is connected, please refer to chapter 11 for further information about calibrating multiple channels.

4.4 General Remarks on reloading TTC/12TC Data

- The last known TTC/12TC is loaded automatically on program startup, if activated in the *Options Window* → *Device* tab.

- The last available TTC/12TC can easily be reloaded by opening the TTC-Wizard and pressing the *Reload* button.

- The software shows a warning, if the loaded TTC/12TC is older than 14 days. This value can be changed in the *Seunis.config* (see section 2.2) file by editing the `Old TTC warning after <N> days` entry.

- TTC data is always stored and reloaded with project files. Please be aware that after loading an older file containing valid TTC/12TC-data, the currently active TTC/12TC is replaced.

  Remark: *this behavior is essential for the correct recalculation of the results of the stored data and is explicitly an intended behavior. An option to circumvent this, is to work with workshop files (see chapter 9).*

- The user is not allowed to change time base settings when using a

particular TTC/12TC. A TTC/12TC is only valid for the time base being used during the TTC/12TC calibration measurements.

- If an existing TTC/12TC is reloaded and the current device settings are inconsistent to the time base settings of the reloaded TTC/12TC, the software automatically adjusts the device's time base settings.

- By default, the current TTC/12TC is stored in the user application directory under the filename `.currTTC.mas` (directory where *Seunis.config* is located). If multiple users work with the same TTC/12TC under individual user accounts, it is necessary to change the saving directory due to read/write permissions of the file system. The saving directory can be changed in the *Options Dialog* → *Advanced tab* (see 2.5.4).

4.5 Status Indicators for TTC & 12TC

In the left-lower corner of the *Main Window* the TTC status indicator LEDs are located (see section 2.5.1). The meanings of the colors of the LEDs are described in the table below.

LED 1, 2, and 3 grey:	TTC/12TC not applicable/activated
LED 1, 2, or 3 red:	no TTC/12TC activated
LED 1 green:	TTC for channel 1 active
LED 1 and 2 green:	DTTC for channel 1 and 2 active
LED 1, 2, and 3 green:	12TC active
Timestamp:	date and time of TTC/12TC measurements

Please note: *a further LED displays whether a reference measurement has been performed (yellow) or not (grey). This can be used to set the reference plane for the spatial x-axis in (D)TDR- or impedance measurements. See section 5.1.2 for further information.*

5. Measurement Modes

In this chapter the specific measurement modes of the T3SP-series devices are described. The availability of measurement modes can be checked by pressing the *Main Windows* toolbar button *MODE*. A dialog showing all available measurement modes is raised.

5.1 Impedance Measurements (Modes TDR & DTDR)

Using the ***impedance measurement mode*** is a common task in printed circuit board design and signal integrity testing. This mode allows for measuring single-ended and differential controlled impedance traces. The user can define tolerance masks and the characteristics of the line by means of the *Impedance Measurement Properties Window* (section 5.1.3).

For performing impedance measurements the standard (D)TDR measurement mode must be used. The difference between impedance and TDR (step response) traces is observable in the *Result Visualization Window*, showing (TTC corrected) impedance traces instead of TDR traces. When selecting the impedance visualization mode, a tolerance mask can be enabled.

5.1.1 General Recommendations

- It is highly recommended to activate (D)TTC in order to achieve the highest possible accuracy (see chapter 4).
- A suitable probe and 50Ω coaxial cables (SMA or RPC-3.5) must be used for performing high-performance impedance measurements.
- Single-ended measurements can be carried out either on channel 1 (positive step) or channel 2 (negative step). The polarity of the step is only relevant for a step response trace, but not for impedance or S-parameter measurements.
- In case of differential measurements, a set of phase-matched coaxial cables must be used. It is recommended to use the cables delivered with the unit, otherwise the full performance cannot be guaranteed.
- Prepare your *Samples* in the *Sample List* according to point **6.** of the quick start chapter.
- The results of the impedance measurements are displayed in the *Result Visualization Window* (see Fig. 5). The impedance is displayed vs. traveling time, complying with the time axis in the *Oscilloscope Window*. The tolerance mask can be defined in the *Impedance Measurement Properties Window* (for more details read section 5.1.3).
- In (D)TDR mode some important values (averaged & min./max. impedance in the impedance mask region) are shown in the right upper corner of the *Result Visualization Window* as well as in the yellow result display of the *Main Window* (see Fig. 1).
- The green check-mark in the upper-right corner (*PASS* indicator) of the *Main Window* indicates whether the measurement passed the tolerance check. Otherwise the cross (*FAIL* indicator) indicates that the

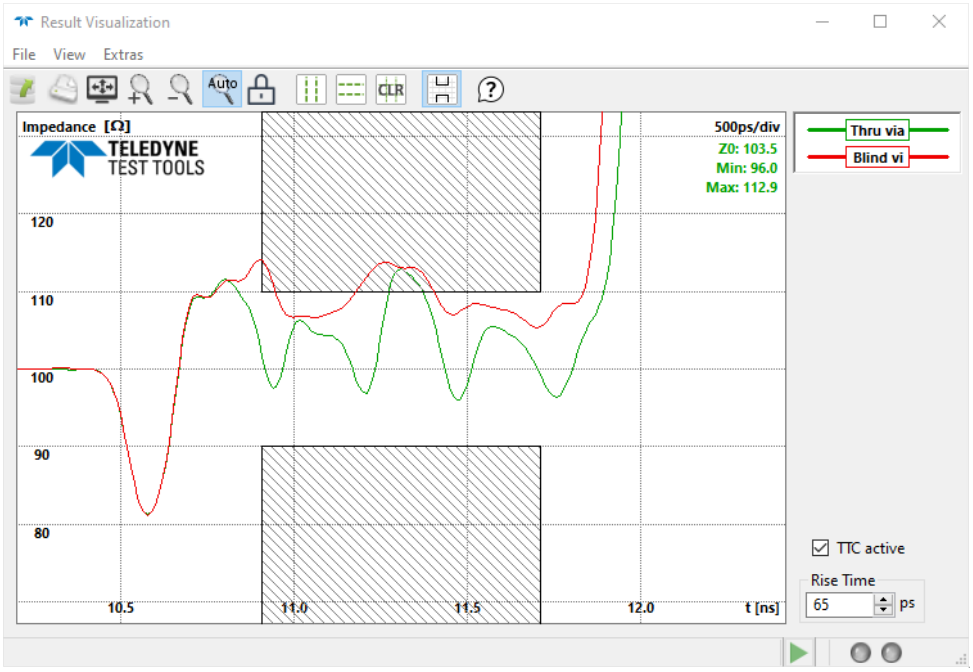


Figure 5: Result visualization of impedance measurements

tolerance check failed. Additional LEDs (green/red) are located in the status bar of the *Result Visualization Window* (only if exactly one sample selected in list).

Please note: *two different options can be chosen to classify the measurement results. In the* ***strict mode****, the measurement is classified as NOT PASSED if the tolerance mask is violated at any point. In the* ***non-strict mode****, the measurement is classified as NOT PASSED if the average impedance result is out of the limits. The mode can be set in the Seunis.config file (see section 2.2) by setting option* `Pass-fail strict` *either to* `"1"` *or* `"0"`*.*

- The tolerance mask can be turned on/off by using the button in the tool bar. This also effects displayed impedance results (average & min./max. impedance) and the small LED indicators in the status bar. The indicators are grayed out if the tolerance mask is switched off.

- The trace shown in the *Result Visualization Window* can be set to impedance or step response via the menu entry *View* $\rightarrow$ *TDR*.

- The x-axis can be changed from time [ns] to a space [cm] visualization via the *View* $\rightarrow$ *TDR* $\rightarrow$ *x-axis* menu entry in the *Result Visualization Window*. Make sure a *Reference Measurement* is performed to move the zero point ($x = 0$ cm) to a well defined value.

  Please note: *the propagation velocity according to the DUT must be set in the Impedance Measurement Properties Window (see section 5.1.3).*

- An automatic zoom can be activated by checking the *Auto Zoom* checkbox or via the menu *View* $\rightarrow$ *Auto Zoom*.

- In time domain measurement modes (*TDR, DTDR*) the zoom can be locked to the *Oscilloscope Window* zoom by pressing the toolbar button with the lock symbol.

- The impedance tolerance mask can be set via the *Extra* $\rightarrow$ *Set...* menu items. For further information see section 5.1.3 about the *Impedance Measurement Properties Window*.

- **Optional:** For an increased accuracy the TTC should be applied. If TTC measurements have been performed, the ***corrected impedance- or TDR-traces*** can be displayed by checking the ***Correction*** checkbox in the *Result Visualization Window*. For a detailed description about working with TTC, please refer to chapter 4 .

- **Please note:** other rise times than the predefined one can be simulated if TTC is activated. This option is capable of characterizing systems with lower and higher bandwidths. For simulating higher bandwidths (lower rise time) an appropriate number of averages is recommended.

5.1.2 Reference Measurement

A *Reference Measurement* can be taken in addition to the TTC/12TC. The software will move the zero point of the spatial axis (x = 0 cm) to the position of the open-end (the coaxial cable or the TDR-probe tip).

The measurement is performed by clicking the REF button in the toolbar of the *Main Window*, by pressing ***F6*** or by using the menu item *Extras* → *Reference Measurement*. The presence of the measurement is indicated by a yellow LED below the TTC/12TC indicators.

Please note:

- The time axis is fixed and will not be influenced by a *Reference Measurement*.
- If no *Reference Measurement* is available but the TTC/12TC is active the start value equals the reference plane of the "Open" calibration measurement.
- Best practice is to take a measurement with a connected TDR-probe (if applicable) but without a DUT.

