R&S®ZNrun Vector Network Analyzer Automation Suite User Manual

1176990602
Version 07

ROHDE&SCHWARZ
Make ideas real

This manual describes the R&S®ZNrun application software and related options:

- R&S®ZNRUN-K1, automated test software for VNAs (1326.7124.02)
- R&S®ZNRUN-K2, multi-client capability (1326.7130.02)
- R&S®ZNRUN-K5, DUT/VNA multiplicity (1334.4250.02)
- R&S®ZNRUN-K6, measurement tuning capability (1334.4237.02)
- R&S®ZNPC, license dongle (1325.6601.02)
- R&S®ZNPC-LS, license dongle PC software for floating license (1325.6601.03)

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The following abbreviation is used throughout this manual: R&S® is abbreviated as R&S.

Contents

1 Introduction

R&S ZNrun is a PC-based software suite for the definition, configuration and execution of automated VNA tests. It controls the involved measurement devices (VNAs, switch matrices, calibration units) and supports many Rohde & Schwarz instruments. A plug-in interface is provided to control additional measurement equipment and devices under test via VISA connections.

R&S ZNrun stands for modularity, extensibility, compatibility and optimized speed of measurement execution. Therefore it is ideal for use in high volume production of multiport devices requiring control during test, e.g. for testing the RF properties in various operating states.

Setting up R&S ZNrun for testing is as simple as describing the test setup (test equipment, DUTs) and defining the test sequence. Configurations are modular and reusable and therefore minimize your configuration time. Based on the configuration, R&S ZNrun calculates a connection plan, which is optimized for both quality and measurement speed. It also calculates an initialization sequence, calibration plan and a speed-optimized test plan. At execution time, R&S ZNrun verifies that the measurement can be performed with the connected measurement equipment.

R&S ZNrun comes with the following applications:

- **ZNrun Server**
  The core of the software suite. Runs and manages Measurement Execution Units (MEUs). A plug-in interface enables user-defined extensions, such as custom devices and post processors. See Chapter 3, "Application Overview", on page 11.
- **ZNrun Workbench**
  The main graphical user interface (GUI) of R&S ZNrun. Allows you to develop, test and tune a MEU, before it is used in the production field. Deploys the MEU to a ZNrun Server and communicates with the server during MEU execution. Integrates or gives access to the other R&S ZNrun applications (ZNrun Calibration Client, ZNrun Measurement Client, ZNrun Visualization Client). See Chapter 4, "ZNrun Workbench", on page 15.
- **ZNrun Calibration Client**
  A GUI application for guiding a technician through all the steps of the calibration process. For laboratory use, it offers a more advanced interface, which allows definition of user-defined calibration tasks. See Chapter 5, "ZNrun Calibration Client", on page 61.
- **ZNrun Measurement Client**
  An application for controlling the execution of a MEU on a ZNrun Server. Provides a graphical and a remote control interface (SCPI commands). A plug-in interface enables user-defined extensions, such as the creation of custom log files and reports. See Chapter 6, "ZNrun Measurement Client", on page 69.
- **ZNrun Visualization Client**
  The ZNrun Visualization Client allows you to visualize and document measurement results. It is available as a stand-alone application and integrated in the ZNrun Workbench. See Chapter 4.5.2, "Visualization Workspace", on page 55.

2 Getting Started

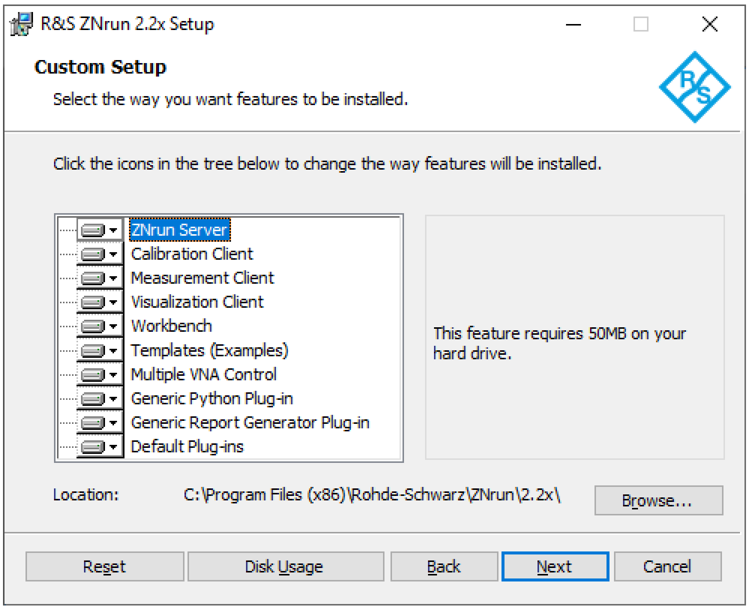
2.1 Installation

R&S ZNrun can be installed on a single PC running Windows 10 (32-bit or 64-bit). A full installation requires up to 600 Mbyte available disk space for the 32-bit, and up to 1.5 Gbyte for the 64-bit installation.

The installer must be run with administrative privileges and possibly finishes with a reboot. The following components are automatically installed, if not already present on the target PC:

- .NET Framework 4.7.2
- R&S VISA library (32-bit or 64-bit), the Rohde & Schwarz implementation of the VISA I/O API
- R&S License Server software

The following features are offered for installation:



- "ZNrun Server", "Calibration Client", "Measurement Client", "Visualization Client", "Workbench": see Chapter 1, "Introduction", on page 5
- "Templates (Examples)": R&S ZNrun also provides a rich application programming interface for the creation of custom plug-ins and clients. To get you started with this API, examples are provided as a Visual Studio 2017 solution. The template examples are installed at
`C:\ProgramData\Rohde-Schwarz\ZNrun\2.30x\Resources\Templates`.
- "Multiple VNA Control": currently not supported

- "Generic Python Plugin": enables Python scripting of ZNrun Server plug-ins.
- "Generic Report Generator Plugin": allows a plugin developer to create PDF reports from a plugin
- "Default Plug-ins": Currently only comprises a single plug-in for the ZNrun Measurement Client. Its source code is included in the "Templates (Examples)" installer feature.
  Note that the provided plug-ins are not part of the regular software maintenance.

For development of custom device or post-processor plugins, you need Microsoft Visual Studio 2017 or higher.

2.2 Running Your First Measurement

Before running your first measurement (using a single VNA), make sure the ZNrun Server machine can access VNA via remote control, using communication interfaces such as LAN, USB, or GPIB. If peripheral devices (calibration units, switch matrices, ...) are also needed, connect them to the VNA.

To run your first measurement on real hardware, perform the following steps:

1. Start the ZNrun Server: select "R&S ZNrun 2.30 > ZNrun Server" from the Windows Start menu.
2. Run the ZNrun Workbench: select "R&S ZNrun 2.30" > "ZNrun Workbench" from the Windows start menu.
   The ZNrun Workbench allows you to create a ZNrun project.
3. Click the "Start" button in the main toolbar of the ZNrun Workbench to trigger the following actions:
   a) The workbench sends the project to the server. If the project is valid, the server creates a "Measurement Execution Unit" (MEU) from it.
   b) The server executes the first measurement cycle.

To run a measurement, a ZNrun Server with a valid license R&S ZNRUN-K1 is required. The license is contained in the Licensing and must be installed on the same machine where the ZNrun Server runs.

2.3 Licensing

Running the ZNrun Server requires a valid core license R&S ZNRUN-K1, and, depending on the desired features, additional licenses for options R&S ZNRUN-K2 etc.

Licenses are available as local and floating variants.

- **Local** licenses must be available on the ZNrun Server.

- **Floating** licenses can also reside on remote license servers that can be reached by the ZNrun Server's license server via LAN.

R&S ZNPC license dongle

R&S ZNRUN licenses "live" on dedicated R&S ZNPC IC chips that are delivered as a smart card and a USB dongle. You can either use the smart card with a smart card reader, or remove the license chip and insert it into the USB dongle.

Figure 2-1: R&S ZNPC license dongle

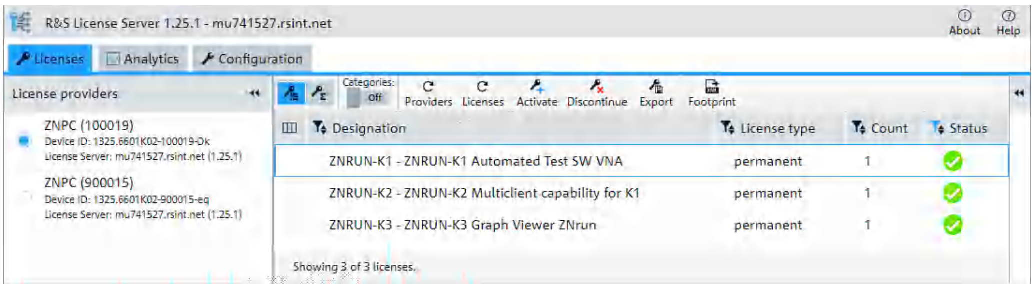
In any case, the license chip must be properly detected by the license server instance on the PC it is physically connected to. Make sure the RSSmartCardService driver is installed, when the smart card or dongle is connected to this PC for the first time.

R&S License Server

The R&S License Server is used for option management on a PC, device or server. It supports:

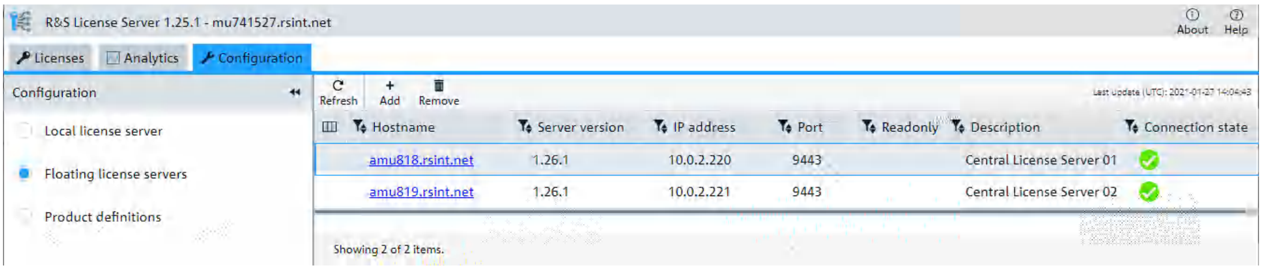
- parallel usage of local dongles by multiple applications ("shared access")
- license verification via LAN, using https connections to central license servers with floating licenses

If the ZNrun Server complains about missing licenses, run the R&S License Server Manager browser app from the Windows start menu of the ZNrun Server PC ("Start" > "R&S License Server" > "R&S License Server Manager"). Make sure the required R&S ZNPC licenses are visible in the "Licenses" tab.



If you want to use local licenses but no local licenses are visible, verify that the smart card or license dongle is properly inserted into the smart card reader or USB port of the ZNrun Server PC, respectively. If a license dongle is used, make sure that the IC chip is fully inserted into the dongle (see Figure 2-1).

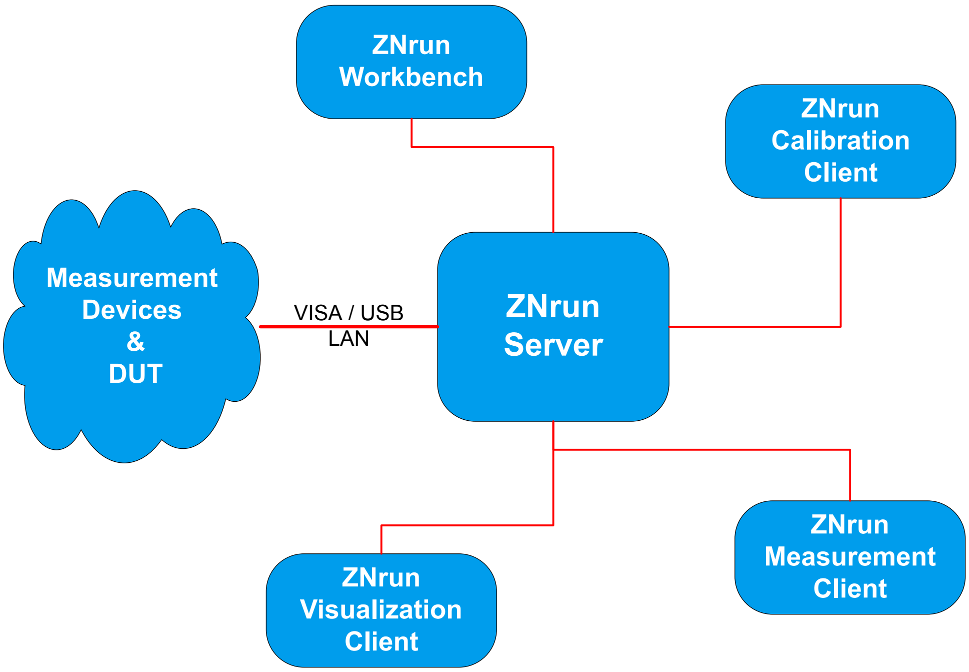
If you want to use floating licenses, make sure to define one or more remote floating license servers in the license server manager of the ZNrun Server PC and check their connection state.



For more information, see the R&S License Server help, which can be opened from the "Help" icon in the top right corner of the R&S License Server Manager pages.

3 Application Overview

The R&S ZNrun software suite consists of a central server component (ZNrun Server) and a set of client applications (ZNrun Workbench, ZNrun Calibration Client, ZNrun Measurement Client, ZNrun Visualization Client). See Chapter 1, "Introduction", on page 5.



3.1 Client-Server Architecture

The **ZNrun Server** manages the communication with the measurement instruments and the DUT. Rohde & Schwarz instruments are controlled via VISA and/or proprietary USB protocols. Additional test equipment and DUTs can be controlled via VISA or the RFFE/GPIO ports of the R&S ZNA, R&S ZNB or R&S ZNBT. Any type of hardware or software interface can be integrated with R&S ZNrun via the plug-in interface.

The **ZNrun Workbench** allows you to create ZNrun project files, which, when deployed to the ZNrun Server, define one or more server-side Measurement Execution Units (MEUs).

Before starting the actual measurement, the involved vector network analyzers have to be calibrated for full system error correction and/or absolute power level correctness. For this purpose, the R&S ZNrun provides the **ZNrun Calibration Client**, a simple graphical user interface, suitable for guiding a technician through the required calibration steps. For laboratory use, it offers an advanced interface that allows to define custom calibration tasks.

The **ZNrun Measurement Client** allows you to connect to a Measurement Execution Unit that was previously uploaded to the ZNrun Server. It provides a graphical user interface for measurement execution. It shows a stop watch timer that is synchronized with the measurements, which makes it easy to measure the execution time of measurement cycles or single steps. The measurements steps can be performed without interruption – in a so called measurement cycle – or step by step. It is also possible to execute several measurement cycles in succession. Measurement results are written to the hard disk on-the-fly.

It can take some seconds until all parameters have been uploaded to the devices and all communication paths have been tested. However, this upload is done only once: all following measurements require a minimum amount of setup time.

3.2 ZNrun Server

The ZNrun Server can accommodate multiple Measurement Execution Units, but with option R&S ZNrun-K1 alone you can only run one at a time. For parallel execution of multiple Measurement Execution Units, you need option R&S ZNrun-K2.

In addition to VISA, the server can communicate over arbitrary communication interfaces via plug-ins. Plug-ins allow external hardware (such as DUTs and 3rd party measurement equipment) to be synchronized with measurements.

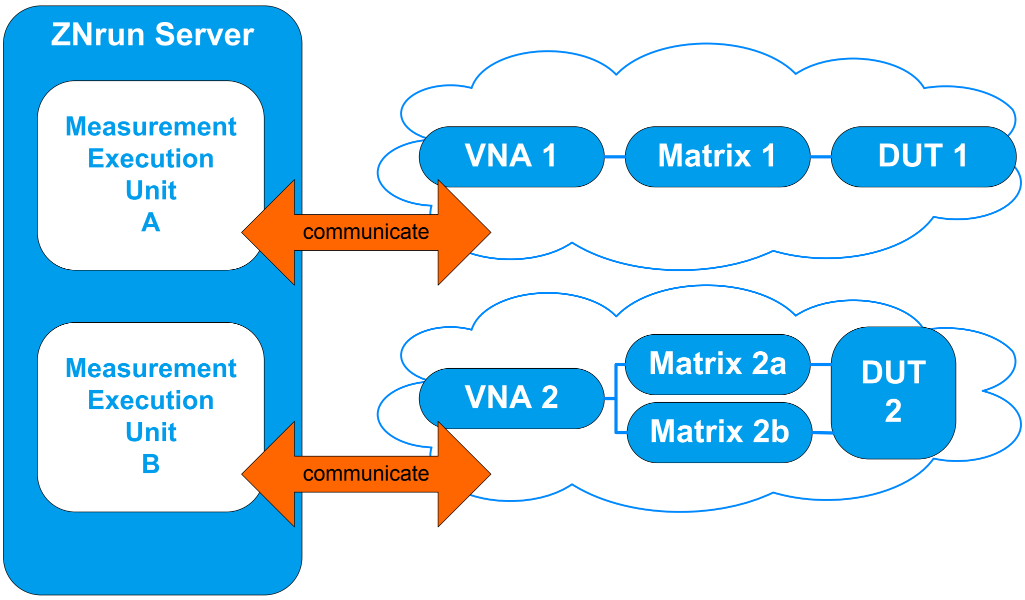


Figure 3-1: ZNrun Server with two Measurement Execution Units

3.3 DUT-Centric Approach

The DUT and its measurements represent the core of the R&S ZNrun data model ("DUT Measurement Plan").

Typically, DUTs are implemented as "system on a chip" and do not support coaxial connectors. Such a DUT comprises several logical ports that are connected to physical ports using a measurement adapter. The measurement devices can be connected toe the physical ports of the measurement adapter.

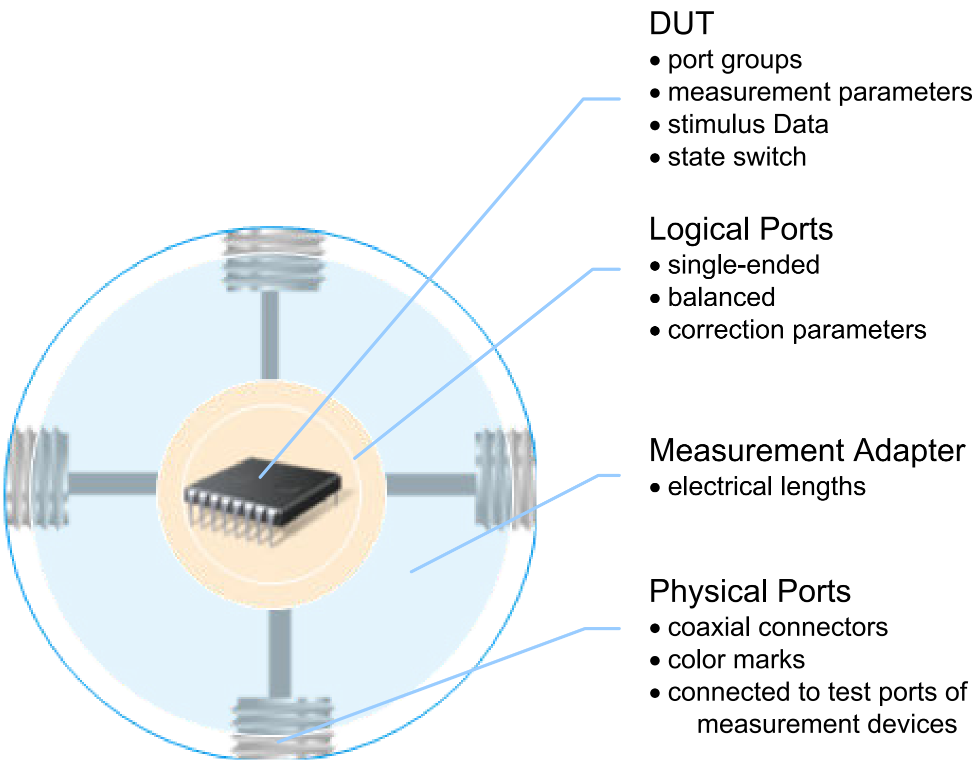


Figure 3-2: DUT model

The DUT Measurement Plan defines the parameters to be measured at or between certain logical ports. It also defines how the measurement is done, e.g. it describes the stimuli the VNA provides during the measurement.