5.1.3 Impedance Measurement Properties Window

The *Impedance Measurement Properties Window* gives the user the opportunity to specify his measurement objects in more detail (see Fig. 6). It can be opened via the *Main Window* menu entry *Edit* → *Properties*.

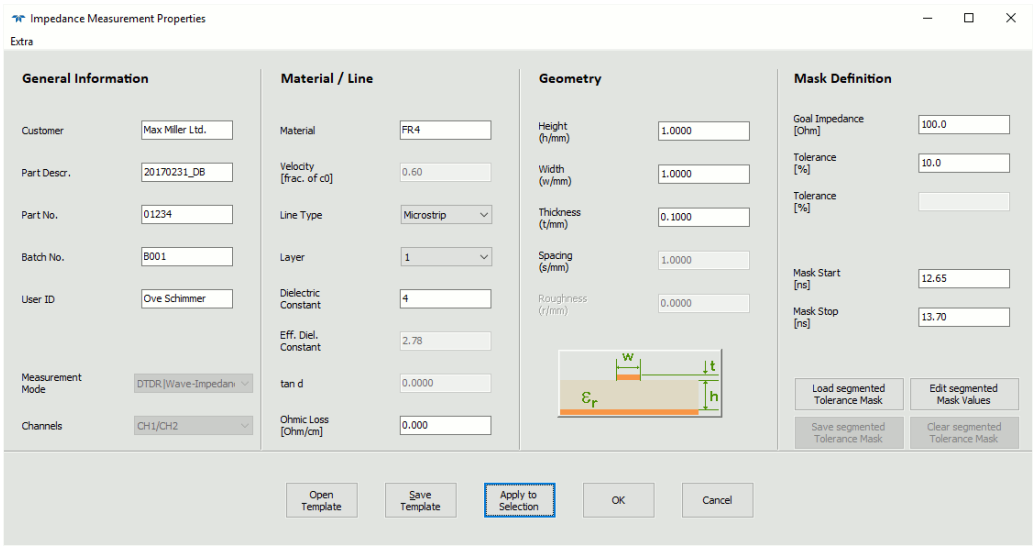


Figure 6: Impedance measurement properties window

General information can be passed to identify the measurements for later use. Some details are necessary for a realistic characterization of the measurement objects.

Remark: *the software displays the x-axis of the impedance trace vs. the traveling time t[ns] or versus a spatial resolution L[cm]. The software needs some of the information (explicitly the velocity or alternatively line-type and geometry) to convert the traveling-time into spatial information. Furthermore the reference plane can be set to the TDR probe tip, by performing a reference measurement (F6 or Extras → Reference Measurement).*

- The *General Information* group holds information about the objects under test and about the user. The information is used for creating impedance reports and is stored in *Project Files*.

  1. In the *Customer* field information can be stored for each sample.

  2. The labeling of the next three fields (by default *Part Descr., Part No., Batch No.*) can be customized in the *Seunis.config* (see 2.2) file by customizing the lines `LabReplace SetWin(…)`. Changes can be made for each installed language separately.

  3. The *User ID* is a permanent setting and cannot be altered here. Changes must be made in the *Options Dialog* (see section 2.5.4, click menu *Extras* → *Options*).

  4. The fields *Measurement Mode* and *Channel* are purely informative and cannot be changed here.

- In the *Material / Line* specification group some useful information about the measurement object can be handled:

  ☞ The *Material* field is purely informative.

☞ If the *Line Type* is set to *Other* the propagation *Velocity* can be defined as fraction of speed of light. Otherwise it is calculated based on the *Line Type* and the defined geometry.

☞ In the *Line Type* selection box the user can chose between *Airline, Microstrip, Stripline, Coaxial Line* and *Other*. The selection affects the propagation velocity. If the velocity shall be set manually, please select *Other*.

☞ The dielectric constant affects the propagation velocity of the signal (except line-type *Air Line* or *Other* is selected) and therefore has influence on the x-axis [cm] in the *Result Visualization Window* and the exported impedance report.

☞ The $\tan\delta$ field is currently not used for this kind of impedance measurements and therefore purely informative.

☞ Using the *Ohmic Loss* functionality enables for the compensating of the slopes in impedance traces due to ohmic losses. The ohmic loss of a line yields to an increasing impedance trace over time/space which is not related to the wave impedance of the line. This loss value can be set in order to remove the slope. Setting the field to "auto" will result in an automatic compensation for the currently selected sample(s).

The value can automatically be calculated by the software from the impedance slopes of existing measurements:

○ Make sure a valid reference measurement (yellow LED in the TTC indicator) is available.

○ Go to the *Main Window* and select the sample(s) which shall be considered for the automatic ohmic loss calcula-

tion.

- ○ Click the menu entry *Extra* → *Calculate Impedance Slopes*.
- ○ A dialog is raised, showing a table with calculated impedance slopes of selected samples. The mean value can now be applied to the selected samples.

Please note: *another suitable method for determining reasonable values for Ohmic Losses is to measure the same line from both ends and to adjust the value until the measured wave impedance of the beginning of the first measurement matches to the end of the second.*

Remark: *use the automatic slope determination only if you are familiar with this topic. It is recommended to use this function only in combination with plain lines (as commonly used on impedance test coupons) with a length of at least 50mm.*

- In the *Geometry* field the definitions for microstrip- and striplines (single-ended and/or differential) can be set. In the context of the impedance measurements the values are used to calculate the propagation velocity. If another line type is selected, they have no influence and can be set to some default values (e.g. h = 1mm, w = 1mm, t = 0.1mm).

  Remark: *the propagation velocity depends on the dielectric constant, the line-type and (in case of e.g. top/bottom-layer lines) on the particular geometry. Complex models described in specialized literature are integrated in the software. Please be aware, that these models cover a wide range of parameters and make no claim of being exhaustive.*

  Please note: *the roughness of the conductor is not taken into account.*

- The y-tolerance mask can be defined by setting the nominal impedance and tolerance values.

- The tolerance x-axis [ns] can directly be set as follows:

  ☞ By typing the values in [ns] into the specific fields.

  ☞ By capturing the current zoom of the oscilloscope window: zooming into the TDR-curve and pressing *Extra* → *Capture current Oscilloscope Axis* in the menu of the *Impedance Measurement Properties Window*.

  ☞ By using the marker positions of the *Oscilloscope Window*: *Extra* → *Capture Markers* in the menu of the *Impedance Measurement Properties Window*.

  ☞ By clicking *Extra* → *Set by Norm* in the menu of the *Impedance Measurement Properties Window*. Using this function requires a completed impedance measurement of a transmission line with an open-ended termination. Furthermore a reference measurement is required (indicated by the yellow LED in the TTC indicator field, see section 5.1.2).

- For the user's convenience pre-defined impedance measurement settings can be stored in and loaded from a template `itx` files.

- To create a properties `itx` file template, specify the values and press the *Save Template* button. It is recommended to save the template under a meaningful filename.

- To apply pre-defined properties to *Samples* in the *Main Window*, proceed as follows:

  ☞ Select all rows of the *Sample List* to be set according to the predefinitions.

☞ Open the *Impedance Measurement Properties Window* by right-clicking one of the selected rows and pressing *Properties*.

☞ Press the *Open Template* button and select the `itx` file with the pre-definitions.

☞ Press the *Apply to Selection* button.

5.1.4 User-defined Impedance Masks

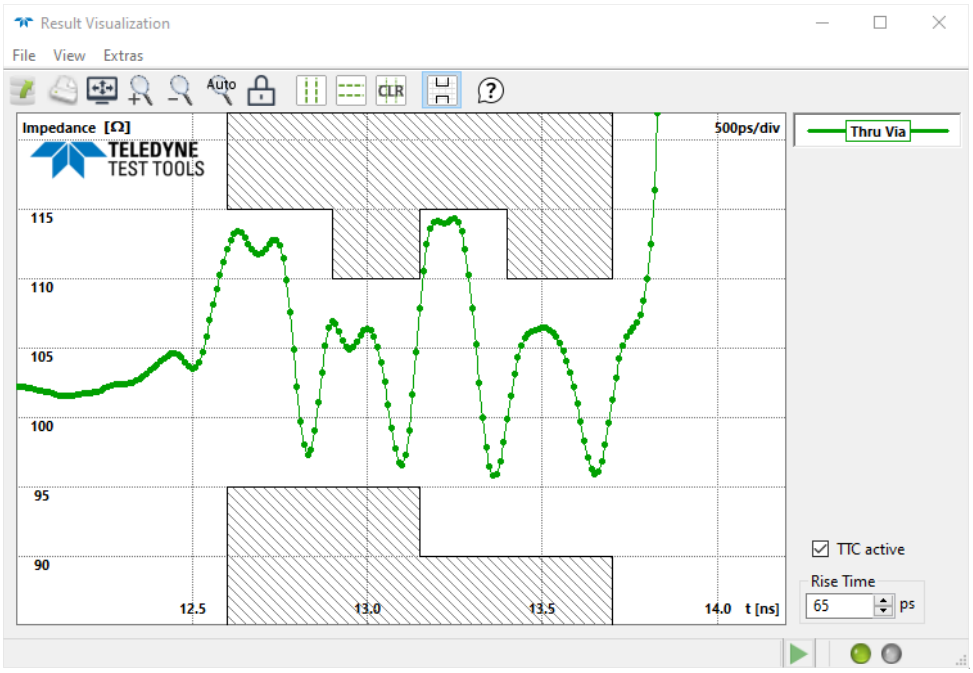


Figure 7: User-defined (segmented) tolerance mask

The software supports user-defined (also called segmented) impedance masks as shown in Fig. 7). Masks can be

- defined manually by clicking the button *Edit segmented Mask Values*,
- loaded from an `xml` definition file by clicking button *Load segmented*

Tolerance Mask (a sample `xml` file is included in the software installation and can be found in the program subfolder *Examples*),

- saved via the button *Save segmented Tolerance Mask* to an `xml` file,
- cleared via the button *Clear segmented Tolerance Mask* (in this case the standard rectangular tolerance mask becomes active again).

Another option to generate a user defined (segmented) tolerance mask is to use the integrated mask generator. Click the menu item *Extras* → *Create Impedance Mask* in the *Main Window* and the software will guide you through the creation process. The generated `xml` file is not applied automatically and must be loaded afterwards.

5.2 (D)S11 - Measurement Mode (Return Loss)

These measurement modes (single-ended & differential) are for acquiring the frequency dependent reflection coefficients (S_{11}-parameter). Frequency- and time domain signals are connected via the Fourier-Transform thus TDR signals can be transformed into S_{11} by applying a proper signal preprocessing in combination with a Fast-Fourier-Transform (*FFT*). It is essential to activate the *TTC* before using this mode (detailed information about applying *TTC* can be found in chapter 4).

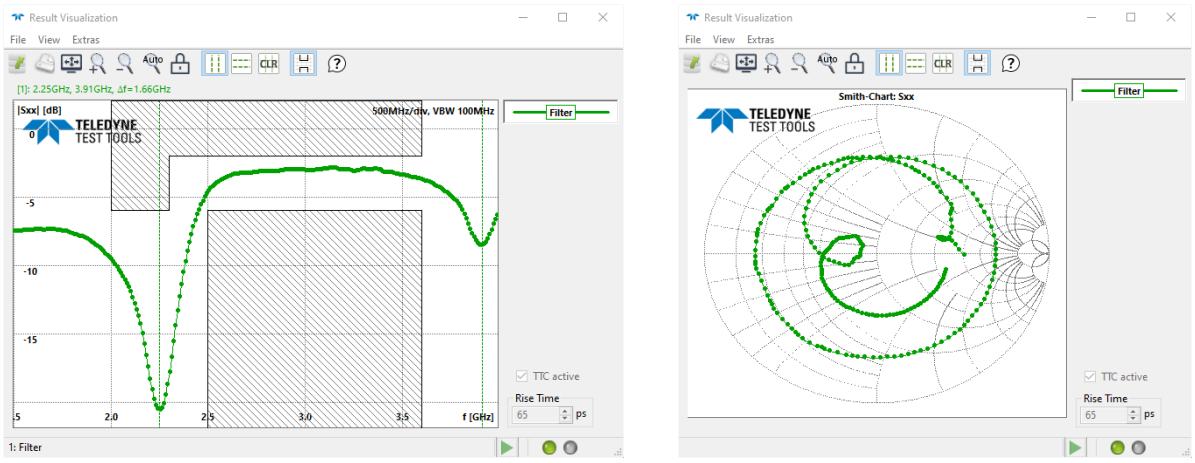


Figure 8: Magnitude and Smith-Chart of reflection coefficient S_{11}

- Right-click an existing sample and select S_{11} measurement mode.
- *TTC* must be activated for measuring S_{11}-parameters, indicated by a green LED in the *Main Window*.
- Measurements can be performed either on channel 1 or 2 (only on a channel where *TTC* is activated).
- It can be switched between the different result domains magnitude-, phase, Smith-Chart and VSWR view. For this purpose use the menu entry *View* $\rightarrow$ *S-Parameter* or CTRL-ALT-F11/F12.

- Multiple samples can be plotted by selecting rows in the sample list while pressing down the CTRL-key.
- A quick way to create a rectangular tolerance mask is to use the menu item *Extras→Set x/y-Axis in selected Samples*.
- User-defined tolerance masks can be used for pass/fail analysis. Use the *Impedance Measurement Properties Window* for loading a segmented tolerance mask (see also section 5.1.4). An example tolerance mask can be found in the *Examples* subdirectory.

  Please note: *masks are only applicable to magnitude and VSWR traces.*
- Smoothing of the traces (see section 6) can be activated via the *Advanced* tab in the *Options Dialog* (see section 2.5.4).
- The results can be exported to various formats (e.g. Excel, CSV, Matlab, and Touchstone) via the menu entry *File → Export*.
- The frequency axis can be adjusted by changing to the *Result Visualization Window* and pressing the shortcut ALT-F or via the menu item *View → S-Parameter → Change Frequency*. The frequency setting is stored in the *Project Files*.

5.3 S-Parameters (Scattering Matrix, optional)

The *Full 2-Port* mode (*F2P*) is an optional measurement mode for measuring the frequency dependent S_{XY}-parameters[1] for single-ended 2-port DUTs. It is essential to perform a twelve-term calibration (*12TC*) before using this mode (detailed information about performing a *12TC* calibrations can be found in chapter 4).

1 S_{XY} is an abbreviation for S_{11}, S_{12}, S_{21}, S_{22}

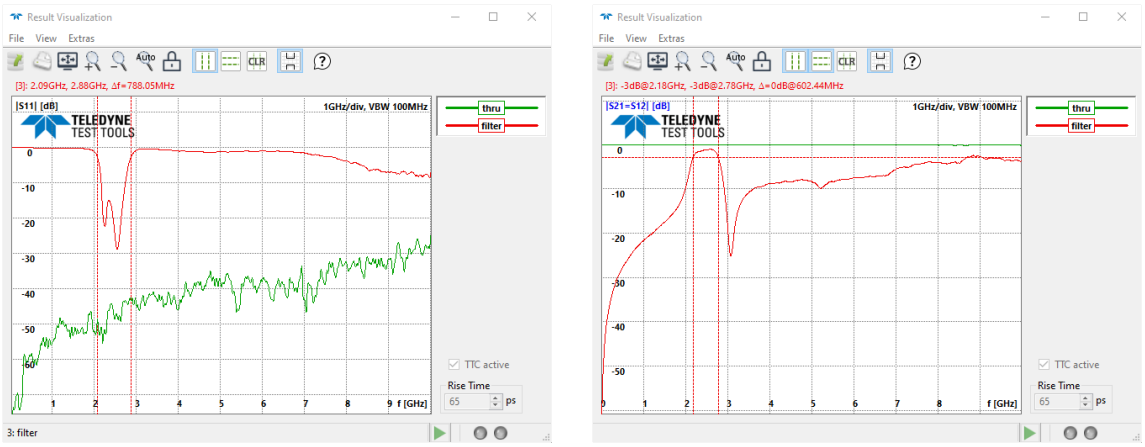


Figure 9: Magnitude of S_{11}- and S_{21}-parameters

- Right-click an existing sample and select S_{XY} measurement mode. In case the S_{XY} mode is not available, please Teledyne LeCroy support for further information.
- A *12TC* calibration must be activated for measuring S_{XY}-Parameters, indicated by three green LEDs in the *Main Window*.
- Most of the functionality and handling is similar to the S_{11}-measurements (display, result domains, masks, smoothing, data export, etc.), please refer to section 5.2 for further information on these topics.
- Switching between the different S_{XY}-parameters can be achieved via the menu item *View* → *S-Parameters* → *Select Parameter* → S_{XY} or by pressing the hotkey combination CTRL-ALT-F9/F10.
- A special function to reduce asymmetry effects of the non-ideal measurement system is to equalize the S_{12}/S_{21}-parameters. This option can be activated by checking the *Equalize transmission coefficients in F2P* box in the *Advanced* tab in the *Options Dialog* (see section 2.5.4).

Please note: *currently there is no live mode available in Quick Operation Mode.*

6. Frequency Domain Smoothing

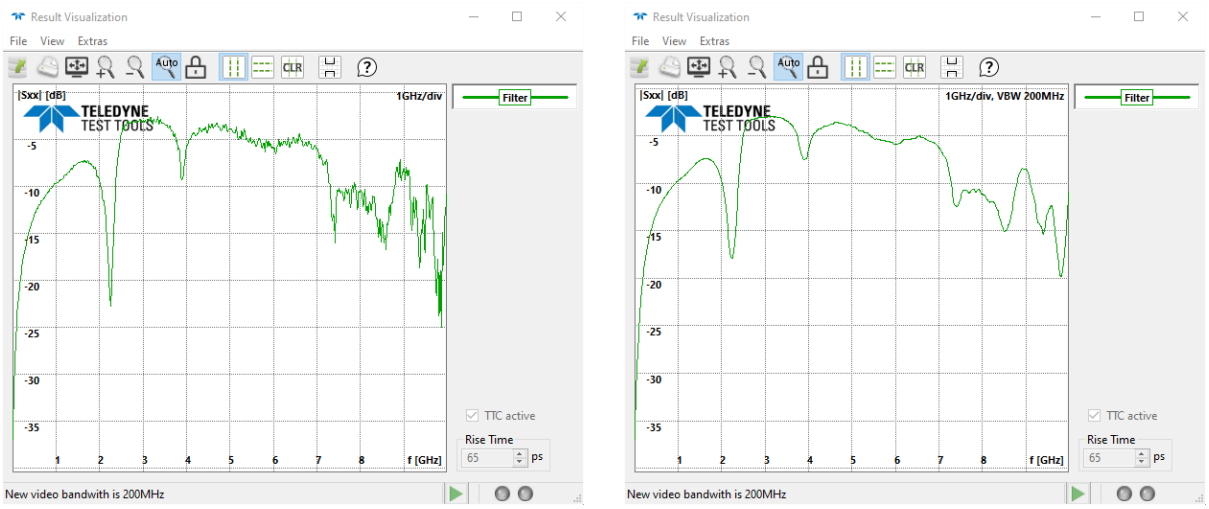


Figure 10: *Result Visualization Window* shows S_{11} with smoothing turned OFF (left) and ON (right), the video bandwidth is 200 MHz.