At certain points in time during a measurement sequence, the ZNrun Server possibly needs to interact with the DUT to change its operating state. The DUT Measurement Plan defines those interactions using "DUT State Switches" or plug-ins.

3.4 ZNrun Project Files

A ZNrun project file is an XML file (with root element `Project`), containing one or more `MeasurementExecutionUnit` XML elements.

Each `MeasurementExecutionUnit` element describes an executable measurement task on the ZNrun Server. It comprises three main child elements:

- a `MeasurementDevicesPlan` element, describing the measurement equipment configuration
- a `DutMeasurementPlan` element, describing the DUT, the measurement adapter (test fixture), and the measurement parameters

- an optional ConnectionPlan element describing the physical connections between measurement devices and measurement adapter. Normally, the ConnectionPlan is calculated on the ZNrun server as part of the optimization process, but it can also be specified explicitly

- The structure of the XML files is defined in various XML schema files that can be found at <ZNrun InstallDir>\Server\Schemas.
- The ZNrun Workbench creates ZNrun projects that contain only a single MeasurementExecutionUnit. Its child elements (MeasurementDevicesPlan, DutMeasurementPlan, ConnectionPlan, ...) are distributed to separate files, which makes it easier to reuse them in other ZNrun projects.

4 ZNrun Workbench

The ZNrun Workbench application provides the main graphical user interface (GUI) of R&S ZNrun. It can be used to develop, test and tune a Measurement Execution Unit (MEU) before it is used in the production field. Furthermore, it gives convenient access to the other client applications (ZNrun Calibration Client, ZNrun Measurement Client, ZNrun Visualization Client).

The ZNrun Workbench supports the two core features of the R&S ZNrun application:

- **Multiplicity** (with option R&S ZNrun-K5)
  - **DUT multiplicity**
    A key feature of the ZNrun Workbench is DUT multiplicity. The ZNrun Workbench natively supports the configuration of measurements on multiple DUTs.
  - **VNA multiplicity**
    The ZNrun Workbench also supports the configuration and execution of a MEU with multiple vector network analyzers.
- **Tuning** (with option R&S ZNrun-K6)
  Tuning is a special feature of the R&S ZNrun framework. It can be used to change and optimize the configuration of a MEU during the execution to maximize the use of the measurement. Furthermore, tuning comes with three tools to enhance the capabilities of the configuration of a MEU with the ZNrun Workbench: "Save Changes", "Create Snapshot", and "Recall Snapshot".

Additionally you can use the ZNrun Workbench to roll out a MEU to multiple test stations.

Workflow

The workflow with the ZNrun Workbench is separated into five phases:

Figure 4-1: ZNrun Workbench workflow

4.1 Application Overview

The ZNrun Workbench is the central graphical user interface to start and control the components of the R&S ZNrun. The same layout is used for all application phases.

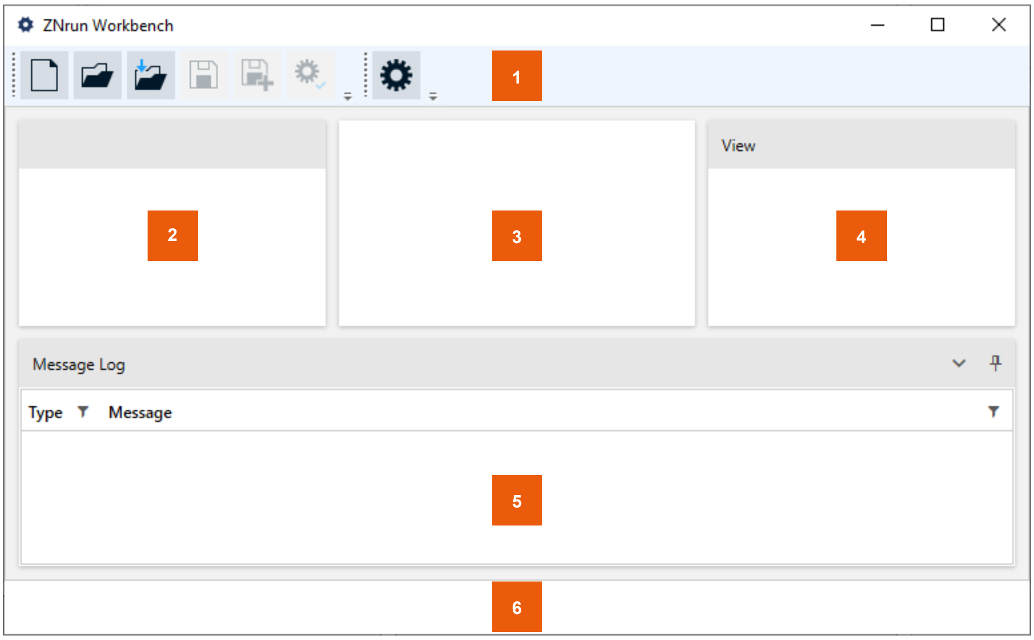


Figure 4-2: Overview of the ZNrun Workbench layout

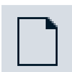
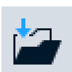
1 = Main toolbar
2 = "DUT Center" panel
3 = Workspace
4 = "View" panel
5 = Log panel
6 = Status bar

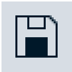
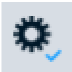
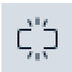
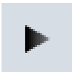
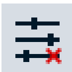
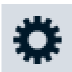
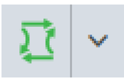
4.1.1 Main Toolbar

The main toolbar contains the controls to configure and execute a Measurement Execution Unit (MEU). It allows you to start the calibration client, see Chapter 4.4, "Calibration Phase", on page 54, and the visualization client, see Chapter 4.5, "Execution and Visualization Phase", on page 54.

In the configuration phase, the main toolbar has four functional tool groups:

Table 4-1: Main toolbar actions in configuration phase

Group	Icon	Name	Action
Basic commands		New	Creates a MEU configuration with the ZNrun Workbench data structure.
		Open workbench file	Loads an existing MEU configuration from a ZNrun Workbench data structure.
		Open ZNrun project	Loads the data structure from an existing R&S ZNrun project.

Group	Icon	Name	Action
		Save	Saves all changes to the working ZNrun Workbench file system.
		Save as	Saves the MEU configuration in the ZNrun Workbench file system format.
		Validate	Validates the MEU configuration
Import tools		Import stimuli	Stimuli can be imported from XML files containing valid `DutMeasurementPlan` serializations. For details, see Chapter 4.3.3, "Import Stimuli", on page 52.
Execution tools		Go to execution	Switches to the execution phase (see Chapter 4.5, "Execution and Visualization Phase", on page 54 for details).
		Repeat	Activates the continuous loop of the measurement cycle.
		Start	Switches to the execution phase and starts the measurement cycle.
Rollout tools		Go to rollout	Switches to the rollout phase (see Chapter 4.6, "Rollout Phase", on page 56 for details)
Settings tools		Activate tuning	Activates the tuning in the execution phase (see Chapter 4.5.1.1, "Tuning", on page 55 for details).
		Settings	Launches the "Settings" dialog (Chapter 4.1.7, "Options", on page 23)
		DUT-related calibration	Launches the calibration client (see Chapter 4.4, "Calibration Phase", on page 54)
		Launch visualization client	Launches the visualization client (see Chapter 4.5.2, "Visualization Workspace", on page 55)

In the execution phase, the main toolbar also has four functional groups:

Table 4-2: Main toolbar actions in execution phase

Group		Name	Action
Settings tools		Activate tuning	Activates tuning (see Chapter 4.5.1.1, "Tuning", on page 55 for details). Once tuning is activated, it cannot be deactivated unless you leave the execution phase.
		Settings	Launches the "Settings" dialog (Chapter 4.1.7, "Options", on page 23)
		Launch visualization client	Launches the visualization client (see Chapter 4.5.2, "Visualization Workspace", on page 55)
Execution tools		Leave	Leaves the execution phase and returns to the configuration phase.
		Repeat	Activates or deactivates the continuous loop of the measurement cycle.
		Start	Starts the execution of the measurement cycle.
		Step	Performs one step in the measurement cycle.
		Abort	Aborts the running execution of the measurement cycle.
		Log cycle execution	Logs the execution of one complete cycle to a log file on the system.
		Show connections (PDF)	Shows the connection plan of the current MEU in your PDF file viewer.
Tuning tools		Save	Saves the changed configuration to the ZNrun Workbench data structure.
		Create snapshot	Saves a temporary copy of the current configuration. If a changed configuration is saved, the snapshot is deleted.
		Recall snapshot	Loads the configuration of the snapshot. If no snapshot exists, the original configuration is loaded.
Visualization tools		Add new visualization	Adds a new visualization workspace in the workspace area.

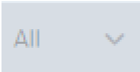
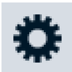
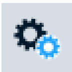
Group		Name	Action
		Remove	Drag and drop charts from the visualization workspace to the bin to remove charts.
		DUT selection	Choose a DUT index from the dropdown menu. If a new graph is created in the workspace, only the measurements related to the DUT index are displayed.

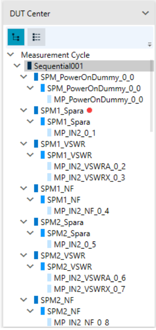
Table 4-3: Main toolbar actions in rollout phase

Group		Name	Action
Settings tools		Settings	Launches the "Settings" dialog (Chapter 4.1.7, "Options", on page 23)
Rollout tools		Leave rollout	Leaves the rollout phase and returns to the configuration phase.
		Generate projects	Generates MEUs from the master MEU and the test stations according to your rollout plan.
		Roll out	Rolls out generated MEUs to their dedicated test stations.
		Abort	Aborts queued packages to be rolled out.
		Log rollout status	Logs the status of current rollout session to a log file on the file system.
		Overwrite	Activates or deactivates whether or not existing generated MEUs shall be overwritten during "Generate projects".

4.1.2 DUT Center

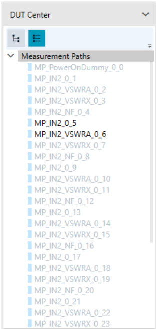
The "DUT Center" displays the measurement cycle with all its measurement paths. You can select between two different representations:

- "Structured Shape": Visualization of the measurement cycle in a tree-like structure. For every element (sequential context, parallel context, or step) a breakpoint for the execution phase of the whole measurement cycle can be set or deleted from the context menu. If a breakpoint is set, a red dot is displayed on the right of the specific element.



In the example above, a breakpoint is set for `StimulusPortgroupMeasurement` "SPM1_Spara".

- "Flattened Shape": Flat outline of all measurements currently available. All measurements used in the measurement cycle are grayed out. Every measurement can be released (i.e. excluded) from the measurement cycle with the right click context menu.



In the example above, measurement paths "MP_IN2_0_5" and "MP_IN2_VSWRA_0_6" are released.

Hovering over a measurement path displays additional information. In the configuration phase, the port group, stimulus and switch & state are shown. In the execution phase, a short notation for the measurement parameter, the destination port, and the source port are shown.

4.1.3 Workspace

The main window area is reserved for the configuration of the MEU or for the visualization of measurements. Each configuration group can be displayed in the workspace as a separate tab. In the top half of each tab, a list overview of all configurations is shown. In the bottom half, a more detailed configuration of each list element is displayed. See section Chapter 4.3.2, "Expert Mode", on page 30 for a detailed explanation of all configuration capabilities.

All tabs in the workspace are floatable and dockable.

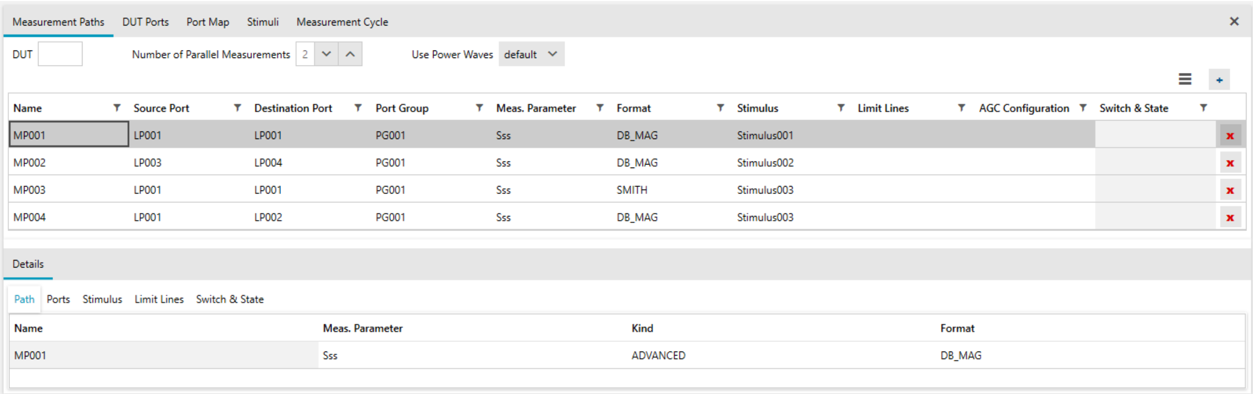
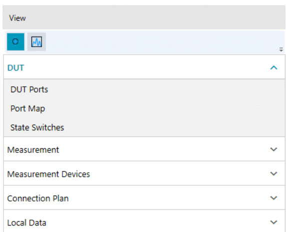


Figure 4-3: Populated workspace

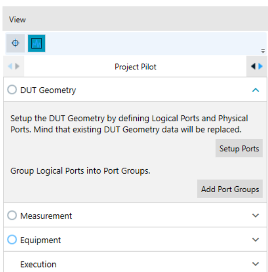
4.1.4 Configuration View

The "Configuration View" is the main tool for selecting configuration settings. It offers two different modes:

- In "Expert" mode, all configuration settings are listed. Selecting a configuration setting opens the corresponding tab in the workspace.

  See Chapter 4.3.2, "Expert Mode", on page 30 for details.
- The "Project Pilot" mode lets you quickly configure MEUs from scratch. A reduced quantity of configuration settings and the automation of most of the configurations simplifies the configuration phase.

  The "Project Pilot" can also be used to modify an existing ZNrun Workbench project. See Chapter 4.3.1, "Project Pilot", on page 26 for details.

4.1.5 Log Views

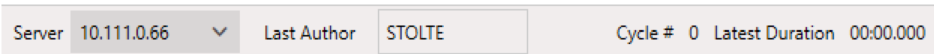
By default, the log views are docked at the bottom of the ZNrun Workbench window.

The "Message Log" displays upcoming events during the execution of the ZNrun Workbench.

The "Validation Log" displays MEU validation results.

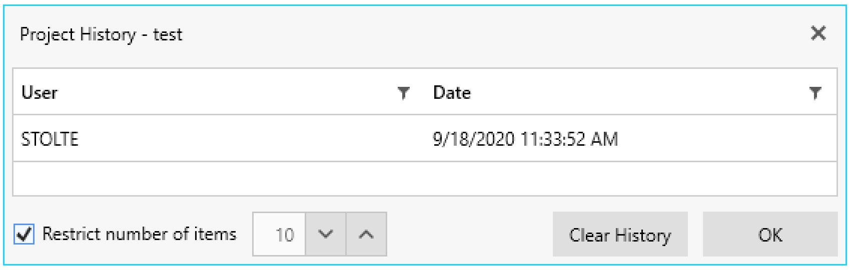
From its context menu, you can copy the selected message to the clipboard, or clear the related log.

4.1.6 Status Bar

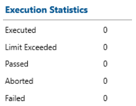


The status bar of the ZNrun Workbench window gives access to the following information/settings:

- Server connection
  Select an item from the list of detected ZNrun Servers
- Project (modification) history
  The last author is displayed in the status bar. Click the corresponding status bar section to view the full project history.

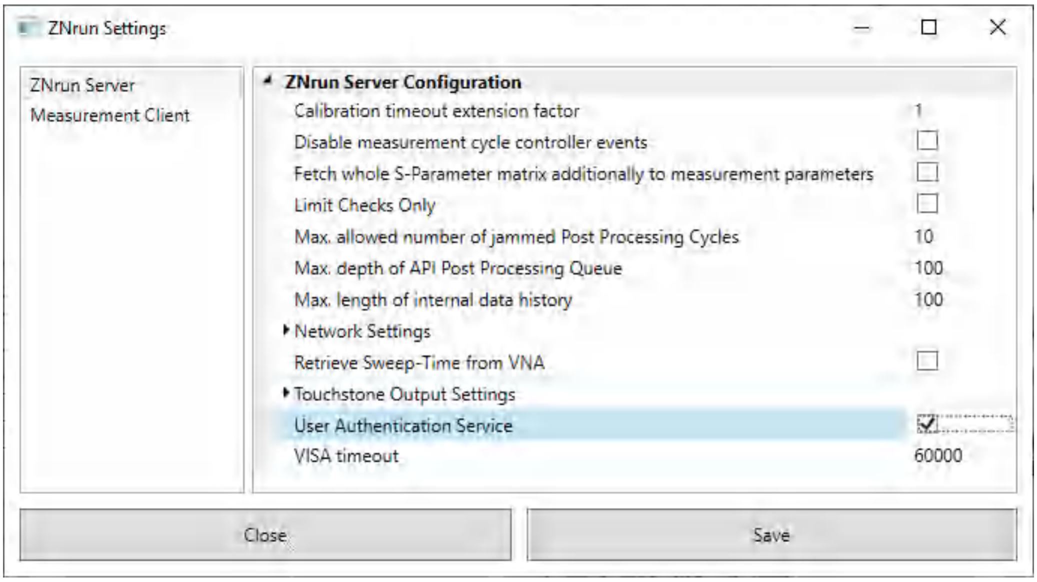
  The project (modification) history is tracked in the `ProjectHistory.xml` file, that is maintained by the ZNrun Workbench together with the `Project.xml`.
- Measurement execution status, including the number of measurement cycles and the duration of the last measurement cycle (execution phase only)
  Hovering over the measurement execution status calls up a popup that displays the detailed execution statistics:



Authenticated users (optional)

To limit the projects that can be run on a particular ZNrun Server to those last modified by a particular group of users:

1. enable user authentication in the "ZNrun Settings" client (Windows Start menu > "R&S ZNrun 2.30" > "ZNrun Settings" > ZNrun Server > "User Authentication Servce")

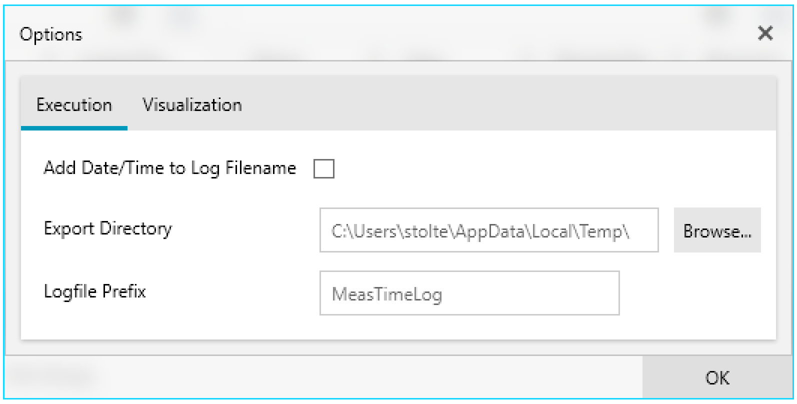


2. maintain a newline-separated list of authenticated users in `C:\ProgramData\Rohde-Schwarz\ZNrun\<version>\AuthenticatedUsers.txt` on the ZNrun Server.