To achieve smoothing of frequency domain traces, a moving average filter can be activated. The degree of averaging is specified by means of the *Video bandwidth*, which can be setup via the menu entry *Extras* $\rightarrow$ *Change Video Bandwidth* of the *Result Visualization Window*. The set value is retained from then on and saved in project `mas` files.

The term video bandwidth actually comes from RF spectrum analysis, but is used accordingly in this context. The default value is 20 MHz. The current bandwidth is shown in the *Result Visualization Window*, if smoothing is activated in frequency domain measurement.

An example of a smoothed trace is shown in Fig. 10. The left plot shows the original curve, while the smoothed trace is shown on the right. The video bandwidth is set to 200 MHz. To switch frequency domain smoothing ON/OFF, open the *Advanced* tab of the *Options Dialog* (see section 2.5.4). The smoothing functionality can be used in all frequency domain measurement modes.

7. De-Embedding

In addition to the TTC & 12TC calibration method described in chapter 4, the Seunis measurement software features a frequency domain method for de-embedding components like adapters, cables, probes and also more complex systems like multiplexers (chapter 11). In this context all parts just mentioned are referred to as *fixtures*.

In the following sections the basic principles and practical approaches to de-embed fixtures are described. A basic requirement for using the de-embedding functionality is that the system has been calibrated (TTC/12TC) beforehand.

7.1 De-Embedding Basics

The applied frequency domain method is well-established and widely used for de-embedding. Subsequently the task of measuring an unkown single-ended 2-port element (DUT) shall be solved. For this purpose the full 2-port measurement mode (see section 5.3) has to be used. Please note that measuring de-embedded S_{11} and DS_{11} (see section 5.2) can be achieved accordingly.

The solution of the given problem (see Fig. 11) can be described as follows:

- Prerequisite for the application of this method is the knowledge of the S-parameters of the fixtures.
- Without de-embedding only the S-parameters of the unknown overall system can measured. Potential errors introduced by the fixtures detoriate the accuracy of the measurement results.
- The overall system can be decomposed into the subcomponents DUT and fixture 1 & 2.

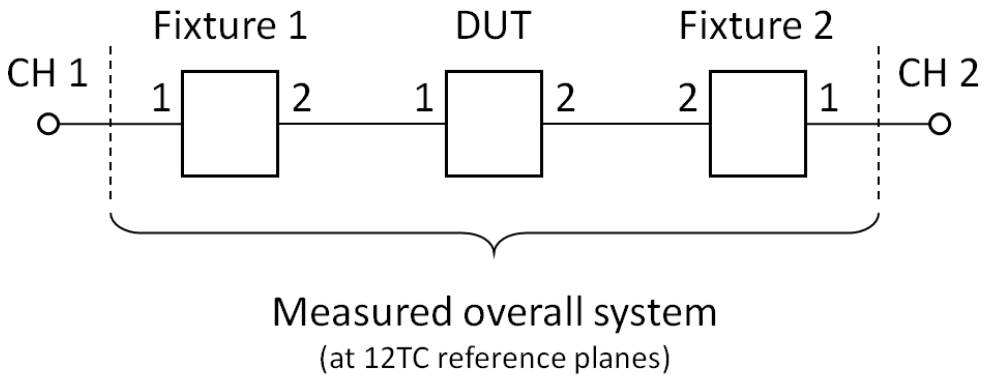


Figure 11: Decomposition of overall system into subcomponents

- The S-parameters of the fixtures and DUT are internally converted to T-parameters.
- The inverses of the fixture T-parameters are multiplied from the left and right by the overall system T-parameters.
- The result describes the DUT exclusively and is converted back to S-parameters.

In summary, it is necessary to provide the software with the S-parameters (see section 7.2) of the fixtures for the de-embedding task. The S-parameters can either be made available by the supplier of the fixture or be determined by the user. The determination of these parameters is far from trivial and can be done by simulation or by measurement (or a combination of both). The Seunis software itself can be used to characterize the adapters, please refer to section 7.3.

7.2 The De-Embedding Dialog

Loading the S-parameters of the fixtures can be done via the *De-Embedding Dialog* (see Fig. 12). The dialog can be opened via the tool button  which

can be found in toolbar of the *Main Window*. If no de-embedding parameters are loaded, the button is grey and becomes green only after the S-parameters are loaded.

The S-parameters to be loaded must be available in Touchstone (version 1 or 2) files, which can either be `s2p` (2-port) or `s4p` (4-port) files. In case a `s4p` file is provided, the user has to take care of selecting the correct ports, enabling the software to extract the desired set of 2-port parameters from the Touchstone file.

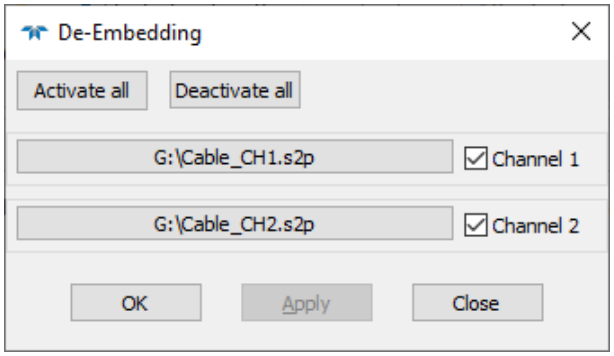


Figure 12: De-Embedding Dialog

For loading the fixtures S-parameters please proceed as follows:

1. Open the *De-Embedding Dialog*.
2. Select the Touchstone file for channel 1 and 2. In case a `s4p` is selected, a user input dialog for the ports association opens.
3. Press the *Apply* or the *OK* button. Pressing *OK* applies the parameters and closes the dialog immediately.
4. The de-embedding of the individual channels can be (de)activated by setting the corresponding checkboxes.

Please note: *the de-embedding parameters are* ***not*** *saved in* `sqc` *files, consequently it is recommended to use the* `mas` *file format whenever applying the de-embedding functionality.*

The performance and accuracy of the de-embedding algorithm depends on the quality of the underlying S-parameters of the fixtures. Please find below some **recommendations** to achieve the best possible results:

- Required: make sure the upper cut-off frequency is greater than or equal to the cut-off frequency of your TDR-device.
- Required: make sure the lower cut-off frequency is less than or equal to the frequency given by the formula $f_{min} = (N_p \cdot t_s)^{-1}$, where N_p is the number of points and t_s the sampling time. Both parameters can be found in the *Oscilloscope Window* (see section 2.5.2).
- Recommended: better results can be obtained if the frequency increment is equal or less than f_{min}.

7.3 Creating De-Embedding S-Parameters

Please note: *the full 2-port measurement mode according to section 5.3 is required to use this functionality.*

The Seunis software basically can be used to measure 2-port S-parameters and is therefore suitable to characterize fixtures as discussed in section 7.1. A typical use case is to calibrate the instrument at the end of the coaxial cables where interchangeable components are connected between cable and DUT. The prerequisite is the fixtures to be characterized can be connected to the 12TC-calibrated TDR-system (most likely via SMA-connectors).

To create the S-parameter set for de-embedding according to the requirements and recommendations stated in section 7.2 it is recommended to proceed as follows:

1. Perform a full 2-port calibration (12TC)
2. Set the number of averages to a high number (>1000)
3. Activate frequency domain smoothing (see chapter 6)
4. Activate equalization of transmission coefficiants (see section 5.3)
5. Create a *Sample* and set the measurement mode to full 2-port
6. Measure the fixture
7. Adjust the frequency axis in the *Result Visualization Window* by using the menu item *Extras* → *Set optimized Frequency for De-Embedding*, accept the suggested frequency setting.
8. Export the data to a Touchstone `s2p` file by using the  tool in the *Result Visualization Window*.

7.4 Additional Remarks on De-Embedding

- De-embedding is an advanced functionality and requires some experience. It is recommended to critically evaluate the results and improve the de-embedding parameters if necessary.
- De-embedding can be applied in time-domain measurement modes. In this case the reflection of the DUT is shifted to the left on the time-axis. The fixture removed by the de-embedding algorithm seems to "disappear".

8. Import & Export Modules

The software is capable of exporting data to various formats. Currently the following *ImExModules* are available:

- PDF-Export
- CSV-Export
- Touchstone 1.0 Export
- Matlab-Export

Please note: *all software ImExModules (DLLs) have to be located in the Seunis binary subfolder (usually this is* `c:\Program Files<(X86)>\seunis\bin`*) to be found at startup.*

Info: *exporting of unformatted results (as they can be displayed graphically) is also possible via the export button of the Result Visualization Window (see section 2.5.3).*

8.1 PDF-Export Module

The PDF module is currently available for the following measurement modes:

1. **TDR/DTDR Impedance Measurements:**

   When starting the export, the user can select different options to specify the PDF output (front page, summary table, diagrams, group statistic):

   Front page: Stating overall percentage of "PASSED measurements" and a brief overview over the measurement campaign. By default a

signature field is printed to the PDF. This can be replaced by an "automatic generated" statement (*Seunis.config*: `Suppress signature in pdf = "true"`).

Summary table: List showing the results for the individual measurements.

Diagrams: Impedance traces (incl. tolerance masks) for individual measurements and additional details in side tables.

Group statistics: The user can specify criterions (dialog appears). The software groups the measurements respectively and shows additional information for these groups (mean/min./max. impedance and standard deviation, pass/fail).

Please note: *some specific information for the PDF export can be switched on/off in the Advanced tab in the Options Dialog (see section 2.5.4).*

2. ***S_{11}/DS_{11}* Measurements:** The (differential) reflection coefficient DS_{11} and S_{11} are exported to two diagrams: the magnitude (in dB) and phase vs. frequency. Additionally an overview table is created.

3. **Full 2-Port Measurements:** The magnitude (in dB) vs. frequency of all S-parameters are exported to four diagrams. Additionally an overview table is created.

Further information as system state, user & device IDs, and freely definable *Project Comment*[1] and *Test Standard*[2] IDs are printed to the PDF reports.

Please note: *measurements of different kinds (e.g. TDR/S11) cannot be combined into a single PDF file. In this case the measurement mode of the first selected sample*

1 *Project Comment* can be set via the main menu entries *Edit* → *Project Comment*
2 The default *Test Standard* can be set in the config file *Seunis.config*

is chosen and all samples with different measurement modes are ignored. However single-ended and differential measurements in similar modes can be exported into the same PDF.

8.2 CSV-Export Module

For this export module two different modes are available. If the sample list only contains **TDR/DTDR measurements, a summary table similar to the PDF-export** is generated. In all other cases, only a summary of the measurements similar to the sample list including some additional information is created.

Please note: *the CSV delimiter can be changed in the Seunis.config (see section 2.2).*

8.3 Touchstone-Export

S-parameter data can be exported to the *Touchstone* format. Each selected sample is exported into an individual file. The frequency data points are exported in MHz, the scattering parameter values as magnitudes and degrees. Please use the *Export* button in the *Result Visualization Window*.

8.4 Matlab-Export

TDR and S-parameter data can be exported to Matlab files by pressing the *Export* button in the *Result Visualization Window*.

9. Workshop Files

The workshop files are intended to enable a quick start of measurements with a (frequently used) base setup. By means of the main menu entries *File* → *Save Workshop File* and *File* → *Load Workshop File* the current state of the software can easily be saved and restored in the `swsf` workshop file. The following settings/states are stored and loaded:

- Current *Sample List*
- Current *Macro List*
- Location of last known *Reference Measurement*.

Automatic impedance masks positioning:

In a laboratory environment it may happen that the setup partially changes from time to time. For example impedance measurements with predefined tolerance masks require a constant measurement setup with respect to the position of the mask position - this position varies with the length of the used cable.

A position-detection algorithm allows for an automatic adaption of the positions of the tolerance masks upon loading a workshop file.

Please note: to be able to use this functionality correctly, it is **very important** that a current *Reference Measurement* has been made.

10. ESD-Protection Module

RF measurement devices can severely and permanently be damaged by electrostatic discharge (ESD) impacts. In many laboratories special ESD precautions are taken to avoid damages of electronic equipment.

To provide a higher degree of protection, the TDR device is equipped with an ESD-protection module, based on high-performance coaxial RF-switches. The RF input circuitry is protected by isolating the devices RF-signal detectors from the coaxial connectors at times no measurements are carried out.

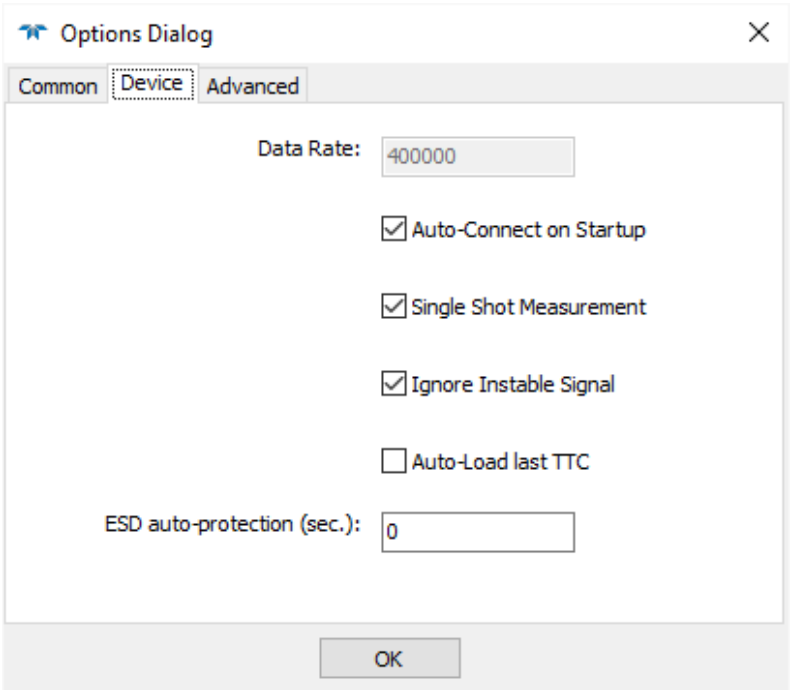


Figure 13: Changing the auto-protection time in the options dialog

The user can define a protection time in the *Options Dialog* (see Fig. 13). The protection time defines the number of seconds after which the signal detector is automatically isolated from the coaxial input connector. Setting

the time to "0" means that the protection is activated automatically directly after measurement.

Furthermore the ESD protection can be deactivated by using the ESD button  in the toolbar of the *Main Window*.

11. RF-Multiplexer (optional Hardware)

T3 time-domain reflectometers can be operated with an external unit to expand the number of channels that can be acquired in parallel (see Fig. 14). The control of the multiplexer is fully integrated in the Seunis software, including the opportunity to perform a TTC/12TC calibration for all channels separately. Please note that the multiplexer must be connected to the computer while starting the software.

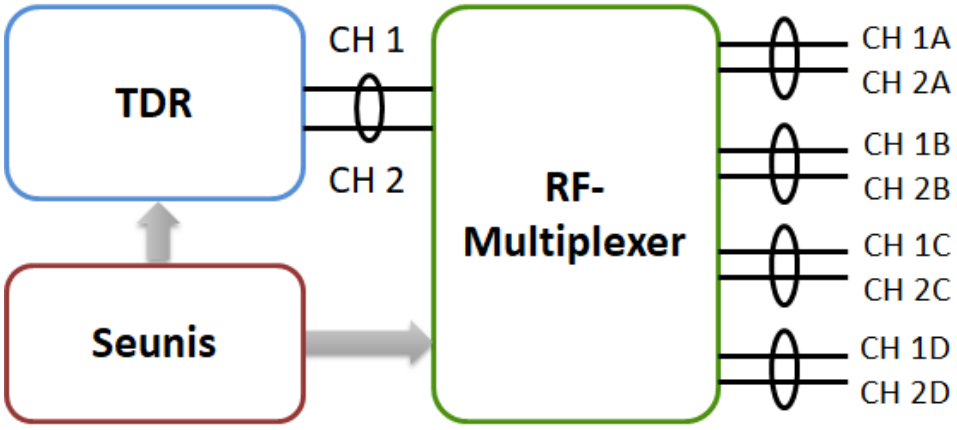


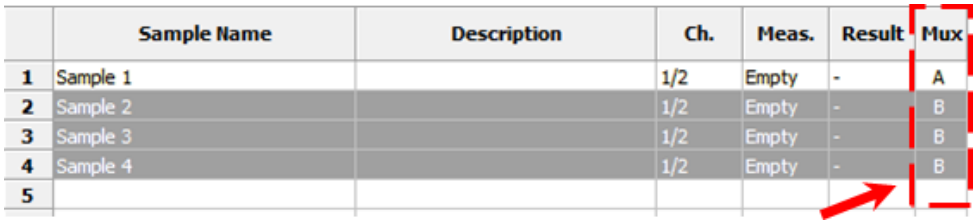
Figure 14: TDR equipped with external DP4T-Multiplexer

11.1 Assigning Channels to Samples

If a multiplexer unit is detected by the software, an additional **Mux** column is added to the *Sample List* (see Fig. 15), indicating the multiplexer channels of the samples. Furthermore the currently selected multiplexer channel is displayed in the status bar of the *Main Window* and in the upper-left corner of the oscilloscope display.

The multiplexer channel can be selected in the *RF Multiplexer Dialog*, shown in Fig. 16. The dialog can be opened via the *Main Window* menu entry *Extras*

→ *RF Multiplexer* or by using the shortcut CTRL-M. The number of available channels is detected automatically.



	Sample Name	Description	Ch.	Meas.	Result	Mux
1	Sample 1		1/2	Empty	-	A
2	Sample 2		1/2	Empty	-	B
3	Sample 3		1/2	Empty	-	B
4	Sample 4		1/2	Empty	-	B
5						

Figure 15: Additional Multiplexer Column in the Sample List

To assign a new multiplexer channel, simply select one or multiple samples from the list and open the *RF Multiplexer Dialog*. Select the new channel and close the dialog. In case multiple samples are selected, the user is requested to confirm the new channel assignment.

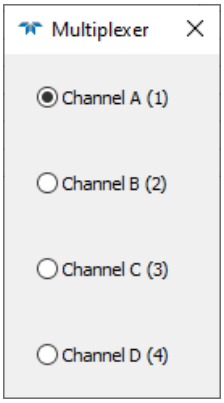


Figure 16: Multiplexer Dialog

Remark: *multiplexer channels are enumerated in capital letters to avoid confusion with CH1 (channel 1, in-phase) and CH2 (channel 2, inverted) of the differential TDR devices. The numeric counter in parentheses is shown for user convenience only (see Fig. 16) and should not be confused with CH1/CH2 as mentioned above.*

Please note: *Changing the multiplexer channels of already measured samples is not possible.*

11.2 Calibration of the Multiplexer (TTC/12TC)

To remove errors introduced by the multiplexer, it is recommended to calibrate all channels individually, the calibration plane then is CH 1A to CH 2D in Fig. 14. Please select multiplexer CH-A before starting the *Calibration Wizard* (see section 4.3), because this is essential for a multi-channel TTC/12TC calibration process. Please perform the calibration according to the points listed below:

1. Select multiplexer channel
2. Open the wizard and follow the instructions
3. Depending on the currently selected multiplexer channel, one of the following three cases a, b or c occurs at the end of the calibration process:

    a. **Wizard started for CH-A while calibration is NOT ACTIVE yet for ALL channels:**

    This is the standard case when starting a new multiplexer calibration. The user is informed, that the just performed calibration will be applied to all channels. This is essential at this point to maintain the internal integrity of the software, even though the calibration for the remaining multiplexer channels may not be perfect.