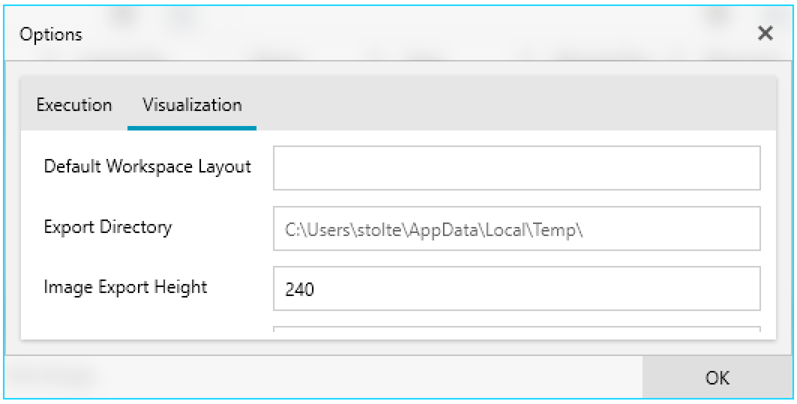
4.1.7 Options

The "Options" dialog is accessible via the main toolbar.

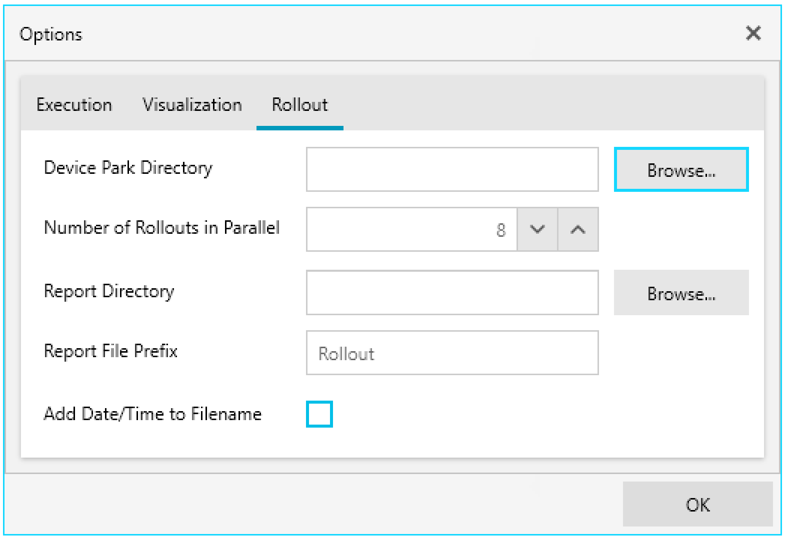
- On the "Execution" tab, you can choose to add date and time to the created measurement cycle log file names. Furthermore, you can specify the export directory and define the logfile prefix.



- On the "Visualization" tab, you can set the default workspace layout. Furthermore, you can specify the export directory, and the height of the images exported from the visualization workspace.



- On the "Rollout" tab, you can specifiy where your Device Park is located and how many rollouts shall be performed in parallel. See Chapter 4.6, "Rollout Phase", on page 56 for details. Furthermore, you can specify the report directory and define the report file prefix.



4.2 Getting Started

There are three ways to get started with the ZNrun Workbench:

- You can create a Measurement Execution Unit (MEU) configuration with the ZNrun Workbench data structure using the first button in the main toolbar
- You can open an already existing MEU configuration from a ZNrun Workbench file (`*.znwbf`).
- You can load the MEU configuration from a ZNrun project file of a previous R&S ZNrun version. The ZNrun Workbench automatically converts the ZNrun project to a ZNrun Workbench project.

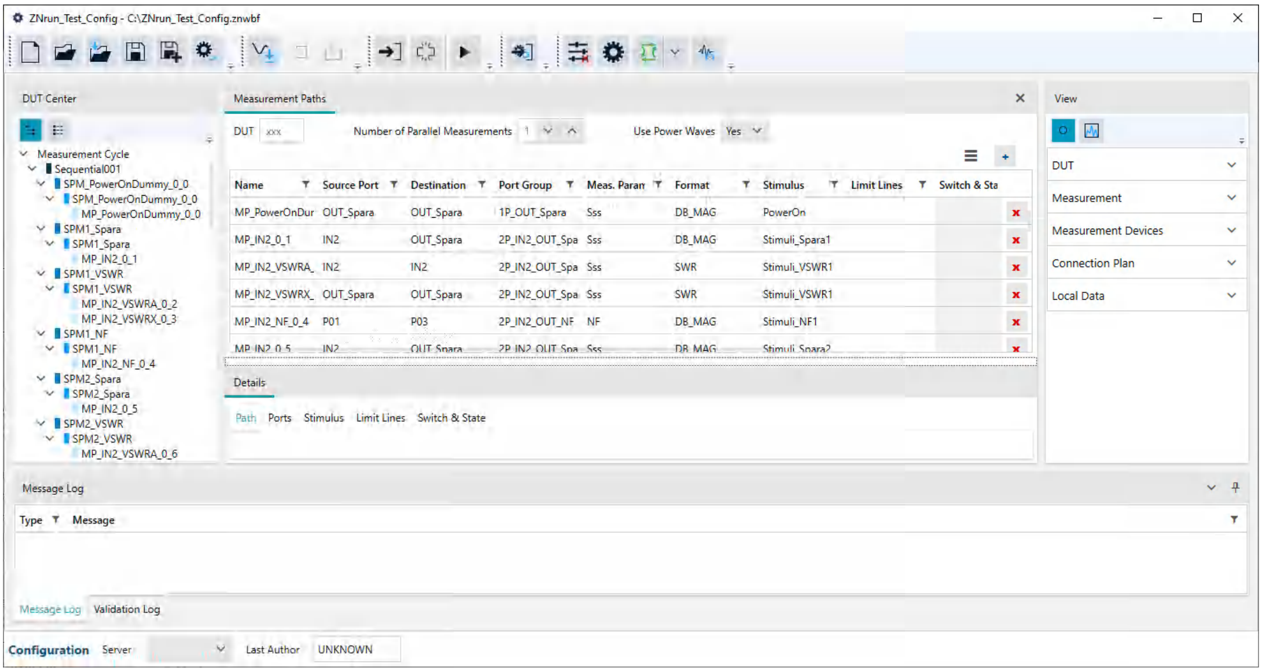


Figure 4-4: Successfully loaded ZNrun Workbench file.

- If loading the MEU configuration from file was unsuccessful, an error message is displayed in the Message Log.
- If a ZNrun Server IP-address is specified in the ZNrun Workbench file, and the server is available, the workbench uses this server for execution of the MEU. Otherwise, a R&S ZNrun server has to be selected from the drop-down menu of the available server connections.

After creating or loading a MEU configuration, the following actions in the main tool bar are enabled:

- Save all changes to the working ZNrun Workbench file system.
- Save your MEU configuration in the ZNrun Workbench file system format.
- Validate the MEU configuration.

4.3 Configuration Phase

In the configuration phase, you use Configuration View to define or modify the MEU. From this phase, calibration of devices or execution of measurements can be started. Additionally it is possible to switch to Chapter 4.6, "Rollout Phase", on page 56.

To change between "Project Pilot" and "Expert" mode, go to the "View" widget and select the appropriate icon.

left icon = Expert Mode
right icon = Project Pilot

4.3.1 Project Pilot

The "Project Pilot" allows you to configure MEUs from scratch quickly. The "Project Pilot" proceeds in four steps:

Figure 4-5: Workflow in the project pilot mode

4.3.1.1 DUT Geometry

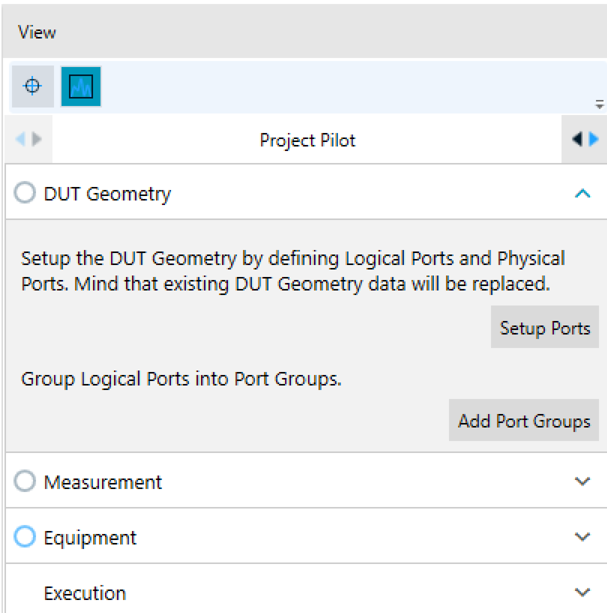


Figure 4-6: Project Pilot, step 1: DUT Geometry definition

The "DUT Geometry" definition is subdivided into three steps:

1. Set up the logical and physical ports.
2. Group logical ports into port groups.
3. Configure the DUT ports in detail.

   If at least one physical port, one logical port and one port group are defined, the change indicator next to DUT geometry label turns from gray to blue.

1. Set up the logical and physical ports
   Use the "Setup Ports" button to open the corresponding dialog.

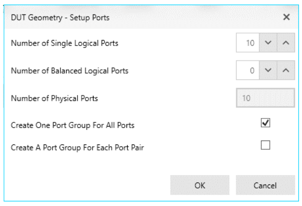


Figure 4-7: Setup Ports dialog

   Specify the number of single-ended and balanced logical ports. These values determine the number of physical ports, because each single-ended logical port contributes one physical port and each balanced logical port contributes two physical ports.
   At this step, you can also apply two simple port grouping mechanisms: group all ports in one group, and/or group each port pair. The next step offers a free configuration of port groups.

2. Group logical ports into port groups
   Use the "Add Port Groups" button to open the corresponding dialog.

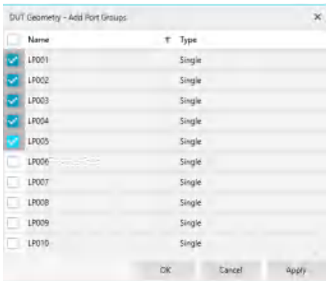


Figure 4-8: Add Port Groups dialog

   Select one or more logical ports from the list of available logical ports, then press "Apply" or "OK" to join them in a port group.

3. Configure the DUT ports in detail.
   In the last step of the "DUT Geometry" configuration of the "Project Pilot", you can adjust the DUT ports as in expert mode, see "DUT Ports" on page 31.

4.3.1.2 Measurement

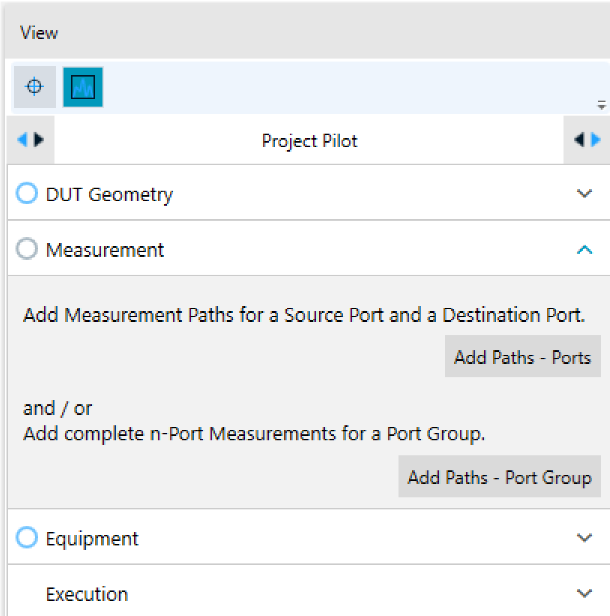


Figure 4-9: Project Pilot, step 2: Measurement definition

The definition of measurements proceeds in three steps:

1. Add measurement paths for the source port and a destination port.
2. Add complete n-port measurements for a port group.
3. Configure the measurements in detail.

   If at least one measurement path is defined, the change indicator next to measurement label turns from gray to blue.

1. Add measurement paths for the source port and a destination port.
   Use the "Add Paths – Ports" button to open the corresponding dialog. From here, you can create measurement paths with user-defined parameters such as "Source Port", "Destination Port", "Format", "Start Frequency", "Stop Frequency", and "Number of Points".

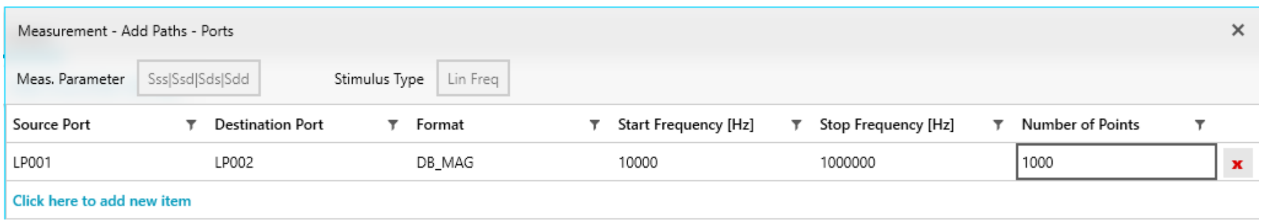


Figure 4-10: Add Paths – Ports dialog

If a stimulus with the same "Start Frequency", "Stop Frequency", and "Number of Points" exists, the ZNrun Workbench automatically assigns it to the measurement

path. Otherwise the ZNrun Workbench creates a linear frequency stimulus with these parameters and assigns it to the measurement path.
By default, the "Add Paths – Ports" dialog selects "Sss" as the measurement parameter.

2. Add complete n-port measurements for a port group.
Use the "Add Paths – Port Group" button to open the corresponding dialog. You can select a whole port group to create measurement paths for each port pair of the port group. Similar to step 1, the parameters are "Format", "Start Frequency", "Stop Frequency", and "Number of Points".

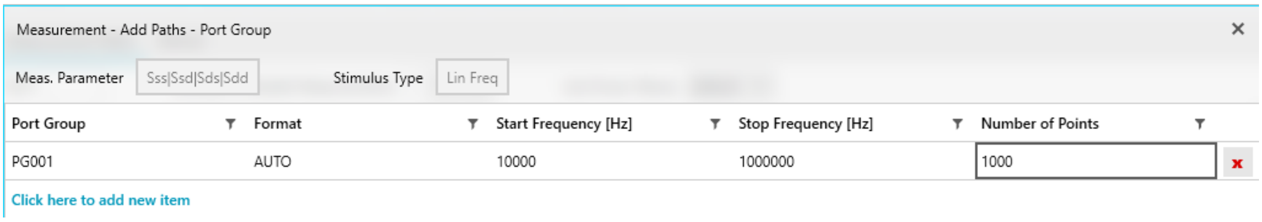


Figure 4-11: Add Paths – Ports Group dialog

The same logic as in step 1 applies to the reuse or creation of stimulus objects. And also the "Add Paths – Ports Group" dialog selects "Sss" as the default measurement parameter.

3. Configure the measurements in detail.
In the last step of the measurement configuration of the "Project Pilot", you can adjust the measurement parameters as in the expert mode, see Chapter 4.3.2.2, "Measurement Configuration", on page 33.

4.3.1.3 Equipment

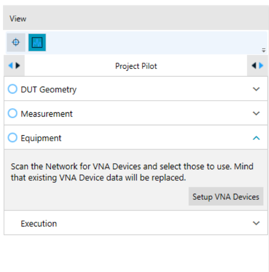


Figure 4-12: Project Pilot, step 3: Equipment definition

The equipment definition is done in a single step.

► Use the "Setup VNA Devices" button to open the corresponding dialog.

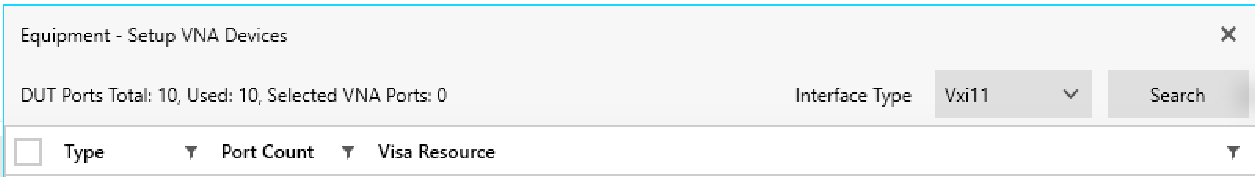


Figure 4-13: Setup VNA Devices dialog

Choose the interface type and search in the network for VNA devices. The list displays the available devices with their type, port count, and the visa resource. During the import of the device information, all existing data is overwritten. Hence, you have to confirm every replacement of an already existing VNA device.

4.3.1.4 Execution

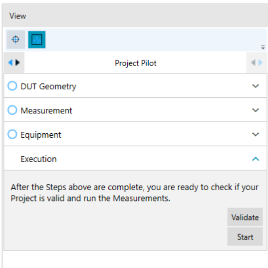


Figure 4-14: Project Pilot, step 4: Execution

Finally, you can send the MEU to the selected ZNrun Server for validation or execution of the MEU.

4.3.2 Expert Mode

In "Expert" mode, you can use the full capabilities of the ZNrun Workbench to configure every aspect of the MEU. To change a specific configuration setting, you can choose an item from the navigation view ("View") which is then displayed in the workspace.

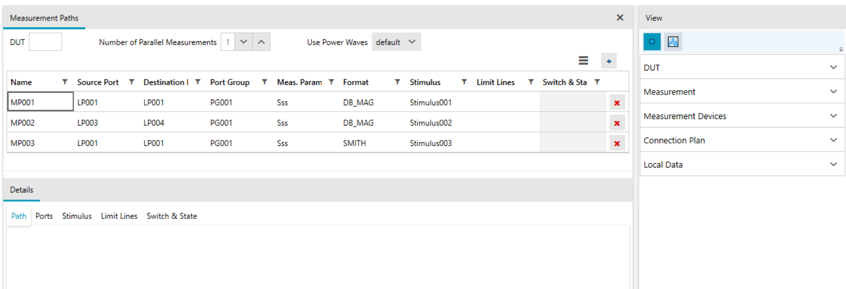
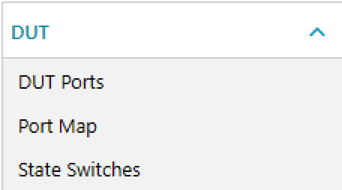


Figure 4-15: Expert mode: workspace and navigation view

4.3.2.1 DUT Configuration

The purpose of the "DUT" configuration group is to give access to all DUT-related configuration settings.