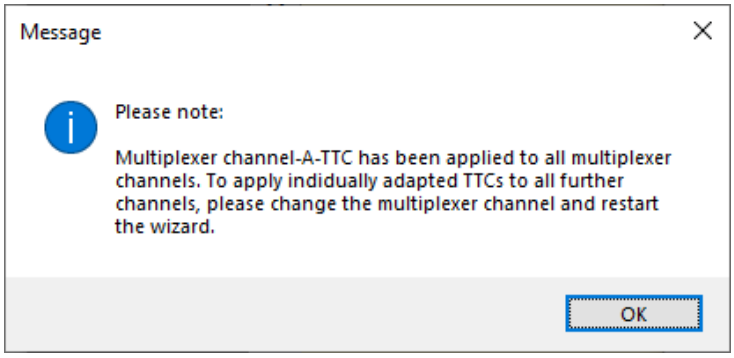


Figure 17: TTC/12TC will be applied to all channels

b. Wizard started for ANY OTHER than CH-A:

This is the standard case when calibrating all further multiplexer channels. After finalizing the current calibration, it is automatically applied to the current mulitplexer channel.

c. Wizard started for CH-A while calibration is already ACTIVE for ALL channels:

In this special case, the user has for any reason repeated the calbration of CH-A. The software needs to be informed whether it shall be applied to ALL channels or to CH-A only.

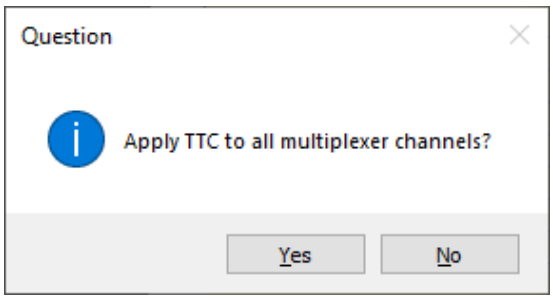


Figure 18: Inquiry whether changes should be applied to all channels

4. After the calibration of all channels is completed, save your work to a `mas` *Project File*. Otherwise turn back to step **1.** now and continue the calibration for the remaing multiplexer channels.

Please note: *Loading and saving TTC/12TC calibrations via the internal load & save function of the wizard is not possible for multi-channel calibrations. It is recommended to save the calibration as standard* `mas` *project file instead.*

11.3 De-Embedding of the Multiplexer

As the calibration of the multiplexer unit according to section 11.2 is quite labor-intensive, the de-embedding functionality (see chapter 7) can be used as an alternative to minimize the errors caused by the multiplexer.

The advantage is, that only the TDR system needs to be calibrated while the multiplexer influence is de-embedded. The basic requirement for this is the availability of the S-parameters for all signal paths of the multiplexer. In this scenario the calibration takes place in the plane CH1 / CH2 right before the multiplexer (see Fig. 14). The work flow to de-embed the multiplexer is described below.

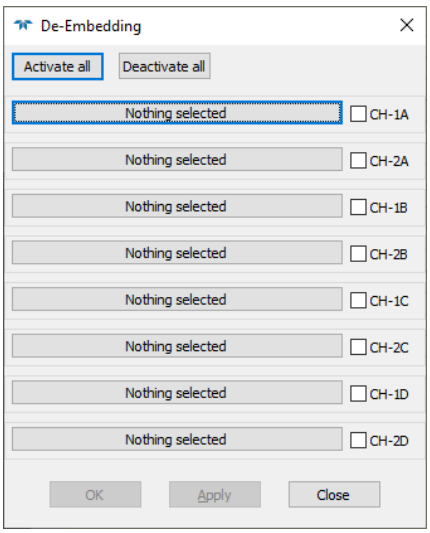


Figure 19: De-embedding Dialog for Multiplexer

1. Make sure the S-parameters for all multiplexer channels are available as Touchstone `s2p` files.

   Remark: *If the parameters are unavailable, it is possible to create them as described in section 7.3.*

2. Perform the TTC/12TC-calibration according to chapter 4 at the end of the cables to be connected to the multiplexer. At the end of the wizard, the user is informed that the calibration just performed is now applied to all channels, as described in section **11.2**, no. **3.a.**

3. Connect the TDR to the multiplexer via coaxial cable(s).

4. Open the *De-Embedding Dialog* via the tool button  in the *Main Window* and select all corresponding Touchstone files for the individual channels.

5. Close the dialog with OK and save your work to a `mas` *Project File*. The de-embedding tool button  should have turned green meanwhile.

11.4 Additional Remarks on Multiplexing

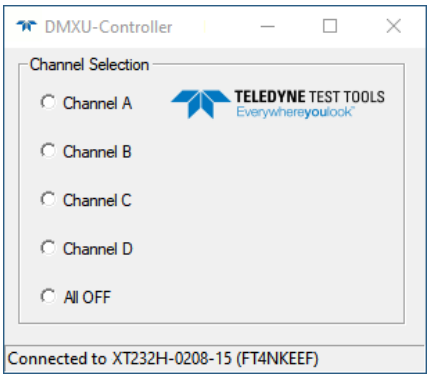


Figure 20: Stand-alone executable *WinD4MX.exe* for Multiplexers

- Together with the Seunis program a tool called `WinD4MX.exe` is installed. The small graphical tool can be used to control the USB-multiplexer without starting Seunis.
- For integration of external multiplexer units in customized software environments other than Seunis, please contact Teledyne LeCroy support. Programming interfaces are available upon request.

12. Additional Information

12.1 Description of the Toolbar Items in the Main Window

Save your project file at any time by clicking the disk symbol in the toolbar or by using the File menu entry *File* → *Save (as…)*.

Load projects by clicking the toolbar's folder button or using the menu entry *File* → *Open*.

The export icon starts a user dialog, where a specific export module can be chosen. All selected samples will be exported in the specific format. If no sample is chosen, the complete sample list will be exported. Seunis is able to export data in some foreign formats via the *File* menu. Custom specific export filters are available upon request.

Selects a specific measurement mode for the currently selected samples.

Opens the property window for impedance measurement and mask settings.

Use the magic wand to open the TTC/12TC calibration wizard.

Opens the *De-Embedding* dialog. See chapter 7 for further information.

Switches the ESD-protection on and off.

Sample list operation mode (default).

Macro operation mode, for performing recurring measurements with different measurement modes or settings.

Quick operation mode allows for performing quick-measurements without using the sample list.

REF

Trigger a reference measurement. The reference point can alternatively be set via the menu entry *Extras* → *Set reference manually* in the *Result Visualization Window*.

12.2 Description of the Toolbar Items in the Result Window

Export the displayed data to various formats. Currently supported are `csv`, `xlsx`, `mat`, `jpg` and Touchstone (for S_{11}/S_{XY} data only).

Print results to any installed printer on your system.

Full zoom out, fits the full diagram into the window. Can also be done by double-clicking the right mouse button.

Zoom into or out of the diagram, can also be done with mouse wheel.

Automatic zoom adjusts the axes to the currently shown data range. If impedance traces with activated tolerance mask are shown, the area around the mask is focused.

Lock the *Result Visualization Window* zoom to the *Oscilloscope Window* axes for time domain results. Further zooming is possible while the lock is activated.

Display and hide the vertical and horizontal cursors.

Clear all currently set cursors.

Display and hide the tolerance mask.

Displays helpful hints for working in the *Result Visualization Window*.

12.3 Description of the Main Window Menu Items

File:

New:	Creates a new empty sample list
Open:	Opens an existing sample list.
Save:	Saves the current sample list. An existing file with the same name will be overwritten.
Save As:	Saves the current sample list. A question dialog appears, if the file name already exists.
Recent Files:	Open one of the recently used files.
Load Workshop File	Open a workshop file for restoring a macro list, sample list and the last valid *TTC/12TC*.
Save Workshop File	Save the current the macro list, sample list and the link to the current *TTC/12TC*.
Export:	Information of all selected samples will be exported to a file. The export format depends on the selected export module.
Import:	Open the import module dialog.

Macro-List:	Submenu → for further information please refer to section 2.6.2.
Install:	Installs calibration kit datasets (`ckd` files). Furthermore a company logo (JPEG-image) can be installed, which should be approximately in a 2:1 format. Please be aware that administrator privileges are required to install the company logo.
Print:	Prints out brief overview information of current project.
Print Preview:	Shows the print preview.
Exit:	Exits the program. If unsaved changes are available in the project and/or the macro list, a *Save as* user dialog is raised.

Edit:

New Sample:	Creates a new sample in the list.
Insert Sample:	Inserts a new sample into the list at the selected row.
Delete Sample(s):	Deletes the selected sample(s).
Delete Avg. Meas.:	Deletes all repetition measurements all selected samples.
Previous Sample:	Jumps to previous line in the list
Next Sample:	Jumps to next line in the list

Cut:	Cut sample for copying it to another position
Copy:	Copy contents of selected cells into clipboard.
Clone:	Same as copy, except for the actual measurement data.
Paste:	Paste content of clipboard.
Select by criterion:	Selects samples by certain criterion.
Select all:	Selects complete sample list.
Sort Sample List:	Sorts the samples in the list by sample names.
Rename Samples:	Rename multiple samples in list using wildcard symbol *.
Project Comment:	Create a project related comment. This can be printed to PDF reports.
Select meas. mode:	Select a measurement mode.
Properties:	Opens the impedance measurement property window.

View:

TDR Curves:	Opens the oscilloscope window with TDR curves.
Result Visualization:	Opens the result visualization window.

Save default Arrangement:	Saves current window settings to user-specific default arrangement.
Arrange Windows (user-default):	Arranges the windows to the user-default settings.
Arrange Windows (factory-default):	Recall the factory-default windows arrangement.
Log Window:	Opens a window prompting the contents of the current log-file. This can be very useful for debugging. The log-file is usually located in the same folder as the configuration file.

Extras:

Measure:	Trigger measurement.
Reference Measurement:	Trigger reference measurement.
Clear Reference Measurement:	Clear reference measurement.
Three-Term Correction:	Open the TTC/12TC wizard.
RF Multiplexer:	Open the RF multiplexer dialog (optional).
Change Sample Settings:	Change a particular setting for one or multiple samples.
Calculate Impedance Slopes:	Calculates (and modifies) the impedance slopes of selected samples.

Create Impedance Mask:	Create a user-defined impedance tolerance mask, based on an existing sample.
Enumerate Samples:	Enumerate selected samples automatically.
Connect:	If the device is not connected, press this button to connect.
Language:	Change the language setting.
Options:	Opens a user dialog for changing options.

Help:

Device Info:	Gives some information about the device state.
User Manual:	Opens this manual.
Credits:	Show credits for used 3rd party software packages.
About:	Information about the software.

12.4 Keyboard Shortcuts

Key	Function
CTRL-N	New project
CTRL-O	Open project
CTRL-S	Save project
ALT-CTRL-S	Save project as...
CTRL-E	Export
CTRL-I	Install (calibration kit data, company logo)
CTRL-P	Print
CTRL-ALT-P	Print preview
CTRL-Q	Exit Seunis
CTRL-SPACE	New sample
INS	Insert sample
DEL	Delete sample(s)
CTRL-D	Deletes all measurements of selected sample(s)
F7	Step to previous line
F8	Step text line
CTRL-X	Cut sample(s)
CTRL-C	Copy sample(s)
CTRL-V	Paste sample(s)
CTRL-ALT-C	Select samples by criterion
CTRL-A	Select all
ALT-M	Select measurement mode
ALT-I	Open impedance properties window
CTRL-T	Oscilloscope window
CTRL-R	Result visualization window
ALT-W	Arrange windows according to user-defined setting
CTRL-ALT-W	Reset default window arrangement to factory default

CTRL-ALT-SHIFT-W	Reset default window arrangement to factory default (single-screen)
ALT-L	Open log window
F5	Measure
F6	Reference measurement (yellow LED)
ALT-T	Open three term correction (TTC) wizard
CTRL-M	Open multiplexer dialog (optional)
CTRL-U	Fill table downwards with clones of currently selected sample
ALT-P	Reactivate password protection for advanced options
CTRL-ALT-I	Show information about currently selected sample
ALT-F	Change frequency axis (in result visualization window)
ALT-X	Change x-axis to spatial (in result visualization window)
CTRL-ALT-F9/F10	Previous/next parameter (in result visualization window)
CTRL-ALT-F11/F12	Previous/next result domain (in result visualization window)

13. Technical Specifications

13.1 T3SP-Series Mainframes

Model	T3SP10D	T3SP15D
Operating Frequency	10 GHz	15 GHz
S-parameter Measurements	Single-ended S_{11} and Differential S_{dd11}	Full Single-ended S_{11}, S_{21}, S_{12}, S_{22} and Differential S_{dd11}
Calibration Method	OSL	OSL and OSLT
Connector Type	SMA	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)	n.a.	DC ≤f <5 GHz: ±0.5 dB 5 GHz ≤f <10 GHz: ±0.75 dB 10 GHz ≤f <15 GHz: ±1 dB
Time Domain Displays	Oscilloscope Mode, Z – normalized to specified rise time, Step response	
File Outputs	CSV, Matlab, Touchstone 1.0, PDF-Report	

Pulser / Sampler and Time base

Step Amplitude	150 mV Single-ended / 300 mV differential (nominal top-base, 50 Ω termination)	
Rise Time	50 ps	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 μV_{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	

Model	T3SP10D	T3SP15D

Internal ESD Protection Relays

Frequency Rating	>10 GHz	>15 GHz
Rated Life	2 million actuations per contact	

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 × 210 × 82.5 mm With connectors: 242 × 210 × 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)

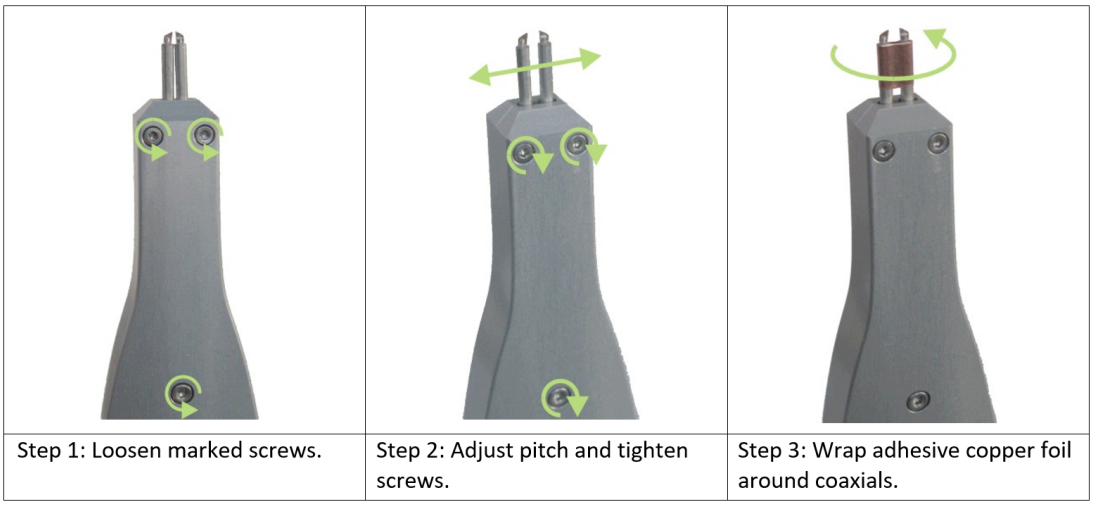
Recommended PC Configuration

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

13.2 T3SP-DPROBE

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

The T3SP-DPROBE combines flexible pitch adjustment and extraordinary high frequency performance up to 18GHz. To obtain optimal results, please execute the following steps for adjusting the probe pitch:



Step 1: Loosen marked screws.	Step 2: Adjust pitch and tighten screws.	Step 3: Wrap adhesive copper foil around coaxials.

Especially step 3 is of great importance for reliable high frequency measurements. The adhesive copper foil is available from Teledyne LeCroy probe accessories kits. If no foil is available, alternatively a conductive wire may be used, too.

13.3 T3SP-DPROBE-F

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	

13.4 T3SP-SEP

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 x 9.0 mm	(length x diameter)
Material	Brass	
Specials		direct in-circuit TDR testing

13.5 T3SP-SEPROBE-F

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 x 32 x 13.2 mm	casing only
	131 x 32 x 15.6 mm	with connectors and tips
Material	Polystyrene	

14. Troubleshooting

Problem	Approach
The device cannot be found.	This is usually due to problems with the USB communication. In this case, please check the USB connectors and the drivers in the Windows Device Manager. Latest D2XX-Drivers can be found at www.ftdichip.com or be requested from Teledyne LeCroy support.
After starting the software the following warning appears: "No valid measurement modes found!"	The software attempts to read out the measuring modes from the device. Possibly the connection is not established correctly. Make sure the device is turned on (check if ON/OFF buttons LED lights or blinks red) and the USB connection has been established (see beginning of chapter 2). If the message still appears, check the *Seunis.config* file, if the entry `Auto connect` is set to `true`.
The red LED of the ON/OFF button is blinking red.	This is not an error but means that the battery is currently recharged. The LED blinks green while the device is turned off and the battery is charged.
The programs windows do not show up or are arranged strangely.	Press *CTRL-ALT-W* to restore the factory-default window arrangement.

No calibration kit is available for performing the three-term calibration (open, short, load, thru)	No `ckd` file containing calibration kit coefficients can be found by the software. Make sure it is copied to the programs *Config* subfolder. Alternatively it can be installed via the keyboard shortcut CTRL-I or the menu entry *File* $\rightarrow$ *Install* in the *Main Window*.
When pressing the measurement button, the message "Temperature not stable" appears.	The internal device temperature must be stable for ensuring the internal temperature compensation to work properly. This message usally appears at startup or if the device is exposed to extreme temperature changes.

15. Safety Instructions

15.1 Operating Environment

Temperature	0°C to 40°C Direct sunlight, radiators, and other heat sources should be avoided and have to be taken into account when assessing the ambient temperature.
Humidity	5% to 90% RH (non condensing) up to 31°C decreasing linearly to 50% RH at 40°C
Altitude	Up to 3000m at or below 30°C

15.2 Power

AC Voltage	100-240VAC (±10%) at 50-60Hz automatic AC voltage selection
DC Voltage	24V
Power Consumption	0.2W (Standby) 9.0W (ESD-Protection disabled) 17.0W (ESD-Protection enabled) 36.0W (ESD-Protection enabled & optional Accu charged with max. current)
Battery (optional)	MGL9017 from Enix Power Solutions (Lithium-Ion, 14.8V, 2.6Ah, 38.5Wh). For shipment, please refer to current IATA Lithium Battery Guidance Document.

15.3 Safety Symbols & Terms

Where the following symbols or terms appear on the instrument front or rear panels, or in this manual, they alert you to important safety considerations.