DUT Ports

The "DUT Ports" workspace gives access to the DUT port definition, which consists of in three steps:

1. Define the physical ports.
2. Define the logical ports.
3. Define the port groups.

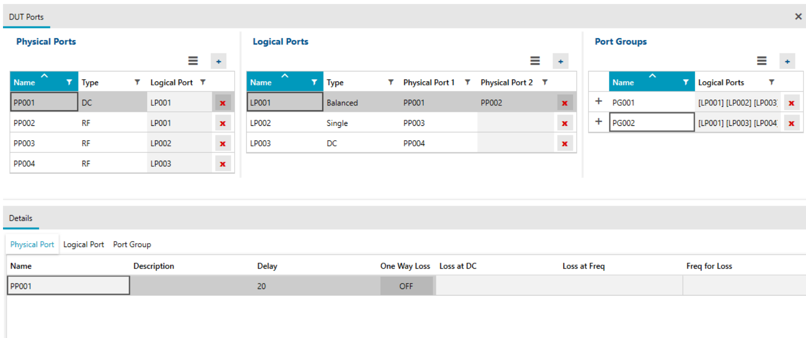


Figure 4-16: DUT ports workspace

1. "Physical Ports"
   The physical ports of the DUT can be added ("+") or removed ("x") in the "Physical Ports " list of the workspace. There you can declare the type of the physical ports to be either RF or DC.
   In the "Details" view, you can add a textual description of the physical port and specify its delay. Furthermore you can toggle "One Way Loss" ON and define the related parameters "Loss at DC", "Loss at Frequency", and "Frequency for Loss".

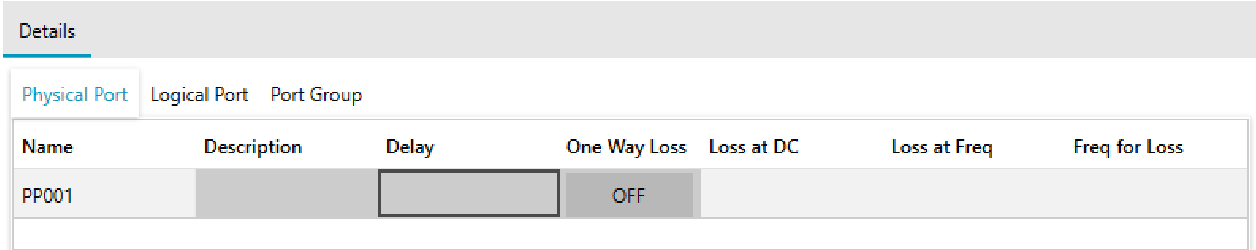


Figure 4-17: Physical port details

2. "Logical Ports"
   A logical port represents the basic element for further definitions of DUT properties and can be added or removed in the "Logical Ports" list of the workspace. There you can declare the type of the logical port to be either single-ended, balanced, or DC. Depending on its type, the logical port comprises one or two physical ports.
   In the "Details" view, you can provide correction properties for the logical port: its reference impedance (common and differential for balanced ports), and de-/embedding information. See the user manual of your VNA for more information.

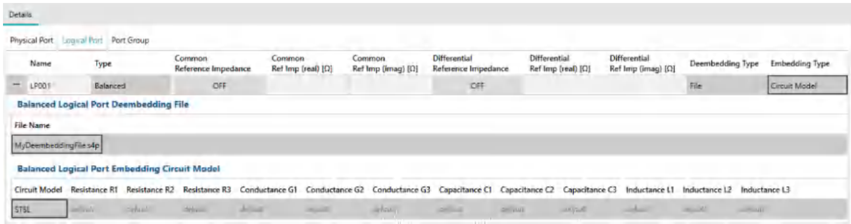


Figure 4-18: Logical port details

3. "Port Groups"
   In general, a DUT consists of one or more groups of logical ports, which together provide a particular functionality. In the "Port Groups" list of the workspace, you can create and remove such port groups.
   In the "Details" view, you can provide ground loop de-/embedding information for the selected port group.

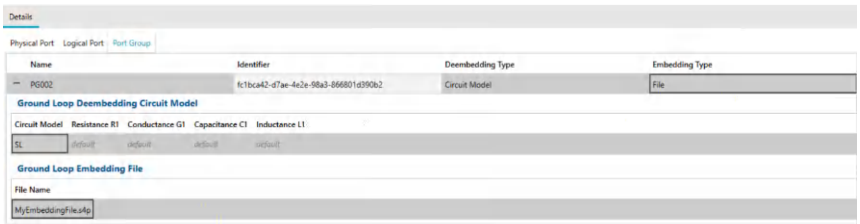


Figure 4-19: Details of one port group

Port Map

The "Port Map" workspace consists of a table that lists the port mappings defined during DUT Ports definition. The table columns are read-only, however you can delete a port mapping using the "x" icon to the right of the related table row.

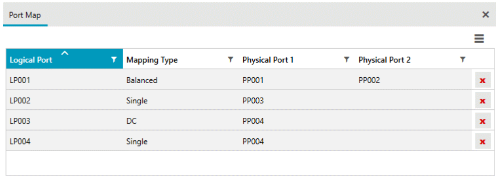


Figure 4-20: Port Map workspace

State Switches

R&S ZNrun focuses on measuring complex DUTs. Besides multiple ports, such a DUT typically provides one or more "control interfaces" that are used to set or request the DUT's state. Depending on the capabilities and applications of the DUT, you have to choose a proper communication path and to define the different states.

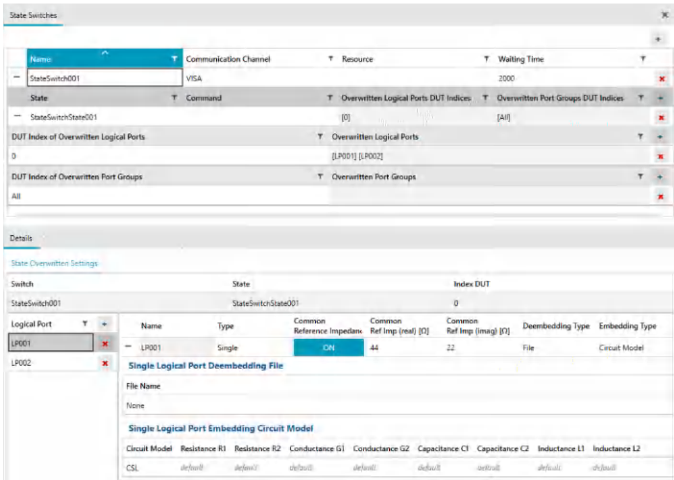
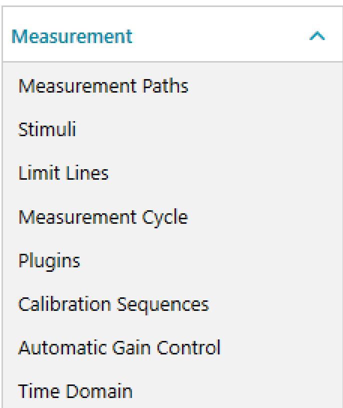


Figure 4-21: State Switch workspace

4.3.2.2 Measurement Configuration

The "Measurement" configuration group allows you to set up the measurement.



Measurement Paths

In the "Measurement Paths" workspace, you can define and configure the collection of all measurement paths. In the top section of the workspace, you can set the meta-parameters "DUT", "Number of Parallel Measurements", and "Use Power Waves". The number of parallel measurements refers to the DUT multiplicity, i.e. the number of DUTs to be measured.

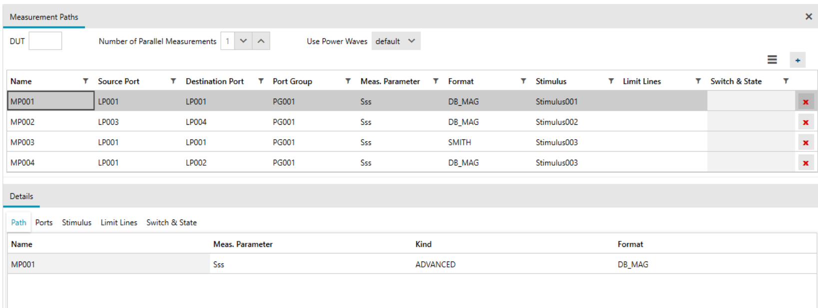


Figure 4-22: Measurement Paths workspace

The menu that can be opened from the hamburger icon above the configuration table, allows you to toggle the visibility of the configuration possibilities.

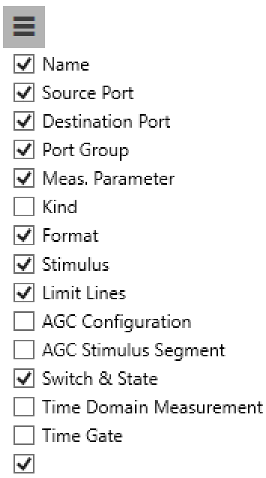


Table 4-4: Configuration possibilities of a measurement path

Name	Options
"Name"	Set a custom name for the measurement path.
"Source Port"	Select the source port of the measurement from the list of available ports specified in the DUT ports configuration. The source port has to be in the specified port group.
"Destination Port"	Select the destination port of the measurement from the list of available ports specified in the DUT ports configuration. The destination port has to be in the specified port group.
"Port Group"	Assign a port group to the measurement path. The port group is specified in the DUT ports configuration. The source port and the destination port have to be in the specified port group.
"Measurement Parameter"	Select the mixed mode S-parameter to be measured.
"Kind"	Select the measurement result to be calculated. ● "ADVANCED" ● "INSERTION_LOSS" ● "RETURN_LOSS" ● "VSWR" ● "ATTENUATION" ● "ISOLATION" ● "BALANCED_AMPLITUDE" ● "BALANCED_PHASE"
"Format"	Select how the result is formatted (a.k.a. "Trace Format") ● "DB_MAG" ● "LIN_MAG" ● "IMAG" ● "REAL" ● "PHASE" ● "UNWRAP_PHASE" ● "SMITH"
"Stimulus"	Select a stimulus from the list of available stimuli defined in the Stimuli configuration.
"Limit Lines"	Select a limit line from the list of available limit lines specified in the Limit Lines configuration.
"AGC Configuration"	Select an AGC configuration table from the list of available AGC configuration tables specified in the Automatic Gain Control configuration.
"AGC Stimulus Segment"	Select an AGC stimulus segment from the list of available AGC stimulus segments specified in the Automatic Gain Control configuration.
"Switch & State"	In the "Details" view, add the required State Switches by clicking the "+" icon and selecting the appropriate "Switch". Then specify the appropriate "State" and "Command".
"Time Domain"	Select one of the time domain measurements configured in the Time Domain workspace.
"Time Gate"	Select one of the time gates configured in the Time Domain workspace

Stimuli

In the "Stimuli" workspace, you can define and configure the stimuli you later want to use for different measurement and calibration purposes. New stimuli can be created in the list overview or can be imported with the "Import Stimuli" option, see Chapter 4.3.3, "Import Stimuli", on page 52 for details.

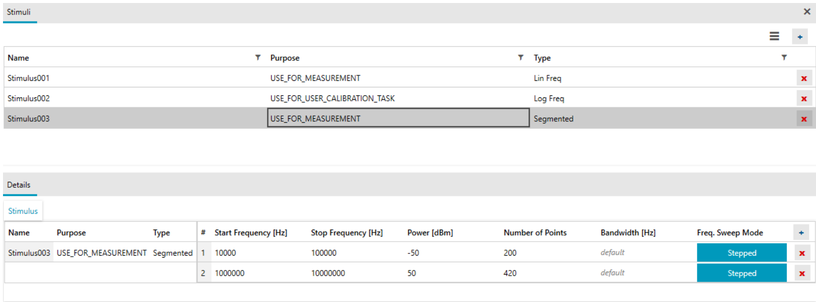


Figure 4-23: Stimuli workspace

The menu that can be opened from the hamburger icon above the configuration table, allows you to toggle the visibility of the configuration possibilities.

A stimulus is defined by a VNA sweep type ("Type") and the corresponding sweep parameters.

Table 4-5: Supported stimulus parameters

Sweep type	Sweep parameters
"Lin Freq" (linear frequency)	• "Start Frequency" • "Stop Frequency" • "Power " (optional) • "Number of Points" • IF "Bandwidth" (optional) • "Freq. Sweep Mode"
"Log Freq" (logarithmic frequency)	• "Start Frequency" • "Stop Frequency" • "Power " (optional) • "Number of Points" • IF "Bandwidth" (optional)
"Segmented" (segmented frequency)	Each segment represents the frequency range of a linear frequency sweep. You can define it with the same parameters (see first table row).
"Power" (dB-linear power)	• "Start Power" • "Stop Power" • "CW Frequency" • "Number of Points" • IF "Bandwidth" (optional)

Sweep type	Sweep parameters
"CW Mode" (continuous wave)	• "CW Frequency" • "Power " (optional) • "Number of Points" • IF "Bandwidth" (optional)
"Time"	• CW Frequency • "Power " (optional) • "Number of Points" • IF "Bandwidth" (optional) • "Stop Time"

Limit Lines

In the "Limit Lines" workspace, you can define the limits you want to apply to subsequent measurements.

- A single "Linear" limit line imposes straight-lined upper and/or lower limits on scalar results for a particular stimulus range.
- A "Formula"-defined limit line imposes an upper or lower limit on scalar results for a particular stimulus range.
- A "Circle" imposes a limit on complex (two-dimensional) results.

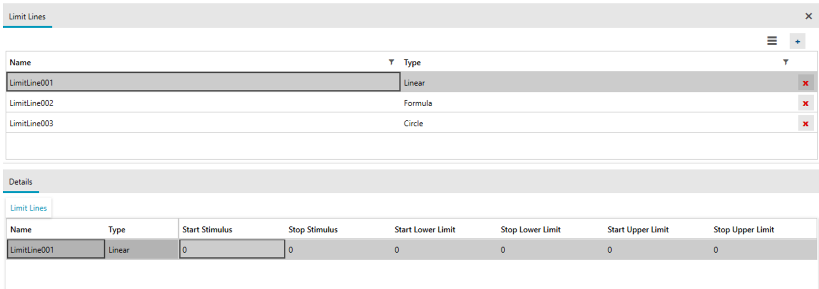


Figure 4-24: Limit Lines workspace

The "Details" section allows you to configure the selected limit line in detail.

Table 4-6: Limit line parameters

Line type	Parameters
"Linear" (straight line)	• "Start Stimulus" • "Stop Stimulus" • "Start Lower Limit" • "Stop Lower Limit" • "Start Upper Limit" • "Stop Upper Limit"
"Formula" (formula-defined)	• "Start Stimulus" • "Stop Stimulus" • "Formula". See the user manual of your VNA for supported formulas and their syntax. • Limit "Type": upper or lower
Circle (circular)	• "Radius" • "Center X" • "Center Y"

Measurement Cycle

A measurement cycle represents a physical measurement on one or more DUTs. You can specify the order in a tree-like structure as shown in Figure 4-25. If no measurement cycle is defined, the R&S ZNrun server automatically creates a cycle.

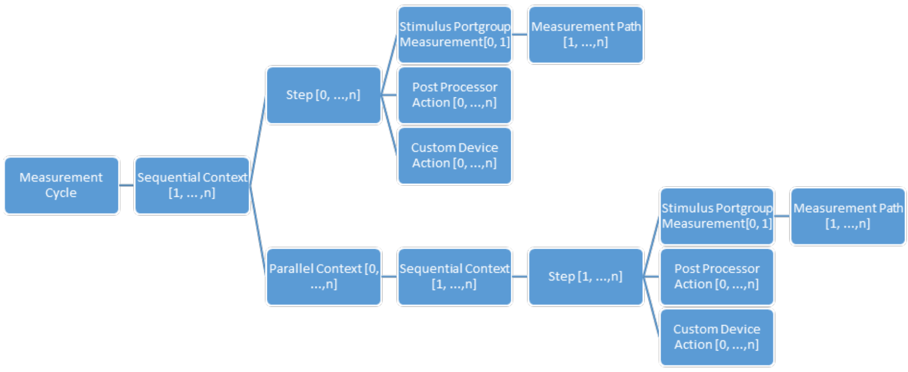


Figure 4-25: Measurement cycle tree structure

The definition of the measurement cycle is done in three steps:

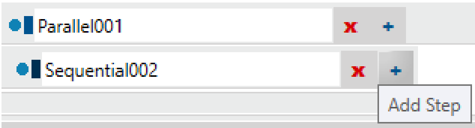
1. Define the structure of the measurement cycle.
2. Define the constituent Stimulus Portgroup Mesurements (SPMs).
3. Define the constituent custom device actions and post processor actions.

1. Define the structure of the measurement cycle.
   As shown in the Figure 4-25, you can add multiple top-level sequential contexts to the measurement cycle.

To every top-level sequential context, you can add multiple steps and parallel contexts.

To each parallel context, you can add further sequential contexts. During the execution phase, the ZNrun Server runs these sequential contexts in parallel.

To a sequential context inside a parallel context, you can add multiple steps.



For an example of a complete measurement cycle tree structure, see the following screenshot.

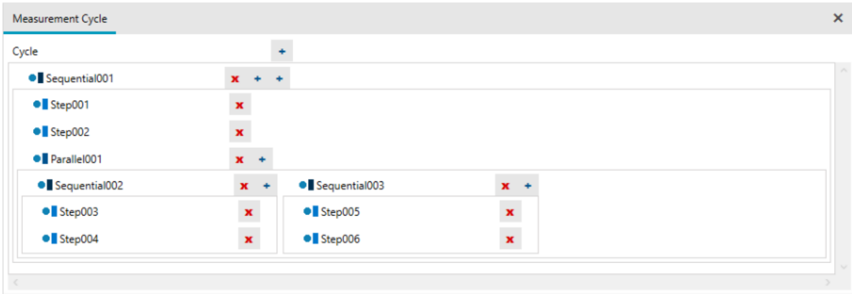
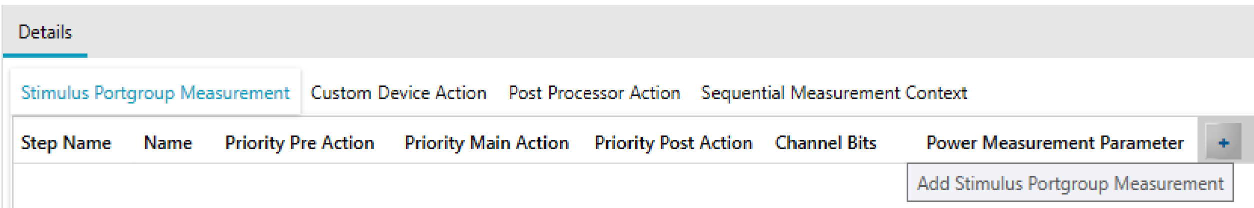


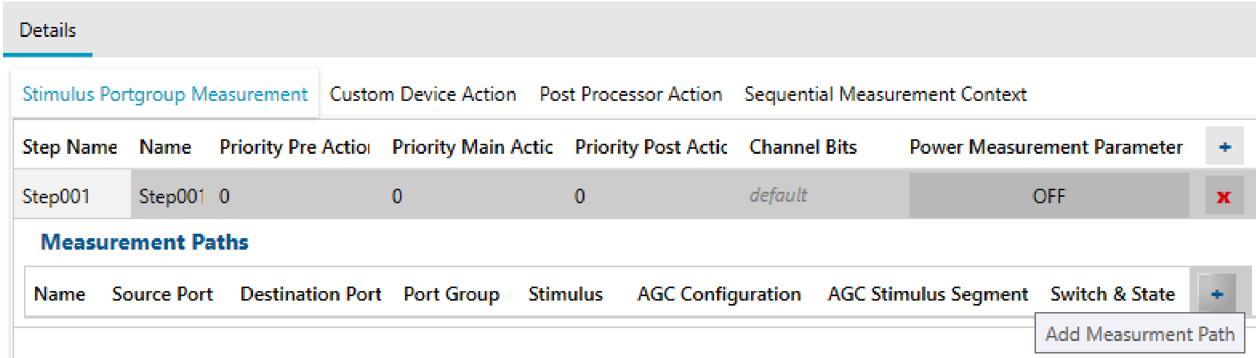
Figure 4-26: Measurement Cycle workspace.

You can assign a custom name to each sequential context, parallel context, or step. For a sequential context, you can also specify a purpose in the "Sequential Measurement Context tab" tab of the "Details" area.
To disable or enable a sequential context, parallel context or step, click the corresponding tree node icon (blue circle).
Sequential contexts, parallel contexts, and steps can function as breakpoints in the execution of the measurement, i.e. to step or pause commands. Click to the left of the corresponding tree node icon to set or remove a breakpoint. A red circle indicates an active breakpoint.
A measurement step is a container for stimulus port groups measurements, custom device actions and postprocessors.

2. Add and configure a "Stimulus Portgroup Measurement" (SPM)
To add an SPM to a measurement step, select the step in the "Measurement Cycle" workspace and click the "+" icon in the header of the SPM table ("Details" area > "Stimulus Portgroup Measurement" tab).



To add a measurement path to the SPM, select the SPM in the SPM table and click the "+" icon in the header of the "Measurement Paths" table.



You can also drag a released (unused) measurement path from the flattened view of the "DUT Center" to the "Measurement Cycle" workspace. Drop it on an existing step or on the free space below the last step of a sequential context. The latter automatically adds a step containing this measurement path.
A yellow right-pointing triangle indicates possible drop targets.

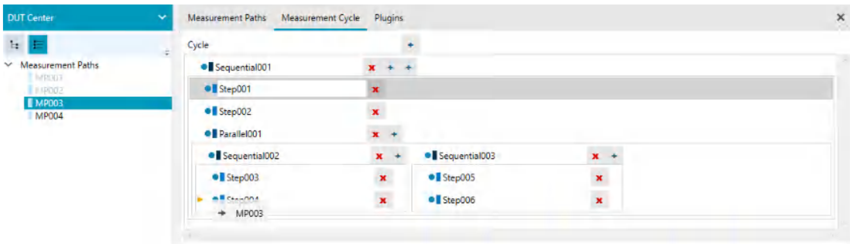
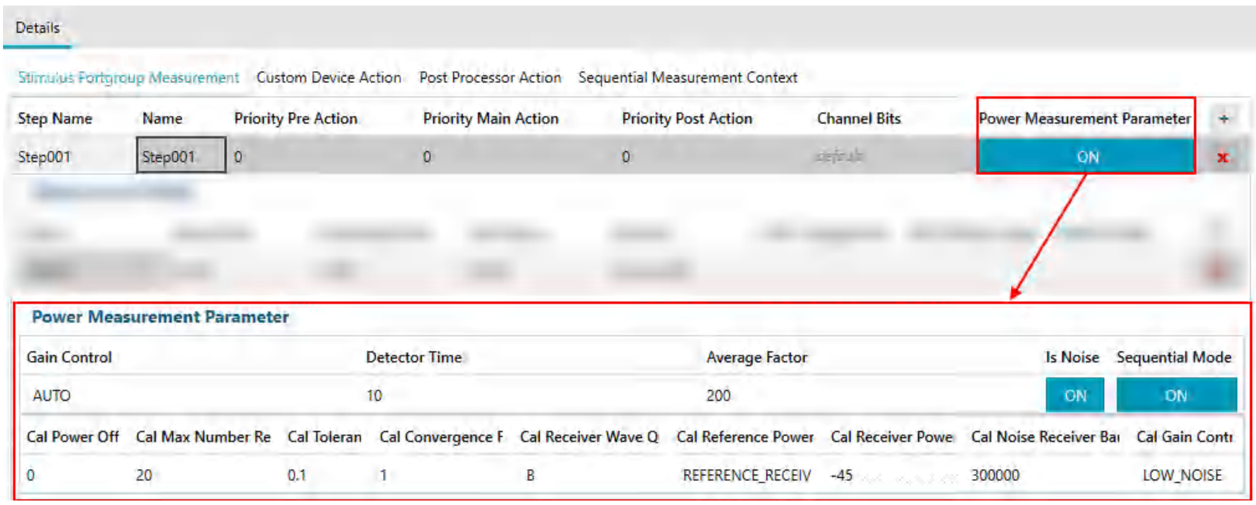


Figure 4-27: Drag & drop of a released measurement path

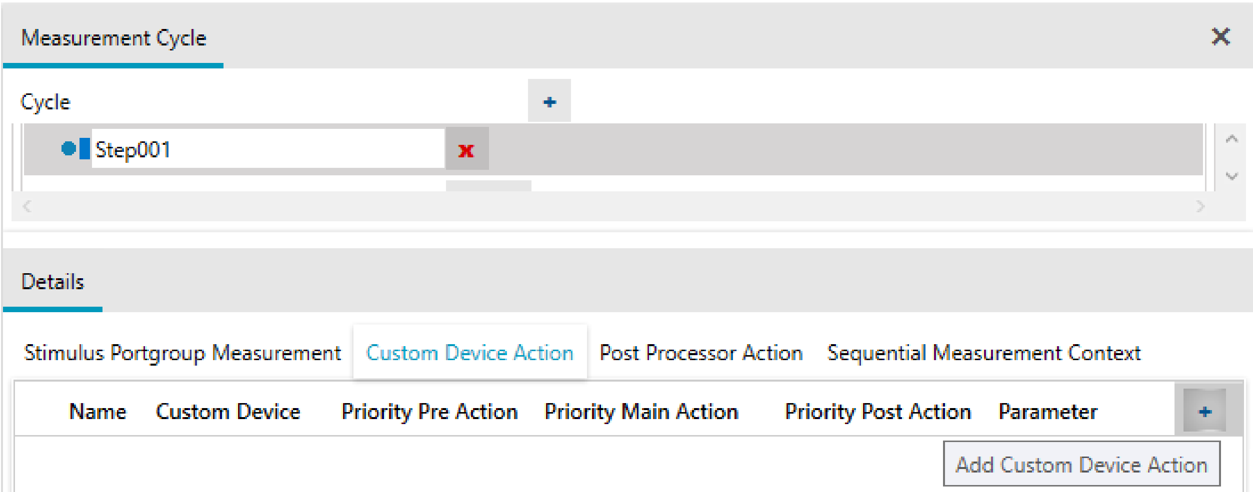
In the SPM table, you can configure the SPM properties "Name", "Priority Pre Action", "Priority Main Action", "Priority Post Action", "Channel Bits", and toggle the "Power Measurement Parameter" settings. If you switch the latter ON, the "Stimulus Portgroup Measurement" tab displays an additional "Power Measurement Parameter" table that allows for an in-depth configuration of receive power settings.



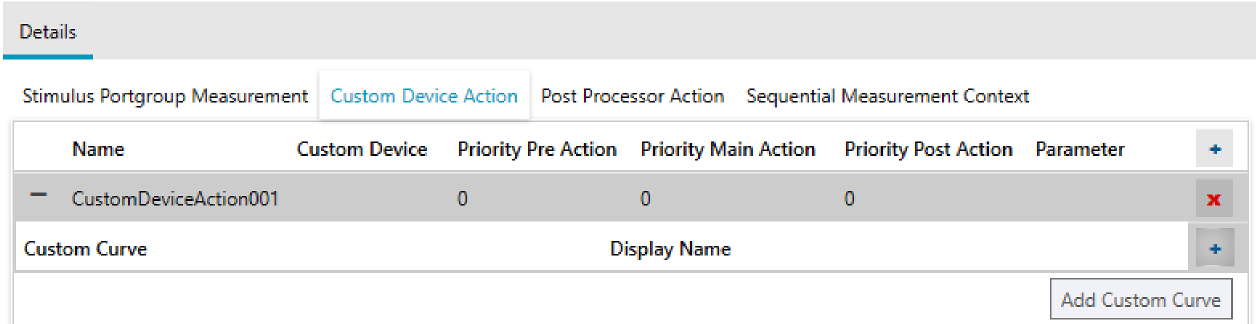
Note that a measurement step executes in a single VNA channel. Hence each measurement path in every SMP of a measurement step must have identical channel settings ("Port Group", "Stimulus", "AGC Configuration", "AGC Stimulus Segment", "Switch & State").

Figure 4-28: Stimulus Portgroup measurement detail configuration

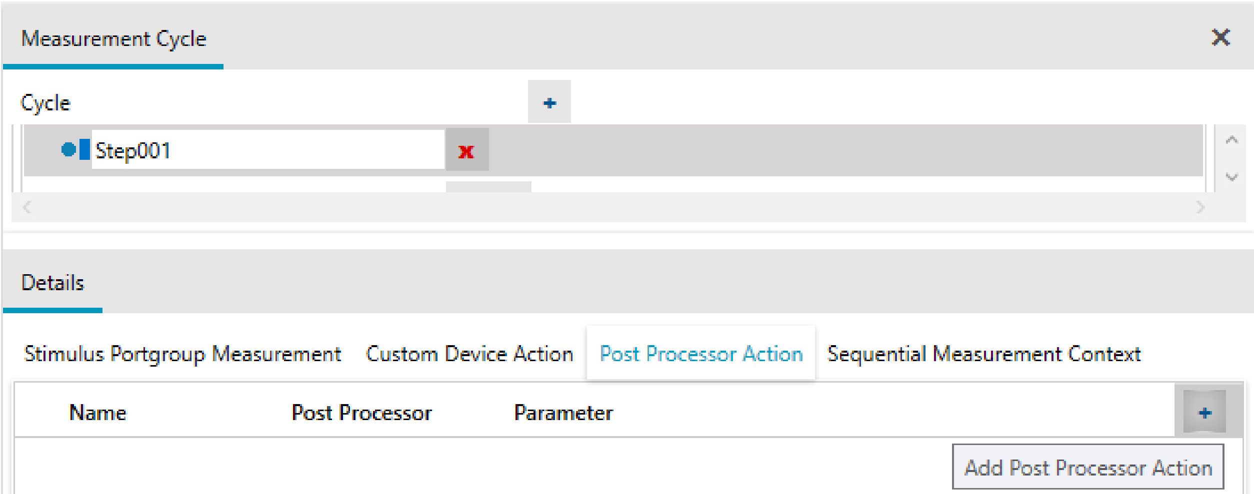
3. Define the custom device actions and post processor actions.
To add a custom device action to a measurement step, select the step in the "Measurement Cycle" workspace, activate the "Custom Device Action" tab in the "Details" area, and click the "+" icon in the table header.



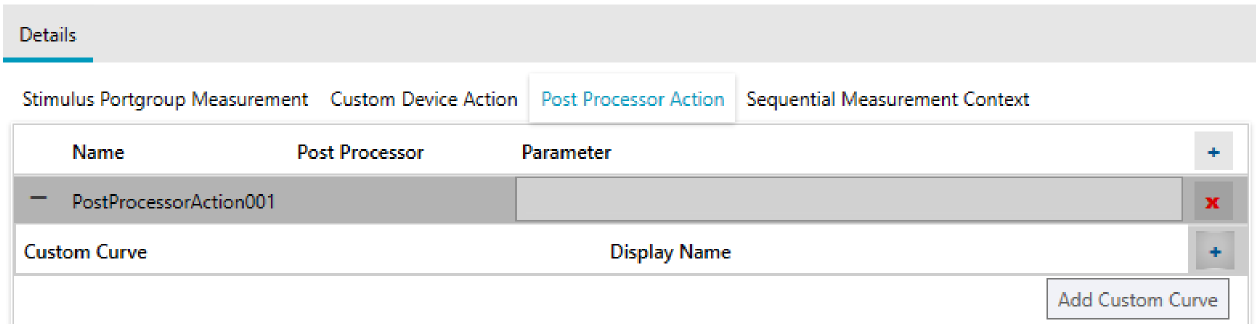
For each custom device action you can specify a custom "Name" and the parameters "Custom Device", "Priority Pre Action", "Priority Main Action", "Priority Post Action", and "Parameter".
To add a "Custom Curve" to the custom device action, click the "+" icon in the "Custom Curve" table header.



Similarly, to add a custom post processor action to a measurement step, select the step in the "Measurement Cycle" workspace, activate the "Post Processor Action" tab in the "Details" area, and click the "+" icon in the table header.



Here a custom "Name", the "Post Processor" and a "Parameter" can be specified. To add a "Custom Curve" to the post processor action, click the "+" icon in the "Custom Curve" table header.

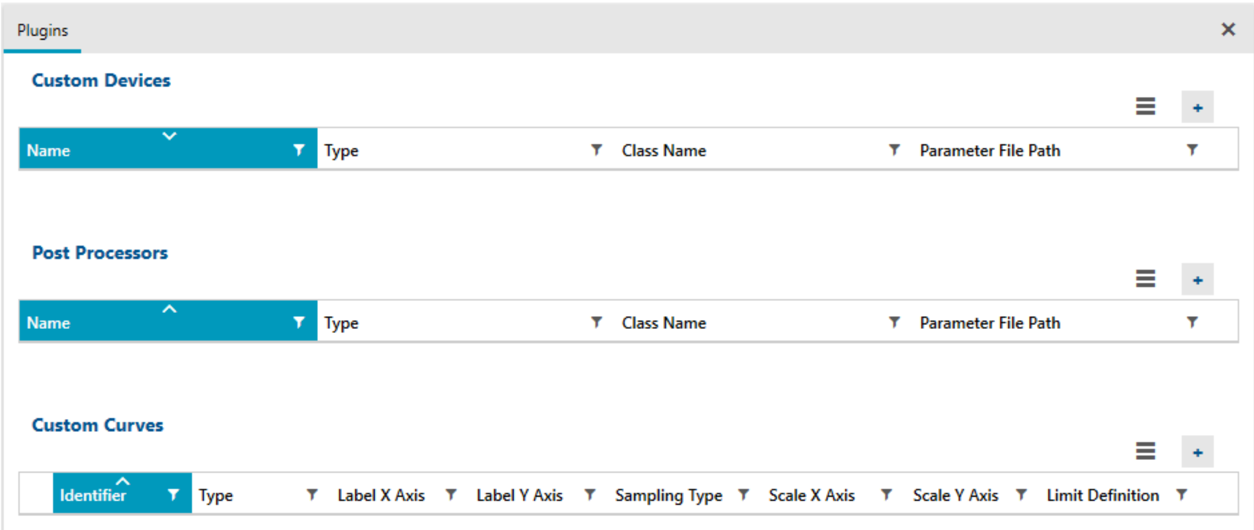


You can define custom devices, post processors and custom curves in the Plugins workspace.

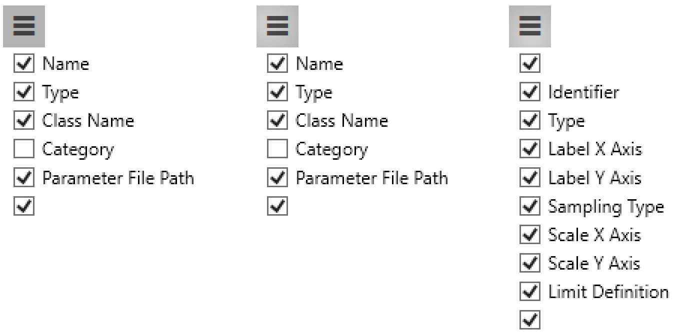
Plugins

In the "Plugins" workspace you can configure custom devices, post processors and custom curves.

Use the "+" icons to add a plugin of the respective plug-in type.



The menus that can be opened from the hamburger icons above the configuration tables, allow you to toggle the visibility of the plug-in type-specific columns.



left = custom devices
middle = post processors
right = custom curves

Table 4-7: Settings for plugins

Plug-in type	Setting	Description
"Custom Devices"	"Name"	A descriptive name of the custom device.
	Type	The implementation type: ● ".NET Assembly" ● "Python"
	"Class Name"	The fully qualified name of the custom device class, including its namespace.
	"Category"	Plug-in category (read-only): the fully qualified name of the `ICustomDevice` interface

Plug-in type	Setting	Description
	"Parameter File Path"	The path to the corresponding parameter file (read-only). The path is a local resource. It can be specified in the Extension Registrations workspace.
"Post Processors"	Name	A descriptive name of the post processor.
	Type	The implementation type: ● ".NET Assembly" ● "Python"
	"Class Name"	The full qualified name of the post processor class, including its namespace.
	"Category"	Plug-in category (read-only): the fully qualified name of the `IPostProcessor` interface
	"Parameter File Path"	The path to the corresponding parameter file (read-only). The path is a local resource. It can be specified in the Extension Registrations workspace.
"Custom Curves"	"Identifier"	The string identifier of the custom curve.
	"Type"	The graph type: ● "Cartesian" ● "Polar" ● "Smith" ● "Smith Inverted"
	"Label X Axis" / "Label Y Axis"	The label of the x-axis/y-axis.
	"Sampling Type"	● "None" (initial state, must be changed) ● "Range": – "Start" – "Stop" – "Number of Points" ● Points (list of points)

Plug-in type	Setting	Description
	"Scale X Axis" / "Scale Y Axis"	The scale of the x-axis/y-axis. Only editable for "Cartesian" curves. ● Linear ● Logarithmic
	"Limit Definition"	Switches limit definition for the respective custom curve ON or OFF. If set to ON, a "Limit Definition" table appears beneath the custom curve. You can assign a "Name" and "Rank" to this limit. For cartesian curves ("Cartesian"), the limit consists of a set of straight limit lines, each of them defined via: ● Limit "Type" ("Upper Limit" or "Lower Limit") ● "Start Value X" ● "Stop Value X" ● "Start Value Y" ● "Stop Value Y" For complex curves ("Polar", "Smith", "Smith Inverted"), the limit consists of a single circular value range, defined via: ● Radius ● Center X ● Center Y

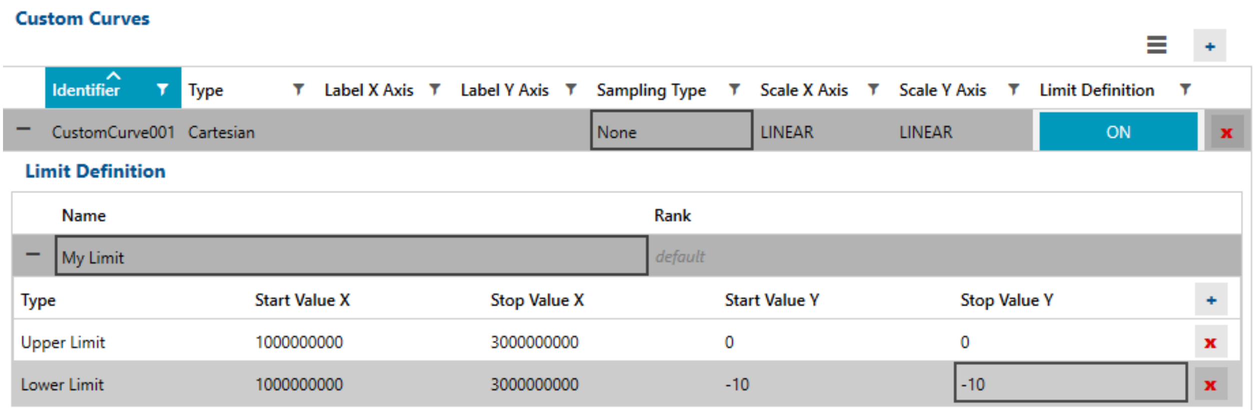


Figure 4-29: Limit definition: cartesian curve

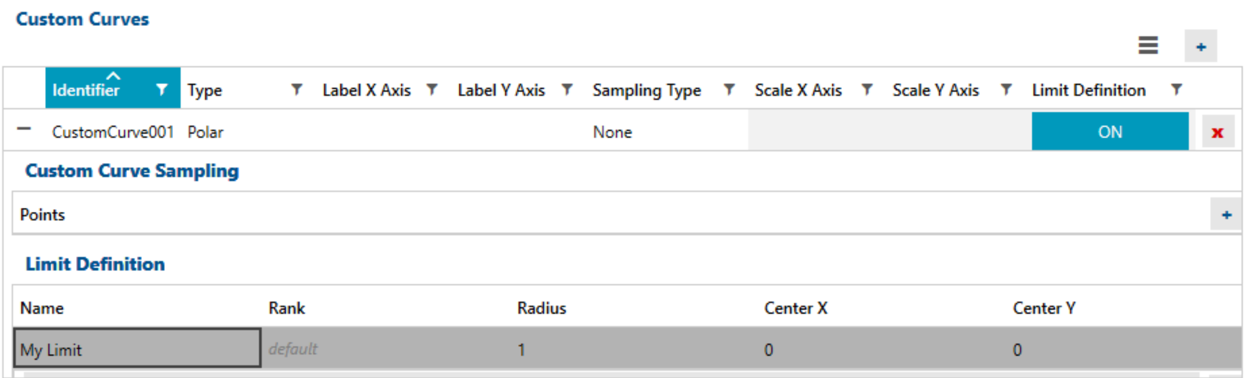


Figure 4-30: Limit definition: complex curve

Calibration Sequence

In the "Calibration Sequence" workspace, you can specify different calibration sequences for custom device actions. For each calibration step, a custom device with a parameter has to be chosen.