	This symbol is used where ESD-precautions are required. This is especially true if the fully integrated ESD-protection is disabled (e.g. during a measurement).
	This symbol is used to denote a safety ground connection.
	Power On / Standby (Off).

15.4 Safety Requirements

This safety instruction section contains information and warnings that must be observed to keep the Teledyne LeCroy T3SP High Differential Time Domain Reflectometers (T3SP15D & T3SP10D) operating in a correct and safe condition. You are required to follow generally accepted safety procedures in addition to the safety precautions specified in this section.

a. USE PROPER CORD:

Use only the power supply and power cord shipped with this instrument and certified for your country.

b. MAINTAIN GROUND:

The power supply is grounded through the power cord grounding conductor. To avoid electric shock, connect only to a grounded mating outlet.

c. OBSERVE ALL TERMINAL RATINGS:

Do not apply a voltage to any input that exceeds the maximum rating of that input. Refer to the markings next to the terminals for maximum allowed values.

d. USE ONLY WITHIN OPERATIONAL ENVIROMENT LISTED:

Do not use the instrument outdoors, in wet or explosive environments.

e. EXERCISE CARE WHEN LIFTING AND CARRYING:

Unplug all power and ground connectors before moving the instrument.

f. DO NOT REMOVE THE COVERS OR INSIDE PARTS:

Refer all maintenance to qualified personnel.

g. DO NOT OPRATE WITH SUSPECTED FAILURES:

Check body and cables regularly. If any part is damaged, cease operation immediately and sequester the instrument from inadvertent use.

16. Maintenance

- Do not use abrasive cleaning agents. To remove tenacious contaminations use a commercial, non-abrasive cleaning agent.
- If necessary, clean the T3SP carefully by wiping it with a humid cloth.
- Keep the instrument in the provided casing, while not being used.

17. Certifications

Teledyne LeCroy certifies compliance to the following standards as of the time of publication. Please see the EC Declaration of Conformity document shipped with your product for current certifications.

17.1 EMC Compliance

17.1.1 EC DECLARATION OF CONFORMITY - EMC

The instrument meets intent of EC Directive 2014/30/EU for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications listed in the Official Journal of the European Communities:

EN 61326-1:2013, EN 61326-2-1:2013 EMC requirements for electrical equipment for measurement, control, and laboratory use [1]

Electromagnetic Emissions:

EN 55011:2016+A1:2017, Radiated and Conducted Emissions Group 1, Class A [2,3]

EN 61000-3-2:2014 Harmonic Current Emissions, Class A

EN 61000-3-3:2013 Voltage Fluctuations and Flickers, Pst = 1

Electromagnetic Immunity:

EN 61000-4-2:2009 Electrostatic Discharge, 4 kV contact, 8 kV air, 4 kV vertical/horizontal coupling planes [4]

EN 61000-4-3:2006+ A2:2010 RF Radiated Electromagnetic Field, 3 V/m, 80 - 1000 MHz; 3 V/m, 1.4 - 2 GHz; 1 V/m, 2 - 2.7 GHz

EN 61000-4-4:2012 Electrical Fast Transient/Burst, 1 kV on power supply lines, 0.5 kV on I/O signal data and control lines [4]

EN 61000-4-5:2014+A1:2017 Power Line Surge, 1 kV AC Mains, L-N, L-PE, N-PE [4]

EN 61000-4-6:2014 RF Conducted Electromagnetic Field, 3 V_{rms}, 0.15 - 80 MHz

EN 61000-4-11:2004+A1:2017 Mains Dips and Interruptions, 0%/1 cycle, 70%/25 cycles, 0%/250 cycles [4,5]

1 To ensure compliance with all applicable EMC standards, use high-quality shielded interface cables.
2 Emissions which exceed the levels required by this standard may occur when the instrument is connected to a test object.
3 This product is intended for use in nonresidential areas only. Use in residential areas may cause electromagnetic interference.
4 Meets Performance Criteria "B" limits of the respective standard: during the disturbance, product undergoes a temporary degradation or loss of function or performance which is self-recoverable.
5 Performance Criteria "C" applied for 70%/25 cycle voltage dips and for 0%/250 cycle voltage interruption test levels per EN61000-4-11.

European Contact:*

Teledyne GmbH, European Division
Im Breitspiel 11c
D-69126 Heidelberg, Germany
Tel: +49 6221 82700

17.1.2 AUSTRALIA & NEW ZEALAND DECLARATION OF CONFORMITY – EMC

The instrument complies with the EMC provision of the Radio Communications Act per the following standards, in accordance with requirements imposed by Australian Communication and Media Authority (ACMA):

AS/NZS CISPR 11:2015 Radiated and Conducted Emissions, Group 1, Class A.

Australia / New Zealand Contacts:*

RS Components Pty Ltd.
Suite 326 The Parade West
Kent Town, South Australia 5067

RS Components Ltd.
Units 30 & 31 Warehouse World
761 Great South Road
Penrose, Auckland, New Zealand

* Visit teledynelecroy.com/support/contact for the latest contact information.

17.2 Safety Compliance

17.2.1 EC DECLARATION OF CONFORMITY – LOW VOLTAGE

The instrument meets intent of EC Directive 2014/35/EU for Product Safety. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

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

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

The design of the instrument has been verified to conform to the following limits put forth by these standards:

- Mains Supply Connector: Overvoltage Category II, instrument intended to be supplied from the building wiring at utilization points (socket outlets and similar).
- Measuring Circuit Terminals: No rated measurement category. Terminals not intended to be connected directly to the mains supply.
- Unit: Pollution Degree 2, operating environment where normally only dry, non-conductive pollution occurs. Temporary conductivity caused by condensation should be expected.

17.3 Environmental Compliance

17.3.1 END-OF-LIFE HANDLING

The instrument is marked with this symbol to indicate that it complies with the applicable European Union requirements of Directives 2012/19/EU and 2006/66/EC on Waste Electrical and Electronic Equipment (WEEE) and Batteries.

The instrument is subject to disposal and recycling regulations that vary by country and region. Many countries prohibit the disposal of waste electronic equipment in standard waste receptacles. For more information about proper disposal and recycling of your Teledyne LeCroy product, please visit teledynelecroy.com/recycle.

17.3.2 RESTRICTION OF HAZARDOUS SUBSTANCES (RoHS)

EC DECLARATION OF CONFORMITY – RoHS

Unless otherwise specified, all the materials and processes are compliant with RoHS Directive 2011/65/EU in its entirety, inclusive of any further amendments or modifications of said Directive.

CHINA RoHS 2

Unless otherwise specified, all the materials and processes are compliant with the latest requirements of China RoHS 2. The hazardous substances contained in the instrument are disclosed in accordance with the standards SJ/T 11364-2014 (Marking for the restricted use of hazardous substances in electronic and electrical products) and GB/T 26572-2011 (Requirements on concentration limits for certain restricted substances in electrical and electronic products). The instrument is marked with an appropriate Environmental Friendly Use Period (EFUP) symbol. The packaging materials include the appropriate recycling labels. The below substance disclosure tables (in Chinese and English languages) provide the required compliance information.

部件名称	有毒有害物质和元素					
	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr6+)	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
PCBAs	X	O	O	O	O	O
机械硬件	O	O	O	O	O	O
金属片	O	O	O	O	O	O
塑料部件	O	O	O	O	O	O
电缆组件	X	O	O	O	O	O
显示器	O	O	O	O	O	O
电源	O	O	O	O	O	O
风扇	O	O	O	O	O	O
电池	O	O	O	O	O	O
电源线	O	O	O	O	O	O
外部电源(如有)	X	O	O	O	O	O
探头(如有)	X	O	O	O	O	O
熔丝(如有)	O	O	O	O	O	O
产品外壳(如有)	O	O	O	O	O	O
适配器/模块(如有)	O	O	O	O	O	O
鼠标(如有)	O	O	O	O	O	O
O: 表明该有毒有害物质在该部件所有均质材料中的含量均在SJ/T11364-2014标准规定的限量要求之下。						
X: 表示该有毒有害物质至少在该部件的某一均质材料中的含量超出SJ/T11364-2014标准规定的限量要求。						

EFUP （对环境友好的使用时间）：30年。

使用条件：参阅用户手册“环境条件”部分的规定。

探头EFUP：10年。

Part Name	Toxic or Hazardous Substances and Elements					
	Lead (Pb)	Mercury (Hg)	Cadmium (Cd)	Hexavalent Chromium (Cr6+)	Polybrominated Biphenyls (PBB)	Polybrominated Diphenyl Ethers (PBDE)
PCBAs	X	O	O	O	O	O
Mechanical Hardware	O	O	O	O	O	O
Sheet Metal	O	O	O	O	O	O
Plastic Parts	O	O	O	O	O	O
Cable Assemblies	X	O	O	O	O	O
Display	O	O	O	O	O	O
Power Supply	O	O	O	O	O	O
Fans	O	O	O	O	O	O
Batteries	O	O	O	O	O	O
Power Cord	O	O	O	O	O	O
Ext Power Supply (if present)	X	O	O	O	O	O
Probes (if present)	X	O	O	O	O	O
Fuse (if present)	O	O	O	O	O	O
Product Case (if present)	O	O	O	O	O	O
Adapters/Modules (if present)	O	O	O	O	O	O
Mouse (if present)	O	O	O	O	O	O
O: Indicates that this toxic or hazardous substance contained in all of the homogeneous materials for this part is below the limit requirement specified in SJ/T11364-2014.						
X: Indicates that this toxic or hazardous substance contained in at least one of the homogenous materials used for this part is above the limit requirement specified in SJ/T11364-2014.						

EFUP (Environmental Friendly Use Period): 30 years.

Use Conditions: Refer to the environmental conditions stated in the User Manual.

EFUP for Probes: 10 years.