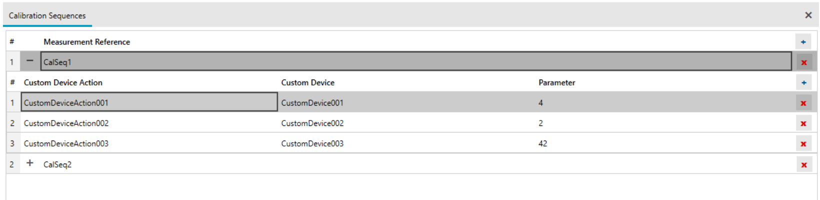


Figure 4-31: Calibration Sequence workspace

Automatic Gain Control

"Automatic Gain Control" (AGC) enables a receiver to sense and adapt its signal input to optimize dynamic range and avoid overload conditions from strong signals or dynamically changing signals across successive scans.

In the "Automatic Gain Control" workspace, you can define and configure AGC tables for the VNA types supporting AGC. Furthermore you can group this AGCs tables to AGC segment maps.

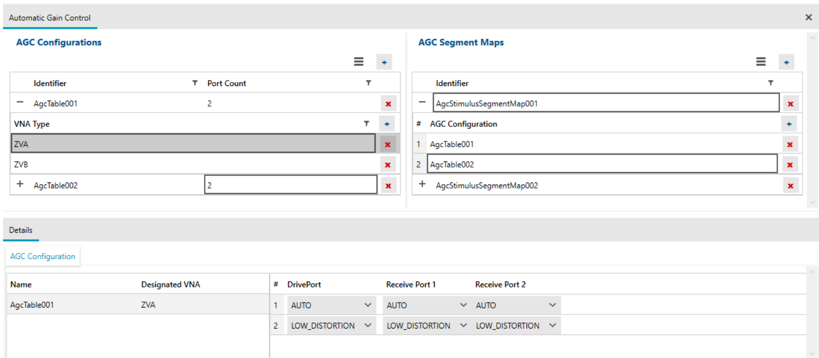


Figure 4-32: Automatic Gain Control workspace

Time Domain

Vector network analyzers are able to measure the complex S-parameters of a device under test (DUT) for different frequencies. By applying an inverse Fourier transform, these frequency domain results can be transformed to the time domain, and represented as the impulse response or step response of the DUT. In the time domain, some DUT characteristics can be analyzed easily, for instance faults in cables can be directly localized.

Moreover, special time domain filters, so-called gates, can be used to suppress unwanted signal components such as multireflections. By transforming the gated time domain representation back to the frequency domain, the unwanted signal components are also removed from the S-parameter representation.

In the "Time Domain" workspace, you can configure the two parts of the time domain measurement.

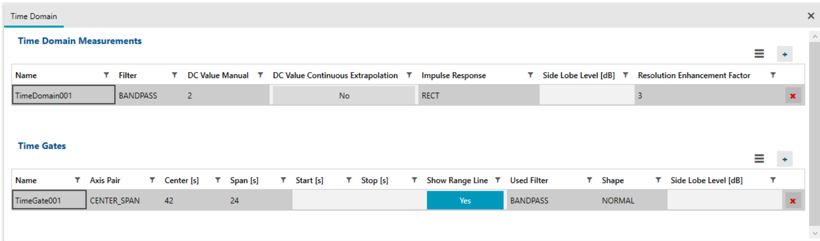


Figure 4-33: Time Domain workspace

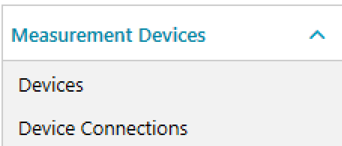
Table 4-8: Time domain measurement settings

Category	Setting	Description
Time domain measurement	"Name"	The name of the time domain measurement.
	"Filter"	• "BANDPASS" impulse response • "LOWPASS" impulse response • "LOWPASS_STEP" response
	"DC Value Manual"	Sets the DC value manually, if "DC Value Continuous Extrapolation" is disabled.
	"DC Value Continuous Extrapolation"	Enables or disables the continuous extrapolation of the DC value. If enabled ("YES"), "DC Value Manual" is disabled.
	"Impulse Response"	Shape of the filter applied in the frequency domain: • "RECT" (rectangular) • "HANN" • "HAMM" (Hamming) • "BOHM" (Bohman) • "DCH" (Dolph-Chebyshev)
	"Side Lobe Level"	If the impulse response is set to "DCH", the side lobe level can be edited.
	"Resolution Enhancement Factor"	A factor of 1 means that the original sweep range and the measured sweep points are used for the time domain transformation. With higher resolution enhancement factors, the measurement data are extrapolated using a linear prediction method. As a result, the time domain resolution can be improved.
"Time Gate"	"Name"	The name of the time gate.
	"Axis Pair"	• CENTER_SPAN • START_STOP

Category	Setting	Description
	"Center"/"Span"	The center/span of the time gate. Only editable if "Axis Pair" is set to "CENTER_SPAN".
	"Start"/"Stop"	Sets the start/stop value of the time gate. Only editable if "Axis Pair" is set to "START_STOP".
	"Show Range Line"	Displays or hides the range line.
	"Used Filter"	• "BANDPASS": only the time domain information inside the time gate is considered • "NOTCH": only the time domain information inside the time gate is considered
	"Shape"	Shape of the filter applied in the time domain: • "RECT" (rectangular) • "HANN" • "HAMM" (Hamming) • "BOHM" (Bohman) • "DCH" (Dolph-Chebyshev)
	"Side Lobe Level"	If "Shape" is set to "DCH", the side lobe level can be edited.

4.3.2.3 Measurement Devices Configuration

The purpose of the measurement devices configuration group is the definition of all measurement-related configuration settings.



Devices

The "Devices" workspace allows you to add and configure VNAs, switch matrices, calibration units, calibration kits, and power meters.

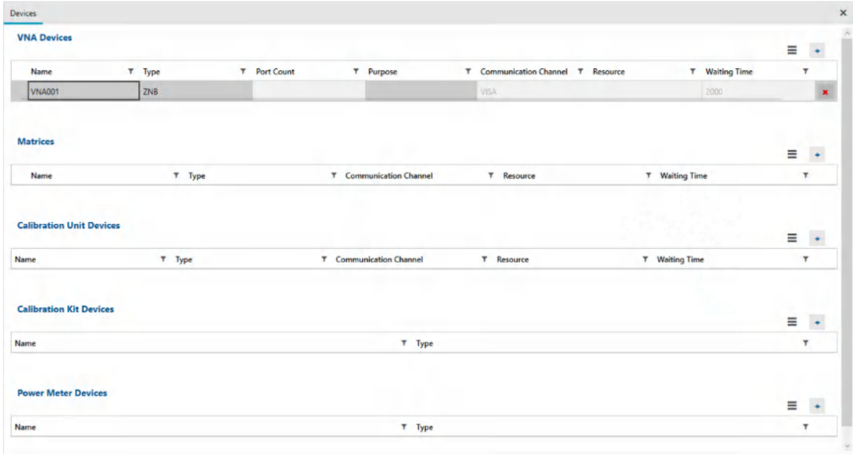


Figure 4-34: Devices workspace

For calibration units, calibration kits and power meters, the configuration is straightforward.

For VNAs and switch matrices, you have to configure the RF ports (and DC ports for an R&S ZNB/ZNBT with option B81).

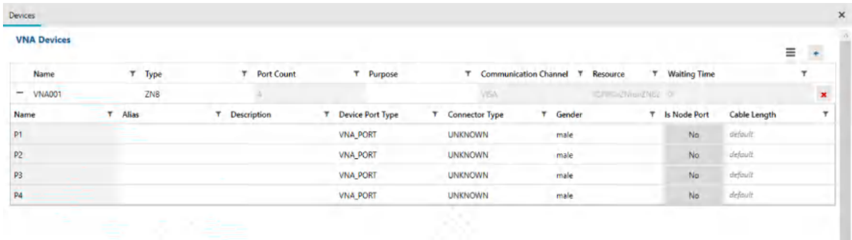


Figure 4-35: VNA Devices configuration

Table 4-9: Measurement device port types

Device category	"Device Port Type"	Description
	"GENERIC"	Default value if no specification of the port type is needed for a certain measurement device category.
"VNA Devices"	"VNA_PORT"	An RF port of a VNA, usually represented by a coaxial connector. This port type provides a receiver and a signal generator at the same time.
	VNA_DC_PORT	A DC port of a VNA. There is no possibility to generate a signal at this type of port.

Device category	"Device Port Type"	Description
"Matrices"	MATRIX_VNA_PORT	A matrix port that is typically connected to a VNA port. In cascaded matrix configurations, a "MATRIX_VNA_PORT" is connected to a "MATRIX_TEST_PORT" of another matrix. Currently this is **not** supported.
	MATRIX_TEST_PORT	A matrix port that is typically used as a test port, i.e. that is connected to the measurement adapter of a DUT. In cascaded matrix configurations, a "MATRIX_TEST_PORT" is connected to a "MATRIX_VNA_PORT" of another matrix. Currently this is **not** supported.

Device Connections

The "Device Connections" workspace allows you to define of the connections between VNAs and switch matrices.

Figure 4-36: Device Connections workspace.

4.3.2.4 Connection Plan Configuration

According to the R&S ZNrun API, a `ConnectionPlan` relates `MeasurementDevice`s and `DUTmeasurementPlan`s. It has an impact on the execution of the measurement cycle and the required physical (re-) connections. The "Connection Plan" workspace allows you to configure a `ConnectionPlan` data structure, possibly including DUT multiplicity and VNA multiplicity.

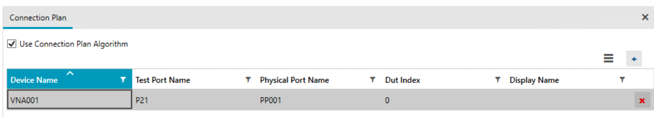


Figure 4-37: Connection Plan workspace

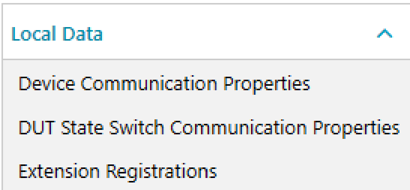
The ZNrun Workbench can calculate the connection plan automatically ("Use Connection Plan Algorithm"). However, if you provide a list of connections for a VNA device, they are respected by the connection plan algorithm. If more than one VNA is used, the connection plan algorithm has to be disabled and all connection have to be defined manually.

Click the "+" icon above the "Connection Plan" table to add a new connection. Use the "Device Name" and "Test Port Name" to select a test port on the VNA or matrix. Use the "Physical Port Name" and "DUT Index" to select the connected DUT port. Finally specify a "Display Name" for the connection (optional).

The "DUT Index" refers to a physical DUT. The number of DUTs can be defined via the "DUT" setting in the Measurement Paths workspace.

4.3.2.5 Local Data Configuration

In this configuration group, you can specify the local data of the ZNrun project, i.e. the project data that probably have to be modified, when the project is deployed to another ZNrun Server instance.



Device Communication Properties

The "Device Communication Properties" workspace gathers the communication properties of all measurement devices. All communication properties are editable.

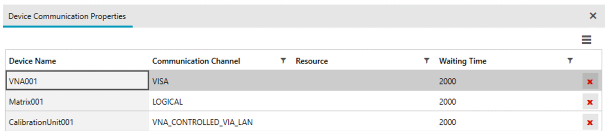


Figure 4-38: Device Communication Properties workspace

If you remove a row from the "Device Communication Properties" table, the corresponding device is **not** removed from the measurement plan. Only its communication properties are reset.

DUT State Switch Communication Properties

This workspace gathers the communication properties of all state switches. All communication properties are editable.

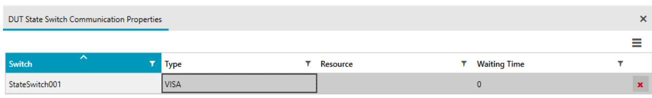


Figure 4-39: DUT State Switch Communication Properties workspace.

If you remove a row from the "DUT State Switch Communication Properties" table, the corresponding state switch is **not** removed from the measurement plan. Only its communication properties are reset.

Extension Registrations

The "Extension Registrations" workspace gathers information on registered plugins. It displays "Category" and "Class Name" of every custom device and post processor defined in the Plugins workspace. Here you can specify a local path to a parameter file ("Parameter File Path").

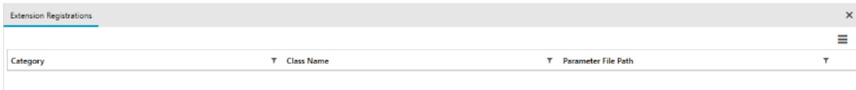
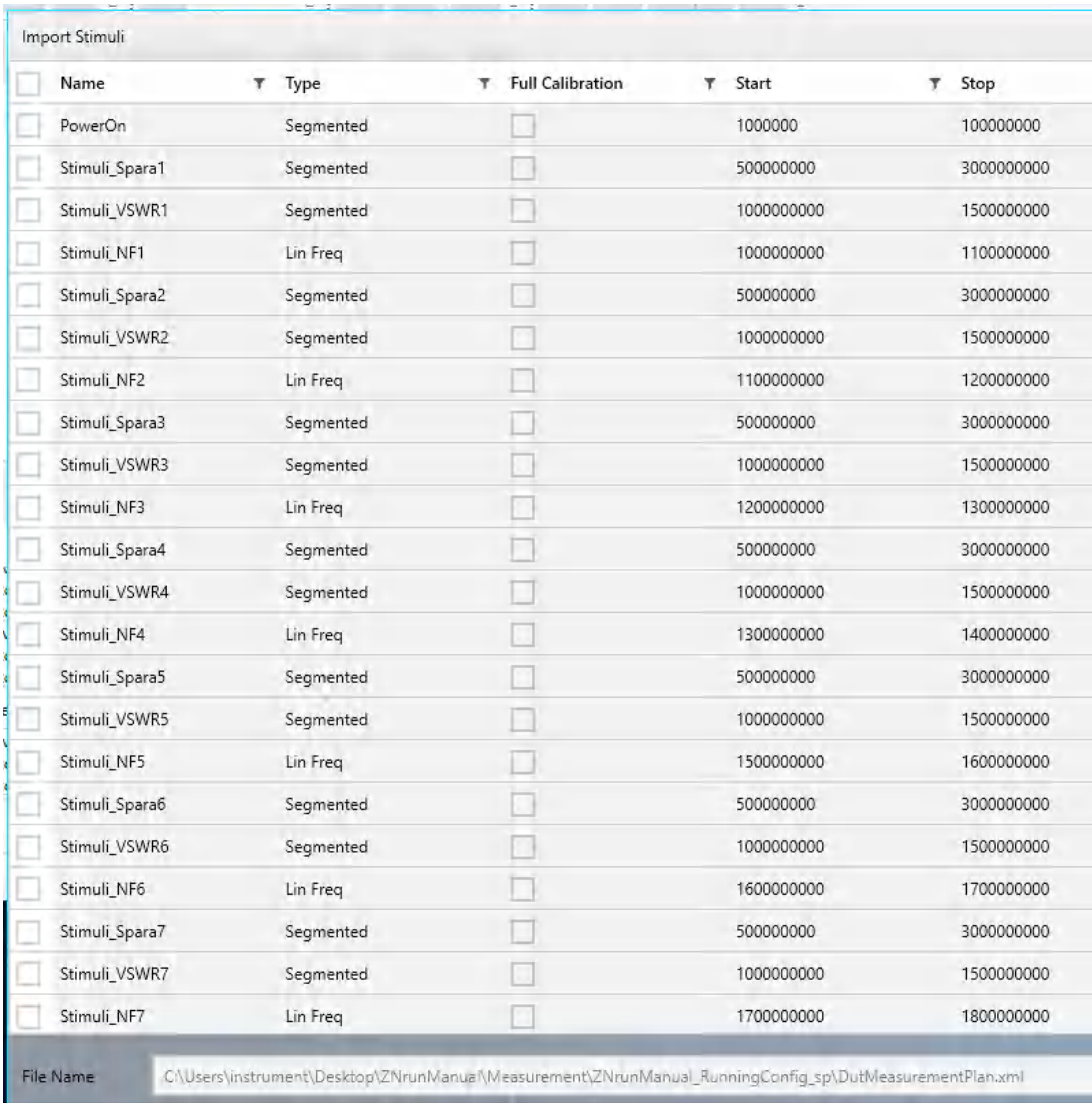


Figure 4-40: Extension Registrations workspace

If you remove a row from the "Extension Registrations" table, the corresponding extension is **not** removed from the list of plug-ins. Only the parameter file path is deleted.

4.3.3 Import Stimuli

You can import stimuli from file. Select the "Import Stimuli" icon from the Chapter 4.1.1, "Main Toolbar", on page 16 and pick an `*.xml` file that contains a valid serialization of a `DutMeasurementPlan`. For example, you can use the `DutMeasurementPlan.xml` that is created by the ZNrun Workbench when the workbench project is saved. The ZNrun Workbench automatically extracts all stimuli from the `DUTmeasurementPlan` and displays them in a list.



Import Stimuli

Name	Type	Full Calibration	Start	Stop
PowerOn	Segmented	☐	1000000	100000000
Stimuli_Spara1	Segmented	☐	500000000	3000000000
Stimuli_VSWR1	Segmented	☐	1000000000	1500000000
Stimuli_NF1	Lin Freq	☐	1000000000	1100000000
Stimuli_Spara2	Segmented	☐	500000000	3000000000
Stimuli_VSWR2	Segmented	☐	1000000000	1500000000
Stimuli_NF2	Lin Freq	☐	1100000000	1200000000
Stimuli_Spara3	Segmented	☐	500000000	3000000000
Stimuli_VSWR3	Segmented	☐	1000000000	1500000000
Stimuli_NF3	Lin Freq	☐	1200000000	1300000000
Stimuli_Spara4	Segmented	☐	500000000	3000000000
Stimuli_VSWR4	Segmented	☐	1000000000	1500000000
Stimuli_NF4	Lin Freq	☐	1300000000	1400000000
Stimuli_Spara5	Segmented	☐	500000000	3000000000
Stimuli_VSWR5	Segmented	☐	1000000000	1500000000
Stimuli_NF5	Lin Freq	☐	1500000000	1600000000
Stimuli_Spara6	Segmented	☐	500000000	3000000000
Stimuli_VSWR6	Segmented	☐	1000000000	1500000000
Stimuli_NF6	Lin Freq	☐	1600000000	1700000000
Stimuli_Spara7	Segmented	☐	500000000	3000000000
Stimuli_VSWR7	Segmented	☐	1000000000	1500000000
Stimuli_NF7	Lin Freq	☐	1700000000	1800000000

File Name C:\Users\instrument\Desktop\ZNrunManual\Measurement\ZNrunManual_RunningConfig_sp\DutMeasurementPlan.xml

Figure 4-41: Import Stimuli dialog

Use the checkboxes to the left to select the stimuli to be imported.

There are three different "Import" modes:

- **Replace:** All new stimuli are imported. Duplicates are replaced with the imported stimuli.
- **Rename:** All new stimuli are imported. The ZNrun Workbench assigns all duplicates a new unique identifier.
- **Skip:** All new stimuli are imported. Duplicates are not imported.

The default stimuli import mode is "Rename".

4.4 Calibration Phase

After the Measurement Execution Unit (MEU) has been configured, you can proceed with the calibration using the "ZNrun Calibration Client".

To launch the ZNrun Calibration Client in "DUT Related Calibration"-mode, click the calibration icon in the Main Toolbar.

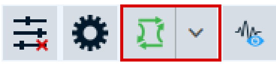


Figure 4-42: Calibration toolbar icon with calibration mode selector

To select another calibration mode ("Full Calibration", "User Defined Calibration", "DUT Related Calibration Without Connection Test"), use the drop-down menu beneath the calibration icon.

For a description of the ZNrun Calibration Client, see Chapter 5, "ZNrun Calibration Client", on page 61.

4.5 Execution and Visualization Phase

After the configuration and calibration of the Measurement Execution Unit (MEU), you can finally proceed with the execution and visualization of the measurement.

4.5.1 Execution View

The "Execution View " workspace gathers all information of the MEU execution. In this workspace, the measurement cycle is displayed in a tree like structure, similar to the Measurement Cycle configuration workspace.

Additional information such as the execution status, execution duration or calibration status of a sequential context, parallel context or step is displayed to the right of the corresponding tree node.

Figure 4-43: Execution View workspace

In the same way as described for the measurement cycle configuration workspace, you can enable or disable the execution of nodes and set or delete breakpoints.

To start and manipulate the execution, you can use the execution tools in the main toolbar (see Table 4-2).

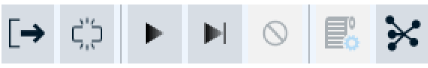


Figure 4-44: Toolbar icons for the execution phase

4.5.1.1 Tuning

Tuning is a special feature of the R&S ZNrun framework. It enables you to change and optimize the configuration of a MEU during the execution phase.

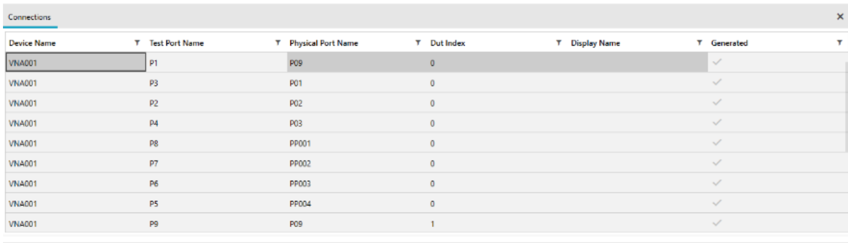
A parameter change affects all instances of the MEU. Furthermore, tuning comes with three tools to enhance the capabilities of the configuration of a MEU with the ZNrun Workbench:

Figure 4-45: Tuning tools

4.5.1.2 Connections

In the "Connections" workspace, the connection plan is displayed.

It contains the information of the Connection Plan Configuration, plus all automatically generated connections (indicated by a checkmark in "Generated" column).



Connections

Device Name	Test Port Name	Physical Port Name	Dut Index	Display Name	Generated
VNA001	P1	P09	0		✓
VNA001	P3	P01	0		✓
VNA001	P2	P02	0		✓
VNA001	P4	P03	0		✓
VNA001	P8	PP001	0		✓
VNA001	P7	PP002	0		✓
VNA001	P6	PP003	0		✓
VNA001	P5	PP004	0		✓
VNA001	P9	P09	1		✓

Figure 4-46: Connections workspace

4.5.2 Visualization Workspace

The outcomes of the measurements can be displayed in the "Visualization" workspace. You can either create an empty chart and drag & drop a "Stimulus Portgroup Measurement" from the "DUT Center" onto it. Or you can display a "Stimulus Portgroup Measurement" directly, by dragging & dropping it from the "DUT Center" to the workspace. To delete a chart, drag and drop it to the bin in the Chapter 4.1.1, "Main Toolbar", on page 16 of the ZNrun Workbench.

To focus on the results of a particular DUT, select the corresponding DUT index from the dropdown menu. Then newly created charts only display the measurements related to this DUT.

All charts are updated during the execution of the measurement cycle. All charts can be edited using the visualization tools:

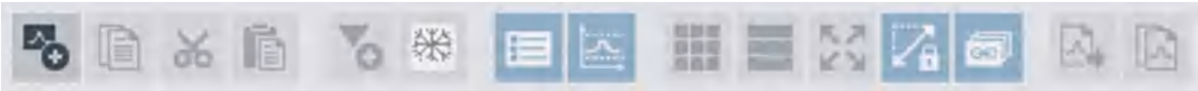


Table 4-10: Visualization tools (from left to right)

Group	Name	Action
Basic tools	Add empty chart	Adds a new empty chart to the workspace.
Visualization tools	Add marker	Adds a marker to the chart. The position of the marker in the chart can be changed by dragging. A legend entry is created.
	Freeze trace	Adds the current trace of the chart permanently to the chart. Creates a legend entry.
	Show legends	Shows or hides the legend of a chart.
	Show limits	Shows the limit lines of the measurement path in the chart.
Layout tools	Grid layout	Arranges the charts in a dynamic grid layout. The size of the charts is fixed.
	Stack layout	Arranges the charts stacked over one another. The width of the chart is dynamically adjusted.
	Maximize view	Adjusts the size of the chart to the size of the workspace.
	Keep aspect ratio	Keeps the aspect ratio of all charts equal. A change of the aspect ratio of one chart affects all charts.
	Couple chart sizes	Keeps the size of all charts equal. A change of the size of one chart affects all charts.
Export tools	Export chart to file	Exports the selected chart as .PNG. The destination folder is chosen by a dialog.
	Copy chart to clipboard	Copies the selected chart to the clipboard.

4.6 Rollout Phase

You can use ZNrun Workbench to roll out a valid Measurement Execution Unit (MEU) to multiple test stations, controlled by one or multiple ZNrun Server(s). The MEU loaded in ZNrun Workbench serves as master MEU. The test stations must be described as your "Device Park".

A **test station** is a set of devices comprising, for example:

- one or more VNAs
- one or more DUT adapters
- matrix devices (optional)
- calibration devices (optional)

To control rollout, use the rollout tools in the main toolbar (see Table 4-3).

4.6.1 Device Park

The "Device Park" describes your available test stations (VNAs, matrices). It is located in an arbitrary root directory on your file system.

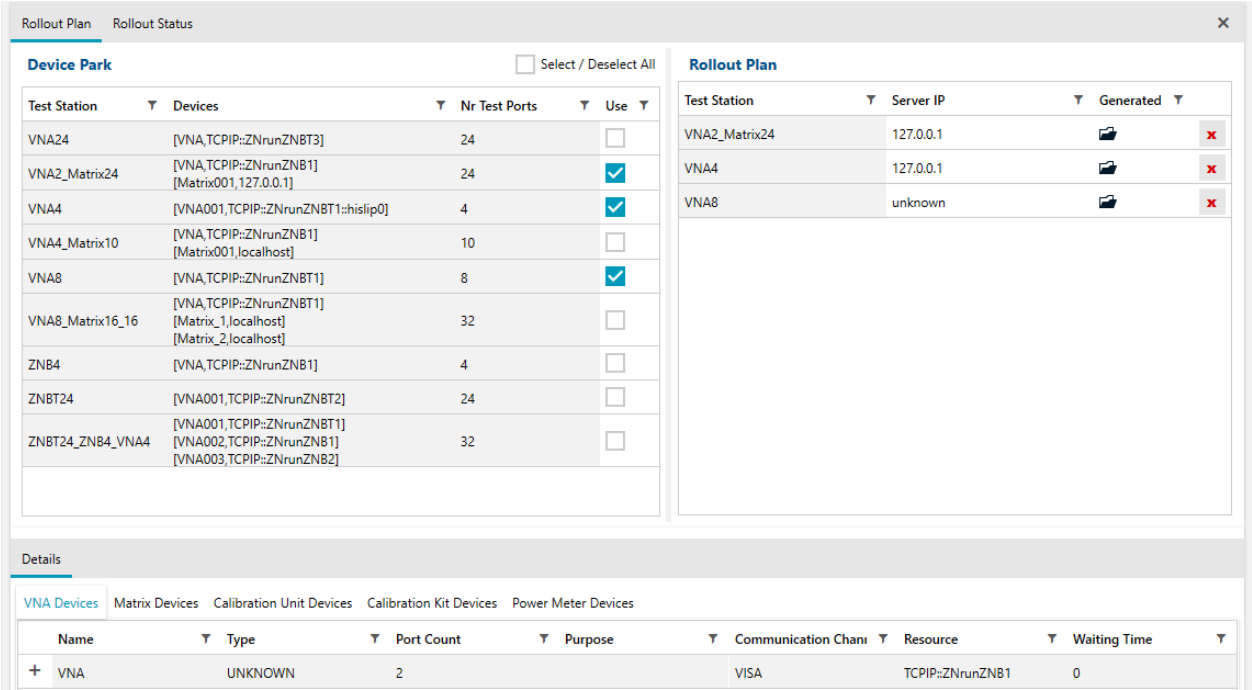
Each test station in the device park is represented by a subdirectory. The name of the directory is used as name of the test station. Each test station subdirectory needs to contain a `MeasurementDevicesPlan.xml` and a `MeasurementDevicesLocalData.xml` file:

```
<Root>
|-- <TestStationName>
  |-- <MeasurementDevicesPlan>.xml
  |-- <MeasurementDevicesLocalData>.xml
|-- <TestStationName>
  |-- <MeasurementDevicesPlan>.xml
  |-- <MeasurementDevicesLocalData>
```

Additional files in the subdirectory are ignored for rollout.

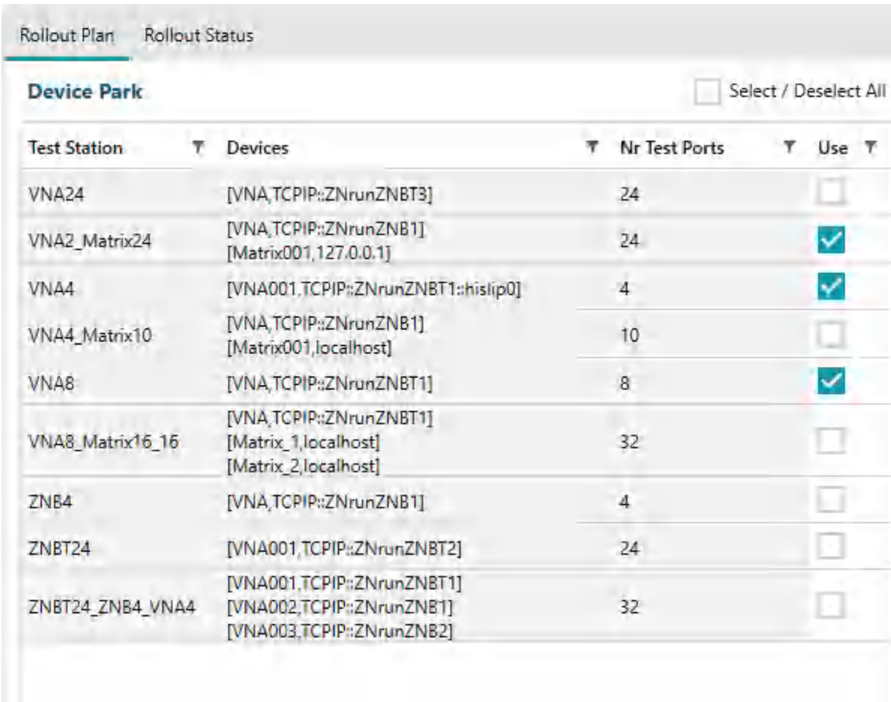
Set up the root directory of your device park in the "Rollout" tab of the options dialog (see Chapter 4.1.7, "Options", on page 23).

4.6.2 Rollout Plan View



Device Park section

The upper left part of the "Rollout Plan" presents the device park in tabular form, each test station identified by its configured "Test Station" name.



For each test station, the corresponding table row displays:

- the constituent "Devices" (resource strings)
- the overall "Nr. of Test Ports" available for DUT connections

Tick the "Use" checkbox for those test stations, to which you want to roll out the master MEU.

A test station that does not offer sufficient test ports for the master MEU is grayed out and cannot be used for rollout.

When you select a test station, the "Details" view provides more details:

Details

VNA Devices | Matrix Devices | Calibration Unit Devices | Calibration Kit Devices | Power Meter Devices

	Name	Type	Port Count	Purpose	Communication Chan	Resource	Waiting Time
+	VNA	UNKNOWN	2		VISA	TCPIP::ZNrunZNB1	0

Rollout Plan section

The test stations selected for "Use" in the Device Park section are transferred to the "Rollout Plan" section in upper right part of the "Rollout Plan" view.

Rollout Plan

Test Station	Server IP	Generated	
VNA2_Matrix24	127.0.0.1		x
VNA4	127.0.0.1		x
VNA8	unknown		x

For each test station, enter the IP address of the ZNrun Server to be used for rollout ("Server IP"). Then click the "Generate projects" button in the main tool bar (see Table 4-3).

A generated MEU comprises all components of the master MEU, except for any measurement devices and their local data, which are read from the used test station.

Manual changes to generated MEUs

At that point, you can apply manual changes to the generated MEUs. Manual changes can be necessary to adjust individual test stations (e. g. to set up de-/embedding) or the connection plan.

Edit the project files manually or in the ZNrun Workbench, or run a script to perform the necessary changes.

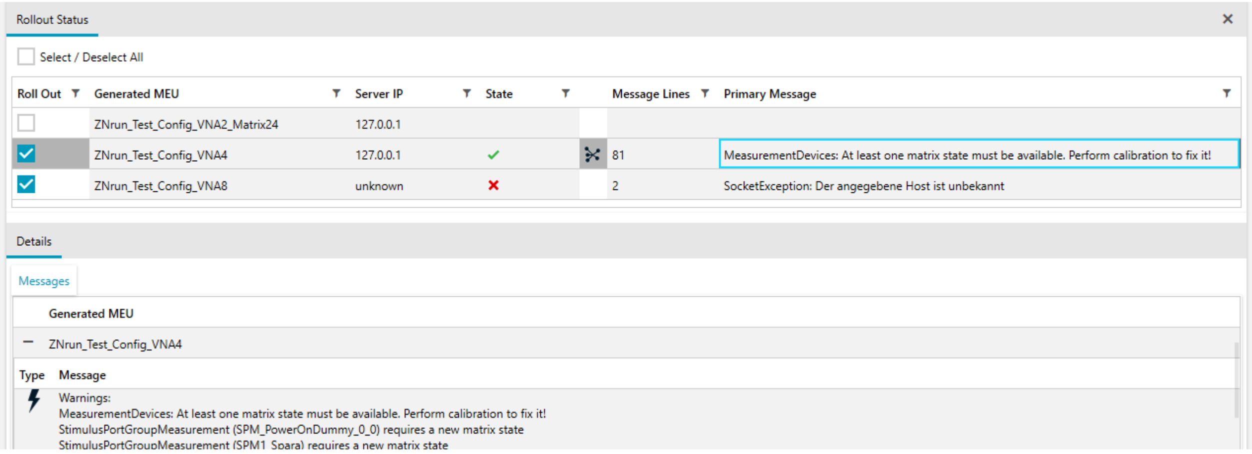
Repeated MEU generation

If you have modified your master MEU or the test stations in your device park, you have to regenerate the MEUs. Toggle the "Overwrite" button in the main tool bar to allow formerly generated MEUs to be overwritten (see Table 4-3).

Note that MEU regeneration also overwrites any manual changes applied to the formerly generated MEUs.

4.6.3 Rollout Status View

When your generated measurement execution units are ready for rollout, open the "Rollout Status" view.



For each "Generated MEU" that you want to roll out right now, tick the "Roll Out" checkbox in the respective column. Then click the "Roll out" button in the main tool bar (see Table 4-3).

The rollout process starts and for each selected "Generated MEU" the "State" column indicates the rollout progress. A connection plan generated by the respective ZNrun Server can be downloaded using the "Connections" icon

The ZNrun Workbench collects the messages received from the related ZNrun Servers. The "Rollout Status" view displays the number of "Message Lines" collected, and a "Primary Message". When you select a generated MEU, the "Details" view presents all messages.

You can repeat rollout for the same or a different selection of generated MEUs. The "Rollout Status" view reflects the status for all the rollouts performed during the current rollout session.

Rollout status log

You can log the rollout status of the current session to a file, according to your options (see Chapter 4.1.7, "Options", on page 23). Click the "Log rollout status" button in the main tool bar (see Table 4-3).

5 ZNrun Calibration Client

R&S ZNrun comes with a graphical calibration client that can be accessed via the Windows Start menu item "R&S ZNrun [version]" > "ZNrun Calibration Client".

The calibration client has a simple user interface suitable for guiding a technician through all the steps of the calibration process. For laboratory use, it offers a more advanced interface which allows definition of user-defined calibration tasks.

5.1 Calibration Modes

The ZNrun Calibration Client offers 4 different calibration modes:

- **DUT-related calibration**
  The required calibration tasks are derived from an existing `DUTMeasurementPlan`, i.e. the calibration fits exactly to the measurement requirements of a particular DUT (stimuli, test ports, states of matrix and switches). Every measurement parameter in the `DUTMeasurementPlan` is calibrated exactly without interpolation, which is the preferred option if a fast and accurate calibration is desired.
  Depending on the individual measurement steps, this option can lead to individual calibrations for every measurement step.
- **Generic calibration**
  Creates a multi-purpose calibration for a set of test ports, based on user-defined calibration stimuli settings. The intention is to use a common calibration for multiple DUTs and test ports without the need to recalibrate. Make sure to define a sufficient frequency range to prevent uncalibrated traces.
  In contrast to DUT-related calibration, a generic calibration usually results in interpolated calibrations for a given `DUTMeasurementPlan`.
  If switch matrices are involved, only a subset of the possible matrix routes is calibrated, compromising between calibration effort/time and application benefit.
- **Full calibration**
  Similar to generic calibration, but with every possible switch matrix route being calibrated. This calibration mode enables full flexibility of test port usage.
- **User-defined calibration**
  Allows the creation of any calibration or recalibration. The three calibration modes described above can serve as starting points, but you can even define custom calibrations based on a single calibration standard (Open, Short, Match, Through …).

Depending on how matrix devices are controlled, there are restrictions while combining test ports into groups simultaneously used by measurement or calibration.

Partial port group calibration (default) – matrix directly controlled by ZNrun Server

The test ports are divided into groups whose size is equal to the number of used matrix VNA ports, and for whom routes between the related matrix test ports and matrix VNA ports exist. All such port combinations are calibrated. Transmission measurements between two ports are then restricted to the combinations covered in the partial port group calibration. This mechanism can be used with all supported VNAs.

Full port group calibration – matrix directly controlled by VNA

All possible groups of test ports, whose size is equal to the number of used matrix VNA ports and for whom routes between the related matrix test ports and matrix VNA ports exist, are fully calibrated. You can then measure transmission parameters between each pair of test ports without restriction. The downside is an increased calibration time, because the number of calibration procedures can be large. This mechanism can be used for VNAs whose firmware supports matrix control.

5.2 Deployment

The ZNrun Calibration Client offers two different modes of operation:

- **Calibration step mode**: execution of the actual calibration process in a step-by-step manner
- **Calibration task mode**: configuration of user-defined calibration tasks which can be executed in the calibration step mode afterwards

The operation mode of the calibration client can be controlled via command-line arguments.

By default the ZNrun Calibration Client connects to a ZNrun Server running on the same machine and conducts a generic calibration (see Chapter 5.1, "Calibration Modes", on page 61) in calibration step mode.

5.3 Command Line Interface

The ZNrun Calibration Client can be parameterized using a shortcut link or directly via Windows command prompt.

Figure 5-1: Help screen of the ZNrun Calibration Client

The help screen is displayed on erroneous command-line arguments or if the '--help' parameter is used. It offers text selection and copy to clipboard [CTRL]+[C] functionality.

Command-line examples

```
ZNrunCalibrationClient.exe --ip=192.168.1.42 --load="DUT3425" -c DUT_RELATED_CALIBRATION
```

- Connect to the ZNrun Server running at IP address 192.168.1.42
- Create, load and use a MEU named `DUT3425`
- Conduct a DUT-related calibration in step-by-step mode

```
ZNrunCalibrationClient.exe --ip=192.168.1.42 --noautoconnect
--edit
```

- Connect to the ZNrun Server running at IP address 192.168.1.42.
- Do not connect to a MEU that is already loaded. Instead, the ZNrun Calibration Client presents a dialog that lets you choose the MEU to load or connect to.
- Start in calibration task mode.

```
ZNrunCalibrationClient.exe --load="DUT3425" --check="v 2.0"
--edit
```

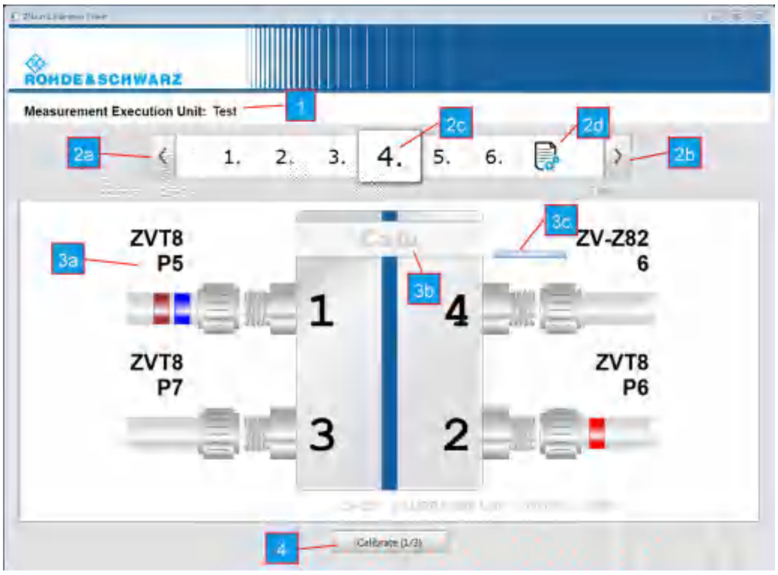
- Connect to ZNrun Server running on the same machine
- Create, load and use a MEU named `DUT3425`
- Make sure that the loaded version was saved under version `v 2.0` and that its content was not modified.
- Start in calibration task mode.

Note that you have to use quotation signs if a command line argument contains whitespace characters (e.g. "`v 2.0`").

5.4 Execution of Calibration Steps

The GUI in calibration step mode is separated into two major parts:

- List of calibration steps
- Connection scheme of the current calibration step



1 = Name of the MEU
2 = List of calibration steps
2a = Step backward
2b = Step forward
2c = Current calibration step
3 = Connection scheme of the current calibration step

3a = Graphical representation of connecting instruction
3b = Unique name of the calibration device
3c = Changed indicator – modified connection related to the previous step
4 = Perform calibration step

Keyboard shortcuts can be used to navigate through the list of calibration steps and to trigger calibration step procedures.

Table 5-1: ZNrun Calibration Client: Keyboard shortcuts

Keyboard shortcut	Related user control	Description
← **or** ↓	2a	Step forward through list of calibration steps
→ **or** ↑	2b	Step backward through list of calibration steps
Pos1	-	Go to the beginning of list
End	-	Go to the end of list
Enter	3b	Perform calibration of current step

5.5 Representation of the Calibration Devices

The connection scheme shows a graphical representation of the calibration unit/kit and how cables have to be connected to the measurement devices.

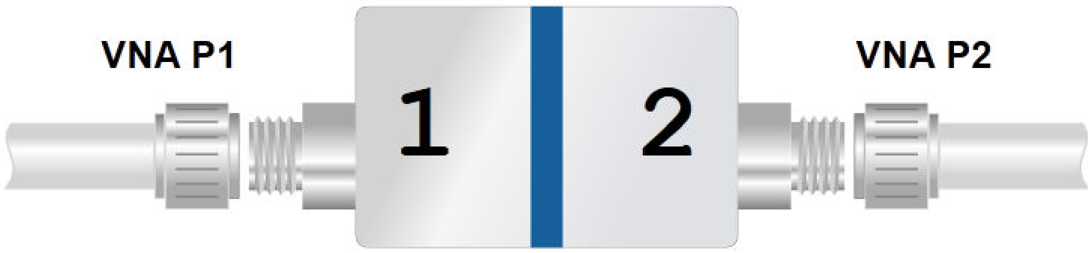


Figure 5-2: 2-port calibration unit

Figure 5-3: 8-port calibration unit

Cables can be marked with user-defined names and up to three colors. Once you have connected all cables, press the calibration button. A symbol in the upper right corner of each of calibration step represents the result of the calibration procedure. If successful, a green check mark is displayed. An exclamation mark in a yellow triangle represents an error. In addition, a tooltip provides further information about the result.

If a calibration step was successfully executed, the dialog automatically proceeds to the next calibration step. Cable connections that have to be changed are marked with a blue "change indicator". For example, in Calibration using a calibration unit: step 1 successfully executed four of eight connections have to be changed before the step can be executed.

Before performing the calibration step, the application runs an automatic connection test. If an invalid or missing connection is detected, this connection is marked with a blinking red color mark and the calibration is canceled. For example, in Calibration using a calibration unit: wrong connection in step 2 connection between calibration unit port 6 and measurement test port "ZV-Z82 4" is invalid.

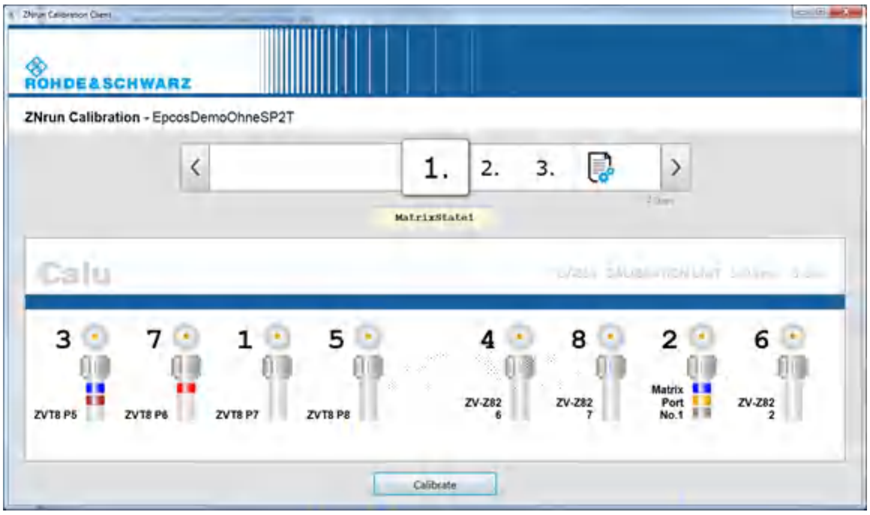


Figure 5-4: Calibration using a calibration unit: before step 1

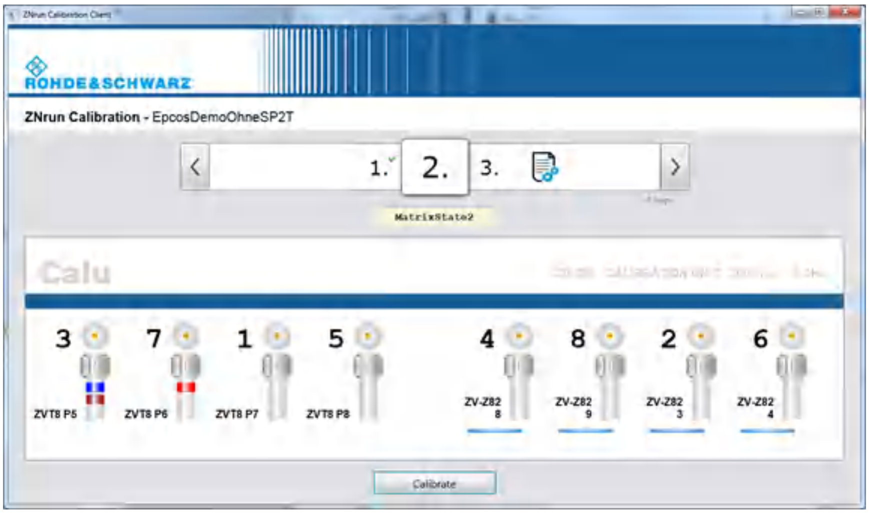


Figure 5-5: Calibration using a calibration unit: step 1 successfully executed

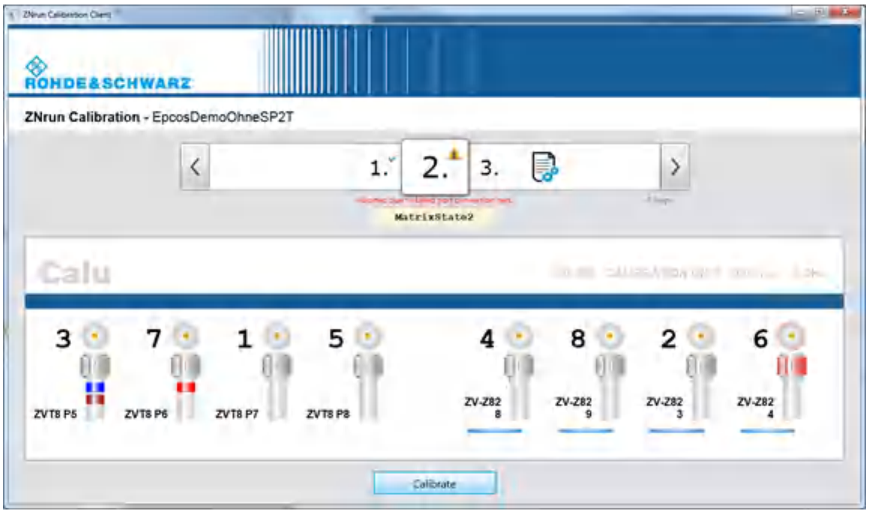


Figure 5-6: Calibration using a calibration unit: wrong connection in step 2

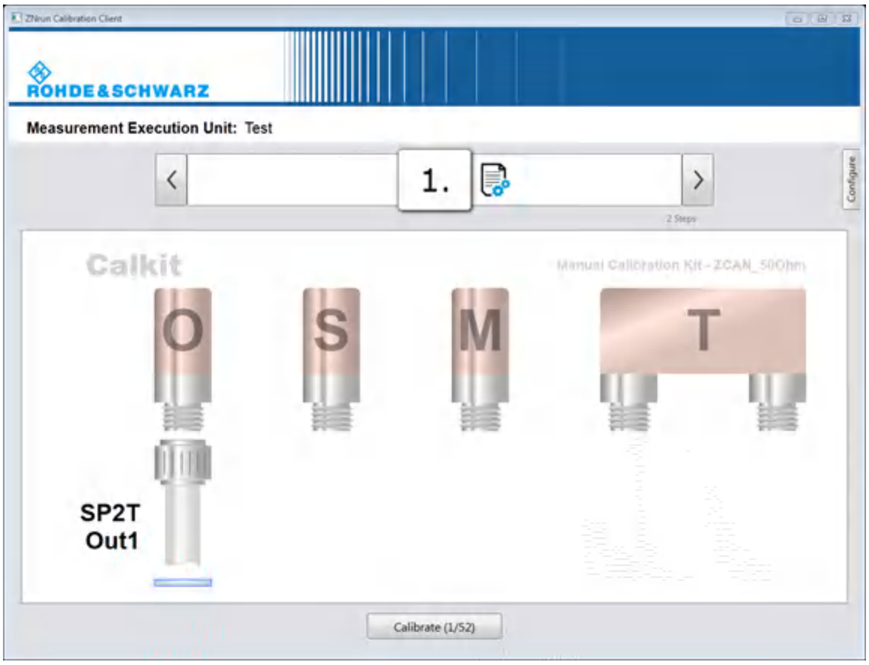


Figure 5-7: Calibration using a calibration kit

5.6 Reporting

After the calibration has been successfully executed, a report can be generated in PDF format. The report provides information about the individual calibration steps, comprising:

- **General information** such as current date, operator name and optional comments

- A list of **actions** (represented by execution timestamp, action description and result) including both user actions and automatic actions such as requesting information about client and server version.

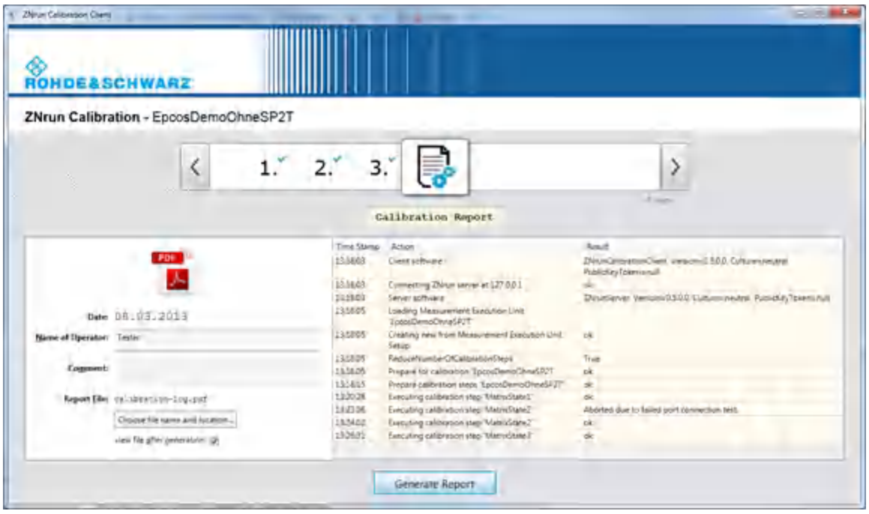


Figure 5-8: Report generation view

6 ZNrun Measurement Client

The R&S ZNrun installer comes with a measurement execution client implementation that can be accessed via the Windows Start menu item "R&S ZNrun [version] > ZNrun Measurement Client".

The ZNrun Measurement Client provides a clean and simple graphical user interface which allows to control the execution of a pre-configured `MeasurementExecutionUnit`. In addition it provides a remote control interface that allows to control the measurement execution via SCPI commands. A plug-in interface enables user-defined extensions such as the creation of custom log files and reports.

Figure 6-1: ZNrun Measurement Client

6.1 Basic Functions

The "Load Measurement Execution Unit Setup" allows to re-/load a Measurement Execution Unit. Re-/loading a Measurement Execution Unit re-/initializes the related measurement devices.

The Measurement Steps of the Measurement Cycle defined by the Measurement Execution Unit are displayed as table rows. The table columns represent the Measurement Step name, "Next" and "Disabled?" switches (see Advanced Features), and the path to the "File" where the results of the Measurement Step shall be stored.

A spinner control allows to specify the number *n* of Measurement Cycles to be executed.

The "Start / Continue", "Pause" and "Stop" buttons allow a basic control of the Measurement Cycle execution. When the "Start" button is pressed, the client executes the

Measurement Cycle *n* times or until the "Pause" or "Stop" button is pressed. "Continue" resumes a paused execution.

The stop watch allows to measure the execution time.

Errors that occur during the loading or execution phase are shown in status row on the bottom of the dialog. If an error occurs during the execution of a particular MeasurementStep, this step is marked in red. In addition, a tooltip shows the error text.

6.2 Advanced Features

In addition to the Basic Functions described above, the ZNrun Measurement Client offers advanced functionality to control the execution of MeasurementCycles. These functions are:

- Stepwise Execution
- Breakpoints at Measurement Steps
- Disabled Measurement Steps

Measurement Steps can be executed step by step. To initiate this mode, press "Step" button or set a breakpoint at that Measurement Step and press "Start" button. If a Measurement Cycle is paused at a breakpoint, the execution can be resumed by using "Step" or "Continue" button. Breakpoints are set by a mouse click on "Next" column of a MeasurementStep in the list view. A red dot in "Next" column represents an active breakpoint. A blue arrow shows the Measurement Step to be executed next when the "Step" button is pressed.

Measurement Steps can be disabled by activating the checkbox in the "Disabled?" column.

Glossary: Frequently used terms

C

Configuration phase: State of a measurement execution unit in which you can set, change or remove configuration data. It is not possible to calibrate devices or execute measurements in this state.

Connection plan: A connection plan describes the HF connections between the test ports of the measurement devices and the measurement adapter carrying the DUT (DUT measurement plan). Formally, the `ConnectionPlan` data structure links a `MeasurementDevices` to a `DUTMeasurementPlan`.

D

DUT measurement plan: The `DUTMeasurementPlan` data structure describes the device under test (including the measurement adapter) and the parameters to be measured. It corresponds to a particular type of DUT and does **not** contain any information about the measurement devices to be used.

E

Execution phase: State of a measurement execution unit in which the measurements – described by the configuration data – can be run. In this state, the configuration data cannot be modified and is the basis for calculating the measurement cycle. The measurement cycle can be steered using the `IMeasurementControl` interface.

M

Measurement cycle: Represents the measurement process which is calculated from the configuration data of the measurement execution unit. The cycle consists of a sequence of measurement steps. It is possible to label the cycle with a unique identifier which allows distinguishing successive cycles.

Measurement devices: The `MeasurementDevices` data structure describes a set of measurement devices that can be used to measure a DUT (vector network analyzers, switch matrices, calibration units) . It includes information about the connections between VNAs and switch matrices, but does **not** contain any information about potential measurement objects and the parameters to be measured (see DUT measurement plan).

Measurement execution unit: A measurement execution unit represents a measuring task for a DUT with all measurement equipment and properties. Technically, it is an instance of `IMeasurementExecutionUnit` on the ZNrun Server, holding the three database components `MeasurementDevices`, `DUTMeasurementPlan` and `ConnectionPlan` (see measurement devices, DUT measurement plan and connection plan, respectively). The database is managed by the MEU and is the basis for all measurement executions.

Measurement step: Container for stimulus portgroup measurements. A measurement step is non-interruptible but can function as a breakpoint in a measurement cycle. All stimulus port group measurements within a measurement step are executed in parallel.

S

Stimulus port group measurement: A specific measurement, defined by a set of measurement parameters, a group of DUT ports and a stimulus description. User-specific actions (provided by plug-ins) can be hooked onto stimulus port group measurements.